
**Information technology —
Telecommunications and information
exchange between systems — Local and
metropolitan area networks — Specific
requirements —**

**Part 11:
Wireless LAN medium access control
(MAC) and physical layer (PHY)
specifications**

AMENDMENT 4

*Technologies de l'information — Télécommunications et échange
d'information entre systèmes — Réseaux locaux et métropolitains —
Exigences spécifiques —*

*Partie 11: Spécifications du contrôle d'accès du milieu sans fil (MAC) et
de la couche physique (PHY)*

AMENDEMENT 4



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IEEE Standard for Information technology—
Telecommunications and information exchange between systems
Local and metropolitan area networks—
Specific requirements

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

Amendment 4: Enhancements for Very High Throughput for Operation in Bands below 6 GHz

IEEE Computer Society

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IEEE Std 802.11ac™-2013
(Amendment to
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as amended by IEEE Std 802.11ae™-2012,
IEEE Std 802.11aa™-2012,
and IEEE Std 802.11ad™-2012)

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Throughput for Operation in Bands below 6 GHz**

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

Approved 11 December 2013

IEEE-SA Standards Board

Abstract: The purpose of this amendment is to improve the IEEE 802.11™ wireless local area network (WLAN) user experience by providing significantly higher basic service set (BSS) throughput for existing WLAN application areas and to enable new market segments for operation below 6 GHz including distribution of multiple multimedia/data streams.

Keywords: 256-QAM, beamforming, IEEE 802.11ac™, multi-user MIMO, noncontiguous frequency segments, very high throughput, wider bandwidth

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The purpose of this amendment is to improve the IEEE 802.11 wireless local area network (WLAN) user experience by providing significantly higher basic service set (BSS) throughput for existing WLAN application areas and to enable new market segments for operation below 6 GHz including distribution of multiple multimedia/data streams.

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**IEEE Standard for Information technology—
Telecommunications and information exchange between systems
Local and metropolitan area networks—
Specific requirements**

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

**Amendment 4: Enhancements for Very High
Throughput for Operation in Bands below 6 GHz**

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(This amendment is based on IEEE Std 802.11™-2012, as amended by IEEE Std 802.11ae™-2012, IEEE Std 802.11aa™-2012, and IEEE Std 802.11ad™-2012.)

NOTE—The editing instructions contained in this amendment define how to merge the material contained therein into the existing base standard and its amendments to form the comprehensive standard. The editing instructions are shown in **bold italic**. Four editing instructions are used: change, delete, insert, and replace. **Change** is used to make corrections in existing text or tables. The editing instruction specifies the location of the change and describes what is being changed by using ~~strike through~~ (to remove old material) and underscore (to add new material). **Delete** removes existing material. **Insert** adds new material without disturbing the existing material. Deletions and insertions may require renumbering. If so, renumbering instructions are given in the editing instruction. **Replace** is used to make changes in figures or equations by removing the existing figure or equation and replacing it with a new one. Editorial instructions, change markings, and this NOTE will not be carried over into future editions because the changes will be incorporated into the base standard.¹

¹Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

3. Definitions, acronyms and abbreviations

3.1 Definitions

Delete the following definition from 3.1 (note that the definition is inserted with changes into 3.2):

medium access control (MAC) management protocol data unit (MMPDU)

Insert the following definitions into 3.1 in alphabetic order:

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

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

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

frequency segment: A contiguous block of spectrum used by a transmission.

multi-user multiple input, multiple output (MU-MIMO): A technique by which multiple stations (STAs), each with one or more antennas, either simultaneously transmit to a single STA or simultaneously receive from a single STA independent data streams over the same radio frequencies.

NOTE—IEEE 802.11 supports only downlink (DL) MU-MIMO. See DL-MU-MIMO.

multi-user (MU) physical layer (PHY) protocol data unit (PPDU): A PPDU that carries one or more PHY service data units (PSDUs) for one or more stations (STAs) using the downlink multi-user multiple input, multiple output (DL-MU-MIMO) technique.

noncontiguous transmission: A transmission that uses nonadjacent frequency segments.

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

3.2 Definitions specific to IEEE 802.11

Change the following definitions in 3.2:

20 MHz mask physical layer (PHY) ~~convergence procedure (PLCP)~~ protocol data unit (PPDU): A Clause 18 PPDU, a Clause 19 orthogonal frequency division multiplexing (OFDM) PPDU, or a Clause 20 20 MHz high-throughput (HT) PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW20 and the CH_OFFSET parameter equal to CH_OFF_20. The PPDU is transmitted using a 20 MHz transmit spectral mask defined in Clause 18, Clause 19, or Clause 20. One of the following PPDU:

- a) A Clause 18 PPDU transmitted using the transmit spectral mask defined in Clause 18.
- b) A Clause 19 orthogonal frequency division multiplexing (OFDM) PPDU transmitted using the transmit spectral mask defined in Clause 19.

- c) A high-throughput (HT) PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW20 and the CH_OFFSET parameter equal to CH_OFF_20 transmitted using the 20 MHz transmit spectral mask defined in Clause 20.
- d) A very high throughput (VHT) PPDU with TXVECTOR parameter CH_BANDWIDTH equal to CBW20 transmitted using the 20 MHz transmit spectral mask defined in Clause 22.
- e) A Clause 18 PPDU transmitted by a VHT STA using the transmit spectral mask defined in Clause 22.
- f) A HT PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW20 and the CH_OFFSET parameter equal to CH_OFF_20 transmitted by a VHT STA using the 20 MHz transmit spectral mask defined in Clause 22.

20 MHz physical layer (PHY) convergence procedure (PLCP)-protocol data unit (PPDU): A Clause 16 PPDU, Clause 18 PPDU (when using 20 MHz channel spacing), Clause 17 PPDU, Clause 19 orthogonal frequency division multiplexing (OFDM) PPDU, ~~or~~ Clause 20 20 MHz high-throughput (HT) PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW20 ~~or~~ Clause 22 20 MHz very high throughput (VHT) PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to CBW20.

40 MHz mask physical layer (PHY) convergence procedure (PLCP)-protocol data unit (PPDU): One of the following PPDUs:

- 1) ~~a~~ A 40 MHz high-throughput (HT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW40) transmitted using the 40 MHz transmit spectral mask defined in Clause 20.
- 2) ~~a~~ A 40 MHz non-HT duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to NON_HT_CBW40) transmitted by a non-very-high-throughput (non-VHT) STA using the 40 MHz transmit spectral mask defined in Clause 20.
- 3) A 40 MHz non-HT duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW40) transmitted by a very high throughput (VHT) STA using the 40 MHz transmit spectral mask defined in Clause 22.
- 4) ~~a~~ A 20 MHz HT PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW20 and the CH_OFFSET parameter equal to either CH_OFF_20U or CH_OFF_20L transmitted using the 40 MHz transmit spectral mask defined in Clause 20.
- 5) A 20 MHz VHT PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to CBW20 transmitted using the 40 MHz transmit spectral mask defined in Clause 22.
- 6) A 40 MHz VHT PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to CBW40 transmitted using the 40 MHz transmit spectral mask defined in Clause 22.
- 7) A 40 MHz HT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW40) transmitted by a VHT STA using the 40 MHz transmit spectral mask defined in Clause 22.
- 8) A 20 MHz non-HT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW20) transmitted using the 40 MHz transmit spectral mask defined in Clause 20.
- 9) A 20 MHz non-HT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW20) transmitted by a VHT STA using the 40 MHz transmit spectral mask defined in Clause 22.

The PPDU is transmitted using a 40 MHz transmit spectral mask defined in Clause 20 (High Throughput (HT) PHY specification).

40 MHz physical layer (PHY) convergence procedure (PLCP)-protocol data unit (PPDU): A 40 MHz high-throughput (HT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW40), or a 40 MHz non-HT duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to NON_HT_CBW40 or TXVECTOR parameter CH_BANDWIDTH equal to CBW40) as defined in Clause 20, or a 40 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW40).

high-throughput (HT) null data packet (NDP) announcement: A physical layer (PHY) ~~convergence procedure (PLCP)~~-protocol data unit (PPDU) that contains one or more +HTC frames (i.e., frames with an HT (high-throughput) Control field) that have the HT NDP Announcement subfield equal to 1.

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

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

- 1) 40 MHz non-HT duplicate: A transmission format of the PHY that replicates a 20 MHz non-HT transmission in two adjacent 20 MHz channels.
- 2) 80 MHz non-HT duplicate: A transmission format of the PHY that replicates a 20 MHz non-HT transmission in four adjacent 20 MHz channels.
- 3) 160 MHz non-HT duplicate: A transmission format of the PHY that replicates a 20 MHz non-HT transmission in eight adjacent 20 MHz channels.
- 4) 80+80 MHz non-HT duplicate: A transmission format of the PHY that replicates a 20 MHz non-HT transmission in two frequency segments of four adjacent 20 MHz channels where the two frequency segments of channels are not adjacent.

non-high-throughput (non-HT) duplicate physical layer ~~(PHY) convergence procedure (PLCP)~~ protocol data unit (PPDU): A PPDU transmitted by a Clause 20 ~~or Clause 22~~ physical layer (PHY) with the TXVECTOR FORMAT parameter equal to NON_HT and the CH_BANDWIDTH parameter equal to NON_HT_CBW40, CBW40, CBW80, CBW160, or CBW80+80.

non-high-throughput (non-HT) physical layer ~~(PHY) convergence procedure (PLCP)~~ protocol data unit (PPDU): A Clause 20 ~~or Clause 22~~ physical layer (PHY)-PPDU with the TXVECTOR FORMAT parameter equal to NON_HT.

payload protected (PP) aggregate medium access control (MAC) service data unit (A-MSDU): An A-MSDU that is protected with CTR with CBC-MAC Protocol (CCMP) or Galois Counter Mode Protocol (GCMP) but does not include the A-MSDU Present field (bit 7 of the QoS Control field) in the construction of the additional authentication data (AAD).

per-frame sequence counter: For Temporal Key Integrity Protocol (TKIP), the counter that is used as the nonce in the derivation of the per-frame encryption key. For Counter mode with Cipher-block chaining Message authentication code Protocol (CCMP) or Galois Counter Mode Protocol (GCMP), the per-frame initialization vector (IV).

robust-security-network-association- (RSNA-) capable equipment: A device that contains a station (STA) that is able to create RSNAs. Such a device might use pre-RSNAs because of configuration. Notice that RSNA-capable does not imply full compliance with the RSNA Protocol Implementation Conformance Statement (PICS). A legacy device that has been upgraded to support Temporal Key Integrity Protocol (TKIP) might be RSNA-capable, but is not compliant with the PICS if it does not also support Counter mode with Cipher-block chaining Message authentication code Protocol (CCMP) using CCMP-128.

secondary channel: A 20 MHz channel associated with a primary channel used by high-throughput (HT) stations (STAs) for the purpose of creating a 40 MHz channel or used by very high throughput (VHT) stations (STAs) for the purpose of creating the primary 40 MHz channel.

signaling and payload protected (SPP) aggregate medium access control (MAC) service data unit (A-MSDU): An A-MSDU that is protected with CTR with CBC-MAC Protocol (CCMP) or Galois Counter Mode Protocol (GCMP) and that includes the A-MSDU Present field (bit 7 of the QoS Control field) in the construction of the additional authentication data (AAD).

Insert the following definitions in 3.2 in alphabetic order:

80 MHz mask physical layer (PHY) protocol data unit (PPDU): A PPDU that is transmitted using the 80 MHz transmit spectral mask defined in Clause 22 and that is one of the following:

- a) An 80 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80)
- b) An 80 MHz non-high-throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80)
- c) A 20 MHz non-HT, high-throughput (HT), or VHT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW20)
- d) A 40 MHz non-HT duplicate, HT, or VHT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW40)

80 MHz physical layer (PHY) protocol data unit (PPDU): A Clause 22 80 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80) or a Clause 22 80 MHz non-high-throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80).

160 MHz mask physical layer (PHY) protocol data unit (PPDU): A PPDU that is transmitted using the 160 MHz transmit spectral mask defined in Clause 22 and that is one of the following:

- a) A 160 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH set to CBW160)
- b) A 160 MHz non-high-throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW160)
- c) A 20 MHz non-HT, high-throughput (HT), or VHT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW20)
- d) A 40 MHz non-HT duplicate, HT, or VHT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW40)
- e) An 80 MHz non-HT duplicate or VHT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80)

160 MHz physical layer (PHY) protocol data unit (PPDU): A Clause 22 160 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW160) or a Clause 22 160 MHz non-high-throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW160).

80+80 MHz mask physical layer (PHY) protocol data unit (PPDU): A PPDU that is transmitted using the 80+80 MHz transmit spectral mask defined in Clause 22 and that is one of the following:

- a) An 80+80 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH set to CBW80+80)
- b) An 80+80 MHz non-high-throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH set to CBW80+80)

80+80 MHz physical layer (PHY) protocol data unit (PPDU): A Clause 22 80+80 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80+80) or a Clause 22 80+80 MHz non-high-throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80+80).

bandwidth signaling transmitter address (TA): A TA that is used by a very high throughput (VHT) station (STA) to indicate the presence of additional signaling related to the bandwidth to be used in subsequent transmission in an enhanced distributed channel access (EDCA) transmission opportunity (TXOP). It is represented by the IEEE medium access control (MAC) individual address of the transmitting VHT STA but with the Individual/Group bit set to 1.

basic service set (BSS) basic very high throughput (VHT) modulation and coding scheme (MCS) and number of spatial streams (NSS) set (BSS basic VHT-MCS and NSS set): The set of MCS and NSS tuples that are supported by all VHT stations (STAs) that are members of a VHT BSS.

beamforming steering matrix: A matrix that describes the mapping of space-time streams to transmit antennas and for which the values have been determined using knowledge of the channel between transmitter and receiver with the goal of improving reception at the receiver.

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

end-of-frame (EOF) pad: The 0 to 3 octets used to pad an aggregate medium access control (MAC) protocol data unit (A-MPDU) to the last octet of the associated physical layer convergence procedure (PLCP) service data unit (PSDU) when the A-MPDU is carried in a very high throughput (VHT) physical layer (PHY) protocol data unit (PPDU).

high-throughput (HT) beamformee: An HT station (STA) that receives an HT physical layer (PHY) protocol data unit (PPDU) that was transmitted using a beamforming steering matrix and that supports an HT transmit beamforming feedback mechanism as described in either 9.29.2 or 9.29.3.

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

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

NOTE—The MMPDU occupies a position in the management plane similar to that of the MAC service data unit (MSDU) in the data plane. The MMPDU can be fragmented (under certain circumstances) and in that case is carried in multiple management MPDUs. This illustrates the similarity of the MMPDU to the MSDU.

multi-user (MU) beamformee: A non-access-point (non-AP) station (STA) that receives a physical layer (PHY) protocol data unit (PPDU) that was transmitted using a multi-user beamforming steering matrix and that supports the very high throughput (VHT) transmit beamforming feedback mechanism with a VHT null data packet (NDP) Announcement frame that includes more than one STA Info field as described in 9.31.5.

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

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

non-high-throughput (non-HT): A modifier meaning neither high-throughput (HT) nor very high throughput (VHT).

non-primary channel: In a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz very high throughput (VHT) basic service set (BSS), any 20 MHz channel other than the primary 20 MHz channel.

physical layer (PHY) protocol data unit (PPDU): The unit of data exchanged between two peer PHY entities to provide the PHY data service. When the PHY is partitioned into physical layer convergence protocol (PLCP) and physical medium dependent (PMD) sublayers, the format of the PPDU is defined by the PLCP.

primary 20 MHz channel: In a 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz very high throughput (VHT) basic service set (BSS), the 20 MHz channel that is used to transmit 20 MHz physical layer (PHY) protocol data units (PPDUs). In a VHT BSS, the primary 20 MHz channel is also the primary channel.

primary 40 MHz channel: In an 80 MHz, 160 MHz, or 80+80 MHz very high throughput (VHT) basic service set (BSS), the 40 MHz channel that is used to transmit 40 MHz physical layer (PHY) protocol data units (PPDUs).

primary 80 MHz channel: In a 160 MHz or 80+80 MHz very high throughput (VHT) basic service set (BSS), the 80 MHz channel that is used to transmit 80 MHz physical layer (PHY) protocol data units (PPDUs).

primary access category (AC): The access category (AC) associated with the enhanced distributed channel access function (EDCAF) that gains channel access.

secondary 20 MHz channel: In a 40 MHz very high throughput (VHT) basic service set (BSS), the 20 MHz channel adjacent to the primary 20 MHz channel that together form the 40 MHz channel of the 40 MHz VHT BSS. In an 80 MHz VHT BSS, the 20 MHz channel adjacent to the primary 20 MHz channel that together form the primary 40 MHz channel of the 80 MHz VHT BSS. In a 160 MHz or 80+80 MHz VHT BSS, the 20 MHz channel adjacent to the primary 20 MHz channel that together form the primary 40 MHz channel of the 160 MHz or 80+80 MHz VHT BSS. In a VHT BSS, the secondary 20 MHz channel is also the secondary channel.

secondary 40 MHz channel: In an 80 MHz very high throughput (VHT) basic service set (BSS), the 40 MHz channel adjacent to the primary 40 MHz channel that together form the 80 MHz channel of the 80 MHz VHT BSS. In a 160 or 80+80 MHz VHT BSS, the 40 MHz channel adjacent to the primary 40 MHz channel that together form the primary 80 MHz channel.

secondary 80 MHz channel: In a 160 MHz or 80+80 MHz very high throughput (VHT) basic service set (BSS), the 80 MHz channel not including the primary 20 MHz channel, that together with the primary 80 MHz channel forms the 160 MHz or 80+80 MHz channel of the 160 MHz or 80+80 MHz VHT BSS.

secondary access category (AC): An access category (AC) that is not associated with the enhanced distributed channel access function (EDCAF) that gains channel access.

NOTE—Traffic associated with a secondary AC can be included in a multi-user (MU) physical layer (PHY) protocol data unit (MU PPDU) that includes traffic associated with the primary AC. There could be multiple secondary ACs at a given time.

user: An individual or group of stations (STAs) identified by a single receive address (RA) in the context of single-user multiple input, multiple output (SU-MIMO) or multi-user multiple input, multiple output (MU-MIMO).

very high throughput (VHT) basic service set (BSS): A BSS in which a Beacon frame transmitted by a VHT station (STA) includes the VHT Operation element.

very high throughput (VHT) beamformee: A VHT station (STA) that receives a VHT physical layer (PHY) protocol data unit (PPDU) that was transmitted using a beamforming steering matrix and that supports the VHT transmit beamforming feedback mechanism as described in 9.31.5.

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

very high throughput modulation and coding scheme (VHT-MCS): A specification of the VHT physical layer (PHY) parameters that consists of modulation order (e.g., BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM) and forward error correction (FEC) coding rate (e.g., 1/2, 2/3, 3/4, 5/6) and that is used in a VHT PHY protocol data unit (PPDU).

very high throughput (VHT) multi-user (MU) physical layer (PHY) protocol data unit (PPDU): A VHT PPDU with a format that is capable of carrying up to four PHY service data units (PSDUs) for up to four users and is transmitted using the downlink multi-user multiple input, multiple output (DL-MU-MIMO) technique.

very high throughput (VHT) physical layer (PHY) protocol data unit (PPDU): A PPDU transmitted with the TXVECTOR parameter FORMAT equal to VHT.

very high throughput (VHT) single medium access control (MAC) protocol data unit (VHT single MPDU): An MPDU that is the only MPDU in an aggregate MPDU (A-MPDU) carried in a VHT physical layer (PHY) protocol data unit (PPDU) and that is carried in an A-MPDU subframe with the EOF subfield of the MPDU delimiter field equal to 1.

very high throughput (VHT) single-user-only (SU-only) beamformee: A VHT beamformee that does not receive VHT multi-user (MU) physical layer (PHY) protocol data units (PPDUs).

very high throughput (VHT) single-user-only (SU-only) beamformer: A VHT beamformer that does not transmit VHT multi-user (MU) physical layer (PHY) protocol data units (PPDUs).

very high throughput (VHT) single-user (SU) physical layer (PHY) protocol data unit (PPDU): A VHT PPDU transmitted with the TXVECTOR parameters FORMAT equal to VHT and GROUP_ID equal to 0 or 63.

3.3 Abbreviations and acronyms

Change the following abbreviation in 3.3:

PPDU	PLCP protocol data unit <u>or PHY protocol data unit</u>
------	--

Insert the following abbreviations into 3.3 in alphabetic order:

BW	bandwidth
DL-MU-MIMO	downlink multi-user multiple input, multiple output
EOF	end-of-frame
GCMP	Galois Counter Mode Protocol
GID	group identifier
MU	multi-user
MU-MIMO	multi-user multiple input, multiple output
NSS	number of spatial streams
STF	Short Training field

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SU	single-user
SU-MIMO	single-user multiple input, multiple output
VHT	very high throughput

4. General description

4.3 Components of the IEEE 802.11 architecture

4.3.4 Distribution system (DS) concepts

4.3.4.3 Robust security network association (RSNA)

Change the first paragraph of 4.3.4.3 as follows:

An RSNA defines a number of security features in addition to wired equivalent privacy (WEP) and IEEE 802.11 authentication. These features include the following:

- Enhanced authentication mechanisms for STAs
- Key management algorithms
- Cryptographic key establishment
- Enhanced data cryptographic encapsulation mechanisms, such as Counter mode with Cipher-block chaining Message authentication code Protocol (CCMP), Galois Counter Mode Protocol (GCMP), and, optionally, Temporal Key Integrity Protocol (TKIP).
- Fast basic service set (BSS) transition (FT) mechanism
- Enhanced cryptographic encapsulation mechanisms for robust management frames

Insert the following subclause, 4.3.10a, after 4.3.10:

4.3.10a Very high throughput (VHT) STA

This subclause summarizes the normative requirements for an IEEE 802.11 VHT STA stated elsewhere in this standard.

The IEEE 802.11 VHT STA operates in frequency bands below 6 GHz excluding the 2.4 GHz band.

A VHT STA is an HT STA that, in addition to features supported as an HT STA, supports VHT features identified in Clause 8, Clause 9, Clause 10, Clause 13, Clause 18, and Clause 22.

The main PHY features in a VHT STA that are not present in an HT STA are the following:

- Mandatory support for 40 MHz and 80 MHz channel widths
- Mandatory support for VHT single-user (SU) PPDU
- Optional support for 160 MHz and 80+80 MHz channel widths
- Optional support for VHT sounding protocol to support beamforming
- Optional support for VHT multi-user (MU) PPDU
- Optional support for VHT-MCSs 8 and 9

The main MAC features in a VHT STA that are not present in an HT STA are the following:

- Mandatory support for the A-MPDU padding of a VHT PPDU
- Mandatory support for VHT single MPDU
- Mandatory support for responding to a bandwidth indication (provided by the RXVECTOR parameters CH_BANDWIDTH_IN_NON_HT and DYN_BANDWIDTH_IN_NON_HT) in a non-HT and non-HT duplicate RTS frame
- Optional support for MPDUs of up to 11 454 octets

- Optional support for A-MPDU pre-end-of-frame (pre-EOF) padding (see 9.12.2 (A-MPDU length limit rules)) of up to 1 048 575 octets
- Optional support for VHT link adaptation

Most VHT features, among other benefits, increase the maximum throughput achievable between two VHT STAs over that achievable using HT features alone. The VHT features are available to VHT STAs associated with a VHT AP in a BSS. A subset of the VHT features is available for use between two VHT STAs that are members of the same IBSS. Similarly, a subset of the VHT features is available for use between two VHT STAs that have established mesh peering. A subset of the VHT features is available for use between two VHT STAs that have established a TDLS link.

The support for VHT transmit beamforming sounding and VHT MU PPDU in a VHT AP and more than one VHT STA within a VHT BSS enables the optional use of downlink MU multiple input, multiple output (DL-MU-MIMO). With DL-MU-MIMO the AP can create up to four A-MPDUs, each carrying MPDUs destined for an associated MU-capable STA. The AP uses group identifiers (GIDs) to signal potential recipient STAs. The AP transmits the A-MPDUs simultaneously in separate space-time streams such that each recipient STA is able to demodulate the space-time streams carrying its A-MPDU. The simultaneous transmission of A-MPDUs in a single VHT MU PPDU provides a means to increase aggregate throughput over that achieved by sending the A-MPDUs in separate SU PPDU.

The use of certain HT features, such as RIFS, is not permitted for STAs operating as VHT STAs.

4.5 Overview of the services

4.5.4 Access control and data confidentiality services

4.5.4.1 General

Change the last paragraph of 4.5.4.1 as follows:

An RSNA uses the IEEE 802.1X authentication service along with enhanced data cryptographic encapsulation mechanisms, such as TKIP, ~~and CCMP~~, and GCMP to provide access control. The IEEE 802.11 station management entity (SME) provides key management via an exchange of IEEE 802.1X EAPOL-Key frames. Data confidentiality and data integrity are provided by RSN key management together with the enhanced data cryptographic encapsulation mechanisms.

4.5.4.7 Replay detection

Change 4.5.4.7 as follows:

The replay detection mechanism defines a means by which a STA that receives a data or protected Robust Management frame from another STA can detect whether the received frame is an unauthorized retransmission. This replay protection mechanism is provided for data frames for STAs that use enhanced data cryptographic encapsulation mechanisms. The replay protection mechanism is also provided for robust management frames for STAs that use CCMP, GCMP, and Broadcast/Multicast Integrity Protocol (BIP).

4.5.4.9 Robust management frame protection

Change the second and third paragraphs of 4.5.4.9 as follows:

Management frame protection protocols in an infrastructure BSS or IBSS apply to robust management frames after RSNA PTK establishment for protection of individually addressed frames is completed and

after delivery of the GTK to protect group addressed frames. Robust management frame protection is implemented by CCMP, GCMP, BIP, and the SA Query procedure.

Management frame protection protocols in an MBSS apply to individually addressed frames after establishment of the RSNA MTK, and to group addressed frames indicated as “Group Addressed Privacy” in Table 8-38. Robust management frame protection is implemented ~~by~~ with CCMP and GCMP.

4.9 Reference model

4.9.1 General

Insert the following paragraph after the first paragraph of 4.9.1:

The description of the VHT PHY in Clause 22 is provided as one layer and is not separated into PLCP and PMD sublayers.

5. MAC service definition

5.1 Overview of MAC services

5.1.2 Security services

Change the first, second, and fifth paragraphs of 5.1.2 as follows:

Security services in IEEE Std 802.11 are provided by the authentication service and the CCMP, GCMP, and BIP mechanisms. The scope of the security services provided is limited to station-to-station data and robust management frame transmissions. When CCMP or GCMP is used, the data confidentiality service is provided for data frames and individually addressed robust management frames. For the purposes of this standard, CCMP and GCMP ~~are~~ is viewed as ~~a~~-logical services located within the MAC sublayer as shown in the reference model, Figure 4-14 (in 4.9). Actual implementations of CCMP and GCMP are transparent to the LLC and other layers above the MAC sublayer.

The security services provided by CCMP and GCMP in IEEE Std 802.11 are as follows:

- a) Data Confidentiality;
- b) Authentication; and
- c) Access control in conjunction with layer management.

BIP provides message integrity and access control for group addressed robust management frames.

During the authentication exchange, both parties exchange authentication information as described in Clause 11 and Clause 12.

The MAC sublayer security services provided by CCMP, GCMP, and BIP rely on information from nonlayer-2 management or system entities. Management entities communicate information to CCMP, GCMP, and BIP through a set of MAC sublayer management entity (MLME) interfaces and MIB attributes; in particular, the decision tree for CCMP, GCMP, and BIP defined in 11.8 is driven by MIB attributes.

5.2 MAC data service specification

5.2.2 MA-UNITDATA.request

5.2.2.2 Semantics of the service primitive

Change the fifth paragraph of 5.2.2.2 as follows:

The data parameter specifies the MSDU to be transmitted by the MAC sublayer entity. ~~For IEEE Std 802.11,~~
~~¶The length of the MSDU shall be less than or equal to the value shown in Table 8-0a.~~ Table 8-13c.

6. Layer management

6.1 Overview of management model

Insert the following paragraph after the third paragraph of 6.1:

The description of the VHT PHY in Clause 22 is provided as one layer and is not separated into PLCP and PMD sublayers.

6.3 MLME SAP interface

6.3.3 Scan

6.3.3.3 MLME-SCAN.confirm

6.3.3.3.2 Semantics of the service primitive

Insert the following rows at the end of the untitled table describing BSSDescriptions in 6.3.3.3.2:

Name	Type	Valid range	Description	IBSS adoption
VHT Capabilities	As defined in frame format	As defined in 8.4.2.160	The values from the VHT Capabilities element. The parameter is present if dot11VHTOptionImplemented is true and a VHT Capabilities element was present in the Probe Response or Beacon frame from which the BSSDescription was determined. The parameter is not present otherwise.	Do not adopt
VHT Operation	As defined in frame format	As defined in 8.4.2.161	The values from the VHT Operation element. The parameter is present if dot11VHTOptionImplemented is true and a VHT Operation element was present in the Probe Response or Beacon frame from which the BSSDescription was determined. The parameter is not present otherwise.	Adopt

6.3.4 Synchronize

6.3.4.2 MLME-JOIN.request

6.3.4.2.2 Semantics of the service primitive

Change the primitive parameter list in 6.3.4.2.2 as follows:

The primitive parameters are as follows:

MLME-JOIN.request(
 SelectedBSS,
 JoinFailureTimeout,
 ProbeDelay,
 OperationalRateSet,
 HTOperationalMCSSet,

OperationalVHTMCS_NSSSet
VendorSpecificInfo
)

Insert the following row before the VendorSpecificInfo row in the parameter table in 6.3.4.2.2:

Name	Type	Valid range	Description
OperationalVHTMCS_NSSSet	Set of <VHT-MCS, NSS> tuples, constrained so that the MCS values are expressible using the encoding described for the Supported VHT-MCS and NSS Set field in 8.4.2.160.3	As defined in the Rx VHT-MCS Map and Rx Highest Supported Long GI Data Rate subfields in the Supported VHT-MCS and NSS Set field in 8.4.2.160.3	The set of VHT-MCS values for each number of spatial streams that the STA desires to use for communication within the BSS. This set is a superset of the <VHT-MCS, NSS> tuples in the BSS basic VHT-MCS and NSS set (see 10.39.7). The parameter is present if dot11VHTOptionImplemented is true and not present otherwise.

6.3.4.2.4 Effect of receipt

Insert the following paragraph at the end of 6.3.4.2.4:

If the MLME of a VHT STA receives an MLME-JOIN.request primitive with a SelectedBSS parameter containing a BSSDescription with a Basic VHT-MCS and NSS Set field in the VHT Operation element that contains any unsupported <VHT-MCS, NSS> tuple, the MLME response in the resulting MLME-JOIN.confirm primitive shall contain a ResultCode parameter that is not set to the value SUCCESS.

6.3.7 Associate

6.3.7.2 MLME-ASSOCIATE.request

6.3.7.2.2 Semantics of the service primitive

Change the primitive parameter list in 6.3.7.2.2 as follows:

The primitive parameters are as follows:

MLME-ASSOCIATE.request(
 PeerSTAAddress,
 AssociateFailureTimeout,
 CapabilityInformation,
 ListenInterval,
 Supported Channels,
 RSN,
 QoSCapability,
 Content of FT Authentication elements,
 SupportedOperatingClasses,
 HT Capabilities,
 Extended Capabilities,
 20/40 BSS Coexistence,
 QoSTrafficCapability,
 TIMBroadcastRequest,
 EmergencyServices,
 DMG Capabilities,
 Multi-band local,
 Multi-band peer,
 MMS,

VHT Capabilities,
VendorSpecificInfo
)

Insert the following row before the VendorSpecificInfo row in the parameter table in 6.3.7.2.2:

Name	Type	Valid range	Description
VHT Capabilities	As defined in VHT Capabilities element	As defined in 8.4.2.160	Specifies the parameters in the VHT Capabilities element that are supported by the STA. The parameter is present if dot11VHTOptionImplemented is true and not present otherwise.

6.3.7.3 MLME-ASSOCIATE.confirm

6.3.7.3.2 Semantics of the service primitive

Change the primitive parameter list in 6.3.7.3.2 as follows:

The primitive parameters are as follows:

```
MLME-ASSOCIATE.confirm(
    ResultCode,
    CapabilityInformation,
    AssociationID,
    SupportedRates,
    EDCAPParameterSet,
    RCPI.request,
    RSNl.request,
    RCPI.response,
    RSNl.response,
    RMEEnabledCapabilities,
    Content of FT Authentication elements,
    SupportedOperatingClasses,
    HT Capabilities,
    Extended Capabilities,
    20/40 BSS Coexistence,
    TimeoutInterval,
    BSSMaxIdlePeriod,
    TIMBroadcastResponse,
    QoSMapSet,
    QMFPolicy,
    DMG Capabilities,
    Multi-band local,
    Multi-band peer,
    MMS,
    VHT Capabilities,
    VendorSpecificInfo
)
```