IEEE P802.11ax™/D1.0, November 2016
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IEEE P802.11ah™/D9.0,
IEEE P802.11aq™/D3.0,
IEEE P802.11ak™/D2.0,
and IEEE P802.11aj™/D3.0)

IEEE P802.11ax™/D1.0

Draft 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 6: Enhancements for High Efficiency WLAN

Prepared by the 802.11 Working Group of the

LAN/MAN Standards Committee
of the
IEEE Computer Society

Abstract: This amendment defines modifications to both the IEEE 802.11 physical layer (PHY) and the medium access control (MAC) sublayer for high efficiency operation in frequency bands between 1 GHz and 6 GHz.

Keywords: high efficiency, PHY, physical layer, MAC, medium access control, OFDMA, orthogonal frequency division multiple access, wireless local area network, WLAN

Introduction

This introduction is not part of IEEE P802.11ax /D1.0, November 2016, IEEE Standard for Information technology—Telecommunications and information exchange between systems—Local and metropolitan area network—Specific requirements—Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications—Amendment 6: Enhancements for High Efficiency WLAN.

This amendment defines modifications to both the IEEE 802.11 physical layer (PHY) and the medium access control (MAC) sublayer for high efficiency operation in frequency bands between 1 GHz and 6 GHz.

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

Amendment 6: Enhancements for High Efficiency WLAN

[This amendment is based on IEEE P802.11REVmc/D8.0 amended by IEEE P802.11ai/D10.0, IEEE P802.11ah/D9.0, IEEE P802.11aq/D3.0, IEEE P802.11ak/D2.0 and IEEE P802.11aj/D3.0]

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Table 1—Draft Status

Draft	Date	Status
D0.1	2016-03-03	Converted to FrameMaker from 16/0024r1 Proposed draft specification
D0.2	2016-06-06	Includes tentative resolutions for most editorials. Includes resolutions for technical comments motioned in May 2016 session.
D0.3	2016-08-11	Includes resolutions for technical comments motioned in July 2016 session.
D0.4	2016-08-26	Included motioned draft changes from July 2016 session and corrected errors
D0.5	2016-09-30	Included comment resolutions and other changes motioned at the September 2016 session
D1.0	2016-11-30	Includes all approved changes. Ready for WG ballot.

3. Definitions, acronyms, and abbreviations

3.2 Definitions specific to IEEE 802.11

Change the following definitions:

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

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

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

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 19 (High Throughput (HT) PHY specification).

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 21 (Very High Throughput (VHT) PHY specification).

e) A Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) PPDU transmitted by a VHT STA using the transmit spectral mask defined in Clause 21 (Very High Throughput (VHT) PHY specification).

f) An 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 21 (Very High Throughput (VHT) PHY specification).

g) An high efficiency (HE) PPDU with with TXVECTOR parameter CH_BANDWIDTH equal to CBW20 transmitted using the 20 MHz transmit spectral mask defined in Clause 28 (High Efficiency (HE) PHY specification).

20 MHz physical layer (PHY) protocol data unit (PPDU): A Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) PPDU, Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) PPDU (when using 20 MHz channel spacing), Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) PPDU, Clause 18 (Extended Rate PHY (ERP) specification) orthogonal frequency division multiplexing (OFDM) PPDU, Clause 19 (High Throughput (HT) PHY specification) 20 MHz high throughput (HT) PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW20, or Clause 21 (Very High Throughput (VHT) PHY specification(11ac)) 20 MHz very high throughput (VHT) PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to CBW20, or Clause 28 (High Efficiency (HE) PHY specification) 20 MHz high efficiency (HE) PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to CBW20.

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

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 19 (High Throughput (HT) PHY specification).

b) 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 19 (High Throughput (HT) PHY specification).

c) 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 21 (Very High Throughput (VHT) PHY specification).

d) 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 19 (High Throughput (HT) PHY specification).

e) 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 21 (Very High Throughput (VHT) PHY specification).

f) 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 21 (Very High Throughput (VHT) PHY specification).

g) 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 21 (Very High Throughput (VHT) PHY specification).

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

i) 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 21 (Very High Throughput (VHT) PHY specification).

j) A 40 MHz high efficiency (HE) PPDU with with TXVECTOR parameter CH_BANDWIDTH equal to CBW40 transmitted using the 40 MHz transmit spectral mask defined in Clause 26 (High Efficiency (HE) PHY specification).

k) A 40 MHz HT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to HT_CBW40) transmitted by a HE STA using the 40 MHz transmit spectral mask defined in Clause 28 (High Efficiency (HE) PHY specification).

l) A 40 MHz VHT PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW40) transmitted by a HE STA using the 40 MHz transmit spectral mask defined in Clause 28 (High Efficiency (HE) PHY specification).

m) A 40 MHz non-HT duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW40) transmitted by a HE (HE) STA using the 40 MHz transmit spectral mask defined in Clause 28 (High Efficiency (HE) PHY specification).

40 MHz physical layer (PHY) 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), or a 40 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW40)), or Clause 28 (High Efficiency (HE) PHY specification) 40 MHz high efficiency (HE) PPDU with the TXVECTOR parameter CH_BANDWIDTH equal to CBW40.

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 21 (Very High Throughput (VHT) PHY specification) and that is one~~ One of the following:

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

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

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

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

e) An 80 MHz high efficiency (HE) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80) using the 80 MHz transmit spectral mask defined in Clause 28 (High Efficiency (HE) PHY specification).

f) f) An 80 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80) using the 80 MHz transmit spectral mask defined in Clause 28 (High Efficiency (HE) PHY specification).

g) g) An 80 MHz non-high throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80) using the 80 MHz transmit spectral mask defined in Clause 28 (High Efficiency (HE) PHY specification).

80 MHz physical layer (PHY) protocol data unit (PPDU): A Clause 21 (Very High Throughput (VHT) PHY specification) 80 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80) or, a Clause 21 (Very High Throughput (VHT) PHY specification) 80 MHz non-high throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80), or Clause 28 (High Efficiency (HE) PHY specification) 80 MHz high efficiency (HE) PPDU with the 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 21 (Very High Throughput (VHT) PHY specification(11ac)) and that is one~~ One of the following:

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

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

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

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

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

f) A 160 MHz high efficiency (HE) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW160) using the 160 MHz transmit spectral mask defined in Clause 28 (High Efficiency (HE) PHY specification)

g) A 160 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW160) using the 160 MHz transmit spectral mask defined in Clause 28 (High Efficiency (HE) PHY specification)

h) A 160 MHz non-high throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW160) using the 160 MHz transmit spectral mask defined in Clause 28 (High Efficiency (HE) PHY specification)

160 MHz physical layer (PHY) protocol data unit (PPDU): A Clause 21 (Very High Throughput (VHT) PHY specification) 160 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW160) or, a Clause 21 (Very High Throughput (VHT) PHY specification)

160 MHz non-high throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW160) or Clause 28 (High Efficiency (HE) PHY specification) 160 MHz high efficiency (HE) PPDU with the (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 21 (Very High Throughput (VHT) PHY specification) and that is one~~ One of the following:

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

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

c) An 80+80 MHz high efficiency (HE) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80+80) using the 80+80 MHz transmit spectral mask defined in Clause 28 (High Efficiency (HE) PHY specification)

d) An 80+80 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80+80) using the 80+80 MHz transmit spectral mask defined in Clause 28 (High Efficiency (HE) PHY specification)

e) An 80+80 MHz non-high throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80+80) using the 80+80 MHz transmit spectral mask defined in Clause 28 (High Efficiency (HE) PHY specification)

80+80 MHz physical layer (PHY) protocol data unit (PPDU): A Clause 21 (Very High Throughput (VHT) PHY specification) 80+80 MHz very high throughput (VHT) PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80+80) or, a Clause 21 (Very High Throughput (VHT) PHY specification) 80+80 MHz non-high throughput (non-HT) duplicate PPDU (TXVECTOR parameter CH_BANDWIDTH equal to CBW80+80)) or Clause 28 (High Efficiency (HE) PHY specification) 80+80 MHz high efficiency (HE) PPDU with the (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) or an high efficiency (HE) 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.

Insert the following definitions maintaining alphabetical order:

high efficient (HE) dual beacon: A BSS transmits beacons in two PHY modes, in non-HE format and in HE extended range PHY format. The beacons transmitted in HE_EXT_SU PHY format enables BSS discoverability and BSS operating parameters distribution in the whole BSS coverage.

non-orthogonal frequency division multiple access (non-OFDMA): A full bandwidth HE transmission with 242-tone RU, 484-tone RU, 996-tone RU, 2×996-tone RU, or 2×996-tone RU allocated for 20 MHz, 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz transmission, respectively.

target wake time (TWT) scheduling STA: A STA that schedules broadcast TWTs and provides these schedules in a broadcast TWT element.

target wake time (TWT) scheduled STA: A STA that follows the schedules provided in a broadcast TWT element.

3.4 Abbreviations and acronyms

Insert the following acronym definitions (maintaining alphabetical order):

DCM	Dual carrier modulation
DL	Downlink
DL MU	Downlink multi-user
HE	High efficiency
OBO	Orthogonal frequency division multiple access (OFDMA) backoff
OCW	Orthogonal frequency division multiple access (OFDMA) contention window
OFDMA	Orthogonal frequency-division multiple access
OMI	Operation mode indication
PPE	PHY padding extension
MU-RTS	Multi-user request to send
UL	Uplink
UL MU	Uplink multi-user

4. General description

4.3 Components of the IEEE Std 802.11 architecture

Insert a new subclause after subclause 4.3.12 as follows:

4.3.14a High efficiency (HE) STA

The IEEE 802.11 HE STA operates in frequency bands between 1 GHz and 6 GHz.

In the 5 GHz band, the following apply:

— An HE AP is also a VHT AP
— An HE non-AP STA supporting 20 MHz, 40 MHz, 80 MHz, 160 MHz and 80+80 MHz is also a VHT non-AP STA
— An HE non-AP STA shall support operation in 20 MHz channel bandwidth only

In the 2.4 GHz band, the following apply:

— An HE non-AP STA is also an HT non-AP STA
— An HE non-AP STA shall support operation in 20 MHz channel bandwidth only

The main PHY features in an HE STA that are not present in VHT STA or HT non-AP STA are the following:

— Mandatory support for DL and UL OFDMA
— Mandatory support for 26-, 52-, 106-, 242-tone RUs in a 20 MHz channel
— Mandatory support for 26-, 52-, 106-, 242- and 484-tone RUs in a 40 MHz channel
— Mandatory support for 26-, 52-, 106-, 242-, 484- and 996-tone RUs in an 80 MHz channel
— Mandatory support for 26-, 52-, 106-, 242-, 484-, 996- and 2x996-tone RUs in a 160 MHz channel
— Mandatory support for DL MU-MIMO by an HE AP that supports 4 or more spatial streams when MU-MIMO is done on the entire PPDU bandwidth
— Optional support for 1024-QAM on 242-, 484- and 996-tone RUs
— Optional support for the HE sounding protocol to support beamforming
— Optional support for HE-MCSs 10 and 11

The main MAC features in an HE STA that are not present in VHT STA or HT non-AP STA are the following:

— Mandatory support for the basic trigger frame.
— Mandatory support for dynamic fragmentation level 0
— Optional support for Multi-STA BlockAck
— Optional support for target wake up time (TWT) operation
— Optional support for OFDMA-based random access

An HE AP uses the Trigger frame to initiate MU OFDMA or MU-MIMO transmissions in the UL direction. The Trigger frame identifies non-AP STAs participating in the MU UL transmissions and assigns transmission resources. Multi-STA BlockAck frames are used by the AP to acknowledge the transmissions from multiple non-AP STAs. Scheduled Trigger frames are sent by the AP to allow for non-AP STA power save. The Trigger frames schedule may be set between the non-AP STA and the AP using TWT operation.

6. Layer management

6.1 Overview of management model

6.2 Generic management primitives

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 BSSDescription table:

Name	Type	Valid range	Description	IBSS adoption
HE Capabilities	As defined in frame format	As defined in 9.4.2.218 (HE Capabilities element)	Specifies the parameters within the HE Capabilities element that are supported by the STA. The parameter is present if dot11HEOptionImplemented is true; otherwise, this parameter is not present.	Do not adopt
HE Operation	As defined in frame format	As defined in 9.4.2.219 (HE Operation element)	Specifies the parameters within the HE Operation element that are supported by the AP. The parameter is present if dot11HEOptionImplemented is true.	Adopt

6.3.4 Synchronization

6.3.4.2 MLME-JOIN.request

6.3.4.2.2 Semantics of the service primitive

Change the primitive parameters as follows (note that not all existing parameters in the baseline are shown):

The primitive parameters are as follows:

MLME-JOIN.request(
...
AdvertisementProtocolInfo,
<u>HE Capabilities,</u>
VendorSpecificInfo
)

Insert the following entry into the unnumbered table in this subclause:

Name	Type	Valid range	Description
HE Capabilities	As defined in HE Capabilities element.	As defined in 9.4.2.218 (HE Capabilities element)	Specifies the parameters within the HE Capabilities element that are supported by the STA. The parameter is present if dot11HEOptionImplemented is true; otherwise, this parameter is not present.

6.3.7 Associate

6.3.7.4 MLME-ASSOCIATE.indication

6.3.7.4.2 Semantics of the service primitive

Change the primitive parameters as follows (not all existing parameters in the baseline are shown):

The primitive parameters are as follows:

MLME-ASSOCIATE.indication(
...,
<u>HE Capabilities,</u>
VendorSpecificInfo
)

Insert the following entry into the unnumbered table in this subclause:

Name	Type	Valid range	Description
HE Capabilities	As defined in HE Capabilities element.	As defined in 9.4.2.218 (HE Capabilities element)	Specifies the parameters within the HE Capabilities element that are supported by the peer STA. The parameter is present if it is present in the Association Request frame received from the STA; otherwise, this parameter is not present.

6.3.8 Reassociate

6.3.8.4 MLME-REASSOCIATE.indication

6.3.8.4.2 Semantics of the service primitive

Change the primitive parameters as follows (not all existing parameters in the baseline are shown):

The primitive parameters are as follows:

MLME-REASSOCIATE.indication(
...
<u>HE Capabilities,</u>
VendorSpecificInfo
)

Insert the following entry into the unnumbered table in this subclause:

Name	Type	Valid range	Description
HE Capabilities	As defined in HE Capabilities element.	As defined in 9.4.2.218 (HE Capabilities element)	Specifies the parameters within the HE Capabilities element that are supported by the peer STA. The parameter is present if it is present in the Reassociation Request frame received from the STA; otherwise, this parameter is not present.

6.3.11 Start

6.3.11.2 MLME-START.request

6.3.11.2.2 Semantics of the service primitive

Change the primitive parameters as follows (not all existing parameters in the baseline are shown):

MLME-START.request(

...,
HE Capabilities,
HE Operation,
VendorSpecificInfo
)

Insert the following entry into the unnumbered table in this subclause:

Name	Type	Valid range	Description
HE Capabilities	As defined in HE Capabilities element.	As defined in 9.4.2.218 (HE Capabilities element)	Specifies the parameters within the HE Capabilities element that are supported by the MAC entity. The parameter is present if dot11HEOptionImplemented is true; otherwise, this parameter is not present.
HE Operation	As defined in HE Operation element.	As defined in 9.4.2.219 (HE Operation element)	The additional HE capabilities to be advertised for the BSS. The parameter is present if dot11HEOptionImplemented is true; otherwise, this parameter is not present.

6.3.27 Management of direct links

6.3.27.4 6.3.27.4 MLME-DLS.indication

6.3.27.4.2 6.3.27.4.2 Semantics of the service primitive

Change the primitive parameters as follows (not all existing parameters in the baseline are shown):

MLME-DLS.indication(

...,
HE Capabilities,
VendorSpecificInfo
)

Insert the following entry to the unnumbered table in this subclause:

Name	Type	Valid range	Description
HE Capabilities	As defined in HE Capabilities element.	As defined in 9.4.2.218 (HE Capabilities element)	Specifies the parameters within the HE Capabilities element that are supported by the MAC entity. The parameter is optionally present if dot11HEOptionImplemented is true; otherwise, not present.

8. PHY service specification

8.3 Detailed PHY service specifications

8.3.5 PHY SAP detailed service specification

8.3.5.2 PHY-DATA.request

8.3.5.2.2 Semantics of the service primitive

Change the subclause as follows:

The primitive provides the following parameter:

PHY-DATA.request(
DATA
USER_INDEX
STA_INDEX
)

The DATA parameter is an octet of value X'00' to X'FF'.

The USER_INDEX parameter (typically identified as u for a VHT STA; see NOTE 1 at the end of Table 21-1 (TXVECTOR and RXVECTOR parameters)) is present for a VHT MU PPDU and indicates the index of the user in the TXVECTOR to which the accompanying DATA octet applies; otherwise, this parameter is not present.

The STA_INDEX parameter (obtained from STA_ID_LIST in Table 28-1 (TXVECTOR and RXVECTOR parameters) is present for an HE MU PPDU and indicates the index of the user in the TXVECTOR to which the accompanying DATA octet applies; otherwise, this parameter is not present.

8.3.5.3 PHY-DATA.indication

8.3.5.3.2 Semantics of the service primitive

Change the subclause as follows:

The primitive provides the following parameter:

PHY-DATA.request(
DATA
STA_INDEX
)

The DATA parameter is an octet of value X'00' to X'FF'.

The STA_INDEX parameter is present for an HE trigger-based PPDU and indicates the index of the user in the RXVECTOR to which the accompanying DATA octet applies; otherwise, this parameter is not present.

8.3.5.10 PHY-CCARESET.request

8.3.5.10.3 When generated

Insert the following after the 1st paragraph:

This primitive is also generated by the MAC sublayer for the local PHY entity when the conditions are met to perform OBSS_PD-based spatial reuse operation as defined in 27.9.2 (OBSS_PD-based spatial reuse operation).

8.3.5.12 PHY-CCA.indication

8.3.5.12.2 Semantics of the service primitive

Change Table 8-5 (The channel-list parameter elements) as follows:

Table 8-5—The channel-list parameter elements

channel-list element	Meaning
primary	In an HT STA that is not a VHT STA, indicates that the primary 20 MHz channel is busy. In a VHT STA, indicates that the primary 20 MHz channel is busy according to the rules specified in 21.3.18.5.3 (CCA sensitivity for signals occupying the primary 20 MHz channel). In a TVHT STA, indicates that the primary channel is busy according to the rules specified in 22.3.18.6.3 (CCA sensitivity for signals occupying the primary channel). In an HE STA, indicates that the primary 20 MHz channel is busy according to the rules specified in 28.3.17.6.3 (CCA sensitivity for signals occupying the primary 20 MHz channel).
secondary	In an HT STA that is not a VHT STA, indicates that the secondary channel is busy. In a VHT STA, indicates that the secondary 20 MHz channel is busy according to the rules specified in 21.3.18.5.4 (CCA sensitivity for signals not occupying the primary 20 MHz channel). In a TVHT STA, indicates that the secondary channel is busy according to the rules specified in 22.3.18.6.4 (CCA sensitivity for signals not occupying the primary channel). In an HE STA, indicates that the secondary 20 MHz channel is busy according to the rules specified in 28.3.17.6.4 (CCA sensitivity for signals not occupying the primary 20 MHz channel).
secondary40	Indicates that the secondary 40 MHz channel is busy according to the rules specified in 21.3.18.5.4 (CCA sensitivity for signals not occupying the primary 20 MHz channel). In a TVHT STA, indicates that the secondary TVHT_2W channel is busy according to the rules specified in 22.3.18.6.4 (CCA sensitivity for signals not occupying the primary channel). In an HE STA, indicates that the secondary 40 MHz channel is busy according to the rules specified in 28.3.17.6.4 (CCA sensitivity for signals not occupying the primary 20 MHz channel).
secondary80	Indicates that the secondary 80 MHz channel is busy according to the rules specified in 21.3.18.5.4 (CCA sensitivity for signals not occupying the primary 20 MHz channel). In an HE STA, indicates that the secondary 80 MHz channel is busy according to the rules specified in 28.3.17.6.4 (CCA sensitivity for signals not occupying the primary 20 MHz channel).

8.3.5.12.3 When generated

Change the first paragraph as follows:

For Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) to Clause 20 (Directional multi-gigabit (DMG) PHY specification) PHYs, this primitive is generated within aCCATime of the occurrence of a change in the status of the primary channel from channel idle to channel busy or from channel busy to channel idle or when the elements of the channel-list parameter change. For Clause 21 (Very High Throughput (VHT) PHY specification(11ac)) ~~and~~, Clause 22 (Television Very High Throughput (TVHT) PHY specification) and Clause 28 (High Efficiency (HE) PHY specification) PHYs, this primitive is generated when the status of the channel(s) changes from channel idle to channel busy or from channel busy to channel idle or when the elements of the channel-list parameter change. This includes the period of time when the PHY is receiving data. The timing of PHY-CCA.indication primitives related to transitions on secondary channel(s) is PHY specific. Refer to specific PHY clauses for details about CCA behavior for a given PHY.

9. Frame formats

9.2 MAC frame formats

9.2.4 Frame fields

9.2.4.1 Frame Control field

9.2.4.1.3 Type and Subtype subfields

Change the row below and insert a new row immediately after it in Table 9-1 (Valid type and subtype combinations) as follows:

Table 9-1—Valid type and subtype combinations

Type value B3 B2	Type description	Subtype value B7 B6 B5 B4	Subtype description
01	Control	0000~~–0011~~<ANA>	Reserved
01	Control	<ANA>	Trigger

9.2.4.1.8 More Data subfield

Change the 4th and 5th paragraphs as follows:

An AP optionally sets the More Data subfield to 1 in Ack frames sent to a non-DMG non-HE STA and in Ack, BlockAck and Multi-STA BlockAck frames sent to an HE STA from which it has received a frame that contains a QoS Capability element in which the More Data Ack subfield is equal to 1 and that has one or more ACs that are delivery enabled and that is in PS mode to indicate that the AP has a pending transmission for the STA. An HE AP indicates that it can set the More Data subfield to 1 by setting the More Data Ack subfield to 1 in the QoS Info field of frames it transmits.

A TDLS peer STA optionally sets the More Data subfield to 1 in Ack frames sent to a non-HE STA and in Ack, BlockAck, and Multi-STA BlockAck frames sent to an HE STA that has TDLS peer PSM enabled and that has the More Data Ack subfield equal to 1 in the QoS Capability element of its transmitted TDLS Setup Request frame or TDLS Setup Response frame to indicate that it has a pending transmission for the STA. An HE TDLS peer STA indicates that it can set the More Data subfield to 1 by setting the More Data Ack subfield to 1 in the QoS Capability element it transmits.

9.2.4.1.10 +HTC/Order subfield

Change this subclause as follows:

The +HTC/Order subfield is 1 bit in length. It is used for two purposes:

— It is set to 1 in a non-QoS Data frame transmitted by a non-QoS STA to indicate that the frame contains an MSDU, or fragment thereof, that is being transferred using the StrictlyOrdered service class.

— It is set to 1 in a QoS Data or Management frame transmitted with a value of HT_GF, HT_MF, VHT, HE or S1G for the FORMAT parameter of the TXVECTOR to indicate that the frame contains an HT Control field.

— It is set to 1 in an S1G RTS frame to indicate that the intended recipient of the frame has permission to extend the TXOP as described in 10.51.5.4 (Relay-shared TXOP protection mechanisms).

Otherwise, the +HTC/Order field is set to 0.

NOTE—The +HTC/Order field is always set to 0 for frames transmitted by a DMG STA.

9.2.4.5 QoS Control field

9.2.4.5.4 Ack Policy subfield

Change Table 9-9 (Ack Policy subfield in QoS Control field of QoS Data frames) as follows (only relevant row shown):

Table 9-9—Ack Policy subfield in QoS Control field of QoS Data frames

Bits in QoS Control field		Meaning
Bit 5	Bit 6	
0	1	No explicit acknowledgment, ~~or~~ PSMP Ack or MU Ack. When bit 6 of the Frame Control field (see 9.2.4.1.3 (Type and Subtype subfields)) is set to 1: There might be a response frame to the frame that is received, but it is neither the Ack frame nor any Data frame of subtype +CF-Ack. The Ack Policy subfield for QoS CF-Poll and QoS CF-Ack +CF-Poll Data frames is set to this value. When bit 6 of the Frame Control field (see 9.2.4.1.3 (Type and Subtype subfields)) is set to 0: The acknowledgment for a frame indicating PSMP Ack when it appears in a PSMP downlink transmission time (PSMP-DTT) is to be received in a later PSMP uplink transmission time (PSMP-UTT). The acknowledgment for a frame indicating PSMP Ack when it appears in a PSMP-UTT is to be received in a later PSMP-DTT. For a frame that is carried in a DL HE MU PPDU: The Ack Policy subfield for the frame that solicits an immediate response in an HE Trigger-based PPDU is set to this value (MU Ack). The addressed recipient returns an Ack, BlockAck, or Multi-STA BlockAck frame in the HE trigger-based PPDU format after a SIFS period, according to the procedures defined in 10.3.2.11.2 (Acknowledgement procedure for HE MU PPDU in MU format) and 27.5.2 (UL MU operation). NOTE—Bit 6 of the Frame Control field (see 9.2.4.1.3 (Type and Subtype subfields)) indicates the absence of a data Frame Body field. When equal to 1, the QoS Data frame contains no Frame Body field, and any response is generated in response to a QoS CF-Poll or QoS CF-Ack +CF-Poll frame, but does not signify an acknowledgment of data. When set to 0, the QoS Data frame contains a Frame Body field, which is acknowledged as described in 10.29.2.7 (PSMP acknowledgment rules).

9.2.4.5.6 Queue Size subfield

Change subclause 9.2.4.5.6 as follows:

The Queue Size subfield is an 8-bit field that indicates the amount of buffered traffic for a given TC or TS at the STA sending this frame. A non-AP HE STA uses the Queue Size subfield to indicate the amount of buffered traffic intended for the STA identified by the receive address of the frame containing the QoS Control field. The Queue Size subfield is present in QoS Data and QoS Null frames sent by non-AP STAs with bit 4 of the QoS Control field equal to 1. The AP ~~might~~ can use information contained in the Queue Size subfield to determine the TXOP duration assigned to the STA or to determine the UL resources assigned to the HE STA (see 27.5.2 (UL MU operation)).

The queue size value is the total size, rounded up to the nearest multiple of 256 octets and expressed in units of 256 octets, of all MSDUs and A-MSDUs buffered at the STA (excluding the MSDU or A-MSDU of the present QoS Data frame sent by a non-HE STA and including the MSDUs or A-MSDUs contained in the present (A-)MPDU sent by an HE STA) in the delivery queue used for MSDUs and A-MSDUs with TID values equal to the value in the TID subfield of this QoS Control field. A queue size value of 0 is used solely to indicate the absence of any buffered traffic in the queue used for the specified TID. A queue size value of 254 is used for all sizes greater than 64 768 octets. A queue size value of 255 is used to indicate an unspecified or unknown size. If a QoS Data frame is fragmented and is not carried in an A-MPDU, the queue size value can remain constant in all fragments even if the amount of queued traffic changes as successive fragments are transmitted. If a QoS Data frame is fragmented and is carried in an A-MPDU, the queue size value is set as defined in 10.13.1 (A-MPDU contents).

9.2.4.6 HT Control field

9.2.4.6.1 General

Remove Figure 9-8 (HT Control field).

Insert Table 9-9a as follows:

Table 9-9a—HT Control field

Variant	Bit 0 (value)	Bit 1 (value)	Bit 2-29	Bit 30	Bit 31
HT variant	VHT (0)	HT Control Middle		AC Constraint	RDG/More PPDU
VHT variant	VHT (1)	HE (0)	VHT Control Middle	AC Constraint	RDG/More PPDU
HE variant	VHT (1)	HE (1)	Aggregated Control		

Change the paragraphs below of 9.2.4.6.1 as follows:

The HT Control field has ~~two~~ three forms~~,~~: the HT variant, ~~and~~ the VHT variant, and the HE variant. These forms differ in the values of the VHT and HE subfields and in their formats, which are shown in Table 9-9a (HT Control field). ~~The two forms differ in the format of the HT Control Middle subfield, described in 9.2.4.6.2 (HT variant) for the HT variant and in 9.2.4.6.3 (VHT variant) for the VHT variant and in the value of the VHT subfield.~~

The VHT subfield, which is B0 of the HT Control field, and the HE subfield, which is B1 of the HT Control field, indicate the variant of the HT Control field. The VHT subfield is set to 0 to indicate an HT variant HT Control field. The VHT subfield is set to 1 and the HE subfield is set to 0 to indicate a VHT variant HT Control field. The VHT subfield is set to 1 and the HE subfield is set to 1 to indicate an HE variant HT Control field.

The HT Control Middle subfield is defined in 9.2.4.6.2 (HT variant) and the VHT Control Middle subfield is defined in 9.2.4.6.3 (VHT variant).

The Aggregated Control subfield is defined in 9.2.4.6.4 (A-Control).

~~The VHT subfield of the HT Control field indicates whether the HT Control Middle subfield is the VHT Variant or the HT Variant. The VHT subfield is set to 1 to indicate that the HT Control Middle subfield is the VHT Variant and is set to 0 to indicate that the HT Control Middle subfield is the HT Variant.~~

9.2.4.6.3 VHT variant

Change the paragraph below as follows:

The format of the VHT Control Middle subfield of the VHT variant HT Control field is shown in Figure 9-13 (VHT Control Middle subfield of the VHT variant HT Control field).

Change Figure 9-13 (VHT Control Middle subfield of the VHT variant HT Control field) as follows (remove Reserved field and change title):

	~~B1~~	B2	B3 B5	B6 B8	B9 B23	B24 B26	B27	B28	B29
	~~Reserved~~	MRQ	MSI/ STBC	MFSI/ GID-L	MFB	GID-H	Coding Type	FB Tx Type	Unsolicited MFB
Bits:	~~1~~	1	3	3	15	3	1	1	1

Figure 9-13—VHT Control Middle subfield of the VHT variant HT Control field

Insert a new subclause 9.2.4.6.4 following 9.2.4.6.3:

9.2.4.6.4 A-Control

9.2.4.6.4.1 General

The format of the Aggregated Control (A-Control) subfield of the HE variant HT Control field is shown in Figure 9-15a (Aggregated Control subfield of the HE variant HT Control field).

	Aggregate Control			
	Control 1	...	Control N	Padding
Bits:	4 or more		4 or more	0 or more

Figure 9-15a—Aggregated Control subfield of the HE variant HT Control field

The A-Control subfield contains a sequence of one or more Control subfields. The format of each Control subfield is defined in Figure 9-15b (Control subfield format). The Control subfield with Control ID subfield equal to 0, if present, is the first subfield of the sequence.

The Control ID subfield indicates the type of information carried in the Control Information subfield. The length of the Control Information subfield is fixed for each value of the Control ID subfield that is not

	B0 B3	
	Control ID	Control Information
Bits:	4	variable

Figure 9-15b—Control subfield format

reserved. The values of the Control ID subfield and the associated length of the Control Information subfield are defined in Table 9-18a (Control ID subfield values).

Table 9-18a—Control ID subfield values

Control ID value	Meaning	Length of the Control Information subfield (bits)	Content of the Control Information subfield
0	UL MU response scheduling	26	See 9.2.4.6.4.2 (UL MU response scheduling)
1	Operating Mode	12	See 9.2.4.6.4.3 (Operating Mode)
2	HE link adaptation	16	See 9.2.4.6.4.4 (HE link adaptation)
3	Buffer Status Report (BSR)	26	See 9.2.4.6.4.5 (Buffer Status Report (BSR))
4	UL Power Headroom	8	See 9.2.4.6.4.6 (UL power headroom)
5	Bandwidth Query Report (BQR)	10	See 9.2.4.6.4.7 (Bandwidth Query Report (BQR))
6	Reverse Direction Protocol (RDP)	8	
7-15	Reserved		

The Padding subfield, if present, follows the last Control subfield and is set to a sequence of zeros so that the length of the A-Control subfield carried in the HT Control field is 30 bits.

9.2.4.6.4.2 UL MU response scheduling

If the Control ID subfield is 0, the Control Information subfield contains scheduling information for an HE trigger-based PPDU that carries an immediate acknowledgment and follows the HE MU PPDU containing the Control Information subfield (see 27.5.2.2 (Rules for soliciting UL MU frames)).

The format of the Control Information subfield is defined in Figure 9-15c (Control Information subfield format when Control ID subfield is 0).

The UL PPDU Length subfield indicates the length of the HE trigger-based PPDU response and is set to the number of OFDM symbols the Data field of the HE trigger-based PPDU minus 1. The duration of the HE trigger-based PPDU is calculated as defined in 28.4.2 (TXTIME and PSDU_LENGTH calculation).

The RU Allocation subfield indicates the resource unit (RU) assigned for transmitting the HE trigger-based PPDU response and is defined in 9.3.1.23 (Trigger frame format).

	B0 B4	B5 B12	B13 B17	B18 B22	B23 B24	B25
	UL PPDU Length	RU Allocation	DL Tx Power	UL Target RSSI	UL MCS	Reserved
Bits:	5	8	5	5	2	1

Figure 9-15c—Control Information subfield format when Control ID subfield is 0

The DL TX Power subfield indicates the AP transmit power, combined over all TX antennas and averaged in 20 MHz BW, used for the soliciting frame, in units of dBm. The transmit power, P_{TX}, is calculated as $P_{TX} = -20 + 2 \times F_{Val}$, where F_{Val} is the value of the DL TX Power subfield, except for the value 31, which is reserved.

The UL Target RSSI subfield indicates the AP target receive power, i.e., averaged RSSI over all AP's antennas, for the responding STA when transmitting the HE trigger-based PPDU, in units of dBm. The target receive power, TRSSI, is calculated as $T_{RSSI} = -90 + 2 \times F_{Val}$, except for the value 31 that indicates to the STA to transmit at maximum power for the assigned MCS.

NOTE—It is possible that a STA can not satisfy the target RSSI due to its hardware or regulatory limitation.

The UL MCS subfield indicates the MCS, from MCS0 to MCS3, to be used by the receiving STA for the HE trigger-based PPDU (see 28.5 (Parameters for HE-MCSs)).

9.2.4.6.4.3 Operating Mode

If the Control ID subfield is 1, the Control Information subfield contains information related to the operating mode change of the STA transmitting the frame containing this information (see 27.8 (Operating mode indication)).

The format of the Control Information subfield is defined in Figure 9-15d (Control Information subfield format when Control ID subfield is 1).

	B0 B2	B3 B4	B5	B6 B8	B9 B11
	Rx NSS	Channel Width	UL MU Disable	Tx NSS	Reserved
Bits:	3	2	1	3	3

Figure 9-15d—Control Information subfield format when Control ID subfield is 1

The Rx NSS subfield indicates the maximum number of spatial streams, N_{SS}, that the STA can receive and is set to $N_{SS} - 1$.

The Channel Width subfield indicates the operating channel width supported by the STA in reception, and is set to 0 for 20 MHz, 1 for 40 MHz, 2 for 80 MHz, and 3 for 160 MHz and 80+80 MHz.

The UL MU Disable subfield indicates whether UL MU operation is suspended or resumed by the non-AP STA. The UL MU Disable subfield is set to 1 to indicate that UL MU operation is suspended; otherwise it is set to 0 to indicate that UL MU operation is resumed. An AP sets the UL MU Disable subfield to 0.

The Tx NSS subfield indicates the maximum number of spatial streams, N_{SS}, that the STA can transmit and is set to $N_{SS} - 1$.

9.2.4.6.4.4 HE link adaptation

If the Control ID subfield is 2, the Control Information subfield contains information related to the HE link adaptation procedure (see 9.31.4 (Link adaptation using the HE variant HT Control field)).

The format of the Control Information subfield is defined in Figure 9-15e (Control Information subfield format when Control ID subfield is 2).

	B0 B2	B3 B6	B7 B15
	NSS	HE-MCS	Reserved
Bits:	3	4	9

Figure 9-15e—Control Information subfield format when Control ID subfield is 2

The NSS subfield indicates the recommended number of spatial streams, N_{SS}, and is set to $N_{SS} - 1$.

The HE-MCS subfield indicates the recommended HE-MCS, and is set to the HE-MCS Index value (defined in 28.5 (Parameters for HE-MCSs)).

9.2.4.6.4.5 Buffer Status Report (BSR)

The Control Information subfield, when the Control ID subfield is 3, contains buffer status information used for UL MU operation (see 27.5.2.5 (HE buffer status feedback operation for UL MU)).

The format of the Control Information subfield is defined in Figure 9-15f (Control Information subfield format when Control ID subfield is 3).

	B0 B3	B4 B5	B6 B7	B8 B9	B10 B17	B18 B25
	ACI Bitmap	Delta TID	ACI High	Scaling Factor	Queue Size High	Queue Size All
Bits:	4	2	2	2	8	8

Figure 9-15f—Control Information subfield format when Control ID subfield is 3

The ACI Bitmap subfield indicates the access categories for which the buffer status is reported and its encoding is shown in Table 9-18b (ACI Bitmap subfield encoding). Each bit of the bitmap is set to 1 to indicate that the buffer status of the AC, which ACI is identified by the location of the bit in the ACI Bitmap subfield, is reported and set to 0 otherwise.

Table 9-18b—ACI Bitmap subfield encoding

B0	B1	B2	B3
AC_BE	AC_BK	AC_VI	AC_VO

The Delta TID subfield, together with the values of the AC Bitmap subfield, indicate the number of TIDs for which the STA is reporting the buffer status. The encoding of the Delta TID subfield is defined in Table 9-18c (Delta TID subfield encoding).

Table 9-18c—Delta TID subfield encoding

Number of bits in the ACI Bitmap subfield that are set to 1	Mapping of Delta TID subfield value and number of TIDs, N_{TID}
0	Values 0 to 2 are not applicable; Value 3 indicates 8 TIDs (i.e., all ACs have traffic)
1	Value 0 indicates 1 TID; Value 1 indicates 2 TIDs; Values 2 to 3 are not applicable;
2	Value 0 indicates 2 TID; Value 1 indicates 3 TIDs; Value 2 indicates 4 TIDs; Value 3 is not applicable;
3	Value 0 indicates 3 TID; Value 1 indicates 4 TIDs; Value 2 indicates 5 TIDs; Value 3 indicates 6 TIDs;
4	Value 0 indicates 4 TID; Value 1 indicates 5 TIDs; Value 2 indicates 6 TIDs; Value 3 indicates 7 TIDs;
NOTE—The number of TIDs can be obtained as $N_{TID} = N_{ones} + F_{Val}$, where N_{ones} is the number of bits set to one in the AC Bitmap subfield, and F_{Val} is the value of the Delta TID subfield except when N_{ones} is equal to 0 for which there is the $N_{TID} = 8$ case.	

The ACI High subfield indicates the ACI of the AC for which the BSR is indicated in the Queue Size High subfield.

The Scaling Factor subfield indicates the unit *SF*, in octets, of the Queue Size subfields. *SF* is equal to:

16 if the Scaling Factor subfield is 0

128 if the Scaling Factor subfield is 1

2 048 if the Scaling Factor subfield is 2

16 384 if the Scaling Factor subfield is 3

The Queue Size High subfield indicates the amount of buffered traffic, in units of *SF* octets, for the AC identified by the ACI High subfield.

The Queue Size All subfield indicates the amount of buffered traffic, in units of *SF* octets, for all the ACs identified by the ACI Bitmap subfield.

The queue size values in the Queue Size High and Queue Size All subfields are the total sizes, rounded up to the nearest multiple of SF octets, of all MSDUs and A-MSDUs buffered at the STA (including the MSDUs or A-MSDUs contained in the present (A-)MPDU) in the delivery queues used for MSDUs and A-MSDUs with AC(s) that are specified in the ACI High and ACI Bitmap subfields, respectively. A queue size value of 254 is used for all sizes greater than $254 \times SF$ octets. A queue size value of 255 is used to indicate an unspecified or unknown size. If a QoS Data frame is fragmented and is not carried in an A-MPDU, the queue size value can remain constant in all fragments even if the amount of queued traffic changes as successive fragments are transmitted. If a QoS Data frame is fragmented and is carried in an A-MPDU, the queue size values are set according to the rules in 10.9 (HT operation).

9.2.4.6.4.6 UL power headroom

The Control Information subfield, when the Control ID subfield is 4, contains the UL power headroom used for power pre-correction (see 26.3.13.2 (Power pre-correction).

	B0 B5	B6 B7
	UL Power Headroom	Reserved
Bits:	6	2

Figure 9-15g—Control Information subfield format when the Control ID subfield is 4

The 5 LSBs (B0-B4) of the UL Power Headroom subfield indicate the available power headroom in units of dB, for the current MCS. The resolution for the UL power headroom reported in UL Power Headroom subfield is 1 dB. The UL Power Headroom subfield carries a value 0 to 31 that maps to 0 dB to 31 dB. B5 of the UL Power Headroom subfield is set to 1 to indicate that the minimum transmit power for the current MCS is reached by the STA and set to 0 otherwise.

9.2.4.6.4.7 Bandwidth Query Report (BQR)

The Control Information subfield, when the Control ID subfield is 5, contains the Bandwidth Query Report used for Bandwidth Query report operation to assist HE DL HE MU transmission (see 27.5.1.3 (HE bandwidth query report operation for DL MU)).

	B0 B7	B8 B9
	Available Channel Bitmap	Reserved
Bits:	8	2

Figure 9-15h—Control Information subfield format when the Control ID subfield is 5

Bandwidth Query Report used for bandwidth query report operation to assist DL HE MU transmission (see 25.5.1.3. (Bandwidth query report operation).

The Available Channel Bitmap subfield encoding is defined in Table 9-18d (Available Channel Bitmap subfield encoding).

Table 9-18d—Available Channel Bitmap subfield encoding

	B0	B1	B2	B3	B4	B5	B6	B7
20 MHz	Set to 1 if the channel is available, set to 0 otherwise	Set to 0	Set to 0	Set to 0	Set to 0	Set to 0	Set to 0	Set to 0
40 MHz	Set to 1 if the lower frequency 20 MHz channel is available and set to 0 otherwise	Set to 1 if the higher frequency 20 MHz channel is available and set to 0 otherwise	Set to 0	Set to 0	Set to 0	Set to 0	Set to 0	Set to 0
80 MHz	Set to 1 if the lowest frequency 20 MHz channel is available and set to 0 otherwise	Set to 1 if the second lowest frequency 20 MHz channel is available and set to 0 otherwise	Set to 1 if the third lowest frequency 20 MHz channel is available and set to 0 otherwise	Set to 1 if the fourth lowest frequency 20 MHz channel is available and set to 0 otherwise	Set to 0	Set to 0	Set to 0	Set to 0
160 MHz and 80+80 MHz	Set to 1 if the lowest frequency 20 MHz channel of the primary 80 MHz channel is available and set to 0 otherwise	Set to 1 if the second lowest frequency 20 MHz channel of the primary 80 MHz channel is available and set to 0 otherwise	Set to 1 if the third lowest frequency 20 MHz channel of the primary 80 MHz channel is available and set to 0 otherwise	Set to 1 if the fourth lowest frequency 20 MHz channel of the primary 80 MHz channel is available and set to 0 otherwise	Set to 1 if the lowest frequency 20 MHz channel of the secondary 80 MHz channel is available and set to 0 otherwise	Set to 1 if the second lowest frequency 20 MHz channel of the secondary 80 MHz channel is available and set to 0 otherwise	Set to 1 if the third lowest frequency 20 MHz channel of the secondary 80 MHz channel is available and set to 0 otherwise	Set to 1 if the fourth lowest frequency 20 MHz channel of the secondary 80 MHz channel is available and set to 0 otherwise
NOTE—The lowest frequency 20 MHz channel may not be the primary 20 MHz channel. Refer to Figure 8-1 and Figure 8-2 in section 8.3.5.12.2 for details.								

9.2.4.6.4.8 Reverse direction protocol (RDP)

The Control Information subfield for the RDP Trigger frame is shown in Figure 9-15i (Control Information subfield format when the Control ID subfield is 6)

The AC Constraint subfield of the RDP field indicates whether the mapped AC of an RD Data frame is constrained to a single AC, and is defined in Table 9-10 (AC Constraint subfield values), except that a value

	B0	B1	B2 B7
	AC Constraint	RDG/More PPDU	Reserved
Bits:	1	1	6

Figure 9-15i—Control Information subfield format when the Control ID subfield is 6

of 1 indicates that the response from an HE STA contains Data frames from the same AC or higher AC as defined in 10.28.4 (Rules for RD responder).

The RDG/More PPDU subfield is defined in Table 9-11 (RDG/More PPDU subfield values).

9.2.4.7 Frame Body field

9.2.4.7.1 General

Change as Table 9-19 (Maximum data unit sizes (in octets) and durations (in microseconds)) follows:

Table 9-19—Maximum data unit sizes (in octets) and durations (in microseconds)

	Non-HT non-VHT non-DMG PPDU and non-HT duplicate PPDU	HT PPDU	VHT PPDU	HE PPDU	DMG PPDU
MMPDU size	2304	2304	See NOTE 1	See NOTE 1	2304
MSDU size	2304	2304	2304	2304	7920
A-MSDU size	3839 or 4065 (see NOTE 2) (HT STA, see also Table 9-162 (Subfields of the HT Capability Information field)), or N/A (non-HT STA, see also 10.12 (A-MSDU operation))	3839 or 7935 (see also Table 9-162 (Subfields of the HT Capability Information field))	See NOTE 3	See NOTE 3	7935
MPDU size	See NOTE 4	See NOTE 5	3895 or 7991 or 11 454 (see also Table 9-249 (Subfields of the VHT Capabilities Information field))	3895 or 7991 or 11 454 (see also Table 9-249 (Subfields of the VHT Capabilities Information field))	See NOTE 5

Table 9-19—Maximum data unit sizes (in octets) and durations (in microseconds) *(continued)*

	Non-HT non-VHT non-DMG PPDU and non-HT duplicate PPDU	HT PPDU	VHT PPDU	HE PPDU	DMG PPDU
PSDU size (see NOTE 7)	2^{12}–1 (see Table 15-5 (DSSS PHY characteristics), Table 16-4 (HR/DSSS PHY characteristics), Table 17-21 (OFDM PHY characteristics), Table 18-5 (ERP characteristics))	2^{16}–1 (see Table 19-25 (HT PHY characteristics))	4 692 480 (~$2^{22.16}$) (see Table 21-29 (VHT PHY characteristics))	6,500,631 (~$2^{22.63}$) (see Table 28-46 (HE PHY characteristics))	2^{18}–1 (see Table 20-32 (DMG PHY characteristics))
PPDU duration (see NOTE 7)	See NOTE 6	5484 (HT_MF; see 10.26.4 (L_LENGTH and L_DATARATE parameter values for HT-mixed format PPDUs)) or 10 000 (HT_GF; see Table 19-25 (HT PHY characteristics))	5484 (see Table 21-29 (VHT PHY characteristics))	5484 (see Table 21-29 (VHT PHY characteristics))	2000 (see Table 20-32 (DMG PHY characteristics))

NOTE 1—No direct constraint on the maximum MMPDU size; indirectly constrained by the maximum MPDU size (see 9.3.3.1 (Beacon frame format)).

NOTE 2—Indirect constraint from the maximum PSDU size: 2^{12}–1 octets minus the minimum QoS Data frame overhead (26 octets for the MAC header and 4 octets for the FCS).

NOTE 3—No direct constraint on the maximum A-MSDU size; indirectly constrained by the maximum MPDU size.

NOTE 4—No direct constraint on the maximum MPDU size; indirectly constrained by the maximum MSDU/MMPDU or (for HT STAs only) A-MSDU size.

NOTE 5—No direct constraint on the maximum MPDU size; indirectly constrained by the maximum A-MSDU size.

NOTE 6—No direct constraint on the maximum duration, but an L_LENGTH value above 2332 might not be supported by some receivers (see last NOTE in 10.26.4 (L_LENGTH and L_DATARATE parameter values for HT-mixed format PPDUs)).

NOTE 7—The values for maximum PSDU size and maximum PPDU duration are informative only. References to the normative requirements are provided.

9.2.5 Duration/ID field (QoS STA)

9.2.5.2 Setting for single and multiple protection under enhanced distributed channel access (EDCA)

Change item a) of the 2nd paragraph as follows:

The Duration/ID field is determined as follows:

a) Single protection settings.

1) For an RTS frame that is not part of a dual clear-to-send (CTS) exchange and is not part of a BDT exchange, the Duration/ID field is set to the estimated time, in microseconds, required to transmit the pending frame, plus one CTS frame, plus one Ack or BlockAck frame if required, plus any NDPs required, plus explicit feedback if required, plus applicable IFSs.

1a) In an MU-RTS frame, the Duration/ID field is set to the estimated time, in microseconds, required for the pending frame, plus one CTS frame, plus the time for the solicited HE trigger-based PPDU if required, plus the time to transmit an acknowledgement frame for the solicited HE trigger-based PPDU if required, plus applicable IFSs.

...

3 In a BlockAckReq frame, the Duration/ID field is set to the estimated time required to transmit one Ack or BlockAck frame, as applicable, plus one SIFS.

3a In a MU-BAR frame, the Duration/ID field is set to the time required for the solicited HE trigger-based PPDU plus one SIFS.

...

6) In individually addressed QoS Data frames with the Ack Policy subfield equal to No Ack or Block Ack, for Action No Ack frames, and for group addressed frames, the Duration/ID field is set to one of the following:

i) i) If the frame is the final fragment of the TXOP, 0

ii) ii) Otherwise, the estimated time required for the transmission of the following frame and its response frame, if required (including appropriate IFSs)

7) In a Basic Trigger frame, the Duration/ID field is set to the estimated time required to transmit the solicited HE trigger-based PPDU, plus the estimated time required to transmit multiple BlockAck frames, Ack frames or a Multi-STA BlockAck frame, plus applicable SIFSs.

Change item b) of the 2nd paragraph as follows:

b) Multiple protection settings. The Duration/ID field is set to a value D as follows:

4) Else $T_{END-NAV} - T_{PPDU} \le D \le T_{TXOP-REMAINING} - T_{PPDU}$

where

$T_{SINGLE\text{-}MSDU}$ is the estimated time required for the transmission of the allowed frame exchange sequence defined in 10.22.2.8 (TXOP limits) (for a TXOP limit of 0), including applicable IFS durations

$T_{PENDING}$ is the estimated time required for the transmission of

—Pending MPDUs of the same AC

—Any associated immediate response frames

—Any HT NDP, VHT NDP, or Beamforming Report Poll frame transmissions and explicit feedback response frames

—Applicable IFSs

—Any RDG

—Any pending QoS Null frame exchanges by paged STAs

—Any pending PS-Poll or NDP PS-Poll frame exchanges by paged STAs

—Any DL MU PPDUs

—Any HE trigger-based PPDUs

—Any Trigger frames to solicit HE trigger-based PPDUs

T_{TXOP} is the duration given by dot11EDCATableTXOPLimit (dot11QAPEDCATableTXOPLimit for the AP) for that AC

$T_{TXOP\text{-}REMAINING}$ is T_{TXOP} less the time already used time within the TXOP

$T_{END\text{-}NAV}$ is the remaining duration of any NAV set by the TXOP holder, or 0 if no NAV has been established

T_{PPDU} is the time required for transmission of the current PPDU

9.2.5.7 Setting for control response frames

Change as follows:

This subclause describes how to set the Duration/ID field for CTS, Ack, and BlockAck frames transmitted by a QoS STA.

In a CTS frame that is not part of a dual CTS sequence transmitted in response to an RTS frame, the Duration/ID field is set to the value obtained from the Duration/ID field of the RTS frame that elicited the response minus the time, in microseconds, between the end of the PPDU carrying the RTS frame and the end of the PPDU carrying the CTS frame.

<u>In a CTS frame that is transmitted in response to an MU-RTS frame, the Duration/ID field is set to the value obtained from the Duration/ID field of the MU-RTS frame that elicited the CTS frame minus the time, in microseconds, between the end of the PPDU carrying the MU-RTS frame and the end of the PPDU carrying the CTS frame.</u>

In an Ack frame, the Duration/ID field is set to the value obtained from the Duration/ID field of the frame that elicited the response minus the time, in microseconds between the end of the PPDU carrying the frame that elicited the response and the end of the PPDU carrying the Ack frame.

In a BlockAck frame transmitted in response to a BlockAckReq <u>or MU-BAR </u>frame or transmitted in response to a frame containing an implicit block ack request, the Duration/ID field is set to the value obtained from the Duration/ID field of the frame that elicited the response minus the time, in microseconds between the end of the PPDU carrying the frame that elicited the response and the end of the PPDU carrying the BlockAck frame.

<u>In a BlockAck frame transmitted in response to a frame carried in HE trigger-based PPDU, the rule of setting Duration/ID field is described in 9.2.5.2 (Setting for single and multiple protection under enhanced distributed channel access (EDCA)).</u>

9.3 Format of individual frame types

9.3.1 Control frames

9.3.1.2 RTS frame format

Change the 3rd paragraph as follows:

The TA field is the address of the STA transmitting the RTS frame or the bandwidth signaling TA of the STA transmitting the RTS frame. In an RTS frame transmitted by a VHT STA<u> or an HE STA</u> in a non-HT or non-HT duplicate format and where the scrambling sequence carries the TXVECTOR parameters CH_BANDWIDTH_IN_NON_HT and DYN_BANDWIDTH_IN_NON_HT (see 10.3.2.6 (VHT RTS procedure)), the TA field is a bandwidth signaling TA.

9.3.1.3 CTS frame format

Change the 2nd paragraph of this subclause as follows:

When the CTS frame is a response to an RTS frame, the value of the RA field of the CTS frame is set to the address from the TA field of the RTS frame with the Individual/Group bit forced to the value 0. When the CTS frame is a response to an MU-RTS frame, the value of the RA field of the CTS frame is set to the address from the TA field of the MU-RTS frame.

9.3.1.5 PS-Poll frame format

Change the 2nd paragraph as follows:

The BSSID is the address of the STA contained in the AP. The TA field is the address of the STA transmitting the frame or a bandwidth signaling TA. In a PS-Poll frame transmitted by a VHT STA or a HE STA in a non-HT or non-HT duplicate format and where the scrambling sequence carries the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT, the TA field value is a bandwidth signaling TA. The ID field contains the AID value assigned to the STA transmitting the frame by the AP in the (Re)Association Response frame that established that STA's current association, with the two MSBs set to 1.

9.3.1.6 CF-End frame format

Change the last paragraph as follows:

When transmitted by a non-DMG STA, the BSSID (TA) field is the address of the STA contained in the AP except that the Individual/Group bit of the BSSID (TA) field is set to 1 in a CF-End frame transmitted by a VHT STA to a VHT AP or an HE STA to an HE AP in a non-HT or non-HT duplicate format to indicate that the scrambling sequence carries the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT. When transmitted by a DMG STA, the TA field is the MAC address of the STA transmitting the frame.

9.3.1.8 BlockAckReq frame format

9.3.1.8.1 Overview

Change the 4th paragraph as follows:

The TA field value is the address of the STA transmitting the BlockAckReq frame or a bandwidth signaling TA. In a BlockAckReq frame transmitted by a VHT STA or an HE STA in a non-HT or non-HT duplicate format and where the scrambling sequence carries the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT, the TA field value is a bandwidth signaling TA.

9.3.1.8.2 Basic BlockAckReq variant

Change Figure 9-28 as follows:

	B0 B3	B4 B15
	Fragment Number ~~(0)~~	Starting Sequence Number
Bits:	4	12

Figure 9-28—Block Ack Starting Sequence Control subfield

9.3.1.9 BlockAck frame format

9.3.1.9.1 Overview

Change Figure 9-33 as follows:

	B0	~~B1~~	~~B2~~	~~B3~~ ~~B4~~	B1 B4	~~B5~~B6 B11	B12 B15
	BA Ack Policy	~~Multi-TID~~	~~Compressed Bitmap~~	~~GCR Mode~~	BA Type	Reserved	TID_INFO
Bits:	1	~~1~~	~~1~~	~~2~~	4	~~8~~7	4

Figure 9-33—BA Control field

Change the 3rd paragraph as follows:

The RA field of the BlockAck frame that is not a Multi-STA BlockAck variant is ~~the address of the recipient STA that requested the Block Ack~~ set to the TA field of the soliciting frame or the address of the recipient STA whose data/management frames are acknowledged. An HE AP that transmits a Multi-STA BlockAck frame with different values of the AID subfield in Per STA Info subfields sets the RA field to the broadcast address. An HE AP that transmits a Multi-STA BlockAck frame with a single AID subfield or with the same values of the AID subfield in Per STA Info subfields sets the RA field to the address of the recipient STA that requested the Block Ack or to the broadcast address. An HE non-AP STA transmits a Multi-STA BlockAck frame with a single AID subfield or with the same values of the AID subfield in Per STA Info subfields and sets the RA field to the TA field of the soliciting frame or the address of the recipient STA whose data/management frames are acknowledged.

Change the 4th paragraph as follows:

The TA field value is the address of the STA transmitting the BlockAck frame or a bandwidth signaling TA in the context of HT-delayed Block Ack. In a BlockAck frame transmitted in the context of HT-delayed Block Ack by a VHT STA or an HE STA in a non-HT or non-HT duplicate format and where the scrambling sequence carries the TXVECTOR parameter CH_BANDWIDTH_IN_NON_HT, the TA field value is a bandwidth signaling TA.

Change the 6th paragraph of this subclause as follows:

For BlockAck frames sent under Delayed and HT-delayed agreements, the BA Ack Policy subfield of the BA Control field has the meaning shown in Table 9-23 (BA Ack Policy subfield). For BlockAck frames sent under other types of agreement, the BA Ack Policy subfield is reserved. An HE STA does not send a Multi-STA BlockAck frame under Delayed and HT-delayed agreements.

Change Table 9-24 as follows:

Table 9-24—BlockAck frame variant encoding

~~Multi-TID subfield value~~	~~Compressed Bitmap subfield value~~	~~GCR subfield value~~	BA Type (B1 B2 B3 B4)	BlockAck frame variant
~~0~~	~~0~~	~~00~~	0000	Basic BlockAck
		~~01~~	0001	Reserved
		~~10~~	0010	Reserved
		~~11~~	0011	Reserved
~~0~~	~~1~~	~~00~~	0100	Compressed BlockAck
		~~01~~	0101	GLK-GCR BlockAck
		~~10~~	0110	GCR BlockAck
		~~11~~	0111	Reserved
~~1~~	~~0~~	~~00~~	1000	Extended Compressed BlockAck
		~~01~~	1001	Reserved
		~~10~~	1010	Reserved
		~~11~~	1011	Reserved
~~1~~	~~1~~	~~00~~	1100	Multi-TID BlockAck
		~~01~~	1101	~~Reserved~~ Multi-STA BlockAck
		~~10~~	1110	Reserved
		~~11~~	1111	Reserved

Change the 7th paragraph of this subclause as follows:

The ~~values of the Multi-TID, Compressed Bitmap, and GCR~~ BA Type subfield~~s~~ of the BA Control field determines which of the BlockAck frame variants is represented, as indicated in the Table 9-24 (BlockAck frame variant encoding).

9.3.1.9.3 Compressed BlockAck variant

Change subclause 9.3.1.9.3 (including Figure 9-34) as follows:

The TID_INFO subfield of the BA Control field of the Compressed BlockAck frame contains the TID for which this BlockAck frame is sent.

The BA Information field of the Compressed BlockAck frame comprises the Block Ack Starting Sequence Control subfield and the Block Ack Bitmap subfield, as shown in Figure 9-35 (BA Information field (Compressed BlockAck)). The Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield contains the sequence number of the first MSDU or A-MSDU for which this BlockAck frame is sent. The value of this subfield is defined in 10.24.7.5 (Generation and transmission of BlockAck frames by an HT STA or DMG STA). ~~The Fragment Number subfield of the Block Ack Starting Sequence Control subfield is set to 0.~~

	Block Ack Starting Sequence Control	Block Ack Bitmap
Octets:	2	8 or 32

Figure 9-34—BA Information field (Compressed BlockAck)

The Fragment Number subfield is set as defined in Table 9-24a (Fragment Number subfield encoding for the Compressed BlockAck variant)

Insert the following table:

Table 9-24a—Fragment Number subfield encoding for the Compressed BlockAck variant

Fragment Number subfield			Fragmentation Level 3 (ON/OFF)	Block Ack Bitmap subfield length (octets)	Maximum number of MSDUs/A-MSDUs that can be acknowledged
B3	B2-B1	B0			
0	0	0	OFF	8 octets	64
0	1	0		Reserved	Reserved
0	2	0		32 octets	256
0	3	0		Reserved	Reserved
0	0	1	ON	8 octets	16
0	1	1		Reserved	Reserved
0	2	1		32 octets	64
0	3	1		Reserved	Reserved
1	Any	Any		Reserved	Reserved
NOTE—A Compressed BlockAck frame with B0 of the Fragment Number subfield set to 1 can only be sent to an HE STA whose HE Fragmentation Support subfield in the HE Capabilities element it transmits is 3 (see 27.3 (Fragmentation)).					

Change the remainder of 9.3.1.9.3 as follows:

When B0 of the Fragment Number subfield is 0, the Block Ack Bitmap subfield of the BA Information field of the Compressed BlockAck frame is used to indicate the receive status of up to 64 or 256 MSDUs and A-MSDUs depending upon the value of B2-B1 in the Fragment Number subfield as shown in Table 9-24a (Fragment Number subfield encoding for the Compressed BlockAck variant).~~The Block Ack Bitmap subfield of the BA Information field of the Compressed BlockAck frame is 8 octets in length and is used to indicate the received status of up to 64 MSDUs and A-MSDUs.~~ Each bit that is equal to 1 in the compressed Block Ack Bitmap subfield acknowledges the successful reception of a single MSDU or A-MSDU in the order of sequence number, with the first bit of the Block Ack Bitmap subfield corresponding to the MSDU or A-MSDU with the sequence number that matches the value of the Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield.

When B0 of the Fragment Number subfield is 1, the Block Ack Bitmap subfield of the BA Information field of the Compressed BlockAck frame is used to indicate the receive status of up to 16 or 64 MSDUs and A-MSDUs depending upon the value B2-B1 in the Fragment Number subfield as shown in Table 9-24a (Fragment Number subfield encoding for the Compressed BlockAck variant). If bit position n of the Block Ack Bitmap subfield is 1, it acknowledges receipt of an MPDU with sequence number value SN and fragment number value FN with $n = 4 \times (SN - SSN) + FN$, where SSN is the value of the Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield and the operations on the sequence numbers are performed modulo 4096. If bit position n of the Block Ack Bitmap subfield is 0, it indicates that the MPDU has not been received.

NOTE—When the B0 of the Fragment Number subfield is equal to 1 then the Block Ack Bitmap subfield is split into (Block Ack Bitmap subfield length)/4 subbitmaps, each of which indicates receive status for up to 4 fragments of each of the MSDUs as indicated in Table 9-24a (Fragment Number subfield encoding for the Compressed BlockAck variant). For an A-MSDU, only the first bit of the subbitmap is used, as fragmentation is not allowed in an A-MSDU.

Insert a new subclause after 9.3.1.9.6:

9.3.1.9.7 Multi-STA BlockAck variant

The format defined below is used for multi-STA multi-TID, and multi-STA single TID BlockAck variant. Multi-STA BlockAck frames shall be supported if either UL MU or multi-TID A-MPDU operation is supported.

The TID_INFO subfield of the BA Control field of the Multi-STA BlockAck frame is reserved.

The BA Information field of the Multi-STA BlockAck frame comprises one or more Per STA Info subfields. The Per STA Info subfield is shown in Figure 9-38a (Per STA Info subfield format).

	Per AID TID Info	Block Ack Starting Sequence Control	Block Ack Bitmap
Octets:	2	0 or 2	0, 4, 8, 16 or 32

Figure 9-38a—Per STA Info subfield format

The Per AID TID Info subfield is shown in Figure 9-38b (Per AID TID Info subfield format).

	B0 B10	B11	B12 B15
	AID	Ack Type	TID
Bits:	11	1	4

Figure 9-38b—Per AID TID Info subfield format

When Multi-STA BlockAck variant is intended for a non-AP STA, the AID subfield carries the AID of the non-AP STA for which the Per STA Info subfield is intended. When the Multi-STA BlockAck variant is intended for an AP, the AID subfield is set to 0.

NOTE—One or more Per STA Info subfields with same value of the AID subfield and different values of the TID subfields can be present in the Multi-STA BlockAck frame.

The TID subfield contains the TID for which the acknowledgment or block acknowledgment contained in the Per AID TID Info subfield applies.

NOTE—When a Multi-STA BlockAck frame is used to acknowledge a management frame, the TID value is set to 15.

If the Ack Type subfield is 1 and the TID value of the Per AID TID Info subfield is less than 8 or equal to 15, then the Block Ack Starting Sequence Control and Block Ack Bitmap subfields are not present and the Per STA Info subfield acknowledges successful reception of a single MPDU indicated by the TID of the Per AID TID Info subfield. If the Ack Type subfield is 1 and the TID subfield of the Per AID TID Info field is 14, then the Block Ack Starting Sequence Control and Block Ack Bitmap are not present and the Per STA Info field acknowledges successful reception of all the MPDUs carried in the eliciting A-MPDU. The Ack Type field is not set to 1 when responding to a BlockAckReq frame or an MU-BAR frame. If the Ack Type subfield is 0, then the Block Ack Starting Sequence Control and Block Ack Bitmap subfields are present.

The context and the presence of each optional subfields in a Per STA Info subfield in a Multi-STA BlockAck frame is as defined in Table 9-24b (Context of the Per STA Info subfield and presence of optional subfields).

Table 9-24b—Context of the Per STA Info subfield and presence of optional subfields

Ack Type subfield value	TID subfield values	Presence of optional subfields in the Per STA Info field		Context of a Per STA Info field in a Multi-STA BlockAck frame
0	0-7	Block Ack Starting Sequence Control	Present	Block acknowledgment context: Sent as a response to an A-MPDU that solicits an immediate block acknowledgement or to a BAR frame
		Block Ack Bitmap	Present	
1	0-7	Block Ack Starting Sequence Control	Not present	Acknowledgment context: Sent as a response to an MPDU or VHT Single MPDU that solicits an immediate acknowledgment
		Block Ack Bitmap	Not present	
0 or 1	8 to 13	N/A	N/A	Reserved
0	14	N/A	N/A	Reserved
1	14	Block Ack Starting Sequence Control	Not present	All block acknowledgment context: Sent as a response to an A-MPDU that solicits an immediate response and all MPDUs contained in the A-MPDU are received successfully
		Block Ack Bitmap	Not present	
0	15	N/A	N/A	Reserved
1	15	Block Ack Starting Sequence Control	Not present	Action Ack frame acknowledgment context: Sent as a response to an Action Ack frame carried in an A-MPDU that solicits an immediate acknowledgment
		N/A	Not present	

If the Ack Type field is 0, the Fragment Number subfield encoding is defined in Table 9-24c (Fragment Number subfield encoding for the Multi-STA BlockAck variant).

Table 9-24c—Fragment Number subfield encoding for the Multi-STA BlockAck variant

Fragment Number subfield			Fragmentation Level 3 (ON/OFF)	Block Ack Bitmap subfield length (octets)	Maximum number of MSDUs/A-MSDUs that can be acknowledged
B3	**B2-B1**	**B0**			
0	0	0	OFF	8 octets	64
0	1	0		16 octets	128
0	2	0		32 octets	256
0	3	0		4 octets	32
0	0	1	ON	8 octets	16
0	1	1		16 octets	32
0	2	1		32 octets	64
0	3	1		4 octets	8
1	Any	Any		Reserved	Reserved
NOTE—A Multi-STA BlockAck frame with B0 of the Fragment Number subfield set to 1 can only be sent to an HE STA whose HE Fragmentation Support subfield in the HE Capabilities element it transmits is 3 (see 27.3 (Fragmentation)).					

When B0 of the Fragment Number subfield of the Block Ack Starting Sequence Control subfield is 0, the Block Ack Starting Sequence Control subfield is as defined in Figure 9-28. The BA Information field of the Multi-STA BlockAck frame contains an 8-octet, 16-octet, 32-octet or 4-octet Block Ack Bitmap subfield depending on B2-B1 of the Fragment Number subfield as defined in the Table 9-24c (Fragment Number subfield encoding for the Multi-STA BlockAck variant). Each bit that is equal to 1 in the Block Ack Bitmap subfield acknowledges the successful reception of a single MSDU or A-MSDU in the order of sequence number with the first bit of the Block Ack Bitmap subfield corresponding to the MSDU or A-MSDU with the sequence number that matches the value of the Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield.

When B0 of the Fragment Number subfield of the Block Ack Starting Sequence Control subfield is 1, the Block Ack Bitmap subfield of the BA Information field of the Multi-STA Block Ack frame is used to indicate the receive status of up to 16, 32, 64 or 8 MSDUs and A-MSDUs depending on B2-B1 of the Fragment Number subfield as shown in the Table 9-24c (Fragment Number subfield encoding for the Multi-STA BlockAck variant). If bit position n of the Block Ack Bitmap subfield is 1, it acknowledges receipt of an MPDU with sequence number value SN and fragment number value FN with $n = 4 \times (SN - SSN) + FN$, where SSN is the value of the Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield and the operations on the sequence numbers are performed modulo 4096. If bit position n of the Block Ack Bitmap subfield is 0, it indicates that the MPDU has not been received.

NOTE—When B0 of the Fragment Number subfield is 1 then the Block Ack Bitmap field is split into Block Ack Bitmap field length/4 subbitmaps, each of which indicates receive status for 4 fragments of each of the MSDUs as indicated in Table 9-24c (Fragment Number subfield encoding for the Multi-STA BlockAck variant). For an A-MSDU, only the first bit of the subbitmap is used, as fragmentation is not allowed in an A-MSDU.

Change the title of 9.3.1.20 as follows:

9.3.1.20 VHT/HE NDP Announcement frame format

Insert the following at the end of 9.3.1.20:

The HE NDP Announcement uses the same Frame Control Type as the VHT NDP Announcement. The frame format of the HE NDP Announcement frame with multiple STA info field is shown in Figure 9-51a (HE NDP Announcement frame format).

	Frame Control	Duration	RA	TA	Sounding Dialog Token	STA Info 1	…	STA Info *n*	FCS
Octets:	2	2	6	6	1	4		4	4

Figure 9-51a—HE NDP Announcement frame format

Bit 1 of the Sounding Dialog Token is set to 1 to indicate an HE NDP Announcement frame.

The format of the STA Info subfield in an HE NDP Announcement Frame is defined in Figure 9-51b (STA Info subfield format in an HE NDP Announcement frame).

	B0 B10	B11 B24	B25 B26	B27	B28	B29 B31
	AID11	Partial BW Info	Feedback Type And Ng	Disambiguation	Codebook Size	Nc
Bits:	11	14	2	1	1	3

Figure 9-51b—STA Info subfield format in an HE NDP Announcement frame

The Partial BW Info subfield is defined in Figure 9-51c (Partial BW Info subfield).

	B0 B6	B7 B13
	RU Start Index	RU End Index
Bits:	7	7

Figure 9-51c—Partial BW Info subfield

The RU Start Index subfield of the Partial BW subfield indicates the first 26-tone RU for which the HE beamformer is requesting feedback. The RU End Index subfield of the Partial BW subfield indicates the last 26-tone RU for which the HE beamformer is requesting feedback.

The Feedback Type And Ng and Codebook Size subfields are defined inTable 9-25a (Feedback Type And Ng subfield and Codebook Size subfield encoding)

Table 9-25a—Feedback Type And Ng subfield and Codebook Size subfield encoding

Feedback Type + Ng + codebook size	Description
000	SU, Ng4, quantization resolution (ϕ, ψ) = {4, 2}
001	SU, Ng4, quantization resolution (ϕ, ψ) = {6, 4}
010	SU, Ng16, quantization resolution (ϕ, ψ) = {4, 2}
011	SU, Ng16, quantization resolution (ϕ, ψ) = {6, 4}
100	MU+Ng4, quantization resolution (ϕ, ψ) = {7, 5}
101	MU+Ng4, quantization resolution (ϕ, ψ) = {9, 7}
110	CQI only feedback
111	MU+Ng16, quantization resolution (ϕ, ψ) = {9, 7}

The Disambiguation subfield is set to 1 to prevent a VHT STA from wrongly determining it's AID in the HE STA Info.

Insert a new subclause after 9.3.1.22:

9.3.1.23 Trigger frame format

The Trigger frame solicits and allocates resources for UL MU transmissions a SIFS after the PPDU that carries the Trigger frame. The Trigger frame also carries other information required by the responding STA to send an HE trigger-based PPDU.

The frame format for the Trigger frame is as defined in Figure 9-52c (Trigger frame).

	Frame Control	Duration	(RA)	TA	Common Info	User Info	...	User Info	Padding	FCS
Octets:	2	2	6	6	8 or more	5 or more		5 or more	variable	4

Figure 9-52c—Trigger frame

The Duration field is set as defined in 9.2.5 (Duration/ID field (QoS STA)).

The RA field of the Trigger frame is the address of the recipient STA.If the Trigger frame has one User Info field then the RA of the Trigger frame is the STA's MAC Address. If the Trigger frame has multiple User Info fields then the RA of the Trigger Frame is the broadcast address.If the Trigger Type field is GCR MU-BAR, the RA field is set to the MAC address of the group for which reception status is being requested.

The TA field value is the address of the STA transmitting the Trigger frame.

The Common Info field is defined in Figure 9-52d (Common Info field).

	B0 B3	B4 B15	B16	B17	B18 B19	B20 B21	B22	B23 B25	B26
	Trigger Type	Length	Cascade Indication	CS Required	BW	GIAnd LTF Type	MU-MIMO LTF Mode	Number Of HE-LTF Symbols	STBC
Bits:	4	12	1	1	2	2	1	3	1

	B27	B28 B33	B34 B36	B37 B52	B53	B54 B62	B63	
	LDPC Extra Symbol Segment	AP TX Power	Packet Extension	Spatial Reuse	Doppler	HE-SIG-A Reserved	Reserved	Trigger Dependent Common Info
Bits:	1	6	3	16	1	9	1	variable

Figure 9-52d—Common Info field

The Trigger Type subfield indicates the type of the Trigger frame. The Trigger frame can include an optional Trigger Dependent Common Info field and optional Trigger Dependent User Info field. The Trigger Type subfield encoding is defined in Table 9-25a (Trigger Type subfield encoding).

Table 9-25a—Trigger Type subfield encoding

Trigger Type field value	Description
0	Basic Trigger
1	Beamforming Report Poll
2	MU-BAR
3	MU-RTS
4	Buffer Status Report Poll (BSRP)
5	GCR MU-BAR
6	Bandwidth Query Report Poll (BQRP)
7-15	Reserved

The Length subfield of the Common Info field indicates the value of the L-SIG Length field of the HE trigger-based PPDU that is the response to the Trigger frame.

If the Cascade Indication subfield is 1, then a subsequent Trigger frame as defined in 27.7 (TWT operation) and in 27.14.2 (Power save with UL OFDMA-based random access) follows the current Trigger frame. Otherwise the Cascade Indication subfield is 0.

The CS Required subfield is set to 1 to indicate that the STAs identified in the User Info fields are required to use ED to sense the medium and to consider the medium state and the NAV in determining whether or not to respond. The CS Required subfield is set to 0 to indicate that the STAs identified in the User Info fields are not required to consider the medium state or the NAV in determining whether or not to respond.

The BW subfield indicates the bandwidth in the HE-SIG-A of the HE trigger-based PPDU and is defined in Table 9-25b (BW subfield encoding).

Table 9-25b—BW subfield encoding

BW subfield value	Description
0	20 MHz
1	40 MHz
2	80 MHz
3	80+80 MHz or 160 MHz

The GI And LTF Type subfield of the Common Info field indicates the GI and HE-LTF type of the HE trigger-based PPDU response. The GI And LTF Type subfield encoding is defined in Table 9-25c (GI And LTF Type subfield encoding).

Table 9-25c—GI And LTF Type subfield encoding

GI And LTF field value	Description
0	1x LTF + 1.6 μs GI
1	2x LTF + 0.8 μs GI
2	2x LTF + 1.6 μs GI
3	4x LTF + 3.2 μs GI

The MU-MIMO LTF Mode subfield of the Common Info field indicates the LTF mode of the UL MU-MIMO HE trigger-based PPDU response. The AP shall set the MU-MIMO LTF Mode subfield to Single

Stream pilot if the triggered UL PPDU contains partial or full UL OFDMA allocation. The MU-MIMO LTF Mode subfield encoding is defined in Table 9-25d (MU-MIMO LTF Mode subfield encoding).

Table 9-25d—MU-MIMO LTF Mode subfield encoding

MU-MIMO LTF subfield value	Description
0	Single stream pilots
1	Mask LTF sequence of each spatial stream by a distinct orthogonal code

The Number Of HE-LTF Symbols subfield of the Common Info field indicates the number of HE-LTF symbols present in the HE trigger-based PPDU response. The number of HE-LTF symbols is a function of the total number of space-time streams. For non-OFDMA PPDUs, the encoding of the Number Of HE-LTF Symbols subfield is defined in Table 22-13. For OFDMA PPDUs, the number of HE-LTFs is greater than or equal to the maximum across RUs of the total number of space time streams. The encoding of the Number Of HE-LTF Symbols subfield is the same as the Number of HE-LTF Symbols in HE-SIG-A2, which is defined in Table 28-18 (HE-SIG-A field of an HE trigger-based PPDU).

The STBC subfield of the Common Info field indicates the status of STBC encoding of the HE trigger-based PPDU response. It is set to 1 if STBC encoding is used and set to 0 otherwise.

The LDPC Extra Symbol Segment subfield of the Common Info field indicates the status of LDPC extra symbol segment. It is set to 1 when LDPC extra symbol segment is present and set to 0 otherwise.

The AP Tx Power subfield of the Common Info field indicates the combined average power per 20 MHz bandwidth of all transmit antennas used to transmit the trigger frame at the HE AP. The resolution for the transmit power reported in the Common Info field is 1 dB. The AP Tx Power subfield encoding is defined in Table 9-25e (AP Tx Power subfield encoding).

Table 9-25e—AP Tx Power subfield encoding

AP Tx Power subfield value	Description
0-60	Values 0 to 61 maps to –20 dBm to 40 dBm
61-63	Reserved

The Packet Extension subfield of the Common Info field indicates the packet extension duration of the trigger-based PPDU response. The first two bits indicate the pre-FEC padding factor and the third bit indicates the PE-Disambiguity.

The Spatial Reuse subfield carries the value for the Spatial Reuse field in the HE-SIG-A field of the HE trigger-based PPDU transmitted as a response to the Trigger frame. For HE trigger-based PPDU, four SR fields are signaled:

— For 20 MHz one SR field corresponding to entire 20 MHz (other 3 fields indicate identical values)

— For 40 MHz two SR fields for each 20 MHz (other 2 fields indicate identical values)
— For 80 MHz four SR fields for each 20 MHz
— For 160 MHz four SR fields for each 40 MHz

When operating 40 MHz in 2.4GHz band, two SR fields, SR field 1 and SR field 2, are set to same values. When operating 80+80 MHz, SR field 3 is set to same value as SR field 1, and SR field 4 is set to the same value as SR field 2.

The Doppler subfield indicates a high doppler mode of transmission.

The HE-SIG-A Reserved subfield indicate the values of the reserved bits in HE-SIG-A2 of the HE trigger-based PPDU transmitted as a response to the Trigger frame. Bits B54 to B62 in the Trigger frame are set to 1 and correspond to the bits B7 to B15 in the HE-SIG-A2 of the HE trigger-based PPDU with B54 in the Trigger frame corresponding to B7 in the HE-SIG-A2 of the HE trigger-based PPDU and so on.

The User Info field is defined in Figure 9-52e (User Info field).

	B0 B11	B12 B19	B20	B21 B24	B25	B26 B31	B32 B38	B39	
	AID12	RU Allocation	Coding Type	MCS	DCM	SS Allocation	Target RSSI	Reserved	Trigger Dependent User Info
Bits:	12	8	1	4	1	6	7	1	variable

Figure 9-52e—User Info field

The AID12 subfield of the User Info field carries the least significant 12 bits of the AID of the STA for which the User Info field is intended. An AID12 subfield that is 0 indicates that the User Info field identifies an RU for random access.User Info fields with AID = 0 shall be allocated only after User Info fields with AID not equals to 0, if any, and before the MAC padding field, if present.

The RU Allocation subfield of the User Info field indicates the RU used by the HE trigger-based PPDU of the STA identified by the AID12 subfield. The RU Allocation subfield is 8 bits in length. The first bit, B12, indicates the allocated RU is located in the primary or non-primary 80 MHz (zero for primary and one for non-primary). The mapping of the subsequent 7 bits, B19-B13, indices to the RU allocation is defined in Table 9-25f (The encoding of B19-B13 of the RU Allocation subfield).

Table 9-25f—The encoding of B19-B13 of the RU Allocation subfield

B19-B13	Description	Number of entries
0000000 - 0100100	Possible 26-tone RU cases in 80 MHz	37
0100101 - 0110100	Possible 52-tone RU cases in 80 MHz	16
0110101 - 0111100	Possible 106-tone RU cases in 80 MHz	8
0111101 - 1000000	Possible 242-tone RU cases in 80 MHz	4
1000001 - 1000010	Possible 484-tone RU cases in 80 MHz	2
1000011	996-tone RU cases in 80 MHz	1
1000100	2×996-tone RU case	1
Total		69

B12 is set to 0 for a 20 MHz, 40 MHz and 80 MHz PPDU. For the 2×996-tone RU case, B12 is set to 1. The mapping of subsequent 7 bits indices B19-B13 to RU index in each row depends on the BW bits in Common Info field:

— For a 20 MHz PPDU, the mapping of B19-B13 to RU allocation follows the RU index in Table 28-3 (Subcarrier indices for RUs in a 20 MHz HE PPDU) in an increasing order. B19-B13 are 0000000 indicates 26-tone RU1 [–121: –96], 0001000 indicates 26-tone RU9 [96: 121], and 0001001-0100100 are not used. B19-B13 are 0100101 indicates 52-tone RU1 [–121: –70], 0101000 indicates 52-tone RU4 [70: 121], and 0101001-0110100 are not used. B19-B13 are 0110101 indicates 106-tone RU1 [–122: –17], 0110110 indicates 106-tone RU2 [17: 122], and 0110111-0111100 are not used. B19-B13 are 0111101 indicates 242-tone RU1 [–122: –2, 2:122], and 0111110-1000000 are not used.

— For a 40 MHz PPDU, the mapping of B19-B13 to RU allocation follows the RU index in Table 28-4 (Subcarrier indices for RUs in a 40 MHz HE PPDU) in an increasing order. B19-B13 are 0000000 indicates 26-tone RU1 [–243: –218], 0010001 indicates 26-tone RU18 [218: 243], and 0010010-0100100 are not used. B19-B13 are 0100101 indicates 52-tone RU1 [–243: –192], 0101100 indicates 52-tone RU8 [192: 243], and 0101101-0110100 are not used. Similar ordering is followed for 106-tone RU, 242-tone RU and 484-tone RU.

— For an 80 MHz, 160 MHz and 80+80 MHz PPDU, the mapping of B19-B13 to RU allocation follows the RU index in Table 28-5 (Subcarrier indices for RUs in an 80 MHz HE PPDU) in an increasing order. B19-B13 are 0000000 indicates 26-tone RU1 [–499: –474], and 0100100 indicates 26-tone RU37 [474: 499]. B19-B13 are 0100101 indicates 52-tone RU1 [–499: –448], and 0110100 indicates 52-tone RU16 [448: 499]. Similar ordering is followed for 106-tone RU, 242-tone RU, 484-tone RU and 996-tone RU. For a 160 MHz and 80+80 MHz PPDU, B19-B13 are 1000100 indicates 2×996-tone RU.

The Coding Type subfield of the User Info field indicates the code type of the HE trigger-based PPDU response of the STA identified by the AID12 subfield. Set to 0 for BCC and set to 1 for LDPC.

The MCS subfield of the User Info field indicates the MCS of the HE trigger-based PPDU response of the STA identified by the AID12 subfield. The encoding of the MCS field is as defined in 28.3.7 (HE modulation and coding schemes (HE-MCSs)).

The DCM subfield of the User Info field indicates dual carrier modulation of the HE trigger-based PPDU response of the STA identified by the AID12 subfield. A value of 1 indicates that the HE trigger-based PPDU response shall use DCM as defined in 28.3.11.15 (Dual carrier modulation). A value 0 indicates that DCM is not be used.

The SS Allocation subfield of the User Info field indicates the spatial streams of the HE trigger-based PPDU response of the STA identified by the AID12 subfield. The format of the SS Allocation subfield is defined in Figure 9-52f (SS Allocation subfield format).

	B26 B28	B29 B31
	Starting Spatial Stream	Number Of Spatial Streams
Bits:	3	3

Figure 9-52f—SS Allocation subfield format

The Target RSSI subfield of the User Info field indicates the target received signal power of the HE trigger-based PPDU response. The resolution for the Target RSSI subfield in the User Info field is 1 dB. The Target RSSI subfield encoding is defined in Table 9-25g (Target RSSI subfield encoding).

Table 9-25g—Target RSSI subfield encoding

Target RSSI subfield	Description
0-90	Values 0 to 90 map to –100 dBm to –20 dBm
91-126	Reserved
127	Indicates to the STA to transmit an HE trigger-based PPDU response at its maximum transmit power for the assigned MCS

The Padding field extends the frame length to give the recipient STAs more time to prepare a response. The Padding field of the Trigger frame, if present, is an integer number of octets ≥ 2: Padding field starts with special STAID[11:0] as 0xFFF and the rest bits of the Padding field are all set to one. 0xFFF is reserved as the special value to indicate the start of the MAC padding. The length of the Padding field is in units of octets and is set as defined in the following formulas.

For a non-HT PPDU, HT PPDU and VHT PPDU the length of the Padding field is given by Equation (9-ax1).

$$L_{PAD,\,MAC} = \left\lceil \frac{N_{DBPS} m_{PAD}}{8} \right\rceil \text{octets} \tag{9-ax1}$$

where

$$m_{PAD} = \begin{cases} 0, \text{max TF MAC Padding Duration among receiving STAs} = 0\ \mu\text{s} \\ 2, \text{max TF MAC Padding Duration among receiving STAs} = 8\ \mu\text{s} \\ 4, \text{max TF MAC Padding Duration among receiving STAs} = 16\ \mu\text{s} \end{cases}$$

For an HE PPDU, the length of the Padding field is given by Equation (9-ax2).

$$L_{PAD,MAC} = \left\lceil \frac{N_{DBPS,SHORT} m_{PAD}}{8} \right\rceil \text{octets} \tag{9-ax2}$$

where

$$m_{PAD} = \begin{cases} 0, \text{max TF MAC Padding Duration among receiving STAs} = 0\ \mu s \\ 2, \text{max TF MAC Padding Duration among receiving STAs} = 8\ \mu s \\ 4, \text{max TF MAC Padding Duration among receiving STAs} = 16\ \mu s \end{cases}$$

STBC is disallowed for Trigger Frame transmission.

9.3.1.23.1 Basic Trigger variant

If the Trigger frame is a Basic Trigger variant, the Trigger Dependent Common Info field is not present and the Trigger Dependent User Info field is defined in Figure 9-52g (Trigger Dependent User Info field for the Basic Trigger variant).

	B0 B1	B2 B4	B5	B6 B7
	MPDU MU Spacing Factor	TID Aggregation Limit	AC Preference Level	Preferred AC
Bits:	2	3	1	2

Figure 9-52g—Trigger Dependent User Info field for the Basic Trigger variant

The MPDU MU Spacing Factor subfield indicates the value by which the minimum MPDU start spacing defined in Table 8-159 is multiplied. The MPDU MU Spacing Factor subfield encoding is defined in Table 9-25h (MPDU MU Spacing Factor subfield encoding).

Table 9-25h—MPDU MU Spacing Factor subfield encoding

Value	Description
0	Multiplier = 1
1	Multiplier = 2
2	Multiplier = 4
3	Multiplier = 8

The TID Aggregation Limit subfield indicates the maximum number of TIDs that can be aggregated by a STA in a multi-TID A-MPDU carried in the responding HE trigger-based PPDU.

NOTE–A value of 7 in the TID Aggregation Limit subfield indicates to the STA that it can aggregate QoS Data frames from any number of different TID values in the multi-TID A-MPDU.

The value in the TID Aggregation Limit subfield in Trigger frame is less than or equal to the value indicated in the Multi-TID Aggregation Support field in the HE Capabilities element (see 9.4.2.218 (HE Capabilities element)).

The AC Preference Level subfield is set to 1 to indicate that MPDUs with TIDs that correspond to the AC indicated in the Preferred AC subfield are recommended with respect to TIDs from other ACs. The AC Preference Level subfield is set to 0 if the AP does not have a recommendation.

The Preferred AC subfield indicates the AC that is recommended for aggregation of MPDUs of ACs belonging to the same AC as indicated or higher priority AC(s) within a multi-TID A-MPDU sent as a response to the Trigger frame (see 9.3.1.23 (Trigger frame format)). The encoding of the Preferred AC subfield is shown in Table 9-25i (Preferred AC subfield encoding).

Table 9-25i—Preferred AC subfield encoding

Value	Description
0	AC_VO
1	AC_VI
2	AC_BE
3	AC_BK

9.3.1.23.2 Beamforming Report Poll variant

If the Trigger frame is a Beamforming Report Poll variant, the Trigger Dependent Common Info field is not present and the Trigger Dependent User Info field is defined in Figure 9-52h (Trigger Dependent User Info field for the Beamforming Report Poll variant).

	Feedback Segment Retransmission Bitmap
Octets:	1

Figure 9-52h—Trigger Dependent User Info field for the Beamforming Report Poll variant

The Feedback Segment Retransmission Bitmap subfield indicates the requested feedback segments of an HE Compressed Beamforming report. If the bit in position n ($n = 0$ for LSB and $n = 7$ for MSB) is 1, then the feedback segment with the Remaining Feedback Segments subfield in the HE MIMO Control field equal to n is requested. If the bit in position n is 0, then the feedback segment with the Remaining Feedback Segments subfield in the HE MIMO Control field equal to n is not requested.

9.3.1.23.3 MU-BAR variant

The Trigger Dependent Common Info field is not present in the MU-BAR variant Trigger frame. The Trigger Dependent User Info field of the MU-BAR variant Trigger frame is defined in Figure 9-52i (Trigger Dependent User Info field for the MU-BAR variant).

	BAR Control	BAR Information
Octets:	2	variable

Figure 9-52i—Trigger Dependent User Info field for the MU-BAR variant

The BAR Control subfield is defined in 9.3.1.8 (BlockAckReq frame format).

The BAR Information subfield is defined in 9.3.1.8 (BlockAckReq frame format). The Fragment number field is set accordingly to Table 9-24a (Fragment Number subfield encoding for the Compressed BlockAck variant) for a compressed BAR variant and Table 9-24c (Fragment Number subfield encoding for the Multi-STA BlockAck variant) for a Multi-TID BAR variant.

9.3.1.23.4 MU-RTS variant

The MU-RTS frame format is a variant of Trigger frame format as shown in Figure 9-52c (Trigger frame).

The RA field of the MU-RTS frame is set to the broadcast address.

NOTE—The TA field value is the address of the STA transmitting the MU-RTS frame.

The Common Info field is defined in Figure 9-52d (Common Info field).

The Trigger Type subfield is set to 3 to indicate MU-RTS variant.

The BW subfield indicates the total PPDU bandwidth, and is defined in Table 9-25b (BW subfield encoding).

The Length, GI And LTF Type, MU MIMO LTF Mode, Number of LTFs, STBC, LDPC Extra Symbol Segment, AP TX Power, Packet Extension, Spatial Reuse and HE-SIG-A Reserved fields are reserved.

NOTE—The Trigger Dependent Common Info field is not present in the MU-RTS frame.

The User Info field is defined in Figure 9-52e (User Info field).

The MCS, Coding Type, DCM, SS Allocation and Target RSSI fields are reserved.

The RU Allocation subfield in the User Info field addressed to the STA follows the same definition as described in 9.3.1.23 (Trigger frame format) and indicates whether the CTS frame is transmitted on the primary 20 MHz channel, primary 40 MHz channel, primary 80 MHz channel, 160 MHz channel, or 80+80 MHz channel.

B12 of the RU Allocation subfield is set to 0 for indication of primary 20 MHz/40 MHz/80 MHz. For 160 MHz/80+80 MHz indication, B12 of the RU Allocation subfield is set to 1. The mapping of B19-B13 to RU Allocation subfield follows the RU index in Table 28-3 (Subcarrier indices for RUs in a 20 MHz HE PPDU) in an increasing order.

If the BW subfield indicates 20 MHz, then the 242-tone RU entry 0111101 for B19-B13 indicates primary 20 MHz channel.

If the BW subfield indicates 40 MHz, then the 242-tone RU entry for B19-B13 corresponding to the primary 20 MHz channel indicates primary 20 MHz; the 484-tone RU entry 1000001 for B19-B13 indicates the primary 40 MHz channel.

If the BW subfield indicates 80 MHz or 80+80 MHz or 160 MHz, then the 242-tone RU entry for B19-B13 corresponding to the primary 20 MHz indicates the primary 20 MHz channel, the 484-tone RU entry for B19-B13 corresponding to the primary 40 MHz indicates the primary 40 MHz channel and the 996-tone RU entry 1000011 for B19-B13 indicates the primary 80 MHz channel.

If the Bandwidth field indicates 80+80 MHz or 160 MHz, then the entry 1000100 for B19-B13 indicates primary and secondary 80 MHz.

NOTE—The Trigger Dependent User Info field is not present in the MU-RTS frame.

9.3.1.23.5 BSRP variant

The BSRP variant Trigger frame format is as defined in Figure 9-52c (Trigger frame).

The Common Info field of the BSRP variant Trigger frame is defined in Figure 9-52d (Common Info field) and the Trigger Dependent Common Info field is not present.

The User Info field of the BSRP variant Trigger frame is defined in Figure 9-52e (User Info field) and the Trigger Dependent User Info field is not present.

9.3.1.23.6 GCR MU-BAR variant

The Trigger Dependent Common Info field of the GCR MU-BAR variant Trigger frame is defined in Figure 9-52j (Trigger Dependent Common Info field for the GCR MU-BAR variant). GCR MU-BAR frame does not have a Trigger Dependent User Info field.

	BAR Control	BAR Information
Octets:	2	variable

Figure 9-52j—Trigger Dependent Common Info field for the GCR MU-BAR variant

The BAR Control subfield is defined in 9.3.1.8 (BlockAckReq frame format).

The BAR Information subfield is defined in 9.3.1.8 (BlockAckReq frame format). The Fragment number field is set according to Table 9-24a (Fragment Number subfield encoding for the Compressed BlockAck variant) for a compressed BAR variant and Table 9-24c (Fragment Number subfield encoding for the Multi-STA BlockAck variant) for a Multi-TID BAR variant.

9.3.1.23.7 Bandwidth Query Report Poll variant

The Bandwidth Query Report Poll (BQRP) variant Trigger frame format is as defined in Figure 9-52c (Trigger frame).

The Common Info field of the BQRP variant Trigger frame is defined in Figure 9-52d (Common Info field) and the Trigger Dependent Common Info field is not present.

The User Info field of the BQRP variant Trigger frame is defined in Figure 9-52e (User Info field) and the Trigger Dependent User Info field is not present.

The CS Required subfield is set to 1.

9.3.2 Data frames

9.3.3 Management frames

9.3.3.1 Beacon frame format

Editor's Note: Order: 11ai adds 66-69, 11ah adds none, 11aq adds 70-71, 11ak adds 67 (appears to be out of date), 11aj adds none.

Insert the following new rows (header row shown for convenience) into Table 9-27 (Beacon frame body):

Table 9-27—Beacon frame body

Order	Information	Notes
73	HE Capabilities	The HE Capabilities element is present when dot11HEOptionImplemented is true; otherwise it is not present.
74	HE Operation	The HE Operation element is present when dot11HEOptionImplemented is true; otherwise it is not present.
75	TWT	The TWT element is optionally present when dot11TWTOptionActivated is true; otherwise it is not present.
76	RAPS	The RAPS element is optionally present when dot11OFDMARandomAccessOptionImlemented is true; otherwise it is not present.
77	BSS Color Change Announcement	The BSS Color Change Announcement element is optionally present when dot11HEOptionImplemented is true; otherwise it is not pre-sent.

9.3.3.5 Association Request frame format

Editor's Note: Order: 11ai adds 24-28, 11ah adds 29-38, 11ak adds 24 (appears to be out of date), 11aj adds two (numbers unassigned)

Insert the following new row (header row shown for convenience) into Table 9-29 (Association Request frame body):

Table 9-29—Association Request frame body

Order	Information	Notes
43	HE Capabilities	The HE Capabilities element is present when dot11HEOptionImplemented is true; otherwise it is not present.

9.3.3.6 Association Response frame format

Editor's Note: Order: 11ai adds 31-36, 11ah adds 37-49, 11aq adds none, 11ak adds 30-31 (appears to be out of date), 11aj adds three (numbers unassigned)

Change Table 9-30 (Association Response frame body) as follows maintaining numeric order (only rows with changes are shown):

Table 9-30—Association Response frame body

Order	Information	Notes
29	TWT	~~The TWT element is optionally present if dot11TWTOptionActivated is true; otherwise not present.~~ The TWT element is present if dot11TWTOptionActivated is true and the TWT element is present in the Association Request frame that elicited this Association Response frame. The TWT element is optionally present if dot11TWTOptionActivated is true and the TWT Requester Supported field in the HE Capabilities in the Association Request frame that elicited this Association Response frame is one.
54	HE Capabilities	The HE Capabilities element is present when dot11HEOptionImplemented is true; otherwise it is not present.
55	HE Operation	The HE Operation element is present when dot11HEOptionImplemented is true; otherwise it is not present.
56	BSS Color Change Announcement	The BSS Color Change Announcement element is optionally present when dot11HEOptionImplemented is true; otherwise it is not pre-sent.

9.3.3.7 Reassociation Request frame format

Editor's Note: Order: 11ai adds 29-33, 11ah adds 34-43, 11aq adds none, 11ak adds 29 (appears to be out of date), 11aj adds two (numbers unassigned)

Insert the following row in Table 9-31 (Reassociation Request frame body) (header shown for convenience):

Table 9-31—Reassociation Request frame body

Order	Information	Notes
47	HE Capabilities	The HE Capabilities element is present when dot11HEOptionImplemented is true; otherwise it is not present.

9.3.3.8 Reassociation Response frame format

Editor's Note: Order: 11ai adds 35-49, 11ah adds 41-52, 11aq adds none, 11ak adds 34 and 30 (appears to be an error), 11aj adds three (numbers unassigned)

Change Table 9-32 (Reassociation Response frame body) as follows maintaining numeric order (only rows with changes are shown):

Table 9-32—Reassociation Response frame body

Order	Information	Notes
42	TWT	~~The TWT element is optionally present if dot11TWTOptionActivated is true; otherwise not present.~~ The TWT element is present if dot11TWTOptionActivated is true and the TWT element is present in the Reassociation Request frame that elicited this Reassociation Response frame. The TWT element is optionally present if dot11TWTOptionActivated is true and the TWT Requester Supported field in the HE Capabilities in the Reassociation Request frame that elicited this Association Response frame is one.
55	HE Capabilities	The HE Capabilities element is present when dot11HEOptionImple-mented is true; otherwise it is not present.
56	HE Operation	The HE Operation element is present when dot11HEOptionImple-mented is true; otherwise it is not present.
57	BSS Color Change Announcement	The BSS Color Change Announcement element is optionally present when dot11HEOptionImplemented is true; otherwise it is not pre-sent.

9.3.3.10 Probe Request frame format

Editor's Note: Order: 11ai adds 20-21, 11ah adds 22-27, 11aq adds none, 11ak adds 20 (appears to be out of date), 11aj adds three (numbers unassigned)

Insert the following new row (header row shown for convenience) into Table 9-33 (Probe Request frame body):

Table 9-33—Probe Request frame body

Order	Information	Notes
32	HE Capabilities	The HE Capabilities element is present when dot11HEOptionImple-mented is true; otherwise it is not present.

9.3.3.11 Probe Response frame format

Editor's Note: Order: 11ai adds 70-73, 11ah adds 74-84, 11aq adds 85-86, 11ak adds 70 (appears to be out of date), 11aj adds four (numbers unassigned)

Insert the following new rows into Table 9-34 (Probe Response frame body) (header shown for convenience):

Table 9-34—Probe Response frame body

Order	Information	Notes
92	HE Capabilities	The HE Capabilities element is present when dot11HEOptionImplemented is true; otherwise it is not present.
93	HE Operation	The HE Operation element is present when dot11HEOptionImplemented is true; otherwise it is not present.
94	TWT	The TWT element is optionally present when dot11TWTOptionActivated and dot11HEOptionImplemented is true; otherwise it is not present.
95	RAPS	The RAPS element is optionally present when dot11OFDMARandomAccessOptionImlemented is true; otherwise it is not present.
96	BSS Color Change Announcement	The BSS Color Change Announcement element is optionally present when dot11HEOptionImplemented is true; otherwise it is not pre-sent.

9.4 Management and Extension frame body components

9.4.1 Fields that are not elements

9.4.1.11 Action field

Change Table 9-47 as follows (insert new row and updated reserved row):

Table 9-47—Category values

Code	Meaning	See subclause	Robust	Group addressed privacy
	...			
<ANA>	HE	9.6.28 (HE Action frame details)	No	No
<ANA>	Quiet Time Period	9.6.23a (Quiet Time Period Action frame details)	No	No
~~21~~<ANA>–125	Reserved	—	—	—
	...			

Insert the following subclauses after 9.4.1.61:

9.4.1.62 HE MIMO Control field

The HE MIMO Control field is included in every HE Compressed Beamforming frame (see 9.4.1.63 (HE Compressed Beamforming Report field)). The HE MIMO Control field is defined in Figure 9-121a (HE MIMO Control field).

	B0 B2	B3 B5	B6 B7	B8	B9	B10 B11	B12 B14	B15	B16 B22	B23 B29	B30 B35	B36 B39
	Nc Index	Nr Index	BW	Grouping	Codebook Information	Feedback Type	Remaining Feedback Segments	First Feedback Segment	RU Start Index	RU End Index	Sounding Dialog Token Number	Reserved
Bits:	3	3	2	1	1	2	3	1	7	7	6	4

Figure 9-121a—HE MIMO Control field

The subfields for the HE MIMO Control Fields are defined in Table 9-76a (HE MIMO Control field encoding).

Table 9-76a—HE MIMO Control field encoding

Subfield	**Description**
Nc Index	Indicates the number of columns, *Nc*, in the compressed beamforming feedback matrix minus 1: Set to 0 for *Nc* = 1 Set to 1 for *Nc* = 2 … Set to 7 for *Nc* = 8
Nr Index	Indicates the number of rows, *Nr*, in the compressed beamforming feedback matrix minus 1: Set to 0 for *Nr* = 1 Set to 1 for *Nr* = 2 … Set to 7 for *Nr* = 8
BW	Indicates the channel width used to determine the starting and ending subcarrier indexes when interpreting the RU Start Index and RU End Index subfields. Set to 0 for 20 MHz Set to 1 for 40 MHz Set to 2 for 80 MHz Set to 3 for 160 MHz and 80+80 MHz
Grouping	Indicates the subcarrier grouping, *Ng*, used for the compressed beamforming feedback matrix: Set to 0 for *Ng* = 4 Set to 1 for *Ng* = 16

Table 9-76a—HE MIMO Control field encoding *(continued)*

Codebook Information	Indicates the size of codebook entries: If Feedback Type is SU: Set to 0 for 2 bits for ψ, 4 bits for ϕ Set to 1 for 4 bits for ψ, 6 bits for ϕ If Feedback Type is MU: Set to 0 for 5 bits for ψ, 7 bits for ϕ Set to 1 for 7 bits for ψ, 9 bits for ϕ NOTE—The codebook size for MU Feedback with Ng = 16 is limited to (ϕ, ψ) = {9, 7}
Feedback Type	Indicates the feedback type: Set to 0 for SU Set to 1 for MU Set to 2 for CQI feedback 3 is reserved
Remaining Feedback Segments	Indicates the number of remaining feedback segments for the associated VHT Compressed Beamforming frame: Set to 0 for the last feedback segment of a segmented report or the only feedback segment of an unsegmented report. Set to a value between 1 and 6 for a feedback segment that is neither the first nor the last of a segmented report. Set to a value between 1 and 7 for a feedback segment that is not the last feedback segment of a segmented report. In a retransmitted feedback segment, the field is set to the same value associated with the feedback segment in the original transmission.
First Feedback Segment	Set to 1 for the first feedback segment of a segmented report or the only feedback segment of an unsegmented report. Set to 0 if not the first feedback segment or if the VHT Compressed Beamforming Report field and MU Exclusive Beamforming Report field are not present in the frame. In a retransmitted feedback segment, the field is set to the same value associated with the feedback segment in the original transmission.
RU Start Index	The starting RU index indicates the first 26-tone RU for which the HE beamformer is requesting feedback.
RU End Index	The ending RU index indicates the last 26-tone RU for which the HE beamformer is requesting feedback.
Sounding Dialog Token Number	The ending RU index indicates the last RU26 for which the HE beamformer is requesting feedback.

In an HE Compressed Beamforming frame not carrying all or part of an HE Compressed Beamforming report, the Nc Index, Nr Index, Channel Width, Grouping, Codebook Information, Feedback Type and Sounding Dialog Token Number subfields are reserved, the First Feedback Segment subfield is set to 0 and the Remaining Feedback Segments subfield is set to 7.

9.4.1.63 HE Compressed Beamforming Report field

The HE Compressed Beamforming Report field is used in the HE Compressed Beamforming And CQI frame (see 9.6.28.2 (HE Compressed Beamforming And CQI frame format)) to carry average SNR of each space-time stream and compressed beamforming feedback matrices V for use by a transmit beamformer to determine steering matrices Q, as described in 10.32.3 (Explicit feedback beamforming) and 19.3.12.3 (Explicit feedback beamforming).

The size of the HE Compressed Beamforming Report field depends on the values in the HE MIMO Control field. The HE Compressed Beamforming Report field contains HE Compressed Beamforming Report information or successive (possibly zero-length) portions thereof in the case of segmented HE Compressed Beamforming and CQI feedback (see 27.6 (HE sounding protocol)). HE Compressed Beamforming Report information is included in the HE Compressed Beamforming and CQI feedback if an SU feedback type or an MU feedback type is indicated in the Feedback Type field in the HE MIMO Control field.

The HE Compressed Beamforming Report information contains the channel matrix elements indexed, first, by matrix angles in order shown in Table 9-67 (Order of angles in the Compressed Beamforming Feedback Matrix subfield), and second, by data and pilot subcarrier index from lowest frequency to highest frequency. The explanation on how these angles are generated from the beamforming feedback matrix V is given in 19.3.12.3.6 (Compressed beamforming feedback matrix) in Table 9-67 (Order of angles in the Compressed Beamforming Feedback Matrix subfield), Nc is the number of columns in a compressed beamforming feedback matrix determined by the Nc Index field of the HE MIMO Control field, Nr is the number of rows in a compressed beamforming feedback matrix determined by the Nr Index field of the HE MIMO Control field.

The beamforming feedback matrix V is formed by the beamformee as follows. The beamformer transmits an NDP with $N_{STS,NDP}$ space-time streams, where $N_{STS,NDP}$ may take a value between 2 and 8. Based on this NDP, the beamformee estimates the $N_{RX,BFEE} \times N_{STS,NDP}$ channel, and based on that channel it determines a $Nr \times Nc$ orthogonal matrix V, where Nr and Nc satisfy Equation (8-1).

Further restrictions on Nc are described in 28.2 (HE PHY service interface). The angles are quantized as defined in Table 9-68 (Quantization of angles).

The HE Compressed Beamforming Report information has the same structure and order defined in Table 9-76b (HE Compressed Beamforming Report information).

Table 9-76b—HE Compressed Beamforming Report information

Field	Size (bits)	Meaning
Average SNR of Space-Time Stream 1	8	Signal-to-noise ratio at the beamformee for space-time stream 1 averaged over all data subcarriers. See Table 9-71 (Average SNR of Space-Time Stream i subfield).
...		...
Average SNR of Space-Time Stream Nc	8	Signal-to-noise ratio at the beamformee for space-time stream Nc averaged over all data subcarriers. See Table 9-71 (Average SNR of Space-Time Stream i subfield).
Compressed Beamforming Feedback Matrix V for subcarrier $k = scidx(0)$	$Na \times (b_{\psi} + b_{\phi})/2$	Compressed beamforming feedback matrix defined in Table 9-67 (Order of angles in the Compressed Beamforming Feedback Matrix subfield).
Compressed Beamforming Feedback Matrix V for subcarrier $k = scidx(1)$	$Na \times (b_{\psi} + b_{\phi})/2$	Compressed beamforming feedback matrix defined in Table 9-67 (Order of angles in the Compressed Beamforming Feedback Matrix subfield).

Table 9-76b—HE Compressed Beamforming Report information *(continued)*

Compressed Beamforming Feedback Matrix *V* for subcarrier $k = scidx(2)$	$Na \times (b_{\psi} + b_{\phi})/2$	Compressed beamforming feedback matrix defined in Table 9-67 (Order of angles in the Compressed Beamforming Feedback Matrix subfield).
...		...
Compressed Beamforming Feedback Matrix *V* for subcarrier $k = scidx(Ns - 1)$	$Na \times (b_{\psi} + b_{\phi})/2$	Compressed beamforming feedback matrix defined in Table 9-67 (Order of angles in the Compressed Beamforming Feedback Matrix subfield).

In Table 9-76b (HE Compressed Beamforming Report information), *Ns* is the number of subcarriers for which the Compressed Beamforming Feedback Matrix subfield is sent back to the beamformer. A beamformee may choose to reduce Ns by using a method referred to as grouping, in which only a single Compressed Beamforming Feedback Matrix is reported for each group of *Ng* adjacent subcarriers. For HE Compressed Beamforming Report, *Ns* is a function of the RU Start Index, RU End Index and Grouping subfields in the HE MIMO Control field (see 9.4.1.62 (HE MIMO Control field)). Subcarriers $scidx(0)$ and $scidx(Ns - 1)$ represent the S (Start)-tone corresponding to the RU Start Index and E (End)-tone corresponding to the RU End Index, respectively.

For 40 MHz and 80 MHz, when the aforementioned S-tone and E-tone indices lie on the same side of DC, $scidx(i) = scidx(i - 1) + Ng$, where $1 \leq i \leq Ns - 2$. However, when the S-tone and E-tone indices lie on different sides of DC, the following relationships hold separately for the two sides of DC.

For the left of DC, $scidx(i) = scidx(i - 1) + Ng$, where $1 \leq i \leq L$ and $scidx(L) = -4$.

For the right of DC, $scidx(i) = scidx(i - 1) + Ng$, where $L + 2 \leq i \leq Ns - 2$ and $scidx(L + 1) = 4$.

The S-tone and E-tone corresponding to the possible RU indices are listed in Table 9-76c (Feedback subcarrier indices indicating start 26-tone RU index and end 26-tone RU index for Ng = 4) for $Ng = 4$ and Table 9-76d (Feedback subcarrier indices indicating start 26-tone RU index and end 26-tone RU index for Ng = 16) for $Ng = 16$. For 160 MHz, to determine the S-tone and E-tone, RUs 37 to 73 occupying the higher 80 MHz use the same entries in Table 9-76c (Feedback subcarrier indices indicating start 26-tone RU index and end 26-tone RU index for Ng = 4) and Table 9-76d (Feedback subcarrier indices indicating start 26-tone RU index and end 26-tone RU index for Ng = 16) as RUs 0 to 36 occupying the lower 80 MHz. For 20 MHz, $scidx(i)$, where $1 \leq i \leq Ns - 2$, includes all subcarrier indices between the S-tone and the E-tone subcarrier indices described in Table 9-76e (Feedback subcarrier indices for 20 MHz bandwidth for Ng = 4 and Ng = 16) for $Ng = 4$ and $Ng = 16$.

Table 9-76c—Feedback subcarrier indices indicating start 26-tone RU index and end 26-tone RU index for *Ng* = 4

80 MHz 26-tone RU Index	80 MHz (S, E) FB tone	40 MHz 26-tone RU Index	40 MHz (S, E) FB tone	20 MHz 26-tone RU Index	20 MHz (S, E) FB tone

Table 9-76c—Feedback subcarrier indices indicating start 26-tone RU index and end 26-tone RU index for *Ng* = 4 *(continued)*

0	–500, –472	0	= (S, E) for 80 MHz + 256		
1	–476, –448	1			
2	–448, –420	2			
3	–420, –392	3			
4	–392, –364	4			
5	–368, –340	5			
6	–340, –312	6			
7	–312, –284	7			
8	–288, –260	8			
9	–260, –232				
10	–232, –204				
11	–204, –176				
12	–180, –152				
13	–152, –124				
14	–124, –96			0	–122, –96
15	–100, –72			1	= (S, E) for 80 MHz + 4
16	–72, –44			2	
17	–44, –16			3	= (S, E) for 80 MHz
18	–16, 16			4	
19	16, 44			5	
20	44, 72			6	= (S, E) for 80 MHz – 4
21	72, 100			7	
22	96, 124			8	
23	124, 152				
24	152, 180				
25	176, 204				
26	204, 232				

Table 9-76c—Feedback subcarrier indices indicating start 26-tone RU index and end 26-tone RU index for *Ng* = 4 *(continued)*

27	232, 260				
28	260, 288	9	= (S, E) for 80 MHz – 256		
29	284, 312	10			
30	312, 340	11			
31	340, 368	12			
32	364, 392	13			
33	392, 420	14			
34	420, 448	15			
35	448, 476	16			
36	472, 500	17			

Table 9-76d—Feedback subcarrier indices indicating start 26-tone RU index and end 26-tone RU index for *Ng* = 16

80 MHz 26-tone RU index	80 MHz (S, E) FB tone	40 MHz 26-tone RU index	40 MHz (S, E) FB tone	20 MHz 26-tone RU index	20 MHz (S, E) FB tone
0	–500, –468	0	= (S, E) for 80 MHz + 256		
1	–484, –436	1			
2	–452, –420	2			
3	–420, –388	3			
4	–404, –356	4			
5	–372, –340	5			
6	–340, –308	6			
7	–324, –276	7			
8	–292, –260	8			
9	–260, –228				
10	–244, –196				
11	–212, –164				
12	–180, –148				

Table 9-76d—Feedback subcarrier indices indicating start 26-tone RU index and end 26-tone RU index for *Ng* = 16 *(continued)*

<table>
<tr><td>13</td><td>−164, −116</td><td></td><td></td><td></td><td></td></tr>
<tr><td>14</td><td>−132, −84</td><td></td><td></td><td>0</td><td>−122, −96</td></tr>
<tr><td>15</td><td>−100, −68</td><td></td><td></td><td>1</td><td rowspan="2">= (S, E) for 80 MHz + 4</td></tr>
<tr><td>16</td><td>−84, −36</td><td></td><td></td><td>2</td></tr>
<tr><td>17</td><td>−52, −4</td><td></td><td></td><td>3</td><td rowspan="3">= (S, E) for 80 MHz</td></tr>
<tr><td>18</td><td>−20, 20</td><td></td><td></td><td>4</td></tr>
<tr><td>19</td><td>4, 52</td><td></td><td></td><td>5</td></tr>
<tr><td>20</td><td>36, 84</td><td></td><td></td><td>6</td><td rowspan="2">= (S, E) for 80 MHz – 4</td></tr>
<tr><td>21</td><td>68, 100</td><td></td><td></td><td>7</td></tr>
<tr><td>22</td><td>84, 132</td><td></td><td></td><td>8</td><td></td></tr>
<tr><td>23</td><td>116, 164</td><td></td><td></td><td></td><td></td></tr>
<tr><td>24</td><td>148, 180</td><td></td><td></td><td></td><td></td></tr>
<tr><td>25</td><td>164, 212</td><td></td><td></td><td></td><td></td></tr>
<tr><td>26</td><td>196, 244</td><td></td><td></td><td></td><td></td></tr>
<tr><td>27</td><td>228, 260</td><td></td><td></td><td></td><td></td></tr>
<tr><td>28</td><td>260, 292</td><td>9</td><td rowspan="9">= (S, E) for 80 MHz – 256</td><td></td><td></td></tr>
<tr><td>29</td><td>276, 324</td><td>10</td><td></td><td></td></tr>
<tr><td>30</td><td>308, 340</td><td>11</td><td></td><td></td></tr>
<tr><td>31</td><td>340, 372</td><td>12</td><td></td><td></td></tr>
<tr><td>32</td><td>356, 404</td><td>13</td><td></td><td></td></tr>
<tr><td>33</td><td>388, 420</td><td>14</td><td></td><td></td></tr>
<tr><td>34</td><td>420, 452</td><td>15</td><td></td><td></td></tr>
<tr><td>35</td><td>436, 484</td><td>16</td><td></td><td></td></tr>
<tr><td>36</td><td>468, 500</td><td>17</td><td></td><td></td></tr>
</table>

Table 9-76e—Feedback subcarrier indices for 20 MHz bandwidth for *Ng* = 4 and *Ng* = 16

Ng	Subcarrier indeces
4	–122, –120, –116, –112, –108, –104, –100, –96, –92, –88, –84, –80, –76, –72, –68, –64, –60, –56, –52, –48, –44, –40, –36, –32, –28, –24, –20, –16, –12, –8, –4, –2, 2, 4, 8, 12, 16, 20, 24, 28, 32, 36, 40, 44, 48, 52, 56, 60, 64, 68, 72, 76, 80, 84, 88, 92, 96, 100, 104, 108, 112, 116, 120, 122
16	–122, –116, –100, –84, –68, –52, –36, –20, –4, –2, 2, 4, 20, 36, 52, 68, 84, 100, 116, 122

The Average SNR of Space-Time Stream *i* subfield in Table 9-76b (HE Compressed Beamforming Report information) is an 8-bit twos complement integer defined in Table 9-71 (Average SNR of Space-Time Stream i subfield).

The $AvgSNR_i$ in Table 9-71 (Average SNR of Space-Time Stream i subfield) is found by computing the SNR per subcarrier in decibels for the subcarriers identified in Table 9-76c (Feedback subcarrier indices indicating start 26-tone RU index and end 26-tone RU index for Ng = 4) for *Ng* = 4 and Table 9-76d (Feedback subcarrier indices indicating start 26-tone RU index and end 26-tone RU index for Ng = 16) for *Ng* = 16, and then computing the arithmetic mean of those values. Each SNR value per subcarrier in stream *i* (before being averaged) corresponds to the SNR associated with the column *i* of the beamforming feedback matrix *V* determined at the beamformee. Each SNR corresponds to the predicted SNR at the beamformee when the beamformer applies all columns of the matrix *V*.

For HE beamformee, supporting *Ng* = 16 in the HE Compressed Beamforming Report field is optional for both SU and MU feedback types. A beamformer shall not request *Ng* = 16 in an HE NDP Announcement frame if the beamformee does not indicate support for *Ng* = 16 in the HE Capabilities element it transmits (see 9.4.2.218 (HE Capabilities element)).

For an HE beamformee, supporting the codebook size (ϕ, ψ) = {4, 2} in the HE Compressed Beamforming Report field is optional for SU feedback type. A beamformer shall not request codebook size (ϕ, ψ) = {4, 2} in an HE NDP Announcement frame if the beamformee does not indicate support for the codebook size (ϕ, ψ) = {4, 2} in the HE Capabilities element it transmits (see 9.4.2.218 (HE Capabilities element)).

For an HE beamformee, supporting codebook size (ϕ, ψ) = {7, 5} in the HE Compressed Beamforming Report field is optional for MU feedback type. A beamformer shall not request the codebook size (ϕ, ψ) = {7, 5} in an HE NDP Announcement frame if the beamformee does not indicate support for the codebook size (ϕ, ψ) = {7, 5} in the HE Capabilities element it transmits (see 9.4.2.218 (HE Capabilities element)).

9.4.1.64 HE MU Exclusive Beamforming Report field

The MU Exclusive Beamforming Report field is used by the HE Compressed Beamforming And CQI frame (see 9.6.28.2 (HE Compressed Beamforming And CQI frame format)) to carry explicit feedback in the form of delta SNRs. The information in the HE Compressed Beamforming Report field and the HE MU Exclusive Beamforming Report field can be used by the transmit MU beamformer to determine the steering matrices *Q*, as described in 28.3.3.8 (DL MU-MIMO).

The size of the HE MU Exclusive Beamforming Report field depends on the values in the HE MIMO Control field. The HE MU Exclusive Beamforming Report field contains HE MU Exclusive Beamforming Report information or successive (possibly zero-length) portions thereof in the case of segmented HE Compressed Beamforming and CQI feedback (see 27.6 (HE sounding protocol)). HE Compressed

Beamforming Report information and HE MU Exclusive Beamforming Report information are included in the HE Compressed Beamforming and CQI feedback if the MU feedback type is indicated in the Feedback Type field in the HE MIMO Control field.

The HE MU Exclusive Beamforming Report information consists of Delta SNR subfields for each of the space-time stream (1 to *Nc*) of a subset of subcarriers typically spaced *Ng* apart, where *Ng* is signaled in the Grouping subfield of the HE MIMO Control field. Starting from the lowest frequency subcarrier and continuing to the highest frequency subcarrier. Specifically, the locations of the feedback subcarriers for delta SNR subfield shall be identical to the subcarrier locations of the compressed *V* matrices feedback.

No padding is present between $\Delta SNR_{k,i}$, in the HE MU Exclusive Beamforming Report field, even if they correspond to different subcarriers. The subset of subcarriers included is determined by the values of the RU Start Index, RU End Index, and Grouping subfield of the HE MIMO Control field. For each subcarrier included, the deviation in dB of the SNR of that subcarrier for each column of *V* relative to the average SNR of the corresponding space-time stream is computed using Equation (9-2).

The HE MU Exclusive Beamforming Report information has the same structure and order Table 9-76f (HE MU Exclusive Beamforming Report information).

Table 9-76f—HE MU Exclusive Beamforming Report information

Field	Size (bits)	Meaning
Delta SNR for space-time stream 1 for subcarrier $k = scidx(0)$	4	$\Delta SNR_{scidx(0),1}$ as defined in Equation (9-2).
...		...
Delta SNR for space-time stream Nc for subcarrier $k = scidx(0)$	4	$\Delta SNR_{scidx(0),Nc}$ as defined in Equation (9-2).
Delta SNR for space-time stream 1 for subcarrier $k = scidx(1)$	4	$\Delta SNR_{scidx(1),1}$ as defined in Equation (9-2).
...		...
Delta SNR for space-time stream Nc for subcarrier $k = scidx(1)$	4	$\Delta SNR_{scidx(1),Nc}$ as defined in Equation (9-2).
...		...
Delta SNR for space-time stream 1 for subcarrier $k = scidx(Ns - 1)$		$\Delta SNR_{scidx(Ns-1),1}$ as defined in Equation (9-2).
...		...
Delta SNR for space-time stream Nc for subcarrier $k = scidx(Ns - 1)$		$\Delta SNR_{scidx(Ns-1),Nc}$ as defined in Equation (9-2).

In Table 9-76f (HE MU Exclusive Beamforming Report information), *Ns* and *scidx()* are defined in 9.4.1.63 (HE Compressed Beamforming Report field).

9.4.1.65 HE CQI-only Report field

The HE CQI-only Report field is used by the HE Compressed Beamforming And CQI frame (see 9.6.28.2 (HE Compressed Beamforming And CQI frame format)) to carry the per-RU average SNRs of each space-time stream, where each per-RU average SNR is the arithmetic mean of the SNR in decibels over a 26-tone RU for which the feedback is being requested.

The size of the HE Compressed Beamforming Report field depends on the values in the HE MIMO Control field. The HE Compressed Beamforming Report field contains HE CQI-only Report information or successive (possibly zero-length) portions thereof in the case of segmented HE Compressed Beamforming and CQI feedback (see 27.6 (HE sounding protocol)). HE CQI-only Report information is included in the HE Compressed Beamforming and CQI feedback if the CQI-only feedback type is indicated in the Feedback Type field of the HE MIMO Control field. The structure of the HE CQI-only Report field is shown in Table 9-76g (HE CQI-only Report information).

Table 9-76g—HE CQI-only Report information

Field	Size (bits)	Meaning
Average SNR for space-time stream 1 for RU index $k = ruidx(0)$	6	SNR at the beamformee for space-time stream 1 averaged over 26-tone RU. See Table 9-76h (Average SNR of RU index k for space-time stream i subfield).
...		
Average SNR for space-time stream *Nc* for RU index $k = ruidx(0)$	6	SNR at the beamformee for space-time stream *Nc* averaged over 26-tone RU. See Table 9-76h (Average SNR of RU index k for space-time stream i subfield).
Average SNR for space-time stream 1 for RU index $k = ruidx(1)$	6	SNR at the beamformee for space-time stream 1 averaged over 26-tone RU. See Table 9-76h (Average SNR of RU index k for space-time stream i subfield).
...		
Average SNR for space-time stream *Nc* for RU index $k = ruidx(1)$	6	SNR at the beamformee for space-time stream *Nc* averaged over 26-tone RU. See Table 9-76h (Average SNR of RU index k for space-time stream i subfield).
...		
Average SNR for space-time stream 1 for RU index $k = ruidx(Ncqi - 1)$	6	SNR at the beamformee for space-time stream 1 averaged over 26-tone RU. See Table 9-76h (Average SNR of RU index k for space-time stream i subfield).
...		
Average SNR for space-time stream *Nc* for RU index $k = ruidx(Ncqi - 1)$	6	SNR at the beamformee for space-time stream *Nc* averaged over 26-tone RU. See Table 9-76h (Average SNR of RU index k for space-time stream i subfield).

Ncqi is the number of RU indices for which the CQI-only report is sent back to the beamformer. *Ncqi* is a function of the RU Start Index and RU End Index subfields in the HE MIMO Control field. The RU indices $ruidx(0)$ and $ruidx(Ncqi - 1)$ correspond to the RU Start Index and RU End Index subfields, respectively. The RU index $ruidx(i) = ruidx(i - 1) + 1$, where $1 \le i \le Ncqi - 2$.

The Average SNR of space-time stream *i* for the RU index *k* subfield in the Table 9-76g (HE CQI-only Report information) is an 6-bit twos complement integer whose definition is shown in Table 9-76h (Average SNR of RU index k for space-time stream i subfield).

Table 9-76h—Average SNR of RU index *k* for space-time stream *i* subfield

Average SNR of RU index *k* for space-time stream *i*	$AvgSNR_{k,i}$ (dB)
–32	≤ –10
–31	–9
–30	–8
...	
30	52
31	≥ 53

The $AvgSNR_{k,i}$ in Table 9-76h (Average SNR of RU index k for space-time stream i subfield) is found by computing the arithmetic mean of the SNR per subcarrier in decibels for space-time stream *i* over the subcarriers in RU index *k* for which the feedback is being requested.

9.4.2 Elements

9.4.2.1 General

Insert the following new rows into Table 9-77 (Element IDs) (header row shown for convenience):

Table 9-77—Element IDs

Element	Element ID	Element ID Extension	Extensible
HE Capabilities (see 9.4.2.213 (HE Capabilities element))	<ANA>	N/A	Yes
HE Operation (see 9.4.2.214 (HE Operation element))	<ANA>	N/A	Yes
RAPS element (see 9.4.2.220 (OFDMA-based Random Access Parameter Set (RAPS) element))	255	<ANA>	Yes
MU EDCA Parameter Set (see 9.4.2.221 (MU EDCA Parameter Set element))	255	<ANA>	Yes

9.4.2.3 Supported Rates and BSS Membership Selectors element

Insert a new last row in Table 9-78 (BSS membership selector value encoding) as follows:

Table 9-78—BSS membership selector value encoding

Value	Feature	Interpretation
125	HE PHY	Support for the mandatory features of Clause 28 (High Efficiency (HE) PHY specification) is required in order to join the BSS that was the source of the Supported Rates and BSS Membership Selectors element or Extended Supported Rates and BSS Membership Selectors element containing this value.

9.4.2.6 TIM element

Insert the following at the end of the subclause:

When included in TIM frames and FILS discovery frames at the beginning of a broadcast TWT SP by an HE AP:

— The DTIM count field is reserved

— The DTIM period is reserved

— Bit number *N* in the traffic indication virtual bitmap that corresponds to an HE non-AP STA with AID *N* is determined as follows:

- Bit number *N* in the traffic indication virtual bitmap is 0 if the AP does not intend to transmit to the STA or to trigger the STA for an UL MU transmission during the TWT SP and before the next TWT SP.
- Otherwise, bit number *N* in the traffic indication virtual bitmap is 1.

9.4.2.27 Extended Capabilities element

Insert the following rows into Table 9-135 (Extended Capabilities element) (header row shown for convenience):

Table 9-135—Extended Capabilities element

Bit	Information	Notes
<ANA>	TWT Requester Support	A STA sets the TWT Requester Support field to 1 when dot11TWTOptionActivated is true, and sets it to 0 otherwise. See 11.11.9.9 (TWT section).
<ANA>	TWT Responder Support	A STA sets the TWT Responder Support field to 1 when dot11TWTOptionActivated is true, and sets it to 0 otherwise. See 11.11.9.9 (TWT section).

9.4.2.139 ADDBA Extension element

Change Figure 9-531 (ADDBA Capabilities field format) as follows:

	B0	B1 B2	~~B1~~B3 B7
	No-Fragmentation	HE Fragmentation Operation	Reserved
Bits:	1	2	~~7~~ 5

Figure 9-531—ADDBA Capabilities field format

Change the last paragraph as follows:

The No-Fragmentation subfield determines whether a fragmented MSDU can be carried in the MPDU sent under the block ack agreement. When this subfield set to 1 in the ADDBA Request frame, it indicates that the non-HE originator is not fragmenting sent MSDUs. When this subfield set to 1 in the ADDBA Response frame, it indicates that the non-HE recipient is not capable of receiving fragmented MSDUs. The No-Fragmentation subfield is reserved when transmitted by an HE STA.

Insert the following as the new last paragraph:

The HE fragmentation Operation subfield is reserved when transmitted by a non-HE STA. The HE fragmentation operation subfield when transmitted by an HE STA indicates the level of dynamic fragmentation that is supported as a recipient for the TID which is defined in the ADDBA frame as follows:

— A value of 0 in the ADDBA Request frame indicates that the originator does not intend to send fragmented MSDUs for the TID specified in the Block Ack Parameter Set field of the ADDBA Request frame.

— When this subfield set to 1 in the ADDBA Request frame, it indicates that the originator intends to send fragmented MSDUs under fragmentation level 1 (see 27.3.3.2 (Level 1 dynamic fragmentation)) for the TID specified in the Block Ack Parameter Set field of the ADDBA Request frame.

- When this subfield set to 2 in the ADDBA Request frame, it indicates that the originator intends to send fragmented MSDUs under fragmentation level 2 (see 27.3.3.3 (Level 2 dynamic fragmentation)) for the TID specified in the Block Ack Parameter Set field of the ADDBA Request frame.
- When this subfield set to 0 in the ADDBA Response frame, it indicates that the recipient is not capable of receiving fragmented MSDUs for the TID specified in the Block Ack Parameter Set field of the ADDBA Response frame.
- When this subfield set to 1 in the ADDBA Response frame, it indicates that the recipient is capable of receiving fragmented MSDUs under fragmentation level 1 only for the TID specified in the Block Ack Parameter Set field of the ADDBA Response frame.
- When this subfield set to 2 in the ADDBA Response frame, it indicates that the recipient is capable of receiving fragmented MSDUs under fragmentation levels 1 and 2 for the TID specified in the Block Ack Parameter Set field of the ADDBA Response frame.

9.4.2.200 TWT element

Change Figure 9-589av (TWT element format) as follows (add arrow and associated text):

Repeat for each TWT parameter set when the Broadcast field is 1

	Element ID	Length	Control	Request Type	Target Wake Time	TWT Group Assign ment	Nominal Minimum TWT Wake Duration	TWT Wake Interval Mantiss a	Broadcast TWT ID	TWT Channel	NDP Paging (optional)
Octets:	1	1	1	2	8 or 0	9 or 3 or 0	1	2	0 or 1	1	0 or 4

Figure 9-589av—TWT element format

Change Figure 9-589aw (Control field format) as follows.

	B1	B2	B3	B4	~~B3~~B5 B8
	NDP Paging Indicator	Responder PM Mode	Broadcast	Wake TBTT Negotiation	Reserved
Bits:	1	1	1	1	~~6~~4

Figure 9-589aw—Control field format

Insert the following two paragraphs after the 5th paragraph ("The Responder PM Mode subfield..."):

The Broadcast field indicates if the TWT SP(s) indicated by the TWT element are for broadcast or individual TWT(s) as defined in 10.43 (Target wake time (TWT)). The Broadcast field is 1 to indicate that the TWT SP(s) defined by the TWT element are associated with broadcast TWT(s). The Broadcast field is 0, otherwise.When the Broadcast field is 1 then one or more TWT parameter sets are contained in the TWT element where the TWT parameter set is the set of subfields that occur after the Control subfield. Otherwise, only one TWT parameter set is contained in the TWT element. An S1G STA sets the Broadcast field to 0.

The Wake TBTT Negotiation subfield indicates that the scheduled STA transmitting the TWT element is indicating a value for the next wake TBTT for a broadcast TWT in the Target Wake Time field and is indicating a value for a wake interval between Beacon frames in the TWT Wake Interval Mantissa and TWT Wake Interval Exponent fields as described in 27.7.3.4 (Negotiation of wake TBTT and listen interval). The Wake TBTT Negotiation subfield is set to 0 in TWT elements transmitted by a responding STA and by a scheduling STA.

Change Figure 9-589ax (Request Type field format) as follows (B4 from "Reserved" to "Trigger").

	B0	B1 B3	B4	B5	B6	B7 B9	B10 B14	B15
	TWT Request	TWT Setup Command	~~Reserved~~ Trigger	Implicit	Flow Type	TWT Flow Identifier	TWT Wake Interval Exponent	TWT Protection
Bits:	1	3	1	1	1	3	5	1

Figure 9-589ax—Request Type field format

Change Table 9-257l (TWT Setup Command field values) as follows:

Table 9-262k—TWT Setup Command field values

TWT Setup Command field value	Command name	Description when transmitted by a TWT requesting STA, Wake TBTT Negotiation subfield = 0	Description when transmitted by a TWT responding STA, Wake TBTT Negotiation subfield = 0	Description when transmitted by a TWT scheduled STA, Wake TBTT Negotiation subfield = 1	Description when transmitted by a TWT scheduling STA, Wake TBTT Negotiation subfield = 1
0	Request TWT	The Target Wake Time field of the TWT element contains 0s as the TWT responding STA specifies the target wake time value for this case, other TWT parameters* are suggested by the TWT requesting STA in the TWT request.	N/A	N/A	N/A
1	Suggest TWT	TWT requesting STA includes a set of TWT parameters such that if the requested target wake time value and/or other TWT parameters cannot be accommodated, then the TWT setup might still be accepted.	N/A	The Target Wake Time field of the TWT element contains 0s as the TWT scheduling STA specifies the target wake time value for this case, other TWT parameters are suggested by the TWT scheduled STA in the TWT request.	N/A

Table 9-262k—TWT Setup Command field values *(continued)*

2	Demand TWT	TWT requesting STA includes a set of TWT parameters such that if the requested target wake time value and/or other TWT parameters cannot be accommodated, then the TWT setup will be rejected.	N/A	The Target Wake Time field of the TWT element contains 0s as the TWT scheduling STA specifies the target wake time value for this case, other TWT parameters are demanded by the TWT scheduled STA in the TWT request.	N/A
3	TWT Grouping	N/A	TWT responding STA suggests TWT group parameters that are different from the suggested or demanded TWT parameters of the TWT requesting STA	N/A	N/A
4	Accept TWT	N/A	TWT responding STA accepts the TWT request with the TWT parameters (See NOTE) indicated in the TWT element transmitted by the responding STA	N/A	TWT scheduling STA accepts the TWT request with the TWT parameters (see NOTE) indicated in the TWT element transmtted by the TWT scheduled STA.
5	Alternate TWT	N/A	TWT responding STA suggests TWT parameters that are different from TWT requesting STA suggested or demanded TWT parameters	N/A	N/A

Table 9-262k—TWT Setup Command field values *(continued)*

6	Dictate TWT	N/A	TWT responding STA demands TWT parameters that are different from TWT requesting STA TWT suggested or demanded parameters	N/A	N/A
7	Reject TWT	N/A	TWT responding STA rejects TWT setup	N/A	TWT scheduling STA rejects TWT setup
NOTE—TWT Parameters are: TWT, Nominal Minimum Wake Duration, TWT Wake Interval and TWT Channel subfield values indicated in the element. The Trigger subfield value indicated in the element is also a TWT parameter for an HE STA.					

Insert the following paragraph after the 8th paragraph ("The TWT Setup Command subfield values..."):

The Trigger field indicates if the TWT SP indicated by the TWT element includes Trigger frames as defined in 10.43 (Target wake time (TWT)). The Trigger field is set to 1 to indicate that at least one Trigger frame is transmitted during the TWT SP. The Trigger field is set to 0 otherwise.

Change the 9th paragraph as follows:

The TWT Flow Identifier subfield contains a 3-bit value which identifies the specific information for this TWT request uniquely from other requests made between the same TWT requesting STA and TWT responding STA pair. For a TWT SP that is indicated in a TWT response transmission that is a broadcast TWT SP, the TWT Flow Identifier subfield contains a value that indicates recommendations on the types of frames that are transmitted by scheduled STAs during the broadcast TWT SP, encoded according to Table 9-262k1 (TWT Flow Identifier field for a broadcast TWT element).

Insert a new table as follows:

Table 9-262k1—TWT Flow Identifier field for a broadcast TWT element

TWT Flow Identifier field value	Description when transmitted in a broadcast TWT element
0	No constraints on the frames transmitted during a broadcast TWT SP.

Table 9-262k1—TWT Flow Identifier field for a broadcast TWT element

1	Frames transmitted during a broadcast TWT SP by a TWT scheduled STA are recommended to be limited to: — Frames with reduced payload sizes that deliver control feedback: • PS-Poll and QoS Null frames • Feedback can be contained is the QoS Control field or in the HE variant HT Control field of the frame, whichever is present (see 27.5.1 (HE DL MU operation), 27.5.2 (UL MU operation), 27.8 (Operating mode indication), 25.14 (Link adaptation using the HE variant HT Control field), etc.) — Frames that are sent as part of a sounding feedback exchange (see 27.6 (HE sounding protocol)) — Management frames • Action, or Action No Ack frames There are no restrictions on the frames transmitted by the scheduling STA of the broadcast TWT SP. Trigger frames transmitted by the AP during the broadcast TWT SP will not contain RUs for random access (see 27.7.3.2 (Rules for TWT scheduling STA)).
2	Frames transmitted during a broadcast TWT SP by a TWT scheduled STAT are recommended to be limited to: — Frames with reduced payload sizes that deliver control feedback: • PS-Poll and QoS Null frames • Feedback can be contained is the QoS Control field or in the HE variant HT Control field of the frame, whichever is present (see 27.5.1 (HE DL MU operation), 27.5.2 (UL MU operation), 27.8 (Operating mode indication), 25.14 (Link adaptation using the HE variant HT Control field), etc.) — Frames that are sent as part of a sounding feedback exchange (see 27.6 (HE sounding protocol)) — Management frames • Action, Action No Ack frames or (Re-)Association Request frames There are no restrictions on the frames transmitted by the scheduling STA of the broadcast TWT SP. Trigger frames transmitted by the AP during the broadcast TWT SP will contain at least one RU for random access (see 27.7.3.2 (Rules for TWT scheduling STA)).
3	No constraints on the frames transmitted during a broadcast TWT SP. The AP transmits a TIM frame or a FILS discovery frame including a TIM element at the beginning of the TWT SP.
4-7	Reserved

Change the 10th paragraph as follows:

In a TWT element transmitted by a TWT requesting or scheduled STA, the TWT wake interval is equal to the average time that the TWT requesting STA expects to elapse between successive TWT SPs. In a TWT element transmitted by a TWT responding or scheduling STA, the TWT wake interval is equal to the average time that the TWT responding STA expects to elapse between successive TWT SPs. In a TWT element contained in a TWT request that is sent by the scheduled STA to negotiate the wake intervals for Beacon frames that contain a TWT element that indicates a broadcast TWT, the TWT wake interval indicates the value of the listen interval (see 10.44.3.4 (Negotiation of TBTT and listen interval)). The TWT Wake Interval Exponent subfield is set to the value of the exponent of the TWT wake interval value in microseconds, base 2. The TWT wake interval of the requesting STA is equal to (TWT Wake Interval Mantissa) $\times 2^{(\text{TWT Wake Interval Exponent})}$.

Change the 11th paragraph as follows:

When transmitted by a TWT requesting STA or a TWT scheduled STA, the Target Wake Time field contains a positive integer which corresponds to a TSF time at which the STA requests to wake, or a value of zero when the TWT Setup Command subfield contains the value corresponding to the command "Request TWT". The Target Wake Time field is 8 octets when the Broadcast field is 0; otherwise it is 2 octets with the lowest bit of the 2 octets corresponding to bit 4 of the relevant TSF value. When a TWT responding STA or a TWT scheduling STA with dot11TWTGroupingSupport equal to 0 transmits a TWT element to the TWT requesting STA, the TWT element contains a value in the Target Wake Time field which corresponds to a TSF time at which the TWT responding STA requests the TWT requesting STA or TWT scheduled STA to wake for the corresponding TWT SP and it does not contain the TWT Group Assignment field.

Insert the following paragraph after paragraph 21 ("The TWT Wake Interval Mantissa..."):

The Broadcast TWT ID subfield is present if the Broadcast subfield in the Control subfield has a value of 1, otherwise the Broadcast TWT ID subfield is not present. Within a TWT element that includes a TWT setup command value of Request TWT, Suggest TWT or Demand TWT, the Broadcast TWT ID, if present, indicates a specific Broadcast TWT in which the transmitting STA is requesting to participate. Within a TWT element that includes a TWT setup command value of Accept TWT, Alternate TWT, Dictate TWT or Reject TWT, the Broadcast TWT ID, if present, indicates a specific Broadcast TWT for which the transmitting STA is providing TWT parameters. Within a TWT element that includes a TWT setup command value of TWT Grouping, the Broadcast subfield is 0 and the Broadcast TWT ID, is not present. The value 0 in the Broadcast TWT ID subfield indicates the special broadcast TWT whose membership corresponds to all STAs that are members of the BSS corresponding to the BSSID of the management frame carrying the TWT element.

Change the 22nd and subsequent two paragraphs as follows:

When transmitted by a TWT requesting STA, the TWT Channel field contains a bitmap indicating which channel the STA requests to use as a temporary primary channel during a TWT SP. When transmitted by a TWT responding STA, the TWT Channel field contains a bitmap indicating which channel the TWT requesting STA is allowed to use as a temporary channel during the TWT SP. Each bit in the bitmap corresponds to one minimum width channel for the band in which the TWT responding STA's associated BSS is currently operating, with the least significant bit corresponding to the lowest numbered channel of the operating channels of the BSS.The minimum width channel is equal to the SST Channel Unit field of the SST Operation element if such an element has been previously received or is equal to 1 MHz for a BSS with a BSS primary channel width of 1 MHz and 2 MHz for a BSS with a BSS primary channel width of 2 MHz if no such element has been previously received from the AP to which the SST STA is associated. A value of 1 in a bit position in the bitmap transmitted by a TWT requesting STA means that operation with that channel as the primary channel is requested during a TWT SP. A value of 1 in a bit position in the bitmap transmitted by a TWT responding STA means that operation with that channel as the primary channel is allowed during the TWT SP. The TWT Channel field is not present when the TWT Broadcast field has the value 1.

~~A TWT requesting STA sets the TWT Protection subfield to 1 to request the TWT responding STA to provide protection of the set of TWT SPs corresponding to the requested TWT flow identifier by allocating RAW(s) that restrict access to the medium during the TWT SP(s) for that(those) TWTs. A TWT requesting STA sets the TWT Protection subfield to 0 if TWT protection by RAW allocation is not requested for the corresponding TWT(s).~~

A TWT requesting STA sets the TWT Protection subfield to 1 to request the TWT responding STA to provide protection of the set of TWT SPs corresponding to the requested TWT flow identifier by:

- Allocating RAW(s) that restrict access to the medium during the TWT SP(s) for that (those) TWTs that are set up within an S1G BSS
- Enabling NAV protection during the TWT SP(s) for that (those) TWTs that are set up within an HE BSS

A TWT requesting STA sets the TWT Protection subfield to 0 if TWT protection by RAW allocation is not requested for the corresponding TWT(s).

A TWT scheduled STA sets the TWT Protection subfield to 0.

~~When transmitted by a TWT responding STA that is an AP, the TWT Protection subfield indicates whether the TWT SP(s) identified in the TWT element will be protected. A TWT responding STA sets the TWT Protection subfield to 1 to indicate that the TWT SP(s) corresponding to the TWT flow identifier(s) of the TWT element will be protected by allocating RAW(s) that restrict access to the medium during the TWT SP(s) for that(those) TWT(s). A TWT responding STA sets the TWT Protection subfield to 0 to indicate that the TWT SP(s) identified in the TWT element might not be protected from TIM STAs by allocating RAW(s).~~

When transmitted by a TWT responding STA or TWT scheduling STA that is an AP, the TWT Protection subfield indicates whether the TWT SP(s) identified in the TWT element will be protected. A TWT responding STA or TWT scheduling STA sets the TWT Protection subfield to 1 to indicate that the TWT SP(s) corresponding to the TWT flow identifier(s) of the TWT element will be protected by:

- Allocating RAW(s) that restrict access to the medium during the TWT SP(s) for that (those) TWT(s) when the responding STA or scheduling STA is an S1G STA.
- Enabling NAV protection during the TWT(s) for that (those) TWTs when the responding STA or scheduling STA is not an S1G STA

A TWT responding STA or TWT scheduling STA sets the TWT Protection subfield to 0 to indicate that the TWT SP(s) identified in the TWT element might not be protected.

Insert the following new subclauses after the last subclause in 9.4.2:

9.4.2.218 HE Capabilities element

9.4.2.218.1 General

An HE STA declares that it is an HE STA by transmitting the HE Capabilities element.

The HE Capabilities element contains a number of fields that are used to advertise the HE capabilities of an HE STA. The HE Capabilities element is defined in Figure 9-589cj (HE Capabilities element format)..

	Element ID	Length	HE MAC Capabilities Information	HE PHY Capabilities Information	Tx Rx HE MCS NSS Support	PPE Thresholds (optional)
Octets:	1	1	5	9	2 or more	variable

Figure 9-589cj—HE Capabilities element format

The Element ID and Length fields are defined in 9.4.2.1 (General).

The HE MAC Capabilities Information, HE PHY Capabilities Information, Tx Rx HE MCS NSS Support, and PPE Thresholds fields are defined in the subclauses below.

9.4.2.218.2 HE MAC Capabilities Information field

The format of the HE MAC Capabilities Information field is defined in Figure 9-589ck (HE MAC Capabilities Information field format).

	B0	B1	B2	B3 B4	B5 B7	B8 B9	B10 B11	B12 B14
	+HTC HE Support	TWT Requester Support	TWT Responder Support	Fragmentation Support	Maximum Number of Fragmented MSDUs	Minimum Fragment Size	Trigger Frame MAC Padding Duration	Multi-TID Aggregation Support
Bits:	1	1	1	2	3	2	2	3

	B15 B16	B17	B18	B19	B20	B21	B22	B23	B24
	HE Link Adaptation	All Ack Support	UL MU Response Scheduling Support	A-BSR Support	Broadcast TWT Support	32-bit BA Bitmap Support	MU Cascade Support	Ack-Enabled Multi-TID Aggregation Support	Group Addressed Multi-STA BlockAck In DL MU Support
Bits:	2	1	1	1	1	1	1	1	4

	B25	B26	B27 B28	B29	B30	B31	B32
	OMI A-Control Support	OFDMA RA Support	Maximum A-MPDU Length Exponent	A-MSDU Fragmentation Support	Flexible TWT Schedule Support	Rx Control Frame to MultiBSS	BSRP A-MPDU Aggregation
Bits:	1	1	2	1	1	1	1

	B33	B34	B35 B39
	QTP Support	A-BQR Support	Reserved
Bits:	1	1	5

Figure 9-589ck—HE MAC Capabilities Information field format

The subfields of the HE MAC Capabilities Information field are defined in Table 9-262z (Subfields of the HE MAC Capabilities Information field).

Table 9-262z—Subfields of the HE MAC Capabilities Information field

Subfield	Definition	Encoding
+HTC-HE Support	Indicates if the STA supports the reception of an HE variant HT Control field carried in a QoS Data, QoS Null, or Management frame.	Set to 1 if the STA supports reception of an HE variant HT Control field. Set to 0 otherwise.
TWT Requester Support	Indicates support by an HE STA for the role of TWT requesting STA as described in 10.44 (Target wake time (TWT)).	Set to 1 if dot11TWTOptionActivated is true and the STA supports TWT requester STA functionality (see 10.44 (Target wake time (TWT))). Set to 0 otherwise.
TWT Responder Support	Indicates support by an HE STA for the role of TWT responder STA as described in 10.44 (Target wake time (TWT)).	Set to 1 if dot11TWTOptionActivated is true and the STA supports TWT responder STA functionality (see 10.44 (Target wake time (TWT))). Set to 0 otherwise.
Fragmentation Support	Indicates the level of dynamic fragmentation that is supported by a STA as a recipient.	Set to 0 for no support for dynamic fragmentation. Set to 1 for support for dynamic fragments that are contained within a S-MPDU, no support for dynamic fragments within an A-MPDU that is not a S-MPDU. Set to 2 for support for dynamic fragments that are contained within a Single MPDU and support for up to one dynamic fragment for each MSDU and each MMPDU within an A-MPDU or multi-TID A-MPDU that is not a Single MPDU. Set to 3 for support for dynamic fragments that are contained within a Single MPDU and support for multiple dynamic fragments for each MSDU within an A-MPDU or multi-TID AMPDU and up to one dynamic fragment for each MMPDU in a multi-TID A-MPDU that is not a Single MPDU.
Maximum Number of Fragmented MSDUs	Indicates the maximum number of fragmented MSDUs that can be concurrently received by a STA.	The maximum number of fragmented MSDUs, N_{max}, defined by this field is $N_{max} = 2^{\text{Maximum Number Of F-MPDUs}}$, except for a value of the Maximum Number of Fragmented MSDUs equal to 7 which indicates that there is no restriction.

Table 9-262z—Subfields of the HE MAC Capabilities Information field

Minimum Fragment Size	Indicates the minimum payload size in octets of the first fragment of an MSDU that is supported by the STA.	Set to 0 to indicate no restriction on the minimum payload size. Set to 1 to indicate a minimum payload size of 128 octets. Set to 2 to indicate a minimum payload size of 256 octets. Set to 3 to indicate a minimum payload size of 512 octets.
Trigger Frame MAC Padding Duration	Indicates the additional amount of time defined as *MinTrigProcTime*, in microseconds, needed for a non-AP STA to process a received Trigger frame.	Set to 0 to indicate no additional processing time. Set to 1 to indicate 8 us of processing time. Set to 2 to indicate 16 us of processing time. Remaining values are reserved.
Multi-TID Aggregation Support	Indicates the number of TIDs minus 1 of QoS Data frames that an HE STA can aggregate in a multi-TID A-MPDU as described in 27.10.4 (A-MPDU with multiple TIDs).	Set to the number of TIDs minus 1 of QoS Data frames that an HE STA can aggregate in a multi-TID A-MPDU.
HE Link Adaptation Capable	Indicates whether the STA supports link adaptation using the HE variant HT Control field.	If +HTC-HE Support is 1: Set to 0 (No Feedback) if the STA does not provide HE MFB. Set to 2 (Unsolicited) if the STA provides only unsolicited HE MFB. Set to 3 (Both) if the STA can provide HE MFB in response to HE MRQ and if the STA provides unsolicited HE MFB. The value 1 is reserved. Reserved if +HTC-HE Support is 0.
All ACK Support	Indicates whether the STA supports reception of a Multi-STA Block-Ack frame under the all ack context (see 25.4.2)	Set to 1 is the STA supports reception of a Multi-STA BlockAck frame under the all ack context. Set to 0 otherwise.
UL MU Response Scheduling Support	Indicates support for receiving an MPDU that contains an UL MU Response Scheduling A-Control field.	If +HTC-HE Support is 1: Set to 1 if the STA supports reception of the UL MU Response Scheduling A-Control field. Set to 0 otherwise. Reserved if +HTC-HE Support is 0.
A-BSR Support	Indicates support by an AP for receiving an (A-)MPDU that contains a BSR in the A-Control subfield and support by a non-AP STA for generating an (A-)MPDU that contains a BSR in the A-Control subfield.	If +HTC-HE Support is 1: Set to 1 if the STA supports the BSR A-Control field functionality. Set to 0 otherwise. Reserved if +HTC-HE Support is 0.
Broadcast TWT Supported	Indicates support by an HE non-AP STA for the role of TWT scheduled STA and by an AP for the role of TWT scheduling STA as described in 27.7.3 (Broadcast TWT operation).	Set to 1 when the STA supports broadcast TWT functionality. Set to 0 otherwise.

Table 9-262z—Subfields of the HE MAC Capabilities Information field

32-bit BA Bitmap Support	Indicates whether the STA supports reception of a Multi-STA BlockAck frame that has a 32-bit BlockAck Bitmap intended to it.	Set to 1 if the STA supports reception of a Multi-STA BlockAck frame that has a 32-bit Block Ack Bitmap subfield intended to it. Set to 0 otherwise.
MU Cascading Supported	Indicates whether the STA supports participating in an MU Cascading sequence (see 27.5.3 (HE MU cascading operation)).	Set to 1 if the STA supports MU cascading operation. Set to 0 otherwise.
Ack-enabled Multi-TID Aggregation Support	Indicates support by a STA to receive a multi-TID A-MPDU that can solicit either Ack or Block-Ack, or both, as described in 27.10.4 (A-MPDU with multiple TIDs).	Set to 1 when the STA supports reception of this multi-TID A-MPDU format. Set to 0 otherwise.
Group Addressed Multi-STA Block-Ack In DL MU Support	Indicates support by a non-AP STA for the reception of a group-addressed Multi-STA BlockAck frame that is sent in a DL MU PPDU in a non-broadcast RU.	Set to 1 when the STA supports its reception. Set to 0 otherwise.
OMI A-Control Support	Indicates support for receiving an MPDU that contains an OMI A-Control field.	If +HTC-HE Support is 1: Set to 1 if the STA supports reception of the OMI A-Control field. Set to 0 otherwise. Reserved if +HTC-HE Support is 0.
OFDMA RA Supports	Indicates support for a non-AP STA to follow the OFDMA random access procedure and for an AP to send Trigger frames that allocate random RUs (see 27.5.2.6 (UL OFDMA-based random access)).	Set to 1 if supported. Set to 0 otherwise.
Maximum A-MPDU Length Exponent		
A-MSDU Fragmentation Support	The A-MSDU Fragmentation Support subfield indicates support for the reception of fragmented A-MSDUs.	Set to 1 to indicate support for the receipt of fragmented A-MSDUs. Set to 0 to indicate that reception of fragmented A-MSDUs is not supported.
Flexible TWT Schedule Support	Indicates support for the reception of TWT Information frames with any nonzero value in the Next TWT field.	Set to 1 if the STA supports reception of a TWT Information frame with a nonzero value in the Next TWT field. Set to 0 otherwise.
Rx Control Frame to MultiBSS	Indicates whether the non-AP STA when associated with a BSS corresponding to a nontransmitted BSSID supports reception of a control frame with TA equal to the transmitted BSSID	Set to 1 if supported. Set to 0 otherwise.

Table 9-262z—Subfields of the HE MAC Capabilities Information field

BSRP A-MPDU Aggregation	Indicates whether or not the STA accepts a BSRP Trigger frame that is aggregated with other control, data and management frames in an A-MPDU destined to the STA	Set to 1 if supported. Set to 0 otherwise.
QTP Support	The QTP Support field indicates support by an HE STA for Quiet Time Period (QTP) operation as described in 11.47 (Quieting HE STAs in a HE BSS).	If the field is set to 1, the HE STA supports QTP functionality. Otherwise, set to 0.
A-BQR Support	Indicates support by an AP for receiving an (A-)MPDU that contains a BQR in the A-Control subfield and support by a non-AP STA for generating an (A-)MPDU that contains a BQR in the A-Control subfield.	If +HTC-HE Support is 1: Set to 1 if the STA supports the BQR A-Control field functionality. Set to 0 otherwise. Reserved if +HTC-HE Support is 0.

If the HE STA includes a VHT Capabilities element, the Maximum A-MPDU Length Exponent subfield in HE Capabilities element combined with the Maximum A-MPDU Length Exponent subfield in VHT Capabilities element indicate the maximum length of A-MPDU that the STA can Receive where EOF padding is not included in this limit. When Maximum A-MPDU Length Exponent subfield in HE Capabilities element is 0, the value in Maximum A-MPDU Length Exponent subfield in VHT Capabilities element indicates the maximum length of A-MPDU that the STA can Receive which follows the definition in 9.4.2.158.2 (VHT Capabilities Info field). When Maximum A-MPDU Length Exponent subfield in HE Capabilities element is 1 or 2, the value in Maximum A-MPDU Length Exponent subfield in VHT Capabilities element is 7 and the length defined by the field is $2^{(20+ \text{Maximum A-MPDU Length Exponent subfield in HE Capabilities element})}-1$. The value 3 in Maximum A-MPDU Length Exponent subfield in HE Capabilities element is reserved.

If the HE STA does not include VHT Capabilities element, the Maximum A-MPDU Length Exponent subfield in HE Capabilities element combined with the Maximum A-MPDU Length Exponent subfield in HT Capabilities element indicate the maximum length of A-MPDU that the STA can Receive where EOF padding is not included in this limit. When Maximum A-MPDU Length Exponent subfield in HE Capabilities element is 0, the value in Maximum A-MPDU Length Exponent subfield in HT Capabilities element indicates the the maximum length of A-MPDU that the STA can Receive which follows the definition in 9.4.2.56.3 (HT Capabilities Info field). When Maximum A-MPDU Length Exponent subfield in HE Capabilities element is 1 or 2, the value in Maximum A-MPDU Length Exponent subfield in HT Capabilities element is 7 and the length defined by the field is $2^{(16+ \text{Maximum A-MPDU Length Exponent subfield in HE Capabilities element})} - 1$. The value 3 in Maximum A-MPDU Length Exponent subfield in HE Capabilities element is reserved.

9.4.2.218.3 HE PHY Capabilities Information field

The format of the HE PHY Capabilities Information field is defined in Figure 9-589cl (HE PHY Capabilities Information field format).

	B0	B1 B7	B8 B11	B12	B13	B14 B15	B16 B17	B18 B19	B20 B21
	Dual Band Support	Channel Width Set	Preamble Puncturing Rx	Device Class	LDPC Coding In Payload	HE-LTF And GI For HE PPDUs	HE-LTF And GI For NDP	STBC Tx & Rx	Doppler
Bits:	1	7	4	1	1	2	2	2	2

	B22 B23	B24 B26	B27 B29	B30	B31	B32	B33	B34 B36
	UL MU	DCM Encoding Tx	DCM Encoding Rx	UL HE MU PPDU Payload Support	SU Beamformer	SU Beamformee	MU Beamformer	Beamformee STS For ≤ 80 MHz
Bits:	2	3	3	1	1	1	1	3

	B37 B39	B40 B42	B43 B45	B46 B48	B49 B51	B52	B53
	NSTS Total For ≤ 80 MHz	Beamformee STS For > 80 MHz	NSTS Total For > 80 MHz	Number Of Sounding Dimensions For ≤ 80 MHz	Number Of Sounding Dimensions For > 80 MHz	Ng = 16 For SU Feedback Support	Ng = 16 For MU Feedback Support
Bits:	2	3	3	1	1	1	1

	B54	B55	B56 B58	B59	B60	B61	B62
	Codebook Size (ϕ, ψ) = {4, 2} For SU Support	Codebook Size (ϕ, ψ) = {7, 5} For MU Support	Beamforming Feedback With Trigger Frame	HE ER SU PPDU Payload	DL MU-MIMO On Partial Bandwidth	PPE Threshold Present	SRP-based SR Support
Bits:	1	1	3	1	1	1	1

	B63	B64	B65 B71
	Power Boost Factor α_r Support	4x HE-LTF And 0.8 μs GI Support For HE PPDUs	Reserved
Bits:	1	1	7

Figure 9-589cl—HE PHY Capabilities Information field format

The subfields of the HE PHY Capabilities Information field are defined in Table 9-262aa (Subfields of the HE PHY Capabilities Information field).

Table 9-262aa—Subfields of the HE PHY Capabilities Information field

Subfield	Definition	Encoding
Dual Band Support	Indicates support of both 2.4 GHz and 5 GHz frequency bands	Set to 0 if not supported. Set to 1 if supported.
Channel Width Set	B1: Indicates STA support 40 MHz channel width in 2.4 GHz B2: Indicates STA support 40 MHz and 80 MHz channel width in 5 GHz B3: Indicates STA supports 160 MHz channel width in 5 GHz B4: Indicates STA supports 160/80+80 MHz channel width in 5 GHz B5: If B1 is set to 0, then B5 indicates support of 242/106/52/26-tone RU mapping in 40 MHz channel width in 2.4 GHz. Otherwise Reserved. B6: If B2, B3, and B4 are set to 0, then B6 indicates support of 242-tone RU mapping in 40 MHz and 80 MHz channel width in 5 GHz. Otherwise Reserved. B7: Reserved	B1 set to 0 if not supported. B1 set to 1 if supported. B2 set to 0 if not supported, i.e., it indicates 20 MHz only device in 5 GHz. B2 set to 1 if supported. Note AP always sets B2 to 1. B3 set to 0 if not supported. B3 set to 1 if supported. If B3 set to 1 then B2 is set to 1. B4 set to 0 if not supported. B4 set to 1 if supported. If B4 set to 1 then B3 is set to 1. B5 set to 0 if not supported. B5 set to 1 if supported. B6 set to 0 if not supported. B6 set to 1 if supported. NOTE: B1 and B5 are only applicable to 2.4 GHz and ignored at the receiver when HE PHY capabilities advertised on 5 GHz. B2, B3, B4, and B6 are only applicable to 5 GHz and ignored at the receiver when HE PHY capabilities advertised of 2.4 GHz.
Preamble Puncturing Rx	B8: Indicates STA supports reception of preamble puncturing in 80 MHz, where in the preamble only the secondary 20 MHz is punctured B9: Indicates STA supports reception of preamble puncturing in 80 MHz, where in the preamble only one of the two 20 MHz sub-channels in the secondary 40 MHz is punctured B10: Indicates STA supports reception of preamble puncturing in 160 MHz or 80+80 MHz, where in the primary 80 MHz of the preamble only the secondary 20 MHz is punctured B11: Indicates STA supports reception of preamble puncturing in 160 MHz or 80+80 MHz, where in the primary 80 MHz of the preamble, the primary 40 MHz is present	B8 set to 0 if not supported. B8 set to 1 if supported. B9 set to 0 if not supported. B9 set to 1 if supported. B10 set to 0 if not supported. B10 set to 1 if supported. B11 set to 0 if not supported. B11 set to 1 if supported.

Table 9-262aa—Subfields of the HE PHY Capabilities Information field

Subfield	Definition	Encoding
Device Class	Indicates transmitting STA is a Class A or a Class B device.	Set to 1 to indicate STA is a Class A device. Set to 0 to indicate STA is a Class B device. Note: This field is reserved when transmitting STA is an AP STA.
LDPC Coding In Payload	Indicates support of transmission and reception of LDPC encoded packets	Set to 1 if supported by the STA. Set to 0 otherwise.
HE-LTF And GI For HE PPDUs	B14: Indicates support of reception of 1x LTF and 0.8 us guard interval duration for HE SU PPDUs. B15: Indicates support of reception of 1x LTF and 1.6 us guard interval duration for HE Trigger-based PPDUs.	Set to 1 if supported by the STA. Set to 0 otherwise.
HE-LTF And GI For NDP	B16: For a transmitting STA acting as beamformer, it indicates support of NDP transmission using 4x LTF and 3.2 us guard interval duration B17: For a transmitting STA acting as beamformee, it indicates support of NDP reception using 4x LTF and 3.2 us guard interval duration	If the SU Beamformer Capable field is set to 1 then B16 set to 1 if supported by the STA. Set B16 to 0 otherwise. If SU Beamformer Capable field is set to 0 then B16 is reserved. If the SU Beamformee Capable field is set to 1 the B17 set to 1 if supported by the STA.Set B17 to 0 otherwise.
STBC Tx And Rx	B18 indicates support for the transmission of HE PPDUs using STBC with one spatial stream B19 indicates support for the reception of HE PPDUs using STBC with one spatial stream	B18 set to 1 if supported by the STA. Set to 0 otherwise. B19 set to 1 if supported by the STA. Set to 0 otherwise.
Doppler	B20 indicates transmitting STA supports transmitting HE PPDUs with Doppler procedure B21 indicates transmitting STA supports receiving HE PPDUs with Doppler procedure	B20 set to 1 if supported by the STA. Set to 0 otherwise. B21 set to 1 if supported by the STA. Set to 0 otherwise.
UL MU	If the transmitting STA is an AP: B22 indicates STA supports of reception of full bandwidth UL MU-MIMO transmission. B23 indicates STA supports of reception of UL MU-MIMO transmission on an RU in an HE MU PPDU where the RU does not span the entire PPDU bandwidth. If the transmitting STA is a non-AP STA: B22 indicates STA supports of transmission of full bandwidth UL MU-MIMO transmission. B23 indicates STA supports of transmission of UL MU-MIMO transmission on an RU in an HE MU PPDU where the RU does not span the entire PPDU bandwidth.	B22 set to 1 if supported by the STA. Set to 0 otherwise. B23 set to 1 if supported by the STA. Set to 0 otherwise. NOTE—If the non-AP STA sets B23 (Uplink MU-MIMO on Partial Bandwidth) to 0, it shall support transmitting SU RU within an HE MU PPDU where some other RU is employing UL MU-MIMO

Table 9-262aa—Subfields of the HE PHY Capabilities Information field

Subfield	Definition	Encoding
DCM encoding at Tx and Rx	B24 - B26 Signals support of Tx of (i) packet payload with dual sub-carrier modulation at a STA and (ii) DCM encoded HE-SIG-B in an HE MU PPDU at a STA. The signaling includes maximum constellation and the maximum number of spatial streams that are supported with DCM. B27 - B29 Signals support of reception of (i) packet payload with dual sub-carrier modulation at a STA and (ii) DCM encoded HE-SIG-B in an HE MU PPDU at a STA. The signaling includes maximum constellation and the maximum number of spatial streams that are supported with DCM.	B25:B24 signals Maximum Constellation 00: Does not support DCM, 01: BPSK , 10: QPSK, 11: 16-QAM B26 signals maximum number of spatial streams with DCM 0: 1 spatial stream, 1: 2 spatial streams. B28:B27 signals Maximum Constellation 00: Does not support DCM, 01: BPSK, 10: QPSK, 11: 16-QAM B29 signals maximum number of spatial streams with DCM 0: 1 spatial stream, 1: 2 spatial streams
UL HE MU PPDU Payload Support	Indicates that the STA supports the reception of an HE MU PPDU payload over full bandwidth and partial bandwidth (106-tone RU within 20 MHz).	Set to 0 if not supported. Set to 1 if supported. This field is reserved for a non-AP STA.
SU Beamformer	Indicates support for operation as an SU beamformer.	Set to 0 if not supported. Set to 1 if supported. Set to 1 if sent by an HE AP with support for 4 or more spatial streams
SU Beamformee	Indicates support for operation as an SU beamformee.	Set to 0 if not supported. Set to 1 if supported. Set to 1 if sent by a non-AP STA.
MU Beamformer	Indicates support for operation as an MU Beamformer.	Set to 0 if not supported. Set to 0 if the SU Beamformer subfield is 0. Set to 0 if sent by a non-AP STA. Set to 1 if supported. Set to 1 if SU Beamformer subfield is set to 1. Set to 1 if sent by an AP.
Beamformee STS For ≤ 80 MHz	The maximum number of space-time streams that the STA can receive in an HE NDP	If SU beamformee capable, set to maximum number of space-time streams that the STA can receive in an HE NDP minus 1. The minimum value of this field is 3. Otherwise, reserved.
NSTS Total For ≤ 80 MHz	The maximum value for $N_{STS,total}$ that can be sent to the STA in a DL MU-MIMO transmission on full or partial bandwidth	If SU beamformee capable, set to maximum number of total space-time streams that the STA can receive minus 1. The minimum value of this field is 3. Otherwise reserved.

Table 9-262aa—Subfields of the HE PHY Capabilities Information field

Subfield	Definition	Encoding
Beamformee STS For > 80 MHz	The maximum number of space-time streams that the STA can receive in an HE NDP	If SU beamformee capable, set to maximum number of space-time streams that the STA can receive in an HE NDP minus 1. The minimum value of this field is 3. Otherwise, reserved.
NSTS Total For > 80 MHz	The maximum value for $N_{STS,total}$ that can be sent to the STA in an DL MU-MIMO transmission on full or partial bandwidth	If SU beamformee capable, set to maximum number of total space-time streams that the STA can receive minus 1. The minimum value of this field is 3. Otherwise reserved.
Number Of Sounding Dimensions For ≤ 80 MHz	Beamformer's capability indicating the maximum value of the TXVECTOR parameter NUM_STS for an HE NDP	If SU beamformer capable, set to the maximum supported value of the TXVECTOR parameter NUM_STS minus 1. Otherwise, reserved
Number Of Sounding Dimensions For > 80 MHz	Beamformer's capability indicating the maximum value of the TXVECTOR parameter NUM_STS for an HE NDP	If SU beamformer capable, set to the maximum supported value of the TXVECTOR parameter NUM_STS minus 1. Otherwise, reserved
Ng = 16 For SU Feedback Support	Indicates if the HE beamformee is capable of feedback with tone grouping of 16 in the HE Compressed Beamforming Report field for a SU-type feedback.	Set to 1 if supported. Set to 0 otherwise.
Ng = 16 For MU Feedback Support	Indicates if the HE beamformee is capable of feedback with tone grouping of 16 in the HE Compressed Beamforming Report field for a MU-type feedback	Set to 1 if supported. Set to 0 otherwise.
Codebook Size (ϕ, ψ) = {4, 2} For SU Support	Indicates if the HE beamformee is capable of feedback with codebook size (ϕ, ψ) = {4, 2} in the HE Compressed Beamforming Report field for a SU-type feedback.	Set to 1 if supported. Set to 0 otherwise.
Codebook Size (ϕ, ψ) = {7, 5} For MU Support	Indicates if HE beamformee is capable of feedback with codebook size (ϕ, ψ) = {7, 5} in the HE Compressed Beamforming Report field for a MU-type feedback.	Set to 1 if supported. Set to 0 otherwise.
Tx Beamforming Feedback With Trigger Frame	If the transmitting STA is an AP STA: B56: indicates support of reception of SU-Type partial and full bandwidth feedback B57: indicates support of reception of MU-Type partial bandwidth feedback B58 indicates support of reception of CQI-Only partial and full bandwidth feedback If the transmitting STA is a non-AP STA: B56: indicates support of transmission of SU-Type partial and full bandwidth feedback B57: indicates support of transmission of MU-Type partial bandwidth feedback B58: indicates support of transmission of CQI-Only partial and full bandwidth feedback	Set B56 to 1 if SU-Type partial and full bandwidth feedback supported by the STA. Set to 0 otherwise. Set B57 to 1 if MU-Type partial bandwidth feedback supported by the STA. Set to 0 otherwise. Set B58 to 1 if CQI-Only partial and full bandwidth feedback supported by the STA. Set to 0 otherwise.

Table 9-262aa—Subfields of the HE PHY Capabilities Information field

Subfield	Definition	Encoding
HE ER SU Payload	Indicates the support of transmission and reception of an HE extended range SU PPDU payload transmitted over the right 106-tone RU within primary 20 MHz channel.	Set to 1 if supported. Set to 0 otherwise.
DL MU-MIMO on Partial BW	Indicates that the non-AP STA supports reception of a DL MU-MIMO transmission on an RU in an HE MU PPDU where the RU does not span the entire PPDU bandwidth.	Set to 1 if supported by the non-AP STA. Set to 0 if not supported by the non-AP STA. This field is reserved for an AP.
PPE Threshold Present	Indicates whether or not the PPE Threshold field is present.	Set to 1 if PPE Threshold field is present. Set to 0, otherwise
SRP-based SR Support	Indicates that the STA supports SRP-based SR operation	Set to 1 if supported. Set to 0 otherwise.
Power Boost Factor α_r Support	Indicates that the STA supports a power boost factor α_r for the *r*-th RU in the range [0.5, 2]	Set to 1 if supported. Set to 0 otherwise.
4x HE-LTF And 0.8 µs GI Support For HE PPDUs	Indicates support for the reception of 4x LTF and 0.8 µs guard interval duration for HE SU PPDUs.	Set to 1 if supported. Set to 0 otherwise.

A STA that declares support for HE trigger-based PPDUs shall also declare whether they belong to class A or class B. Class A STAs are high capability devices and class B STAs are low capability devices.

9.4.2.218.4 Tx Rx HE MCS Support field

The Tx Rx HE MCS Support field format is defined in Figure 9-589cm (Tx Rx HE MCS Support field format).

	B0 B2	B3 B5	B6 B10	B11 B15		
	Highest NSS Supported M1	Highest MCS Supported	Tx BW Bitmap	Rx BW Bitmap	Tx MCS NSS Descriptors	Rx MCS NSS Descriptors
Bits:	3	3	5	5	$n \times 8$	$m \times 8$

Figure 9-589cm—Tx Rx HE MCS Support field format

The Highest NSS Supported M1 subfield indicates the highest NSS value minus 1, supported by the STA that transmitted this subfield. The Highest NSS Supported M1 value is applicable to both transmissions and receptions but does not necessarily apply to all combinations of PPDU bandwidth and MCS. The PPDU bandwidth and MCS values that do not support the NSS value indicated in this subfield are described in the Tx MCS NSS Descriptors and Rx MCS NSS Descriptors subfields, if present. If no Tx MCS NSS Descriptors subfield is present, then the STA supports transmission of all combinations of PPDU bandwidth identified by the Channel Bandwidth Set field at each NSS and MCS indicated in the Highest NSS Supported M1 and Highest MCS Supported subfields. If no Rx MCS NSS Descriptors subfield is present, then the STA supports reception of all combinations of PPDU bandwidth identified by the Channel Bandwidth Set field at each NSS and MCS indicated in the Highest NSS Supported M1 and Highest MCS Supported subfields.

The Highest MCS Supported subfield indicates whether the STA transmitting this subfield supports the optional MCS values of MCS8, MCS9, MCS10, MCS11. The encoding of this field is defined in Table 9-262ab (Highest MCS Supported subfield encoding). The Highest MCS Supported value is applicable to both

Table 9-262ab—Highest MCS Supported subfield encoding

Highest MCS Supported subfield value	Highest supported MCS of the transmitting STA
0	MCS7
1	MCS8
2	MCS9
3	MCS10
4	MCS11
5-7	Reserved

transmissions and receptions but does not necessarily apply to all combinations of PPDU bandwidth and NSS. The PPDU bandwidth and NSS values that do not support the MCS value indicated in this subfield are described in the Tx MCS NSS Descriptors and Rx MCS NSS Descriptors subfields, if present. If no Tx MCS NSS Descriptors subfield is present, then the STA supports transmission of all combinations of PPDU bandwidth identified by the Channel Bandwidth Set field at each NSS and MCS indicated in the Highest NSS Supported M1 and Highest MCS Supported subfields. If no Rx MCS NSS Descriptors subfield is present, then the STA supports reception of all combinations of PPDU bandwidth identified by the Channel Bandwidth Set field at each NSS and MCS indicated in the Highest NSS Supported M1 and Highest MCS Supported subfields.

Each bit of the Tx BW Bitmap indicates whether a set of TX MCS NSS Descriptor field(s) are present for a specific PPDU bandwidth. The bits correspond to the ordered set of PPDU bandwidth values of 20 MHz, 40 MHz, 80 MHz, 80+80 and 160 MHz with the bit in the lowest numbered bit position corresponding to 20 MHz. A bit in the Tx BW Bitmap is set to 1 to indicate that the corresponding Tx MCS NSS Descriptor for that bandwidth is present; otherwise the bit is set to 0.

Each bit of the Rx BW Bitmap indicates whether a set of RX MCS NSS Descriptor field(s) are present for a specific bandwidth of operation. The bits correspond to the ordered set of PPDU values of 20 MHz, 40 MHz, 80 MHz, 80+80 and 160 MHz with the bit in the lowest numbered bit position corresponding to 20 MHz. A bit in the Rx BW Bitmap is set to 1 to indicate that the corresponding Rx MCS NSS Descriptor for that bandwidth is present; otherwise the bit is set to 0.

If all of the bits of the Tx BW Bitmap subfield and all of the bits of the Rx BW Bitmap subfield are zero, then none of the subfields of the Tx Rx HE MCS Support field beyond Highest MCS Supported need to be present. If either the Tx BW Bitmap subfield or the Rx BW Bitmap subfield has at least one bit set to 1, then both the Tx BW Bitmap subfield and the Rx BW Bitmap subfield are present, even if one of these subfields has the value of all zeros.

Each Tx MCS NSS Descriptor indicates the value of the highest supported NSS for the indicated MCS for a specific bandwidth of operation and for all MCS that are higher than the indicated MCS up to but not including the next MCS in the set for this bandwidth. MCS values that are lower than the lowest specified MCS within a set of Tx MCS NSS Descriptor fields implicitly support transmission of PPDUs using the highest NSS value indicated in the Highest NSS Supported subfield.

Each Rx MCS NSS Descriptor indicates the value of the highest supported NSS for the indicated MCS for a specific bandwidth of operation and for all MCS that are higher than the indicated MCS up to but not including the next MCS in the set for this bandwidth. MCS values that are lower than the lowest specified MCS within a set of Rx MCS NSS Descriptor fields implicitly support reception of PPDUs using the highest NSS value indicated in the Highest NSS Supported subfield.

The Tx MCS NSS Descriptor and Rx MCS NSS Descriptor subfield format is defined in Figure 9-589cn (Tx MCS NSS Descriptor and Rx MCS NSS Descriptor subfield format).

	B0 B3	B4 B6	B7
	MCS	NSS	Last MCS NSS
Bits:	4	3	1

Figure 9-589cn—Tx MCS NSS Descriptor and Rx MCS NSS Descriptor subfield format

The MCS subfield of the Tx MCS NSS Descriptor and Rx MCS NSS Descriptor subfields indicates an MCS value encoded as an unsigned integer.

The NSS subfield of the Tx MCS NSS Descriptor and Rx MCS NSS Descriptor subfields indicates an NSS value encoded as an unsigned integer. The NSS indicated by the field corresponds to the MCS value in the same Tx MCS NSS Descriptor or Rx MCS NSS Descriptor subfield. The value 0 indicates that there is no support for this combination of PPDU bandwidth and this MCS and higher.

The Last MCS NSS subfield indicates the last Tx MCS NSS Descriptor or Rx MCS NSS Descriptor for a set of Tx MCS NSS Descriptors or Rx MCS NSS Descriptors corresponding to a single PPDU bandwidth value. The Last MCS NSS subfield is set to 1 to indicate that the current Tx MCS NSS Descriptor or Rx MCS NSS Descriptor is the last descriptor for the corresponding PPDU bandwidth. Otherwise the subfield is set to 0.

9.4.2.218.5 PPE Thresholds field

The format of the PPE Thresholds field is defined in Figure 9-589co (PPE Thresholds field format).

	B0 B2	B3 B6		
	NSS M1	RU Index Bitmask	PPE Thresholds Info	PPE Pad
Bits:	3	4	variable	variable

Figure 9-589co—PPE Thresholds field format

The NSS M1 subfield contains an unsigned integer that is equal to the number of NSS values minus one for which PPE threshold values are included in the PPE Thresholds Info field.

The RU Index Bitmask subfield contains a bitmask that indicates whether PPE threshold values are present for each of four RU allocation sizes according to their RU Allocation Index values. For example, when B3 is set to 1, PPE threshold values are present for the RU allocation corresponding to RU allocation index 0 and when B3 is set to 0, PPE threshold values are not present for the RU allocation corresponding to RU allocation index 0.

The PPE Thresholds Info field is (NSS M1 + 1) × Number of bits set to 1 in the RU Index Bitmask subfield × 6 bits in length. The format of the PPE Thresholds Info field is defined in Figure 9-589cp (PPE Thresholds Info field format).

	PPET16 for NSS1 for RU*x*	PPET8 for NSS1 for RU*x*	...	PPET16 for NSS1 for RU*m*	PPET8 for NSS1 for RU*m*	...	PPET16 for NSS*n* for RU*m*	PPET8 for NSS*n* for RU*m*
Bits:	3	3		3	3		3	3

Figure 9-589cp—PPE Thresholds Info field format

PPE threshold values appear in increasing NSS value and increasing RU index value order, where lower-numbered PPE Thresholds Info field bits contain PPE threshold values corresponding to lower numbered NSS values and within a set of PPE Threshold subfields corresponding to a single value of NSS, lower-numbered PPE Thresholds Info field bits contain PPE threshold values corresponding to lower numbered RU index values. Subfields PPET16 for NSS*n* for RU*b* and PPET8 for NSS*n* for RU*b* are present for all values of *n* and *b* where:

$1 \le n \le (\text{NSS M1} + 1)$

$b = [x, \ \ldots, m]$

where $[x, \ldots, m]$ is the set of integers equal to the ordered list of bit positions of all bits that are set to 1 in the RU Index Bitmask subfield, with *x* being the lowest value.

Each PPET8 for NSS*n* for RU*b* subfield and PPET16 for NSS*n* for RU*b* subfield contains an integer that corresponds to a constellation index value related to the transmission constellation of an HE PPDU as defined in Table 9-262ac (Constellation index)..

Table 9-262ac—Constellation index

Constellation Index	Corresponding Transmission Constellation
0	BPSK
1	QPSK
2	16-QAM
3	64-QAM
4	256-QAM
5	1024-QAM
6	Reserved
7	None

The PPET8 for NSS*n* for RU*b* subfield and PPET16 for NSS*n* for RU*b* subfield values are combined to determine the Maximum PE value for HE PPDUs that are transmitted to the STA sending this field and using NSS = *n* and an RU allocation corresponding to RU Allocation Index *b*, for each value of NSS and RU specified by the field. For all values of n and b for which PPET8 and PPET16 are not present, the Maximum PE value is 0 for HE PPDUs that are transmitted to the STA using NSS = *n* and an RU allocation corresponding to RU Allocation Index *b*. The value for each PPET8 for NSS*n* for RU*m* is always less than the value of PPET16 for NSS*n* for RU*m*. The encoding is described in Table 9-262ad (PPET8 and PPET16 encoding).

Table 9-262ad—PPET8 and PPET16 encoding

Result of comparison of the constellation index *x* of an HE PPDU with NSS value *n* and RU value Allocation size that corresponds to the RU Allocation index = (*b* + DCM) to the value in the PPET8 for NSS*n* for RU*m* subfield	Result of comparison of the constellation index of an HE PPDU with NSS value *n* and RU value Allocation size that corresponds to the RU Allocation index = value (*b* + DCM) to the value in the PPET16 for NSS*n* for RU*m* subfield	Maximum PE value for an HE PPDU transmitted to this STA using the constellation index = *x*, NSS = *n* and RU Allocation size that corresponds to the RU Allocation index = (*b* + DCM)
x greater than or equal to PPET8	*x* less than PPET16 or PPET16 equal to None	8 µs
x greater than PPET8 or PPET8 equal to None	*x* greater than equal to PPET16	16 µs
All other combinations not otherwise listed in this table		0
NOTE—DCM = 1 when the HE PPDU uses DCM; DCM = 0 otherwise.		

The RU Allocation Index encoding is indicated in Table 9-262ae (RU Allocation Index encoding).

Table 9-262ae—RU Allocation Index encoding

RU Allocation Index value	RU allocation size
0	242
1	484
2	996
3	2×996

The PPE Pad field contains all zeros. The number of bits in the PPE Pad field is the number of bits required to round the length of the PPE Thresholds Info field up to the next integer number of octets.

9.4.2.219 HE Operation element

The operation of HE STAs in an HE BSS is controlled by the HT Operation element, the VHT Operation element and the HE Operation element. The format of the HE Operation element is defined in Figure 9-589cq (HE Operation element format).

	Element ID	Length	HE Operation Parameters	Basic HE MCS And NSS Set	VHT Operation Information
Octets:	1	1	4	3	3

Figure 9-589cq—HE Operation element format

The Element ID and Length fields are defined in 9.4.2.1 (General).

The format of the HE Operation Parameters field is defined in Figure 9-589cr (HE Operation Parameters field format).

	B0 B5	B6 B8	B9	B10 B19	B20	B21 B28	B29	B30	B31
	BSS Color	Default PE Duration	TWT Required	HE Duration Based RTS Threshold	Partial BSS Color	MaxBSSID Indicator	Tx BSSID Indicator	BSS Color Disabled	Dual Beacon
Bits:	6	3	1	10	1	8	1	1	1

Figure 9-589cr—HE Operation Parameters field format

The BSS Color field is an unsigned integer whose value is the BSS color of the BSS corresponding to the AP which transmitted this element, except that a value of 0 in this field indicates that there is no BSS color for this BSS.

The BSS Color field is an unsigned integer whose value is the BSS Color of the BSS corresponding to the AP, IBSS STA, mesh STA or TDLS STA that transmitted this element, except that a value of 0 in this field is used if one or more intended recipient STAs of an HE PPDU is not a member of a transmitting STA's BSS.

The Default PE Duration subfield indicates the PE duration in units of 4 µs, for an HE trigger-based PPDU that is solicited with UL MU Response Scheduling in the A-Control subfield. Values 5-7 of the Default PE Duration subfield are reserved.

The TWT Required subfield is set to 1 to indicate that the AP requires the non-AP HE STAs to operate in the role of either TWT requesting STA, as described 27.7.2 (Individual TWT agreements), or TWT scheduled STA, as described in 27.7.3 (Broadcast TWT operation) and set to 0 otherwise.

The HE Duration Based RTS Threshold field enables an HE AP to manage RTS/CTS usage by HE non-AP STAs that are associated with it. The HE Duration Based RTS Threshold field contains the duration based RTS threshold in units of 32 µs, which enables the use of RTS/CTS except for values 0 and 1023. The value 0 indicates that RTS/CTS must be used for all frame exchanges. The value 1023 indicates that HE duration-based RTS is disabled.

The Partial BSS Color field indicates whether or not the BSS applies an AID assignment rule using the partial BSS color bits. If the Partial BSS Color field is set to 1, then the 4 least significant bits of BSS color are used in AID assignment. If the Partial BSS Color field is set to 0, no partial BSS color bits are used in the AID assignment.

An HE AP corresponds to a nontransmitted BSSID if the AP's BSSID can be derived from Multiple BSSID element present in the Beacon or Probe Response frame transmitted by another AP (i.e., the AP identified by the Transmitted BSSID). The Tx BSSID Indicator indicates whether an HE AP corresponds to transmitted BSSID. The definition of MaxBSSID Indicator is same as the MaxBSSID Indicator in Multiple BSSID element. An HE AP corresponding to a nontransmitted BSSID sets Tx BSSID Indicator to 0. An HE AP corresponding to a transmitted BSSID sets Tx BSSID Indicator to 1. An HE AP corresponding to Nontransmitted BSSID or a transmitted BSSID sets the MaxBSSID Indicator field to non-zero value.An AP corresponding to neither a nontransmitted BSSID nor a transmitted BSSID sets both MaxBSSID Indicator and Tx BSSID Indicator to 0.

The BSS Color Disabled subfield indicates whether the transmitting AP recommends the associated STAs to disable the use of BSS Color parameter when making decisions related to Intra-PPDU power save and setting Intra BSS NAV. An HE AP sets the BSS Color Disabled subfield to 1 if the HE AP decides to disable the use of the BSS color for the BSS that it serves, for example, after detecting a BSS Color overlap in the neighborhood as described in 27.11.4 (BSS_COLOR); otherwise the HE AP sets the BSS Color Disabled subfield to 0.

If a HE non-AP STA receives from associated AP a BSS Color Disabled subfield value equal to 1 in the HE Operation element the HE non-AP STA should not exclusively use BSS Color parameter in making decision related to Intra-PPDU power save and for setting Intra BSS NAV. Instead, the non-AP STA should use the MAC header to make such decisions (see 27.11.4 (BSS_COLOR)). HE non-AP STA may (re)enable BSS Color related features once it receives from the associated AP a BSS Color Disabled subfield equal to 0 in an HE Operation element.

The Dual Beacon subfield indicates whether the HE AP transmits beacons using two PHY formats, one in a non-HE format and other in an HE_EXT_SU PHY format. The Dual Beacon subfield also indicates the TBTT offset of Beacon frame in HE extended range SU PPDU in 11.1.3.10 (Beacon generation in an HE BSS). The subfield is set to 0, if the HE AP transmits beacons in one PHY format. The subfield is set to 1 if the HE AP transmits beacons in an HE extended range SU PPDU and a non-HE PPDU.

The Basic HE MCS And NSS Set field indicates the HE-MCSs for each number of spatial streams in HE PPDUs that are supported by all HE STAs in the BSS (including IBSS and MBSS). The Basic HE MCS And NSS Set field is a bitmap of size 24 bits. Each 3 bit pair in the bitmap indicates the supported HE-MCS set for NSS from 1 to 8. The Basic HE-MCS And NSS Set field is defined in Figure 9-589cs (Basic HE-MCS And NSS Set field format).

	B0 B2	B3 B5	B6 B8	B9 B11	B12 B14	B15 B17	B18 B20	B21 B23
	Max HE MCS For 1 SS	Max HE MCS For 2 SS	Max HE MCS For 3 SS	Max HE MCS For 4 SS	Max HE MCS For 5 SS	Max HE MCS For 6 SS	Max HE MCS For 7 SS	Max HE MCS For 8 SS
Bits:	3	3	3	3	3	3	3	3

Figure 9-589cs—Basic HE-MCS And NSS Set field format

The Max HE MCS For n SS subfield (where *n* = 1, ..., 8) is encoded as follows:

— 0 indicates support for HE-MCS 0-7 for *n* spatial streams

— 1 indicates support for HE-MCS 0-8 for *n* spatial streams

— 2 indicates support for HE-MCS 0-9 for *n* spatial streams

— 3 indicates support for HE-MCS 0-10 for *n* spatial streams

— 4 indicates support for HE-MCS 0-11 for *n* spatial streams

— 5-7 are reserved

The structure of the VHT Operation Information field is defined in Figure 9-564 (VHT Operation Information field) and its subfields are defined in Table 9-252 (VHT Operation Information subfields).

9.4.2.220 OFDMA-based Random Access Parameter Set (RAPS) element

The metrics of the OFDMA-based random access mechanism (see 27.5.2.6 (UL OFDMA-based random access)) are signaled in the RAPS element. The format of the RAPS element is defined in Figure 9-589ct (RAPS element format).

	Element ID	Lenght	Element ID Extension	OCW Range
Octets:	1	1	1	1

Figure 9-589ct—RAPS element format

The Element ID, Length, Element ID Extension fields are defined in 9.4.2.1 (General).

The OCW Range field indicates the minimum and maximum values of the OCW (OFDMA contention window) derived from the fields defined in Figure 9-589cu (OCW Range field format).

	B0 B2	B3 B5	B6 B7
	EOCWmin	EOCWmax	Reserved
Octets:	3	3	2

Figure 9-589cu—OCW Range field format

The EOCWmin field indicates the minimum value of OCW for the initial HE trigger-based PPDU transmission using UL OFDMA-based random access. The OCWmin parameter is used by a STA either for an initial transmission or following a successful HE trigger-based PPDU transmission and is derived from the value in the EOCWmin field as

$$\mathrm{OCWmin} = 2^{\mathrm{EOCWmin}} - 1$$

The EOCW_max field indicates the maximum value of OCW for UL OFDMA-based random access. The OCW_max parameter used by a STA for its retransmission attempts of UL OFDMA-based random access is derived from the value in the EOCWmax field as

$$\mathrm{OCWmax} = 2^{\mathrm{EOCWmax}} - 1$$

9.4.2.221 MU EDCA Parameter Set element

The MU EDCA Parameter Set element provides information needed by non-AP STAs that are UL MU capable for proper operation of the QoS facility during the CP. The format of the MU EDCA Parameter Set element is defined in Figure 9-589cv (MU EDCA Parameter Set element).

	Element ID	Length	Element ID Extension	MU QoS Info	MU AC_BE Parameter Record	MU AC_BK Parameter Record	MU AC_VI Parameter Record	MU AC_VO Parameter Record
Octets:	1	1	1	1	3	3	3	3

Figure 9-589cv—MU EDCA Parameter Set element

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

For an infrastructure BSS, the MU EDCA Parameter Set element is used by the AP to establish policy (by changing default MIB attribute values), to change policies when accepting new STAs or new traffic, or to adapt to changes in offered load. The most recent MU EDCA Parameter Set element received by a STA is used to update the appropriate MIB values.

The format of the MU QoS Info field is the same as the field defined in 9.4.1.17 (QoS Info field). The MU QoS Info field contains the EDCA Parameter Set Update Count subfield, which is initially set to 0 and is incremented each time any of the MU AC parameters changes. This subfield is used by non-AP STAs to determine whether the MU EDCA parameter set has changed and requires updating the appropriate MIB attributes.

The formats of MU AC_BE, MU AC_BK, MU AC_VI, and MU AC_VO Parameters fields are identical and are illustrated in Figure 9-589cw (MU AC Parameter Record field format).

	ACI/AIFSN	ECWmin/ ECWmax	MU EDCA Timer
Octets:	1	1	1

Figure 9-589cw—MU AC Parameter Record field format

The format of the ACI/AIFSN field is illustrated in Figure 9-262 (ACI/AIFSN field) and the encoding of its subfields is as defined in 9.4.2.29 (EDCA Parameter Set element), except that a value 0 of the AIFSN field indicates that the AIFS is equal to the value of the MU EDCA Timer, i.e. EDCA is disabled for the duration specified by the MUEDCATimer for the corresponding AC.

The format of the ECWmin/ECWmax field is illustrated in Figure 9-263 (ECWmin and ECWmax fields) and the encoding of its subfields is as defined in 9.4.2.29 (EDCA Parameter Set element).

The MU EDCA Timer field indicates the duration of time, in units of 8 TUs, for which the provided MU EDCA parameters are used by an HE STA after reception of a Basic variant Trigger frame for the corresponding AC.

9.4.2.222 BSS Color Change Announcement element

The BSS Color Change Announcement element is used by an HE AP to advertise a BSS Color change and the value of the new BSS color. The format of the BSS Color Change Announcement element is shown in Figure 9-589cx (BSS Color Change Announcement element format).

	Element ID	Length	Element ID Extension	Color Switch Countdown	New BSS Color Information
Octets:	1	1	1	1	1

Figure 9-589cx—BSS Color Change Announcement element format

The Element ID, Length, and Element ID Extension fields are defined in 9.4.2.1 (General).

The Color Switch Countdown field is set to the number of TBTTs that remain until the STA sending the BSS Color Change Announcement element switches to the new BSS Color. A value of 0 indicates that the switch occurs at the current TBTT if the element is carried in a Beacon frame or the next TBTT following the frame that carried the element if the frame is not a Beacon.

The format of the New BSS Color Information field is as defined in Figure 9-589cy (New BSS Color field format). The New BSS Color sub-field is set to the new BSS Color value that the HE AP intends to use starting from the TBTT at which the Color Switch Countdown reaches 0.

	B0 B5	B6 B7
	New BSS Color	Reserved
Bits:	6	2

Figure 9-589cy—New BSS Color field format

The BSS Color Change Announcement element can be included in HE BSS Color Change Announce-ment frame, Beacon, Probe Response, and (Re-)Association Response frames. The use of BSS Color Change Announcement elements and frames is described in 27.16.2 (Selecting and advertising new BSS Color).

9.4.2.223 Quiet Time Period Setup element

The Quiet Time Period Setup element defines a period for an STA-to-STA operation (see 11.47 (Quieting HE STAs in a HE BSS)).

This quiet time period may be used to improve the probability of channel access for HE STAs participating in the STA-2-STA operation.

The Quiet Time Period Setup element is shown Figure 9-589cz (Quiet Time Period Setup element).

	Element ID	Length	Element ID Extension	Quiet Period Duration	Vendor Specific Service Identifier
Octets:	1	1	1	2	2

Figure 9-589cz—Quiet Time Period Setup element

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Quiet Duration field is set to duration, expressed in TUs, no larger than the value indicated in the Quiet Period Duration field of the Quiet Time Period Request element sent by the requester HE STA.

The Vendor Specific Service ID field indicates a specified operation, and the HE STA supporting it can transmit frames. The Vendor Specific Service ID field contains a public unique identifier assigned by the IEEE.

9.4.2.224 Quiet Time Period Request element

The Quiet Time Period Request element defines a periodic sequence of quiet periods that the requester HE STA requests the responder AP to schedule. The format of the Quiet Time Period Request element is shown in Figure 9-589da (Quiet Time Period Request element).

	Element ID	Length	Element ID Extension	Dialog Token	Quiet Period Offset	Quiet Period Duration	Quiet Period Interval	Repetition Count	Vender Specific Service Identifier
Octets:	1	1	1	2	2	2	2	1	2

Figure 9-589da—Quiet Time Period Request element

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Dialog Token field is used to identify the Quiet Time Period request and response dialog.

The Quiet Period Offset field is set to the offset of the start of the first quiet period from the Quiet Time Period Request frame that contains this element, expressed in TUs. The reference time is the start of the preamble of the PPDU that contains this element.

The Quiet Period Interval field is set to the spacing between the start of two consecutive quiet time periods, expressed in TUs.

The Quiet Duration field is set to duration of the Quiet Period, expressed in TUs.

The Repetition Count field is set to the number of requested quiet periods.

The Vendor Specific Service Identifier field indicates a specified operation, and the HE STA supporting it can transmit frames. The Vendor Specific Service Identifier field contains a public unique identifier assigned by the IEEE.

9.4.2.225 Quiet Time Period Response element

The Quiet Period Response element defines the feedback information from the AP that received the Quiet Period Request element. The format of the Quiet Period Response element is shown in Figure 9-589db (Quiet Time Period Response element).

	Element ID	Length	Element ID Extension	Dialog Token	Quiet Period Offset	Quiet Period Duration	Quiet Period Interval	Repetition Count	Vender Specific Service Identifier	Status Code
Octets:	1	1	1	2	2	2	2	1	2	2

Figure 9-589db—Quiet Time Period Response element

The Element ID and Length fields are defined in 9.4.2.1 (General).

The Dialog Token field is used to identify the Quiet Time Period request and response dialog.

The Quiet Period Offset field is set to the offset of the start of the first quiet period from the Quiet Time Period Request frame that contains this element, expressed in TUs. The reference time is the start of the preamble of the PPDU that contains this element.

The Quiet Period Interval field is set to the spacing between the start of two consecutive quiet time periods, expressed in TUs.

The Quiet Duration field is set to duration of the Quiet Period, expressed in TUs.

The Repetition Count field is set to the number of requested quiet periods.

The Vendor Specific Service ID field indicates a specified operation, and the HE STA supporting it can transmit frames. The Vendor Specific Service ID field contains a public unique identifier assigned by the IEEE.

The Status Code field is used in a response Management frame to indicate the success or failure of a requested operation.

9.6 Action frame format details

9.6.4 DLS Action frame details

9.6.4.2 DLS Request frame format

Insert the following new rows (header row shown for convenience) into Table 9-299 (DLS Request frame Action field format) after the row for Order 11:

Table 9-299—DLS Request frame Action field format

Order	Information	Notes
12	HE Capabilities	The HE Capabilities element is present when dot11HEOptionImplemented is true; otherwise it is not present.
13	HE Operation	The HE Operation element is present when dot11HEOptionImplemented is true; otherwise it is not present.

9.6.4.3 DLS Response frame format

Insert the following new row (header row shown for convenience) into Table 9-300 (DLS Response frame Action field format) after the row for Order 11:

Table 9-300—DLS Response frame Action field format

Order	Information	Notes
12	HE Capabilities	The HE Capabilities element is present when dot11HEOptionImplemented is true; otherwise it is not present.

9.6.5 Block Ack Action frame details

9.6.5.1 General

Change Table 9-302 (Block Ack Action field values) as follows:

Table 9-302—Block Ack Action field values

Block Ack Action field values	Meaning
0	ADDBA Request
1	ADDBA Response
2	DELBA
3	L3 FRAG ADDBA Request
4	L3 FRAG ADDBA Response
5	L3 FRAG DELBA
~~3~~6–255	Reserved

9.6.8 Public Action details

9.6.8.16 TDLS Discovery Response frame format

Insert the following new rows (header row shown for convenience) into Table 9-317 (TDLS Discovery Response Action field format) after the row for Order 17:

Table 9-317—TDLS Discovery Response Action field format

Order	Information	Notes
18	HE Capabilities	The HE Capabilities element is present when dot11HEOptionImplemented is true; otherwise it is not present, The HE Capabilities element is defined in 9.4.2.218 (HE Capabilities element)

9.6.8.36 FILS Discovery frame format

Change Table 9-325a (FILS Discovery frame format) as follows (only modified rows are shown):

Table 9-325a—FILS Discovery frame format

Order	Information	Notes
~~6~~	~~Vendor Specific element~~	~~One or more Vendor Specific elements are optionally present.~~
7	TIM element	The TIM element is optionally present when dot11TWToptionActivated and dot11HEOptionImplemented are true, otherwise it is not present.

Insert the following at the end of the subclause:

The FILS Discovery frame may include a TIM element, which is defined in 9.4.2.6 (TIM element), for operation as defined in 27.14.3 (Opportunistic power save in congested environment).

9.6.13 TDLS Action field formats

9.6.13.2 TDLS Setup Request Action field format

Insert the following new rows (header row shown for convenience) into Table 9-343 (Information for TDLS Setup Request Action field) after the row for Order 20:

Table 9-343—Information for TDLS Setup Request Action field

Order	Information	Notes
21	HE Capabilities	The HE Capabilities element is present when dot11HEOptionImplemented is true; otherwise it is not present. The HE Capabilities element is defined in 9.4.2.218 (HE Capabilities element)

9.6.13.3 TDLS Setup Request Action field format

Insert the following new row (header row shown for convenience) into Table 9-344 (Information for TDLS Setup Response Action field) after the row for Order 22:

Table 9-344—Information for TDLS Setup Response Action field

Order	Information	Notes
23	HE Capabilities	The HE Capabilities element is present when dot11HEOptionImplemented is true and the Status Code is SUCCESS; otherwise it is not present. The HE Capabilities element is defined in 9.4.2.218 (HE Capabilities element)

9.6.13.4 TDLS Setup Confirm Action field format

Insert the following new row (header row shown for convenience) into Table 9-345 (Information for TDLS Setup Confirm Action field) after the row for Order 12:

Table 9-345—Information for TDLS Setup Confirm Action field

Order	Information	Notes
13	HE Operation	The HE Operation element is present when dot11HEOptionImplemented is true, the TDLS Setup Response frame contained an HE Capabilities element and the Status Code is SUCCESS; otherwise it is not present. The HE Operation element is defined in 9.4.2.219 (HE Operation element).

9.6.16 Self-protected Action frame details

9.6.16.2 Mesh Peering Open frame format

9.6.16.2.2 Mesh Peering Open frame details

Insert the following new row (header row shown for convenience) into Table 9-365 (Mesh Peering Open frame Action field format) after the row for Order 21:

Table 9-365—Mesh Peering Open frame Action field format

Order	Information	Notes
22	HE Capabilities	The HE Capabilities element is present when dot11HEOptionImplemented is true; otherwise it is not present.
23	HE Operation	The HE Operation element is present when dot11HEOptionImplemented is true; otherwise it is not present.

9.6.16.3 Mesh Peering Confirm frame format

9.6.16.3.2 Mesh Peering Confirm frame details

Insert the following new row (header row shown for convenience) into Table 9-366 (Mesh Peering Open frame Action field format) after the row for Order 17:

Table 9-366—Mesh Peering Open frame Action field format

Order	Information	Notes
18	HE Capabilities	The HE Capabilities element is present when dot11HEOption-Implemented is true; otherwise it is not present.
19	HE Operation	The HE Operation element is present when dot11HEOptionIm-plemented is true; otherwise it is not present.

9.6.28 HE Action frame details

9.6.28.1 HE Action field

An HE Action field, in the octet immediately after the Category field, differentiates the HE Action frame formats. The HE Action field values associated with each frame format within the HE category are defined in Table 9-421z (HE Action field values).

Table 9-421z—HE Action field values

Value	Meaning
0	HE Compressed Beamforming And CQI
1	HE BSS Color Change Announcement
2-255	Reserved

9.6.28.2 HE Compressed Beamforming And CQI frame format

The HE Compressed Beamforming And CQI frame is an Action No Ack frame of category HE. The Action field of an HE Compressed Beamforming And CQI frame contains the information shown in Table 9-421aa (HE Compressed Beamforming And CQI frame Action field format).

Table 9-421aa—HE Compressed Beamforming And CQI frame Action field format

Order	Information
1	Category
2	HE Action
3	HE MIMO Control
4	HE Compressed Beamforming Report (see 9.4.1.63 (HE Compressed Beamforming Report field))
5	HE MU Exclusive Beamforming Report (see 9.4.1.64 (HE MU Exclusive Beamforming Report field))
6	HE CQI-only Report (see 9.4.1.65 (HE CQI-only Report field))

The Category field is defined in Table 9-47 (Category values).

The HE Action field is defined in Table 9-421z (HE Action field values).

The HE MIMO Control field is always present in the frame. The presence and contents of the HE Compressed Beamforming Report field, HE MU Exclusive Beamforming Report field and HE CQI-only Report field are dependent on the values of Feedback Type subfield of HE MIMO Control field.

No vendor-specific elements are present in HE Compressed Beamforming and CQI frame.

9.6.28.3 HE BSS Color Change Announcement frame format

The HE BSS Color Change Announcement frame is an Action or Action No ACK frame of category HE. The Action field of a HE BSS Color Change Announcement frame contains the information shown in Table 9-421ab (HE BSS Color Change Announcement frame Action field format).

Table 9-421ab—HE BSS Color Change Announcement frame Action field format

Order	Information
1	Category
2	HE Action
3	BSS Color Change Announcement

The Category field is defined in Table 9-47 (Category values).

The HE Action field is defined in Table 9-421z (HE Action field values).

The BSS Color Change Announcement element as defined in 9.4.2.222 (BSS Color Change Announcement element) is always present in the frame.

No Vendor-Specific elements are present in HE BSS Color Change Announcement frame.

9.6.29 Quiet Time Period Action frame details

9.6.29.1 Quiet Time Period Action field

Several Action frame formats are defined to support Quiet Time Period functionality for STA-to-STA operation. A Quiet Time Period Action field, in the octet immediately after the Category field, differentiates the Quiet Time Period Action frame formats. The Quiet Time Period Action field values associated with each frame format within the Quiet Time Period category are defined in Table 9-421ac (Quiet Time Period Action field values).

Table 9-421ac—Quiet Time Period Action field values

Value	Meaning
0	Quiet Time Period Setup
1	Quiet Time Period Request
2	Quiet Time Period Response
3-255	Reserved

9.6.29.2 Quiet Time Period Setup frame format

The Quiet Time Period Setup frame is an Action No Ack frame of category Quiet Time Period. It is sent by AP to set up a quiet period for the operation indicated by Quiet Time Period Setup element. The Action field of a Quiet Time Period Setup frame contains the information shown in TTable 9-421ad (Quiet Time Period Setup frame Action field format).

Table 9-421ad—Quiet Time Period Setup frame Action field format

Order	Information
1	Category
2	Quiet Time Period Action
3	Quiet Time Period Setup element (see 9.4.2.223 (Quiet Time Period Setup element))

9.6.29.3 Quiet Time Period Request frame format

The Quiet Time Period Request frame is an Action frame of category Quiet Time Period. It is sent by HE STA to request a quiet period for the operation indicated by Quiet Time Period Request element. The Action field of a Quiet Time Period Setup frame contains the information shown in Table 9-421ae (Quiet Time Period Request frame Action field format).

Table 9-421ae—Quiet Time Period Request frame Action field format

Order	Information
1	Category
2	Quiet Time Period Action
3	Quiet Time Period Request element (see 9.4.2.224 (Quiet Time Period Request element))

9.6.29.4 Quiet Time Period Response frame format

The Quiet Time Period Request frame is an Action frame of category Quiet Time Period. It is sent by HE STA to request a quiet period for the operation indicated by Quiet Time Period Request element. The Action field of a Quiet Time Period Setup frame contains the information shown in Table 9-421af (Quiet Time Period Response frame Action field format).

Table 9-421af—Quiet Time Period Response frame Action field format

Order	Information
1	Category
2	Quiet Time Period Action
3	Quiet Time Period Response element (see 9.4.2.225 (Quiet Time Period Response element))

9.7 Aggregate MPDU (A-MPDU)

9.7.1 A-MPDU format

Change the 4th paragraph as follows:

The EOF Padding field is shown in Figure 9-739 (EOF Padding field format). This is present only in a VHT <u>or HE </u>PPDU.

Change the 6th and subsequent paragraphs as follows:

In a VHT <u>or HE </u>PPDU, the following padding is present, as determined by the rules in 10.13.6 (A-MPDU padding for VHT PPDU):

— 0–3 octets in the Padding subfield of the final A-MPDU subframe (see Figure 9-740 (A-MPDU subframe format)) before any EOF padding subframes. The content of these octets is unspecified.

— Zero or more EOF padding subframes in the EOF Padding Subframes subfield.

— 0–3 octets in the EOF Padding Octets subfield. The content of these octets is unspecified.

An A-MPDU pre-EOF padding refers to the contents of the A-MPDU up to, but not including, the EOF Padding field.

NOTE—A-MPDU pre-EOF padding includes any A-MPDU subframes with 0 in the MPDU Length field and 0 in the EOF field inserted in order to meet the minimum MPDU start spacing requirement.

The maximum length of an A-MPDU in an HT PPDU is 65 535 octets. The maximum length of an A-MPDU in a DMG PPDU is 262 143 octets. The maximum length of an A-MPDU pre-EOF padding in a VHT PPDU is 1 048 575 octets. The maximum length of an A-MPDU pre-EOF padding in an HE PPDU is 4 194 303 octets. The length of an A-MPDU addressed to a particular STA can be further constrained as described in 10.13.2 (A-MPDU length limit rules).

Change Table 9-422 as follows:

Table 9-422— MPDU delimiter fields (non-DMG)

Field	Size (bits)	Description
EOF	1	End of frame indication. Set to 1 in an A-MPDU subframe that has 0 in the MPDU Length field and that is used to pad the A-MPDU in a VHT or HE PPDU as described in 10.13.6 (A-MPDU padding for VHT PPDU). Set to 1 in the MPDU delimiter of a S-MPDU as described in 10.13.7 (Setting the EOF field of the MPDU delimiter). Set to 0 otherwise.
Reserved	1	
MPDU Length	14	Length of the MPDU in octets. Set to 0 if no MPDU is present. An A-MPDU subframe with 0 in the MPDU Length field is used as defined in 10.13.3 (Minimum MPDU Start Spacing field) to meet the minimum MPDU start spacing requirement and also to pad the A-MPDU to fill the available octets in a VHT or HE PPDU as defined in 10.13.6 (A-MPDU padding for VHT PPDU).
CRC	8	8-bit CRC of the preceding 16 bits
Delimiter Signature	8	Pattern that may be used to detect an MPDU delimiter when scanning for an MPDU delimiter. The unique pattern is 0x4E (see NOTE below).
NOTE—The ASCII value of the character 'N' was chosen as the unique pattern for the value in the Delimiter Signature field.		

Change the 12th and 13th paragraph as follows:

The format of the MPDU Length field when transmitted by a non-DMG STA is shown in Figure 9-743. The MPDU Length Low subfield contains the 12 low order bits of the MPDU length. In a VHT or HE PPDU, the MPDU Length High subfield contains the two high order bits of the MPDU length. In an HT PPDU, the MPDU Length High subfield is reserved.

The MPDU length value is derived from the MPDU Length field subfields as follows:

$$L_{MPDU} = \begin{cases} L_{low} + L_{high} \times 4096, & \text{VHT PPDU} \\ L_{low}, & \text{HT PPDU} \\ L, & \text{DMG PPDU} \end{cases} \tag{9-5}$$

where

L_{low} is the value of the MPDU Length Low subfield

L_{high} is the value of the MPDU Length High subfield

L is the value of the MPDU Length field

NOTE—The format of the MPDU Length field maintains a common encoding structure for ~~both~~ HE, VHT and HT PPDUs. For HT PPDUs, only the MPDU Length Low subfield is used, while for VHT PPDUs, both subfields are used.

9.7.3 A-MPDU contents

Change the 1st paragraph of this subclause as follows:

In a non-DMG PPDU, an A-MPDU is a sequence of A-MPDU subframes carried in a single PPDU with one of the following combinations of RXVECTOR or TXVECTOR parameter values:

- The FORMAT parameter set to VHT
- The FORMAT parameter set to HT_MF or HT_GF and the AGGREGATION parameter set to 1
- The FORMAT parameter set to S1G, S1G_DUP_1M, or S1G_DUP_2M and the AGGREGATION parameter set to 1
- The FORMAT parameter set to HE_SU, HE_MU, HE_TRIG or HE_EXT

Insert the following paragraph:

An A-MPDU carried in an HE SU PPDU, HE extended range SU PPDU, HE trigger-based PPDU and HE MU PPDU can include MPDUs with different values of the TID field as described in 27.10.4 (A-MPDU with multiple TIDs).

Change the 3rd paragraph as follows:

All of the MPDUs within an A-MPDU are addressed to the same RA. All of the MPDUs within an A-MPDU have the same TA. All QoS Data frames within an A-MPDU that have a TID for which an HT-immediate block ack agreement exists have the same value for the Ack Policy subfield of the QoS Control field.

Change the 5th paragraph as follows:

The Duration/ID fields in the MAC headers of all MPDUs in an A-MPDU carry the same value. The Duration/ID fields in the MAC headers of MPDUs in A-MPDUs carried in the same VHT MU PPDU, the same HE MU PPDU or all HE trigger-based PPDUs addressed to the same AP ~~all~~ carry the same value.

NOTE 1—The reference point for the Duration/ID field is the end of the PPDU carrying the MPDU. Setting the Duration/ID field to the same value in the case of A-MPDU aggregation means that each MPDU consistently specifies the same NAV setting.

Change the 7th and 8th paragraph as follows:

An A-MPDU is transmitted in one of the contexts specified in Table 9-424 (A-MPDU contexts) as defined by the description in the "Definition of context" column~~, independently of whether the A-MPDU is contained in a VHT MU PPDU or an SU PPDU~~. The further restrictions of A-MPDU content are defined in the conditions of various contexts. Ordering of MPDUs within an A-MPDU is not constrained, except where noted in these tables. See 10.13.1 (A-MPDU contents).

A VHT MU PPDU does not carry more than one A-MPDU that contains one or more MPDUs soliciting an immediate response. An HE MU PPDU does not carry more than one A-MPDU that contains one or more MPDUs soliciting an immediate response that is not carried in an HE trigger-based PPDU.

NOTE 2—The TIDs present in a data enabled A-MPDU context are also constrained by the channel access rules (for a TXOP holder; see 10.22.2 (HCF contention based channel access (EDCA)) and 10.22.3 (HCF controlled channel access (HCCA))) and the RD response rules (for an RD responder, see 10.28.4 (Rules for RD responder)). This is not shown in these tables.

NOTE 3—If a STA supports A-MSDUs of 7935 octets (indicated by the Maximum A-MSDU Length field in the HT Capabilities element), A-MSDUs transmitted by that STA within an A-MPDU carried in a PPDU with FORMAT HT_MF or HT_GF are constrained so that the length of the QoS Data frame carrying the A-MSDU is no more than 4095 octets. The 4095-octet MPDU length limit does not apply to A-MPDUs carried in VHT or DMG PPDUs. The use of A-MSDU within A-MPDU might be further constrained as described in 9.4.1.14 (Block Ack Parameter Set field) through the operation of the A-MSDU Supported field.

Change Table 9-424 (A-MPDU Contexts) as follows:

Table 9-424—A-MPDU Contexts

Name of Context	Definition of Context	Table defining permitted contents
Data Enabled Immediate Response	The A-MPDU is transmitted outside a PSMP sequence by a TXOP holder, TXOP responder or an RD responder including potential immediate responses.	Table 9-425 (A-MPDU contents in the data enabled immediate response context)
Data Enabled No Immediate Response	The A-MPDU is transmitted outside a PSMP sequence by a TXOP holder, TXOP responder that does not include or solicit an immediate response. See NOTE.	Table 9-426 (A-MPDU contents in the data enabled no immediate response context)
PSMP	The A-MPDU is transmitted within a PSMP sequence.	Table 9-427 (A-MPDU contents in the PSMP context)
Control Response	The A-MPDU is transmitted by a STA that is neither a TXOP holder nor an RD responder or the A-MPDU is transmitted by AP in an HE BSS that also needs to transmit one of the following immediate response frames: Ack BlockAck frame with a TID for which an HT-immediate block ack agreement exists Multi-STA BA for acknowledging multi-TID A-MPDU	Table 9-428 (A-MPDU contents MPDUs in the control response context)
S-MPDU context	The A-MPDU is transmitted within a VHT PPDU or an HE PPDU and contains an S-MPDU.	Table 9-429 (A-MPDU contents in the S-MPDU context)

NOTE—This context includes cases when no response is generated or when a response is generated later by the operation of the delayed block ack rules.

Change Table 9-425 (A-MPDU contents in the data enabled immediate response context) as follows:

Table 9-425—A-MPDU contents in the data enabled immediate response context

<table>
<tr><th>MPDU Description</th><th colspan="2">Conditions</th></tr>
<tr><td>Ack</td><td>If the preceding PPDU contains an MPDU that requires an Ack frame response, a single Ack frame at the start of the A-MPDU.</td><td rowspan="3">In a non-DMG STA other than an HE STA: at most one of ~~these~~ Ack and HT-immediate BlockAck MPDUs is present.

In an HE STA: at most one of these MPDUs is present.

In a DMG STA: at most one Ack frame is present, and zero or more HT-immediate BlockAck frames are present.</td></tr>
<tr><td>HT-immediate BlockAck</td><td>In a non-DMG STA: if the preceding PPDU contains an implicit or explicit block ack request for a TID for which an HT-immediate block ack agreement exists, at most one BlockAck frame for this TID, in which case it occurs at the start of the A-MPDU.

In a DMG STA: if the preceding PPDU contains an implicit or explicit block ack request for a TID for which an HT-immediate block ack agreement exists, one or more copies of the same BlockAck for this TID.</td></tr>
<tr><td>Multi-STA BlockAck</td><td>In an HE STA: If the preceding PPDU that carried a multiple-TID A-MPDU contains implicit or explicit block ack requests for multiple TIDs for which HT-immediate block ack agreement exist, at most one Multi-STA BA frame, in which case it occurs at the start of the A-MPDU.</td></tr>
<tr><td>Delayed BlockAcks</td><td colspan="2">BlockAck frames with the BA Ack Policy subfield equal to No Acknowledgment with a TID for which an HT-delayed block ack agreement exists.</td></tr>
<tr><td>Delayed block ack data</td><td colspan="2">QoS Data frames with a TID that corresponds to a Delayed or HT-delayed block ack agreement.
These have the Ack Policy field equal to Block Ack.</td></tr>
<tr><td>Action No Ack</td><td colspan="2">Action No Ack frames.</td></tr>
<tr><td>Delayed BlockAckReqs</td><td colspan="2">BlockAckReq frames with a TID that corresponds to an HT-delayed block ack agreement in which the BA Ack Policy subfield is equal to No Acknowledgment.</td></tr>
</table>

Table 9-425—A-MPDU contents in the data enabled immediate response context *(continued)*

<table>
<tr><th>MPDU Description</th><th colspan="2">Conditions</th></tr>
<tr><td>Data frames without HT-immediate block ack agreement</td><td>QoS Data frames with multiple TIDs which have no HT-immediate block ack agreement

See NOTE 1.</td><td rowspan="6">Of these, at most one of the following is present in a non-DMG BSS except HE BSS:
— One or more QoS Data frames with the Ack Policy field equal to Implicit Block Ack Request
— A BlockAckReq frame

Of these, at most one of the following is present in a DMG BSS:
— One or more QoS Data frames with the Ack Policy field equal to Implicit Block Ack Request
— QoS Null MPDU with Ack Policy set to No Ack
— A BlockAckReq frame with an optional QoS Null MPDU with Ack Policy set to No Ack

Of these, at most one of the following is present between two HE STAs:
— One or more QoS Data frames from multiple TIDs with the Ack Policy field equal to Implicit Block Ack Request/MU Ack/AckRequest, at most one Action, optional QoS Null with Ack Policy set to No Ack, Basic Trigger frame or BSRP Trigger frame only when AP transmits the A-MPDU
— QoS Null MPDU with Ack Policy set to No Ack
— One of BolckAckReq and Multi-TID BlockAckReq frame
— Basic Trigger frame or BSRP Trigger frame only when AP transmits the A-MPDU</td></tr>
<tr><td>Data frames sent under an HT-immediate block ack agreement</td><td>QoS Data frames with the same TID, which corresponds to an HT-immediate block ack agreement.

QoS Data frames with multiple TIDs, which correspond to multiple HT-immediate block ack agreements.

See NOTE 1.</td></tr>
<tr><td>QoS Null MPDUs with Ack Policy set to No Ack</td><td>In a DMG BSS, QoS Null MPDUs with Ack Policy set to No Ack.

In an HE BSS, QoS Null MPDUs with Ack Policy set to No Ack.</td></tr>
<tr><td>Immediate BlockAckReq</td><td>At most one BlockAckReq frame with a TID that corresponds to an HT-immediate block ack agreement.
This is the last MPDU in the A-MPDU.

It is not present if any QoS Data frames for that TID are present.

At most one of the following cases:
— Multi-TID BlockAckReq frame with TIDs that correspond to an HT-immediate block ack agreement. This is after data and management frames in the A-MPDU.
— This is the last MPDU in the A-MPDU</td></tr>
<tr><td>Action</td><td>At most one Action frame</td></tr>
<tr><td>Trigger</td><td>One or more Trigger frames where the Trigger Type field is Basic Trigger, MU-BAR, or BSRP.

See NOTE 2</td></tr>
<tr><td colspan="3">NOTE 1—~~These~~ The MPDUs from the same TID all have the Ack Policy field equal to the same value, which is either Implicit Block Ack Request (Ack Request), MU Ack or Block Ack.
NOTE 2—An AP including a Trigger frame and BlockAck frame is not required to include QoS Data in that A-MPDU</td></tr>
</table>

Change Table 9-426 (A-MPDU contents in the data enabled no immediate response context) as follows:

Table 9-426—A-MPDU contents in the data enabled no immediate response context

MPDU Description	Conditions
Delayed BlockAcks	BlockAck frames for a TID for which an HT-delayed block ack agreement exists with the BA Ack Policy subfield equal to No Acknowledgment.
Delayed Block Ack data	QoS Data frames with a TID that corresponds to a Delayed or HT-delayed block ack agreement. These have the Ack Policy field equal to Block Ack.
Data without a block ack agreement	QoS Data frames with a TID that does not correspond to a block ack agreement. These have the Ack Policy field equal to No Ack and the A-MSDU Present subfield equal to 0.
Action No Ack	Action No Ack frames.
Delayed BlockAckReqs	BlockAckReq frames with the BA Ack Policy subfield equal to No Acknowledgment and with a TID that corresponds to an HT-delayed block ack agreement.
Trigger	If the A-MPDU is transmitted by an AP, one or more Trigger frames where the Trigger Type field is Basic Trigger or BSRP. See NOTE 1.
QoS Null frame with Ack Policy field set to No Acknowledgment	Zero of more QoS Null MPDUs with Ack Policy field set to No Acknowledgment sent by an HE STA.
NOTE 1—An AP including Trigger frame and BlockAck is not required to include QoS Data in that A-MPDU.	

Change Table 9-428 (A-MPDU contents MPDUs in the control response context) as follows:

Table 9-428—A-MPDU contents MPDUs in the control response context

<table>
<tr><th>MPDU</th><th colspan="2">Conditions</th></tr>
<tr><td>Ack</td><td>Ack frame transmitted in response to an MPDU that requires an Ack frame.</td><td rowspan="3">One Ack and BlockAck frame is present at the start of the A-MPDU in a BSS that is not an HE BSS.

One of these is present at the start of the A-MPDU between two HE STAs.</td></tr>
<tr><td>BlockAck</td><td>BlockAck frame with a TID that corresponds to an HT-immediate block ack agreement.</td></tr>
<tr><td>Multi-STA BlockAck</td><td>If the preceding PPDU that carried multi-TID A-MPDU contains implicit or explicit block ack requests for multiple TIDs for which HT-immediate block ack agreement exist, at most one Multi-STA BlockAck frame.</td></tr>
<tr><td>Action No Ack</td><td colspan="2">+HTC Action No Ack frames carrying a Management Action Body containing an explicit feedback response or BRP frame.</td></tr>
<tr><td>QoS Null frame with Ack Policy field set to No Acknowledgment</td><td colspan="2">Zero of more QoS Null MPDUs with Ack Policy field set to No Acknowledgment sent by an HE STA.</td></tr>
</table>

10. MAC sublayer functional description

10.2 MAC architecture

10.2.4 Hybrid coordination function (HCF)

10.2.4.2 HCF contention based channel access (EDCA)

Insert the following after the 4th paragraph (the 4th paragraph begins "The QoS AP shall announce the EDCA parameters..."):

In addition, an HE AP may change the EDCA access parameters for HE non-AP STAs that are UL MU capable, by including an MU EDCA Parameter Set element in the Beacon frame, Probe Response frame, and (Re-)Association Response frame. An HE non-AP STA that receives an MU EDCA Parameter Set element from its associated AP follows the rules defined in 27.2.3 (Obtaining an EDCA TXOP for UL MU capable STAs).

10.3 DCF

10.3.1 General

Change the 6th paragraph as follows:

The virtual CS mechanism is achieved by distributing reservation information announcing the impending use of the medium. The exchange of RTS and CTS frames prior to the actual Data frame is one means of distribution of this medium reservation information. The RTS and CTS frames contain a Duration field that defines the period of time that the medium is to be reserved to transmit the actual Data frame and the returning Ack frame. A STA receiving either the RTS frame (sent by the originating STA) or the CTS frame (sent by the destination STA) shall process the medium reservation. Thus, a STA might be unable to receive from the originating STA and yet still know about the impending use of the medium to transmit a Data frame. The exchange of MU-RTS and simultaneous CTS responses by HE STAs prior to the actual Data frames is another means of distribution of this medium reservation information.

Change the 12th paragraph as follows:

~~The~~ When HE duration-based RTS is disabled, the use of the RTS/CTS mechanism is under control of dot11RTSThreshold. This attribute may be set on a per-STA basis. This mechanism allows STAs to be configured to initiate RTS/CTS either always, never, or only on frames longer than a specified length.

When HE duration-based RTS is enabled, the use of the RTS/CTS mechanism is under control of dot11DurationRTSThreshold. This mechanism requires STAs to use an RTS/CTS exchange for individually addressed frames when the duration of the TXOP is greater than the duration threshold indicated by dot11DurationRTSThreshold.

NOTE 1—A STA configured not to initiate the RTS/CTS mechanism updates its virtual CS mechanism with the duration information contained in a received RTS or CTS frame, and responds to an RTS frame addressed to it with a CTS frame if permitted by medium access rules.

10.3.2 Procedures common to the DCF and EDCAF

10.3.2.1 CS mechanism

Change the 3rd and 4th paragraph of the subclause as follows:

A first virtual CS mechanism shall be provided by all MAC entities, and an additional second virtual CS mechanism shall be provided by an S1G MAC entity. The first mechanism is referred to as the NAV. The NAV maintains a prediction of future traffic on the medium based on duration information that is announced in RTS/CTS frames by non-DMG STAs, MU-RTS/CTS by HE STAs as defined in 10.3.2.8a, and RTS/DMG CTS frames by DMG STAs prior to the actual exchange of data. The duration information is also available in the MAC headers of all frames sent during the CP other than PV1 MAC frames and PS-Poll frames and during the BTI, the A-BFT, the ATI, the CBAP, and the SP. The duration information may also be available in the RXVECTOR parameter TXOP_DURATION when an HE PPDU is received.

The CS mechanism combines the NAV state and the STA's transmitter status with physical CS to determine the busy/idle state of the medium. The NAV may be thought of as a counter, which counts down to 0 at a uniform rate. When the counter is 0, the virtual CS indication is that the medium is idle; when the counter is nonzero, the indication is busy. The virtual CS indication of medium for HE STAs with two NAVs is described in 27.2.2 (Updating two NAVs). If a DMG STA supports multiple NAVs as defined in 10.36.10 (Updating multiple NAV) and all counters are 0, the virtual CS indication is that the medium is idle; when at least one of the counters is nonzero, the indication is busy. The medium shall be determined to be busy when the STA is transmitting.

10.3.2.3 IFS

10.3.2.3.7 EIFS

Change the 2nd paragraph of 10.3.2.3.7 as follows:

EIFS shall not be invoked if the NAV is updated by the frame that would have caused an EIFS. EIFS shall not be invoked for an A-MPDU if one or more of its frames are received correctly. EIFS shall not be invoked if a valid TXOP_DURATION parameter is present in the RXVECTOR of a received HE PPDU.

10.3.2.4 Setting and resetting the NAV

Change the 1st four paragraph as follows (the 2nd paragraph is broken into three paragraphs):

This subclause describes the setting and resetting of the NAV for non-DMG STAs and DMG STAs that support a single NAV. DMG STAs that support multiple NAVs shall update their NAVs according to the procedures described in 10.36.10 (Updating multiple NAV). HE STAs with two NAV timers shall update their NAV timers according to the procedures described in 27.2.2 (Updating two NAVs).

A STA that receives at least one valid frame in a PSDU can update its NAV with the information from any valid Duration field in the PSDU. If the STA is not an HE STA and ~~When~~ the received frame's RA is equal to the STA's own MAC address, the STA shall not update its NAV. If the STA is an HE STA and the STA is solicited for an immediate response by the PPDU carrying the received frame, the STA shall not update its NAV. If the STA is an HE STA, the STA is a TXOP holder, and the frame is solicited by the STA, then the STA shall not update its NAV. Further, when the received frame is a DMG CTS frame and its TA is equal to the STA's own MAC address, the STA shall not update its NAV. For all other received frames the STA shall update its NAV when the received Duration is greater than the STA's current NAV value. Upon receipt of a PS-Poll frame, a STA shall update its NAV settings as appropriate under the data rate selection rules using a duration value equal to the time, in microseconds, required to transmit one Ack frame plus one SIFS, but only when the new NAV value is greater than the current NAV value. If the calculated duration includes a fractional microsecond, that value is rounded up to the next higher integer.

A STA shall update the NAV with the duration information indicated by the RXVECTOR parameter TXOP_DURATION if and only if all the following conditions are met:

— The RXVECTOR parameter TXOP_DURATION is not all 1s.

— The STA does not receive a frame with the duration information indicated by a Duration field in the PSDU of the PPDU carrying the RXVECTOR parameter TXOP_DURATION

— The duration information indicated by the RXVECTOR parameter TXOP_DURATION is greater than the STA's current NAV value

— The PPDU that carried information of the RXVECTOR parameter is not HE trigger-based PPDU triggered by the STA

Various additional conditions may set or reset the NAV, as described in 10.4.3.3 (NAV operation during the CFP). When the NAV is reset, a PHY-CCARESET.request primitive shall be issued. The exact time of updating the NAV is described as follows. This NAV update operation is performed when the PHY-RXEND.indication primitive is received, except when the PHYRXEND.indication primitive is received before the end of the PPDU, in this case, this NAV update operation is performed at the expected end of the PPDU.

Figure 10-5 (RTS/CTS/data/Ack and NAV setting) indicates the NAV for STAs that might receive the RTS frame, while other STAs might receive only the CTS frame, resulting in the lower NAV bar as shown (with the exception of the STA to which the RTS frame was addressed).

A STA that used information from an RTS or MU-RTS frame as the most recent basis to update its NAV setting is permitted to reset its NAV if no PHY-RXSTART.indication primitive is received from the PHY during a NAVTimeout period starting when the MAC receives a PHY-RXEND.indication primitive corresponding to the detection of the RTS or MU-RTS frame.

Insert the following at the end of 10.3.2.4:

An HE AP may use the HE duration-based RTS threshold to configure the use of RTS/CTS initiated by a non-AP HE STA.

Insert a new subclause following 10.3.2.4:

10.3.2.4a Duration-based RTS/CTS

In dense environments, managing RTS usage by an AP can help the overall interference situation since the AP may have better view of the network situation. To improve spectrum utilization, RTS usage should be duration-based, rather than length-based.

Insert a new subclause following 10.3.2.8:

10.3.2.8a MU-RTS/CTS procedure

10.3.2.8a.1 General

The MU-RTS/CTS procedure allows an AP to protect an MU transmission. An HE AP may transmit an MU-RTS frame to solicit simultaneous CTS responses from one or more HE STAs.

Figure 10-9a (Example of MU-RTS/CTS/DL MU PPDU/Acknowledgement Response and NAV setting) shows an example of the exchange of MU-RTS and simultaneous CTS responses to protect DL MU PPDU and acknowledgement responses..

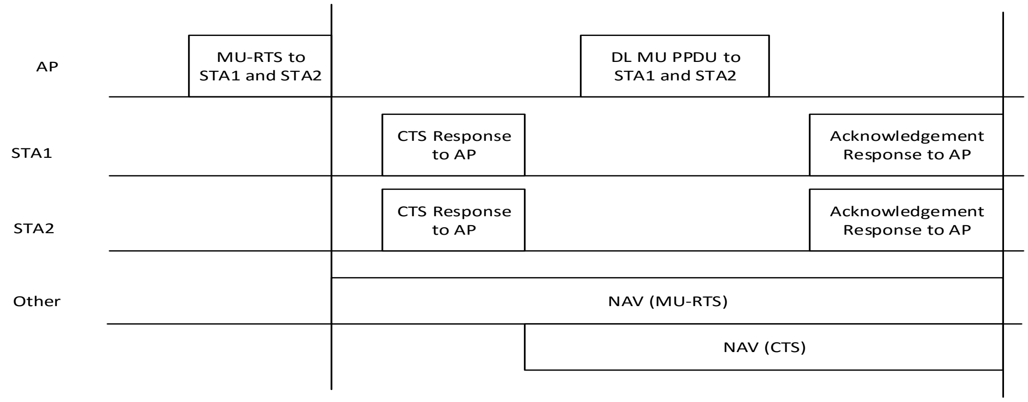


Figure 10-9a—Example of MU-RTS/CTS/DL MU PPDU/Acknowledgement Response and NAV setting

Figure 10-9b (Example of MU-RTS/CTS/Trigger/HE trigger-based PPDU/Multi-STA BlockAck and NAV setting) shows an example of the exchange of MU-RTS and simultaneous CTS responses to protect the scheduled HE trigger-based PPDU and Multi-STA BlockAck frame.

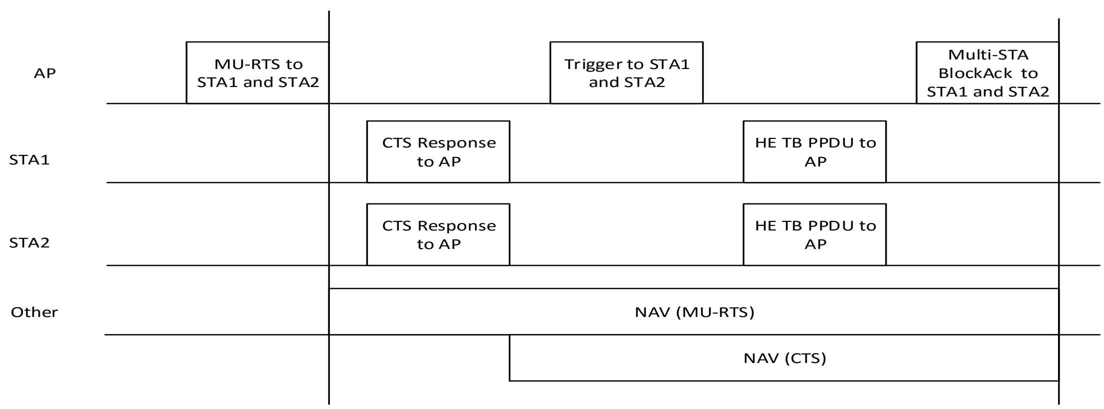


Figure 10-9b—Example of MU-RTS/CTS/Trigger/HE trigger-based PPDU/Multi-STA BlockAck and NAV setting

10.3.2.8a.2 MU-RTS procedure

The transmitter of an MU-RTS frame shall not request a STA to send a CTS frame response in a 20 MHz channel that is not occupied by the PPDU that contains the MU-RTS frame. In each 20 MHz channel occupied by the PPDU that contains an MU-RTS frame, the transmitter of the MU-RTS frame shall request at least one STA to send a CTS frame response that occupies the 20 MHz channel.

After transmitting an MU-RTS frame, the STA shall wait for a CTSTimeout interval with a value of aSIFSTime + aSlotTime + aRxPHYStartDelay. This interval begins when the MAC receives a PHY-TXEND.confirm primitive. If a PHY-RXSTART.indication primitive does not occur during the CTSTimeout interval, the STA shall conclude that the transmission of the MU-RTS frame has failed, and this STA shall invoke its backoff procedure upon expiration of the CTSTimeout interval. If a PHY-RXSTART.indication primitive does occur during the CTSTimeout interval, the STA shall wait for the corresponding PHY-RXEND.indication primitive to determine whether the MU-RTS frame transmission was successful. The recognition of a valid CTS frame sent by the recipient of the MU-RTS frame, corresponding to this PHY-RXEND.indication primitive, shall be interpreted as successful response, permitting the frame exchange sequence to continue. The recognition of anything else, including any other valid frame, shall be interpreted as failure of the MU-RTS frame transmission.

An MU-RTS frame shall not be carried in an HE MU PPDU.

10.3.2.8a.3 CTS response to MU-RTS

If an HE STA receives an MU-RTS frame, the HE STA shall commence the transmission of a CTS frame response at the SIFS time boundary after the end of a received PPDU when all the following conditions are met:

- The MU-RTS frame has one of the User Info fields addressed to the STA.
- The UL MU CS condition described in 27.5.2.4 (UL MU CS mechanism) indicates the medium is idle. The ED-based CCA during the SIFS after receiving an MU-RTS frame and virtual CS functions are used to determine the state of the medium to respond to an MU-RTS frame.
- The RU Allocation subfield in the User Info field addressed to the STA indicates either the primary 20 MHz channel, primary 40 MHz channel, primary 80 MHz channel, 160 MHz channel, or 80+80 MHz channel.
- The MU-RTS frame is sent by the AP with which the STA is associated and the value of the basic NAV is 0.

The CTS frame sent in response to an MU-RTS frame shall be carried in a non-HT or non-HT duplicate PPDU.

An HE non-AP STA transmitting a CTS frame in response to an MU-RTS frame shall set the TXVECTOR parameter SCRAMBLER_INITIAL_STATE to the same value as the RXVECTOR parameter SCRAMBLER_INITIAL_STATE of the received MU-RTS frame. The data rate to be used for the non-HT PPDU response shall be 6 Mb/s (see 17.1.1 General).

A CTS frame sent in response to an MU-RTS frame shall be transmitted on the 20 MHz channels indicated in the RU Allocation subfield of the User Info field of the MU-RTS frame when the indicated 20 MHz channels are all idle. If any 20 MHz channel indicated in the RU Allocation subfield of the User Info field is busy, the CTS frame response shall not be transmitted.

Figure 10-9c (An example of an MU-RTS frame soliciting CTS frame responses on the primary 40 MHz channel) shows an example of the exchange of MU-RTS and simultaneous CTS frame responses on the primary 40 MHz channel. In this example, MU-RTS is transmitted in a 40 MHz non-HT duplicate PPDU on the primary 40 MHz channel. Further, the MU-RTS frame requests STA1 to transmit a CTS frame response in a non-HT PPDU on the primary 20 MHz channel and STA2 to transmit a CTS frame response in a 40 MHz non-HT duplicate PPDU on the primary 40 MHz channel.

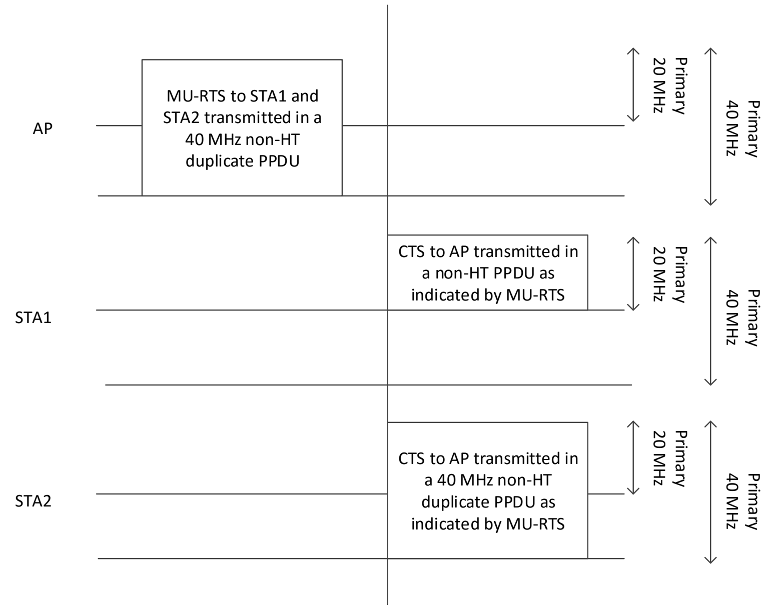


Figure 10-9c—An example of an MU-RTS frame soliciting CTS frame responses on the primary 40 MHz channel

A STA that transmits a CTS frame in response to an MU-RTS frame shall follow the synchronization requirement as defined in 17.3.9.10 (Pre-correction accuracy requirements).

10.3.2.10 MU acknowledgement procedure

Insert a new subclause heading before the first paragraph as follows:

10.3.2.10.1 Acknowledgement procedure for DL MU PPDU in SU format

Change the subclause as follows:

The acknowledgment procedure performed by a STA that receives MPDUs that were transmitted within a VHT MU PPDU or an HE MU PPDU for DL transmission is the same as the acknowledgment procedure for MPDUs that were not transmitted within a VHT MU PPDU or an HE MU PPDU for DL transmission.

NOTE−All MPDUs transmitted within a VHT MU PPDU or an HE MU PPDU for DL transmission are contained within A-MPDUs, and the rules specified in 9.7.3 (A-MPDU contents) prevent an immediate response carried in SU format to more than one of the A-MPDUs.

Responses to A-MPDUs within a VHT MU PPDU or an HE MU PPDU for DL transmissionthat are not immediate responses to the VHT MU PPDU or the HE MU PPDU for DL transmission are transmitted in response to explicit BlockAckReq frames by the AP. Examples of VHT MU PPDU frame exchange sequences are shown in Figure 10-11 (An example of a TXOP containing a VHT MU PPDU transmission with an immediate acknowledgment to the VHT MU PPDU) and Figure 10-12 (An example of a TXOP containing a VHT MU PPDU transmission with no immediate acknowledgment to the VHT MU PPDU).

Recovery within the TXOP that contains a VHT MU PPDU or an HE MU PPDUfor DL transmission can be performed according to the rules of 10.22.2.7 (Multiple frame transmission in an EDCA TXOP). BlockAck-

Request frames related to A-MPDUs within a VHT MU PPDU or an HE MU PPDU for DL transmission can be transmitted in a TXOP separate from the one that contained the VHT MU PPDU or the HE MU PPDU for DL transmission.

NOTE 1—A BlockAck frame or an Ack frame is sent in immediate response to the BlockAckReq frame for HT-immediate or HT-delayed Block Ack, respectively. An Ack frame might be sent in immediate response carried in SU format to a Single MPDU in the VHT MU PPDU or the HE MU PPDU for DL transmission. A Multi-STA Block Ack frame is sent in immediate response to the BlockAckReq frame with multi-TID BAR variant or MU-BAR frame with multi-TID BAR variant.

NOTE 2—A BlockAckRequest frame would typically not be sent to a STA in the case where the A-MPDU to the STA contained no MPDUs requiring acknowledgment. It could be sent if MPDUs in a previous A-MPDU remain unacknowledged.

Insert a new subclauses 10.3.2.10.2 and 10.3.2.10.3 as follows:

10.3.2.10.2 Acknowledgement procedure for DL MU PPDU in MU format

A non-AP STA that is the recipient, within an HE MU PPDU, of a QoS Data frame or QoS Null frame that solicits an immediate response with Ack Policy equal to MU Ack in the QoS Control field, of an MU-BAR frame, or of an MMPDU that solicits an immediate response, shall send the immediate response according to the scheduling information defined by the UL trigger information that is carried either in the Trigger frame(s) or UL MU Response Scheduling A-Control field. If no valid Trigger frame(s) (see 9.3.1.23 (Trigger frame format)) or UL MU Response Scheduling A-Control field (see 9.2.4.6.4.2 (UL MU response scheduling)) is received, then the STA shall not respond. An example of UL OFDMA acknowledgement to an HE MU PPDU is shown in Figure 10-12a (An example of an HE MU PPDU transmission with an immediate UL OFDMA acknowledgement).

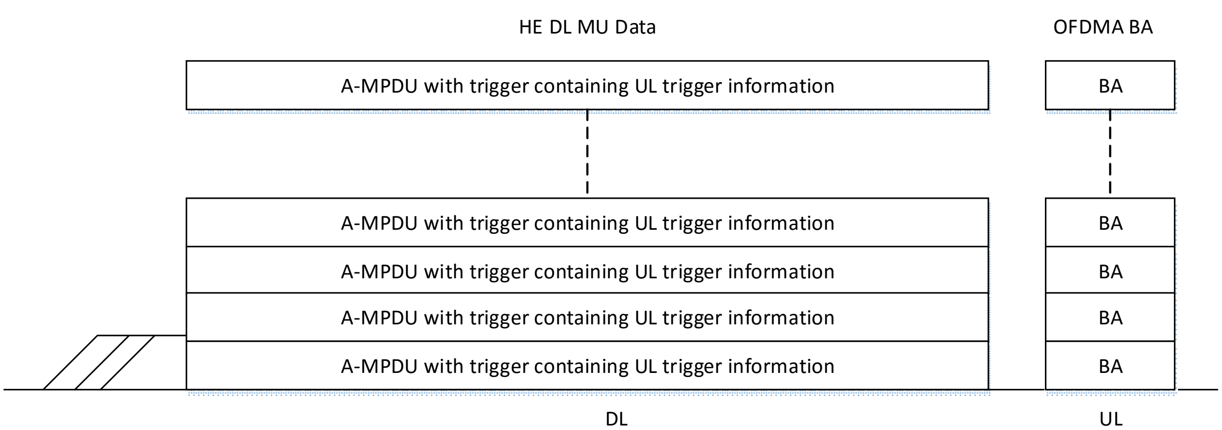


Figure 10-12a—An example of an HE MU PPDU transmission with an immediate UL OFDMA acknowledgement

An AP may use an MU-BAR variant Trigger frame to solicit acknowledgment frames from multiple HE STAs to which the AP has sent QoS Data frame(s) with the Ack Policy subfield equal to Block Ack or from which the AP has not received immediate acknowledgement frames after sending QoS Data frame(s) with the Ack Policy subfield equal to MU Ack in an HE MU PPDU.

10.3.2.10.3 Acknowledgement procedure for an UL MU transmission

When receiving frames from more than one STA that are part of an UL MU transmission (see 9.42.2) and that require an immediate acknowledgement (i.e., the Ack Policy subfield of the eliciting QoS Data frame is equal to Normal Ack or Implicit BAR), an AP may send either multiple BlockAck frames (or Ack frames) in an HE MU PPDU, or a Multi-STA BlockAck frame (see 27.4 (Block acknowledgement)). Multi-STA BlockAck frame transmissions are allowed in a non-HT Duplicate PPDU, HT PPDU, VHT PPDU, HE SU PPDU, HE extended range SU PPDU and OFDMA HE MU PPDU. After a successful reception of an UL frame requiring acknowledgment, transmission of the DL acknowledgement shall commence after a SIFS, without regard to the busy/idle state of the medium.Specifically, when an AP transmits an immediate acknowledgement in HE MU PPDU in response to (A-)MPDU sent in HE trigger-based PPDU, the AP should send it within the 20 MHz channel(s) where the pre-HE modulated fields of the HE trigger-based PPDU sent by the STA are located. The immediate acknowledgement is either a BlockAck frame, Ack frame or Multi-STA Block Ack frame.

An example of a DL OFDMA BA is shown in Figure 10-12b (An example of an UL MU transmission with an immediate DL MU transmission containing individually addressed BlockAck frames acknowledging the frames received from the respective STAs).

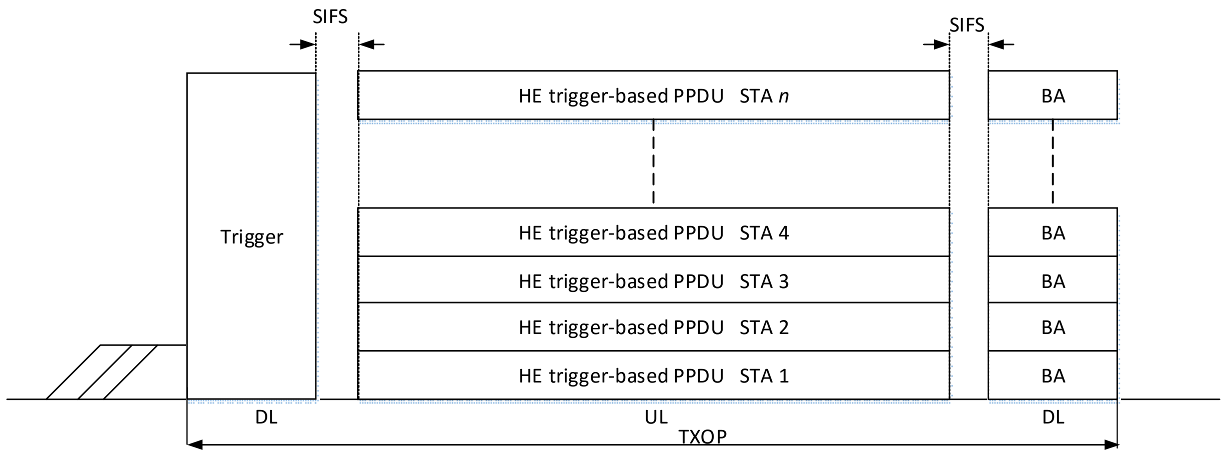


Figure 10-12b—An example of an UL MU transmission with an immediate DL MU transmission containing individually addressed BlockAck frames acknowledging the frames received from the respective STAs

An example of a Multi-STA BlockAck frame acknowledgement in a non-HT, HT, VHT or HE SU PPDU is given in Figure 10-12c (An example of UL MU transmissions with an immediate Multi-STA BlockAck frame acknowledging the MPDUs).

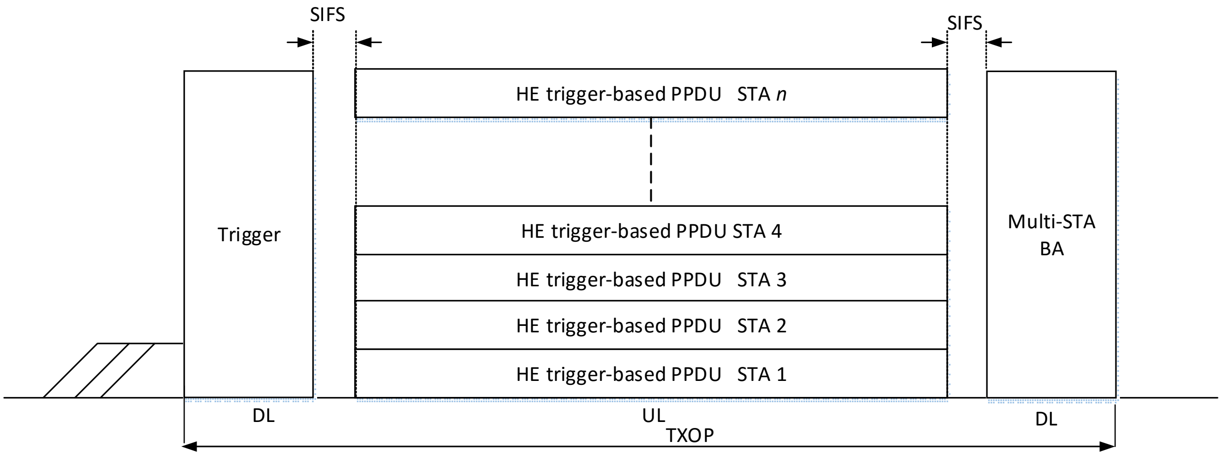


Figure 10-12c—An example of UL MU transmissions with an immediate Multi-STA BlockAck frame acknowledging the MPDUs

An example of a Multi-STA BlockAck frame acknowledgement in a non-HT Duplicate PPDU is given in Figure 10-12d (An example of UL MU transmissions with an immediate DL non-HT duplicate PPDU containing the Multi-STA BlockAck frame).

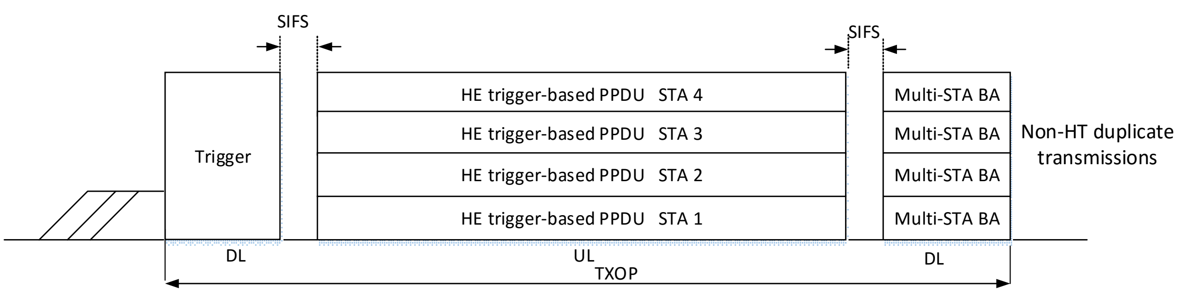


Figure 10-12d—An example of UL MU transmissions with an immediate DL non-HT duplicate PPDU containing the Multi-STA BlockAck frame

The Ack Policy subfield of a QoS data frame sent in an HE trigger-based PPDU shall not be set to Block Ack.

A STA may use a BlockAckReq frame to solicit the acknowledgment frame(s), to whom the STA sent the QoS Data frame(s) with Ack Policy subfield equal to Block Ack or from whom the STA did not receive the immediate acknowledgement frames after sending QoS Data frame(s) in a HE trigger-based PPDU with Ack Policy subfield equal to Normal Ack or Impilcit BAR.

10.3.5 Individually addressed MPDU transfer procedure

~~A~~ When HE duration-based RTS is disabled, a STA using the DCF shall use an RTS/CTS exchange for individually addressed frames when the length of the PSDU is greater than the length threshold indicated by dot11RTSThreshold. When HE duration-based RTS is enabled, a non-AP STA using the DCF or EDCA shall use an RTS/CTS exchange for individually addressed frames when the duration of the TXOP is greater than the duration threshold indicated by dot11DurationRTSThreshold. A STA may also use an RTS/CTS exchange for individually addressed frames when it is necessary to distribute the NAV or when it is necessary to establish protection (see 10.26 (Protection mechanisms)). Otherwise a STA using the DCF shall not use the RTS/CTS exchange.

If dot11RTSThreshold is 0 or dot11DurationRTSThreshold is 0, all MPDUs shall be delivered with the use of RTS/CTS. If dot11RTSThreshold is larger than the maximum PSDU length, all PSDUs shall be delivered without RTS/CTS exchanges.

NOTE—A non-AP STA that transmits the MPDUs in an HE trigger-based PPDU is exempt from these requirements.

When an RTS/CTS exchange is used, the PPDU containing the PSDU shall be transmitted starting one SIFS after the end of the CTS frame.

NOTE—No regard is given to the busy or idle status of the medium when transmitting this PSDU.

When an RTS/CTS exchange is not used, the PSDU shall be transmitted following the success of the basic access procedure. With or without the use of the RTS/CTS exchange procedure, the STA that is the destination of a Data frame shall follow the acknowledgment procedure.

10.5 Fragmentation

Change the 2nd paragraph as follows:

With static fragmentation, t~~T~~he length of each fragment shall be an equal number of octets for all fragments except the last, which may be smaller. The length of each fragment shall be an even number of octets, except for the last fragment of an MSDU or MMPDU, which may be either an even or an odd number of octets. The length of a static fragment shall never be larger than dot11FragmentationThreshold unless security encapsulation is invoked for the MPDU. If security encapsulation is active for the MPDU, then the MPDU shall be expanded by the encapsulation overhead and this may result in a fragment larger than dot11FragmentationThreshold. Unless the conditions described in 27.3.2 (Support and requirements for dynamic fragmentation) are met, static fragmentation is used.

Change the 4th paragraph as follows:

A STA shall be capable of receiving fragments, containing all or part of an MSDU, of arbitrary length that is less than or equal to the maximum MSDU size as specified in Table 9-19 (Maximum data unit sizes (in octets) and durations (in microseconds)) ~~defined in 9.2.3 (General frame format), plus any security encapsulation overhead, plus MAC header and FCS~~.

10.7 Multirate support

10.7.1 Overview

Change the last two paragraphs as follows:

For specific PHYs, the value of the Duration/ID field is determined using the PLME-TXTIME.request primitive and the PLME-TXTIME.confirm primitive. These specific PHYs are defined in:

— Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) for HR/DSSS
— Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) for OFDM
— Clause 18 (Extended Rate PHY (ERP) specification) for ERP

— Clause 19 (High Throughput (HT) PHY specification) for HT
— Clause 20 (Directional multi-gigabit (DMG) PHY specification) for DMG
— Clause 21 (Very High Throughput (VHT) PHY specification) for VHT
— Clause 22 (Television Very High Throughput (TVHT) PHY specification) for TVHT
— Clause 28 (High Efficiency (HE) PHY specification) for HE

The two PLME-TXTIME primitives are defined in the respective PHY specifications:

— 16.3.4 (HR/DSSS TXTIME calculation) for HR TXTIME calculation
— 17.4.3 (OFDM TXTIME calculation) for OFDM TXTIME calculation
— 18.5.3.2 (ERP-OFDM TXTIME calculations)
— 19.4.3 (TXTIME calculation) for HT TXTIME calculation
— 20.12.3 (TXTIME calculation) for DMG PLME TXTIME calculation
— 21.4.3 (TXTIME and PSDU_LENGTH calculation) for VHT PLME TXTIME calculation
— 22.4.3 (TXTIME and PSDU_LENGTH calculation) for TVHT PLME TXTIME calculation
— 28.4.2 (TXTIME and PSDU_LENGTH calculation) for HE PLME TXTIME calculation

10.7.6 Rate selection for Control frames

10.7.6.5 Rate selection for control response frames

10.7.6.5.2 Selection of a rate or MCS

Insert the following at the end of the subclause:

The rate, HT-MCS, <VHT-MCS, NSS> tuple or <HE-MCS, NSS> tuple selected by an HE AP for a Block-Ack frame or Ack frame that is an immediate response to frames received in an HE trigger-based PPDU shall be selected from those supported by the STA addressed in the frame.

An AP that transmits a Multi-STA BlockAck frame in a non-HT PPDU, HT PPDU, VHT PPDU or HE PPDU shall use a rate, HT-MCS, <VHT-MCS, NSS> tuple or <HE-MCS, NSS> tuple, respectively, that is supported by all the recipients.

10.7.9 Modulation classes

Change Table as follows:

Table 10-6—Modulation classes

Description of modulation	Condition that selects this modulation class			
	Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) to Clause 18 (Extended Rate PHY (ERP) specification) PHYs or Clause 20 (Directional multi-gigabit (DMG) PHY specification) PHY	**Clause 19 (High Throughput (HT) PHY specification) PHY**	**Clause 21 (Very High Throughput (VHT) PHY specification) PHY**	**Clause 28 (High Efficiency (HE) PHY specification)**
DSSS and HR/DSSS	Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) or Clause 16 (High rate direct sequence spread spectrum (HR/DSSS) PHY specification) transmission	FORMAT is NON_HT. NON_HT_MODULATION is ERP-DSSS or ERP-CCK.	N/A	N/A
ERP-OFDM	18.4 (ERP operating specifications (general)) transmission	FORMAT is NON_HT. NON_HT_MODULATION is ERP-OFDM.	N/A	N/A
OFDM	Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) transmission	FORMAT is NON_HT. NON_HT_MODULATION is OFDM or NON_HT_DUP_OFDM.	FORMAT is NON_HT. NON_HT_MODULATION is OFDM or NON_HT_DUP_OFDM.	FORMAT is NON_HT. NON_HT_MODULATION is OFDM or NON_HT_DUP_OFDM.
HT	N/A	FORMAT is HT_MF or HT_GF.	FORMAT is HT_MF or HT_GF.	FORMAT is HT_MF or HT_GF.
DMG Control	Clause 20 (Directional multi-gigabit (DMG) PHY specification) transmission and MCS is 0	NA	NA	N/A
DMG SC	Clause 20 (Directional multi-gigabit (DMG) PHY specification) transmission and $1 \le MCS \le 12$	NA	NA	N/A

Table 10-6—Modulation classes *(continued)*

Description of modulation	Condition that selects this modulation class			
	Clause 15 (DSSS PHY specification for the 2.4 GHz band designated for ISM applications) to Clause 18 (Extended Rate PHY (ERP) specification) PHYs or Clause 20 (Directional multi-gigabit (DMG) PHY specification) PHY	Clause 19 (High Throughput (HT) PHY specification) PHY	Clause 21 (Very High Throughput (VHT) PHY specification) PHY	Clause 28 (High Efficiency (HE) PHY specification)
DMG OFDM	Clause 20 (Directional multi-gigabit (DMG) PHY specification) transmission and $13 \leq MCS \leq 24$	NA	NA	N/A
DMG Low-power SC	Clause 20 (Directional multi-gigabit (DMG) PHY specification) transmission and $25 \leq MCS \leq 31$	NA	NA	N/A
VHT	N/A	N/A	FORMAT is VHT.	FORMAT is VHT
HE	N/A	N/A	N/A	FORMAT is HE_SU, HE_EXT_SU, HE_MU and HE_TRIG

10.7.10 Non-HT basic rate calculation

Change as follows:

This subclause defines how to convert an HT MCS ~~or~~, a VHT-MCS or an HE-MCS to a non-HT basic rate for the purpose of determining the rate of the response frame. It consists of two steps as follows:

a) Use the modulation and coding rate determined from the HT MCS (defined in 19.5 (Parameters for HT MCSs)) or VHT-MCS (defined in 21.5 (Parameters for VHT-MCSs)) or HE-MCS (defined in 28.5 (Parameters for HE-MCSs)) to locate a non-HT reference rate by lookup into Table 10-7 (Non-HT reference rate).[1] In the case of an MCS with UEQM, the modulation of stream 1 is used.

b) The non-HT basic rate is the highest rate in the BSSBasicRateSet that is less than or equal to this non-HT reference rate.

[1] For example, if an HT PPDU transmission uses 64-QAM and coding rate of 3/4, the related non-HT reference rate is 54 Mb/s.

Change Table 10-7 (Non-HT reference rate) as follows:

Table 10-7—Non-HT reference rate

Modulation	Coding rate (R)	Non-HT reference rate (Mb/s)
BPSK	1/2	6
BPSK	3/4	9
QPSK	1/2	12
QPSK	3/4	18
16-QAM	1/2	24
16-QAM	3/4	36
64-QAM	1/2	48
64-QAM	2/3	48
64-QAM	3/4	54
64-QAM	5/6	54
256-QAM	3/4	54
256-QAM	5/6	54
1024-QAM	3/4	54
1024-QAM	5/6	54

NOTE—In a TVWS band, the non-HT reference rate is scaled as described in 22.2.4 (Support for NON_HT and HT formats).

10.9 HT Control field operation

Change 10.9 as follows:

If the value of dot11HTControlFieldSupported is true, a STA shall set the +HTC Support subfield of the HT Extended Capabilities field of the HT Capabilities element to 1 in HT Capabilities elements that it transmits. If the value of dot11VHTControlFieldOptionImplemented is true, a STA shall set the +HTC-VHT Support subfield of the VHT Capabilities Information field of the VHT Capabilities element to 1 in VHT Capabilities elements that it transmits. If dot11HEControlFieldOptionImplemented is true, a STA shall set the +HTC-HE Support subfield of the HE Capabilities Information field of the HE Capabilities element to 1 in HE Capabilities elements that it transmits.

A STA that has a value of true for at least one of dot11RDResponderOptionImplemented, dot11MCSFeedbackOptionImplemented, and dot11AlternateEDCAActivated shall set dot11HTControlFieldSupported or dot11VHTControlFieldOptionImplemented or both to true. A STA for which at least one of dot11HEULMUResponseSchedulingOptionImplemented, dot11HEMCSFeedbackOptionImplemented or dot11OMIOptionImplemented is true shall set dot11HEControlFieldOptionImplemented to true.

An HT variant HT Control field shall not be present in a frame addressed to a STA unless that STA declares support for +HTC-HT in the HT Extended Capabilities field of its HT Capabilities element (see 9.2.4.6 (HT Control field)).

A VHT variant HT Control field shall not be present in a frame addressed to a STA unless that STA declares support for +HTC-VHT in the VHT Capabilities Information field of its VHT Capabilities element.

NOTE—An HT STA that does not support +HTC (HT or VHT variant) that receives a +HTC frame addressed to another STA still performs the CRC on the actual length of the MPDU and uses the Duration/ID field to update the NAV, as described in <reference>.

An HE variant HT Control field shall not be present in a frame addressed to a STA unless that STA declares support for +HTC-HE in the HE Capabilities Information field of its HE Capabilities element. The HE variant HT Control field carried in the frame may contain a Control subfield supported by the intended receiver that has:

- A value of 0 in the Control ID subfield when the transmitting STA expects an HE trigger-based PPDU that carries an immediate acknowledgement, as described in 27.5.2 (UL MU operation).
- A value of 1 in the Control ID subfield when the transmitting STA changes the receive operating mode, as described in 27.8 (Operating mode indication).
- A value of 2 in the Control ID subfield when the transmitting STA follows the HE link adaptation procedure, as described in 10.31.4 (Link adaptation using the HE variant HT Control field).
- A value of 3 in the Control ID subfield when the transmitting STA follows the corresponding buffer status report procedure, as described in 27.5.2.5 (HE buffer status feedback operation for UL MU)
- A value of 4 in the Control ID subfield when the transmitting STA follows the UL MU operation procedure, as described in 28.3.14.2 (Power pre-correction).
- A value of 5 in the Control ID subfield when the transmitting STA follows the bandwidth query report procedure, as described in 27.5.1.3 (HE bandwidth query report operation for DL MU).

If the HT Control field is present in an MPDU aggregated in an A-MPDU, then all MPDUs of the same frame type (i.e., having the same value for the Type subfield of the Frame Control field) aggregated in the same A-MPDU shall contain an HT Control field. The HT Control field of all MPDUs containing the HT Control field aggregated in the same A-MPDU shall be set to the same value.

If an A-Control field is present in a frame then it shall contain at least one Control subfield, and the Control subfield shall be present in the A-Control field only if it is supported by the receiving STA; otherwise it shall not be present. At most one Control subfield with a given Control ID value shall be present in the A-Control field of QoS Data or Management frames carried in an (A-)MPDU.

NOTE—An A-Control field that is present in a frame cannot contain only the Padding subfield.

An HE STA that receives an A-Control field shall ignore the remainder of the A-Control field that follows a Control ID subfield whose value is not recognized or is not supported by the STA.

10.10 Control Wrapper operation

Change as follows:

A STA supporting the HT Control field that receives a Control Wrapper frame shall process it as though it received a frame of the subtype of the wrapped frame. An HE STA shall not send a Control Wrapper frame to another HE STA.

10.12 A-MSDU operation

Change the 3rd paragraph as follows:

An A-MSDU shall be carried, without fragmentation, within a single QoS Data frame, when the recipient has not indicated support for reception of fragmented A-MSDUs. An A-MSDU may be fragmented and each fragment transmitted within a single QoS Data frame, when the recipient has indicated support for reception of fragmented A-MSDUs. Support for reception of fragmented A-MSDUs is indicated with the Fragmented A-MSDU Support bit of the HE Capabilities element.

10.13 A-MPDU operation

10.13.1 A-MPDU contents

Change the 2nd paragraph as follows:

When an A-MPDU contains multiple QoS Control fields, bit~~s~~ 4 shall be identical across all MPDUs that contain the QoS Control fields and bits 8–15 of these QoS Control fields shall be identical across all MPDUs with equal value of the TID subfield.

10.13.2 A-MPDU length limit rules

Change as follows:

A STA indicates in the Maximum A-MPDU Length Exponent field in its HT Capabilities element the maximum A-MPDU length that it can receive in an HT PPDU. A STA indicates in the Maximum A-MPDU Length Exponent field in its VHT Capabilities element the maximum length of the A-MPDU pre-EOF padding that it can receive in a VHT PPDU. A DMG STA indicates in the Maximum A-MPDU Length Exponent field in its DMG Capabilities element the maximum A-MPDU length that it can receive. A STA indicates in the Maximum A-MPDU Length Exponent field in its HE Capabilities element the maximum length of the A-MPDU pre-EOF padding that it can receive in an HE PPDU. The encoding of these fields is defined in Table 9-163 (Subfields of the A-MPDU Parameters field) for an HT PPDU, in Table 9-249 (Subfields of the VHT Capabilities Information field) for a VHT PPDU, ~~and~~ in Table 9-229 (Subfields of the A-MPDU Parameters subfield) for a DMG STA, and in 9.4.2.213 (HE Capabilities element).

A VHT STA that sets the Maximum A-MPDU Length Exponent field in its VHT Capabilities element to a value in the range 0 to 3 shall set the Maximum A-MPDU Length Exponent in its HT Capabilities to the same value. A VHT STA that sets the Maximum A-MPDU Length Exponent field in the VHT Capabilities element to a value larger than 3 shall set the Maximum A-MPDU Length Exponent in its HT Capabilities element to 3.

Using the Maximum A-MPDU Length Exponent fields in the HT Capabilities, ~~and~~ VHT Capabilities, and HE Capabilities elements, the STA establishes at association the maximum length of an A-MPDU pre-EOF padding that can be sent to it. An HT STA shall be capable of receiving A-MPDUs of length up to the value indicated by the Maximum A-MPDU Length Exponent field in its HT Capabilities element. A VHT STA shall be capable of receiving A-MPDUs where the A-MPDU pre-EOF padding length is up to the value indicated by the Maximum A-MPDU Length Exponent field in its VHT Capabilities element. An HE STA shall be capable of receiving A-MPDUs where the A-MPDU pre-EOF padding length is up to the value indicated by the Maximum A-MPDU Length Exponent field in its HE Capabilities element.

A STA shall not transmit an A-MPDU in an HT PPDU that is longer than the value indicated by the Maximum A-MPDU Length Exponent field in the HT Capabilities element received from the intended receiver. MPDUs in an A-MPDU carried in an HT PPDU shall be limited to a maximum length of 4095 octets. A STA shall not transmit an A-MPDU in a VHT PPDU where the A-MPDU pre-EOF padding length is longer than the value indicated by the Maximum A-MPDU Length Exponent field in the VHT Capabilities element received from the intended receiver. A DMG STA shall not transmit an A-MPDU that is longer than the value indicated by the Maximum A-MPDU Length Exponent field in the DMG Capabilities element received from the intended receiver. A STA shall not transmit an A-MPDU in an HE PPDU where the A-MPDU pre-EOF padding length is longer than the value indicated by the Maximum A-MPDU Length Exponent field in the HE Capabilities element received from the intended receiver.

10.22 HCF

10.22.2 HCF contention based channel access (EDCA)

10.22.2.2 EDCA backoff procedure

Change the 2nd paragraph as follows:

For the purposes of this subclause, transmission failure of an MPDU is defined as follows:

— After transmitting an MPDU (even if it is carried in an A-MPDU or as part of a VHT MU PPDU that is sent using TXVECTOR parameter NUM_USERS > 1) that requires ~~an~~ one or more immediate response:

  — The STA shall wait for a timeout interval of duration aSIFSTime + aSlotTime + aRxPHYStartDelay, starting when the MAC receives a PHY-TXEND.confirm primitive. If a PHY-RXSTART.indication primitive does not occur during the timeout interval, the transmission of the MPDU has failed.

  — If a PHY-RXSTART.indication primitive does occur during the timeout interval, the STA shall wait for the corresponding PHY-RXEND.indication primitive to recognize ~~a~~ one or more valid response MPDUs (see Annex G) that either does not have a TA field or is sent by ~~the~~ one or more recipients of the MPDU requiring a response. If anything else, including any other valid frame, is recognized, the transmission of the MPDU has failed.

— The nonfinal (re)transmission of an MPDU that is delivered using the GCR unsolicited retry retransmission policy (10.22.2.11.2 (Unsolicited retry procedure))) is defined to be a failure.

— In all other cases, the transmission of the MPDU has not failed.

Change the last paragraph as follows:

If the backoff procedure is invoked for reason c), d), e) or f) above, or the transmission failure of a non-initial frame by the TXOP holder], the value of CW[AC] shall be updated as follows before invoking the backoff procedure:

— If the QSRC[AC] or the QLRC[AC] has reached dot11ShortRetryLimit or dot11LongRetryLimit respectively, CW[AC] shall be reset to CWmin[AC].

— If dot11RobustAVStreamingImplemented is true and either the QSDRC[AC] or the QLDRC[AC] has reached dot11ShortDEIRetryLimit or dot11LongDEIRetryLimit, respectively, CW[AC] shall be reset to CWmin[AC].

— Otherwise,

  — If CW[AC] is less than CWmax[AC], CW[AC] shall be set to the value (CW[AC] + 1) × 2 – 1.

  — If CW[AC] is equal to CWmax[AC], CW[AC] shall be left unchanged.

  — For an HE STA, if CW[AC] is greater than CWmax[AC], CW[AC] shall be set to CWmax[AC].

Insert the following at the end of subclause 10.22.2.2:

When an HE STA successfully receives the corresponding acknowledgement frame in response to the MPDU sent in HE trigger based PPDU, the backoff for the associated EDCAF resumes the backoff counter countdown.

When an HE STA does not receive the corresponding acknowledgement frame in response to the MPDU sent in HE trigger based PPDU, the backoff for the associated EDCAF resumes the backoff counter countdown.

If an HE STA does not successfully receive the corresponding acknowledgement frame in response to the MPDU sent in an HE trigger based PPDU, the short retry counters and long retry counters for the associated EDCAF are not changed.

10.22.2.4 Obtaining an EDCA TXOP

Change the last paragraph and insert a new paragraph as follows:

A STA shall save the TXOP holder address for the BSS in which it is associated, which is the MAC address from the Address 2 field of the frame that initiated a frame exchange sequence except when this is a CTS frame, in which case the TXOP holder address is the Address 1 field. If the TXOP holder address is obtained from a Control frame, a VHT STA or HE STA shall save the nonbandwidth signaling TA value obtained from the Address 2 field. If a non-VHT non-HE STA receives an RTS frame with the RA address matching the MAC address of the STA and the MAC address in the TA field in the RTS frame matches the saved TXOP holder address, then the STA shall send the CTS frame after SIFS, without regard for, and without resetting, its NAV. If a VHT STA or HE STA receives an RTS frame with the RA address matching the MAC address of the STA and the nonbandwidth signaling TA value obtained from the Address 2 field in the RTS frame matches the saved TXOP holder address, then the STA shall send the CTS frame after SIFS, without regard for, and without resetting, its NAV. When a STA receives a frame addressed to it that requires an immediate response, except for RTS and Trigger frames (see 27.5.2.4 (UL MU CS mechanism)), it shall transmit the response independent of its NAV. The saved TXOP holder address shall be cleared when the NAV is reset or when the NAV counts down to 0.

During an EDCA TXOP, Address 2 field excluding the Individual/Group bit of all control frames sent by a TXOP holder shall be set to the same address value.

Change the title of subclause 10.22.2.5 as follows:

10.22.2.5 EDCA channel access in a VHT, HE or TVHT BSS

Change 4th paragraph as follows:

If a STA is permitted to begin a TXOP (as defined in 10.22.2.4 (Obtaining an EDCA TXOP)) and the STA has at least one MSDU pending for transmission for the AC of the permitted TXOP, the STA shall perform exactly one of the following actions:

a) Transmit a 160 MHz or 80+80 MHz mask PPDU if the secondary channel, the secondary 40 MHz channel, and the secondary 80 MHz channel were idle during an interval of PIFS immediately preceding the start of the TXOP.

b) Transmit an 80 MHz mask PPDU on the primary 80 MHz channel if both the secondary channel and the secondary 40 MHz channel were idle during an interval of PIFS immediately preceding the start of the TXOP.

c) Transmit a 40 MHz mask PPDU on the primary 40 MHz channel if the secondary channel was idle during an interval of PIFS for the 5 GHz band and DIFS for an HE STA operating in the 2.4 GHz band immediately preceding the start of the TXOP.

d) Transmit a 20 MHz mask PPDU on the primary 20 MHz channel.

e) Restart the channel access attempt by invoking the backoff procedure as specified in 10.22.2 (HCF contention based channel access (EDCA)) as though the medium is busy on the primary channel as indicated by either physical or virtual CS and the backoff timer has a value of 0.

f) Transmit a TVHT_4W or TVHT_2W+2W mask PPDU if the secondary TVHT_W channel and the secondary TVHT_2W channel were idle during an interval of PIFS immediately preceding the start of the TXOP.

g) Transmit a TVHT_2W or TVHT_W+W mask PPDU if the secondary TVHT_W channel was idle during an interval of PIFS immediately preceding the start of the TXOP.

h) Transmit a TVHT_W mask PPDU on the primary TVHT_W channel.

NOTE 1—In the case of rule e), the STA selects a new random number using the current value of CW[AC], and the retry counters are not updated (as described in 10.22.2.7 (Multiple frame transmission in an EDCA TXOP); backoff procedure invoked for event a)).

NOTE 2—For ~~both~~ an HT, ~~and~~ a VHT and an HE STA, an EDCA TXOP is obtained based on activity on the primary channel (see 10.22.2.4 (Obtaining an EDCA TXOP)). The width of transmission is determined by the CCA status of the nonprimary channels during the PIFS interval for the 5 GHz band or DIFS interval for an HE STA operating in the 2.4 GHz band before transmission (see ~~VHT description in~~ 10.3.2 (Procedures common to the DCF and EDCAF)).

10.22.2.6 Sharing an EDCA TXOP

Change the 1st three paragraphs as follows:

This mode applies only to an AP that supports DL-MU-MIMO or DL-OFDMA. The AC associated with the EDCAF that gains an EDCA TXOP becomes the primary AC. TXOP sharing is allowed when primary AC traffic is transmitted in a VHT MU PPDU or an HE MU PPDU and resources permit traffic from secondary ACs to be included, targeting up to four STAs if it is transmitted in the VHT MU PPDU. The inclusion of secondary AC traffic in a VHT MU PPDU shall not increase the duration of the VHT MU PPDU beyond that required to transport the primary AC traffic. The inclusion of secondary AC traffic in an HE MU PPDU is described in 27.10.4 (A-MPDU with multiple TIDs). If a destination in a VHT MU PPDU is targeted by frames in the queues of both the primary AC and at least one secondary AC, the frames in the primary AC queue shall be transmitted to the destination first, among a series of downlink transmissions within a TXOP. The decision of which secondary ACs and destinations are selected for TXOP sharing, as well as the order of transmissions, are implementation specific and out of scope of this standard. For an HE MU PPDU, the inclusion of secondary AC traffic in the HE MU PPDU shall not cause the TXOP limit of the primary AC to be exceeded.

When sharing, the TXOP limit that applies is the TXOP limit of the primary AC.

NOTE—An AP can protect an immediate response by preceding the VHT MU PPDU or the HE MU PPDU (which might have TXVECTOR parameter NUM_USERS > 1) with an RTS/CTS exchange or an MU-RTS/CTS exchange or a CTS-to-self transmission.

10.22.2.7 Multiple frame transmission in an EDCA TXOP

Change the 1st paragraph as follows:

A frame exchange, in the context of multiple frame transmission in an EDCA TXOP, may be one of the following:

— A frame not requiring immediate acknowledgment (such as a group addressed frame or a frame transmitted with an acknowledgment policy that does not require immediate acknowledgment) or an A-MPDU containing only such frames

— A frame requiring acknowledgment (such as an individually addressed frame transmitted with an acknowledgment policy that requires immediate acknowledgment) or an A-MPDU containing at least one such frame, followed after SIFS by a corresponding acknowledgment frame

— A Trigger frame or a frame carrying an UL MU Response Scheduling A-Control subfield followed after SIFS by the requested immediate response
— Either
  — a VHT NDP Announcement frame followed after SIFS by a VHT NDP followed after SIFS by a PPDU containing one or more VHT Compressed Beamforming frames, or
  — a Beamforming Report Poll frame followed after SIFS by a PPDU containing one or more VHT Compressed Beamforming frames

A DL MU PPDU may carry MPDUs addressed to multiple recipients, hence multiple frame exchanges are performed simultaneously. If at least one of those frame exchanges requires an immediate response (i.e. the AP includes at least one Trigger frame or UL MU Response Scheduling A-Control field) and if the AP receives an immediate response with at least one correct MPDU from at least one of the solicited STAs, the rules in this subclause apply.

Change the 7th and 8th paragraphs as follows:

If a TXOP is protected by an RTS or CTS frame carried in a non-HT or a non-HT duplicate PPDU, the TXOP holder shall set the TXVECTOR parameter CH_BANDWIDTH of a PPDU as follows:
— To be the same or narrower than RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT of the last received CTS frame in the same TXOP, if the RTS frame with a bandwidth signaling TA and TXVECTOR parameter DYN_BANDWIDTH_IN_NON_HT set to Dynamic has been sent by the TXOP holder in the last RTS/CTS exchange.
— Otherwise, to be the same or narrower than the TXVECTOR parameter CH_BANDWIDTH of the RTS frame that has been sent by the TXOP holder in the last RTS/CTS exchange in the same TXOP.

If a TXOP is protected by an MU-RTS or CTS frame carried in a non-HT or a non-HT duplicate PPDU, the TXOP holder shall set the TXVECTOR parameter CH_BANDWIDTH of a PPDU as follows:
— To be the same or narrower than the TXVECTOR parameter CH_BANDWIDTH of the MU-RTS frame that has been sent by the TXOP holder in the last MU-RTS/CTS exchange in the same TXOP, if the RU Allocation subfields of the MU-RTS frame for all intended receiver are equal to the BW subfield in the Common Info field of the MU-RTS frame.
— Otherwise, to be the same or narrower than the TXVECTOR parameter CH_BANDWIDTH of the preceding PPDU that it has transmitted in the same TXOP.

If there is no RTS/CTS or MU-RTS/CTS exchange in non-HT duplicate format in a TXOP, and the TXOP includes at least one non-HT duplicate frame exchange that does not include a PS-Poll, then the TXOP holder shall set the CH_BANDWIDTH parameter in TXVECTOR of a PPDU sent after the first non-HT duplicate frame that is not a PS-Poll to be the same or narrower than the CH_BANDWIDTH parameter in TXVECTOR of the initial frame in the first non-HT duplicate frame exchange in the same TXOP.

10.22.2.8 TXOP limits

Change the 3rd paragraph as follows:

A TXOP limit of 0 indicates that the TXOP holder may transmit or cause to be transmitted (as responses) the following within the current TXOP:

a) One of the following at any rate, subject to the rules in 10.7 (Multirate support)
   1) One or more SU PPDUs carrying fragments of a single MSDU or MMPDU
   2) An SU PPDU or a VHT MU PPDU or an HE MU PPDU or an HE trigger-based PPDU carrying a single MSDU, a single MMPDU, a single A-MSDU, or a single A-MPDU

3) A VHT MU PPDU or an HE MU PPDU carrying A-MPDUs to different users (a single A-MPDU to each user)
4) A QoS Null frame or PS-Poll frame
5) Trigger frame

b) Any required acknowledgments

c) Any frames required for protection, including one of the following:
1) An RTS/CTS or MU-RTS/CTS exchange
2) CTS to itself
3) Dual CTS as specified in 10.3.2.8 (Dual CTS protection)

d) Any frames required for beamforming as specified in 10.30 (Sounding PPDUs), 10.34.5 (VHT sounding protocol) and 10.38 (DMG beamforming).

e) Any frames required for link adaptation as specified in 10.31 (Link adaptation)

f) Any number of BlockAckReq or MU-BAR frames

NOTE 1—This is a rule for the TXOP holder. A TXOP responder need not be aware of the TXOP limit nor of when the TXOP was started.

NOTE 2—This rule prevents the use of RD when the TXOP limit is 0.

Insert the following at the end of the subclause:

When the Duration field value in the MAC header of an HE trigger-based PPDU is set to 0, the HE trigger-based PPDU shall not include any frames that solicit a control response frame from the AP.

10.22.2.9 Truncation of TXOP

Insert the following at the end of the subclause:

An HE STA that receives a CF-End frame should not reset its NAV if any of following conditions is met, otherwise it resets its NAV:

— The received CF-End frame is an inter-BSS frame and the most recent NAV update was due to an intra-BSS frame (see 27.2.1 (Intra-BSS and inter-BSS frame detection)).

— The received CF-End frame is an intra-BSS frame and the most recent NAV update was due to an inter-BSS frame (see 27.2.1 (Intra-BSS and inter-BSS frame detection)).

NOTE 1—For HE STAs with two NAVs, the TXOP truncation rule applies to each NAV separately.

10.22.4 Admission Control at the HC

10.22.4.2 Contention based admission control procedures

10.22.4.2.3 Procedure at non-AP STAs

Change the 8th paragraph as follows:

The MPDUExchangeTime equals the time required to transmit the MPDU sequence. For the case of an MPDU transmitted with Normal Ack policy and without RTS/CTS protection, this equals the time required to transmit the MPDU plus the time required to transmit the expected response frame plus one SIFS. Frame exchange sequences for Management frames and the HE trigger-based PPDU are excluded from the used_-time update. If the used_time value reaches or exceeds the admitted_time value, the corresponding EDCAF shall no longer transmit QoS Data frames or QoS Null MPDUs using the EDCA parameters for that AC as specified in the QoS Parameter Set element. However, a STA may choose to temporarily replace the EDCA parameters for that EDCAF with those specified for an AC of lower priority, if no admission control is required for those ACs.

10.24 Block acknowledgement (block ack)

10.24.10 GCR block ack

10.24.10.3 GCR block ack BlockAckReq and BlockAck frame exchanges

Change the following 2nd and 3rd paragraphs as follows:

When the retransmission policy for a group address is GCR Block Ack, an originator shall not transmit more than the GCR buffer size number of A-MSDUs with RA set to the GCR concealment address and the DA field of the A-MSDU subframe set to the GCR group address before sending a BlockAckReq frame to one of the STAs that has a GCR block ack agreement for this group address. The RA field of the BlockAckReq frame shall be set to the MAC address of the destination STA. Upon reception of the BlockAck frame, an originator may send a BlockAckReq frame to another STA that has a block ack agreement for this group address, and this process may be repeated multiple times. If the originator has a GCR block ack agreement with one or more of the HE STAs for this group address, the originator may send an MU-BAR frame (MU-BAR variant Trigger frame) or GCR MU-BAR frame (GCR MU-BAR variant Trigger frame) to one or more of the HE STAs. Upon reception of the BlockAck frame from one or more HE STAs, the originator may send an MU-BAR frame to one or more other HE STAs that have a GCR block ack agreement, and this process may be repeated multiple times.

NOTE 1—If the originator sends a BlockAckReq frame to a STA with a MAC address that matches the SA in any of the A-MSDUs transmitted during the GCR TXOP, the Block Ack Bitmap subfield does not indicate the MSDUs sourced from this STA. This is because the STA will have discarded all group addressed MPDUs transmitted by the AP that have the source address equal to their MAC address (see 10.3.6 (Group addressed MPDU transfer procedure)).

When a recipient receives a BlockAckReq frame with the GCR Group Address subfield equal to a GCR group address, the recipient shall transmit a BlockAck frame at a delay of SIFS after the BlockAckReq frame. The BlockAck frame acknowledges the STA’s reception status of the block of group addressed frames requested by the BlockAckReq frame. When an HE STA receives an MU-BAR frame with User Identifier subfield set to the AID of the HE STA, the HE STA shall transmit BlockAck frame in the indicated resource unit SIFS after the Trigger frame. The BlockAck frames report the HE STA's reception status of the block of group addressed frames requested by the MU-BAR frame.

Figure 10-36 (Example of a frame exchange with GCR block ack retransmission policy) shows an example of a frame exchange when the GCR block ackretransmission policy is used. The AP sends several A-MSDUs using the GCR block ack retransmission policy. The AP then sends a BlockAckReq frame to group member 1 of the GCR group, waits for the BlockAck frame, and then sends a BlockAckReq frame to group member 2. After receiving the BlockAck frame from GCR group member 2, the AP determines whether any A-MSDUs need to be retransmitted and sends additional A-MSDUs (some of which might be retransmissions of previous A-MSDUs) using the GCR block ack retransmission policy.

Insert the following paragraph and associated figure:

Figure 10-36a (Example of a frame exchange with GCR block ack retransmission policy) shows another example of a frame exchange when the GCR block ack retransmission policy is used. The HE AP sends several A-MSDUs using the GCR block ack retransmission policy. The HE AP then sends an MU-BAR to group members 1 and 2 of the GCR group, waits for the BlockAck frames, and then sends an MU-BAR to group members 3 and 4 and then waits for the BlockAck frame. The HE AP then sends a BAR frame to group member 5, which is a non-HE STA, and waits for the BlockAck frame. After receiving the BlockAck frames, the HE AP determines whether any A-MSDUs need to be retransmitted and sends additional A-

MSDUs (some of which might be retransmissions of previous A-MSDUs) using the GCR block ack retransmission policy.

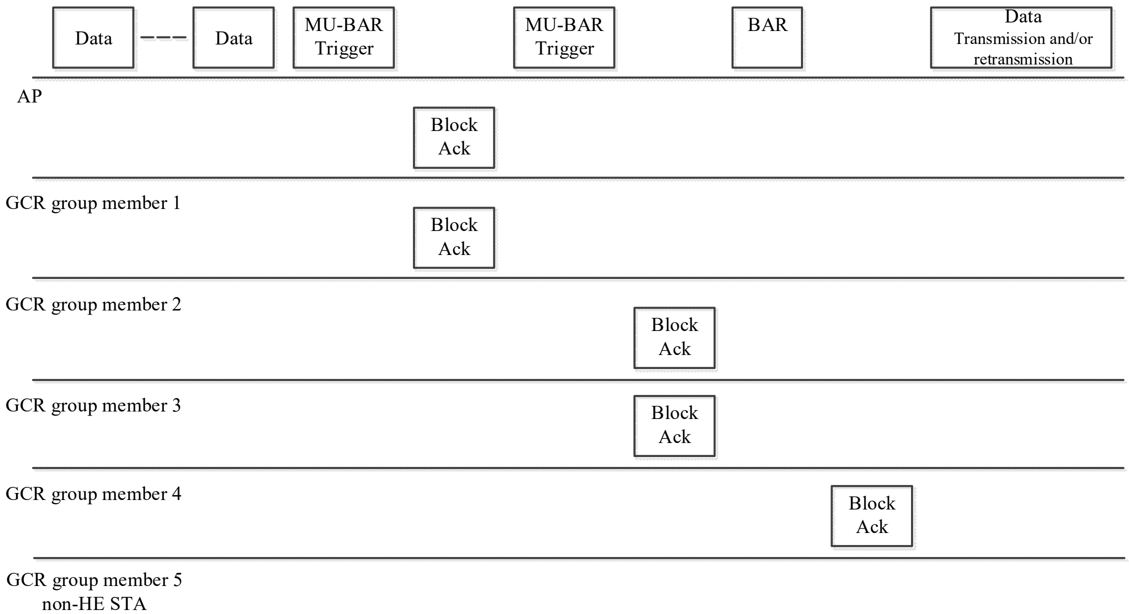


Figure 10-36a—Example of a frame exchange with GCR block ack retransmission policy

Change the 6th,7th and 8th paragraph as follows:

After completing the BlockAckReq or MU-BAR and BlockAck frame exchanges, the originator determines from the information provided in the BlockAck bitmap and from the missing BlockAck frames which, if any, A-MSDUs need to be retransmitted.

An originator adopting the GCR block ack retransmission policy for a GCR group address chooses a lifetime limit for the group address. The originator may vary the lifetime limit for the group address at any time and may use different lifetime limits for different GCR group addresses. The originator transmits and retries each A-MSDU until the appropriate lifetime limit is reached or until each one has been received by all group members to which a BlockAckReq frame or an MU-BAR frame has been sent, whichever occurs first.

For GCR streams with retransmission policy equal to GCR Block Ack, an originator may regularly send a BlockAckReq frame with the GCR Group Address subfield in the BAR Information field set to the GCR group address and the Block Ack Starting Sequence Control subfield set to the Sequence Number field of the earliest A-MSDU of the GCR stream that has not been acknowledged by all group members and has not expired due to lifetime limits, in order to minimize buffering latency at receivers in the GCR group. An originator may also send an MU-BAR frame with AID12 fields set to AIDs of HE STAs that transmit the BlockAck frames and the Block Ack Starting Sequence Control subfield set to the Sequence Number field of the earliest A-MSDU of the GCR stream that has not been acknowledged by all group members and has not expired due to lifetime limits, in order to minimize buffering latency at receivers in the GCR group.

NOTE 2—This is because an originator might transmit Management frames, QoS Data frames with a group address in the Address 1 field (including different GCR streams), and non-QoS Data frames intermingled. Since these are transmitted using a single sequence counter, missing frames or frames sent to group addresses absent from a receiving STA's dot11GroupAddresses table complicate receiver processing for GCR streams with a GCR block ack retransmission policy since the cause of a hole in a receiver's block ack bitmap is ambiguous: it is due either to an MPDU being lost from the GCR stream or to transmissions of MPDUs not related to the GCR service using the same sequence number counter.

Change the last paragraph as follows:

If the beginning of such reception does not occur during the first slot time following a SIFS, then the originator may perform error recovery by retransmitting a BlockAckReq frame or an MU-BAR frame PIFS after the previous BlockAckReq frame or an MU-BAR frame when both of the following conditions are met:

— The carrier sense mechanism (see 10.3.2.1 (CS mechanism)) indicates that the medium is idle at the TxPIFS slot boundary (defined in 10.3.7 (DCF timing relations)) after the expected start of a BlockAck frame, and

— The remaining duration of the GCR TXOP is longer than the total time required to retransmit the GCR BlockAckReq frame or an MU-BAR frame plus one slot time.

NOTE 3—If an originator fails to receive a BlockAck frame in response to a BlockAckReq frame and there is insufficient time to transmit a recovery frame, the AP retransmits the BlockAckReq frame in a new TXOP.

10.28 Reverse direction protocol

10.28.3 Rules for RD initiator

Change the 3rd and subsequent 2 paragraphs as follows:

Transmission of a +HTC or DMG frame by an RD initiator with the RDG/More PPDU subfield equal to 1 (either transmitted as a non-A-MPDU frame, as a VHT single MPDU, or within an A-MPDU) indicates that the duration indicated by the Duration/ID field is available for the RD response burst and RD initiator final PPDU (if present).

NOTE—An HE RD initiator includes the RDG/More PPDU subfield in the RDP A-Control field of QoS Data or Management frames it transmits.

An RD initiator that sets the RDG/More PPDU field to 1 in a +HTC or DMG frame transmitted during a TXOP shall set the AC Constraint subfield to 1 in that frame if the TXOP was gained through the EDCA channel access mechanism and shall otherwise set it to 0. An RD initiator that sets the RDG/More PPDU field to 1 in a DMG frame transmitted during an SP can set the AC Constraint subfield to 1 to limit the Data frames transmitted by the RD responder. An HE non-AP STA RD initiator that sets the RDG/More PPDU field to 1 in a frame transmitted during a TXOP shall set the AC Constraint to 1, while an HE AP RD initiator may set the AC Constraint subfield to 1.

~~An~~ A non-HE RD initiator shall not transmit a +HTC or DMG frame with the RDG/More PPDU subfield set to 1 that requires a response MPDU that is not one of the following frames:

— Ack

— Compressed BlockAck

— Multi-STA BlockAck

10.28.4 Rules for RD responder

Change the 5th and subsequent 2 paragraphs as follows:

An RD responder shall not transmit an MPDU (either individually or aggregated within an A-MPDU) that is not one of the following frames:

— Ack

— Compressed BlockAck

— Compressed BlockAckReq

— Extended Compressed BlockAck

— Extended Compressed BlockAckReq

— Multi-STA BlockAck

— QoS data

— Management

If the AC Constraint subfield is equal to 1, the non-HE RD responder shall transmit Data frames of only the same AC as the last frame received from the RD initiator, while the HE RD responder may transmit A-MPDU with MPDUs from multiple TIDs that are from the same AC or higher ACs, as described in 25.10.4 (A-MPDU with multiple TID).

For a BlockAckReq or BlockAck frame, the AC is determined by examining the TID field. For a Management frame, the AC is AC_VO. The RD initiator shall not transmit a MPDU with the RDG/More PPDU subfield set to 1 from which the AC cannot be determined. If the AC Constraint subfield is equal to 0, the non-HE RD responder may transmit Data frames of any TID, while the HE RD responder may transmit Data frames of any TIDs, as described in 27.10.4 (A-MPDU with multiple TIDs).

10.43 Target wake time (TWT)

10.43.1 TWT overview

Change the 2nd paragraph as follows:

A TWT requesting STA communicates wake scheduling information to its TWT responding STA and the TWT responding STA devises a schedule and delivers TWT values to the TWT requesting STA when a TWT agreement has been established between them. When explicit TWT is employed, a TWT requesting STA wakes and performs a frame exchange and receives the next TWT information in a response from the TWT responding STA as described in 10.43.2.2 (Explicit TWT operation). When implicit TWT is used, the TWT requesting STA calculates the Next TWT by adding a fixed value to the current TWT value as described in 10.43.3 (Implicit TWT operation).

Insert a new paragraph and table after the 9th paragraph:

The result of an exchange of TWT Setup frames is defined in Table 10-19a (TWT setup exchange command interpretation). In general, the meaning of Request TWT is that the transmitting STA will negotiate the TWT parameters for a TWT agreement, Suggest TWT indicates that the transmitting STA offers a set of preferred TWT parameters for a TWT agreement but will accept whatever the responding STA indicates and Demand TWT indicates tha the transmitting STA will accept only the indicated TWT parameters for a TWT agreeement. For a responding STA, accept TWT indicates that the responding STA has initiated a TWT agreement with the given parameters, alternate TWT indicates a counter-offer of TWT parameters without the creation of a TWT agreement and dictate TWT indicates that no TWT agreement is created, but one can be created using the indicated TWT parameters.

Table 10-19a—TWT setup exchange command interpretation

Initiating frame	Response frame	
TWT Setup Command field value within a TWT Setup frame transmitted from first STA to second STA	TWT Setup Command field value within a TWT Setup frame transmitted from second STA to first STA	TWT condition after the completion of the exchange

Table 10-19a—TWT setup exchange command interpretation

Request TWT or Suggest TWT or Demand TWT with Wake TBTT Negotiation subfield = don't care	No frame transmitted	No new active individual TWT agreement exists with the TWT Flow ID corresponding to the Flow ID in the initiating frame. No new active Broadcast individual TWT agreement exists.
Request TWT or Demand TWT with Wake TBTT Negotiation subfield = 0	Accept TWT with Broadcast subfield = 0	An individual TWT agreement is now active and is using the TWT parameters identified in the initiating frame. The TWT parameters in the response frame match the TWT parameters of the initiating frame.
Suggest TWT with Wake TBTT Negotiation subfield = 0	Accept TWT with Broadcast subfield = 0	An individual TWT agreement is now active and is using the TWT parameters identified in the ~~responding~~ response frame.
Request TWT or Suggest TWT or Demand TWT with Wake TBTT Negotiation subfield = 0	Accept TWT with Broadcast subfield = 1	This response is not allowed.
Suggest TWT or Demand TWT with Wake TBTT Negotiation subfield = 0	Alternate TWT or Dictate TWT with Broadcast subfield = 0	This response is not allowed.
Request TWT with Wake TBTT Negotiation subfield = 0	Alternate TWT with Broadcast subfield = 0	No active individual TWT agreement exists with the associated TWT Flow ID. The responder is offering an alternative set of parameters vs. those indicated in the initiating frame, as a means of negotiating TWT parameters with the requester. The requesting STA can send a new request with any set of TWT parameters and the responder might entertain the creation of an individual TWT agreement using those parameters.
Request TWT with Wake TBTT Negotiation subfield = 0	Dictate TWT with Broadcast subfield = 0	No active individual TWT agreement exists with the associated TWT Flow ID. The responder offers an alternative set of parameters vs. those indicated in the TWT request. By selecting "Dictate TWT", the responder indicates that it is not willing to accept any other TWT parameters for the requesting STA at this time. The requesting STA can send a new request, but will only receive an Accept TWT if it uses the dictated TWT parameters.
Request TWT with Wake TBTT Negotiation subfield = 0	Dictate TWT with Broadcast subfield = 1	No active individual TWT agreement exists with the associated TWT Flow ID. A broadcast TWT agreement is now active and is using the TWT parameters identified in the ~~responding frame~~ response frame including a Broadcast TWT ID subfield. The broadcast TWT agreement is not necessarily a newly created broadcast TWT agreement. The responding STA will not create any new individual TWT agreement with the requester at this time. The STA transmitting the initiating frame is not a member of the broadcast TWT.
Request TWT or Suggest TWT or Demand TWT with Wake TBTT Negotiation subfield = 0	Reject TWT with Broadcast subfield = 0	No active individual TWT agreement exists with the associated TWT Flow ID. The responding STA will not create any new individual TWT agreement with the requester at this time.

Table 10-19a—TWT setup exchange command interpretation

Suggest TWT or Demand TWT with Wake TBTT Negotiation subfield = 1	Accept TWT or Alternate TWT or Dictate TWT or Reject TWT with Broadcast subfield = 0	This response is not allowed.
Demand TWT with Wake TBTT Negotiation subfield = 1	Accept TWT with Wake TBTT Negotiation subfield = 1 and Broadcast subfield = 1	An active broadcast TWT agreement exists or has been created with the TWT parameters indicated in the initiating frame and the STA transmitting the initiating frame is a member of the Broadcast TWT identified by the Broadcast TWT ID and the TA of the response frame.
Suggest TWT with Wake TBTT Negotiation subfield = 1	Accept TWT with Wake TBTT Negotiation subfield = 1 and Broadcast subfield = 1	An active broadcast TWT agreement exists or has been created with the TWT parameters indicated in the ~~responding frame~~ response frame and the STA transmitting the initiating frame is a member of the broadcast TWT identified by the broadcast TWT ID and the TA of the response frame.
Request TWT with Wake TBTT Negotiation subfield = 1	Alternate TWT with Wake TBTT Negotiation subfield = 1 and Broadcast subfield = 1	No active broadcast TWT agreement has been created with the TWT parameters indicated in the initiating frame. The responder is offering an alternative set of parameters vs. those indicated in the initiating frame, as a means of negotiating TWT parameters with the requester. The requesting STA can send a new request with any set of TWT parameters and the responder might entertain the creation of a new broadcast TWT agreement using those parameters.
Suggest TWT or Demand TWT with Wake TBTT Negotiation subfield = 1	Alternate TWT with Broadcast subfield = 1	This response is not allowed.
Suggest TWT or Demand TWT with Wake TBTT Negotiation subfield = 1	Dictate TWT with Broadcast subfield = 1	An active broadcast TWT agreement is either created or already exists and is using the TWT parameters identified in the ~~responding frame~~ response frame, including a broadcast TWT ID. The responding STA will not create any new broadcast TWT agreement with the requester at this time
Suggest TWT or Demand TWT with Wake TBTT Negotiation subfield = 1	Reject TWT with Broadcast subfield = 1	~~No new active broadcast TWT agreement is created and the responding STA will not create any new broadcast TWT agreement at this time.~~ The STA transmitting the initiating frame is a not a member of a broadcast TWT identified by the broadcast TWT ID and the TA of the response frame, if such a broadcast TWT exists.
Accept TWT or Alternate TWT or Dictate TWT or Reject TWT with Wake TBTT Negotiation subfield = 0	No frame transmitted	This exchange is not allowed.
Accept TWT with Wake TBTT Negotiation subfield = ~~1~~ 0 and Broadcast subfield = 1	No frame transmitted	~~A~~ When transmitted by a scheduling STA, a broadcast TWT agreement exists and is using the TWT parameters identified in the initiating frame including a broadcast TWT ID. Not permitted to be transmitted by a scheduled STA.

Table 10-19a—TWT setup exchange command interpretation

Alternate TWT or Dictate TWT with Wake TBTT Negotiation subfield = ~~1~~ 0 and Broadcast subfield = 1	No frame transmitted	~~The~~ When transmitted by a scheduling STA, the TWT parameters of the existing broadcast TWT agreement identified by the TWT Flow ID and the TA of the initiating frame have been updated to the values of the TWT parameters of the initiating frame including a broadcast TWT ID. Not permitted to be transmitted by a scheduled STA.
Reject TWT with Wake TBTT Negotiation subfield = ~~1~~ 0 and Broadcast subfield = 1	No frame transmitted	~~The~~ When transmitted by a scheduled STA, the scheduled STA membership in the broadcast TWT agreement identified by the ~~TWT Flow ID~~ broadcast TWT ID and the ~~TA~~ RA of the initiating frame ~~frame~~ is terminated. Not permitted to be transmitted by a scheduling STA.
Reject TWT with Wake TBTT Negotiation subfield = 1 and Broadcast subfield = 1	No frame transmitted	When transmitted by a scheduling STA, the broadcast TWT agreement identified by the broadcast TWT ID and the TA of the initiating frame frame is terminated. Not permitted to be transmitted by a scheduled STA.
Reject TWT with Wake TBTT Negotiation subfield = 0 and Broadcast subfield = 0	No frame transmitted	The individual TWT agreement identified by the TA, RA pair of the transmitted frame and with the corresponding TWT Flow ID is terminated.

NOTE 1—Initiating frames ~~are all required to~~ not explicitly indicating broadcast have Broadcast subfield value of 0.

NOTE 2—Request frame settings not listed in the table are not allowed.

11. MLME

11.1 Synchronization

11.1.3 Maintaining synchronization

11.1.3.8 Multiple BSSID procedure

Insert the following at the end of the subclause:

The AP corresponding to the transmitted BSSID includes the Multiple BSSID element in the Beacon and Probe Response frames it transmits. In an HE AP that operates with multiple BSSIDs, there shall not be more than one AP corresponding to the transmitted BSSID. An HE AP shall set MaxBSSID Indicator and Tx BSSID Indicator as defined in 9.4.2.219.

An HE AP corresponding to a nontransmitted BSSID shall set the MaxBSSID Indicator field in the HE Operation element to a nonzero value. An HE STA that associates with the HE AP whose MaxBSSID Indicator field is set to n and whose Tx BSSID Indicator is set to 0 shall decodes the Beacon frame with Multiple BSSID element whose $48 - n$ MSBs of the BSSID are same as the $48 - n$ MSBs of BSSID of the AP with which the STA is associated.

Insert a new subclause at the end of 11.1.3 as follows:

11.1.3.10 Beacon generation in an HE BSS

An HE AP may transmit beacon frames and group addressed traffic in two PHY formats to ensure the BSS discoverability and BSS operating parameter distribution for the whole BSS coverage.

The HE AP that transmits Beacon frames in two PHY formats shall set the Dual Beacon subfield to 1 in the HE Operation elements it transmits. Otherwise, the AP shall set the field to 0. When Beacon frames are transmitted in two PHY formats, the HE AP shall transmit Beacon frames in non-HE format and in HE_EXT_SU format. The Beacon frame transmitted in non-HE PPDU format has TBTT at the TSF value 0. The TBTT repeats every Beacon interval as indicated in the Beacon frame transmitted in non-HE PPDU format.

The Beacon frame transmitted in HE extended range SU PPDU has TBTT at the TSF value 0 plus the TBTT offset which value is a half of the value of the Beacon Interval field of the Beacon frame sent in non-HE format. The TBTT of the beacon frame transmitted in an HE extended range SU PPDU repeats every beacon interval as indicated in the Beacon frame transmitted in the HE extended range SU PPDU.

The non-HE format and HE EXT_SU PPDU format Beacon frames may contain different set of elements.

11.2 Power management

11.2.2 Power management in a non-DMG infrastructure network

11.2.2.6 AP operation during the CP

Change item g) in the 2nd paragraph as follows:

g) When the AP receives a PS-Poll frame from a STA that is in PS mode, it shall forward to the STA a single buffered BU. The AP shall respond after a SIFS either with a Data or Management frame, or with an Ack frame; in which case the corresponding Data or Management frame is delayed. Until the transmission of this BU either has succeeded or is presumed failed (when maximum retries are exceeded), the AP shall acknowledge but ignore all PS-Poll frames from the same STA. This prevents a retried PS-Poll frame from being treated as a new request to deliver a buffered BU.

For a STA using U-APSD, the AP transmits one BU destined for the STA from any AC that is not delivery-enabled in response to PS-Poll frame from the STA. The AP should transmit the BU from the highest priority AC that is not delivery-enabled and that has a buffered BU. When all ACs associated with the STA are delivery-enabled, the AP transmits one BU from the highest priority AC that has a BU.

For a STA in PS mode and not using U-APSD, the AP shall set the More Data subfield of the response Data or Management frame to 1 to indicate the presence of further buffered BUs (not including the BU currently being transmitted) for the polling STA. For a STA using U-APSD, the AP shall set the More Data subfield to 1 to indicate the presence of further buffered BUs (not including the BU currently being transmitted) that do not use deliveryenabled ACs. When all ACs associated with the STA are delivery-enabled, the AP shall set the More Data subfield to 1 to indicate the presence of further buffered BUs (not including the BU currently being transmitted) using delivery-enabled ACs.

If there are buffered BUs to transmit to the STA, the AP may set the More Data bit in a QoS +CFAck frame to 1 in response to a QoS Data frame to indicate that it has one or more pending BUs buffered for the PS STA identified by the RA in the QoS +CF-Ack frame. An AP may also set the More Data bit in an Ack frame to 1 in response to a QoS Data frame to indicate that it has one or more pending BUs buffered for the PS STA identified by the RA in the Ack frame, if that PS STA has set the More Data Ack subfield in the QoS Capability element to 1. An HE AP may also set the More Data bit in a BlockAck or Multi-STA BlockAck frame to 1 to indicate that it has one or more pending BUs buffered for the HE PS STA identified by the RA in the BlockAck or Multi-STA Blockack frame, if that HE PS STA has set the More Data Ack subfield in the QoS Capability element to 1. An HE AP indicates support of sending Ack, BlockAck, or Multi-STA BlockAck frames with a nonzero More Data subfield by setting the More Data Ack subfield to 1 in the QoS Info field of frames it transmits.

Unless indicated above, the AP shall set the More Data bit to 0.

11.2.2.8 Receive operation for STAs in PS mode during the CP

Change item e) in the 2nd paragraph as follows:

The following rules describe operation of a STA in PS mode during the CP:

e) When dot11FMSActivated is false and ReceiveDTIMs is true, the STA shall wake up early enough to be able to receive either every non-STBC DTIM or every STBC DTIM sent by the AP of the BSS. When dot11FMSActivated is true and ReceiveDTIMs is true and the STA has been granted by the AP an alternate delivery interval for a multicast stream, the STA shall wake up before the non-STBC DTIM or STBC DTIM having Current Count of FMS Counter field set to 0 for that particular FMS stream.

A STA that stays awake to receive group addressed BUs shall elect to receive all group addressed non-STBC transmissions or all group addressed STBC transmissions and remain awake until the More Data subfield of the appropriate type (non-STBC or STBC) of group addressed BUs indicates there are no further buffered group addressed BUs of that type, or until a TIM is received indicating there are no more buffered group addressed BUs of that type, or until an FMS Descriptor element is received indicating that there are no further buffered group addressed BUs for which the STA has previously received an FMS Response element in a frame that has a value in Address 1 that matches its MAC address or that has an Address 1 value that is a group address corresponding to a group of which it is a member and that was transmitted by the AP with which it is associated and which had an Element Status value in the FMS Status subelement of "Accept". If a STA receives a QoS +CFAck frame from its AP with the More Data bit equal to 1, then the STA shall operate exactly as if it received a TIM with its AID bit equal to 1. If a STA has set the More Data Ack subfield in QoS Capability element to 1, then if it receives an Ack frame from its AP with the More Data bit equal to 1, the STA shall operate exactly as if it received a TIM with its AID bit equal to 1. If an HE STA has set the More Data Ack subfield in the QoS Capability element to 1, then if it receives a BlockAck or Multi-STA BlockAck frame from its AP with the More Data bit equal to 1, the STA shall operate exactly as if it received a TIM with its AID bit equal to 1. For example, a STA that is using the PS-Poll delivery method shall issue a PS-Poll frame to retrieve a buffered BU. See also 10.3.6 (Group addressed MPDU transfer procedure).

11.2.2.17 TIM Broadcast

Change the 11th paragraph as follows:

The AP shall increase the value (modulo 256) of the Check Beacon field in the next transmitted TIM frame(s) when a critical update occurs to any of the elements inside the Beacon frame. The following events shall classify as a critical update:

a) Inclusion of a Channel Switch Announcement element

b) Inclusion of an Extended Channel Switch Announcement element

c) Modification of the EDCA parameters element

d) Inclusion of a Quiet element

e) Modification of the DSSS Parameter Set

f) Modification of the CF Parameter Set element

g) Modification of the HT Operation element

h) Inclusion of a Wide Bandwidth Channel Switch element

i) Inclusion of a Channel Switch Wrapper element

j) Inclusion of an Operating Mode Notification element

k) Inclusion of a Quiet Channel element

l) Modification of the VHT Operation element

m) Modification of an HE Operation element

n) Inclusion of a Broadcast TWT element

11.23 Tunneled direct-link setup

11.23.1 General

Change as follows:

The VHT Operation element shall be present in a TDLS Setup Confirm frame when both STAs are VHT capable and the TDLS direct link is not established in the 2.4 GHz band. When the TDLS Setup Confirm frame includes a VHT Operation element, the Basic VHT-MCS And NSS Set field is reserved.

The HE Operation element shall be present in a TDLS Setup Confirm frame when both STAs are HE capable.

11.24 Wireless network management procedures

11.24.6 Fine timing measurement procedure

11.24.6.4 Measurement exchange

Change the 10th paragraph as follows:

For the Fine Timing Measurement frames transmitted during the FTM session:

— The responding STA shall not use a bandwidth wider than that indicated by the STA in the initial Fine Timing Measurement frame.

— The responding STA shall not use an HE format if the STA indicated VHT or HT-mixed or non-HT format in the initial Fine Timing Measurement frame.

— The responding STA shall not use a VHT format if the STA indicated HT-mixed or non-HT format in the initial Fine Timing Measurement frame.

— The responding STA shall not use an HT format if the STA indicated non-HT format in the initial Fine Timing Measurement frame.

Insert a new subclause 11.49 at the end of Clause 11:

11.49 HE BSS operation

11.49.1 AID assign rule

If the value of Partial BSS Color field is set to 1, then the HE AP shall allocate AIDs according to the formula for AID (5: 8)

$$\mathrm{AID}(5:8) = bin[(BCB(0:3) - (BSSID(44:47) \oplus BSSID(40:43)))\ mod\ 2^4, 4]$$

where $BCB(0:3)$ stands for the least significant 4 BSS color bits and $bin[x, 4]$ is the operator that casts decimal value x into 4 bits binary vector.

17. Orthogonal frequency division multiplexing (OFDM) PHY specification

17.2 OFDM PHY specific service parameter list

17.2.2 TXVECTOR parameters

17.2.2.1 General

Insert a new last row into Table 17-1 (TXVECTOR parameters) as follows:

Table 17-1—TXVECTOR parameters

Parameter	Associated primitive	Value
TRIGGER_RESPONDING	PHY-TXSTART.request (TXVECTOR)	If present, false or true. When true, the MAC entity requests that the PHY entity does synchronization as defined in 17.3.9.10 (Pre-correction accuracy requirements). When false, the MAC entity requests that the PHY entity does not have to do synchronization as defined in 17.3.9.10 (Pre-correction accuracy requirements).

Insert a new subclause at the end of 17.2.2 as follows:

17.2.2.6 TRIGGER_RESPONDING

If present, the allowed values are false or true. A parameter value of true indicates that the MAC sublayer is requesting that the PHY entity does synchronization as defined in 17.3.9.10 (Pre-correction accuracy requirements). A parameter value of false indicates that the MAC sublayer is requesting that the PHY entity does not do synchronization as defined in 17.3.9.10 (Pre-correction accuracy requirements).

17.3 OFDM PHY

17.3.9 PHY transmit specifications

Insert a new subclause at the end of 17.3.9 as follows:

17.3.9.10 Pre-correction accuracy requirements

A STA that transmits a PPDU where the TXVECTOR parameter TRIGGER_RESPONDING is true shall pre-compensate for carrier frequency offset (CFO) error and symbol clock error. After compensation, the absolute value of residual CFO error with respect to the PPDU carrying the soliciting MU-RTS frame shall not exceed 2 kHz when measured as the 10% point of CCDF of CFO errors in AWGN at a received power of –60 dBm in the primary 20 MHz. The residual CFO error measurement shall be made on the non-HT PPDU or non-HT duplicate PPDU following the L-STF field. The symbol clock error shall be pre-compensated by the same ppm amount as CFO error.

A STA that transmits an non-HT or non-HT duplicate PPDU where the TXVECTOR parameter TRIGGER_RESPONDING is true shall have timing accuracy of ±0.4 μs relative to the actual ending time of the PPDU carrying the MU-RTS frame. This requirement does not include round trip delay. This requirement is the same as the timing requirement for HE trigger based PPDU.

18. Extended Rate PHY (ERP) specification

18.2 PHY-specific service parameter list

Insert two new last rows into Table 18-1 (TXVECTOR parameters) as follows:

Table 18-1—TXVECTOR parameters

Parameter	Value
CH_BANDWIDTH_IN_NON_HT	If present, CBW20 or CBW40
DYN_BANDWIDTH_IN_NON_HT	If present, Static or Dynamic

Insert two new last rows into Table 18-3 (RXVECTOR parameters) as follows:

Table 18-3—RXVECTOR parameters

Parameter	Value
CH_BANDWIDTH_IN_NON_HT	If present, CBW20 or CBW40
DYN_BANDWIDTH_IN_NON_HT	If present, Static or Dynamic

Insert new Clauses 27 and 28 following Clause 26 as follows:

27. High Efficiency (HE) MAC specification

27.1 Introduction

The use of HCCA and TSPEC are banned at HE STAs.

27.2 Channel Access

27.2.1 Intra-BSS and inter-BSS frame detection

An HE STA determines whether a received frame is an inter-BSS or an intra-BSS frame by using the RXVECTOR parameters (e.g., BSS_COLOR in HE PPDUs or GROUP_ID and PARTIAL_AID in VHT PPDUs) or MAC address.

A frame received by the STA is an intra-BSS frame if one of the following conditions is true:

- The RXVECTOR parameter BSS_COLOR in the received PPDU carrying the frame is the same as the BSS color announced by the AP to which the STA is associated
- The RA field, TA field or BSSID field of the received frame with the Individual/Group bit forced to the value 0 is the same as the BSSID of AP to which the STA is associated
- The AP to which the STA is associated is a member of a Multiple BSSID Set with two or more members and the RA field, TA field or BSSID field of the received frame with the Individual/Group bit forced to the value 0 is same as the BSSID of any member of the Multiple BSSID Set
- The RXVECTOR parameter PARTIAL_AID in the received VHT PPDU with the RXVECTOR parameter GROUP_ID equal to 0 is the same as the BSSID[39:47] of the AP to which the STA is associated
- The value of RXVECTOR parameter PARTIAL_AID [5:8] in the received VHT PPDU with the RXVECTOR parameter GROUP_ID equal to 63 is the same as the partial BSS color announced by the AP to which the STA is associated when the Partial BSS Color field in the most recently received HE Operation element is 1.
- The frame is a control frame that does not have a TA field and the RA matches the saved TXOP holder address for the BSS to which it is associated.

A frame received by the STA is an inter-BSS frame if one of the following conditions is true:

- The RXVECTOR parameter BSS_COLOR of the PPDU carrying the frame is not 0 and does not match the BSS color announced by the AP to which the STA is associated
- When the RXVECTOR parameter BSS_COLOR of the PPDU carrying the frame is not present:
  - The BSSID field of the received frame with Individual/Group bit forced to the value 0, if available, does not match the BSSID of AP to which the STA is associated
  - If the BSSID field is not available, both the RA and TA fields exist, and none of the address fields of the received frame with Individual/Group bit forced to the value 0 match the BSSID of AP to which the STA is associated
- The AP to which the STA is associated is a member of a Multiple BSSID Set with two or more members and the BSSID field of the received frame with Individual/Group bit forced to the value 0, if available, does not match the BSSID of any member of the Multiple BSSID Set
- If the AP to which the STA is associated is a member of a Multiple BSSID Set with two or more members, the BSSID field is not available, both the RA and TA fields exist, and none of the address

fields of the received frame with the Individual/Group bit forced to the value 0 match the BSSID of any member of the Multiple BSSID Set

— The RXVECTOR parameter PARTIAL_AID of the received VHT PPDU frame with the RXVECTOR parameter GROUP_ID equal to 0 is different from the BSSID[39:47] of the AP to which the STA is associated

— The value of RXVECTOR parameter PARTIAL_AID [5:8] in the received VHT PPDU with the RXVECTOR parameter GROUP_ID equal to 63 is different from the partial BSS color announced by the AP to which the STA is associated when the Partial BSS Color field in the most recently received HE Operation element is 1.

— An HE AP receives either a VHT MU PPDU or an HE MU PPDU.

If the received frame satisfies both intra-BSS and inter-BSS conditions, the decision made by using the MAC address takes precedence over the decision made by using the RXVECTOR parameter BSS_COLOR .

If the received frame does not satisfy any of the intra-BSS and inter-BSS conditions, then the frame cannot be determined as intra-BSS or inter-BSS frame.

27.2.2 Updating two NAVs

An HE non-AP STA shall maintain two NAV timers. An HE AP STA may maintain two NAV timers.

The requirements in 10.3.2.1 (CS mechanism) applies to an HE STA maintaining two NAVs with the exception of virtual CS indication of medium. For an HE STA maintaining two NAVs, if both the NAV timers are 0, the virtual CS indication is that the medium is idle; if one of the two NAV timers is nonzero, the virtual CS indication is that the medium is busy.

For the two NAVs maintained by an HE STA, one is identified as intra-BSS NAV, and the second one is identified as basic NAV. Intra-BSS NAV is used to store NAV value, if needed, from a PPDU identified as intra-BSS. Basic NAV is used to store NAV value, if needed, from a PPDU identified as inter-BSS or cannot be identified as intra-BSS or inter-BSS. Note that the method of identifying a PPDU as intra-BSS or inter-BSS is described in 27.2.1 (Intra-BSS and inter-BSS frame detection).

The duration information is indicated by a frame in a PSDU as follows:

— If there is a Duration field in the frame, then the duration information is indicated by the Duration field

— If the frame is PS-Poll, then the duration information is equal to the time, in microseconds, required to transmit one Ack frame plus one SIFS under the data rate selection rules. If the calculated duration information includes a fractional microsecond, that duration information is rounded up to the next higher integer.

A STA shall update the intra-BSS NAV with the duration information indicated by the received frame in a PSDU if and only if all the following conditions are met:

— The frame is identified as intra-BSS according to the rule described in 27.2.1 (Intra-BSS and inter-BSS frame detection)

— The indicated duration information is greater than the STA's current intra-BSS NAV value

— The STA is not solicited an immediate response by the PPDU carrying the frame.

— The frame is not solicited by the STA if the STA is a TXOP holder

A STA shall update the basic NAV with the duration information indicated by the received frame in a PSDU if and only if all the following conditions are met:

— The frame is identified as inter-BSS or cannot be identified as intra-BSS or inter-BSS according to the rule described in 27.2.1 (Intra-BSS and inter-BSS frame detection)
— The indicated duration information is greater than the STA's current basic NAV value
— The STA is not solicited an immediate response by the PPDU carrying the frame.

A STA shall update the intra-BSS NAV with the duration information indicated by the RXVECTOR parameter TXOP_DURATION if and only if all the following conditions are met:

— The RXVECTOR parameter TXOP_DURATION is not set to all 1s
— The PPDU that carried information of the RXVECTOR parameter is identified as intra-BSS according to the rule described in 27.2.1 (Intra-BSS and inter-BSS frame detection)
— The STA does not receive a frame with the duration information indicated by a Duration field in the PSDU of the PPDU carrying the RXVECTOR parameter TXOP_DURATION
— The duration information indicated by the RXVECTOR parameter TXOP_DURATION is greater than the STA's current intra-BSS NAV
— The PPDU that carried information of the RXVECTOR parameter is not an HE trigger-based PPDU triggered by the STA

A STA shall update the basic NAV with the duration information indicated by the RXVECTOR parameter TXOP_DURATION if and only if all the following conditions are met:

— The RXVECTOR parameter TXOP_DURATION is not set to all 1s
— The PPDU that carried information for the RXVECTOR parameter is identified as inter-BSS or cannot be identified as intra-BSS or inter-BSS according to the rule described in 27.2.1 (Intra-BSS and inter-BSS frame detection)
— The STA does not receive a frame with the duration information indicated by a Duration field in the PSDU of the PPDU carrying the RXVECTOR parameter TXOP_DURATION
— The duration information indicated by the RXVECTOR parameter TXOP_DURATION is greater than the STA's current basic NAV

NOTE 1—If a PS-Poll is received carried in a received HE SU PPDU, HE extended range SU PPDU, or HE MU PPDU, then the RXVECTOR parameter TXOP_DURATION does not indicate duration information (see 27.11.5 (TXOP_DURATION).

NOTE 2—Based on the setting rule, if a STA receives a frame with the duration information indicated by both a Duration field in the PSDU and the RXVECTOR parameter TXOP_DURATION, then the duration information indicated by the RXVECTOR parameter TXOP_DURATION is ignored.

NOTE 3—The additional rules of NAV consideration for a STA that is solicited for an immediate response are described in 10.3.2.7 (CTS and DMG CTS procedure), 10.3.2.9 (Acknowledgment procedure), and 27.5.2.4 (UL MU CS mechanism).

Various additional conditions may set or reset the intra-BSS NAV or basic NAV, as described in 10.4.3.3 (NAV operation during the CFP). When one NAV is reset, if the other NAV timer is 0, a PHY-CCARESET.request primitive shall be issued. The exact time of updating the NAVs uses the same rule as defined in 10.3.2.4 (Setting and resetting the NAV).

A STA that maintains two NAVs has the capability to maintain NAV set by intra-BSS PPDU and inter-BSS PPDU separately. Maintaining two NAV is beneficial in dense deployment scenarios where a STA requires protection from frames transmitted by STAs within its BSS, i.e., intra-BSS, and avoid interference from frames transmitted by STAs in neighboring BSS, i.e., inter-BSS. For example, in a TXOP initiated by the associated AP for UL MU transmission, the intra-BSS NAV of the STA can be set by the AP to prevent the STA from contending the channel, and the basic NAV will not be updated by the associated AP so that NAV set by inter-BSS PPDU can be considered in UL MU CS as described in 27.5.2.4 (UL MU CS mechanism).

An HE STA that used information from an RTS or MU-RTS frame as the most recent basis to update its NAV setting is permitted to reset the NAV which is updated by the RTS or MU-RTS if no PHY-RXSTART.indication primitive is received from the PHY during a period with a duration of $2 \times$ aSIFSTime + CTS_Time + aRxPHYStartDelay + $2 \times$ aSlotTime starting when the MAC receives a PHY-RXEND.indication primitive corresponding to the detection of the RTS or MU-RTS frame.

27.2.3 Obtaining an EDCA TXOP for UL MU capable STAs

An UL MU capable non-AP HE STA that receives a Basic Trigger frame that contains a Per User Info field with the AID of the STA, and that receives an immediate response from the AP for the transmitted Trigger-based PPDU, shall update its CWmin[AC], CWmax[AC], AIFSN[AC] and HEMUEDCATimer[AC] state variables to the values contained in the most recently received MU EDCA Parameter Set element sent by the AP to which the STA is associated, for all the ACs from which QoS Data frames were transmitted in the HE trigger-based PPDU.

Each HEMUEDCATimer[AC] shall uniformly count down to 0 when its value is nonzero.

NOTE 1—A non-AP STA that sends a frame to the AP with an OMI A-Control field containing a value of 1 in the UL MU Disable field does not participate in UL MU operation, as such it is exempt from updating its EDCA access parameters to the values contained in the MU EDCA Parameter Set element.

NOTE 2—A non-AP STA that sends a QoS Data frames with Ack policy set to No Ack updates its EDCA access parameters to the values contained in the MU EDCA Parameter Set element irrespective of receiving immediate response from the AP.

When the HEMUEDCATimer[AC] reaches zero, then the HE non-AP UL MU capable STA may update the CWmin[AC], CWmax[AC] and AIFSN[AC] either to the values that are contained in the most recently received EDCA Parameter Set element sent by the AP to which the STA is associated, or to the values contained in the default dot11EDCATable if an EDCA Parameter Set element has not been received.

27.3 Fragmentation

27.3.1 General

An HE STA supports the static fragmentation procedure defined in 10.2.7 (Fragmentation/defragmentation overview), 10.5 (Fragmentation), and 10.6 (Defragmentation). In addition, an HE STA can support the dynamic fragmentation procedure defined in this subclause.

An HE STA can dynamically fragment individually addressed MSDUs, A-MSDUs or MMPDUs and defragment received MPDUs as defined in this subclause, and using the fragmentation/defragmentation processes defined in 10.2.7 (Fragmentation/defragmentation overview) without being subject to the rules defined in that subclause. Dynamic fragmentation provides further flexibility in aggregating the data so that padding can be minimized (see 27.5 (MU operation)).

27.3.2 Support and requirements for dynamic fragmentation

A dynamic fragment is an MPDU, the payload of which carries a portion of an MSDU, A-MSDU or MMPDU. The generation of dynamic fragments follows the rules defined in 10.2.7 (Fragmentation/defragmentation overview) and 10.5 (Fragmentation), except for:

— Generation of dynamic fragments and their transmission within an MPDU or A-MPDU under HT-immediate block ack agreements is allowed for an HE STA under the conditions defined in 27.3.4 (Procedure at the recipient).
— Reception of dynamic fragments is not mandatory. An HE STA declares its dynamic fragments reception capability in the HE Fragmentation Support field of the HE Capabilities element.

- Fragmentation of A-MSDUs is permitted when supported by the recipient
- The length of each fragment is not required to be equal for all fragments of the MSDU, A-MSDU or MMPDU. The length of each fragment may be of any nonzero value, except that the length of the first fragment of an MSDU or A-MSDU shall be greater than or equal to the minimum fragment size specified by the receiver STA in the Minimum Fragment Size subfield of the HE Capabilities element it transmits. An MSDU or A-MSDU with a size that is less than the minimum fragment size shall not be fragmented.

27.3.3 Procedure at the originator

27.3.3.1 General

An originator STA transmitting an MPDU or A-MPDU that contains one or more dynamic fragments shall solicit an immediate response from the recipient STA for each of the fragments contained in the MPDU or A-MPDU, except when the fragments are sent under level 3 dynamic fragmentation (see 27.3.3.4 (Level 3 dynamic fragmentation))..

A STA shall not transmit a fragment containing all or part of an A-MSDU that is greater than the maximum A-MSDU size as specified in Table 9-19 (Maximum data unit sizes (in octets) and durations (in microseconds)).

NOTE—The originator STA sends the fragments in order as defined in 10.5 (Fragmentation), except for level 3 dynamic fragmentation.

If the originator STA received explicit indications in response frames that none of the transmissions of previously transmitted fragment(s) of an MSDU, A-MSDU or MMPDU have been successfully received then the STA may retransmit the full MSDU, A-MSDU or MMPDU instead of retransmitting all the failed fragments. Otherwise, the originator STA may retransmit the failed fragment, in which case the frame body length and contents of the retransmitted fragment shall be the same as the first transmitted fragment and shall remain fixed for the lifetime of the MSDU, A-MSDU or MMPDU at that STA.

NOTE—An explicit indication is the absence of a valid Ack frame, BlockAck frame or Multi-STA BlockAck frame that is expected to be present in the first MPDU of the immediately received A-MPDU, or the absence of a BA Information field in the immediately received Multi-STA BlockAck frame for the TID of the transmitted fragment(s).

An originator STA shall not transmit to a recipient STA an MPDU or A-MPDU containing dynamic fragments that do not satisfy the conditions in the subclauses below.

27.3.3.2 Level 1 dynamic fragmentation

An originator STA may transmit to a recipient STA an MPDU or S-MPDU that contains one dynamic fragment of an MMPDU or of an MSDU that is not sent under a block ack agreement if the recipient STA has indicated a value 1 in the HE Fragmentation Support field of its HE Capabilities element. An originator STA may transmit to a recipient STA an MPDU or S-MPDU that contains one dynamic fragment of an A-MSDU if the recipient STA has indicated a value of 1 in the A-MSDU Fragmentation Support field of its HE Capabilities element.

An originator STA may transmit to a recipient STA an MPDU or S-MPDU that contains one dynamic fragment of an MSDU provided the following conditions are met:

- The HE Fragmentation Support field in the HE Capabilities element received from the STA is 1
- For the block ack agreement associated with the TID of the MSDU, the ADDBA Extension element is present and the HE Fragmentation Operation subfield is 1 in the ADDBA Response frame received from the STA.

The originator STA shall follow the rules defined in 10.13.8 (Transport of S-MPDUs) for generating the S-MPDU.

27.3.3.3 Level 2 dynamic fragmentation

An originator STA may transmit fragmented MMPDUs or MSDUs that are not sent under a block ack agreement to a recipient STA using level 2 dynamic fragmentation if the HE Fragmentation Support field of the HE Capabilities element received from the STA is 2.

An originator STA may transmit fragmented MSDUs under a block ack agreement to a recipient STA using level 2 dynamic fragmentation provided the following conditions are met:

- The HE Fragmentation Support field in the HE Capabilities element received from the STA is 2
- For the block ack agreement associated with the TID of the MSDU, the ADDBA Extension element is present and the HE Fragmentation Operation subfield is 2 in the ADDBA Response frame received from the STA.

Using level 2 dynamic fragmentation, an originator STA may transmit to a recipient STA an MPDU, S-MPDU, or A-MPDU that contains:

- One dynamic fragment of an MSDU, A-MSDU if supported by the recipient, or MMPDU in an MPDU or S-MPDU
  - The originator STA shall follow the rules defined in 10.13.8 (Transport of S-MPDUs) for generating the S-MPDU
- Up to one dynamic fragment of an MSDU, A-MSDU if supported by the recipient, or MMPDU for each MSDU and for the MMPDU in an A-MPDU format
  - The originator STA shall follow the rules defined in 10.24.7.7 (Originator's behavior) for generating the A-MPDU and the rules defined in 27.10.4 (A-MPDU with multiple TIDs) for generating the multi-TID A-MPDU (that can contain the fragment of the MMPDU)

27.3.3.4 Level 3 dynamic fragmentation

An HE STA may transmit an L3 Frag BA Request frame to a receiver STA that has indicated a value of 3 in the HE Fragmentation Support field of the HE Capabilities element it transmits. The receiver STA that accepts the HT-Immediate block ack session shall respond with an L3 Frag BA Response if it has allocated resources for operating in a block ack session with level 3 fragmentation enabled. Otherwise, it shall respond with a BA Response frame to indicate that it has not allocated resources for operating in a block ack session where level 3 fragmentation is enabled.

NOTE—A block ack session with level 3 fragmentation enabled requires a block acknowledgment record that maintains up to 4 bits per MSDU (one bit for each fragment of the MSDU).

An originator STA may transmit to a recipient STA, which has indicated a value 3 in the HE Fragmentation Support field of its HE Capabilities element, an MPDU, S-MPDU, or A-MPDU that contains:

- One dynamic fragment of an MSDU, A-MSDU if supported by the recipient, or MMPDU in an MPDU or S-MPDU
  - The originator STA shall follow the rules defined in 10.13.8 (Transport of S-MPDUs) for generating the S-MPDU
- Up to four dynamic fragments of an MSDU for each MSDU and up to one dynamic fragment of an MMPDU in an A-MPDU, and up to four dynamic fragments of an A-MSDU for each A-MSDU if supported by the recipient
  - The originator STA shall set the Fragment Number subfield of each MPDU to a value less than 4
  - The originator STA shall follow the rules defined in 10.24.7.7 (Originator's behavior) for generating the A-MPDU with the exception that the A-MPDU shall contain MPDUs whose range of

the Sequence Number subfields does not exceed $B_L/4$, where B_L is the length of the Block Ack Bitmap field of the BlockAck or Multi-STA BlockAck frame that corresponds to a TID of a transmitted fragment (see 10.24.7 (HT-immediate block ack extensions) and 27.4 (Block acknowledgement).

27.3.4 Procedure at the recipient

27.3.4.1 General

An HE STA shall set the HE Fragmentation Support subfield of the HE Capabilities element it transmits to 0 if its dot11HEDynamicFragmentationImplemented is false. Otherwise the HE STA shall set the HE Fragmentation Support subfield as follows:

- Set to 1 if the STA supports reception of dynamic fragments following the procedure defined in 27.3.3.2 (Level 1 dynamic fragmentation)
- Set to 2 if the STA supports reception of dynamic fragments following the procedure defined in 27.3.3.3 (Level 2 dynamic fragmentation)
- Set to 3 if the STA supports reception of dynamic fragments following the procedure defined in 227.3.3.4 (Level 3 dynamic fragmentation)

Defragmentation of dynamic fragments shall follow the rules defined in 10.6 (Defragmentation) with the following exceptions:

- The recipient STA shall support the concurrent reception of dynamic fragments of a number of *outstanding* MSDUs, A-MSDUs when supported and MMPDUs from a transmitting STA that is equal to N_{max}, where N_{max} for MSDUs is indicated in the Maximum Number of Fragmented MSDUs subfield of the HE Capabilities element transmitted by the STA, and N_{max} is equal to 1 for MMPDUs. The term *outstanding* refers to an MPDU containing all or part of an MSDU, A-MSDU or MMPDU for which transmission has been started, and for which delivery of the MSDU, A-MSDU or MMPDU has not yet been completed (i.e., an acknowledgment of the final fragment has not been received and the MSDU, A-MSDU or MMPDU has not been discarded due to retries, lifetime, or for some other reason).
- The recipient STA is not subject to the receive timer rules for each of the MSDUs, A-MSDUs and MMPDUs defined in 10.6 (Defragmentation).

A STA that has dot11AMSDUFragmentationOptionImplemented true shall set the A-MSDU Fragmentation Support subfield in the HE Capability element to 1. Otherwise, the STA shall set the A-MSDU Fragmentation Support subfield in the HE Capability element to 0.

A STA that has dot11AMSDUFragmentationOptionImplemented true shall be capable of receiving fragments containing all or part of an A-MSDU of arbitrary length that is less than or equal to the maximum A-MSDU size as specified in Table 9-19 (Maximum data unit sizes (in octets) and durations (in microseconds)).

27.3.4.2 Level 1 dynamic defragmentation

Upon reception of an MPDU or S-MPDU that carries one or more dynamic fragments, the recipient STA responds with an Ack frame when the received fragment is contained in an MPDU or S-MPDU that solicits the immediate response. The receiver STA shall follow the rules defined in 10.3.2.9 (Ack procedure) for generating the Ack frame and the rules defined in 27.4 (Block acknowledgement) for generating the Multi-STA BlockAck frame that contains the acknowledgement for the soliciting S-MPDU carried in a Trigger-based PPDU.

27.3.4.3 Level 2 dynamic fragmentation

Upon reception of an MPDU or A-MPDU that carries one or more dynamic fragments, the recipient STA responds with one of the following frames:

— An Ack frame when the received fragment is contained in an MPDU or S-MPDU that solicits the immediate response. The recipient STA shall follow the rules defined in 10.3.2.9 (Ack procedure) for generating the Ack frame and the rules defined in 27.4 (Block acknowledgement) for generating the Multi-STA BlockAck frame that contains the acknowledgement for the soliciting S-MPDU carried in an HE trigger-based PPDU.

— A BlockAck frame when the received fragments, up to one fragment for each MSDU or A-MSDU, are contained in an A-MPDU that solicits an immediate response. The recipient STA shall follow the rules defined in 10.24.7.5 (Generation and transmission of BlockAck frames by an HT STA or DMG STA) for generating the BlockAck frame and the rules in 27.4 (Block acknowledgement) for generating the Multi-STA BlockAck frame, except that the STA shall:

- Set to 0 the LSB of the Fragment Number subfield in the Block Ack Starting Sequence Control subfield of the BlockAck frame or Multi-STA BlockAck frame that corresponds to a TID of a received fragment
- Set to 1 each bit of the Block Ack Bitmap field that corresponds to a Sequence Number subfield and TID subfield of a successfully received fragment contained in the soliciting A-MPDU or multi-TID A-MPDU
- Update the corresponding block ack record only when an MSDU or A-MSDU that is received in fragments is successfully reconstructed (see 10.6 (Defragmentation)) otherwise it shall not update the block ack record for that MSDU or A-MSDU.

A recipient STA shall discard any fragments that have been received during an HT-immediate BA session for a TID if it receives a BlockAckReq frame from the originator STA for that TID when the fragments have a Sequence Number field value that is less than the value of the Starting Sequence Number field of the BlockAckReq frame (where the comparison of the two values is performed modulo 4096).

27.3.4.4 Level 3 dynamic fragmentation

Upon reception of an MPDU or A-MPDU that carries one or more dynamic fragments, the recipient STA responds with one of the following frames:

— An Ack frame when the received fragment is contained in an MPDU or S-MPDU that solicits the immediate response. The recipient STA shall follow the rules defined in 10.3.2.9 (Ack procedure) for generating the Ack frame and the rules defined in 27.4 (Block acknowledgement) for generating the Multi-STA BlockAck frame that contains the acknowledgement for the soliciting S-MPDU carried in a Trigger-based PPDU.

— A BlockAck frame when the received fragments, one or more fragments for each MSDU or A-MSDU, are contained in an A-MPDU where at least one MPDU's Fragment Number field is of non-zero value that solicits the immediate response and is sent during a BA session that was setup with an L3 FRAG ADDBA Response frame. The recipient STA shall follow the rules in 10.24.7.5 (Generation and transmission of BlockAck frames by an HT STA or DMG STA) for generating the BlockAck frame, except that the STA shall:

- Set to 1 the LSB of the Fragment Number subfield in the Block Ack Starting Sequence Control subfield of the BlockAck frame or Multi-STA BlockAck frame that corresponds to a TID of a received fragment
- Set to 1 each bit in position B of the Block Ack Bitmap field that corresponds to a successfully received fragment and shall set it to 0 otherwise, with B calculated as:
  $B = 4 \times (SN - SSN) + FN$, where the operations on the sequence numbers are performed module 4096
  SN is the value of the Sequence Number subfield of an MPDU containing the fragment for which

the receive status is indicated
SSN is the value of the Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield of the BlockAck frame

- Update the corresponding block ack record only when an MSDU or A-MSDU that is received in fragments is successfully reconstructed (see 10.6 (Defragmentation)). Otherwise it shall not update the block ack record for that MSDU.

The recipient STA shall discard any fragments that have been received during an HT-immediate BA session for a TID if it receives a BlockAckReq frame from the originator STA for that TID when the fragments have a Sequence Number field value that is less than the value of the Starting Sequence Number field of the BlockAckReq frame (where the comparison of the two values is performed modulo 4096).

27.4 Block acknowledgement

27.4.1 Overview

An HE STA can use Compressed BlockAck frame or Multi-STA BlockAck frame after setting up a block ack agreement. An HE STA shall support generation of Compressed BlockAck frames if HT-immediate BA is supported in the role of recipient (see 10.24.7.1 (Introduction). An HE STA shall support generation of Multi-STA BlockAck frame if either UL MU operation (see 27.5.2 (UL MU operation)) or multi-TID A-MPDU operation (27.10.4 (A-MPDU with multiple TIDs)) is supported in the role of recipient.

An HE non-AP STA that sends a Multi-STA BlockAck frame shall set the AID subfield in the Per STA Info field of the Multi-STA BlockAck frame to 0 and the RA field to the BSSID when the intended receiver of the frame is the AP.

When sending Multi-STA BlockAck frame, the HE STA shall transmit the Multi-STA BlockAck using one of rate, MCS, NSS that all of the acknowledgement receivers support.

An HE STA may send a Multi-STA BlockAck frame in response to an HE trigger-based PPDU. A Multi-STA BlockAck frame contains one or more BA Information fields with one or more AIDs and one or more different TIDs. An HE AP that transmits a Multi-STA BlockAck frame with different AID subfield values shall set the RA field to the broadcast address. An HE AP that transmits a Multi-STA BlockAck frame with a single AID subfield or with the same values of the AID subfield in Per STA Info subfields shall set the RA field to the address of the recipient STA that requested the Block Ack or to the broadcast address. An HE non-AP STA shall transmit a Multi-STA BlockAck frame with a single AID subfield or with the same values of the AID subfield in Per STA Info subfields and shall set the RA field to the address of the recipient STA that requested the Block Ack frame.

An HE STA that supports Multi-STA BlockAck shall examine each received Multi-STA sent by an STA with which it has a BA agreement. On receiving such a Multi-STA BlockAck frame a STA performs the following for each BA Information field with its AID:

— If the Ack Type field is 0 then the Block Ack Starting Sequence Control, TID and Block Ack Bitmap fields of the STA Info field are processed according to 10.24.7 (HT-immediate block ack extensions) and 27.3 (Fragmentation).

— If the Ack Type field is 1, then the STA Info field indicates either the acknowledgement of a single MPDU identified by the value of the TID or of all MPDUs carried in the eliciting PPDU, when the TID field is set to 14.

An HE STA that receives a BlockAckReq frame or a MU-BAR variant Trigger frame that contains a Compressed BlockAckReq variant in the User Info field addressed to the STA shall respond with a BlockAck frame as defined in 10.24.7 (HT-immediate block ack extensions) or a Multi-STA BlockAck frame as defined in 27.4 (Block acknowledgement).

An HE STA that receives a Multi-TID BlockAckReq frame or a MU-BAR variant Trigger frame that contains a Multi-TID BlockAckReq variant in the User Info field addressed to the STA shall respond with a Multi-STA BlockAck frame that contains a STA Info subfield with a Block Ack Bitmap subfield for each of the TIDs (with values less than 8) contained in the BlockAckReq frame and the length of each Block Ack Bitmap subfields shall be equal to the solicited Bitmap length (i.e., FN subfields in solicited Block Ack Request Starting Sequence Control and responding Block Ack Starting Sequence Control for the same TID are equal).

If an HE AP does not receive an HE Capabilities element with the Rx Control Frame To MultiBSS set to 1 from a STA, then the HE AP shall not send a Multi-STA Block Ack frame whose destination STAs associate with more than one APs to the STA.

An HE non-AP STA that is associated with a nontransmitted BSSID and has indicated support for receiving Control frames with TA set to the Transmitted BSSID (Rx Control Frame To MultiBSS set to 1 in HE Capabilities element), shall respond with a BlockAck frame whose RA is set either to the (nontransmitted) BSSID it is associated with or the transmitted BSSID (i.e., the TA of the soliciting MU BAR frame).

27.4.2 Acknowledgement, block acknowledgment or all acknowledgement selection in a Multi-STA BlockAck frame

A recipient sets the Ack Type and TID subfields in a Per AID TID Info field of the Multi-STA BlockAck frame sent as a response depending on the acknowledgement context.

a) All Ack context: if the originator had set the All Ack Supported subfield to 1 in the HE Capabilities element, then the recipient may set the Ack Type field to 1 and the TID subfield to 14 to indicate the successful reception of all the MPDUs intended to it carried in the eliciting A-MPDU or multi-TID A-MPDU only. Otherwise the recipient shall not set the Ack Type field to 1 and the TID subfield to 14. The Multi-STA BlockAck frame shall contain only one Per STA Info field addressed to an originator in the Multi-STA BlockAck frame.

b) Ack context: A recipient receiving a single MPDU, that requires an acknowledgment, shall set the Ack Type field to 1 and the TID field to the TID value of that MPDUs to indicate the successful reception of that MPDU.

   If multiple single MPDUs in a Multi-TID A-MPDUs are received by a recipient that supports its reception, the Multi-STA BlockAck frame may contain multiple occurrences of these Per STA Info fields that are intended to an originator, one for each successfully received single MPDU requesting an acknowledgment.

   The allowed values for the TID field in this context are 0 to 7 (for indicating acknowledgement of QoS Data or QoS Null frames) or 15 (for indicating acknowledgement of an Action frame).

c) BlockAck context: The recipient shall set the Ack Type field to 0 and the TID field of a Per STA Info field to the TID value of MPDUs requesting block acknowledgement that are carried in the eliciting A-MPDU or multi-TID A-MPDU.

   The Multi-STA BlockAck frame may contain multiple occurrences of these Per STA Info fields addressed to an originator, one for each MPDU that is requesting block acknowledgement, in which case the Block Ack Starting Sequence Control and Block Ack Bitmap fields shall be set according to 10.24.7 (HT-immediate block ack extensions) for each block ack session, and according to 27.3 (Fragmentation) for each block ack session with dynamic fragmentation.

   The allowed values for the TID field in this context are 0 to 7 (for indicating block acknowledgement of QoS Data frames).

Variable bitmap lengths can be included in the Per STA Info field when the originator and recipient negotiate their use as defined in 27.4.3 (Negotiation of block ack bitmap lengths).

An originator shall examine each received Multi-STA BlockAck frame sent by an STA as a response to a soliciting PPDU.

Upon reception of the Multi-STA BlockAck frame the originator performs the following operations for each Per STA Info field that has an AID field addressed to the originator (i.e., the AID subfield is an AID if the originator is a non-AP STA and is 0 when the originator is an AP):

- If the Ack Type field is 0 then the BlockAck Starting Sequence Control, TID and BA Bitmap fields of the Per STA Info field are processed according to 10.24.7 (HT-immediate block ack mechanism), 27.3 (Fragmentation), and as defined below.
- If the Ack Type field is 1 then the Per STA Info field indicates either the acknowledgement of a single MPDU identified by the value of the TID.
- If the Ack Type field is 1 and the TID subfield of Per AID TID Info field is 14, then the Per STA Info field indicates the acknowledgement of all MPDUs carried in the eliciting PPDU as defined by the acknowledgement context.

27.4.3 Negotiation of block ack bitmap lengths

Both the Compressed BlockAck frame and Multi-STA BlockAck frame allow different Block Ack Bitmap subfield lengths. The length of the Block Ack Bitmap subfield is indicated in the Fragment Number subfield of the Block Ack Starting Sequence Control field as defined in 9.3.1.9 (BlockAck frame format). The Block Ack Bitmap subfield length of a BlockAck frame used during a BA session depends on the negotiated buffer size between the originator and the recipient as indicated below:

- When a Compressed BlockAck frame is used:
  - If the negotiated buffer size is within [1, 64] then a BlockAck Bitmap length of 64 shall be used during the BA session
  - If the negotiated buffer size is within [1, 256] then a BlockAck Bitmap length of either 64 or 256 shall be used during the BA session
- When a Multi-STA BlockAck frame is used:
  - If the negotiated buffer size is within [1, 64] then a BlockAck Bitmap length of either 32 or 64 shall be used during the BA session
  - If the negotiated buffer size is within [1, 128] then a BlockAck Bitmap length of 32, 64 or 128 shall be used during the BA session
  - If the negotiated buffer size is within [1, 256] then a BlockAck Bitmap length of 32, 64, 128 or 256 shall be used during the BA session

The recipient shall not include in the Buffer Size field of an ADDBA Response frame a value that would cause the BlockAck Bitmap length of its block ack responses to exceed the BlockAck Bitmap length that is derived by the Buffer Size field of the ADDBA Request frame sent by the originator.

A recipient shall not include in a transmitted Multi-STA BlockAck frame a BlockAck Bitmap field of size 32 bits that is intended to a STA that has not declared support of its reception in the HE Capabilities element it transmits.

NOTE—The recipient can include in the Multi-STA BlockAck frame BlockAck Bitmap fields of 32 bits for other intended recipients that declare reception support and the nonsupporting recipient needs to parse these fields to be able to locate the block ack information that is intended to it.

A recipient that is the intended receiver of an (multi-TID) A-MPDU, (multi-TID) BlockAckReq frame or MU-BAR variant Trigger frame that solicits an immediate BlockAck frame response for each TID shall follow the rules defined in 10.24.7 (HT-immediate block ack extensions) except that:

— *WinSizeR* is set to the smaller of *BitmapLength* and the value of the Buffer Size field of the associated ADDBA Response frame that established the block ack agreement, where the *BitmapLength* is the largest value for the BlockAckBitmap that can be used by the recipient

— The Starting Sequence Number subfield of the Block Ack Starting Sequence Control subfield shall be set to any value in the range from (*WinEndR* – *BitmapLength* + 1) to *WinStartR*

— The values in the recipient's record of status of MPDUs beginning with the MPDU for which the Sequence Number subfield value is equal to *WinStartR* and ending with the MPDU for which the Sequence Number subfield value is equal to *WinEndR*, wherein the length of the BlockAck Bitmap field shall be greater than or equal to the smallest *BitmapLength* that is greater than *WinEndR* – *WinStartR*

NOTE 1—An HE STA follows the rules in 10.24.7 (HT-immediate block ack extensions) where the value 64 is replaced with *BitmapLength*, and the value 63 is replaced with *BitmapLength* minus 1.

NOTE 2—An HE STA can generate a Block Ack frame with variable length Block Ack Bitmap field in which case the STA ensures that the Block Ack frame response fits within the remaining duration of the TXOP.

If the HE Fragmentation Support subfield in the HE Capabilities element it transmits is 3, then the LSB of the Fragment Number subfield of the BA frame may be set to 1. If the LSB of the Fragment Number subfield of the BA frame is set to 1, then the BA Bitmap fields are re-mapped as defined in 27.3 (Fragmentation).

27.4.4 Per-PPDU acknowledgment selection rules

27.4.4.1 General

A STA that sends a PPDU to an intended recipient can solicit different immediate responses by using the Ack Policy field of QoS Data or QoS Null frames, the type of the frame (e.g., Action, (multi-TID) BAR, MU-BAR variant Trigger frame, etc.) and the EOF field setting when these frames are carried in an A-MPDU or multi-TID A-MPDU.

An HE AP may solicit BlockAck frame responses from multiple HE STAs using a MU-BAR variant Trigger frame. If an MU-BAR variant Trigger frame is aggregated in an A-MPDU then no other BlockAckReq frames shall be present in the same A-MPDU. The MU-BAR variant Trigger frame shall contain either Compressed BlockAckReq variant or Multi-TID BlockAckReq variant in each of the Per User Info fields. An HE AP shall not send a Multi-TID BlockAckReq (neither as part of a Per User Info field intended to the STA in an MU-BAR variant Trigger frame nor as a BAR frame) to a STA that has not indicated support for multi-TID A-MPDU. (Multi-TID) BlockAckReq, BlockAckReq, and MU-BAR variant Trigger frames indicate the length of the soliciting block ack responses according to the FN settings defined in 9.3.1.9 (BlockAck frame format).

27.4.4.2 DL MU PPDU soliciting an SU PPDU response

An AP that sends a DL MU PPDU that intends to solicit an immediate response carried in an SU PPDU shall set the Ack Policy to Normal Ack (or Implicit BAR) for at most one of the (A-)MPDUs contained in the soliciting DL MU PPDU (see 10.3.2.11.2 (MU acknowledgement procedure for DL MU PPDU in SU format) for an example of this sequence). The AP shall not solicit an immediate response for any of the other (A-) MPDUs carried in the DL MU PPDU. The A-MPDUs carried in the soliciting DL MU PPDU shall not contain an Action frame or a MMPDU that solicits a response. A non-AP STA that receives a DL MU PPDU that solicits an immediate response shall follow the following acknowledgment procedure:

1) If the DL MU PPDU carries a S-MPDU intended to it with the Ack Policy equal to Normal Ack, then the STA shall respond with an Ack frame carried in an SU PPDU

2) If the DL MU PPDU carries an A-MPDU intended to it with the Ack Policy equal to Implicit BAR, then the STA shall respond with an Compressed BlockAck frame carried in an SU PPDU

3) If the DL MU PPDU carries a multi-TID A-MPDU intended to it with the Ack Policy equal to Implicit BAR, then the STA shall respond with a Multi-STA BlockAck frame carried in an SU PPDU

NOTE—The control response frame carried in SU PPDU format follows the rules defined in 10.7.6.5 (Rate selection for control response frames).

27.4.4.3 DL MU PPDU soliciting an HE trigger-based PPDU response

An AP that sends a DL MU PPDU that intends to solicit an immediate response carried in an HE trigger-based PPDU shall set the Ack Policy to MU Ack ('01') for each of the (A-)MPDUs for which it intends to solicit an immediate response (see 10.3.2.11.3 (MU acknowledgement procedure for HE MU PPDU in MU format) for an example of this sequence). An Action frame in the DL MU PPDU is always responded with an HE trigger-based PPDU. A non-AP STA that receives a DL MU PPDU that solicits an immediate response shall follow the following acknowledgment procedure:

1) If the DL MU PPDU carries a S-MPDU intended to it that solicits an immediate response, and either an UL MU Response Scheduling A-Control field or a Trigger frame is present, then the STA shall respond with an Ack frame carried in the HE trigger-based PPDU sent as a response.
2) If the DL MU PPDU carries an A-MPDU intended to it that solicits an immediate response, and either a Trigger frame or UL MU Response Scheduling A-Control field is present, then the STA shall respond with a Compressed BlockAck frame carried in the HE trigger-based PPDU sent as a response.
3) If the DL MU PPDU carries a multi-TID A-MPDU intended to it that solicits an immediate response, and either a Trigger frame or an UL MU Response Scheduling A-Control field is present, then the STA shall respond with a Multi-STA BlockAck frame carried in the Trigger-based PPDU sent as a response.

27.4.4.4 HE trigger-based PPDU soliciting a DL SU PPDU response

A non-AP STA that sends an HE trigger-based PPDU as a response to a Basic variant Trigger frame that intends to solicit an immediate response shall set the Ack Policy to Normal Ack/Implicit BAR (see 10.3.2.11.4 (MU acknowledgement procedure for an UL MU transmission) for an example of this sequence). If the HE AP intends to send the response in a DL SU PPDU format, then the HE AP shall follow the following acknowledgment procedure:

1) If the HE trigger-based PPDU carries a Single MPDU from a single STA that solicits an immediate response, then the HE AP shall respond with either an Ack frame or a Multi-STA BlockAck frame with the Ack Type field set to 1 carried in a DL SU PPDU format.
2) If the HE trigger-based PPDU carries an A-MPDU from a single STA that solicits an immediate response, then the HE AP shall respond with a Compressed BlockAck frame, a Multi-STA Block-Ack with the Ack Type field set to 1 and the TID field set to 14 or a Multi-STA BlockAck frame with the Ack Type field set to 0 carried in a DL SU PPDU format.
3) If the HE trigger-based PPDU carries a Multi-TID A-MPDU that solicits an immediate response from a single STA then the HE AP shall send a Multi-STA BlockAck frame carried in a DL SU PPDU format.

If the HE trigger-based PPDU carries Single MPDUs, A-MPDUs, or multi-TID A-MPDUs from more than one STA, or a combination of Single MPDUs from a subset of STAs, A-MPDUs from another subset of STAs, or multi-TID A-MPDUs from another subset of STAs then the AP shall respond with a Multi-STA BlockAck frame carried in a DL SU PPDU format that contains the appropriate settings in each Per STA Info field intended to each STA as defined in the previous subclauses.

27.4.4.5 HE trigger-based PPDU soliciting a DL MU PPDU response

A non-AP STA that sends an HE trigger-based PPDU as a response to a Basic variant Trigger frame that intends to solicit an immediate response shall set the Ack Policy to Normal Ack/Implicit BAR (see 10.3.2.11.4 (MU acknowledgement procedure for an UL MU transmission) for an example of this sequence). If the HE AP intends to send the response in an HE MU PPDU format, then the HE AP shall follow the following acknowledgment procedure:

a) If the HE trigger-based PPDU carries an S-MPDU from more than one STA, or (multi-TID) A-MPDU from more than one STA, or a combination of an S-MPDU from some STAs and (multi-TID) A-MPDU from other STAs, then the HE-AP shall do one of the following:
   - The AP shall respond with Ack frame or an individually addressed Multi-STA BlockAck frame to each of the STAs from which a Single MPDU that solicited an immediate response was received, and with a Compressed BlockAck frame or a Multi-STA BlockAck frame to each of the STAs from which an A-MPDU that solicited an immediate response was received, or a Multi-STA BlockAck frame to each of the STA from which a multi-TID A-MPDU that solicited an immediate response was received. The control response frames for each STA shall be sent in the allocated RU that is identified by the AID of each STA.
   - The AP may respond with group addressed Multi-STA BlockAck frame(s) in an HE MU PPDU if the receivers of group-addressed Multi-STA BlockAck frame announce the support the reception of MU Multi-STA BlockAck frame. The Ack Type field shall be set according to the acknowledgement context.. A HE AP should only transmit a group addressed Multi-STA BlockAck frame in a DL MU PPDU to a non-AP HE STA *n* on the (broadcast RU) RU (26/52/106/242/484/996) that includes the RU used for receiving the immediate preceding HE trigger-based PPDU from STA *n*. There shall be no more than one Multi-STA BlockAck frame that is addressed to multiple recipients carried in a broadcast RU of the DL MU PPDU.

27.5 MU operation

27.5.1 HE DL MU operation

27.5.1.1 General

HE DL MU operation allows an AP to transmit simultaneously to one or more non-AP STAs in DL OFDMA, DL MU-MIMO or both.

An AP shall not transmit to a STA an HE MU PPDU with the HE-SIG-B allocating spatial streams to more than one recipient STA, unless the STA sets the Downlink MU-MIMO On Partial Bandwidth Rx subfield of the HE Capabilities element to 1.

The transmission of each RU in an HE MU PPDU shall be padded to end at the same time, indicated by the L-SIG field as described in 28.3.10.5 (L-SIG).

The padding procedure for each A-MPDU in an HE MU PPDU is defined in 27.10.3 (A-MPDU padding for an HE trigger-based PPDU).

A STA shall not transmit a DL OFDMA With MIMO PPDU that contains a unicast RA that corresponds to a STA from which it has not received an HE Capabilities element with the DL OFDMA With MIMO Support field set to 1.

27.5.1.2 HE MU PPDU payload

The Type and Subtype subfields in the Frame Control field and address type (individually addressed or group addressed) of MPDUs may be different across A-MPDUs in different RUs within a same HE MU PPDU.

Two STA-ID fields in HE-SIG-B shall not have the same value, unless the value is 2046, which is used to indicate an unallocated RU. If an AP sets one of the STA-ID field in the HE-SIG-B field to match the AID of a non-AP STA, then the non-AP STA may disregard any broadcast RU in the same HE MU PPDU.

An MPDU sent in a broadcast RU of an HE MU PPDU shall not include information intended for a STA that is identified as the recipient of another RU in the same HE MU PPDU.

27.5.1.3 HE bandwidth query report operation for DL MU

A non-AP STA with A-BQR Support subfield of its HE Capabilities element equal to 1 delivers bandwidth query reports (BQRs) to assist the AP in allocating DL MU and UL MU resources in an efficient way. The non-AP STA can either implicitly deliver BQRs in the BQR A-Control field of a frame transmitted to the AP (unsolicited BQR) or explicitly deliver BQRs in any frame sent to the AP in response to a BQRP variant Trigger frame (solicited BQR).

A non-AP STA reports its channel availability information (unsolicited BQR) to the AP to which it is associated using the BQR A-Control field of frames it transmits as defined below:

— The HE STA may report the channel availability information in the BQR A-Control subfield of frames it transmits if the AP has indicated its support in the A-BQR Support subfield of its HE Capabilities element; otherwise the STA shall not report the channel availability information in the BQR A-Control subfield.

A HE AP can solicit one or more HE non-AP STAs with A-BQR Support subfield of its HE Capabilities element equal to 1 for their BQR(s) by sending a BQRP variant Trigger frame (see 9.3.1.23 (Trigger frame format)). The non-AP STA with A-BQR Support subfield of its HE Capabilities element equal to 1 responds (solicited BQR) as defined below:

— The STA that receives a BQRP variant Trigger frame shall follow the rules defined in 27.5.2.3 (STA behavior) to generate the HE trigger-based PPDU when the Trigger frame contains the STA's AID in any of the Per User Info fields; otherwise the STA shall follow the rules defined in 27.5.2.6 (UL OFDMA-based random access) to gain access to a random RU and generate the HE trigger-based PPDU when the Trigger frame contains one or more random RU(s).

— The STA shall include in the HE trigger-based PPDU one or more QoS Null or QoS Data frames containing the BQR A-Control field with the channel availability information of the STA when the AP has indicated its support in the A-BQR Support subfield of its HE Capabilities element. The HE STA shall not solicit an immediate response for the frames carried in the HE trigger-based PPDU (e.g., by setting the Ack Policy subfield of the frame to Normal Ack or Implicit BAR).

27.5.2 UL MU operation

27.5.2.1 General

The UL MU operation allows an AP to solicit simultaneous immediate response frames from one or more non-AP STAs. Non-AP STAs transmit their response frames using HE trigger-based PPDU format, in either UL OFDMA, UL MU-MIMO, or both, except when the Trigger frame is of type MU-RTS, in which case the response (CTS) is sent in a non-HT PPDU format (see 10.3.2.8a (MU-RTS/CTS procedure)).

An HE STA with dot11ULMUMIMOOptionImplemented set to true shall set B22 of the UL MU subfield of the HE PHY Capabilities Information field of the HE Capabilities element it transmits to 1. Otherwise, the HE STA shall set B22 of the UL MU subfield to 0.

A non-AP STA with dot11ULMUMIMOOptionImplemented equal to true is referred to as an UL MU capable STA.

An HE STA shall set the UL MU Response Scheduling Support subfield of the HE Capabilities element it transmits to 1 if its dot11HEULMUResponseSchedulingOptionImplemented is true; otherwise the STA shall set it to 0.

A STA shall not transmit a Trigger frame assigning an MU-MIMO RU in an UL OFDMA PPDU when the RU does not span that entire PPDU bandwidth to a STA from which it has not received an HE Capabilities element with B23 of the UL MU subfield of the HE PHY Capabilities Information field set to 1.

A STA shall not transmit a Trigger frame soliciting a full bandwidth UL MU-MIMO HE trigger-based PPDU from a STA from which it has not received an HE Capabilities element with B22 of the UL MU subfield of the HE PHY Capabilities Information field set to 1.

A STA transmitting an UL OFDMA PPDU shall operate as either a class A or class B device as defined in 28.3.14 (Transmit requirements for an HE trigger-based PPDU). A STA that is a class A device shall set the Class A subfield in HE Capabilities elements that it transmits to 1. A STA that is a class B device shall set the Class A subfield in HE Capabilities elements that it transmits to 0.

27.5.2.2 Rules for soliciting UL MU frames

27.5.2.2.1 General

An AP shall not send to a STA an MPDU that contains an UL MU Response Scheduling A-Control subfield, unless the STA has set the UL MU Response Scheduling Support subfield to 1 in the HE Capabilities element it transmits.

An AP may transmit a PPDU that elicits an HE trigger-based PPDU from one or more STAs by including in the PPDU:

— One or more Trigger frames that includes one or more User Info fields addressed to one or more of the recipient STAs. For recipient STAs that are associated with the AP, the User Info field is addressed to a recipient STA if the value of the AID12 subfield of the User Info field is equal to the AID of the STA or to 0 (indicating a random access allocation).. A value of 0 also indicates that non-associated STAs can transmit on the allocated resource using the random access procedure as described in 27.5.2.6 (UL OFDMA-based random access).

— An UL MU Response Scheduling A-Control subfield of individually addressed MPDUs contained in the HE MU PPDU that:
  - Are carried in a S-MPDU format that solicits an immediate Ack frame (see 10.13.8 (Transport of S-MPDUs))
  - Are carried in an A-MPDU format that solicits an immediate BlockAck frame (see 10.24.7.7 (Originator's behavior))
  - Are carried in a multi-TID A-MPDU format that solicits an immediate Multi-STA BA frame (see 27.10.4 (A-MPDU with multiple TIDs))

NOTE—The AP additionally follows the rules defined in 27.3.3 (Procedure at the originator) when fragments are present in the generated MPDU(s).

More than one Trigger frame may be aggregated in an A-MPDU. If more than one Trigger frame is aggregated in an A-MPDU, all of them shall have the same content.

The following two frames shall not be present in the same A-MPDU:

— A Trigger frame with a User Info field addressed to a STA
— An MPDU that contains an UL MU Response Scheduling A-Control subfield and that is addressed to the same STA

When one or more Trigger Frames are aggregated with other frames in an A-MPDU, the following ordering rules apply:

— When an Ack, BlockAck or Multi-STA BlockAck frame is not present in the A-MPDU, a Trigger frame shall be the first MPDU in the A-MPDU
— When an Ack, BlockAck or Multi-STA BlockAck frame is present in the A-MPDU, the Ack, BlockAck or Multi-STA BlockAck frame shall be the first MPDU in the A-MPDU and a Trigger frame shall follow the Ack, BlockAck or Multi-STA BlockAck frame

A non-AP STA shall not send a Trigger frame or an MPDU carrying an UL MU Response Scheduling A-Control field.

A transmitted Trigger frame that contains a User Info field with the AID of a non-AP STA may contain a Padding field, whose length shall ensure that at least *MinTrigProcTime*, in microseconds, passes from the end of the User Info field that contains that AID and the end of the PPDU that contains the Trigger frame, where the *MinTrigProcTime* is equal to the value specified by the non-AP STA in the Trigger Frame MAC Padding subfield of the HE Capabilities element it transmits. The AP shall apply the Trigger Frame MAC Padding field with duration corresponding to the longest value among all STAs that have requested extra *MinTrigProcTime* through Trigger Frame MAC Padding Duration capability.

The AP shall ensure that the duration of the symbols that follow the symbol in the Trigger Frame that contains the last bit of the STA's User Info field is larger than or equal to the *MinTrigProcTime* value specified by the STA.

NOTE 1—The start of the Padding subfield is identified by a User Info field that has a value of the AID equal to 2047, and the remaining subfields of the Padding field are set to 1.

NOTE 2—This rule applies to all variants of the Trigger frame (Basic, MU-BAR, MU-RTS, etc).

27.5.2.2.2 Allowed settings of the Trigger frame fields and UL MU Response Scheduling A-Control subfields

An AP that transmits a Trigger frame shall set the TA field of the frame to one of the following:

— The MAC address of the AP transmitting the frame when dot11MultiBSSIDActivated is false or when dot11MultiBSSIDActivated is true and the Trigger frame is directed to STAs that intend to communicate with the AP
— The MAC address of the transmitted BSSID when dot11MultiBSSIDActivated is true and the Trigger frame is directed to STAs that intend to communicate with at least two different BSSs of the multiple BSSID set and that have indicated reception support for this Trigger frame in the Multiple BSSID Control Support field of the HE Capabilities element it transmits (see 11.1.3.8 (Multiple BSSID procedure)).

NOTE—All MPDUs within an A-MPDU carried in an HE trigger-based PPDU have the same RA (see 9.7.3 (A-MPDU contents). The settings of the address fields of MPDUs within the A-MPDU depend on the type and subtype of the MPDU as defined in 9.3 (Format of individual frame types).

If an HE AP does not receive an HE Capabilities element with the Rx Control Frame To MultiBSS field equal to 1 from a STA, the HE AP shall not send a Trigger frame whose destination STAs associate with more than one APs to the STA. The RA field of the frames sent in response to a MU-RTS frame is set as defined in 9.3.1.3 (CTS frame format). The RA field of the MPDUs sent in response of a MU-BAR is set as defined in 9.3.1.9 (BlockAck frame format). BlockAck frame and Data frames whose RAs are different shall not be aggregated in one A-MPDU in responding to an MU-BAR frame. The RA field of the Data frames and Management frames sent in response to a Trigger frame shall be set to the MAC address of the destination AP.

An AP shall not set any subfields of the Common Info field of a Trigger frame to a value that is not supported by all the recipient STAs of the Trigger frame.

An AP shall set all the subfields, except the Trigger Type subfield, of the Common Info field of a Trigger frame to the same value of the corresponding subfield of the Common Info field of any other Trigger frame that is carried in the same PPDU. An AP shall set the UL PPDU Length and DL Tx Power subfields of an UL MU Response Scheduling A-Control subfield to the same value of the corresponding subfield of any UL MU Response Scheduling A-Control that is carried in the same PPDU. An AP shall set the following subfields of the Common Info field of a Trigger frame accordingly if an UL MU Response Scheduling A-Control subfield is carried in an MPDU within the same PPDU:

- MU-MIMO LTF Mode and STBC are set to 0
- Number of HE-LTF Symbols is set to 1
- Spatial Reuse is set to SR_Disallowed
- GI and LTF Type is set to 3 if the carrying PPDU TXVECTOR parameter CP_LTF_TYPE is 4x LTF + 3.2 µs CP or 2x LTF + 1.6 µs CP; otherwise is set to 2
- CS Required subfield is set to 0

NOTE—STAs obtain the common information either explicitly, or implicitly or both. Explicit information is obtained in the Common Info field of a Trigger frame, or in the UL PPDU Length and DL TX Power subfields of the UL MU Response Scheduling A-Control field contained in the soliciting PPDU. Implicit information is obtained in previously exchanged frames with the AP, e.g., in the BSS Color and the Default PE Duration subfields of the HE Operation element, or from default values specified in 27.5.2.3 (STA behavior).

An AP shall not set any subfields of the User Info field of a Trigger frame to a value that is not supported by the recipient STAs of the User Info field. An AP shall not set any subfields of an UL MU Response Scheduling A-Control subfield in an HE variant HT Control field to a value that is not supported by the recipient STAs of the User Info field.

If a Trigger frame is transmitted in an RU of an HE MU PPDU and the RU is addressed to multiple STAs, then the Trigger frame shall not include any User Info fields addressed to a STA that is identified as recipient of another RU or spatial stream of the same HE MU PPDU.

An HE variant HT Control field with an UL MU Response Scheduling A-Control subfield shall not be included in an MPDU that is group addressed.

If an AP includes one or more Trigger Frames or HE variant HT Control fields with an UL MU Response Scheduling A-Control subfield, then they shall collectively elicit HE trigger-based PPDU responses such that at least one RU is allocated for each 20 MHz channel occupied by the eliciting PPDU. An AP shall not allocate UL subchannel in any 20 MHz channel that is not occupied by the immediately preceding DL PPDU.

The responding STA shall not aggregate QoS Data frames in the multi-TID A-MPDU with a number of TIDs that exceeds the value indicated by the TID Aggregation Limit subfield in the Trigger Dependent User Info field of a Basic Trigger frame (see 9.3.1.23.1 (Basic Trigger variant)) intended to it.

The AP shall set the value in the TID Aggregation Limit subfield in the Type Dependent User Info field to 0 or 1 for an HE STA that has 0 in the Multi-TID Support field of the HE MAC Capabilities Information field of the HE Capabilities element it transmits and is identified by the AID12 subfield of the User Info field of a Basic Trigger frame (see 9.3.1.23 (Trigger frame format)).A value 0 indicates to the STA that it shall not solicit any immediate response for the MPDUs that the STA aggregates in the HE trigger-based PPDU.A value greater than 0 indicates the number of TIDs that the STA can aggregate in the A-MPDU carried in the HE trigger-based PPDU (see 27.10.4 (A-MPDU with multiple TIDs)).

The AP may assign any value between 0 and 7 in the TID Aggregation Limit subfield in the Trigger Dependent User Info field for an HE STA that has a nonzero value in the Multi-TID Support subfield of the HE MAC Capabilities Information field of the HE Capabilities element it transmits and is identified by the AID12 subfield of the User Info field of a Basic Trigger frame.

The AP may assign any value in the AC Preference Level subfield in the Trigger Dependent User Info field for an HE STA identified by the AID12 subfield of the User Info field of a Basic Trigger frame.

The AP may assign any value defined in Table 9-25i (Preferred AC subfield encoding) in the AC Preference Level subfield in the Trigger Dependent User Info field to 1 for an HE STA and identified by the AID12 subfield of the User Info field of a Basic Trigger frame.

NOTE—A STA follows the rules in 27.10.4 (A-MPDU with multiple TIDs) for aggregating the QoS Data frames with multiple TIDs in HE trigger-based PPDUs.

27.5.2.2.3 AP access procedures for UL MU operation

When an AP receives an immediate response with at least one MPDU from at least one STA solicited by a Trigger frame, the procedures described in 9.22.2.7 (Multiple frame transmission in an EDCA TXOP) apply.

When an AP does not receive an immediate response with at least one MPDU from at least one STA solicited by a Trigger frame, i.e., transmission failure, the backoff procedure described in 9.22.2.2 (EDCA backoff procedure) applies.

An AP may use any AC for sending a PPDU that contains only Trigger frames. If the PPDU contains frames that are not Trigger frames in addition to a Trigger frame, then the AP shall follow the rules defined in 10.22.2.6 (Sharing an EDCA TXOP).

An AP may send the Trigger frame using any access category and follows the rules defined in 10.22.2 (HCF contention based channel access (EDCA)) for obtaining and sharing the TXOP.

27.5.2.3 STA behavior

A STA shall not send an HE trigger-based PPDU unless it is explicitly triggered by an AP in one of the operation modes described in this subclause.

The inter-frame space between a PPDU that contains a Trigger frame or contains an UL MU Response Scheduling A-Control field that solicits an immediate response and the HE trigger-based PPDU is SIFS.

A STA shall commence the transmission of an HE trigger-based PPDU at the SIFS time boundary after the end of a received PPDU, when all the following conditions are met

- The received PPDU contains either a Trigger frame (that is not an MU-RTS variant) with a User Info field addressed to the STA, or an MPDU addressed to the STA that contains an UL MU Response Scheduling A-Control subfield. The User Info field is addressed to a STA if the AID12 subfield is equal to the AID of the STA and the STA is associated with the AP. If the STA is not associated with the AP, TBD.
- The CS Required subfield in the Trigger frame is 1 and the UL MU CS condition described in 27.5.2.4 (UL MU CS mechanism) indicates the medium is idle, or the CS Required subfield in a Trigger frame is 0.
- Otherwise, a STA shall not send an HE trigger-based PPDU

A STA transmitting an HE trigger-based PPDU in response to a Trigger frame sets the TXVECTOR parameter as follows:

- The FORMAT parameter shall be set to HE_TRIG
- The PE_DURATION parameter shall be set according to the value of the Packet Extension field in the soliciting Trigger frame
- The TXOP_DURATION parameter shall be set according the rules defined in 27.2.2 (Updating two NAVs)
- The BSS_COLOR parameter shall be set as follows:
  - If the preceding Trigger frame was received in an HE PPDU, then set to the value of the RXVECTOR parameter BSS_COLOR of the HE PPDU
  - If the Trigger frame was received in a non-HE PPDU, then set to the value of the BSS Color subfield of the most recently received HE Operation element for that BSS
- The L_LENGTH parameter shall be set to the value indicated by the Length subfield of the eliciting Trigger frame
- The GI_TYPE and HE_LTF_TYPE parameters shall be set to the value indicated by the GI and LTF Type subfield of the Common Info field of the eliciting Trigger frame
- The NUM_STS parameter shall be set to the number of space time streams indicated by the Number Of Spatial Streams subfield of the SS Allocation field of the User Info field and STBC field in the Common Info field of the Trigger frame
- The CH_BANDWIDTHW parameter shall be set to the value of the BW field in the Common Info field of the eliciting Trigger frame
- The HE_LTF_MODE parameter shall be set to the value indicated by the MU-MIMO LTF Mode subfield of the Common Info field of the eliciting Trigger frame
- The NUMBER_HE_LTF_SYM parameter shall be set to the value indicated by the Number Of HE-LTF Symbols subfield of the Common Info field of the eliciting Trigger frame
- The STBC parameter shall be set to the value indicated by the STBC subfield of the Common Info field of the eliciting Trigger frame
- The LDPC_EXTRA_SYM parameter shall be set to the value indicated by the LDPC Extra Symbol Segment subfield of the Common Info field of the eliciting Trigger frame
- The SPATIAL_REUSE parameter shall be set to the value of the Spatial Reuse field in the Common Info field of the eliciting Trigger frame
- The HE_SIGA_RESERVED parameter shall be set to the value of the HE-SIG-A Reserved field in the Common Info field of the eliciting Trigger frame
- The MCS parameter shall be set to shall be set to the value of the MCS field in the Common Info field of the eliciting Trigger frame
- The DCM parameter shall be set to the value indicated by the DCM subfield of the User Info field of the eliciting Trigger frame
- The STARTING_STS_NUM parameter shall be set to shall be set to the value of the Starting Spatial Stream subfield of the SS Allocation field in the Common Info field of the eliciting Trigger frame
- The FEC_CODING parameter shall be set to the value indicated by the Coding Type subfield of the User Info field of the eliciting Trigger frame
- The RU_ALLOCATION parameter shall be set to the value indicated by the RU Allocation field of the User Info subfield of the eliciting Trigger frame
- The TXPWR_LEVEL_INDEX parameter shall be set to the value based on the Transmit Power Control for HE trigger-based PPDU and based on the value of the AP Tx Power subfield in the Common Info field and the Target RSSI subfield in the User Info field of the eliciting Trigger frame (28.3.14.2 (Power pre-correction)).

A STA transmitting an HE trigger-based PPDU in response to soliciting MPDU(s), containing an UL MU Response Scheduling A-Control subfield, shall set the TXVECTOR parameters as follows:

— N_{SYM} shall be set to the F_{VAL} + 1, where F_{VAL} is the value of the UL PPDU Length subfield of the UL MU Response Scheduling subfield
— UL_TARGET_RSSI, DL_TX_POWER, RU_ALLOCATION, and MCS parameters shall be set to the values of UL Target RSSI, DL TX Power, RU Allocation, and UL MCS subfields of the UL MU Response Scheduling subfield, respectively.
— BW shall be equal to the bandwidth of the soliciting DL MU PPDU
— BSS_COLOR, and DCM shall be set to the values of the RXVECTOR parameters BSS_COLOR, and DCM of the soliciting DL MU PPDU, respectively
— MU_MIMO_LTF_MODE, LDPC_EXTRA, NSTS, STBC, CODING TYPE, SS_ALLOCATION shall all be set to 0
— SPATIAL_REUSE shall be set to the value indicating SR_Disallowed
— PE_DURATION shall be set to the default PE duration value for UL MU response scheduling, which is indicated by the AP in the Default_PE Duration subfield of the HE Operation element it transmits, and the pre-FEC padding factor shall be set to 4 (see 28.3.12 (Packet extension))
— TXOP_DURATION parameter shall be set according the rules defined in 27.2.2 (Updating two NAVs)
— CP_LTF_TYPE parameter shall be set to indicate 4x LTF + 3.2 μs CP if the RXVECTOR parameter CP_LTF_TYPE is 4x LTF + 3.2 μs CP or 2x LTF + 1.6 μs CP ; otherwise shall be set to indicate 2x LTF + 1.6 μs CP

NOTE 1—The HE trigger-based PPDU in this case is only sent in UL OFDMA format and CS is not required prior to its transmission (see 27.5.2.4 (UL MU CS mechanism)).

NOTE 2—The use of BCC limits the available RU sizes as defined in 28.3.11.8 (BCC interleavers).

The STA that responds to a DL MU PPDU containing MPDU(s) addressed to it that include UL MU Response Scheduling A-Control subfield(s) follows the rules defined in 10.3.2.9 (Ack procedure) for generating the Ack frame, the rules defined in 10.24.7.5 (Generation and transmission of BlockAck frames by an HT STA or DMG STA) for generating the BlockAck frame, and the rules defined in 27.4 (Block acknowledgement) for generating the Multi-STA BlockAck frame. The STA shall construct the A-MPDU carried in the trigger-based PPDU as defined in Table 9-428 (A-MPDU contents MPDUs in the control response context) when the A-MPDU containing the UL MU Response Scheduling A-Control subfield solicits an immediate response and as defined in Table 9-426 (A-MPDU contents in the data enabled no immediate response context) when the A-MPDU does not solicit an immediate response.

NOTE—The STA additionally follows the rules defined in 27.3.3 (Procedure at the originator) when fragments are present in the soliciting (A-)MPDU(s).

The MAC padding procedure is described in 10.42.2.1.2.

The content of each A-MPDU in an HE trigger-based PPDU is defined in 9.7.3 (A-MPDU contents) in 27.10.3 (A-MPDU padding for an HE trigger-based PPDU) and subject to the following additional constraints:

— If the Trigger Type field of a Trigger frame is not Basic Trigger, then the STA shall include in the response A-MPDU at least one MPDU of the required type. A Beamforming Report Poll Trigger frame solicits HE Compressed Beamforming Feedback frames (see 27.6 (HE sounding protocol), an MU BAR Trigger frame solicits BlockAck frames (see 27.4 (Block acknowledgement)), and a BSRP Trigger frame solicits QoS Null frames (see 27.5.2.5 (HE buffer status feedback operation for UL MU). The MPDUs included in the response shall not solicit a response.

- If the Trigger Type field of the soliciting Trigger frame is Basic Trigger and the STA does not have a frame of the required type, the STA shall either not transmit a response or transmit one or more QoS Null frames.

A STA that is an intended receiver of a Trigger frame that is not a Basic Trigger frame shall construct the A-MPDU carried in the HE trigger-based PPDU as defined in 9-428 (A-MPDU contents MPDUs in the control response context). A STA that is an intended receiver of a Basic Trigger frame may include MPDUs with any TID in the HE trigger-based PPDU sent in response to a Trigger frame subject the rules of 27.10.4 (A-MPDU with multiple TIDs).

NOTE 1—An AP can include other MPDUs in a soliciting DL MU PPDU that contains Trigger frames as specified in 9.7.3 (A-MPDU contents).

NOTE 2—The frame type of MPDUs may be different across A-MPDUs within a same HE trigger-based PPDU..

27.5.2.4 UL MU CS mechanism

The ED-based CCA and virtual CS functions are used to determine the state of the medium if CS is required before responding to a received Trigger frame. ED-based CCA for UL MU CS follows the same procedure as defined in VHT receiver specification. ED-based CCA is described in 21.3.18.5.2 (CCA sensitivity for operating classes requiring CCA-ED) and virtual CS is defined in 10.3.2.1 (CS mechanism).

A NAV is considered in virtual CS for a STA that is solicited by a Trigger frame for transmission unless one of the following conditions is met:

- The response generated by the STA contains an Ack frame or a BlockAck frame and the Length subfield in the Common Info field of the Trigger frame is less than or equal to 418
- The NAV was set by an intra-BSS frame

NOTE 1—The details of how a STA is solicited by the Trigger frame for transmission are described in 27.5.2.2.2 (Allowed settings of the Trigger frame fields and UL MU Response Scheduling A-Control subfields).

If one or both of the NAVs are considered and the considered NAV's counter is nonzero, then the virtual CS indicates busy. Otherwise, the virtual CS is idle.

If the CS Required subfield in a Trigger frame is set to 1, the STA shall consider the status of the CCA (using Energy Detect defined in 21.3.18.5.2 CCA sensitivity for operating classes requiring CCA-ED) and the virtual carrier sense (NAV) before UL MU transmission in response to the Trigger frame. In this case, the STA shall sense the medium using energy-detect (ED) after receiving the PPDU that contains the Trigger frame (i.e. during the SIFS time), and it shall perform the energy-detect (ED) at least in the subchannel that contains the STA's UL allocation, where the sensed subchannel consists of either a single 20 MHz channel or multiple of 20 MHz channels. The STA may transmit an HE trigger-based PPDU when the 20 MHz channels containing the allocated RUs in the Trigger frame are considered idle; if the STA detects that the 20 MHz channels containing the allocated RUs are not all idle, then the STA shall not transmit anything in the allocated RUs.

If the CS Required subfield in a Trigger frame is set to 0 or an UL MU response scheduling A-Control field is included in the received (A-)MPDU that solicits a response, the STA may respond with an HE trigger-based PPDU without regard to the busy/idle state of the medium.

The CS Required subfield in the MU-RTS variant of the Trigger frame shall be set to 1.

The AP shall set the CS Required subfield to 1 except when all solicited HE trigger-based PPDUs contain an Ack or BlockAck frame and the Length subfield in the Common Info field of the Trigger frame is less than or equal to 418.

NOTE—The threshold value 418 of the Length subfield in the Common Info field of the Trigger frame is obtained from the maximum HE trigger-based PPDU duration, 584 μs, that can be solicited by the UL MU Response Scheduling A-Control subfield based on Equation (28-16). This duration is the sum of 20 μs for the L-STF, L-LTF and L-SIG fields, 20 μs for the RL-SIG, HE-SIG-A and HE-STF fields, 16 μs for the 4x HE-LTF field with 3.2 μs GI, 512 μs for 32 OFDM symbols in the Data field with 3.2 μs GI, and 16 μs PE field (see 9.2.4.6.4.2 (UL MU response scheduling), 27.5.2.3 (STA behavior), and 28.3.4 (HE PPDU formats)).

27.5.2.5 HE buffer status feedback operation for UL MU

A non-AP STA delivers buffer status reports (BSRs) to assist its AP in allocating UL MU resources in an efficient way. The non-AP STA can either implicitly deliver BSRs in the QoS Control field or BSR A-Control field of any frame transmitted to the AP (unsolicited BSR) or explicitly deliver BSRs in any frame sent to the AP in response to a BSRP variant Trigger frame (solicited BSR).

A non-AP STA reports its buffer status (unsolicited BSR) to the AP to which it is associated using either the QoS Control field or the BSR A-Control field of frames it transmits as defined below:

- The HE STA shall report the buffer status for a given TID in the Queue Size subfield of the QoS Control field in QoS Data or QoS Null frames it transmits; except that the STA may set the Queue Size subfield to 255 to indicate an unknown/unspecified BSR for that TID.
  - The HE STA may aggregate multiple QoS Data frames or QoS Null frames in an A-MPDU to report the buffer status for different TIDs. The HE STA shall follow the A-MPDU aggregation rules defined in 27.10.4 (A-MPDU with multiple TIDs) for aggregating QoS Data frames with multiple TIDs. The HE STA does not follow the rules defined in 27.10.4 (A-MPDU with multiple TIDs) for QoS Null frames whose Ack Policy subfield is No Ack.
- The HE STA may report the buffer status in the BSR A-Control subfield of frames it transmits if the AP has indicated its support in the A-BSR Support subfield of its HE Capabilities element; otherwise the STA shall not report the buffer status in the BSR A-Control subfield.
  - The HE STA shall report the buffer status for its preferred AC, indicated by the ACI High subfield, in the Queue Size High subfield of the BSR A-Control field; except that the STA may set the Queue Size High subfield to 255 to indicate an unknown/unspecified BSR for that AC
  - The HE STA shall report the buffer status for all ACs, indicated by the ACI Bitmap subfield, in the Queue Size All subfield of the BSR A-Control field; except that the STA may set the Queue Size All subfield to 255 to indicate an unknown/unspecified BSR for those ACs(#2190, 2191)
  - The HE STA shall set the Delta TID subfield according to Table 9-XX (Delta TID subfield encoding), and the Scaling Factor subfield as defined in 9.2.4.6.4.5 (Buffer Status Report (BSR)).

NOTE 1—The STA can send an unsolicited BSR in response to Basic variant Trigger frames (with or without random RUs, as defined in 27.5.2.3 (STA behavior) and in 27.5.2.6 (UL OFDMA-based random access)) or it can send the unsolicited BSR after accessing the WM using EDCA.

NOTE 2—The STA can include both the QoS Control and the BSR A-Control field in the same frame and it can set the Queue Size subfield of either of them to a value of 255.

An AP can also solicit one or more non-AP STAs for their BSR(s) by sending a BSRP variant Trigger frame (see 9.3.1.23 (Trigger frame format)). The non-AP STA responds (solicited BSR) as defined below:

- The STA that receives a BSRP variant Trigger frame shall follow the rules defined in 27.5.2.3 (STA behavior) to generate the trigger-based PPDU when the Trigger frame contains the STA's AID in any of the Per User Info fields; otherwise the STA shall follow the rules defined in 27.5.2.6 (UL OFDMA-based random access) to gain access to a random RU and generate the Trigger-based PPDU when the Trigger frame contains one or more random RU(s).
- The STA shall include in the HE trigger-based PPDU one or more QoS Null frames containing one or more of the following:

  - The QoS Control field(s) with Queue Size subfields for each of the TIDs for which the STA has buffer status to report to the AP.
  - The BSR A-Control field with the Queue Size All subfield indicating the queue size for all the ACs, indicated by the ACI Bitmap subfield, for which the STA has buffer status to report to the AP when the AP has indicated its support in the A-BSR Support subfield of its HE Capabilities element. The STA shall set Delta TID, SF, ACI High and Queue Size High subfields of the BSR A-Control field as defined in 9.2.4.6.4.5 (Buffer Status Report (BSR))).

— The HE STA shall not solicit an immediate response for the frames carried in the trigger-based PPDU (e.g., by setting the Ack Policy subfield of the frame to Normal Ack or Implicit BAR).

NOTE—Similar to unsolicited BSR, the STA can set Queue Sizes in either QoS Control or BSR A-Control field to 255 to indicate unknown/unspecified BSR for a TID, AC or all AC.

An AP may include a BSRP Trigger frame together with other control, data and management frames in one A-MPDU to a STA if the HE Capabilities element received from the STA has the BSRP A-MPDU Aggregation field equal to 1. If a STA receives a BSRP Trigger frame aggregated with control, data and management frames that asks for acknowledgement, the acknowledgement has high priority to be transmitted.

27.5.2.6 UL OFDMA-based random access

27.5.2.6.1 General

A STA shall set the UL OFDMA RA Support subfield in the HE Capabilities element to 1 if it supports UL OFDMA-based random access and set it 0, otherwise.

UL OFDMA-based random access is a mechanism for HE STAs to randomly select resource units (RUs) assigned by an AP in a soliciting Trigger frame that contains RUs for random access. An RU for random access shall be identified by an AID12 subfield equal to 0 contained in a User Info field of a Trigger frame. An HE AP may transmit a Basic Trigger frame or a BSRP Trigger frame that contains one or more RUs for random access.

The HE AP may include the RAPS element (see 9.4.2.220 (OFDMA-based Random Access Parameter Set (RAPS) element) in Beacon and Probe Response frames it transmits. The AP shall indicate the range of OFDMA contention window (OCW) in the RAPS element for HE STAs to initiate random access following the Trigger frame transmission.

An HE STA shall use the OCWmin and OCWmax values indicated in the RAPS element within the most recently received Beacon or Probe Response regardless of the access category of traffic the HE STA intends to transmit.

NOTE—If the STA does not receive the RAPS element, the STA does not transmit any HE trigger-based PPDU using random access RUs.

The non-AP STA with dot11OFDMARandomAccessOptionImlemented set to true shall maintain an internal OFDMA backoff (OBO) counter. The HE STA shall follow the random access procedure defined in 27.5.2.6.2 (Random access procedure) to contend for an RU assigned for random access.

27.5.2.6.2 Random access procedure

In this subclause, the random access procedure is described with respect to UL OFDMA contention parameters. The procedure is also illustrated in Figure 27-1 (Illustration of the UL OFDMA-based random access procedure). The OFDMA contention window (OCW) is an integer with an initial value of OCWmin.

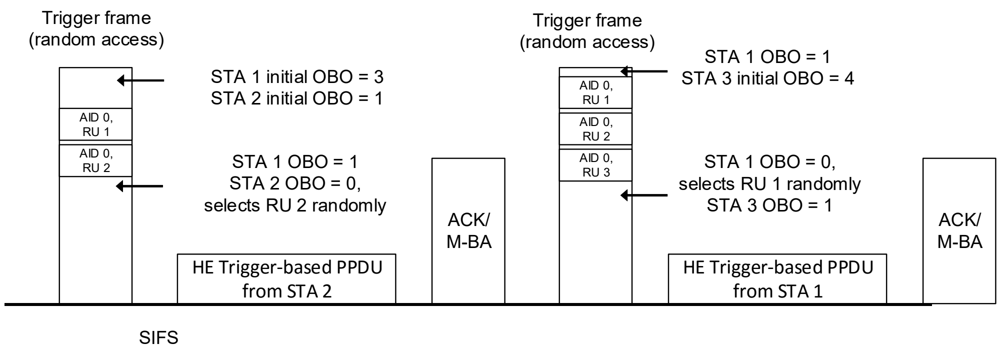


Figure 27-1—Illustration of the UL OFDMA-based random access procedure

An HE AP indicates the values of OCWmin and OCWmax in the RAPS element in a Beacon or Probe Response frame for the random access operation. OCWmax is the upper limit of OCW.

For an initial HE trigger-based PPDU transmission or following a successful HE trigger-based PPDU transmission, when an HE STA obtains the value of OCWmin from the HE AP indicated in the RAPS element, it shall set the value of OCW to the OCWmin and shall initialize its OBO counter to a random value in the range of 0 and OCWmin.

For an HE STA, if the OBO counter is smaller than the number of RUs assigned to AID value 0 in a Trigger frame, then the HE STA shall decrement its OBO counter to zero. Otherwise, the HE STA decrements its OBO counter by a value equal to the number of RUs assigned to AID value 0 in a Trigger frame. For instance, as shown in Figure 27-1 (Illustration of the UL OFDMA-based random access procedure), HE STA 1 and HE STA 2 decrement their nonzero OBO counters by 1 in every RU assigned to AID value 0 for random access within the Trigger frame.

For an HE STA, if the OBO counter is 0 or if the OBO counter decrements to 0, then the STA randomly selects one of the RUs assigned to AID value 0If the selected RU is idle as a result of both physical and virtual carrier sensing as defined in subclause 27.5.2.4 (UL MU CS mechanism), the HE STA transmits its HE trigger-based PPDU in the randomly selected RU. If the selected RU is considered busy as a result of either physical or virtual carrier sensing, then the HE STA shall not transmit its HE trigger-based PPDU in the randomly selected RU and it randomly selects any one of the RUs that are assigned to AID value 0 in the subsequent Trigger frame. If the OBO counter is not zero and does not decrements to 0, the STA resumes with its OBO counter in the next Trigger frame with RUs assigned for random access.

If the HE trigger-based PPDU is successfully transmitted in the randomly selected RU, then the STA shall set its OCW to OCWmin.

NOTE—If the transmitted HE trigger-based PPDU does not solicit an immediate response, then the STA follows the OCW reset rule that applies to successful transmission.

The MU acknowledgment procedure for random access follows the procedure as defined in 10.3.2.10.3 (Acknowledgement procedure for an UL MU transmission).

If a STA transmits an HE trigger-based PPDU that solicits an immediate response in a random access RU and the expected response is not received, the transmission is considered unsuccessful and the STA invokes the UL OFDMA-based random access retransmission procedure as defined in 27.5.2.6.3 (Retransmission procedure for random access).

27.5.2.6.3 Retransmission procedure for random access

If an HE trigger-based PPDU soliciting an immediate response that is sent by a STA in its randomly selected RU (see 27.5.2.6.2 (Random access procedure)) fails, then the STA may attempt to retransmit the HE trigger-based PPDU using random access. This subclause defines the retransmission procedure that a STA may follow using random access.

If the HE trigger-based PPDU is not successfully transmitted in the randomly selected RU, the STA shall update its OCW to $2 \times \text{OCW} + 1$ for every retransmission, until the OCW reaches the value of OCWmax. Once the OCW reaches OCWmax for successive retransmission attempts, the OCW shall remain at the value of OCWmax until the OCW is reset.

27.5.2.7 NDP feedback report procedure

The NDP feedback report is a mechanism for an HE AP to collect short feedbacks from a very high number of HE STAs, in an efficient manner. The feedbacks (e.g. resource requests) are sent without data payloads in response to a Trigger frame. The feedbacks are not for channel sounding. This mechanism is optional for non-AP STA.

27.5.3 HE MU cascading operation

A TXOP can include both DL MU and UL MU transmissions.

If MU Cascading Support field in the HE MAC Capabilities Information field of the HE Capabilities element is set to 1 by both HE AP and HE non-AP STA(s), an HE AP can initiate a cascading sequence of MU PPDUs in a TXOP, allowing alternating HE MU PPDUs and HE trigger-based PPDUs starting with an

HE MU PPDU in the same TXOP, as illustrated in Figure 27-2 (An example of cascading sequence of MU PPDUs).

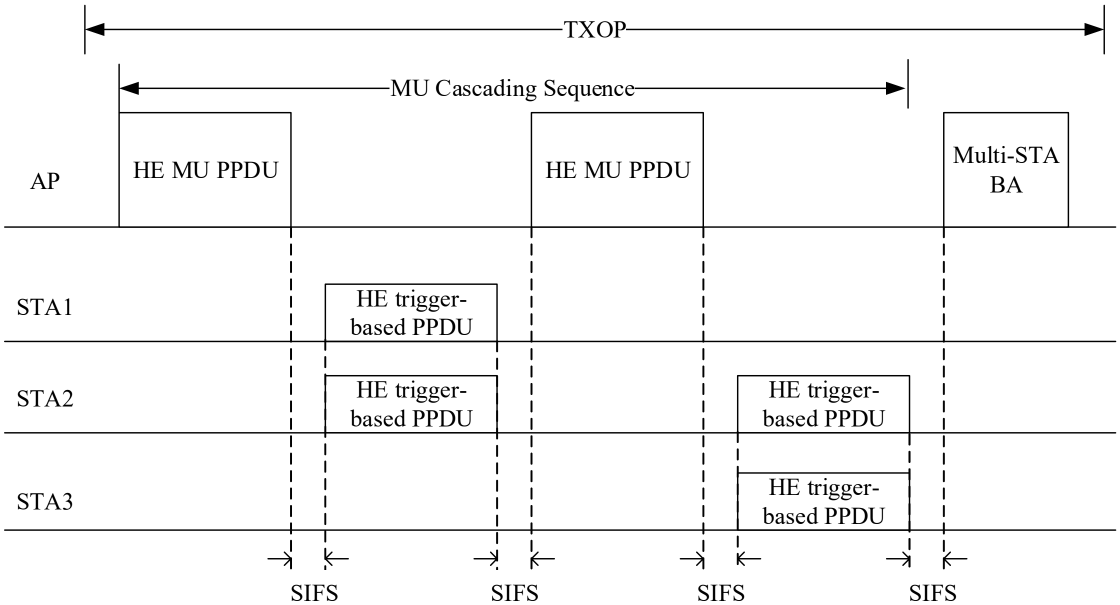


Figure 27-2—An example of cascading sequence of MU PPDUs

An HE MU PPDU transmitted by the AP a SIFS after an HE trigger-based PPDU has the following A-MPDU contents:

— At most one Ack, BlockAck or Multi-STA BlockAck frame for the preceding HE trigger-based PPDU and,

— Zero or more MPDUs and,

— One or more Trigger frames or UL MU Response Scheduling A-Control fields if this is not the last PPDU of the MU cascading sequence.

The presence of an HE MU PPDU with that A-MPDU contents starts an MU cascading sequence within that TXOP.

If MU Cascading Support field in the HE MAC Capabilities Information field of the HE Capabilities element is set to 0 by an HE AP, the HE AP shall not initiate a cascading sequence of MU PPDUs in its TXOP(s).

If MU Cascading Support field in the HE MAC Capabilities Information field of the HE Capabilities element is set to 0 by an HE non-AP STA, the HE AP associated by the HE non-AP STA shall not initiate a cascading sequence of MU PPDUs to the HE non-AP STA in its TXOP(s).

The cascading sequence may have different UL transmitters within each HE trigger-based PPDU. The cascading sequence may have a different set of transmitters in HE trigger-based PPDUs as compared to the HE MU PPDU that immediately follows the HE trigger-based PPDUs within the same TXOP. The cascading sequence may have a different set of receivers in the DL HE MU PPDU as compared to the HE trigger-based PPDUs that immediately follows the DL HE MU PPDU within the same TXOP.

27.6 HE sounding protocol

27.6.1 General

Transmit beamforming and DL MU-MIMO require knowledge of the channel state to compute a steering matrix that is applied to the transmit signal to optimize reception at one or more receivers. HE STAs use the HE sounding protocol to determine the channel state information. As with the VHT sounding protocol, the HE sounding protocol uses explicit feedback mechanism where the HE beamformee measures the channel using a training signal transmitted by the HE beamformer and sends back a transformed estimate of the channel state. The HE beamformer uses this estimate to derive the steering matrix.

27.6.2 Rules for HE sounding protocol sequences

The HE beamformer shall initiate a sounding sequence by transmitting an HE NDP Announcement frame followed by an HE NDP after a SIFS.

If an HE AP does not receive an HE Capabilities element with the Rx Control Frame To MultiBSS subfield in the HE MAC Capabilities Information field equal to 1 from a STA, the HE AP shall not send a NDP Announcement frame whose destination STAs associate with more than one APs to the STA.

If the HE NDP Announcement frame includes more than one STA Info field, the RA field of the HE NDP Announcement frame shall be set to the broadcast address, otherwise it shall be set to the MAC address of the STA whose AID is included in the STA Info field. The HE NDP Announcement frame shall indicate the *Ng*, codebook and *Nc* to be used by the intended receiver STAs for the generation of HE compressed beamforming feedback report except when the HE NDP Announcement frame contains only one STA Info field. When the HE NDP Announcement frame contains only one STA Info field, then the *Ng*, codebook and *Nc* to be used for the generation of the HE compressed beamforming feedback report shall be determined by the recipient of the NDP Announcement frame.

An HE beamformer that transmits an HE NDP Announcement frame with more than one STA Info field shall transmit a Beamforming Report Poll Trigger frame a SIFS after the HE NDP to retrieve HE compressed beamforming feedback from the intended HE beamformees in the same TXOP. The HE beamformer may subsequently send additional Beamforming Report Poll Trigger frames a SIFS after receiving the HE compressed beamforming feedback to retrieve a subset of the feedbacks in the same TXOP.

An HE beamformer that sets the Feedback Type subfield of a STA Info field to MU shall set the Nc Index field to a value less than or equal to the minimum of:

- The maximum number of supported spatial streams according to the corresponding HE beamformee's Rx HE-MCS Map subfield in the supported HE-MCS and NSS set field
- The maximum number of supported spatial streams according to the Rx NSS subfield value in the operating mode field of the most recently received Operating Mode Notification frame or the Operating Mode Notification element with the Rx NSS Type subfield equal to 0 for the corresponding HE beamformee
- The maximum number of supported spatial streams according to the Rx NSS subfield value in the most recently received frame that carried a Received Operating Mode Indication subfield (see 27.8 (Operating mode indication)).

The HE beamformee shall indicate the maximum number of space-time streams it can receive in an HE NDP as well as the total number of space-time streams (summed across all users) it can receive in a DL MU-MIMO packet through the Beamformee STS Capability field. For an HE beamformee, the value of this capability field shall be greater than or equal to 4.

An HE beamformer that sets the Feedback Type subfield of the STA Info field to MU shall set the Ng field value in the STA Info field of the HE NDP Announcement frame to either 0 (for $Ng = 4$) or 1 (for $Ng = 16$).

An HE beamformer with multiple STA Info elements shall set the RU Start Index and RU End Index in the STA Info field to indicate the starting 26-tone RU and the ending 26-tone RU of the requested HE compressed beamforming feedback report only if the HE beamformee indicates it is capable of Partial Bandwidth feedback. The RU Start Index is 7 bits and indicates the lowest 26-tone RU for which the HE beamformer is requesting feedback. The RU End Index is 7 bits and indicates the highest 26-tone RU for which the HE beamformer is requesting feedback. The 26-tone RU location is based on the RXVECTOR parameter CH_BANDWIDTH of the HE NDP Announcement when received in an HE PPDU or the RXVECTOR parameter CH_BANDWIDTH_IN_NON_HT when the HE NDP Announcement is received in a non-HT PPDU. If the HE beamformee is not capable of partial bandwidth feedback or if there is only one STA info element in the NDP Announcement frame then the HE beamformer shall set the RU Start Index and the RU End Index to values indicating a full bandwidth feedback such as in the case of $Ng = 4$, for 80 MHz full bandwidth feedback the RU Start Index and RU End Index is set to 0 and 36, respectively as shown in Table YY-1.

The HE beamformer shall set the starting RU index to a value equal to the maximum of:

— The minimum 26-tone RU located within the channel width in the VHT Operation Information field
— The minimum 26-tone RU located within the channel width in the Receive Operating Mode Notification Indication (see 27.8 (Operating mode indication))

The HE beamformer shall set the ending RU index to a value equal to the minimum of:

— The maximum 26-tone RU located within the channel width in the VHT Operation Information field
— The maximum 26-tone RU located within the channel width in the Receive Operating Mode Notification Indication

An HE beamformer that transmits an HE NDP Announcement frame that has only one STA Info field shall set the Nc Index field to 0 and the Ng field to 0.

An example of HE sounding protocol with a single HE beamformee is shown in Figure 27-3 (An example of the sounding protocol with a single HE beamformee).

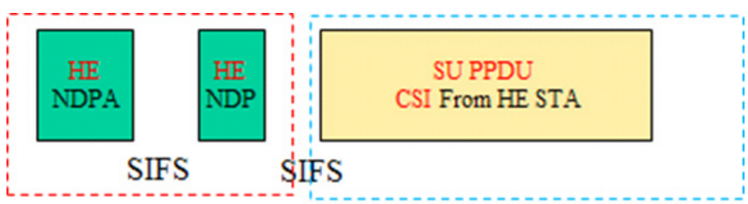


Figure 27-3—An example of the sounding protocol with a single HE beamformee

An HE beamformee that receives an HE NDP Announcement frame from an HE beamformer with which it is associated and that contains the HE beamformee's AID in the AID subfield of STA Info field, and there is only one STA Info field, shall transmit its HE compressed beamforming feedback a SIFS after receiving the HE NDP. The TXVECTOR parameter CH_BANDWIDTH for the PPDU containing the HE compressed beamforming feedback shall be set to indicate a bandwidth not wider than that indicated by the RXVECTOR parameter CH_BANDWIDTH of the HE NDP Frame.

An example of HE sounding protocol with more than one HE beamformee is shown in Figure 27-4 (An example of the sounding protocol with more than one HE beamformee).

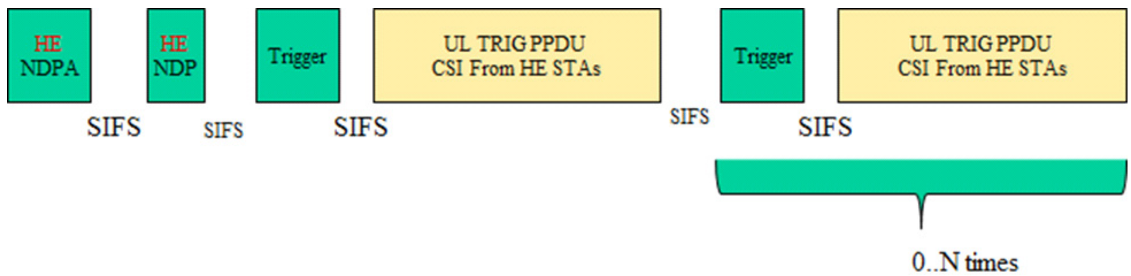


Figure 27-4—An example of the sounding protocol with more than one HE beamformee

A non-AP HE beamformee that receives an HE NDP Announcement frame from an HE beamformer with which it is associated and that contains the HE beamformee's AID in any of the STA Info field, and there are multiple STA Info fields in the HE NDP Announcement, shall compute the HE compressed beamforming feedback after receiving the HE NDP. The STA shall transmit the HE compressed beamforming feedback as a response to a Beamforming Report Poll variant Trigger frame that contains the AID of the STA in any of the User Info fields following the rules defined in 27.5.2.3 (STA behavior).

The value of the Sounding Dialog Token Number in the HE MIMO Control field shall be set to the same value as the Sounding Dialog Token Number field in the corresponding HE NDP Announcement frame.

The HE Compressed Beamforming feedback is comprised of the HE Compressed Beamforming Report information and the MU Exclusive Beamforming Report information.

Supporting SU-type feedback over full BW is mandatory for an HE beamformee participating in the HE sounding protocol with a single beamformee.

The beamformer initiating HE sounding protocol with one beamformee, shall not request MU-type feedback, CQI feedback, and SU-type partial bandwidth feedback, i.e., RU start index and RU end index do not cover full bandwidth, in NDP announcement.

Supporting MU-type feedback over full BW is mandatory for HE beamformees participating in HE sounding protocol with more than one beamformee.

Supporting SU-type feedback over partial BW is optional for HE beamformees participating in HE sounding protocol with more than one beamformee. The beamformer shall not request partial BW SU-type feedback in NDP announcement if the beamformee does not claim support for parital BW SU-type feedback in the HE capabilities field as in 9.4.2.218 (HE Capabilities element).

Supporting MU-type feedback over partial BW is optional for HE beamformees participating in HE sounding protocol with more than one beamformee. The beamformer shall not request partial BW MU-type feedback in NDP announcement if the beamformee does not claim support for parital BW MU-type feedback in the HE capabilities field as in 9.4.2.218 (HE Capabilities element).

Supporting CQI-only feedback with any RU start index and RU end index is optional for HE beamformees participating in HE sounding protocol with more than one beamformee.The beamformer shall not request CQI-only feedback with any RU start index and RU end index in NDP announcement if the beamformee does not claim support CQI-only feedback in the HE capabilities field as in 9.4.2.213 (HE Capabilities Element).

27.6.3 Rules for segmented feedback in HE sounding protocol sequences

HE Compressed beamforming feedback shall be transmitted in a single PPDU unless the size of the feedback is greater than 11 454 octets. The HE beamformer shall support maximum MPDU length for HE Compressed beamforming feedback of size which is the minimum of:

- 11 454 octets
- The size of the HE compressed beamforming feedback requested

27.6.4 HE NDP transmission

An HE NDP shall use the HE SU PPDU format as described in 26.1.4 (PPDU formats). An HE STA shall transmit an HE NDP using the following TXVECTOR parameters:

- APEP_LENGTH set to 0
- HE_LTF_TYPE set to either 2x HE-LTF or 4x HE-LTF
- NUM_STS indicates two or more space-time streams
- CH_BANDWIDTH set to the same value as the TXVECTOR parameter CH_BANDWIDTH in the preceding HE NDP Announcement frame
- GI_TYPE set to either 0.8 us or 1.6 us when HE_LTF_TYPE is set to 2x HE-LTF; otherwise GI_TYPE set to 3.2 us
- PE_DURATION set to 4 us
- SPATIAL_REUSE set to SR disallowed

The number of space-time streams sounded and as indicated by the NUM_STS parameter shall not exceed the value indicated in the Beamformee STS Capability field in the HE Capabilities element of any intended recipient of the HE NDP. The NUM_STS parameter may be set to any value, subject to the constraint of the previous sentence, regardless of the value of the Supported HE-MCS and NSS Set field of the HE Capabilities element at either the transmitter or recipient of the HE NDP.

The destination of an HE NDP is equal to the RA of the immediately preceding HE NDP Announcement frame.

The source of an HE NDP is equal to the TA of the immediately preceding HE NDP Announcement frame.

27.7 TWT operation

27.7.1 General

Target wake times (TWTs) allow STAs to manage activity in the BSS by scheduling STAs to operate at different times in order to minimize contention between STAs and to reduce the required amount of time that a STA in PS mode needs to be awake.

An HE STA can negotiate individual TWT values, as defined in 10.43 (Target wake time (TWT)), subject to the additional rules and restrictions that are defined in 27.7.2 (Individual TWT agreements). An HE AP can deliver broadcast TWT values to HE non-AP STAs, without requiring that an individual TWT agreement has been established between them, as described in 27.7.3 (Broadcast TWT operation).

STAs need not be made aware of the TWT values of other STAs or that a TWT service period (SP) can be used to exchange frames with multiple STAs. Frames transmitted during a TWT SP can be carried in any PPDU format supported by the STAs, including HE MU PPDU, HE trigger-based PPDU, etc.

An HE STA with dot11TWTOptionActivated equal to true shall set:

- The TWT Requester Support subfield to 1 in the HE Capabilities element that it transmits if it supports operating in the role of a TWT requester STA; otherwise set to 0.
- The TWT Responder Support subfield to 1 in the HE Capabilities elements that it transmits if it supports operating in the role of a TWT responding STA; otherwise set to 0.
- The Broadcast TWT Support subfield to 1 in the HE Capabilities element that it transmits if it supports operating in the role of a TWT scheduled STA or in the role of a TWT scheduling STA; otherwise set to 0.

An HE AP shall set the TWT Responder Support subfields of the Extended Capabilities element and HE Capabilities element to 1.

An AP may set the TWT Required subfield to 1 in the HE Operation element it transmits to request TWT participation by all STAs that are associated to it and that have declared support for TWT. A STA that supports TWT and is associated with an AP from which it receives an HE Operation element whose TWT Required subfield is 1 shall either negotiate individual TWT agreements, as defined in 27.7.2 (Individual TWT agreements), or participate in broadcast TWT operation, as defined in 27.7.3 (Broadcast TWT operation).

27.7.2 Individual TWT agreements

An HE STA may negotiate individual TWT agreements with another HE STA as defined in 10.43.1 (TWT overview), except that the STA:

- May set the Responder PM Mode subfield to 1 if it is a TWT responding STA that intends to go to doze state outside of TWT SPs.
  - If the TWT responding STA is an AP then it may set the Responder PM Mode subfield to 1 only if all non-AP STAs, which are associated to it, indicate support of TWT in the role of a TWT requester; otherwise it shall set it to 0.
  - An AP that sets the Responder PM Mode subfield to 1 follows the rules defined in 10.43.7 (TWT Sleep Setup).
- Shall set the Implicit subfield to 1 and the NDP Paging Indicator subfield to 0 in the TWT element it transmits during the TWT setup
- May set the Trigger subfield to 1 in the TWT element it transmits during the TWT setup to negotiate a trigger-enabled TWT
  - A successful TWT agreement whose Trigger subfield in the TWT response sent by the AP is 1 is a trigger-enabled TWT; otherwise it is an implicit TWT
  - A successful TWT agreement whose Flow Type subfield is 1 is an unannounced TWT; otherwise it is an announced TWT
- May set the TWT Channel subfield in the TWT element it transmits to a value that corresponds to the primary channel of the BSS to indicate a 20 MHz operation; otherwise it shall set it to 0.
- May set the TWT Protection field to 1 to indicate that TXOPs within the TWT SPs shall be initiated with a NAV protection mechanism, such as (MU) RTS/CTS, or CTS-to-self frame; otherwise it shall set it to 0.

An HE STA that successfully sets up a TWT agreement with another HE STA shall follow the rules defined in 10.43.1 (TWT overview) and 10.43.4 (Implicit TWT operation), except that the additional rules defined in this subclause supercede the respective rules defined in 10.43.1 (TWT overview) and 10.43.4 (Implicit TWT operation). A TWT or TWT SP that is setup under an implicit TWT agreement is an implicit TWT or implicit TWT SP, respectively (see 10.43.1 (TWT overview). A TWT or TWT SP that is setup under a trigger-enabled TWT agreement is a trigger-enabled TWT or trigger-enabled TWT SP, respectively.

An HE STA that successfully sets up an individual TWT agreement and operates in PS mode shall not be required to listen to Beacon frames, as defined in 11.2.2.1 (General).

An HE AP may send an unsolicited TWT response frame with the Trigger subfield equal to 1 to an HE non-AP STA that has set the TWT Requester Support subfield to 1 in the HE Capabilities elements that it transmits to the AP.

An HE STA shall not transmit BAT, TACK, or STACK frames.

A TWT requesting STA should not initiate transmission of frames to the TWT responding STA outside of negotiated TWT SPs (for both implicit TWT and trigger-enabled TWT) for that TWT agreement and should not initiate transmission of frames to the TWT responding STA within trigger-enabled TWT SPs for that TWT agreement.

NOTE—The STA decides what frames to transmit within or outside TWT SPs.

The TWT responding STA of a trigger-enabled TWT agreement shall schedule for transmission a Trigger frame for the TWT requesting STA, as described in 27.5.2 (UL MU operation), within each TWT SP for that TWT agreement. The TWT responding STA that intends to transmit additional Trigger frames during a trigger-enabled TWT SP shall set the Cascade Indication field of the Trigger frame to 1 to indicate that it will transmit another Trigger frame within the same TWT SP. The TWT responding STA shall set the Cascade Indication field to 0 when the Trigger frame is the last Trigger frame of the TWT SP or when the Trigger frame is sent outside of a TWT SP.

NOTE 1—The TWT responding STA is not required to schedule for transmission a Trigger frame for the TWT requesting STA when the TWT agreement is not a trigger-enabled TWT agreement or when the TWT requesting STA has sent an OMI A-Control field that has the UL MU disable bit equal to 1 (see 27.8 (Operating mode indication).

NOTE 2— The Trigger frame can also be an UL MU Response Scheduling A-Control field contained in an MPDU carried in a DL MU PPDU.

A TWT requesting STA transmits a trigger-based PPDU as a response to a Trigger frame that is intended for it and is sent during a trigger-enabled TWT SP (see 27.5.2 (UL MU operation)). A TWT requesting STA that is in PS mode and is awake shall include a PS-Poll frame or an APSD trigger frame in the trigger-based PPDU if the TWT is an announced TWT unless the STA has already transmitted the PS-Poll or APSD trigger frame within that TWT SP. The STA may include other frames in the trigger-based PPDU.

NOTE–A Trigger frame is intended for a TWT requesting STA if it is sent by the AP to which the STA is associated and the frame contains the STA's AID in any of its Per User Info fields. The Trigger frame can have multiple recipients, each of which is identified by the presence of the recipient's AID in any of its Per User Info fields (see 27.5.2 (UL MU operation)).

A TWT responding STA that receives a PS-Poll frame or an APSD trigger frame from a TWT requesting STA during an announced TWT SP shall follow the rules defined in 11.2.2.2.6 (AP operation during the CP) to deliver buffered BUs to the STA. A TWT responding STA may deliver multiple buffered BUs to the TWT requesting STAs during:

— An announced TWT SP, without following the rules in 11.2.2.2.6 (AP operation during the CP) as long as the BU delivery does not exceed the duration of the TWT SP and the PS STA sending the QoS Null frame does not follow APSD.

— An unannounced TWT SP, without following the rules in 11.2.2.2.6 (AP operation during the CP) as long as the BU delivery does not exceed the duration of the TWT SP.

NOTE—The TWT responding STA can deliver the buffered BUs in an A-MPDU under a block ack agreement if the TWT is an announced TWT and the PS mode of the STA allows it, or if the TWT is an unannounced TWT.

A TWT requesting STA in PS mode that is awake for a TWT SP may transition to the doze state after AdjustedMinimumTWTWakeDuration time has elapsed from the TWT SP start time as identified by the

TWT requesting STA if there is no frame exchange with the STA during the AdjustedMinimumTWTWakeDuration or after an early TWT SP termination event if there is at least one frame exchange with the STA during AdjustedMinimumTWTWakeDuration. The TWT requesting STA may classify any of the following events as an early TWT SP termination event:

1) The reception of a Trigger frame with the Cascade Indication field equal to 0 that is not intended to the STA and does not allocate any random RU during an unannounced TWT
2) The transmission of an acknowledgement in response to a soliciting frame sent by the TWT responding STA that had either the EOSP subfield equal to 1 or the More Data field equal to 0 when the frame does not contain an EOSP subfield
3) The reception of a frame sent by the TWT responding STA that had either the EOSP subfield equal to 1 or the More Data field equal to 0 when the frame does not contain an EOSP subfield

The classification of a More Data field equal to 0 in an Ack, BlockAck and Multi-STA BlockAck frame as an early termination event can occur only when both STAs have indicated support of transmitting or receiving the frame with a nonzero More Data subfield, which is indicated in the More Data Ack subfield of the QoS Info field of frames they transmit (see 11.2.2 (Power management in a non-DMG infrastructure network)).

27.7.3 Broadcast TWT operation

27.7.3.1 General

A TWT scheduling STA is an HE AP with dot11TWTOptionActivated equal to true that includes a broadcast TWT element in the Beacon frame, and follows the rules described in 27.7.3.2 (Rules for TWT scheduling STA). The TWT scheduling STA may also include the broadcast TWT element in broadcast Probe Response frames.

A TWT scheduled STA is an non-AP HE STA that:

— Sets the Broadcast TWT Support field of the HE Capabilities element it transmits to 1
— Receives a broadcast TWT element transmitted by an HE AP that is a TWT scheduling STA and,
— Has not negotiated any implicit TWT agreement with the HE AP as described in 27.7.2 (Individual TWT agreements).

A TWT scheduled STA follows the schedule provided by the TWT scheduling STA as described in 27.7.3.3 (Rules for TWT scheduled STA). A TWT scheduled STA can negotiate the wake TBTT and listen interval for Beacon frames it intends to receive as described in 27.7.3.3 (Rules for TWT scheduled STA).

An example of broadcast TWT operation is shown in Figure 27-5 (Example of broadcast TWT operation), where the AP is the TWT scheduling STA and STA 1 and STA 2 are the TWT scheduled STAs.

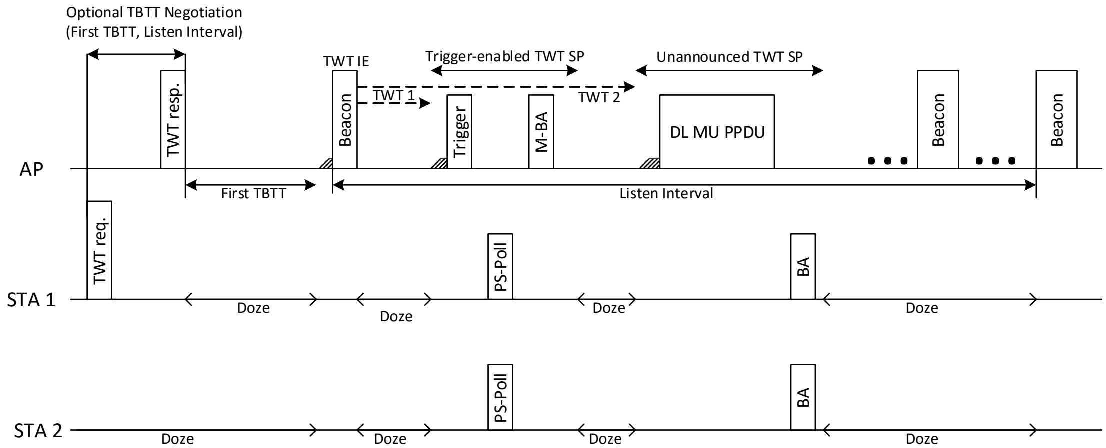


Figure 27-5—Example of broadcast TWT operation

Each broadcast TWT is uniquely identified by the <broadcast TWT ID, MAC address> tuple, where the broadcast TWT ID is the value of the Broadcast TWT ID subfield of a TWT parameter set from the TWT element that describes the broadcast TWT and the MAC address is one of the following:

— The TA of the MMPDU that contains the TWT element if the TWT command value is Accept, Alternate or Dictate
— The RA of the MMPDU that contains the TWT element if the TWT command value is Request, Suggest or Demand

When the TWT command value is Reject, the broadcast TWT is identified by the Broadcast TWT ID subfield and the TA of the MMPDU that contains the TWT element if the Wake TBTT Negotiation subfield is 0 and by the RA of the MPDU that contains the TWT element if the Wake TBTT Negotiation subfield is 1.

27.7.3.2 Rules for TWT scheduling STA

A TWT scheduling STA may include a broadcast TWT element in a Beacon frame that is scheduled at a TBTT (see 11.1.3.2 (Beacon generation in non-DMG infrastructure networks)). The TWT scheduling STA shall include one or more TWT parameter sets in the TWT element, and each TWT parameter set may indicate a periodic occurrence of TWTs. The TWT scheduling STA shall set the NDP Paging Indicator subfield to 0, the Broadcast subfield to 1, the Implicit subfield to 1, and the Responder PM Mode subfield to 0 in the TWT element (see 10.43.7 (TWT Sleep Setup)). Each TWT parameter set specifies the TWT parameters of a specific broadcast TWT that are valid within a broadcast TWT SP. Each specific broadcast TWT is identified as indicated in 27.7.3.1 (General). Individual STAs have membership in broadcast TWTs as the result of negotiation with a scheduling STA as indicated in Table 10-19a (TWT setup exchange command interpretation).

A TWT scheduled STA may include a TWT element with the Wake TBTT Negotiation subfield set to 1 in (Re)Association Request frames.

A TWT scheduling STA may include a TWT element with the Broadcast subfield set to 1 in (Re)Association Response frames.

A TWT scheduling STA should not include a STA's AID in a User Info field of a Trigger frame transmitted within a broadcast TWT SP unless the STA has established membership in the broadcast TWT.

The TWT scheduling STA sets the TWT parameters of each TWT parameter set as described below.

The TWT scheduling STA shall set the TWT Request subfield to 0 and the TWT Setup Command subfield to Accept TWT, except that it may set the TWT Setup Command subfield to:

— Reject TWT when the periodic TWT is being terminated or,
— Alternate TWT when the periodic TWT is being modified

The TWT scheduling STA shall set the Trigger field to 1 to indicate a trigger-enabled TWT. Otherwise, it shall set the Trigger field to 0 to indicate an implicit TWT.

The TWT scheduling STA shall schedule for transmission a Trigger frame addressed to one or more TWT scheduled STAs during a trigger-enabled TWT SP. The TWT scheduling STA that intends to transmit additional Trigger frames during a trigger-enabled TWT SP shall set the Cascade Indication field of the Trigger frame to 1 to indicate that it will transmit another Trigger frame within the same TWT SP. The TWT scheduling STA shall set the Cascade Indication field to 0 when the Trigger frame is the last Trigger frame of the TWT SP or when the Trigger frame is sent outside of a TWT SP.

NOTE 1—The TWT scheduling STA is not required to schedule for transmission a Trigger frame for the TWT scheduled STA when the broadcast TWT is not a trigger-enabled TWT or when the TWT scheduled STA has sent an OMI A-Control field that has the UL MU disable bit equal to 1 (see 27.8 (Operating mode indication)).

NOTE 2—The Trigger frame can also be an UL MU Response Scheduling A-Control field contained in an MPDU carried in a DL MU PPDU.

The TWT scheduling STA shall set the Flow Type field to 1 to indicate an unannounced TWT. Otherwise, it shall set the Flow Type field to 0 to indicate an announced TWT.

The TWT scheduling STA should schedule delivery of DL BUs during unannounced TWT SPs.

The TWT scheduling STA shall set the TWT Flow Identifier field according to Table 9.248l1 (TWT Flow Identifier field for a broadcast TWT element).

The TWT scheduling STA should only send frames that satisfy the TWT flow identifier recommendations listed in Table 9.248l1 (TWT Flow Identifier field for a broadcast TWT element) during the TWT SP(s). A Trigger frame transmitted during a broadcast TWT SP whose TWT parameter set has the TWT Flow Identifier subfield equal to 0 may contain zero or more random RU (see 27.5.2.6 (UL OFDMA-based random access)). A Trigger frame transmitted during a broadcast TWT SP whose TWT parameter set has the TWT Flow Identifier subfield equal to 1 shall contain no random RU (see 27.5.2.6 (UL OFDMA-based random access)). A Trigger frame transmitted during a broadcast TWT SP whose TWT parameter set has the TWT Flow Identifier subfield equal to 2 shall contain at least one random RU (see 27.5.2.6 (UL OFDMA-based random access)).

The TWT scheduling STA shall set the TWT field to the TSF timer [4: 19] at which the first TWT is scheduled for this TWT parameter set.

The TWT scheduling STA shall include a nonzero value for the TWT wake interval in the TWT Wake Interval Exponent and TWT Wake Interval Mantissa fields for a periodic TWT and a zero value for an aperiodic TWT.

The TWT parameters are valid for each successive TWT of the periodic TWT or for the only TWT of the aperiodic TWT.

The TWT scheduling STA may set the TWT Protection field to 1 to indicate that TXOPs within the TWT SP shall be initiated with a NAV protection mechanism defined in 10.3.2.4 (Setting and resetting the NAV), 10.3.2.8a (MU-RTS/CTS procedure), or CTS-to-self as described in 10.3.2.13 (NAV distribution); otherwise it shall set it to 0.

A TWT scheduling STA that receives a PS-Poll or an APSD trigger frame from a TWT scheduled STA during an announced TWT SP shall follow the rules defined in 11.2.2.2.6 (AP operation during the CP) to deliver buffered BUs to the STA. A TWT scheduling STA may deliver multiple buffered BUs to the TWT scheduled STA during:

— An announced TWT SP, without following the rules in 11.2.2.2.6 (AP operation during the CP) as long as the BU delivery does not exceed the duration of the TWT SP and the PS STA sending the QoS Null frame does not follow APSD.
— An unannounced TWT SP, without following the rules in 11.2.2.2..6 (AP operation during the CP) as long as the BU delivery does not exceed the duration of the TWT SP and the STA has switched to AM.

NOTE—The TWT scheduling STA can deliver the buffered BUs in an A-MPDU under a BlockAck agreement.

A TWT scheduling STA should indicate Alternate TWT or Reject TWT in the TWT Command Setup field of the broadcast TWT element for as many DTIM periods as needed to exceed the longest interval any STA is expected to not receive Beacon frames either when:

— The TWT parameters of a periodic TWT have changed, or
— The periodic TWT specified by that TWT parameter set is terminated.

A change in the TWT parameter set occurs in a subsequent DTIM Beacon frame.

27.7.3.3 Rules for TWT scheduled STA

A TWT scheduled STA that receives a broadcast TWT element in a Beacon frame shall follow the rules defined in this subclause to interact with the TWT scheduling STA.

A TWT scheduled STA should not initiate transmission of frames to the TWT scheduling STA outside of broadcast TWT SPs and within trigger-enabled TWT SPs.

A TWT scheduled STA that is in PS mode may go to doze state after receiving the Beacon frame and shall be in the awake state at a broadcast TWT start time during which the STA intends to exchange frames with the TWT scheduling STA. The TWT scheduled STA shall be in the awake state for AdjustedMinimumTWTWakeDuration time that corresponds to that TWT parameter set, except that the STA may go to doze state when a TWT SP termination event occurs. The TWT SP termination event occurs when the AdjustedMinimumWakeDuration time has elapsed from the TWT SP start time as identified by the TWT scheduled STA if there is no frame exchange with the STA during the AdjustedMinimumTWTWakeDuration or after an early TWT SP termination event if there is at least one frame exchange with the STA during AdjustedMinimumTWTWakeDuration. The early TWT SP termination events are as defined below:

1) The reception from the TWT scheduling STA of a Trigger frame with a Cascade Indication field equal to 0 that is not intended to the STA and does not allocate any random RU.
2) The transmission of an acknowledgement in response to a soliciting frame sent by the TWT responding STA that has either the EOSP subfield equal to 1 or the More Data field equal to 0 when the frame does not contain an EOSP subfield.

The reception of a frame sent by the TWT responding STA that has either the EOSP subfield equal to 1 or the More Data field equal to 0 when the frame does not contain an EOSP subfield.

The classification of a More Data field equal to 0 in an Ack, BlockAck and Multi-STA BlockAck frame as an early termination event can occur only when both STAs have indicated support of transmitting or receiving the frame with a nonzero More Data subfield, which is indicated in the More Data Ack subfield of the QoS Info field of frames they transmit (see 11.2.2 (Power management in a non-DMG infrastructure network)).

NOTE—A Trigger frame, sent by the TWT scheduling STA, is defined as intended for the TWT scheduled STA when the Trigger frame contains the AID of the STA in one of its Per User Info fields (see 27.5.2 (UL MU operation)). Otherwise, the Trigger frame is not intended for the STA. If the Trigger frame contains one or more random RU(s) for which the STA can gain access according to 27.5.2.6 (UL OFDMA-based random access) then the STA can follow the rules defined in 27.14.2 (Power save with UL OFDMA-based random access) to determine an early TWT SP termination event.

A TWT scheduled STA transmits a trigger-based PPDU as a response to a Trigger frame that is intended for it and is sent during a trigger-enabled TWT SP (see 27.5.2 (UL MU operation)). The TWT scheduled STA that is in PS mode and is awake shall include a PS-Poll frame or an APSD trigger frame in the trigger-based PPDU if it intends to solicit buffered BUs from the TWT scheduling STA (see 11.2.2.8 (Receive operation for STAs in PS mode during the CP)) unless the STA has already transmitted the PS-Poll or APSD trigger frame within that TWT SP. The STA may include other frames in the HE trigger-based PPDU.

NOTE—A TWT scheduling STA sets the bit in the TIM element of the Beacon frame that corresponds to the AID of the TWT scheduled STA to 1 to indicate that it expects the TWT scheduled STA to solicit available buffered BUs (see 11.2.2.8 (Receive operation for STAs in PS mode during the CP)).

A TWT scheduled STA should only send frames that satisfy the TWT flow identifier recommendations defined in Table 9.248l1 (TWT Flow Identifier field for a broadcast TWT element) during the corresponding TWT SP(s). Frames sent as a response to a Trigger frame are subject to further restrictions as defined in 27.5.2 (UL MU operation).

27.7.3.4 Negotiation of wake TBTT and listen interval

A TWT scheduled STA that intends to operate in power save mode (see 11.2.2.2 (STA Power Management modes)) may transmit a TWT request frame to the TWT scheduling STA that identifies the wake TBTT of the first Beacon frame and the wake interval between subsequent Beacon frames it intends to receive. The TWT request frame shall contain:

- The value of the Wake TBTT Negotiation subfield equal to 1 and the TWT Command field to Suggest TWT or Demand TWT, and
- The value of the requested listen interval between consecutive TBTTs in the TWT Wake Interval Mantissa and TWT Wake Interval Exponent fields.
- All other fields in the TWT element are reserved.

A TWT scheduling STA that receives a TWT request frame from a STA whose value of the Wake TBTT Negotiation subfield is 1 shall respond with a TWT response frame that contains either Accept TWT or Reject TWT in the TWT Command field and, in the case of an Accept TWT, it shall also contain:

- The value of the Wake TBTT Negotiation subfield equal to 1, and
- The value of the allocated first wake TBTT in the Target Wake Time field, and
- The value of the listen interval between consecutive TBTTs in the TWT Wake Interval Mantissa and TWT Wake Interval Exponent fields.
- All other fields in the TWT element are reserved.

After successfully completing the negotiation, the TWT scheduled STA may go to doze state until its TSF matches the next negotiated wake TBTT provided that the STA is in power save mode, and no other condition requires the STA to remain awake. The TWT scheduled STA shall be in the awake state to listen to

Beacon frames transmitted at negotiated wake TBTTs and shall operate as described in 27.7.3.3 (Rules for TWT scheduled STA).

After receiving the Beacon frame at or after TBTT, the TWT scheduled STA may go to doze state until the next wake TBTT if no other condition requires the STA to remain awake.

Either STA can tear down an established negotiation following the tear down procedure described in 10.44.8 (TWT Teardown).

27.7.4 Use of TWT Information frames

An HE STA may transmit a TWT Information frame to its peer STA during an individual TWT session, broadcast TWT session, or at any time if the peer STA has set the Flexible TWT Schedule Support of the HE Capabilities it transmits to 1.

The TWT Information frame shall have the Response Requested subfield equal to 0, the Next TWT Request subfield equal to 0, and one of the following:

- A nonzero value in the Next TWT subfield when the frame is transmitted by a TWT responding STA, a TWT scheduling STA, or by any HE STA to a peer STA that supports TWT
  - The value of the Next TWT shall be selected from existing TWT values for a TWT session if the Flexible TWT Schedule Support field of the peer STA is 0
  - The Next TWT may contain any nonzero value if Flexible TWT Schedule Support field of the peer STA is 1
- A Next TWT subfield that is present when the frame is transmitted by a TWT requesting STA, a TWT scheduled STA, or any HE STA to a peer STA that supports TWT
  - The Next TWT indicates the TWT at which the TWT session is resumed and shall be selected from existing TWT values for that TWT session if the Flexible TWT Schedule Support field of the peer STA is 0
  - The Next TWT may contain any nonzero value if Flexible TWT Schedule Support field of the peer STA is 1
    NOTE—In such case, the TWT requesting STA or TWT scheduled STA or peer STA that transmitted the TWT Information frame preserves the PM mode from the time it sent the TWT Information frame to the time it is expected to wake-up.
- A Next TWT subfield that is not present when the frame is transmitted by a TWT requesting STA or a TWT scheduled STA to indicate suspension of the TWT session

A TWT requesting STA that receives a TWT Information frame follows the rules defined in 10.43.4 (Implicit TWT operation). A TWT requesting STA that receives an acknowledgment in response to a TWT Information frame that:

- Does not contain a Next TWT field shall consider that TWT session suspended, and can follow the procedure in 27.7.3 (Broadcast TWT operation) until the TWT session is resumed.
- Contains a Next TWT field shall consider the corresponding TWT session resumed, starting from the value indicated in the Next TWT field of the transmitted TWT Information frame.

A TWT scheduling STA that receives a TWT Information frame follows the rules defined in 27.7.3.3 (Rules for TWT scheduled STA), except that it shall use the Next TWT value contained in the received TWT Information frame. A TWT scheduling STA that receives an acknowledgment in response to a TWT Information frame that:

- Does not contain a Next TWT field shall consider the TWT session suspended, and can follow the default PS procedure defined in 11.2 (Power management) until the TWT session is resumed.

— Contains a Next TWT field shall consider the corresponding TWT session resumed, starting from the value indicated in the Next TWT field of the transmitted TWT Information frame.

An HE non-AP STA that transmits a TWT Information frame to a peer STA may go to doze state after receiving the acknowledgment and shall be in the awake state at the specified TWT indicated in the TWT Information frame. An HE non-AP STA that receives a TWT Information frame from a peer STA may go to doze state after transmitting the acknowledgment and shall be in the awake state at the specified TWT indicated in the TWT Information frame.

NOTE—The TWT Flow Identifier, together with the MAC addresses of the TWT requesting STA and TWT Responding STA identifies the TWT agreement for which the TWT Information frame is sent (see 10.43.1 (TWT overview)). The receiving STA that has not set up a TWT agreement with that TWT Flow Identifier with the transmitting STA interprets the TWT Information frame as part of a broadcast TWT session or as part of no TWT session.

27.8 Operating mode indication

27.8.1 General

An HE STA can change its operating mode setting either using the procedure described in 11.42 (Notification of operating mode changes), or the procedure described in this subclause. Operating mode indication (OMI) is a procedure used between an OMI initiator and an OMI responder. An HE STA that transmits a frame including an OMI A-Control field is defined as an OMI initiator. An HE STA that receives a frame including an OMI A-Control field is defined as an OMI responder.

If dot11OMIOptionImplemented is true, an HE STA may send a QoS Data or QoS Null frame that contains the OMI A-Control field to indicate a change in its receive and/or transmit operating parameters. An HE AP shall set dot11OMIOptionImplemented to true and the HE AP shall implement the reception of the OMI A-Control field.

The OMI initiator shall indicate a change in its receive operating mode by including the OMI A-Control field in a QoS Data or QoS Null frame that solicits an immediate acknowledgement and is addressed to the OMI responder. The OMI A-Control field indicates that the OMI initiator supports receiving PPDUs with a bandwidth up to the value indicated by the Rx Channel Width subfield and with a number of spatial streams up to the value indicated by the Rx NSS subfield as defined in 27.8.2 (Receive operating mode (ROM) indication).

The OMI initiator shall indicate a change in its transmit operating mode by including the OMI A-Control field in a QoS Data or QoS Null frame that solicits an acknowledgement frame and is addressed to the OMI responder as defined in 27.8.3 (Rules for transmit operation mode (TOM) indication).

27.8.2 Receive operating mode (ROM) indication

The ROM indication allows the OMI initiator to adapt the maximum operating channel width and/or the maximum number of spatial streams it can receive from the OMI responder.

An OMI initiator that sent the frame including the OMI A-Control field should change its OMI parameters, Rx NSS and Rx Channel Width, as follows:

— When the OMI initiator changes an OMI parameter from higher to lower, it should make the change for that parameter only after receiving the immediate acknowledgement from the OMI responder.

— When the OMI initiator changes an OMI parameter from lower to higher, it should make the change for that parameter either after ACK Timeout has expired or after receiving the immediate acknowledgement from the OMI responder.

NOTE—In the event of transmission failure of the frame containing the OMI A-Control field, the OMI initiator attempts the recovery procedure defined in 10.22.2.7 (Multiple frame transmission in an EDCA TXOP).

If an OMI mode change is reported during a TXOP then the change should occur at least after that TXOP.

The OMI responder shall use the values indicated by the Rx Channel Width and Rx NSS subfields of the most recently received OMI A-Control field sent by the OMI initiator to send PPDUs to the OMI initiator in subsequent TXOP.

After transmitting the acknowledgement frame immediate response immediate acknowledgement for the frame containing the OMI A-Control field, the OMI responder may transmit subsequent SU PPDUs or MU PPDUs that are addressed to the OMI initiator.

NOTE—A subsequent PPDU is a PPDU that is intended for the ROM Initiator and needs not be the immediately following PPDU.

27.8.3 Rules for transmit operation mode (TOM) indication

An OMI initiator that is a non-AP STA may indicate changes in its transmit parameters by sending a frame that contains the OMI A-Control field to the OMI responder. The OMI initiator shall set:

- The UL MU Disable subfield to 1 to indicate suspension of the UL MU operation (see 27.5.2 (UL MU operation); otherwise it shall set the UL MU Disable subfield to 0 to indicate resumption or continuation of participation in UL MU operation.
    - An AP that is an OMI initiator shall set the UL MU Disable subfield to 0.
- The Tx NSS subfield to the maximum number of Nss that the STA will use in response to Trigger frames.

NOTE—The Channel Width subfield indicates the maximum channel width that the STA will use in response to Trigger frames

An OMI responder that successfully receives a frame containing an OMI A-Control field from an OMI initiator:

- Shall consider the OMI initiator as not participating in UL MU operation for subsequent TXOPs (see 27.5.2 (UL MU operation)) when the UL MU Disable subfield is 1 in the received OMI A-Control field

NOTE—The STA sets the UL MU Disable subfield to 1 to indicate that it will not respond to all variants of the Trigger frame.

- Shall consider the OMI initiator as participating in UL MU operation for subsequent TXOPs when the UL MU Disable subfield is 0 in the received OMI A-Control field in which case:
    - The maximum number of spatial streams that the OMI initiator can transmit in response to Trigger frames is indicated in the Tx NSS subfield of the OMI A-Control field
    - The maximum channel width over which the OMI initiator can transmit in response to Trigger frames is indicated in the Channel Width subfield of the OMI A-Control field
- Shall indicate a number of spatial streams in the Per User Info field of a Trigger frame, which contains the AID of the OMI initiator, that is less than or equal to the number of spatial streams that is calculated from the Tx NSS subfield of the OMI A-Control field received by the OMI initiator
- Shall indicate a channel width in the RU Allocation subfield of the Per User Info field of a Trigger frame, containing the AID of the OMI initiator, that is less than or equal to the value specified in the Channel Width subfield of the OMI A-Control field received by the OMI initiator

27.9 Spatial reuse operation

27.9.1 General

The objective of the HE spatial reuse operation is to improve the system level performance, the utilization of medium resources and power saving in dense deployment scenarios by early identification of signals from overlapping basic service sets (OBSSs) and interference management.

When the conditions specified in 27.9 (Spatial reuse operation) are met that allow the transmission of an SR PPDU, an HE STA may transmit an SR PPDU to either an HE STA or a non-HE STA.

27.9.2 OBSS_PD-based spatial reuse operation

27.9.2.1 General

If the PHY of a STA issues a PHY-CCA.indication with a value equal to BUSY followed by an RXSTART.indication due to a PPDU reception then the STA's MAC sublayer may a) issue a PHY-CCARESET.request primitive and b) not update its NAV timers based on frames carried in the PPDU if all the following conditions are met:

— The received PPDU is an Inter-BSS PPDU (see 27.2.1 (Intra-BSS and inter-BSS frame detection))
— The RXVECTOR parameter RSSI_LEGACY in the PHY-RXSTART.indication primitive, which defines the received power level measured from the legacy portion of the PPDU is below the OBSS_PD level (defined in 27.9.2.2 (Adjustment of OBSS_PD and transmit power))
— The PPDU is not one of the following:
  • A non-HT PPDU that carries an individually addressed Public Action frame where the RA field is equal to the STA MAC address
  • A non-HT PPDU that carries a group addressed Public Action frame

The PHYCCARESET.request primitive shall be issued at the end of the PPDU if the PPDU is HE SU PPDU or HE extended range SU PPDU and the RXVECTOR parameter SPATIAL_REUSE indicates SR_Delay.

If the PHYCCARESET.request primitive is issued before the end of the PPDU, and a TXOP is initiated within the duration of the PPDU, then the TXOP shall be limited to the duration of the PPDU if the PPDU is HE MU PPDU and the RXVECTOR parameter SPATIAL_REUSE indicates SR_Restricted.

If the inter-BSS frame is carried in an HE extended range SU PPDU (where power of the L-STF/L-LTF symbols is boosted 3 dB), the received power measured based on the legacy preamble and captured in the RXVECTOR parameter RSSI_LEGACY in the PHY-RXSTART.indication primitive shall be decreased by 3 dB to compensate for the power boost factor when compared to the OBSS PD level.

SR Backoff procedure for SR delayed case.

The STA may resume its backoff procedure after the end of the PPDU carrying the SR delay entry by following the procedure defined in 10.22.2 (HCF contention based channel access (EDCA)).

NOTE—The countdown of an existing backoff procedure is suspended until the end of the PPDU carrying the SR delay entry since the medium is busy during the duration of the PPDU carrying the SR delay entry.

If an HE STA's MAC sublayer issues a PHY-CCARESET.request primitive and not update its NAV timer as allowed above, the HE STA may resume its backoff procedure when the medium condition is IDLE as defined in 10.22.2.2 (EDCA backoff procedure).

27.9.2.2 Adjustment of OBSS_PD and transmit power

Adjusting the OBSS_PD level and transmit power can improve the system level performance and the utilization of the spectrum. When using OBSS_PD-based spatial reuse, an HE STA is allowed to adjust the OBSS_PD level in conjunction with its transmit power based on the following adjustment rule:

$$\text{Allowable } OBSS\_PD_{level} \le max(OBSSPD_{min}, min(OBSSPD_{max}, OBSSPD_{min} + (TXPWR_{ref} - TXPWR)))$$

The adjustment rule is illustrated in Figure 27-6 (Illustration of the adjustment rules for OBSS_PD and TX_PWR).

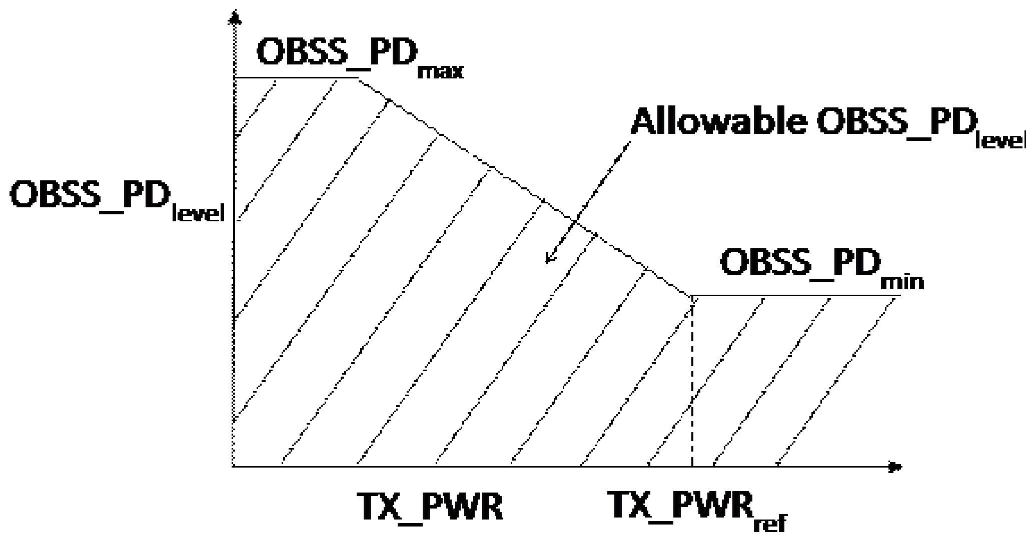


Figure 27-6—Illustration of the adjustment rules for OBSS_PD and TX_PWR

The $OBSS\_PD_{level}$ is applicable to the start of a 20 MHz PPDU received on the primary 20 MHz channel. The $OBSS\_PD_{level}$(40 MHz) which is applicable to the start of a 40 MHz PPDU received on the primary 40 MHz channel, the $OBSS\_PD_{level}$(80 MHz) which is applicable to the start of a 80 MHz PPDU received on the primary 80 MHz channel and the $OBSS\_PD_{level}$(160 MHz or 80+80 MHz) which is applicable to the start of a 160 MHz or 80+80 MHz PPDU, can be derived by the following equations:

— $OBSS\_PD_{level}$(40 MHz)= $OBSS\_PD_{level}$ + 3 dB

— $OBSS\_PD_{level}$(80 MHz)= $OBSS\_PD_{level}$ + 6 dB

— $OBSS\_PD_{level}$(160 MHz or 80+80 MHz) = $OBSS\_PD_{level}$ + 9 dB

$TXPWR_{ref}$ = 21 dBm for non-AP STAs.

$TXPWR_{ref}$ = 21 dBm for an AP with the Highest NSS Supported M1 subfield in the Tx Rx HE MCS Support field of its HE Capabilities element field equal to or less than 1.

$TXPWR_{ref}$ = 25 dBm for an AP with the Highest NSS Supported M1 subfield in the Tx Rx HE MCS Support field of its HE Capabilities element field equal to or greater than 2.

$OBSS\_PD_{min\_default}$ = –82 dBm and $OBSS\_PD_{max\_default}$ = –62 dBm.

$TXPWR$ is the STA transmission power in dBm at the antenna connector.

NOTE—considering the antenna connector definition section 3.1.

A STA can select an $OBSS\_PD_{level}$ during its operation under SR mode. This level can be dynamically adjusted or can be static.

If a STA chooses a specific $OBSS\_PD_{level}$ during its operation under SR mode, the maximum transmit power is defined in Equation (27-1).

$$TXPWR_{max} = \begin{cases} \text{unconstrained, if } OBSS\_PD_{level} = OBSS\_PD_{min} \\ TXPWR_{ref} - (OBSS\_PD_{level} - OBSS\_PD_{min}), \text{ if } OBSS\_PD_{max} \geq OBSS\_PD_{level} > OBSS\_PD_{min} \end{cases} \quad (27\text{-}1)$$

If a STA regards an inter-BSS PPDU as not having been received at all using a specific $OBSS\_PD_{level}$, the STA's power as measured at the output of the antenna connector, shall be equal or lower than the $TXPWR_{max}$, calculated with this specific $OBSS\_PD_{level}$ with Equation (27-1), for the transmissions of any PPDU (including UL TB PPDU) until the end of the TXOP that the STA gains once its backoff reaches zero. The STA may increase the $OBSS\_PD_{level}$ during the backoff procedure, its maximum transmit power being adjusted as defined above. The minimum $OBSS\_PD_{level}$ used by the STA shall be above the received signal strength of the inter-BSS PPDU, which means that the maximum $TXPWR_{max}$ shall be calculated with $OBSS\_PD_{level}$ equal to the received signal strength of the inter-BSS PPDU, with Equation (27-1).

27.10 A-MPDU operation

27.10.1 General

A-MPDU operation for an HE PPDU follows the procedures defined in 10.13 (A-MPDU operation) and, additionally, the procedures defined in this subclause.

27.10.2 A-MPDU padding for an HE SU PPDU, HE extended range SU PPDU and HE MU PPDU

An HE STA that transmits an DL HE MU PPDU that contains one or more PSDUs, each of which carries an A-MPDU, shall construct the A-MPDU(s) as described in 10.13.6 (A-MPDU padding for VHT PPDU).An HE STA that transmits an HE SU PPDU, HE extended range SU PPDU or UL HE MU PPDU that contains one A-MPDU, shall construct the A-MPDU(s) as described in 10.13.6 (A-MPDU padding for VHT PPDU).

27.10.3 A-MPDU padding for an HE trigger-based PPDU

A non-AP STA that transmits an HE trigger-based PPDU shall construct the PSDU carried in the HE trigger-based PPDU as described in this subclause.

The STA computes the PSDU_LENGTH based on the TXVECTOR parameters.

The STA may add A-MPDU subframes to the A-MPDU contained in the PSDU provided that the following constraints are fulfilled:

— The A-MPDU content constraints (see 10.13.1 (A-MPDU contents) and 27.10.4 (A-MPDU with multiple TIDs)) for the intended recipient

— The Length limit constraints (see 9.7.1 (A-MPDU format) and 10.13.2 (A-MPDU length limit rules)) for the intended recipient

— The MPDU start spacing constraints (see 10.13.3 (Minimum MPDU Start Spacing field)) for the intended recipient provided that the following conditions are met:

- The A-MPDU subframes have a value greater than 0 in the MPDU Length field, or have a value 0 in the MPDU Length field and a value 0 in the EOF field.
- After incrementing the A-MPDU_Length with the length of each such added A-MPDU subframe, the relationship A-MPDU_Length ≤ PSDU_LENGTH is true.

Padding is then added such that the resulting A-MPDU contains exactly PSDU_LENGTH octets as follows:

- First, while A-MPDU_Length < PSDU_LENGTH and A-MPDU_Length mod 4 ≠ 0, add an octet to the final A-MPDU subframe's Padding subfield and increment A-MPDU_Length by 1.
- Then, while A-MPDU_Length + 4 < PSDU_LENGTH, add an EOF padding subframe to the EOF Padding Subframes field and increment A-MPDU_Length by 4.
- Finally, while A-MPDU_Length < PSDU_LENGTH, add an octet to the EOF Padding Octets subfield and increment A-MPDU_Length by 1.

The STA shall not add an A-MPDU subframe with EOF equal to 0 after any A-MPDU subframe with EOF set to 1. The STA shall not add an A-MPDU subframe with EOF equal to 1 and with MPDU Length field equal to 0 before an A-MPDU subframe that contains a Single MPDU (see 10.13.7 (Setting the EOF field of the MPDU delimiter)).

An A-MPDU pre-EOF padding is constructed from each user from any of the following:

- A-MPDU subframes constructed from the MPDUs available for transmission from any AC that is selected by the STA
- A-MPDU subframes with 0 in the MPDU Length field and 0 in the EOF field

27.10.4 A-MPDU with multiple TIDs

A multi-TID A-MPDU is an A-MPDU that contains QoS Data frames with two or more different TID values.

An HE STA with dot11MPDUAskedforAckInMultiTIDAMPDU set to true shall set dot11AMPDUwithMultipleTIDOptionImplemented to true. An HE STA with dot11MPDUAskedforAckInMultipleTIDAMPDU set to true shall set the Ack Enabled Multi-TID A-MPDU Support subfield of the HE Capabilities element it transmits to 1; otherwise, the HE STA shall set it to 0. An HE transmitter shall not aggregate MPDU that asks for Ack in a multiple-TID A-MPDU to the HE recipient unless the recipient sets Ack Enabled Multi-TID A-MPDU Support subfield to 1 in its announced HE Capabilities element.

An HE STA shall construct a multi-TID A-MPDU as defined in 9.7 (Aggregate MPDU (A-MPDU)) and 10.13 (A-MPDU operation) except that the EOF subfield shall be set to 1 in a nonzero length MPDU delimiter that precedes a QoS Data frame, or Action frame if the QoS Data frame or Action frame solicits an immediate Ack frame.

A multi-TID A-MPDU may contain multiple noncontiguous nonzero length MPDU delimiters with EOF subfield equal to 1, one for each TID that solicits Ack and/or multiple noncontiguous nonzero length MPDU delimiters with EOF subfield equal to 0, one for each TID that solicits BlockAck.

An HE STA that receives a multi-TID A-MPDU shall respond with a Multi-STA BlockAck frame that contains (see 27.4 (Block acknowledgement)):

- One Per STA Info field indicating an Ack for each successfully received MPDU that solicits a response that is preceded by a nonzero length MPDU delimiter whose EOF is 1 (TID value equals that of the QoS Data/QoS Null frame or 15 for the Action frame),

— One Per STA Info field indicating a BlockAck for each TID of a successfully received MPDU that solicits a response that is preceded by a nonzero length MPDU delimiter whose EOF is 0 (TID value equals that of the QoS Data frame).

An HE STA with dot11AMPDUwithMultipleTIDOptionImplemented set to true shall set the Multi-TID Aggregation Support subfield of the HE Capabilities element it transmits to a nonzero value. Otherwise, the HE STA shall set it to 0.

An HE STA shall not send a multi-TID A-MPDU to an HE STA that has the Multi-TID Aggregation Support subfield in the HE Capabilities element equal to 0.

An HE STA may aggregate in a multi-TID A-MPDU QoS Data frames with multiple TIDs as defined in Table 9-425 (A-MPDU contents in the data enabled immediate response context) or Table 9-426 (A-MPDU contents in the data enabled no immediate response context).

If the multi-TID A-MPDU is transmitted in a PPDU that is not an HE trigger-based PPDU, then the number of different TID values in the multi-TID A-MPDU shall not exceed the number specified by the intended recipient in the Multi-TID Aggregation Support field of the HE Capabilities element.

If the multi-TID A-MPDU is transmitted in an HE trigger-based PPDU, then the number of different TID values in the multi-TID A-MPDU shall not exceed the value specified in the Multi-TID Aggregation Limit subfield in the Trigger Dependent User Info subfield of the User Info field in the Basic Trigger variant Trigger frame that allocated resources for the HE trigger-based PPDU.

A multi-TID A-MPDU shall not be transmitted in an HE SU PPDU or HE extended range SU PPDU except when TXOP limit is not zero for the AC that is used to gain access to the medium. This AC is defined as the primary AC. When TXOP limit is not zero then the STA may aggregate QoS Data frames from one or more TIDs in the A-MPDU under the following conditions:

— The A-MPDU shall be carried in an HE SU PPDU or an HE ER SU PPDU transmitted within the obtained TXOP
— The A-MPDU shall contain one or more MPDUs with any of the TIDs that correspond to the primary AC
— When any of the buffers is empty or when no more MPDUs can be aggregated in the A-MPDU from any of the TIDs that correspond to the primary AC then the A-MPDU may additionally contain one or more MPDUs with TIDs that do not correspond to the primary AC if the TIDs correspond to any AC that has a higher priority with respect to the primary AC and the addition of these MPDUs does not cause the STA to exceed the current TXOP duration

The Multi-STA BlockAck frame shall be used to acknowledge the MPDUs in a multi-TID A-MPDU. The rules for Multi-STA BlockAck are defined in subclause 27.4 (Block acknowledgement).

The responding HE STA with dot11AMPDUwithMultipleTIDOptionImplemented set to true shall not aggregate QoS Data frames in the multi-TID A-MPDU with a number of TIDs that exceeds the value indicated in the TID Aggregation Limit subfield in the Trigger Dependent User Info field of a Basic Trigger variant Trigger frame (9.3.1.23.1 Basic Trigger) intended for it.

For an HE STA with dot11AMPDUwithMultipleTIDOptionImplemented set to true and having a single A-MPDU containing MPDUs with different value of TIDs, the MPDUs with the same TID value may be aggregated in non-contiguous A-MPDU subframes.

When the AP specifies a value defined in Table 9-25i (Preferred AC subfield encoding) in the Preferred AC subfield and a value of 1 in the AC Preference Level subfield in the Trigger Dependent User Info field of a Basic Trigger variant Trigger frame, then an HE STA with dot11AMPDUwithMultipleTIDOptionImplemented set to true and with buffered traffic in the indicated preferred AC should aggregate MPDUs from any one of the TIDs from the same AC or higher AC as indicated in the Preferred AC subfield of the Trigger Dependent User Info field in the Trigger frame.

When the AP specifies a value defined in Table 9-25i (Preferred AC subfield encoding) in the Preferred AC subfield and a value of 1 in the AC Preference Level subfield in the Trigger Dependent User Info field of a Basic Trigger variant Trigger frame, then an HE STA with dot11AMPDUwithMultipleTIDOptionImplemented set to true may aggregate MPDUs from any other TID.

The STA may aggregate MPDUs from TIDs in other ACs within the remaining time to the UL PPDU duration value indicated in the Length subfield in the Common Info field of the Trigger frame.

The total number of TIDs from which QoS Data MPDUs are aggregated by the STA shall not exceed the limit indicated in the TID Aggregation Limit subfield of its User Info field in the Trigger frame.

When the AP specifies a value of 0 in the AC Preference Level subfield in the Trigger Dependent User Info field of a Basic Trigger variant Trigger frame, then an HE STA with dot11AMPDUwithMultipleTIDOptionImplemented set to true may aggregate MPDUs from any AC/TID or combination of TIDs, up to the limit indicated in the TID Aggregation Limit subfield in Trigger Dependent User Info field of the Trigger frame.

An HE STA with dot11AMPDUwithMultipleTIDOptionImplemented set to false should select any one of the TID value within the AC value indicated in the Preferred AC subfield and AC Preference Level subfield is 1 in the Trigger Dependent User Info field of a Basic Trigger variant Trigger frame.

An HE STA with dot11AMPDUwithMultipleTIDOptionImplemented set to false may select a TID from any AC when the AC Preference Level subfield is 0 in the Trigger Dependent User Info field of a Basic Trigger variant Trigger frame.

NOTE—A multi-TID A-MPDU allows the aggregation of an Action Ack frame as well.

An HE AP may aggregate MPDUs from any TIDs in multi-TID A-MPDU for DL HE MU PPDU transmission and the number of TIDs in multi-TID A-MPDU shall not be more than the Multi-TID Aggregation Support announced by the recipient.

27.11 Setting TXVECTOR parameters for an HE PPDU

27.11.1 STA_ID_LIST

Each element of the TXVECTOR parameter STA_ID_LIST identifies the STA or group of STAs that is the recipient of an RU in the HE MU PPDU. If an RU is intended for a single STA, then the STA_ID_LIST element for that RU is set to the AID of the STA receiving the PSDU contained in that RU. If an RU is intended for an AP, then the STA_ID_LIST contains only one element that is set to the AID of the non-AP STA transmitting the PPDU. If an RU is intended for a group of STAs then the STA_ID_LIST element is set as follows:

- For an AP with dot11MultiBSSIDActivated equal to false, if the RU is intended for more than one STA in the BSS, the STA_ID_LIST element is set to 0. The AP may include only one element with this value in a DL MU PPDU.
- For an AP with dot11MultiBSSIDActivated equal to true, if the RU is intended for more than one STA in any of its BSSs, the STA_ID_LIST element is set to partial virtual bitmap value assigned for the group addressed frame (see 9.4.2.6 (TIM element)). The AP may include only one element for each BSSID of the multiple BSSID set in the HE MU PPDU, and the number of such elements shall not exceed the maximum number of BSSs of the multiple BSSID set.

— For an AP with dot11MultiBSSIDActivated equal to true, if the RU is intended for more than one STA on all its BSSs, the STA_ID_LIST element is set to 2047. The AP may include only one element with this value in a DL MU PPDU.

27.11.2 UPLINK_FLAG

The Uplink Flag is carried in the TXVECTOR parameter UPLINK_FLAG of an HE SU PPDU, HE extended range SU PPDU, and HE MU PPDU and is set as follows:

— A STA transmitting an HE PPDU that is addressed to an AP shall set the TXVECTOR parameter UPLINK_FLAG to 1, except when the HE PPDU is an HE extended range SU PPDU with the TXOP Duration field set to all 1s and contains an RTS or CTS frame in which case the STA may set the TXVECTOR parameter UPLINK_FLAG to 0

— An AP transmitting an HE PPDU that is addressed to a non-AP STA shall set the TXVECTOR parameter UPLINK_FLAG to 0

— A STA transmitting an HE PPDU in a direct path to a (T)DLS peer STA, or to a member of an IBSS, or to a mesh STA, shall set the TXVECTOR parameter UPLINK_FLAG to 0

NOTE—A (T)DLS peer STA or the member of an IBSS can identify that the HE PPDU is sent in a direct path from the To DS and From DS fields of the MAC header of its MPDU(s)

The TXVECTOR parameter UPLINK_FLAG is not present for HE trigger-based PPDUs.

27.11.3 BEAM_CHANGE

The TXVECTOR parameter BEAM_CHANGE of an HE SU PPDU, HE extended range SU PPDU shall be set to 1 if the number of spatial streams is greater than 2 or the PPDU is the first PPDU in a TXOP.

27.11.4 BSS_COLOR

The BSS Color is an identifier of the BSS and is used to assist a receiving STA in identifying the BSS from which a PPDU originates so that the STA can use the channel access rules as described in 27.9 (Spatial reuse operation) or reduce power consumption as described in 27.14.1 (Intra-PPDU power save for HE non-AP STAs).

An HE STA transmitting an HE Operation element shall select a value in the range 1 to 63 to include in the BSS Color subfield of the HE Operation element that it transmits and shall maintain that single value of the BSS Color subfield for the lifetime of the BSS. An HE STA that transmitted an HE Operation element shall set the TXVECTOR parameter BSS_COLOR of an HE PPDU to the value indicated in the BSS Color subfield of its HE Operation element.

An HE STA receiving an HE Operation element shall set the TXVECTOR parameter BSS_COLOR of an HE PPDU to the value indicated in the BSS Color subfield of the HE Operation element received from the HE STA with which it is associated or intends to transmit.

An HE STA that received an HE PPDU with RXVECTOR parameter BSS_COLOR with a value between 1 and 63 may ignore the HE PPDU subject to the rules as described in 27.9 (Spatial reuse operation).

An HE STA transmitting an HE SU PPDU or an HE extended range SU PPDU for which one or more intended recipient STAs is not a member of a transmitting STA's BSS shall set the TXVECTOR parameter BSS_COLOR of the HE PPDU to 0.

An HE STA that received an HE SU PPDU or an HE extended range SU PPDU with RXVECTOR parameter BSS_COLOR equal to 0 shall not discard the HE PPDU.

An HE STA associated with an HE AP that is transmitting an HE PPDU in a direct path to a DLS or TDLS peer STA shall set the TXVECTOR parameter BSS_COLOR to the value of the value indicated in the BSS Color subfield of the HE Operation element received from the HE AP.

All APs that are members of a Multiple BSSID Set element shall use the same BSS Color.

An HE AP that decides to discontinue the use of the BSS color for the BSS that it serves, for example, after detecting a BSS Color overlap with an OBSS shall set the value of BSS Color Disabled subfield in the HE Operation element to 1 to inform associated STAs that the BSS Color is disabled; otherwise the AP shall set the BSS Color Disabled subfield to 0.

If the most recently received HE Operation element from the AP to which it is associated contained a value of 1 in the BSS Color Disabled subfield then:

- A HE non-AP STA should use the A1, A2 and Duration/ID fields of the MPDUs contained in the received PPDUs instead of the BSS_COLOR and TXOP_Duration field in the HE-SIG-A field to determine whether the STA should update the Intra-BSS NAV.
- A HE non-AP STA should use the A1, A2 of the MPDUs contained in the received PPDUs instead of the BSS_COLOR and STA_ID_LIST field in the HE SIG A field to determine whether the STA may go to doze state for the duration of that PPDU (see 27.14.1 (Intra-PPDU power save for HE non-AP STAs)).

The HE non-AP STA may use the BSS color if the most recently received HE Operation element from the AP to which it is associated contained a value of 0 in the BSS Color Disabled subfield.

27.11.5 TXOP_DURATION

TXOP Duration field is carried in the TXVECTOR parameter TXOP_DURATION of an HE PPDU and indicates duration information for NAV setting and protection of TXOP.

A STA that transmits an HE SU PPDU, HE extended range SU PPDU, or HE MU PPDU may indicate no duration information for NAV setting by setting the TXVECTOR parameter TXOP_DURATION to all 1s.

If a STA transmits an HE SU PPDU, HE extended range PPDU, or HE MU PPDU that carries a PS-Poll frame, the STA shall set the TXVECTOR parameter TXOP_DURATION to all 1s.

A TXOP responder that transmits an HE trigger-based PPDU shall set the TXVECTOR parameter TXOP_DURATION to all 1s if the RXVECTOR parameter TXOP_DURATION of the soliciting PPDU is set to all 1s.

A TXOP responder that transmits an HE trigger-based PPDU shall not set the TXVECTOR parameter TXOP_DURATION to all 1s if any one of the following condition is met:

- The RXVECTOR parameter TXOP_DURATION of the soliciting PPDU is not set to all 1s
- The RXVECTOR parameter FORMAT of the soliciting PPDU is not equal to HE_SU, HE_MU, or HE_EXT_SU

If the TXVECTOR parameter TXOP_DURATION of an HE PPDU is not set to all 1s, and there exists Duration field in the MAC header of the HE PPDU, the duration information indicated by the TXVECTOR parameter TXOP_DURATION is determined based on the duration information indicated by the Duration field in the MAC header and shall indicate the largest feasible duration information that is smaller than or equal to the duration information indicated by the Duration field.

NOTE 1—Except for a PS-Poll frame, the Duration/ID field in a data frame, management frame and control frame indicates duration information.

NOTE 2—For a TXOP responder, the Duration field in the MAC header of the response PPDU is set based on the Duration field in the MAC header of the soliciting PPDU as described in 9.2.5.7 (Setting for control response frames) or 9.2.5.8 (Setting for other response frames).

For a TXOP responder that transmits an HE trigger-based PPDU carrying a PS-Poll frame, if the TXOP responder does not set the TXVECTOR parameter TXOP_DURATION of the HE trigger-based PPDU to all 1s, the TXOP responder first calculates potential duration information equal to the duration information indicated by the Duration field of the frame that solicits the response minus the time, in microseconds, between the end of the PPDU carrying the frame that soliciting the HE trigger-based PPDU and the end of the HE trigger-based PPDU. If the calculated potential duration information includes a fractional microsecond, the potential duration information is rounded up to the next higher integer. Then the duration information indicated by the TXVECTOR parameter TXOP_DURATION is determined based on the calculated potential duration information and shall indicate the largest feasible duration information that is smaller than or equal to the calculated potential duration information.

The encoding of TXVECTOR/RXVECTOR parameter TXOP_DURATION for indicating duration information is defined in Table 28-1 (TXVECTOR and RXVECTOR parameters).

27.11.6 SPATIAL_REUSE

Spatial Reuse field is carried in the TXVECTOR parameter SPATIAL_REUSE of an HE PPDU and indicates spatial reuse information (See 27.9.2 (OBSS_PD-based spatial reuse operation)).

A STA that transmits an HE SU PPDU or HE extended range SU PPDU may set the TXVECTOR parameter SPATIAL_REUSE to SR_Delay entry only if a Trigger frame is carried in the HE SU PPDU or HE extended range SU PPDU.

A STA that transmits an HE MU PPDU may set the TXVECTOR parameter SPATIAL_REUSE to SR_Restricted entry only if a Trigger frame is carried in the HE MU PPDU.

27.12 HE PPDU post FEC padding and packet extension

An HE STA with dot11PPEThresholdsRequired set to false may set the PPE Thresholds Present subfield in HE Capabilities elements that it transmits to 0.

An HE STA with dot11PPEThresholdsRequired set to true shall set the PPE Thresholds Present subfield in HE Capabilities elements that it transmits to 1.

A STA that sets the PPE Thresholds Present subfield in HE Capabilities elements that it transmits to 1 shall indicate its minimum post-FEC padding and packet extension duration value per constellation, NSS and RU allocation by setting the subfields of the PPE Thresholds field according to 9.4.2.218 (HE Capabilities element) and using the corresponding values from dot11PPEThresholdsMappingTable.

A STA transmitting an HE PPDU to a receiving STA shall include a minimum post-FEC padding as determined by the post-FEC padding pre-FEC padding factor (see 28.3.11 (Data field) and after including the post-FEC padding, the transmitting STA shall include a packet extension that yields a total post-FEC padding plus packet extension that corresponds to at least the value indicated in the HE Capabilities element received from the receiving STA.

27.13 Link adaptation using the HE variant HT Control field

This subclause applies to frame exchange sequences that include PPDUs containing an HE variant HT Control field.

The HE-MCS subfield of the MFB subfield of HE link adaptation field should be set to the highest data-rate, for given transmission properties, that results in frame error rate of 10% or lower for a MPDU length of 3895 octets. The transmission properties, RU_ALLOCATION, DCM, NUM_STS, FEC_CODING, BEAMFORMED, BEAM_CHANGE, and STBC, are determined by the RXVECTOR of the PPDU used to estimate recommended MFB.

27.14 Power management

27.14.1 Intra-PPDU power save for HE non-AP STAs

An HE non-AP STA has dot11IntraPPDUPowerSaveOptionActivated equal to true operates in intra-PPDU power save mode.

An HE non-AP STA that is in intra-PPDU power save mode may enter the doze state until the end of a PPDU currently being received when one of the following conditions is met:

- The PPDU is an HE MU PPDU where the RXVECTOR parameter BSS_COLOR is the BSS color of the BSS with which the STA is associated, the RXVECTOR parameter UL_FLAG is 0 and the RXVECTOR parameter STA_ID_LIST does not include the identifier of the STA or the broadcast identifier(s) intended for the STA.
- The PPDU is an HE MU PPDU, HE SU PPDU or HE extended range SU PPDU and one of the following conditions are true:
  - The RXVECTOR parameter BSS_COLOR is the BSS color of the BSS with which the STA is associated and the RXVECTOR parameter UL_FLAG is 1
  - The RXVECTOR parameter BSS_COLOR is the BSS color of the BSS with which the STA is associated, the RXVECTOR parameter UL_FLAG is 0 and a PHY-RXEND.indication(UnsupportedRate) primitive was received
- The PPDU is an HE trigger-based PPDU where the RXVECTOR parameter BSS_COLOR is the BSS color of the BSS with which the STA is associated
- The PPDU is a VHT PPDU where the RXVECTOR parameter PARTIAL_AID is the BSSID[39:47] of the BSS with which the STA is associated and the RXVECTOR parameter GROUP_ID is 0.
- The PPDU is a PPDU with:
  - An A-MPDU including TA or RA equal to either the BSSID of the BSS with which the STA is associated or the BSSID of any BSS of a multiple BSSID set that the STA's associated BSS belongs to and,
  - The RA is not the MAC address of the STA

An HE STA that is in intra-PPDU power save mode and has entered doze state shall continue to operate its NAV timers and consider the medium busy during doze state and shall transition into awake state at the end of the PPDU.

NOTE—The STA can contend for access to the medium immediately on the expiry of the NAV timers.

27.14.2 Power save with UL OFDMA-based random access

This subclause illustrates the power save mechanisms for HE STAs using the random access procedure (see 27.5.2.6.2 (Random access procedure)).

An HE AP may indicate one or more start times for Trigger frames with random access allocations in the broadcast TWT element that is included in the Beacon frame or a management frame as described in 27.7.3.2 (Rules for TWT scheduling STA). The power save operation is shown in Figure 27-7 (Trigger frame (TF) start time in the Beacon frame for power save operation with random access operation) with the indication of the start time for a Trigger frame with random access allocations in a Beacon frame.

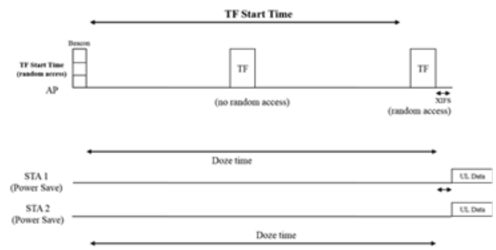


Figure 27-7—Trigger frame (TF) start time in the Beacon frame for power save operation with random access operation

An HE STA that receives a Beacon frame or a management frame containing a TWT element that has a value of 1 in the Broadcast subfield a value of 2 in the TWT Flow Identifier subfield may enter the doze state until the start of that TWT SP as described in 27.7.3.3 (Rules for TWT scheduled STA).

If random access allocations are made in a sequence of Trigger frames within a trigger-enabled TWT SP, then all the Trigger frames in the sequence shall have the Cascade Indication field set to 1, except for the last Trigger frame in the sequence, which shall have the Cascade Indication field set to 0.

An HE STA may use the value indicated in the Cascade Indication field in a Trigger frame to enter the doze state. If the OBO counter decrements to a non-zero value with the random access procedure in a Trigger frame with Cascade Indication field set to 0, it may enter the doze state immediately. If the OBO counter decrements to a non-zero value with the random access procedure in a Trigger frame with Cascade Indication field set to 1, it may remain awake for random access in the cascaded Trigger frame.

27.14.3 Opportunistic power save in congested environment

27.14.3.1 AP operation for opportunistic power save

Opportunistic power save mechanism has the objective for an AP to split a beacon interval into several periodic broadcast TWT SPs and to provide, at the beginning of each SP, the scheduling information to all non-AP STAs. Based on this information, the non-AP STAs may opportunistically go to doze state until the next TWT SP.

To enable opportunistic power save, an AP shall include a TWT element in beacons to set a periodic Broadcast TWT SP with the TWT flow identifier field set to 3.

At the beginning of these periodic TWT SPs, the AP shall transmit a TIM frame or a FILS Discovery frame that includes a TIM element (see 9.4.2.6 (TIM element)). The AP should transmit a FILS Discovery frame instead of a TIM frame if the TWT start time aligns with the transmission time of a FILS Discovery frame.

For any HE non-AP STA for which their associated AP set their corresponding bit in the traffic indication virtual bitmap field of the TIM element to 0, the AP shall neither send unicast or multicast frames to those STAs, nor trigger those STAs for UL MU transmissions during the TWT SP and, unless otherwise specified, until the next TWT SP.

For an HE non-AP STA for which their associated AP set their corresponding bit in the traffic indication virtual bitmap field of the TIM element to 1, if the STA was not served before the next TWT SP then the AP shall set its corresponding bit in the traffic indication virtual bitmap field of the TIM element to 1 in the subsequent TWT SP.

27.14.3.2 STA operation for opportunistic power save

When receiving a TIM element in TIM frame or FILS Discovery frame at the beginning of a broadcast TWT SP, an HE non-AP STA with AID *N* may enter the doze state during the TWT SP and until the next TWT SP, if the bit *N* in the traffic indication virtual bitmap field of the current TIM element is set to 0.

27.15 PPDU format, BW, MCS, NSS, and DCM selection rules

27.15.1 General

An HE STA can transmit different PPDUs formats, with different transmit parameters, such as channel width, MCS, NSS, DCM. This subclause defines the rules followed by an HE STA for selecting these parameters depending on the capabilities of the intended receiver(s) and other considerations.

27.15.2 PPDU format selection

An HE STA may transmit non-HT, HT, VHT PPDUs following the rules defined in 10.7 (Multirate support). An HE STA may transmit an HE SU PPDU or a 242-tone HE extended range SU PPDU to a peer HE STA.

An HE AP transmits HE MU PPDUs as defined in 27.5.1 (HE DL MU operation). An HE non-AP STA transmits HE trigger-based PPDUs as defined in 27.5.2 (UL MU operation).

An HE STA may transmit a 106-tone HE extended range SU PPDU to a peer STA if it has received from the peer STA an HE Capabilities element with the HE extended range SU PPDU Payload field equal to 1; otherwise the STA shall not transmit a 106-tone HE extended range SU PPDU to the peer STA.

An HE non-AP STA may transmit an HE trigger-based PPDU to a peer STA if it has received from the peer STA an HE Capabilities element with the UL MU PPDU Support field equal to 1; otherwise the STA shall not transmit an HE trigger-based PPDU to the peer STA.

An HE STA shall send Control frames in non-HT PPDU format following the rules defined in 10.7.6 (Rate selection for Control frames)) with the following exceptions:

- A Control frame sent in response to an HE extended range SU PPDU, HE SU PPDU, or HE trigger-based PPDU that uses STBC shall be carried in the same format as the soliciting PPDU
- A Control frame sent by the AP as a response to an HE trigger-based PPDU may be carried in any PPDU format that is supported by the intended receiver(s)
- A Control frame sent as a response to an HE PPDU, containing a Trigger frame that is not an MU RTS or containing an UL MU Response Scheduling A-Control field, is carried in an HE trigger-based PPDU (see 27.5.2 (UL MU operation))
- An Ack frame sent as a response to an HE extended range SU PPDU, HE SU PPDU, or HE trigger-based PPDU containing an FTM frame shall be sent in the same PPDU format as the soliciting PPDU
- If a Control frame is sent as a response to a soliciting HE extended range SU PPDU the frame shall be carried in an HE extended range SU PPDU except when the most recent successfully received PPDU sent by the responding STA to the soliciting STA after association was not an HE extended range SU PPDU in which case the control frame shall be carried in non-HT PPDU
- If the Control frame is sent as a response to a soliciting HE SU PPDU then the frame shall be carried in non-HT PPDU except when the most recent successfully received PPDU sent by the responding

STA to the soliciting STA after association was an HE extended range SU PPDU in which case the control frame shall be carried in HE extended range SU PPDU

NOTE—PPDU format switching between non-HT and ER SU PPDU occurs in subsequent TXOPs. A STA that solicits a control frame from a peer STA accounts for the PPDU format of the control frame to calculate the expected duration of the TXOP.

27.15.3 MCS, NSS, BW and DCM selection

An HE STA shall follow the rules defined in 10.7 (Multirate support) and 27.15.4 (Rate selection constraints for HE STAs) for selecting the rate, MCS, NSS, and the rules defined in 10.3.2.6 (VHT RTS procedure), 10.3.2.7 (CTS and DMG CTS procedure), 10.7.6.6 (Channel Width selection for Control frames) and 10.7.11 (Channel Width in non-HT and non-HT duplicate PPDUs) for selecting the channel width (BW) of transmitted PPDUs with the following exceptions:

— MCS, NSS, and BW selection for a Trigger-based PPDU are defined in 27.5.2.3 (STA behavior).
— Rate and BW selection for a CTS sent in response to MU RTS are defined in 10.3.2.8a.3 (CTS response to MU-RTS)
— MCS, and NSS for a Control frame sent in response to an ER SU PPDU shall be <MCS0, 1> and BW shall be 20 MHz.
— NSS and BW selection is further constrained as defined in 27.8 (Operating mode indication) and 11.42 (Notification of operating mode changes).

An HE STA that transmits an HE PPDU shall use an <HE-MCS, NSS> tuple supported by the receiver STA. A <HE-MCS, NSS> tuple is supported if reported as such in the Supported HE-MCS and NSS Set field in the HE Capabilities element received from that STA. When the Supported HE-MCS and NSS set of the receiving STA or STAs is not known, the transmitting STA shall transmit using a <HE-MCS, NSS> tuple in the basic HE-MCS and NSS set. The STA shall select a <HE-MCS, NSS> tuple from the basic HE-MCS and NSS set when protection is required (as defined in 10.26 (Protection mechanisms)) and shall select a <HE-MCS, NSS> tuple from the operational HE-MCS and NSS set parameter of the intended receiver when protection is not required.

If a control response frame is to be transmitted within an HE SU PPDU, HE MU PPDU, the channel width (CH_BANDWIDTH parameter of the TXVECTOR) shall be selected first according to 10.7.6.6 (Channel Width selection for Control frames), and then the <HE-MCS, NSS> tuple shall be selected from a set of <HE-MCS, NSS> tuples called the CandidateMCSSet as described in 10.7.6.5.3 (Control response frame MCS computation).

An HE STA may transmit an HE PPDU with DCM to a peer STA if it has received from the peer STA an HE Capabilities element with the DCM Encoding Rx field equal to 1; otherwise the STA shall not transmit a HE PPDU with DCM to the peer STA. An HE STA transmits an HE trigger-based PPDU with DCM as defined in 27.5.2.3 (STA behavior).

An HE STA that sends a control frame in an ER SU PPDU format shall use:

— DCM encoding if the most recent successfully received PPDU sent by the HE STA to the soliciting STA after association used DCM; otherwise the STA shall not use DCM for the control frame.
— 106-tone HE extended range SU PPDU if the most recent successfully received PPDU sent by the HE STA to the soliciting STA after association was a 106-tone ER SU PPDU.

NOTE—TX parameter switching occurs in subsequent TXOPs. A STA that solicits a control frame from a peer STA accounts for the TX parameter of the control frame to calculate the expected duration of the TXOP.

27.15.4 Rate selection constraints for HE STAs

27.15.4.1 Rx Supported HE-MCS and NSS Set

The Rx Supported HE-MCS and NSS Set of a first HE STA is determined by a second HE STA for each <HE-MCS, NSS> tuple NSS = 1, …, 8 and bandwidth (20 MHz, 40 MHz, 80 MHz, and 160 MHz or 80+80 MHz) from the Supported HE-MCS and NSS Set field received from the first STA as follows:

— If support for the HE-MCS for NSS spatial streams at that bandwidth is mandatory (see 26.5 (Parameters for HE-MCSs)), then the <HE-MCS, NSS> tuple at that bandwidth is supported by the first STA on receive.

— Otherwise, if the Max HE-MCS For n SS subfield (n = NSS) in the Rx HE-MCS Map subfield indicates support, then

— The <HE-MCS, NSS> tuple at that bandwidth is supported by the first STA on receive as defined in 9.4.2.213.3 Tx Rx HE MCS Support field.

— Otherwise, the <HE-MCS, NSS> tuple at that bandwidth is not supported by the first STA on receive.

The <HE-MCS, NSS> tuples excluded by 27.15.4.3 (Additional rate selection constraints for HE PPDUs) can also be eliminated from the Rx Supported HE-MCS and NSS Set.

An HE STA shall not, unless explicitly stated otherwise, transmit a HE PPDU unless the <HE-MCS, NSS> tuple and bandwidth used are in the Rx Supported HE-MCS and NSS Set of the receiving STA(s).

27.15.4.2 Tx Supported HE-MCS and NSS Set

The Tx Supported HE-MCS and NSS Set of a first HE STA is determined by a second STA for each <HE-MCS, NSS> tuple NSS = 1, …, 8 and bandwidth (20 MHz, 40 MHz, 80 MHz, and 160 MHz or 80+80 MHz) from the Supported HE-MCS and NSS Set field received from the first STA as follows:

— If support for the <HE-MCS, NSS> tuple at that bandwidth is mandatory (see 28.5 (Parameters for HE-MCSs)), then the <HE-MCS, NSS> tuple at that bandwidth is supported by the first STA on transmit.

— Otherwise, if the Max HE-MCS For *n* SS subfield (*n* = NSS) in the Tx HE-MCS Map subfield indicates support, then

— The <HE-MCS, NSS> tuple at that bandwidth is supported by the first STA on receive as defined in 9.4.2.218.4 (Tx Rx HE MCS Support field).

— Otherwise, the <HE-MCS, NSS> tuple at that bandwidth is not supported by the first STA on transmit.

27.15.4.3 Additional rate selection constraints for HE PPDUs

The following apply for a STA that transmits a HE PPDU with a number of spatial streams (NSS) less than or equal to 8:

— If the channel width of the PPDU is equal to CBW20 or CBW40, then the STA should not use a <HE-MCS, NSS> tuple if the HE-MCS is equal to 0, 1, 2, or 3 and the HT MCS with value VHT MCS + 8×(NSS – 1) is marked as unsupported in the Rx MCS bitmask of the HT capabilities element of the receiver STA.

— If the channel width of the PPDU is equal to CBW80, CBW160, or CBW80+80, then the STA should not use a <HE-MCS, NSS> tuple if the HE-MCS is equal to 0 or 1 and both the HT MCS values $2 \times \text{HE-MCS} + 8 \times (\text{NSS} - 1)$ and $2 \times (\text{HE-MCS} + 1) + 8 \times (\text{NSS} - 1)$ are marked as unsupported in the Rx MCS bitmask of the HT Capabilities element of the receiver STA.

An example tabulation of this behavior is given in Table 18-4 (Example of rate selection for HE PPDUs).

Table 18-4—Example of rate selection for HE PPDUs

HT MCSs that are marked as unsupported	<HE-MCS, NSS> tuples that are not used for CBW20 and CBW40	<HE-MCS, NSS> tuples that are not used for CBW80, CBW160, and CBW80+80
0, 8, 16	<0, 1>, <0, 2>, <0, 3>	-
1, 9	<1, 1>, <1, 2>	-
10	<2, 2>	-
3	<3, 1>	-
0, 1	<0, 1>, <1, 1>	<0, 1>
2, 3	<2, 1>, <3, 1>	<1, 1>
0, 1, 8, 9	<0, 1>, <1, 1>, <0, 2>, <1, 2>	<0, 1>, <0, 2>

27.16 HE BSS operation

27.16.1 Basic HE BSS functionality

An HE STA has dot11HEOptionImplemented equal to true.

A STA that is starting an HE BSS shall be able to receive and transmit at each of the <HE-MCS, NSS> tuple values indicated by the Basic HE-MCS And NSS Set field of the HE Operation parameter of the MLME-START.request primitive and shall be able to receive at each of the <HE-MCS, NSS> tuple values indicated by the Supported HE-MCS and NSS Set field of the HE Capabilities parameter of the MLME-START.request primitive. The basic HE-MCS and NSS set is the set of <HE-MCS, NSS> tuples that are supported by all HE STAs that are members of an HE BSS. It is established by the STA that starts the HE BSS, indicated by the Basic HE-MCS And NSS Set field of the HE Operation parameter in the MLME-START.request primitive. Other HE STAs determine the basic HE-MCS and NSS set from the Basic HE-MCS And NSS Set field of the HE Operation element in the BSSDescription derived through the scan mechanism (see 11.1.4.1 (General)).

An HE STA shall not attempt to join (MLME-JOIN.request primitive) a BSS unless it supports (i.e., is able to both transmit and receive using) all of the <HE-MCS, NSS> tuples in the basic HE-MCS and NSS set.

NOTE—An HE STA does not attempt to (re)associate with an HE AP unless the STA supports (i.e., is able to both transmit and receive using) all of the <HE-MCS, NSS> tuples in the Basic HE-MCS And NSS Set field in the HE Operation element transmitted by the AP because the MLME-JOIN.request primitive is a necessary precursor to (re)association.

A STA for which dot11HEOptionImplemented is true shall set dot11VeryHighThroughputOptionImplemented or dot11HighThroughputOptionImplemented to true.

A STA that is an HE AP or an HE mesh STA declares its channel width capability in the HE Capabilities element as described in Table 9-262aa (Subfields of the HE PHY Capabilities Information field). If the STA is an HE AP then it shall indicate support for at least 80 MHz channel width if it operates in 5 GHz; otherwise it may indicate any channel width support.

A STA shall set the Supported Channel Width Set subfield of VHT Capabilities and HT Capabilities element it transmits to a value that indicates the same channel width capability as the channel width capability provided in the HE Capabilities element it transmits. A STA shall set all the subfields of the VHT Capabilities and HT Capabilities element it transmits to respective values that indicate the same capabilities provided in the HE Capabilities element it transmits.

At a minimum, an HE STA sets the Rx MCS Bitmask of the Supported MCS Set field of its HT Capabilities element according to the setting of the Rx HE-MCS Map subfield of the Supported HE-MCS and NSS Set field of its HE Capabilities element as follows: for each subfield Max HE-MCS For n SS, $1 < n < 4$, of the Rx HE-MCS Map field with a value other than 3 (no support for that number of spatial streams), the STA shall indicate support for MCSs $8(n – 1)$ to $8(n – 1) + 7$ in the Rx MCS Bitmask, where n is the number of spatial streams, except for those MCSs marked as unsupported as described in 27.15.4.3 (Additional rate selection constraints for HE PPDUs).

A STA that is an HE AP or an HE mesh STA shall set the STA Channel Width subfield in the HT Operation element HT Operation Information field, the Channel Width, Channel Center Frequency Segment 0 and Channel Center Frequency Segment 1 subfields in the HE Operation element VHT Operation Information field to indicate the BSS bandwidth as defined in Table 11-24 (VHT BSS bandwidth).

The setting of the Channel Center Frequency Segment 0 and Channel Center Frequency Segment 1 subfields is shown in Table 11-25 (Setting of Channel Center Frequency Segment 0, Channel Center Frequency Segment 1 and Channel Center Frequency Segment 2 subfields), except that the Max NSS support is provided by the HE STA in frames that contain an HE Capabilities element (see 9.4.2.218 (HE Capabilities element)) and an Operating Mode field (see 9.2.4.6.4.3 (Operating Mode) and 9.4.1.53 (Operating Mode field)), wherein in the table the Max NSS support refers to the HE Max NSS support instead of the VHT Max NSS support for an HE STA.

An HE STA shall determine the channelization using the information in the HT Operation element Primary Channel field when operating in 2.4 GHz and the combination of the information in the HT Operation element Primary Channel field and the HE Operation element VHT Operation Information field Channel Center Frequency Segment 0 and Channel Center Frequency Segment 1 subfields when operating in 5 GHz (see 21.3.14 (Channelization)).

An HE AP or an HE mesh STA shall set the HT Operation element HT Operation Information field Secondary Channel Offset subfield to indicate the secondary 20 MHz channel as defined in Table 9-168 (HT Operation element fields and subfields), if the BSS bandwidth is more than 20 MHz.

An HE STA that is a member of an HE BSS shall follow the same rules that are defined in 11.40.1 (Basic VHT BSS functionality) when transmitting a 20 MHz, 40 MHz, 80 MHz, 160 MHz or 80+80 MHz HE PPDUs with the following exceptions:

— An HE trigger-based PPDU sent in response to a Trigger frame or an UL MU Response Scheduling A-Control field follows the rules defined in 27.5.2.3 (STA behavior).
— An 80 MHz, 160 MHz or 80+80 MHz HE DL MU PPDU with preamble puncture may be transmitted if either the primary 20 MHz or the primary 40 MHz, or both are occupied by the transmission (see Table 28-17 (HE-SIG-A field of an HE MU PPDU)).

An HE STA shall not transmit to a second HE STA using a bandwidth that is not indicated as supported in the Supported Channel Width Set subfield in the HE Capabilities element received from that HE STA.

A STA shall not transmit an MPDU in an HE PPDU to a STA that exceeds the maximum MPDU length capability indicated in the VHT Capabilities element received from the recipient STA or that exceeds the Maximum A-MSDU Length in the HT Capabilities element received from the recipient STA.

A STA shall not transmit an A-MPDU in an HE PPDU to a STA that exceeds the maximum A-MPDU length capability indicated in the HE Capabilities, VHT Capabilities, and HT Capabilities element received from the recipient STA. The maximum A-MPDU length capability is obtained as a combination of the Maximum A-MPDU Length Exponent subfields in the HE Capabilities and VHT Capabilities element if the recipient STA has transmitted the VHT Capabilities; otherwise it is obtained from a combination of the Maximum A-MPDU Length Exponent subfields in the HE Capabilities and the HT Capabilities element.

An HE AP shall set the RIFS Mode field in the HT Operation element to 0.

An HE STA shall follow the rules defined in 11.40 (VHT BSS operation) for channel selection, determining scanning requirements, channel switching, NAV assertion and antenna indication when operating in 5 GHz unless explicitly stated otherwise in Clause 27.

An HE STA shall follow the rules defined in 11.16 (20/40 MHz BSS operation) for channel selection, determining scanning requirements, channel switching, NAV assertion when operating in 2.4 GHz unless explicitly stated otherwise in Clause 27.

27.16.2 Selecting and advertising new BSS Color

An HE AP that sets up a BSS selects a BSS Color as defined in 27.11.4 (BSS_COLOR). An HE AP may choose to change the BSS Color under certain conditions such as when it detects that there is at least one other OBSS AP in the neighborhood that uses the same color as the BSS Color of its BSS.

The algorithm to choose a new BSS Color is beyond the scope of this standard.

An HE AP shall announce its decision to change the BSS Color via the BSS Color Change Announcement element which is carried in the Beacon, Probe Response and (Re)Association Response frames. The AP may also advertise the BSS Color change event via the HE BSS Color Change Announcement frame. The BSS Color change announcement should be advertised for a period of time that is sufficient for all STAs in the BSS, including STAs in power save mode, to have the opportunity to receive at least one BSS Color Change Announcement element before the BSS Color change occurs.

BSS Color change TBTT is the one at which the Color Switch Countdown time has reached 0 and the BSS switches to the new color.

During the time leading up to the BSS Color change TBTT, an HE AP shall continue to advertise the existing BSS Color via the BSS Color subfield in HE Operation element.

At the BSS Color change TBTT, an HE AP shall:

- Set the BSS Color Disabled subfield in the HE Operation element to 0
- Start advertising the new BSS Color via BSS Color subfield in the HE Operation element
- Start using the new BSS color

A HE non-AP STA that receives a BSS Color Change Announcement element shall start using the BSS Color specified in the received BSS Color Change Announcement element subsequent to the BSS Color change TBTT.

A HE non-AP STA in an infrastructure BSS shall not transmit the BSS Color Change Announcement element.

27.16.3 Quieting HE STAs in a HE BSS

27.16.3.1 General

The QTP (Quiet time period) defines a period for STA-to-STA operation during which only the HE STA which supports the STA-to-STA operation can transmit frames. During the period an HE STA should not transmit frames unless it participates in the STA-to-STA operation. All HE STAs in the HE BSS not participating the STA-to-STA operation should stay quiet in the period.

An AP that supports QTP shall set the QTP Support field in the AP's HE Capabilities element to 1 and shall set the QTP Capability field to 0 otherwise.

27.16.3.2 Procedure at the requester HE STA

Upon the reception of an MLME-QTP.request primitive, an HE STA shall perform the following procedure to start the Quiet Time Period Operation (Figure 27-8 (Quieting Time Period operation)):

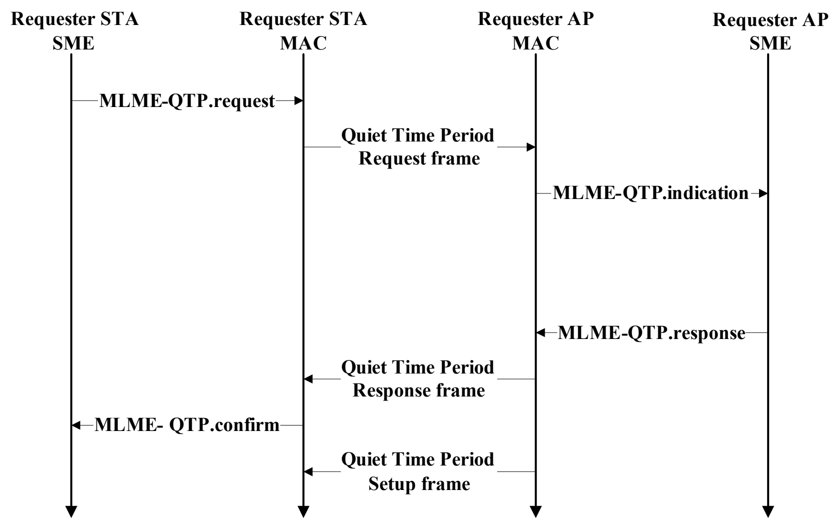


Figure 27-8—Quieting Time Period operation

a) If responder AP and requester HE STA are QTP capable as indicated by the QTP Support field in the HE Capabilities element, the requester HE STA sends a Quiet Time Period Request frame indicating the duration, interval, and type of operation (indicated by vendor specific service type). The requester HE STA may include multiple Quiet Time Period Request elements in one frame for multiple types of STA-to-STA operations.

b) If a Quiet Time Period Response frame is received with the matching dialog token and request token with a status code set to a value of SUCCESS, the AP has confirmed the reception of the Quiet Time Period Request element, and the MLME shall issue an MLME-QTP.confirm primitive indicating the success of the procedure.

c) When a Quite Time Period Setup frame is received, the requested HE STA can transmit frame belongs to the requested type of STA-to-STA operation indicated by the vendor specific service identifier of the Quiet Time Period Response. The transmission of a frame by the HE STA in this period shall follow the CCA rules.

NOTE—The GAS protocol can be used by an HE STA to inform an AP the type of STA-to-STA operations.

27.16.3.3 Procedure at the responder AP

A responder AP may operate as follows (Figure 27-8 (Quieting Time Period operation)):

a) When a QTP Request frame is received from an HE STA, the MLME shall issue an MLME-QTP.indication primitive.

b) Upon receipt of the MLME-QTP.response primitive, the AP may respond by sending Quiet Time Period Response frame.

   1) If the result code is SUCCESS, the request is accepted. The responder AP shall schedule the quiet period(s) according to the accepted request. Contained in the transmitted Quiet Time Period Response frame is the copy of the request token from the requester HE STA. The QTP procedure shall be terminated if the number of quiet periods exceeds the value of the Repetition Count field specified.

   2) If the result code is REJECTED, the request has not been fulfilled.

c) When the scheduled quiet time periods arrive, the responder AP may transmit a Quiet Time Period Setup frame including Quiet Time Period Setup element. Only the HE STA which supports the operation indicated by the Vendor Specific Service Identifier field of the Quiet Time Period Setup element can transmit frames in the quiet time period. The responder AP shall set the Quiet Period Duration field of Quiet Time Period Setup frame to the value no larger than indicated in Quiet Period Duration field of the Quiet Time Period Request element sent by the requester HE STA.

28. High Efficiency (HE) PHY specification

28.1 Introduction

28.1.1 Introduction to the HE PHY

Clause 28 specifies the PHY entity for a high efficiency (HE) orthogonal frequency division multiplexing (OFDM) system. In addition to the requirements in Clause 28, an HE STA shall be capable of transmitting and receiving PPDUs that are compliant with the mandatory requirements of the following PHY specifications:

— Clause 19 (High Throughput (HT) PHY specification) and Clause 21 (Very High Throughput (VHT) PHY specification) when the HE STA with greater than or equal to 80 MHz capability is operating in the 5 GHz band

— Clause 19 (High Throughput (HT) PHY specification) when the 20 MHz only non-AP HE STA is operating in the 5 GHz band

— Clause 19 (High Throughput (HT) PHY specification) when the HE STA is operating in the 2.4 GHz band

The HE PHY with greater than or equal to 80 MHz capability is based on the VHT PHY defined in Clause 21 (Very High Throughput (VHT) PHY specification), which in turn is based on the HT PHY defined in Clause 19 (High Throughput (HT) PHY specification), which in turn is further based on the OFDM PHY defined in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification). The HE PHY with 20 MHz only capability (see 28.3.9 (Mathematical description of signals)) is based on the HT PHY defined in Clause 19, which in turn is based on the OFDM PHY defined in Clause 17. The HE PHY extends the maximum number of users supported for downlink multi-user MIMO (MU-MIMO) transmissions to eight and provides support for downlink and uplink orthogonal frequency division multiple access (OFDMA) as well as for uplink MU-MIMO. Both downlink and uplink MU-MIMO transmissions are supported on portions of the PPDU bandwidth (on resource units greater than or equal to 106 tones) and in an MU-MIMO resource unit, there is support for up to eight users with up to four space-time streams per user with the total number of space-time streams not exceeding eight.

The HE PHY provides support for 20 MHz, 40 MHz, 80 MHz and 160 MHz contiguous channel widths and support for 80+80 MHz non-contiguous channel width, depending on the frequency band and capability. For channel widths greater than or equal to 80 MHz, the HE PHY supports channel puncturing transmissions where one or more of the non-primary 20 MHz channels in an HE MU PPDU with more than one RU is zeroed out.

The HE PHY provides support for 0.8 µs, 1.6 µs and 3.2 µs guard interval durations.

The HE PHY provides support for 3.2 µs (1x LTF), 6.4 µs (2x LTF), and 12.8 µs (4x LTF) LTF symbol durations (symbol duration not including the guard interval). The HE PHY supports a single Data field OFDM symbol duration of 12.8 µs (excluding guard interval).

The HE PHY data subcarrier frequency spacing is a quarter of VHT PHY and HT PHY subcarrier frequency spacing defined in Clause 21 (Very High Throughput (VHT) PHY specification) and Clause 19 (High Throughput (HT) PHY specification), respectively. The HE PHY data subcarriers are modulated using binary phase shift keying (BPSK), BPSK dual-carrier modulation (DCM), quadrature phase shift keying (QPSK), 16-quadrature amplitude modulation (16-QAM), 16-QAM DCM, 64-QAM, 256-QAM and 1024-QAM. Forward error correction (FEC) coding (convolutional or LDPC coding) is used with coding rates of 1/2, 2/3, 3/4 and 5/6.

An HE STA refers to an AP STA and a non-AP STA.

A non-AP STA is inclusive of a 20 MHz-only non-AP STA.

An HE STA shall support the following Clause 28 features:

- Transmission and reception of an HE SU PPDU that consists of a single RU spanning the entire PPDU bandwidth
- Transmission and reception of an HE extended range SU PPDU that consists of a single RU spanning the entire primary 20 MHz PPDU bandwidth
- Binary convolutional coding (transmit and receive). Note that binary convolutional coding is not defined for the following:
  - An HE SU PPDU with a bandwidth greater than 20 MHz
  - An RU of size greater than 242 subcarriers
  - An HE SU PPDU or an RU allocated to a single user with number of spatial streams greater than 4
  - An HE PPDU using HE MCS 10 or 11
- LDPC coding (transmit and receive) in all supported HE PPDU types, RU sizes, and number of spatial streams if the STA supports transmitting and receiving HE SU PPDUs of bandwidths greater than 20 MHz
- LDPC coding (transmit) in all supported HE PPDU types, RU sizes, and number of spatial streams if the STA declares support for transmitting more than 4 spatial streams except when the STA is an 20 MHz only non-AP STA
- LDPC coding (receive) in all supported HE PPDU types, RU sizes, and number of spatial streams if the STA declares support for receiving more than 4 spatial streams except when the STA is an 20 MHz only non-AP STA
- LDPC when declaring support for MCS10 and MCS11
- Transmit and receive of HE-SIG-B field in HE MU PPDUs at HE-MCSs 0 to 5
- HE-MCSs 0 to 7 (transmit and receive) in all supported channel widths and RU sizes for HE SU PPDUs, HE MU PPDUs, and HE_TRIG PPDUs
- 0.8 µs GI duration on both HE-LTF and data symbols when the HE-LTF is a 2x LTF (transmit and receive)
- 1.6 µs GI duration on both HE-LTF and data symbols when the HE-LTF is 1x (transmit and receive) for full bandwidth UL MU-MIMO if the STA supports UL MU-MIMO
- 1.6 µs GI duration on both HE-LTF and data symbols when the HE-LTF is a 2x LTF (transmit and receive)
- 3.2 µs GI duration on both HE-LTF and data symbols when the HE-LTF is a 4x LTF (transmit and receive)
- Single spatial stream HE-MCSs 0 - 2 in primary 20 MHz channel for HE_EXT_SU PPDUs
- 20 MHz channel width and all RU sizes and locations applicable to the 20 MHz channel width in 2.4 GHz and 5 GHz bands (transmit and receive)

An HE STA may support the following Clause 28 features:

- HE-MCSs 8 to 11 (transmit and receive)
- Dual carrier modulation (transmit and receive)
- 0.8 µs GI duration on both HE-LTF and data symbols when the HE-LTF is a 1x LTF (transmit and receive) for HE SU PPDUs
- LDPC coding (transmit) if
  - the maximum number of spatial streams the STA is capable of transmitting in an HE SU PPDU is less than or equal to 4, and
  - the STA is not capable of transmitting an HE SU PPDU with a bandwidth greater than 20 MHz

- LDPC coding (receive) if
  - the maximum number of spatial streams the STA is capable of receiving in an HE SU PPDU is less than or equal to 4, and
  - the STA is not capable of transmitting an HE SU PPDU with a bandwidth greater than 20 MHz
- Single spatial stream HE-MCS 0 in the right 106-tone RU of the primary 20 MHz channel for an HE extended range SU PPDU
- STBC (transmit and receive)

An HE AP shall support the following Clause 28 features:

- Transmission of an HE MU PPDU where none of the RUs utilize MU-MIMO (DL OFDMA)
- Reception of an HE trigger-based PPDU where none of the RUs utilize MU-MIMO (UL OFDMA)
- Transmission of an HE MU PPDU consisting of a single RU spanning the entire PPDU bandwidth and utilizing MU-MIMO (DL MU-MIMO), provided the AP is capable of transmitting 4 or more spatial streams
- 40 MHz and 80 MHz channel widths and all RU sizes and locations applicable to the 40 MHz and 80 MHz channel width in 5 GHz band (transmit and receive)

An HE AP may support the following Clause 28 features:

- MU-MIMO transmission on an RU in an HE MU PPDU where the RU does not span the entire PPDU bandwidth (downlink MU-MIMO with OFDMA)
- MU-MIMO reception on an RU in an HE trigger-based PPDU where the RU spans the entire PPDU bandwidth (uplink MU-MIMO)
- MU-MIMO reception on an RU in an HE trigger-based PPDU where the RU does not span the entire PPDU bandwidth (uplink MU-MIMO with OFDMA)
- Reception of the payload of an HE MU PPDU over a 106-tone RU within a 20 MHz PPDU bandwidth and full bandwidth PPDU
- 40 MHz channel width in the 2.4 GHz band (transmit and receive). If it is supported then all RU sizes and locations applicable to 40 MHz channel width are supported in 2.4 GHz band (transmit and receive)
- 160 MHz and 80+80 MHz channel widths and 2×996-tone RU size applicable to the 160/80+80 MHz channel width in 5 GHz band (transmit and receive)
- Transmission of an HE MU PPDU with preamble puncturing

An HE non-AP STA shall support the following Clause 28 features:

- Reception of an HE MU PPDU where the RU allocated to the non-AP STA is not utilizing MU-MIMO (DL OFDMA)
- Transmission of an HE trigger-based PPDU where the RU allocated to the non-AP STA is not utilizing MU-MIMO (UL OFDMA)
- Reception of an HE MU PPDU consisting of a single RU spanning the entire PPDU bandwidth and utilizing MU-MIMO (DL MU-MIMO). The maximum number of spatial streams per user the non-AP STA can receive in the DL MU-MIMO transmission shall be equal to the minimum of 4 and the maximum number of spatial streams supported for reception of HE SU PPDUs. The total number of spatial streams in the DL MU-MIMO transmission that the non-AP STA can receive shall be at least 4.
- Responding with the requested beamforming feedback in an HE sounding procedure with the maximum number of space-time streams in the HE NDP that the non-AP STA can respond to being at least 4
- 40 MHz and 80 MHz channel widths and all RU sizes and locations applicable to the 40 MHz and 80 MHz channel widths in 5 GHz band (transmit and receive) except if the non-AP STA is

20 MHz-only capable in which case the 40 MHz and 80 MHz channel widths, 996-tone RU, and 484-tone RU sizes in 5 GHz band are not applicable

— A non-AP STA that is 20 MHz-only capable shall support 106/52/26-tone RU sizes and locations in 40 MHz and 80 MHz channel width in 5 GHz band (transmit and receive)

An HE non-AP STA may support the following:

— Transmission of an HE MU PPDU over partial PPDU bandwidth and full PPDU bandwidth
— 40 MHz channel width in the 2.4 GHz band (transmit and receive). If 40 MHz channel width in the 2.4 GHz band is supported then all RU sizes and locations applicable to 40 MHz channel width are supported. If the non-AP STA is 20 MHz-only capable then 40 MHz channel width and 484-tone RU size in 2.4 GHz band are not supported
— 242-, 106-, 52- and 26-tone RU sizes and locations in a 40 MHz channel width in the 2.4 GHz band if the non-AP STA is 20 MHz-only capable
— 242-tone RU sizes and locations in a 40 MHz and 80 MHz channel widths in 5 GHz band if the non-AP STA is 20 MHz-only capable
— 242-tone RU sizes and locations in a 160 MHz and 80+80 MHz channel widths in 5 GHz band if the non-AP STA is 20 MHz-only capable
— 160 MHz and 80+80 MHz channel width and 2×996-tone RU size applicable to the 160 MHz and 80+80 MHz channel width in 5 GHz band (transmit and receive). If the non-AP STA is 20 MHz-only capable then 160 MHz and 80+80 MHz channel width, 2×996-, 996- and 484-tone RU sizes in 5 GHz band are not applicable
— MU-MIMO reception on an RU in an HE MU PPDU where the RU does not span the entire PPDU bandwidth (DL MU-MIMO with OFDMA). The maximum number of spatial streams per user in the DL MU-MIMO with OFDMA transmission that the non-AP STA can receive shall be a minimum of 4 and the maximum number of spatial streams supported for reception of HE SU PPDUs. The total number of spatial streams in the DL MU-MIMO with OFDMA transmission that the non-AP STA can receive shall be at least 4
— MU-MIMO transmit on an RU in an HE trigger-based PPDU where the RU spans the entire PPDU bandwidth (UL MU-MIMO). If it is supported then a total of up to 8 space-time streams are supported
— MU-MIMO transmit on an RU in an HE_TRIG PPDU where the RU does not span the entire PPDU bandwidth (UL MU-MIMO with OFDMA). If it is supported then a total of up to 8 space-time streams are supported

28.1.2 Scope

The services provided to the MAC by the HE PHY consist of the following protocol functions:

a) A function that maps the PSDU received from the MAC into a PPDU for transmission to one or more receiving STAs.

b) A function that defines the characteristics and method of transmitting and receiving data through a wireless medium between two or more STAs. Depending on the PPDU format, these STAs support a mixture of HE, Clause 21 (Very High Throughput (VHT) PHY specification), Clause 19 (High Throughput (HT) PHY specification) and Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) PHYs.A non-AP STA with 20 MHz only capability supports a mixture of HE, Clause 19 and Clause 17 PHYs.

28.1.3 HE PHY functions

28.1.3.1 General

The HE PHY contains two functional entities: the PHY function, and the physical layer management function (i.e., the PLME). Both of these functions are described in detail in 28.3 (HE PHY) and 28.4 (HE PLME). The HE PHY service is provided to the MAC through the PHY service primitives defined in Clause 8 (PHY service specification). The HE PHY service interface is described in 28.2 (HE PHY service interface).

28.1.3.2 PHY management entity (PLME)

The PLME performs management of the local PHY functions in conjunction with the MLME.

28.1.3.3 Service specification method

The models represented by figures and state diagrams are intended to be illustrations of the functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation; the actual method of implementation is left to the discretion of the HE-PHY-compliant developer.

The service of a layer is the set of capabilities that it offers to a user in the next higher layer. Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation.

28.1.4 PPDU formats

The structure of the PPDU transmitted by an HE STA is determined by the TXVECTOR parameters as defined in Table 28-1 (TXVECTOR and RXVECTOR parameters).

The FORMAT parameter determines the overall structure of the PPDU and can take on one of the following values:

- Non-HT format (NON_HT), based on Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) and including non-HT duplicate format.
- HT-mixed format (HT_MF) as specified in Clause 19 (High Throughput (HT) PHY specification).
- HT-greenfield format (HT_GF) as specified in Clause 19 (High Throughput (HT) PHY specification).
- VHT format (VHT) as defined in Clause 21 (Very High Throughput (VHT) PHY specification).
- HE SU PPDU format (HE_SU) carries a single PSDU. With this format the HE-SIG-A field is not repeated. Support for the HE SU PPDU format is mandatory.
- HE extended range SU PPDU format (HE_EXT_SU) carries a single PSDU. It is similar to the HE SU PPDU format, except that the HE-SIG-A field is repeated. Support for the HE extended range SU PPDU format is mandatory.
- HE MU PPDU format (HE_MU) carries one or more PSDUs to one or more users. Support for the HE MU PPDU format is mandatory.
- HE trigger-based PPDU format (HE_TRIG) carries a single PSDU and is sent in response to a PPDU that carries a Trigger frame. The preamble format prior to the HE-STF field is identical to the HE SU PPDU. Support for the HE trigger-based PPDU format is mandatory.

28.2 HE PHY service interface

28.2.1 Introduction

The PHY provides an interface to the MAC through an extension of the generic PHY service interface defined in 8.3.4 (Basic service and options). The interface includes TXVECTOR, RXVECTOR, and PHYCONFIG_VECTOR.

Using the TXVECTOR, the MAC supplies the PHY with per-PPDU transmit parameters. Using the RXVECTOR, the PHY informs the MAC of the received PPDU parameters. Using the PHYCONFIG_VECTOR, the MAC configures the PHY for operation, independent of frame transmission or reception.

28.2.2 TXVECTOR and RXVECTOR parameters

The parameters in Table 28-1 (TXVECTOR and RXVECTOR parameters) are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request primitive and/or as part of the RXVECTOR parameter list in the PHY-RXSTART.indication primitive.

Table 28-1—TXVECTOR and RXVECTOR parameters

Parameter	Condition	Value	TXVECTOR	RXVECTOR
FORMAT		Determines the format of the PPDU. Enumerated type: NON_HT indicates Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) or non-HT duplicate PPDU format. In this case, the modulation is determined by the NON_HT_MODULATION parameter. HT_MF indicates HT-mixed format. HT_GF indicates HT-greenfield format. VHT indicates VHT format. HE_SU indicates HE SU PPDU format. HE_MU indicates HE MU PPDU format. HE_EXT_SU indicates HE extended range SU PPDU format. HE_TRIG indicates HE trigger-based PPDU format.	Y	Y
NON_HT_MODULATION	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).			

Table 28-1—TXVECTOR and RXVECTOR parameters *(continued)*

L_LENGTH	FORMAT is HE_SU, HE_MU or HE_EXT_SU	Not present. NOTE—The Length field of the L-SIG for HE PPDU is defined in Equation (28-11) using the TXTIME value defined in 28.4.2 (TXTIME and PSDU_LENGTH calculation), which in turn depend on other parameters including the TXVECTOR parameter APEP_LENGTH.	N	N
	FORMAT is HE_TRIG	Indicates the value in the Length field of the L-SIG in the range of 1 to 4095. The value comes from the trigger frame which triggers the HE trigger-based PPDU.	Y	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
L_DATARATE	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Not present NOTE—The RATE field in the L-SIG field in HE PPDU is set to the value representing 6 Mb/s in the 20 MHz channel spacing column of Table 17-6 (Contents of the SIGNAL field).	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
LSIGVALID	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Not present	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
SERVICE	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Not present	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
SMOOTHING	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Not present	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
AGGREGATION	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Not present	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
NUM_EXTEN_SS	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Not present	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		

Table 28-1—TXVECTOR and RXVECTOR parameters *(continued)*

ANTENNA_SET	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Not present	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
N_TX	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Indicates the number of transmit chains.	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
EXPANSION_MAT_TYPE	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Set to COMPRESSED_SV.	Y	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
EXPANSION_MAT	FORMAT is HE_SU, HE_EXT_SU or HE_TRIG	Contains a vector in the number of selected subcarriers containing feedback matrices as defined in 28.3.15.2 (Beamforming feedback matrix V) based on the channel measured during the training symbols of previous HE NDP PPDUs or VHT NDP PPDUs.	Y	N
	FORMAT is HE_MU	For each user, contains a vector in the number of all the subcarriers within the RU which is assigned to this user. The vector for each subcarrier contains feedback matrices as defined in in 28.3.15.2 (Beamforming feedback matrix V) based on the channel measured during the training symbols of previous HE NDP PPDUs or VHT NDP PPDUs.	MU	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
CHAN_MAT_TYPE	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Set to COMPRESSED_SV.	N	Y
	FORMAT is HE_MU or HE_EXT_SU or HE_TRIG or (FORMAT is HE_SU and PSDU_LENGTH is greater than 0)	Not present.	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		

Table 28-1—TXVECTOR and RXVECTOR parameters *(continued)*

CHAN_MAT	FORMAT is HE_SU and PSDU_LENGTH is 0	Contains a vector in the number of selected subcarriers containing feedback matrices as defined in 26.3.12.3.2 (Beamforming Feedback) based on the channel measured during the training symbols of previous HE NDP PPDU.	N	Y
	FORMAT is HE_MU or HE_EXT_SU or HE_TRIG or (FORMAT is HE_SU and PSDU_LENGTH is greater than 0)	Not present.	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
DELTA_SNR	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Contains an array of delta SNR values as defined in 9.4.1.64 (HE MU Exclusive Beamforming Report field) based on the channel measured during the training symbols of the received VHT NDP PPDU or HE NDP PPDU. NOTE—In the RXVECTOR this parameter is present only for HE NDP PPDUs for MU sounding.	MU	Y
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
RCPI	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).			
SNR	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	For an HE SU PPDU and HE extended range SU PPDU, contains an array of average values of received SNR measurements for each spatial stream. For and HE MU PPDU, contains an array of average values of received SNR measurements for each spatial stream of the receiver. For HE trigger-based PPDU, contains an array of average values of received SNR measurements for each spatial stream per user. SNR indications of 8 bits are supported. Average value of SNR shall be the sum of the decibel values of SNR per tone divided by the number of tones represented in each stream as described in 9.4.1.63 (HE Compressed Beamforming Report field).	N	Y
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
CQI	FORMAT is HE_SU and PSDU_LENGTH is 0	Contains an array of received per-RU average SNRs for each space-time stream, where each per-RU average SNR is the arithmetic mean of the SNR in decibels over a 26-tone RU as described in 9.4.1.65 (HE CQI-only Report field).	N	Y
	Otherwise	Not present.	N	N

Table 28-1—TXVECTOR and RXVECTOR parameters *(continued)*

NO_SIG_EXTN	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Not present.	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
FEC_CODING	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Indicates which FEC encoding is used. Enumerated type: BCC_CODING indicates binary convolutional code. LDPC_CODING indicates low-density parity check code.	MU	MU
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
LDPC_EXTRA_SYMBOL	FORMAT is HE_TRIG and FEC_CODING is LDPC_CODING	Indicates the presence of the extra OFDM symbol for LDPC in an HE trigger-based PPDU. Set to 1 if an extra OFDM symbol for LDPC is present. Set to 0 if an extra OFDM symbol for LDPC is not present. See 27.5.2.3 (STA behavior) for details	Y	N
	Otherwise	Not present.	N	N
STBC	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Indicates if STBC is used. In an HE MU PPDU where each RU includes no more than 1 user: Set to 1 to indicate all RUs are STBC encoded in the payload Set to 0 to indicate all RUs are not STBC encoded in the payload In HE SU PPDU, HE extended range SU PPDU or HE trigger-based PPDU: Set to 1 to indicate that STBC is used in the payload Set to 0 to indicate that STBC is not used in the payload STBC is not applied in MU-MIMO RUs, in case of HE MU PPDU if any RU is assigned to more than 1 user; STBC is set to 0 to indicate all RUs are not STBC encoded in the payload. STBC is applied only for a single spatial stream ($N_{SS} = 1$). DCM is not used in conjunction with STBC.	Y	Y
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
GI_TYPE	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Indicates the length of the GI for the HE-LTF and HE-Data fields. Enumerated type: 0.8 µs 1.6 µs 3.2 µs NOTE—the length of GI for pre-HE modulated fields is 0.8 µs.	Y	Y
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		

Table 28-1—TXVECTOR and RXVECTOR parameters *(continued)*

TXPWR_LEVEL_INDEX	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	The allowed values for the TXPWR_LEVEL_INDEX parameter are in the range from 1 to numberOfOctets (dot11TxPowerLevelExtended)/2. This parameter is used to indicate which of the available transmit output power levels defined in dot11TxPowerLevelExtended shall be used for the current transmission.	Y	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
RSSI	FORMAT is HE_SU, HE_EXT_SU, HE_MU or HE_TRIG	The allowed values for the RSSI parameter are in the range 0 to 255 inclusive. This parameter is a measure by the PHY of the power observed at the antennas used to receive the current PPDU measured during the reception of the HE-LTF field. RSSI is intended to be used in a relative manner, and it is a monotonically increasing function of the received power.	N	Y
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
RSSI_LEGACY		The allowed values for the RSSI_LEGACY parameter are in the range 0 to 255 inclusive. This parameter is a measure by the PHY of the power observed at the antennas used to receive the current PPDU measured during the reception of PHY legacy preamble. RSSI_LEGACY is intended to be used in a relative manner, and it is a monotonically increasing function of the received power.	N	Y
MCS	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Indicates the modulation and coding scheme used in the transmission of the PPDU. Integer: range 0 to 11	MU	MU
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
DCM	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Set to 1 to indicate that dual carrier modulation is used for the HE-Data field. Set to 0 to indicate that dual carrier modulation is not used for the HE-Data field. NOTE—DCM is only applied to MCS0, MCS1, MCS3 and MCS4. DCM is only applied to 1 and 2 spatial streams. DCM is only applied to HE SU PPDU, HE extend range SU PPDU, and SU RUs in HE MU PPDU. DCM is not applied to MU-MIMO. DCM is not applied to STBC.	MU	MU
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
MCS_SIG_B	FORMAT is HE_MU	Indicates the modulation and coding scheme used for HE-SIG-B field. Integer in the range 0 to 5	Y	Y
	Otherwise	Not present.	N	N

Table 28-1—TXVECTOR and RXVECTOR parameters *(continued)*

DCM_SIG_B	FORMAT is HE_ MU	Set to 1 to indicate that dual carrier modulation is used for the HE-SIG-B field. Set to 0 to indicate that dual carrier modulation is not used for the HE-SIG-B field.	Y	Y
	Otherwise	Not present.	N	N
SIG_B_COMPRESSION_MODE	FORMAT is HE_MU	Used to differentiate full bandwidth MU-MIMO from OFDMA MU PPDU. In case of full bandwidth MU-MIMO set to 1, otherwise set to 0.	Y	N
	Otherwise	Not present.	N	N
REC_MCS	FORMAT is HE_SU, HE_MU or HE_EXT_SU	Indicates the MCS that the receiver recommends	N	O
	FORMAT is HE_TRIG	Not present.	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		

Table 28-1—TXVECTOR and RXVECTOR parameters *(continued)*

CH_BANDWIDTH	FORMAT is HE_SU	Indicates the channel width of the transmitted PPDU. Enumerated type: CBW20 for 20 MHz CBW40 for 40 MHz CBW80 for 80 MHz CBW160 for 160 MHz CBW80+80 for 80+80 MHz	Y	Y
	FORMAT is HE_EXT_SU	Indicates the channel width of the transmitted PPDU. Enumerated type: 242-tone RU Right 106-tone RU within the primary 20 MHz	Y	Y
	FORMAT is HE_MU	Indicates the channel width occupied by the preamble supporting channel bonding. See the Bandwidth field in Table 28-17 (HE-SIG-A field of an HE MU PPDU)	Y	Y
	FORMAT is HE_TRIG	In TXVECTOR, indicates the Bandwidth field of the HE-SIG-A in the transmitted PPDU. In RXVECTOR, indicates the estimated channel width of the received PPDU. Enumerated type: CBW20 for 20 MHz CBW40 for 40 MHz CBW80 for 80 MHz CBW160 for 160 MHz CBW80+80 for 80+80 MHz NOTE—The TXVECTOR parameter CH_BANDWIDTH does not represent the channel width of the transmitted PPDU.	Y	Y
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
DYN_BANDWIDTH_IN_NON_HT	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Not present.	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
CH_BANDWIDTH_IN_NON_HT	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Not present.	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		

Table 28-1—TXVECTOR and RXVECTOR parameters *(continued)*

LENGTH	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Not present.	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
APEP_LENGTH	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	If equal to 0, indicates an HE NDP PPDU. If greater than 0, indicates the number of octets in the range 1 to 1048575 in the A-MPDU pre-EOF padding (see 10.13.2 (A-MPDU length limit rules)) carried in the PSDU.	MU	O
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
PSDU_LENGTH	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Indicates the number of octets in the HE PSDU in the range of 0 to aPSDUMaxLength octets (see Table 28-46 (HE PHY characteristics)). A value of 0 indicates an HE NDP PPDU.	N	Y
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
USER_POSITION	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Not present.	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
NUM_STS	FORMAT is HE_SU	Indicates the number of space-time streams. Integer in the range 1-8.	Y	Y
	FORMAT is HE_EXT_SU	Indicates the number of space-time streams. Integer in the range 1-2.	Y	Y
	FORMAT is HE_MU	Indicates the number of space-time streams. Integer in the range: 1-4 per user per MU-MIMO RU in the TXVECTOR 1-4 per MU-MIMO RU in the RXVECTOR 1-8 per non MU-MIMO RU in the TXVECTOR and RXVECTOR NUM_STS summed over all users per RU is not greater than 8.	MU	MU
	FORMAT is HE_TRIG	Indicates the number of space-time streams. Integer in the range: 1-4 for a MU-MIMO RU in the TXVECTOR 1-4 per user per MU-MIMO RU in the RXVECTOR 1-8 for a non MU-MIMO RU in the TXVECTOR and RXVECTOR NUM_STS summed over all users per RU is not greater than 8.	MU	MU
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		

Table 28-1—TXVECTOR and RXVECTOR parameters *(continued)*

GROUP_ID	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Not present	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
PARTIAL_AID	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Not present	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
TXOP_DURATION	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Indicates a duration of time that is used to update the NAV for this TXOP (see 27.2.2 (Updating two NAVs)), except for a value of 127 (i.e., all 1s) which indicates an invalid value of TXOP duration in the HE-SIG-A field (see 27.11.5 (TXOP_DURATION)). B0 indicates whether the granularity is 8 µs or 128 µs. When B0 is 0, then B1 to B6 indicate a duration, in units of 8 µs, starting from 0 to 504 us (i.e, duration = (8 µs × value of (B1-B6)) µs). When B0 is 1, then B1 to B6 indicate a duration, in units of 128 µs, starting from 512 µs until 8448 µs (i.e, duration = (512 + 128 × value of (B1-B6)) µs). See 27.11.5 (TXOP_DURATION) for more details. NOTE—B1-B6 indicates an integer, where B1 is MSB.	Y	Y
	Otherwise	Not present.	N	N
SPATIAL_REUSE	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Indicates the spatial reuse parameter. There is only one value for an HE SU PPDU, HE extended range SU PPDU and HE MU PPDU. There might be one to four values for an HE trigger-based PPDU depending on the bandwidth of the PPDU. See the Spatial Reuse field definition in 28.3.10.7.2 (Content). See 27.11a (TXVECTOR parameters SPATIAL_REUSE for an HE PPDU) for the setting rule.	Y	Y
	Otherwise	Not present	N	N
DOPPLER	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Indicates whether the doppler effect should be considered for the PPDU. The value is 0 or 1	Y	N
	Otherwise	Not present	N	N

Table 28-1—TXVECTOR and RXVECTOR parameters *(continued)*

NUM_USERS	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Not present. NOTE—number of users for an HE SU PPDU, HE extended range SU PPDU and HE trigger-based PPDU is always 1. The number of users for an HE MU PPDU is determined by RU_ALLOCATION.	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
RU_ALLOCATION	FORMAT is HE_MU	Each 8 bit per 20 MHz PPDU BW for signaling: The RU assignment in frequency domain Number of MU-MIMO allocations See 28.3.10.8.4 (HE-SIG-B common content) for details.	Y	Y
	FORMAT is HE_TRIG	8 bit for RU allocation in the whole bandwidth. See 9.3.1.23 (Trigger frame format) for details	Y	Y
	Otherwise	Not present	N	N
BEAMFORMED	FORMAT is HE_SU or HE_EXT_SU	Set to 1 if a beamforming steering matrix is applied to the waveform in an SU transmission. Set to 0 otherwise.	Y	Y
	FORMAT is HE_MU or HE_TRIG	For a single user allocation in an RU, set to 1 if a beamforming steering matrix is applied, and set to 0 otherwise. For each user in a multi-user allocation in an RU, always set to 0.	MU	O
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
HE_LTF_TYPE	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Indicates the type of HE-LTF. Enumerated type: 1x HE-LTF for 3.2 µs 2x HE-LTF for 6.4 µs 4x HE-LTF for 12.8 µs See 28.3.10.10 (HE-LTF) for details.	Y	Y
	Otherwise	Not present.	N	N
HE_LTF_MODE	FORMAT is HE_TRIG	Indicates whether the UL MU MIMO transmission uses single stream pilots or a mask on each spatial stream of the LTF sequence by a distinct orthogonal code. It is only present for full bandwidth MU-MIMO.	Y	N
	Otherwise	Not present.	N	N
NUM_HE_LTF	FORMAT is HE_TRIG	Indicate the number of HE-LTF symbols. See 27.5.2.3 (STA behavior) for details.	Y	N
	Otherwise	Not present.	N	N

Table 28-1—TXVECTOR and RXVECTOR parameters *(continued)*

HE_SIGA_RESERVED	FORMAT is HE_TRIG	Indicates the Reserved field setting for HE-SIG-A2 of HE trigger based PPDU. See 27.5.2.3 (STA behavior) and Table 28-18 (HE-SIG-A field of an HE trigger-based PPDU) for details.	Y	N
	Otherwise	Not present.	N	N
STARTING_STS_NUM	FORMAT is HE_TRIG	Indicates the starting STS number in the global space-time streams for the UL MU MIMO.	Y	N
	Otherwise	Not present.	N	N
TXOP_PS_NOT_ALLOWED	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Not present	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
TIME_OF_DEPARTURE_REQUE	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).			
RX_START_OF_FRAME_OFFSET	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).			
PREAMBLE_TYPE	FORMAT is NON_HT and NON_HT_MODULATION is one of ERP-DSSS ERP-CCK	Enumerated type: SHORTPREAMBLE LONGPREAMBLE	Y	Y
	Otherwise	Not present	N	N

Table 28-1—TXVECTOR and RXVECTOR parameters *(continued)*

PE_DURATION	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG.	Determines the duration of PE field in an HE PPDU. Possible values are 0 µs, 4 µs, 8 µs, 12 µs and 16 µs. Enumerated type: PE0 for 0 µs PE1 for 4 µs PE2 for 8 µs PE3 for 12 µs PE4 for 16 µs	Y	Y
BEAM_CHANGE	FORMAT is HE_SU or HE_EXT_SU	Boolean value: true indicates that the pre-HE-STF portion of the PPDU is spatially mapped differently from HE-LTF1. false indicates that the pre-HE-STF portion of the PPDU is spatially mapped the same way as HE-LTF1 on each tone.	Y	Y
	Otherwise	Not present		
BSS_COLOR	FORMAT is HE_SU, HE_MU, HE_EXT_SU or HE_TRIG	Set to a value of the AP's choosing within the range 0 to 63 (see 27.11 (Setting TXVECTOR parameters for an HE PPDU)).	Y	Y
	Otherwise	Not present	N	N
UPLINK_FLAG	FORMAT is HE_SU or HE_MU or HE_EXT_SU	Set to 1 if the HE PPDU is addressed to an AP. Set to 0 otherwise (see 27.11 (Setting TXVECTOR parameters for an HE PPDU)).	Y	Y
	Otherwise	Not present	N	N
STA_ID_LIST	FORMAT is HE_MU	Indicates the list of STA IDs for an HE MU PPDU (see 27.11 (Setting TXVECTOR parameters for an HE PPDU)).	MU	Y
	Otherwise	Not present	N	N

Table 28-1—TXVECTOR and RXVECTOR parameters *(continued)*

SCRAMBLER_INTIAL_STATE	FORMAT is NON_HT	In TXVECTOR, if present, indicates the initial state of the scrambler of the transmitted PPDU. In RXVECTOR, indicates the Scrambler Initialization value in the Service field, prior to descrambling.	O	Y
	FORMAT is HE_MU or HE_TRIG	Not present.	N	N
	Otherwise	Indicates the Scrambler Initialization value in the Service field, prior to descrambling.	N	Y
NOTE—In the "TXVECTOR" and "RXVECTOR" columns, the following apply: Y = Present; N = Not present; O = Optional; MU indicates that the parameter is present once for an HE SU PPDU and HE extended range SU PPDU and present per user for an HE MU PPDU. For an HE trigger-based PPDU, MU in the TXVECTOR column indicates that the parameter is present once and MU in the RXVECTOR column indicates the parameter is present per user. Parameters specified to be present per user are conceptually supplied as an array of values indexed by *u*, where *u* takes values 0 to NUM_USERS–1.				

28.3 HE PHY

28.3.1 Introduction

This subclause provides the procedure by which PSDUs are converted to and from transmissions on the wireless medium.

During transmission, a PSDU (in the SU case) or one or more PSDUs (in the MU case) are processed (i.e., scrambled and coded) and appended to the PHY preamble to create the PPDU. At the receiver, the PHY preamble is processed to aid in the detection, demodulation, and delivery of the PSDU.

28.3.2 MU transmission

28.3.2.1 Introduction

The MU transmissions include DL MU transmissions and UL MU transmissions.

The DL MU transmission allows an AP to simultaneously transmit frames to more than one non-AP STAs. For the DL MU transmission, the AP uses the HE MU PPDU format, and employs either DL OFDMA, DL MU-MIMO, or a mixture of both. The UL MU transmission allows an AP to receive simultaneous frames from more than one non-AP STAs. Non-AP STAs transmit their frames using HE trigger-based PPDU format and employ either UL OFDMA, UL MU-MIMO, or a mixture of both.

The HE PHY supports OFDMA transmissions, both in the DL and the UL where different users can occupy different RUs in a PPDU (see 28.3.9 (Mathematical description of signals)). On an RU in a PPDU, it is allowed to have single stream transmissions to one user or spatial multiplexing to one user (SU-MIMO) or spatial multiplexing to multiple users (MU-MIMO). Note that the VHT PHY supports only full bandwidth DL MU-MIMO as described in 21.3.11 (SU-MIMO and DL-MU-MIMO Beamforming). The HE PHY defines DL MU-MIMO and UL MU-MIMO, for the full bandwidth case as well as for the case where they are being used on only certain RUs in the PPDU. The combination of SU transmissions and MU-MIMO transmissions on different RUs in one PPDU is also supported.

28.3.3 OFDMA and SU tone allocation

28.3.3.1 General

Orthogonal Frequency Division Multiple Access (OFDMA) is an OFDM-based multiple access scheme where different subsets of subcarriers are allocated to different users, allowing simultaneous data transmission to or from several users. In OFDMA, in general, users are allocated different subsets of subcarriers which can change from one PPDU to the next. In HE, the time region covers the entire data portion of an HE PPDU, and the frequency region includes a number of contiguous subcarriers with the exception of the RUs which straddle DC where nulls are placed in the middle of the band. The difference between OFDM and OFDMA is illustrated in Table 28-15 (CH_BANDWIDTH and for pre-HE modulated fields). Similar to OFDM, OFDMA employs multiple subcarriers, but the subcarriers are divided into several groups of subcarriers where each group is denoted as a resource unit (RU). The grouping of subcarriers into groups of resource units is referred to as subchannelization.

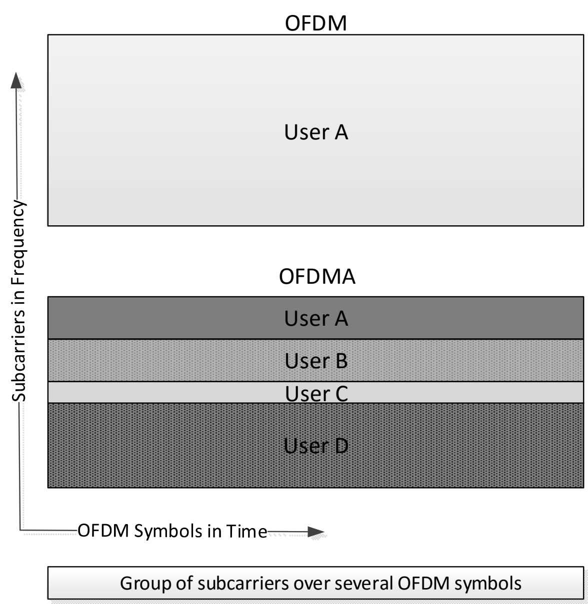


Figure 28-1—Illustration of OFDM and OFDMA concepts

Subchannelization defines subchannels that can be allocated to stations depending on their channel conditions and service requirements. An OFDMA system may allocate different transmit powers to different subchannels.

In OFDMA, an OFDM symbol is constructed of subcarriers, the number of which is a function of the PPDU bandwidth. There are several subcarrier types: 1) Data subcarriers which are used for data transmission; defined in 28.3.3.2 (Resource unit, guard and DC subcarriers), 2) Pilot subcarriers which are utilized for phase information and parameter tracking; defined in 28.3.3.4 (Pilot subcarriers), and 3) unused subcarriers which are not used for data/pilot transmission. The unused subcarriers are the DC subcarrier (defined in 28.3.3.2 (Resource unit, guard and DC subcarriers)), the Guard band subcarriers at the band edges (defined in 28.3.3.2 (Resource unit, guard and DC subcarriers)), and the Null subcarriers (defined in 28.3.3.3 (Null subcarriers)).

28.3.3.2 Resource unit, guard and DC subcarriers

The following resource units (RUs) are defined for DL and UL transmission: a 26-tone RU, 52-tone RU, 106-tone RU, 242-tone RU, 484-tone RU and 996-tone RU and 2×996-tone RU.

The 26-tone RU, 52-tone RU, 106-tone RU and 242-tone RU are used in the 20 MHz, 40 MHz, 80 MHz, 160 MHz and 80+80 MHz HE MU PPDU formats or HE trigger-based PPDU formats using OFDMA transmission, with the exception that if an HE AP operates in a DFS channel where there is a non-HE OBSS, the HE AP shall not trigger any 26-tone RU and the HE non-AP STA shall not respond with 26-tone RU in a HE trigger-based PPDU in which HE data field is conveyed.

NOTE—If a HE non-AP STA does not respond with a 26-tone RU in HE trigger-based PPDU in a DFS channel, then AP is advised to trigger 52-tone RU for the same HE non-AP STA in the next HE trigger-based PPDU transmission.

The 484-tone RU is used in the 40 MHz, 80 MHz, 160 MHz and 80+80 MHz HE MU PPDU formats or HE trigger-based PPDU formats using OFDMA transmission. The 996-tone RU is used in the 80 MHz, 160 MHz and 80+80 MHz HE MU PPDU formats or HE trigger-based PPDU formats using OFDMA transmission. The 2×996-tone RU is used in the 160 MHz and 80+80 MHz HE MU PPDU formats or HE trigger-based PPDU formats using OFDMA transmission.

The 242-tone and larger RUs are used in the HE SU PPDU formats. The 242-tone RU is used in the 20 MHz HE SU PPDU format. The 484-tone RU is used in the 40 MHz HE SU PPDU format. The 996-tone RU is used in the 80 MHz HE SU PPDU format. The 2×996-tone RU is used in the 160 MHz and 80+80 MHz HE SU PPDU formats.

The maximum number of RUs in the 20 MHz, 40 MHz, 80 MHz, 160 MHZ and 80+80 MHz HE PPDU formats are defined in Table 28-2 (Maximum number of RUs for each channel width)..

Table 28-2—Maximum number of RUs for each channel width

RU type	CBW20	CBW40	CBW80	CBW80+80 and CBW160
26-tone RU	9	18	37	74
52-tone RU	4	8	16	32
106-tone RU	2	4	8	16
242-tone RU	1	2	4	8
484-tone RU	N/A	1	2	4
996-tone RU	N/A	N/A	1	2
2×996 tone RU	N/A	N/A	N/A	1

An HE MU PPDU using OFDMA transmission can carry a mixture of 26-, 52-, 106-, 242-, 484 and 996-tone RUs.

Table 28-3—Subcarrier indices for RUs in a 20 MHz HE PPDU

RU type					
26-tone RU	RU 1 [−121: −96]	RU 2 [−95: −70]	RU 3 [−68: −43]	RU 4 [−42: −17]	RU 5 [−16: −4, 4: 16]
	RU 6 [17: 42]	RU 7 [43: 68]	RU 8 [70: 95]	RU 9 [96: 121]	
52-tone RU	RU 1 [−121: −70]	RU 2 [−68: −17]	RU 3 [17: 68]	RU 4 [70: 121]	
106-tone RU	RU 1 [−122: −17]		RU 2 [17: 122]		
242-tone RU	RU 1 [−122: −2, 2:122]				

Table 28-4—Subcarrier indices for RUs in a 40 MHz HE PPDU

RU type					
26-tone RU	RU 1 [−243: −218]	RU 2 [−217: −192]	RU 3 [−189: −164]	RU 4 [−163: −138]	RU 5 [−136: −111]
	RU 6 [−109: −84]	RU 7 [−83: −58]	RU 8 [−55: −30]	RU 9 [−29: −4]	
	RU 10 [4: 29]	RU 11 [30: 55]	RU 12 [58: 83]	RU 13 [84: 109]	RU 14 [111: 136]
	RU 15 [138: 163]	RU 16 [164: 189]	RU 17 [192: 217]	RU 18 [218: 243]	
52-tone RU	RU 1 [−243: −192]	RU 2 [−189: −138]	RU 3 [−109: −58]	RU 4 [−55: −4]	
	RU 5 [4: 55]	RU 6 [58: 109]	RU 7 [138: 189]	RU 8 [192: 243]	
106-tone RU	RU 1 [−243: −138]	RU 2 [−109: −4]	RU 3 [4: 109]	RU 4 [138: 243]	
242-tone RU	RU 1 [−244: −3]		RU2 [3: 244]		
484-tone RU	RU 1 [−244: −3, 3: 244]				

Table 28-5—Subcarrier indices for RUs in an 80 MHz HE PPDU

RU type					
26-tone RU	RU 1 [−499: −474]	RU 2 [−473: −448]	RU 3 [−445: −420]	RU 4 [−419: −394]	RU 5 [−392: −367]
	RU 6 [−365: −340]	RU 7 [−339: −314]	RU 8 [−311: −286]	RU 9 [−285: −260]	
	RU 10 [−257: −232]	RU 11 [−231: −206]	RU 12 [−203: −178]	RU 13 [−177: −152]	RU 14 [−150: −125]
	RU 15 [−123: −98]	RU 16 [−97: −72]	RU 17 [−69: −44]	RU 18 [−43: −18]	RU 19 [−16: −4, 4: 16]
	RU 20 [18: 43]	RU 21 [44: 69]	RU 22 [72: 97]	RU 23 [98: 123]	RU 24 [125: 150]
	RU 25 [152: 177]	RU 26 [178: 203]	RU 27 [206: 231]	RU28 [232: 257]	
	RU 29 [260: 285]	RU 30 [286: 311]	RU 31 [314: 339]	RU 32 [340: 365]	RU 33 [367: 392]
	RU 34 [394: 419]	RU 35 [420: 445]	RU 36 [448: 473]	RU37 [474: 499]	
52-tone RU	RU 1 [−499: −448]	RU 2 [−445: −394]	RU 3 [−365: −314]	RU 4 [−311: −260]	
	RU 5 [−257: −206]	RU 6 [−203: −152]	RU 7 [−123: −72]	RU 8 [−69: −18]	
	RU 9 [18: 69]	RU 10 [72: 123]	RU 11 [152: 203]	RU 12 [206: 257]	
	RU 13 [260: 311]	RU 14 [314: 365]	RU 15 [394: 445]	RU 16 [448: 499]	
106-tone RU	RU 1 [−499: −394]	RU 2 [−365: −260]	RU 3 [−257: −152]	RU 4 [−123: −18]	
	RU 5 [18: 123]	RU 6 [152: 257]	RU 7 [260: 365]	RU 8 [394: 499]	
242-tone RU	RU 1 [−500: −259]	RU 2 [−258: −17]	RU 3 [17: 258]	RU 4 [259: 500]	
484-tone RU	RU 1 [−500: −17]		RU 2 [17: 500]		
996-tone RU	RU 1 [−500: −3, 3: 500]				

A 26-tone RU consists of 24 data subcarriers and 2 pilot subcarriers. The positions of the pilots for the 26-tone RU are defined in 28.3.3.4 (Pilot subcarriers). The location of the 26-tone RUs are fixed as defined in Table 28-3 (Subcarrier indices for RUs in a 20 MHz HE PPDU), Table 28-4 (Subcarrier indices for RUs in a 40 MHz HE PPDU) and Table 28-5 (Subcarrier indices for RUs in an 80 MHz HE PPDU) and shown in Figure 28-2 (RU locations in a 20 MHz HE PPDU), Figure 28-3 (RU locations in a 40 MHz HE PPDU) and Figure 28-4 (RU locations in an 80 MHz HE PPDU) for the 20 MHz, 40 MHz and 80 MHz HE MU PPDU formats or HE trigger-based PPDU formats using OFDMA transmission, respectively. The same structure as used for the 80 MHz HE MU PPDU formats or HE trigger-based PPDU formats using OFDMA transmission is used for each 80 MHz frequency segment of the 160 MHz and 80+80 MHz HE MU PPDU or HE trigger-based PPDU formats using OFDMA transmission. The center 26-tone RU in the 20 MHz and 80 MHz HE MU PPDU or HE trigger-based PPDU formats using OFDMA transmission (Figure 28-2 (RU locations in a 20 MHz HE PPDU) and Figure 28-4 (RU locations in an 80 MHz HE PPDU)) is located on subcarriers [–16: –4, 4: 16].

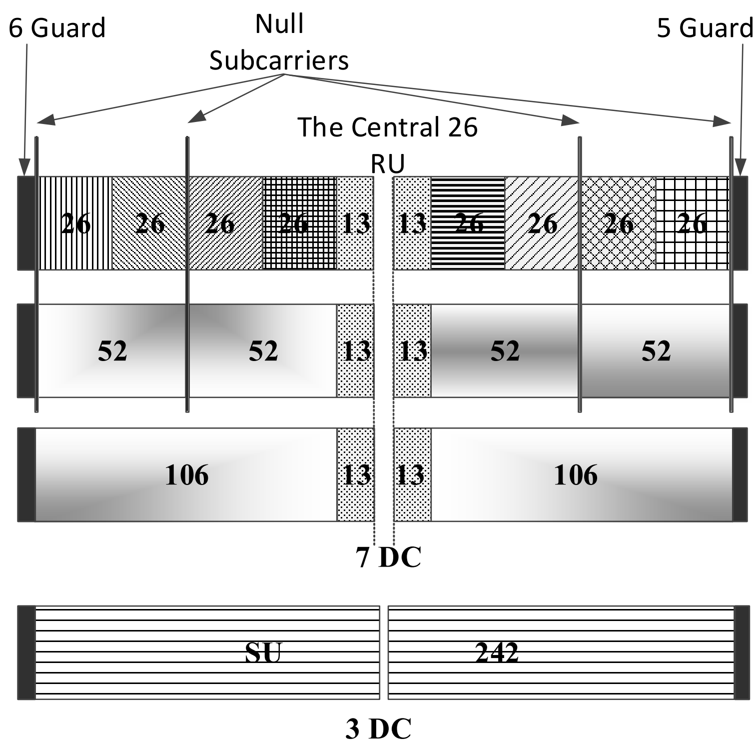


Figure 28-2—RU locations in a 20 MHz HE PPDU

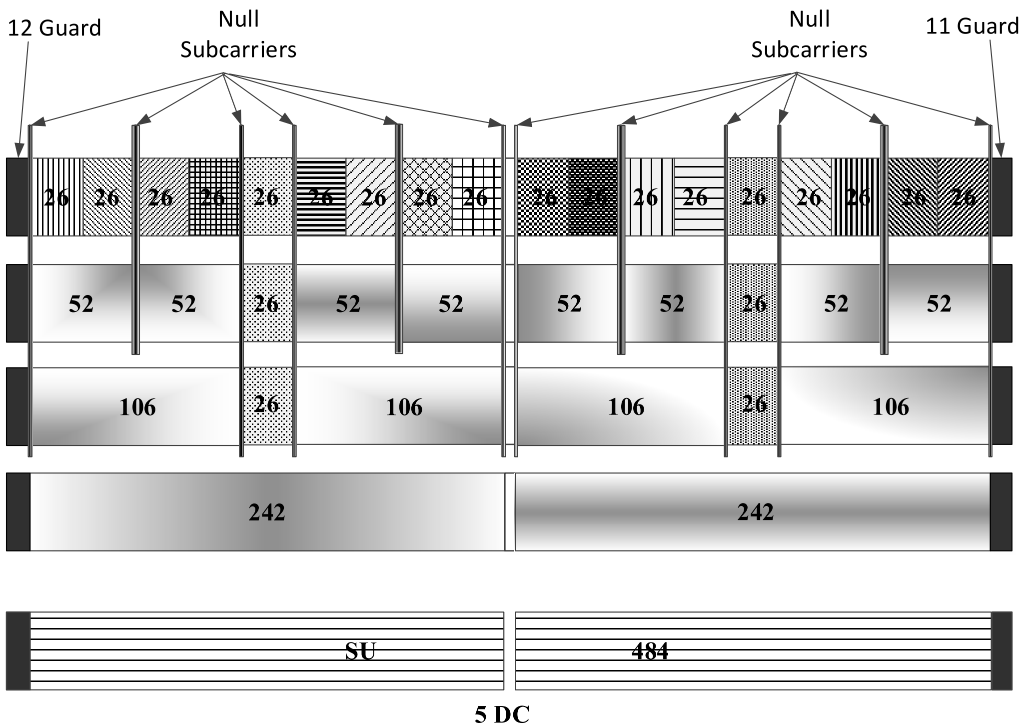


Figure 28-3—RU locations in a 40 MHz HE PPDU

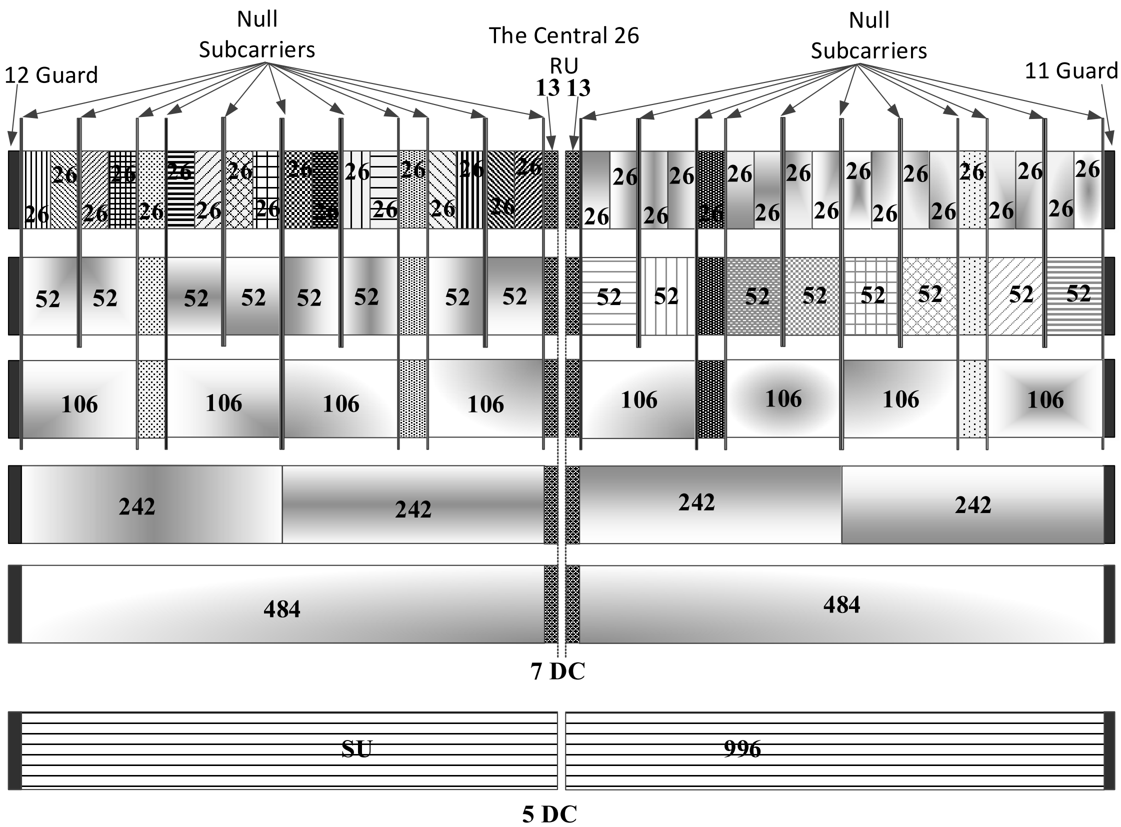


Figure 28-4—RU locations in an 80 MHz HE PPDU

A 52-tone RU consists of 48 data subcarriers and 4 pilot subcarriers. The positions of the pilots for the 52-tone RU are defined in 28.3.3.4 (Pilot subcarriers). The locations of the 52-tone RUs are fixed as defined in Table 28-3 (Subcarrier indices for RUs in a 20 MHz HE PPDU), Table 28-4 (Subcarrier indices for RUs in a 40 MHz HE PPDU) and Table 28-5 (Subcarrier indices for RUs in an 80 MHz HE PPDU) and illustrated in Figure 28-2 (RU locations in a 20 MHz HE PPDU), Figure 28-3 (RU locations in a 40 MHz HE PPDU) and Figure 28-4 (RU locations in an 80 MHz HE PPDU) for the 20 MHz, 40 MHz and 80 MHz HE MU PPDU formats or HE trigger-based PPDU formats using OFDMA transmission, respectively. The same structure as used in the 80 MHz HE MU PPDU format or HE trigger-based PPDU formats using OFDMA transmission is used for each 80 MHz frequency segment of the 160 MHz and 80+80 MHz HE MU PPDU formats or HE trigger-based PPDU formats using OFDMA transmission.

A 106-tone RU consists of 102 data subcarriers and 4 pilot subcarriers. The positions of the pilots for the 106-tone RU are defined in 28.3.3.4 (Pilot subcarriers). The locations of the 106-tone RUs are fixed as defined in Table 28-3 (Subcarrier indices for RUs in a 20 MHz HE PPDU), Table 28-4 (Subcarrier indices for RUs in a 40 MHz HE PPDU) and Table 28-5 (Subcarrier indices for RUs in an 80 MHz HE PPDU) and illustrated in Figure 28-2 (RU locations in a 20 MHz HE PPDU), Figure 28-3 (RU locations in a 40 MHz HE PPDU) and Figure 28-4 (RU locations in an 80 MHz HE PPDU) for the 20 MHz, 40 MHz and 80 MHz HE MU PPDU formats or HE trigger-based PPDU formats using OFDMA transmission, respectively. The same structure as used in the 80 MHz HE MU PPDU formats or HE trigger-based PPDU formats using OFDMA transmission is used for each 80 MHz frequency segment of the 160 MHz and 80+80 MHz HE MU PPDU formats or HE trigger-based PPDU formats using OFDMA transmission.

A 242-tone RU consists of 234 data subcarriers and 8 pilot subcarriers. The positions of pilots for the 242-tone RU are defined in 28.3.3.4 (Pilot subcarriers). The locations of the 242-tone RUs are fixed as defined in Table 28-3 (Subcarrier indices for RUs in a 20 MHz HE PPDU), Table 28-4 (Subcarrier indices for RUs in a 40 MHz HE PPDU) and Table 28-5 (Subcarrier indices for RUs in an 80 MHz HE PPDU) and illustrated in Figure 28-2 (RU locations in a 20 MHz HE PPDU), Figure 28-3 (RU locations in a 40 MHz HE PPDU) and Figure 28-4 (RU locations in an 80 MHz HE PPDU) for the 20 MHz, 40 MHz and 80 MHz HE PPDU formats, respectively. The same structure as used in the 80 MHz HE PPDU formats is used for each 80 MHz frequency segment of the 160 MHz and 80+80 MHz HE PPDU formats.

A 484-tone RU consists of 468 data subcarriers and 16 pilot subcarriers. The position of the pilots for the 484-tone RU is defined in 28.3.3.4 (Pilot subcarriers). The locations of the 484-tone RUs are fixed as defined in Table 28-4 (Subcarrier indices for RUs in a 40 MHz HE PPDU) and Table 28-5 (Subcarrier indices for RUs in an 80 MHz HE PPDU) and illustrated in Figure 28-3 (RU locations in a 40 MHz HE PPDU) and Figure 28-4 (RU locations in an 80 MHz HE PPDU) for the 40 MHz and 80 MHz HE PPDU formats. The same structure as used for the 80 MHz HE PPDU formats is used for each 80 MHz frequency segment of the 160 MHz and 80+80 MHz HE PPDU formats.

A 996-tone RU consists of 980 data subcarriers and 16 pilot subcarriers. The position of the pilots for the 996-tone RU is defined in 28.3.3.4 (Pilot subcarriers). The locations of the 996-tone RUs are fixed and located on subcarrier [–1012: –515, –509: –12] and [12: 509, 515: 1012] for each half of the BW, respectively, for 160 MHz and 80+80 MHz HE PPDU formats.

The 20 MHz HE MU PPDU and HE trigger-based PPDU with more than one RU has 7 DC subcarriers located at [–3: 3]. The 20 MHz HE SU PPDU with a 242-tone RU has 3 DC subcarriers located at [–1: 1]. The 40 MHz HE PPDU with a 484-tone RU has 5 DC subcarriers located at [–2: 2]. An 80 MHz HE MU PPDU and HE trigger-based PPDU with more than one RU has 7 DC subcarriers located at [–3: 3]. The 80 MHz HE SU PPDU with a 996-tone RU has 5 DC subcarriers located at [–2: 2]. The same structure as used in the 80 MHz HE PPDU is used for each 80 MHz frequency segment of the 160 MHz and 80+80 MHz HE PPDU. The DC tones are located on subcarriers [–11: 11].

The 20 MHz HE PPDU format has 11 guard subcarriers (6, 5) located at [–128: –123] and [123: 127] as shown in Figure 28-2 (RU locations in a 20 MHz HE PPDU). The 40 MHz HE PPDU has 23 guard subcarriers (12, 11) located at [–256: –245] and [245: 255] as shown in Figure 28-3 (RU locations in a 40 MHz HE PPDU). The 80 MHz HE PPDU has 23 guard subcarriers (12, 11) located at [–512: –501] and [501: 511] as shown in Figure 28-4 (RU locations in an 80 MHz HE PPDU). For 160 MHz and 80+80 MHz HE PPDUs, the same number of leftmost and rightmost guard subcarriers as 80 MHz are defined at each edge of the 160 MHz.

In an HE MU PPDU, at least *N*x4x26 subcarriers (contiguous or non-contiguous), where *N* is the number of 20 MHz channels' legacy preambles present, shall be occupied throughout the signaled BW.

28.3.3.3 Null subcarriers

There are null subcarriers between the 26-, 52- and 106-tone RU locations as illustrated in Figure 28-2 (RU locations in a 20 MHz HE PPDU), Figure 28-3 (RU locations in a 40 MHz HE PPDU) and Figure 28-4 (RU locations in an 80 MHz HE PPDU). The null subcarriers have zero energy. The indices of the null subcarrier are enumerated in Table 28-6 (Null subcarrier indices).

Table 28-6— Null subcarrier indices

Channel Width	RU Size	Null Subcarrier Indices
20 MHz	26, 52	±69, ±122
	106	none
	242	none
40 MHz	26, 52	±3, ±56, ±57, ±110, ±137, ±190, ±191, ±244
	106	±3, ±110, ±137, ±244
	242, 484	none
80 MHz	26, 52	±17, ±70, ±71, ±124, ±151, ±204, ±205, ±258, ±259, ±312, ±313, ±366, ±393, ±446, ±447, ±500
	106	±17, ±124, ±151, ±258, ±259, ±366, ±393, ±500
	242, 484	none
	996	none

28.3.3.4 Pilot subcarriers

If pilot subcarriers are present in the HE-LTF field, the pilot subcarrier locations in the HE-LTF field and Data field shall be the same, except for the 1x HE-LTF. In the 1x HE-LTF, the pilot locations are the pilot subcarrier indices that are multiples of 4 of the pilot subcarriers for data field. All pilot subcarriers are at the even indices enumerated in Table 28-7 (Pilot subcarrier indices).

Table 28-7— Pilot subcarrier indices

Channel Width	RU Size	Pilot Subcarrier Indices
20 MHz	26, 52	±10, ±22, ±36, ±48, ±62, ±76, ±90, ±102, ±116
	106, 242	±22, ±48, ±90, ±116
40 MHz	26, 52	±10, ±24, ±36, ±50, ±64, ±78, ±90, ±104, ±116, ±130, ±144, ±158, ±170, ±184, ±198, ±212, ±224, ±238
	106, 242, 484	±10, ±36, ±78, ±104, ±144, ±170, ±212, ±238
80 MHz	26, 52	±10, ±24, ±38, ±50, ±64, ±78, ±92, ±104, ±118, ±130, ±144, ±158, ±172, ±184, ±198, ±212, ±226, ±238, ±252, ±266, ±280, ±292, ±306, ±320, ±334, ±346, ±360, ±372, ±386, ±400, ±414, ±426, ±440, ±454, ±468, ±480, ±494
	106, 242, 484	±24, ±50, ±92, ±118, ±158, ±184, ±226, ±252, ±266, ±292, ±334, ±360, ±400, ±426, ±468, ±494
	996	±24, ±92, ±158, ±226, ±266, ±334, ±400, ±468

Table 28-7— Pilot subcarrier indices *(continued)*

160 MHz	26, 52, 106, 242, 484	{pilot subcarrier indices in 80 MHz −512, pilot subcarrier indices in 80 MHz +512}
	996	{for the first 80 MHz, pilot subcarrier indices in 80 MHz −512, for the second 80 MHz, pilot subcarrier indices in 80 MHz +512}

The pilot subcarriers locations for 160 MHz or 80+80 MHz shall use the same 80 MHz locations for both 80 MHz.

28.3.3.5 RU restriction rules when operating 20 MHz

A non-AP STA can operate with 20 MHz, because either it is a 20 MHz-only HE device (see 28.3.9 (Mathematical description of signals)), or it reduces operating channel width to 20 MHz by ROM (see 27.8 (Operating mode indication)). When a 20 MHz operating non-AP STA is either a recipient of 40, 80, 80+80 or 160 MHz DL-OFDMA, or one of transmitters of 40, 80, 80+80 or 160 MHz UL-OFDMA, RU tone mapping in 20 MHz is not aligned with 40, 80, 80+80 or 160 MHz RU tone mapping (see 28.3.3.2 (Resource unit, guard and DC subcarriers)). Due to misalignment of these RU locations, some of these RUs may cause significant performance penalty or interference to neighbor RUs. To improve the throughput and interoperability, some RUs in 20 MHz operating STAs are restricted to be used in 40, 80, 80+80 or 160 MHz OFDMA operation.

An AP shall not assign the following RUs to 20 MHz operating STAs

— For 26-tone RUs, [Table 28-4 (Subcarrier indices for RUs in a 40 MHz HE PPDU) and Table 28-5 (Subcarrier indices for RUs in an 80 MHz HE PPDU)]
  - RU 5 and 14 in 40 MHz DL/UL OFDMA (2 26-tone RUs are restricted)
  - RU 5, 10, 14, 19, 24, 28, 33 in 80 MHz DL/UL OFDMA (7 26-tone RUs are restricted)
  - RU 5, 10, 14, 19, 24, 28, 33 in lower 80 MHz and upper 80 MHz, in 80+80 or 160 MHz DL/UL OFDMA (14 26-tone RUs are restricted)

— For 52-tone RUs, [Table 28-4 (Subcarrier indices for RUs in a 40 MHz HE PPDU) and Table 28-5 (Subcarrier indices for RUs in an 80 MHz HE PPDU)]
  - RU 5, 12 in 80 MHz DL/UL OFDMA (2 of 52-tone RUs are restricted)
  - RU 5, 12 in lower 80 MHz and upper 80 MHz, in 80+80 or 160 MHz DL/UL OFDMA (4 of 52-tone RUs are restricted)

— For 106-tone RUs, [Table 28-4 (Subcarrier indices for RUs in a 40 MHz HE PPDU) and Table 28-5 (Subcarrier indices for RUs in an 80 MHz HE PPDU)]
  - RU 3, 6 in 80MHz DL/UL OFDMA (2 of 106-tone RUs are restricted)
  - RU 3, 6 in lower 80 MHz and upper 80 MHz, in 80+80 or 160 MHz DL/UL OFDMA (4 of 106-tone RUs are restricted)

Center 26-tone RU in primary 20 channel shall not be assigned to any STAs where 20 MHz operating STAs are recipients of 40/80/160/80+80 OFDMA.

It is optional whether all 242-tone RUs of 20 MHz operating STAs to be supported in 40/80/160/80+80 MHz DL-OFDMA. If supported, there is no restriction on 242-tone RUs. A 242-tone RU shall not be allocated to 20 MHz operating STAs in 40/80/160/80+80 for UL-OFDMA.

28.3.3.6 20 MHz only HE STAs

A 20 MHz only HE STA operates with 20 MHz channel width only, in frequency bands between 1 GHz and 6 GHz. A 20 MHz only HE STA operates in the primary 20 MHz channel as a mandatory mode. The supported channel bandwidth is indicated in the Channel Width Set field in the HE Capabilities element. Only a non-AP HE STA can be a 20 MHz-only STA.

An HE AP in 5 GHz shall be 80 MHz capable and operate for both 80 MHz capable non-AP HE STAs and 20 MHz only non-AP HE STAs.

A 20 MHz only non-AP HE STA supports tone mapping of 26-tone RU, 52-tone RU, 106-tone RU and 242-tone RU, for 20 MHz and 40 MHz OFDMA in 2.4 GHz and 5 GHz frequency band, and for 80 MHz, 80+80 MHz and 160 MHz OFDMA in 5 GHz frequency band, where some of RUs are restricted to operate (see 28.3.3.5 (RU restriction rules when operating 20 MHz)).

28.3.3.7 DL MU transmission

DL MU transmission allows an AP to simultaneously transmit to more than one non-AP STA. The AP uses the HE MU PPDU for DL MU transmission.

28.3.3.8 DL MU-MIMO

28.3.3.8.1 Minimum RU size in DL MU-MIMO

A STA capable of receiving DL MU-MIMO transmission on an RU that does not span the entire PPDU bandwidth in an HE MU PPDU shall support reception of DL MU-MIMO transmissions for all RU sizes greater than or equal to 106-tones.

28.3.3.8.2 Maximum number of spatial streams in an HE MU PPDU

An HE STA shall support reception of DL MU-MIMO transmissions on full bandwidth with maximum number of space-time streams (per user) equal to minimum of 4 and the maximum number of space-time streams supported for reception of HE SU PPDUs. The maximum number of space-time streams supported for reception of HE SU PPDUs is indicated for various bandwidths in Tx Rx HE MCS Support field in the HE Capabilities element.

An HE STA shall support reception of DL MU-MIMO transmissions on full bandwidth with the total number of space-time streams (across NUM_USERS) less than or equal to a maximum value indicated by the Nsts_Total support for BW <= 80 MHz and Nsts_Total support for BW > 80 MHz fields in the HE Capabilities element.

All of the aforementioned restrictions on the per-user and total number of space-time-streams are also applicable to an MU-MIMO transmission on an RU in an HE MU PPDU where the RU does not span the entire PPDU bandwidth.

28.3.3.8.3 Resource indication and STA self-identification in an HE MU PPDU

An AP that transmits an HE MU PPDU shall set the UL/DL field in the HE-SIG-A field to 0. A full bandwidth MU-MIMO transmission using HE MU PPDU format has a value of 1 for the SIGB Compression field in HE-SIG-A and the SIGB Common field is not present. If the value of SIGB Compression field in HE-SIG-A is 0, the RU allocation signaling in the HE-SIG-B common field indicates the combination of RUs in current PPDU bandwidth and the number of STAs on each RU for SU/MU-MIMO transmission. The number of users in RU *r* for MU-MIMO transmission, $N_{user,r}$ is indicated together with the RU allocation as defined in Table 28-21 (RU allocation signaling: arrangement and number of MU-MIMO allocations). If the value of the SIGB Compression field in HE-SIG-A is 1, there is no RU allocation signaling in HE-SIG-B Common field and HE-SIG-B contains only User specific fields. The number of STAs in the MU-MIMO group is indicated in the Number Of HE-SIG-B Symbols Or MU-MIMO Users field in HE-SIG-A. For bandwidths larger than 20 MHz, the User block fields are split equitably between two SIG-B channels, i.e., for a *k* user MU-MIMO PPDU, 1, …., ceil(k/2) User block fields are carried in HE-SIG-B content channel 1 and ceil(k/2) + 1, …, *k* User block fields in HE-SIG-B content channel 2. The number of spatial streams, $N_{SS,r,u}$, is indicated by the NSTS field in user specific block as defined in Table 28-22 (Fields of the HE-SIG-B user field for an non-MU-MIMO allocation) and Table 28-23 (Fields of the HE-SIG-B user field for an MU-MIMO allocation). The allocated spatial streams for a designated MU-MIMO user and the total number of spatial streams on the RU are indicated in spatial configuration field of user specific block containing the STA ID of designated MU-MIMO STA as defined in Table 28-24 (Spatial Configuration subfield encoding).

When processing the HE-SIG-B, a STA will look at information of each RU to find out its membership status, i.e., if it belongs to a beamformee group in a certain RU. If $N_{user,r}$ STAs are scheduled in RU r, there are $N_{user,r}$ user specific blocks for RU r. Each user specific block has an 11-bit field indicating the STA ID. A STA identifies itself as a member in the beamformee group in the RU, if its STA ID matches one of the STA IDs. The user position is indicated by the block index. From a multiplexing information lookup table for $N_{user,r}$, the ordered number of spatial streams for all members in the beamformee group in RU r, $N_{SS,r,u}$, $u = 1, \ldots, N_{user,r}$, is obtained. The spatial streams of different users are ordered in accordance to user position values, i.e., the spatial streams for the user in user position 0 come first, followed by the spatial streams for the user in position 1, followed by the spatial streams for the user in position 2, and followed by the spatial streams for the user in position 3, and so on.

A STA is also able to identify the space-time streams intended for other STAs that act as interference. HE-LTF symbols in the DL HE MU PPDU are used to measure the channel for the space-time streams intended for the STA and can also be used to measure the channel for the interfering space-time streams. To successfully demodulate the space-time streams intended for the STA, it is recommended that the STA uses the channel knowledge for all space-time streams to reduce the effect of interfering space-time streams.

If a STA finds that it is a member of the beamformee group in RU r, its corresponding $N_{STS,r,u}$ interpreted from the HE-SIG-B user specific blocks shall not be zero for the STA in the PPDU. If a STA finds that it is not a member of the beamformee group in RU r, then the STA may elect not to process RU r in the remainder of the PPDU.

28.3.3.9 UL MU transmission

28.3.3.9.1 Introduction

UL MU transmissions allow an AP to receive simultaneous frames from more than one non-AP STA. UL MU transmissions are preceded by a Trigger frame from the AP. The non-AP STA uses the HE trigger-based PPDU for UL MU transmission.

28.3.3.10 UL MU-MIMO

28.3.3.10.1 Introduction

UL MU-MIMO is a technique to allow multiple STAs to transmit simultaneously over the same frequency resource to the receiver. The concept is very similar to SU-MIMO where multiple space-time streams are transmitted simultaneously over the same frequency resource utilizing spatial multiplexing through multiple antennas at the transmitter and receiver. The key difference from SU-MIMO is that in UL MU-MIMO, the transmitted streams originate from multiple STAs.

28.3.3.10.2 Minimum RU size in UL MU-MIMO

A STA capable of an UL MU-MIMO transmission on an RU that does not span the entire PPDU bandwidth in an HE trigger-based PPDU shall support UL MU-MIMO transmission for all RU sizes greater than or equal to 106 subcarriers.

28.3.3.10.3 MU-MIMO LTF Mode

A STA capable of UL MU-MIMO transmission on full bandwidth shall support single stream pilot and masking LTF sequence of each spatial stream by a distinct orthogonal code.

A STA capable of UL OFDMA with MU-MIMO transmission on an RU in an HE trigger-based PPDU shall support single stream pilot for any UL OFDMA transmission, including UL OFDMA with MU-MIMO transmission on an RU in an HE trigger-based PPDU.

28.3.3.10.4 Maximum number of spatial streams in an HE trigger-based PPDU

A STA capable of UL MU-MIMO transmission shall support UL MU-MIMO transmissions on full bandwidth with maximum number of space-time streams (per user) equal to minimum of 4 and the maximum number of space-time streams supported for transmission of HE SU PPDUs. The maximum number of space-time streams supported for transmission of HE SU PPDUs is indicated for various bandwidths in Tx Rx HE MCS Support field in the HE Capabilities element.

A STA capable of UL MU-MIMO transmission on the full bandwidth shall support a total of up to 8 space-time streams in the UL MU-MIMO transmission.

All of the aforementioned restrictions on the per-user and total number of space-time-streams are also applicable to an MU-MIMO transmission on an RU in an HE MU PPDU where the RU does not span the entire PPDU bandwidth.

28.3.3.10.5 Resource allocation for an HE trigger-based PPDU

UL MU transmissions are preceded by a Trigger frame from the AP. The Trigger frame indicates the transmitting STAs in the Common Info field about when to transmit the UL MU-MIMO PPDUs, the duration of the payload, and packet-extension. The GI duration for UL OFDMA/MU-MIMO transmissions shall also be explicitly indicated by AP in the Trigger frame. The value of GI duration for all users addressed by the Trigger frame shall be the same. The Trigger frame indicates whether the UL MU transmission following it uses single stream pilots or a mask on each spatial stream of the LTF sequence by a distinct orthogonal code. When single stream pilot is used, no masking is applied to the HE-LTF. Single stream pilot is used for any UL OFDMA transmission, including UL OFDMA with MU-MIMO transmissions. The appropriate MU-MIMO LTF mode indicated by the Trigger frame is used for full bandwidth UL MU-MIMO transmission. The allocated RU and spatial streams are carried in the fields of RU allocation info and SS allocation of User Info field, where Address field is set as the AID of designated MU-MIMO STA.

If a STA finds that there is no User Info field in Trigger frame carrying the STA's AID in the Address field, then the STA will not transmit in the following HE trigger-based PPDU.

28.3.4 HE PPDU formats

Four HE PPDU formats are defined: HE SU PPDU, HE MU PPDU, HE extended range SU PPDU and HE trigger-based PPDU.

The format of the HE SU PPDU is defined as in Figure 28-5 (HE SU PPDU format). This PPDU format is used for SU transmission and, in this format, the HE-SIG-A field is not repeated.

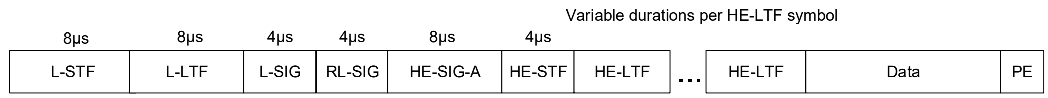


Figure 28-5—HE SU PPDU format

The format of the HE MU PPDU is defined as in Figure 28-6 (HE MU PPDU format). This format is used for transmission to one or more users that is not a response of a Trigger frame. The HE-SIG-B field is present in this format.

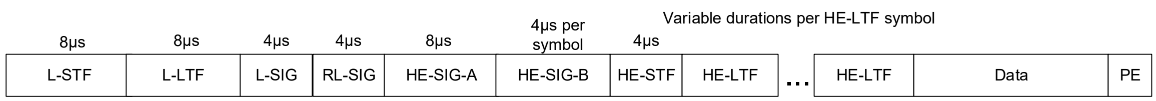


Figure 28-6—HE MU PPDU format

The format of the HE extended range SU PPDU is defined as in Figure 28-7 (HE extended range SU PPDU format). This format is used for SU transmission and, in this format, the HE-SIG-A field is repeated.

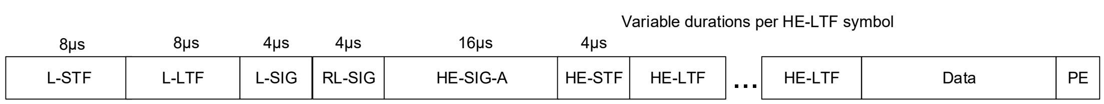


Figure 28-7—HE extended range SU PPDU format

The format of the HE trigger-based PPDU is defined as in Figure 28-8 (HE trigger-based PPDU format). This format is used for a transmission that is a response to a Trigger frame. The HE trigger-based PPDU format is identical to the HE SU PPDU format for the L-STF, L-LTF, L-SIG, RL-SIG, HE-SIG-A fields. The duration of the HE-STF field is 8 µs.

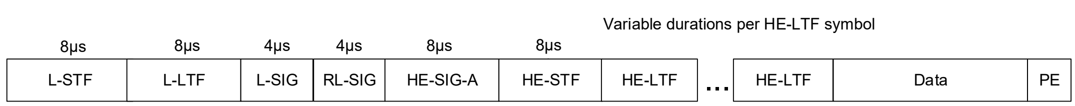


Figure 28-8—HE trigger-based PPDU format

The fields of the HE PPDU formats are summarized in Figure 28-8 (HE PPDU fields).

Table 28-8—HE PPDU fields

Field	Description
L-STF	Non-HT Short Training field
L-LTF	Non-HT Long Training field

Table 28-8—HE PPDU fields *(continued)*

L-SIG	Non-HT SIGNAL field
RL-SIG	Repeated Non-HT SIGNAL field
HE-SIG-A	HE Signal A field
HE-SIG-B	HE Signal B field
HE-STF	HE Short Training field
HE-LTF	HE Long Training field
Data	The Data field carrying the PSDU(s)
PE	Packet Extension field

The RL-SIG, HE-SIG-A, HE-SIG-B, HE-STF, HE-LTF, and PE fields exist only in HE PPDUs. The HE-SIG-B field is present only in the HE MU PPDU. The duration of the PE field is determined by the TXVECTOR parameter PE_DURATION.

The L-STF, L-LTF, L-SIG, RL-SIG, HE-SIG-A, HE-SIG-A-R, and HE-SIG-B fields are referred to as the Pre-HE modulated fields, while the HE-STF, HE-LTF and Data fields are referred to as the HE modulated fields.

28.3.5 Transmitter block diagram

The generation of each field in an HE PPDU uses many of the following blocks:

a) pre-FEC PHY padding
b) Scrambler
c) FEC (BCC or LDPC) encoders
d) post-FEC PHY padding
e) Stream parser
f) Segment parser (for contiguous 160 MHz and noncontiguous 80+80 MHz transmissions)
g) BCC interleaver
h) Constellation mapper
i) DCM tone mapper
j) Pilot insertion
k) Replicate over multiple 20 MHz (if BW > 20 MHz)
l) Multiply by 1st column of $P_{HE\text{-}LTF}$
m) LDPC tone mapper
n) Segment deparser
o) Space time block code (STBC) encoder
p) Cyclic shift diversity (CSD) per STS insertion
q) Spatial mapper
r) Spatial and frequency mapping
s) Inverse discrete Fourier transform (IDFT)
t) Cyclic shift diversity (CSD) per chain insertion

u) Guard interval (GI) insertion

v) Windowing

Figure 28-9 (Transmitter block diagram for the L-SIG, RL-SIG and HE-SIG-A fields for an HE SU PPDU and HE extended range SU PPDU when the Beam Change field is 1 and the HE MU PPDU) to Figure 28-17 (Transmitter block diagram for the Data field of an HE SU PPDU in 80+80 MHz with LDPC encoding) show example transmitter block diagrams. The actual structure of the transmitter is implementation dependent.

In particular, Figure 28-9 (Transmitter block diagram for the L-SIG, RL-SIG and HE-SIG-A fields for an HE SU PPDU and HE extended range SU PPDU when the Beam Change field is 1 and the HE MU PPDU) shows the transmit process for the L-SIG, RL-SIG, and HE-SIG-A fields of an HE PPDU using one frequency segment, when the Beam Change subfield in HE-SIG-A field is set to 1. These transmit blocks are also used to generate the L-STF and L-LTF fields of the HE PPDU when the Beam Change subfield in HE-SIG-A field is set to 1, with the following exceptions:

— The BCC encoder and interleaver as well as constellation mapper are not used when generating the L-STF and L-LTF fields.

— The BCC interleaver is not applied in the repeated HE-SIG-A symbols (i.e. the 2nd and the 4th OFDM symbols of HE-SIG-A field) in the HE extended range SU PPDU.

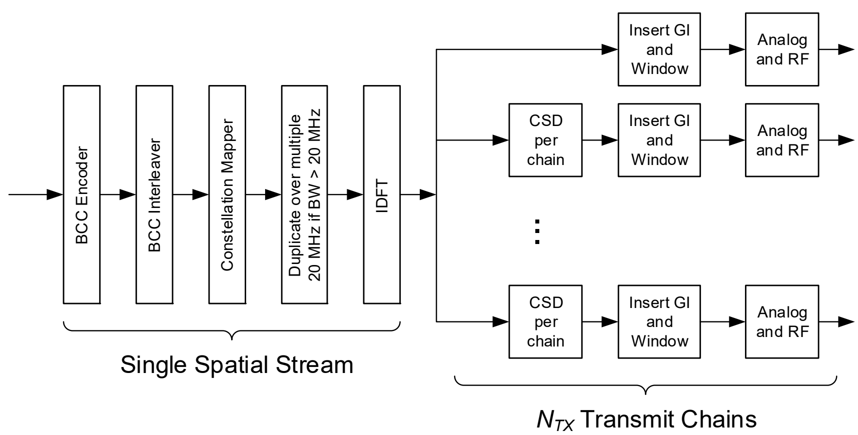


Figure 28-9—Transmitter block diagram for the L-SIG, RL-SIG and HE-SIG-A fields for an HE SU PPDU and HE extended range SU PPDU when the Beam Change field is 1 and the HE MU PPDU

Figure 28-10 (Transmitter block diagram for the L-SIG, RL-SIG and HE-SIG-A fields for an HE SU PPDU and HE extended range SU PPDU when the Beam Change field is 0) shows the transmit process for the L-SIG, RL-SIG, and HE-SIG-A fields of an HE PPDU using one frequency segment, when the Beam Change subfield in HE-SIG-A field is set to 0. These transmit blocks are also used to generate the L-STF and L-LTF fields of the HE PPDU when the Beam Change subfield in HE-SIG-A field is set to 0, with the following exceptions:

— The BCC encoder and interleaver as well as constellation mapper are not used when generating the L-STF and L-LTF fields.

— The BCC interleaver is not applied in the repeated HE-SIG-A field OFDM symbols (i.e., the 2nd and the 4th OFDM symbols of HE-SIG-A field) in the HE extended range SU PPDU.

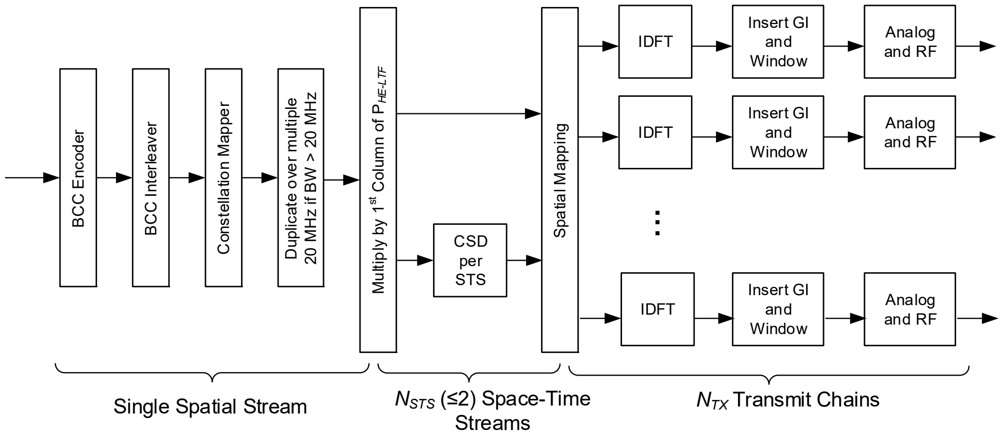


Figure 28-10—Transmitter block diagram for the L-SIG, RL-SIG and HE-SIG-A fields for an HE SU PPDU and HE extended range SU PPDU when the Beam Change field is 0

Figure 28-11 (Transmitter block diagram for the L-SIG, RL-SIG and HE-SIG-A fields of an HE trigger-based PPDU) shows the transmit process for the L-SIG, RL-SIG and HE-SIG-A fields of an HE trigger-based PPDU using one frequency segment. In the HE trigger-based PPDU, the pre-HE-STF preamble, which includes legacy preamble, RL-SIG and HE-SIG-A fields, is sent only on the 20 MHz channels where the STA's HE modulated fields are located. When the HE modulated fields are located in more than one 20 MHz channel, the pre-HE-STF preamble is duplicated over the multiple 20 MHz channels. The BCC encoder and interleaver are not used when generating the L-STF and L-LTF fields.

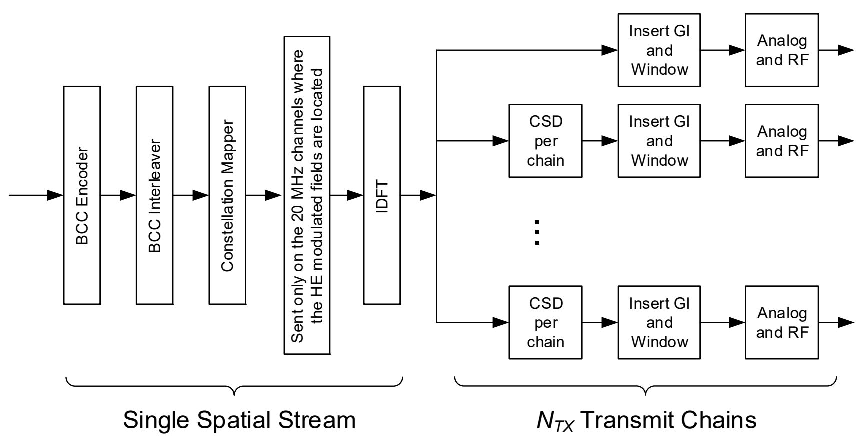


Figure 28-11—Transmitter block diagram for the L-SIG, RL-SIG and HE-SIG-A fields of an HE trigger-based PPDU

Figure 28-12 (Transmitter block diagram for the HE-SIG-B field) shows the transmit process for the HE-SIG-B field of an HE MU PPDU using one frequency segment. This block diagram is for transmitting HE-SIG-B in one 20 MHz subchannel. Refer to 28.3.10.8.1 (Encoding and modulation) for the methods of transmitting HE-SIG-B in 40 MHz, 80 MHz and 160 MHz. The DCM tone mapper is applied only if the DCM indication in HE-SIG-A field is set to 1.

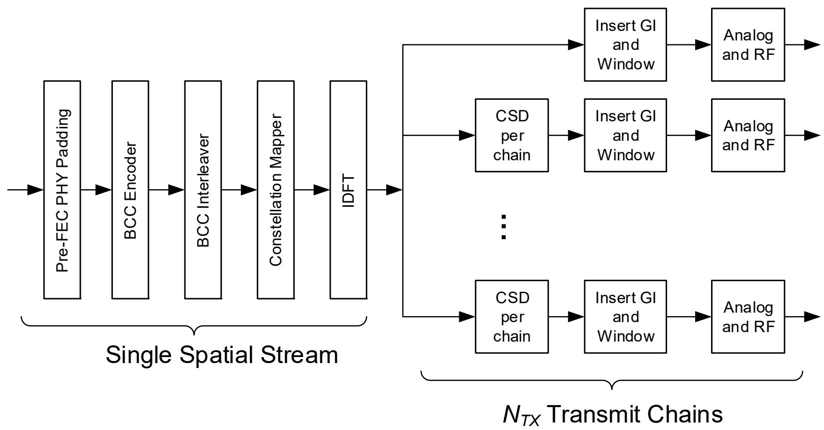


Figure 28-12—Transmitter block diagram for the HE-SIG-B field

Figure 28-13 (Transmitter block diagram for the Data field of an HE SU transmission in a 26-, 52-, 106- or 242-tone RU with BCC encoding) shows the transmitter blocks used to generate the Data field of a single user HE transmission within a 26-, 52-, 106-, or 242-tone RU with BCC encoding for a single frequency segment when the number of spatial stream is less than or equal to 4. This also includes the SU transmission in an RU that is part of a downlink or uplink OFDMA PPDU, and a transmission from one STA that is part of an UL MU-MIMO transmission in current RU. The STBC block may be applied only for single spatial stream and only when DCM is not applied. The DCM tone mapper is applied only when the DCM indication for the RU is set to 1. A subset of these transmitter blocks consisting of the constellation mapper and CSD blocks, as well as the blocks to the right of, and including, the spatial mapping block, are also used to generate the HE-LTF fields. This is illustrated in Figure 28-26 (Generation of HE-LTF symbols per frequency segment in an HE SU PPDU, HE MU PPDU, HE extended range SU PPDU and HE trigger-based PPDU). A subset of these transmitter blocks consisting of the constellation mapper and CSD blocks, as well as the blocks to the right of, and including, the spatial and frequency mapping block of Figure 28-13 (Transmitter block diagram for the Data field of an HE SU transmission in a 26-, 52-, 106- or 242-tone RU with BCC encoding), are also used to generate the HE-STF field. This figure also applies to the data field with BCC encoding in an HE trigger-based PPDU.

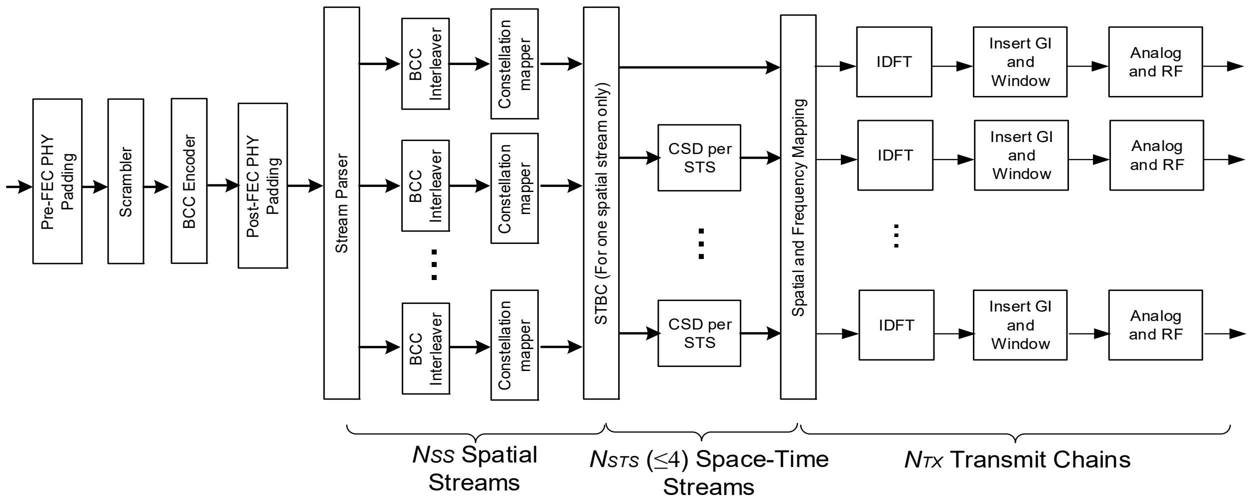


Figure 28-13—Transmitter block diagram for the Data field of an HE SU transmission in a 26-, 52-, 106- or 242-tone RU with BCC encoding

Figure 28-14 (Transmitter block diagram for the Data field of an HE SU transmission in 26-, 52-, 106-, 242-, 484- or 996-tone RU with LDPC encoding) shows the transmitter blocks used to generate the Data field of a single user HE transmission within a 26-, 52-, 106-, 242-, 484-, or 996-tone RU with LDPC encoding for a single frequency segment. This also includes the SU transmission in an RU that is part of a downlink or uplink OFDMA PPDU, and a transmission from one STA that is part of an UL MU-MIMO transmission in current RU. The STBC block may be applied only for single spatial stream and only when DCM is not applied. The DCM tone Mapper is applied only when the DCM indication for the RU is set to 1. This figure also applies to the data field with LDPC encoding in an HE trigger-based PPDU.

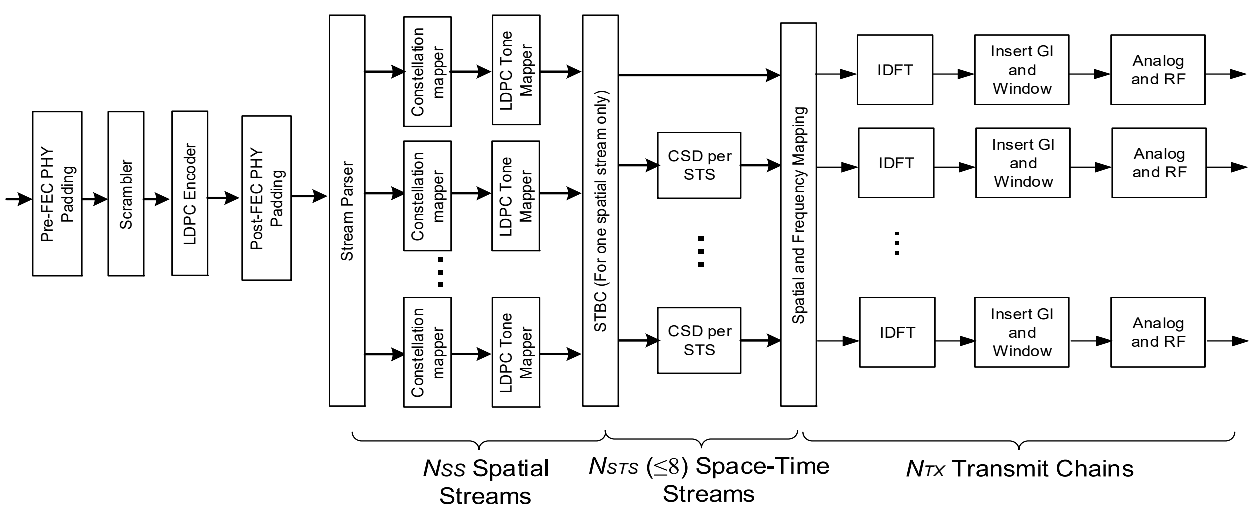


Figure 28-14—Transmitter block diagram for the Data field of an HE SU transmission in 26-, 52-, 106-, 242-, 484- or 996-tone RU with LDPC encoding

Figure 28-15 (Transmitter block diagram for the Data field of an HE downlink MU-MIMO transmission in 106-, 242-, 484- or 996-tone RU with LDPC encoding) shows the transmitter blocks used to generate the Data field of an HE downlink MU-MIMO transmission within a 106-, 242-, 484-, or 996-tone RU with LDPC encoding. This also includes the downlink MU-MIMO transmission in an RU that is part of a downlink OFDMA PPDU.

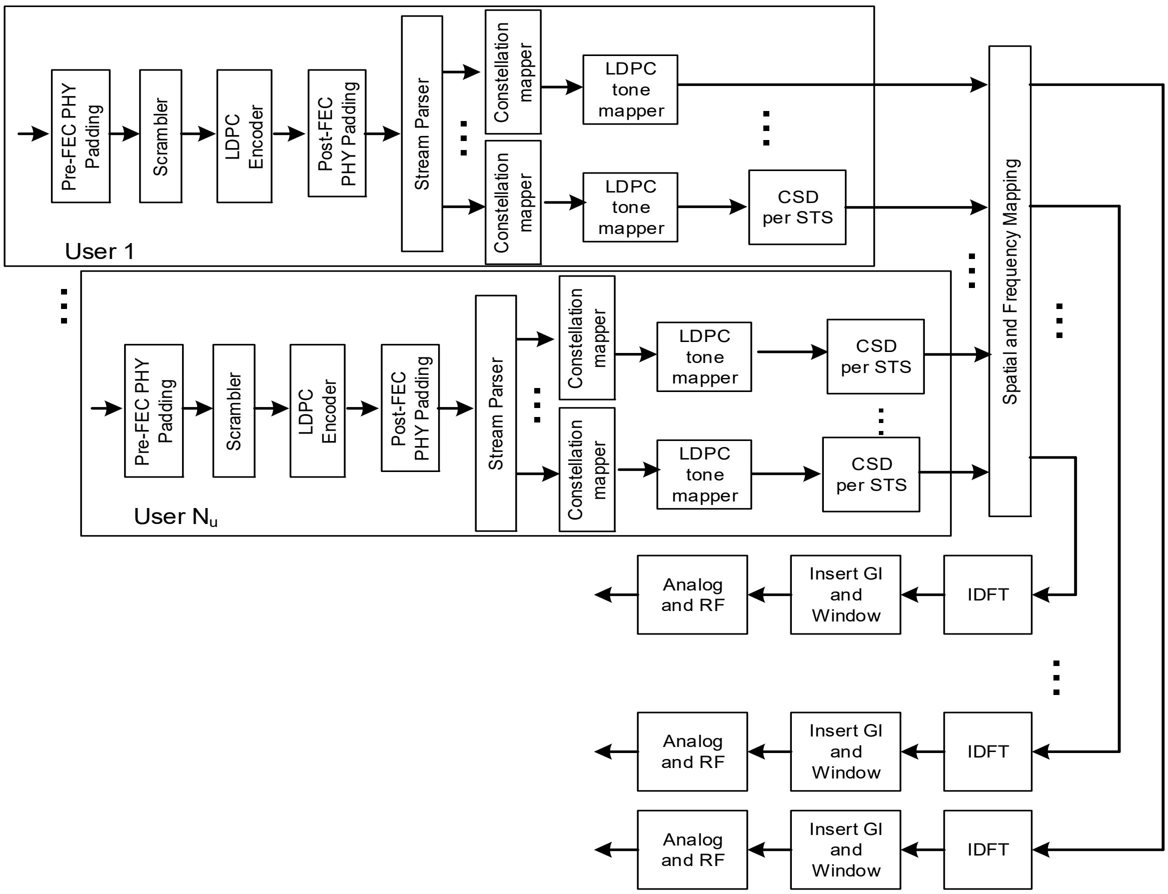


Figure 28-15—Transmitter block diagram for the Data field of an HE downlink MU-MIMO transmission in 106-, 242-, 484- or 996-tone RU with LDPC encoding

Figure 28-16 (Transmitter block diagram for the Data field of an HE SU PPDU in 160 MHz with LDPC encoding) shows the transmitter blocks used to generate the Data field of a single-user HE transmission in 160 MHz with LDPC encoding.

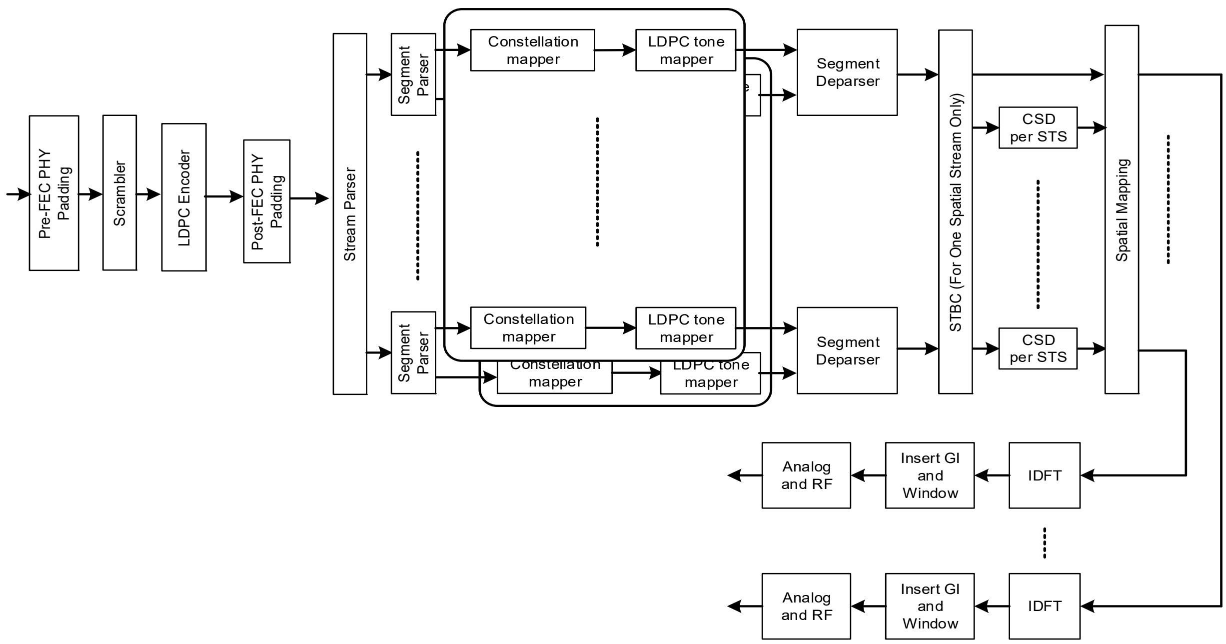


Figure 28-16—Transmitter block diagram for the Data field of an HE SU PPDU in 160 MHz with LDPC encoding

Figure 28-17 (Transmitter block diagram for the Data field of an HE SU PPDU in 80+80 MHz with LDPC encoding) shows the transmitter blocks used to generate the Data field of a single-user HE transmission in 80+80 MHz with LDPC encoding.

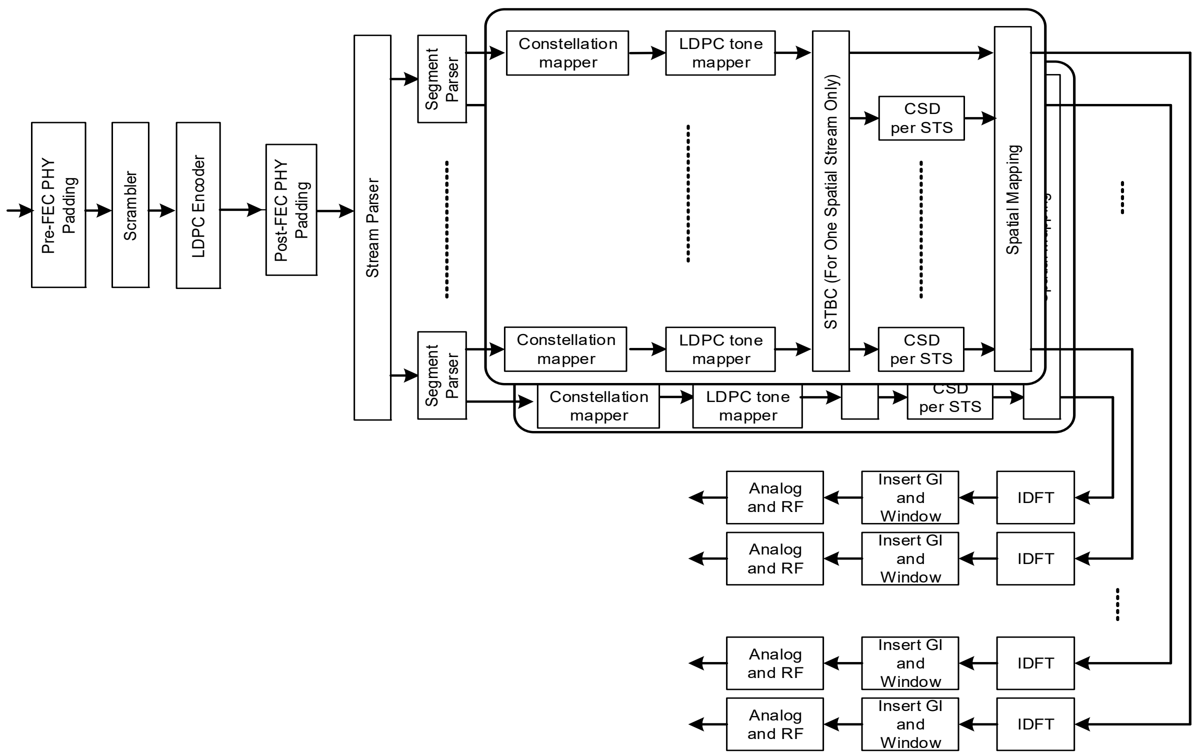


Figure 28-17—Transmitter block diagram for the Data field of an HE SU PPDU in 80+80 MHz with LDPC encoding

28.3.6 Overview of the PPDU encoding process

28.3.6.1 General

This subclause provides an overview of the HE PPDU encoding process.

28.3.6.2 Construction of L-STF

Construct the L-STF field as defined in 28.3.10.3 (L-STF) with the following highlights:

a) Determine the channel bandwidth from the TXVECTOR parameter CH_BANDWIDTH.

b) Sequence generation: Generate the L-STF sequence over the channel bandwidth as described in 28.3.10.3 (L-STF).

c) Phase rotation: Apply appropriate phase rotation for each 20 MHz subchannel as described in 28.3.9 (Mathematical description of signals) and 21.3.7.5 (Definition of tone rotation).

d) IDFT: Compute the inverse discrete Fourier transform.

e) CSD: Apply CSD for each transmit chain and frequency segment as described in 28.3.10.2.1 (Cyclic shift for pre-HE modulated fields).

f) Insert GI and apply windowing: Prepend a GI ($T_{GI,\mathrm{LegacyPreamble}}$) and apply windowing as described in 28.3.9 (Mathematical description of signals).

g) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 28.3.9 (Mathematical description of signals) and 28.3.10 (HE preamble) for details.

28.3.6.3 Construction of L-LTF

Construct the L-LTF field as defined in 28.3.10.4 (L-LTF) with the following highlights:

a) Determine the channel bandwidth from the TXVECTOR parameter CH_BANDWIDTH.

b) Sequence generation: Generate the L-LTF sequence over the channel bandwidth as described in 28.3.10.4 (L-LTF).

c) Phase rotation: Apply appropriate phase rotation for each 20 MHz subchannel as described in 28.3.9 (Mathematical description of signals) and 21.3.7.5 (Definition of tone rotation).

d) IDFT: Compute the inverse discrete Fourier transform.

e) CSD: Apply CSD for each transmit chain and frequency segment as described in 28.3.10.2.1 (Cyclic shift for pre-HE modulated fields).

f) Insert GI and apply windowing: Prepend a GI ($T_{GI,\text{L-LTF}}$) and apply windowing as described in 28.3.9 (Mathematical description of signals).

g) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the carrier frequency of the desired channel and transmit. Refer to 28.3.9 (Mathematical description of signals) and 28.3.10 (HE preamble) for details.

28.3.6.4 Construction of L-SIG

Construct the L-SIG field as the SIGNAL field defined in 28.3.10.5 (L-SIG) with the following highlights:

a) Set the RATE subfield in the SIGNAL field to 6 Mb/s. Set the Length, Parity, and Tail bits in the SIGNAL field as described in 28.3.10.5 (L-SIG).

b) BCC encoder: Encode the SIGNAL field by a convolutional encoder at the rate of R = ½ as described in 28.3.11.5.1 (Binary convolutional coding and puncturing).

c) BCC interleaver: Interleave as described in 28.3.11.8 (BCC interleavers).

d) Constellation Mapper: BPSK modulate as described in 28.3.11.9 (Constellation mapping).

e) Pilot insertion: Insert pilots as described in 28.3.10.5 (L-SIG).

f) Extra tone insertion: Four extra tones are inserted in subcarriers $k \in \{-28, -27, 27, 28\}$ for channel estimation purpose and the values on these four extra tones are $\{-1, -1, -1, 1\}$, respectively.

g) Duplication and phase rotation: Duplicate the L-SIG field over each 20 MHz subchannel of the channel bandwidth. Apply appropriate phase rotation for each 20 MHz subchannel as described in 228.3.9 (Mathematical description of signals) and 21.3.7.5 (Definition of tone rotation).

h) IDFT: Compute the inverse discrete Fourier transform.

i) CSD: Apply CSD for each transmit chain and frequency segment as described in 28.3.10.2.1 (Cyclic shift for pre-HE modulated fields).

j) Insert GI and apply windowing: Prepend a GI ($T_{GI,\text{LegacyPreamble}}$) and apply windowing as described in 28.3.9 (Mathematical description of signals).

k) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain. Refer to 28.3.9 (Mathematical description of signals) and 28.3.10 (HE preamble) for details.

28.3.6.5 Construction of RL-SIG

Construct the RL-SIG field as the repeat SIGNAL field defined in 28.3.10.6 (RL-SIG) with the following highlights:

a) Set the RATE subfield in the repeat SIGNAL field to 6 Mb/s. Set the Length Parity, and Tail bits in the repeat SIGNAL field as described in 28.3.10.6 (RL-SIG).

b) BCC encoder: Encode the repeat SIGNAL field by a convolutional encoder at the rate of R = ½ as described in 28.3.11.5.1 (Binary convolutional coding and puncturing).

c) BCC interleaver: Interleave as described in 28.3.11.8 (BCC interleavers).

d) Constellation Mapper: BPSK modulate as described in 28.3.11.9 (Constellation mapping).

e) Pilot insertion: Insert pilots as described in 28.3.10.6 (RL-SIG).

f) Extra tone insertion: Four extra tones are inserted in subcarriers $k \in \{-28, -27, 27, 28\}$ for channel estimation purpose and the values on these four extra tones are $\{-1, -1, -1, 1\}$, respectively.

g) Duplication and phase rotation: Duplicate the RL-SIG field over each 20 MHz subchannel of the channel bandwidth. Apply appropriate phase rotation for each 20 MHz subchannel as described in 28.3.9 (Mathematical description of signals) and 21.3.7.5 (Definition of tone rotation).

h) IDFT: Compute the inverse discrete Fourier transform.

i) CSD: Apply CSD for each transmit chain and frequency segment as described in 28.3.10.2.1 (Cyclic shift for pre-HE modulated fields).

j) Insert GI and apply windowing: Prepend a GI ($T_{GI,\mathrm{LegacyPreamble}}$) and apply windowing as described in 28.3.9 (Mathematical description of signals).

k) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain. Refer to 28.3.9 (Mathematical description of signals) and 28.3.10 (HE preamble) for details.

28.3.6.6 Construction of HE-SIG-A

For an HE SU PPDU, HE MU PPDU, and HE trigger-based PPDU, the HE-SIG-A field consists of two symbols, HE-SIG-A1 and HE-SIG-A2 as defined in 28.3.10.7 (HE-SIG-A) and is constructed as follows:

a) Obtain the HE-SIG-A field values from the TXVECTOR. Add the reserved bits, append the calculated CRC, and then append the N_{tail} tail bits as shown in 28.3.10.7 (HE-SIG-A). This results in 52 uncoded bits.

b) BCC encoder: Encode the data by a convolution encoder at the rate of R = ½ as described in 17.3.5.6 (Convolution encoder).

c) BCC interleaver: Interleave as described in 17.3.5.7 (Data interleaving).

d) Constellation mapper: BPSK modulate the first 52 interleaved bits as described in 17.3.5.8 (Subcarrier modulation mapping) to form the first symbol of HE-SIG-A. BPSK modulate the second 52 interleaved bits to form the second symbol of HE-SIG-A.

e) Pilot insertion: Insert pilots as described in 17.3.5.9 (Pilot subcarriers).

f) Duplicate and phase rotation: Duplicate HE-SIG-A1 and HE-SIG-A2 over each 20 MHz subchannel of the channel width. Apply the appropriate phase rotation for each 20 MHz subchannel as described in 28.3.9 (Mathematical description of signals) and 21.3.7.5 (Definition of tone rotation).

g) IDFT: Compute the inverse Fourier transform.

h) CSD: Apply CSD for each transmit chain and frequency segment as described in 28.3.10.2.1 (Cyclic shift for pre-HE modulated fields).

i) Insert GI and apply windowing: Prepend a GI ($T_{GI,\mathrm{LegacyPreamble}}$) and apply windowing as described in 28.3.9 (Mathematical description of signals).

j) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 28.3.9 (Mathematical description of signals) and 28.3.10 (HE preamble) for details.

For an HE extended range SU PPDU, the HE-SIG-A field consists of four symbols, HE-SIG-A1, HE-SIG-A2, HE-SIG-A3, and HE-SIG-A4. HE-SIG-A1 and HE-SIG-A2 have the same data bits while

HE-SIG-A3 and HE-SIG-A4 have the same data bits as defined in 28.3.10.7 (HE-SIG-A). The HE-SIG-A field is constructed as follows:

a) Obtain the HE-SIG-A fields from the TXVECTOR. Add the reserved bits, append the calculated CRC, and then append the N_{tail} tail bits as shown in 28.3.10.7 (HE-SIG-A). This results in 52 uncoded bits.

b) BCC encoder: Encode the data by a convolution encoder at the rate of R = ½ as described in 17.3.5.6 (Convolution encoder).

c) BCC interleaver: Interleave the data bits of HE-SIG-A1 and HE-SIG-A3 as described in 17.3.5.7 (Data interleaving). The data bits of HE-SIG-A2 and HE-SIG-A4 are not interleaved.

d) Constellation mapper: BPSK modulate the HE-SIG-A1, HE-SIG-A3, and HE-SIG-A4 data bits as described in 17.3.5.8 (Subcarrier modulation mapping) to form the first, third, and fourth symbol of HE-SIG-A, respectively. QBPSK modulate the HE-SIG-A2 encoded data bits to form the second symbol of HE-SIG-A.

e) Pilot insertion: Insert pilots as described in 17.3.5.9 (Pilot subcarriers).

f) IDFT: Compute the inverse Fourier transform.

g) CSD: Apply CSD for each transmit chain and frequency segment as described in 28.3.10.2.1 (Cyclic shift for pre-HE modulated fields).

h) Insert GI and apply windowing: Prepend a GI ($T_{GI,\mathrm{LegacyPreamble}}$) and apply windowing as described in 28.3.9 (Mathematical description of signals).

i) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 28.3.9 (Mathematical description of signals) and 28.3.10 (HE preamble) for details.

28.3.6.7 Construction of HE-SIG-B

For an HE MU PPDU, the HE-SIG-B field consists of a Common Block field followed by a User Specific field as defined in 28.3.10.8 (HE-SIG-B) and is constructed as follows:

a) Obtain the subfield values for the HE-SIG-B field from the TXVECTOR. Add the reserved bits, append the calculated CRC, and then append the N_{tail} tail bits as shown in 28.3.10.8 (HE-SIG-B).

b) BCC encoder: Encode the Common Block field data and User Specific field data by a convolution encoder as described in 28.3.11.5.1 (Binary convolutional coding and puncturing).

c) BCC interleaver: Interleave as described in 17.3.5.7 (Data interleaving).

d) Constellation mapper: Obtain MCS_SIG_B from the TXVECTOR and use it to modulate the interleaved bits as described in 17.3.5.8 (Subcarrier modulation mapping) to form the HE-SIG-B symbols.

e) Pilot insertion: Insert pilots as described in 17.3.5.9 (Pilot subcarriers).

f) Duplicate and phase rotation: Duplicate HE-SIG-B symbols over each 20 MHz of the CH_BANDWIDTH as described in 28.3.10.8.1 (Encoding and modulation). Apply the appropriate phase rotation for each 20 MHz subchannel as described in 28.3.9 (Mathematical description of signals) and 21.3.7.5 (Definition of tone rotation).

g) IDFT: Compute the inverse Fourier transform.

h) CSD: Apply CSD for each transmit chain and frequency segment as described in 28.3.10.2.1 (Cyclic shift for pre-HE modulated fields).

i) Insert GI and apply windowing: Prepend a GI ($T_{GI,\mathrm{LegacyPreamble}}$) and apply windowing as described in 28.3.9 (Mathematical description of signals).

j) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 28.3.9 (Mathematical description of signals) and 28.3.10 (HE preamble) for details.

28.3.6.8 Construction of HE-STF

The HE-STF field is defined in 28.3.10.9 (HE-STF) and is constructed as follows:

a) Sequence generation: Generate the HE-STF in the frequency domain over the bandwidth indicated by the TXVECTOR parameter CH_BANDWIDTH as described in 28.3.10.9 (HE-STF).
b) Phase rotation: Apply appropriate phase rotation for each 20 MHz subchannel as described in 28.3.9 (Mathematical description of signals) and 21.3.7.5 (Definition of tone rotation).
c) CSD: Apply CSD for each space-time stream and frequency segment as described in 28.3.10.2.2 (Cyclic shift for HE modulated fields).
d) Spatial mapping: Apply the Q matrix as described in 28.3.10.9 (HE-STF).
e) IDFT: Compute the inverse discrete Fourier transform.
f) Insert GI and apply windowing: Prepend a GI; $T_{GI1,\mathrm{Data}}$ for HE SU PPDU, HE extended range SU PPDU, and HE MU PPDU and $T_{GI2,\mathrm{Data}}$ for a HE trigger-based PPDU. Apply windowing as described in 28.3.9 (Mathematical description of signals).
g) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 28.3.9 (Mathematical description of signals) and 21.3.10 (HE preamble) for details.

28.3.6.9 Construction of HE-LTF

The HE-LTF field is defined in 28.3.10.10 (HE-LTF) and is constructed as follows:

a) Sequence generation: Generate the HE-LTF sequence in frequency domain over the bandwidth indicated by CH_BANDWIDTH as described in 28.3.10.10 (HE-LTF).
b) Phase rotation: Apply appropriate phase rotation for each 20 MHz subchannel as described in 28.3.9 (Mathematical description of signals) and 21.3.7.5 (Definition of tone rotation).
c) $A_{\mathrm{HE\text{-}LTF}}$ matrix mapping: Apply the $P_{\mathrm{HE\text{-}LTF}}$ matrix to the data tones of the HE-LTF sequence and apply the $R_{\mathrm{HE\text{-}LTF}}$ or $P_{\mathrm{HE\text{-}LTF}}$ matrix to pilot tones as described in 28.3.10.10 (HE-LTF).
d) CSD: Apply CSD for each space-time stream and frequency segment as described in 28.3.10.2.2 (Cyclic shift for HE modulated fields).
e) Spatial mapping: Apply the Q matrix as described in 28.3.10.10 (HE-LTF).
f) IDFT: Compute the inverse discrete Fourier transform.
g) Insert GI and apply windowing: Prepend a GI indicated by the TXVECTOR parameter GI_TYPE and apply windowing as described in 28.3.9 (Mathematical description of signals).
h) Analog and RF: Upconvert the resulting complex baseband waveform associated with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 28.3.9 (Mathematical description of signals) and 21.3.10 (HE preamble) for details.

28.3.6.10 Construction of the Data field in an HE SU PPDU, HE extended range SU PPDU, and HE trigger-based PPDU

28.3.6.10.1 Using BCC

The construction of the Data field in an HE SU PPDU, HE extended range SU PPDU, and HE trigger-based PPDU with BCC encoding proceeds as follows:

a) The SERVICE field is described in 28.3.11.3 (SERVICE field) and append the PSDU to the SERVICE field.
b) Pre-FEC padding: Append the pre-FEC pad bits and tail bits as described in 28.3.11 (Data field).
c) Scrambler: Scramble the pre-FEC padded data.

d) BCC encoder: BCC encode as described in 28.3.11.5.1 (Binary convolutional coding and puncturing).

e) Post-FEC padding: Append the post-FEC pad bits and packet extension field as described in 28.3.11 (Data field).

f) Stream parser: Rearrange the output of BCC encoder into blocks as described in 28.3.11.6 (Stream parser).

g) Segment parser (if needed): This block is bypassed for 20 MHz transmissions.

h) BCC interleaver: Interleave as described in 28.3.11.8 (BCC interleavers).

i) Constellation mapper: Map to BPSK, QPSK, 16-QAM, 64-QAM, or 256-QAM constellation points as described in 28.3.11.9 (Constellation mapping).

j) Segment deparser (if needed): This block is bypassed for 20 MHz transmissions.

k) STBC: Apply STBC as described in 28.3.11.10 (Space-time block coding).

l) Pilot insertion: Insert pilots following the steps described in 28.3.11.13 (Pilot subcarriers).

m) CSD: Apply CSD for each space-time stream and frequency segment as described in 28.3.10.2.2 (Cyclic shift for HE modulated fields).

n) Spatial mapping: Apply the Q matrix as described in 28.3.11.14 (OFDM modulation).

o) Phase rotation: Apply the appropriate phase rotations for each 20 MHz subchannel as described in 28.3.9 (Mathematical description of signals) and 21.3.7.5 (Definition of tone rotation).

p) IDFT: In an 80+80 MHz transmission, map each frequency subblock to a separate IDFT. Compute the inverse discrete Fourier transform.

q) Insert GI and apply windowing: Prepend a GI and apply windowing as described in 28.3.9 (Mathematical description of signals).

r) Analog and RF: Upconvert the resulting complex baseband waveform with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 28.3.9 (Mathematical description of signals) and 28.3.10 (HE preamble) for details.

28.3.6.10.2 Using LDPC

The construction of the Data field in an HE SU PPDU, HE extended range SU PPDU, and HE trigger-based PPDU with LDPC encoding proceeds as follows:

a) The SERVICE field is described in 28.3.11.3 (SERVICE field) and append the PSDU to the SERVICE field.

b) Pre-FEC padding: Append the pre-FEC padding bits as described in 28.3.11 (Data field). There are no tail bits.

c) Scrambler: Scramble the pre-FEC padded data.

d) LDPC encoder: LDPC encode with APEP_LENGTH in the TXVECTOR as described in 28.3.11.5.2 (LDPC coding).

e) Post-FEC padding: Append the post-FEC pad bits and packet extension field as described in 28.3.11 (Data field).

f) Stream parser: Rearrange the output of LDPC encoder into blocks as described in 28.3.11.6 (Stream parser).

g) Segment parser (if needed): In a 160 MHz or 80+80 MHz transmission with a 2×996-tone RU, divide the output of each stream parser into two frequency subblocks as described in 28.3.11.6 (Stream parser). This block is bypassed for 20 MHz, 40 MHz, and 80 MHz transmissions.

h) Constellation mapper: Map to BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM, or 1024-QAM constellation points as described in 28.3.11.9 (Constellation mapping).

i) LDPC tone mapper: the LDPC tone mapping shall be performed on all LDPC encoded streams as described in 28.3.11.11 (LDPC tone mapper).

j) Segment deparser (if needed): In 160 MHz transmission, merge the two frequency subblocks into one frequency segment as described in 28.3.11.12 (Segment deparser). This block is bypassed for 20 MHz, 40 MHz, 80 MHz, and 80+80 MHz transmissions.

k) STBC: Apply STBC as described in 28.3.11.10 (Space-time block coding).

l) Pilot insertion: Insert pilots following the steps described in 28.3.11.13 (Pilot subcarriers).

m) CSD: Apply CSD for each space-time stream and frequency segment as described in 28.3.10.2.2 (Cyclic shift for HE modulated fields).

n) Spatial mapping: Apply the Q matrix as described in 28.3.11.14 (OFDM modulation).

o) Phase rotation: Apply the appropriate phase rotations for each 20 MHz subchannel as described in 28.3.9 (Mathematical description of signals) and 21.3.7.5 (Definition of tone rotation).

p) IDFT: In an 80+80 MHz transmission, map each frequency subblock to a separate IDFT. Compute the inverse discrete Fourier transform.

q) Insert GI and apply windowing: Prepend a GI and apply windowing as described in 28.3.9 (Mathematical description of signals).

r) Analog and RF: Upconvert the resulting complex baseband waveform with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 28.3.9 (Mathematical description of signals) and 28.3.10 (HE preamble) for details.

28.3.6.11 Construction of the Data field in an HE MU PPDU

28.3.6.11.1 General

In an HE MU transmission, the PPDU encoding process is performed independently in an RU on a per user basis up to the input of the spatial mapping block, except that CSD is performed with knowledge of the space time streams starting index for that user. All user data in an RU is combined and mapped to the transmit chains in the spatial mapping block.

28.3.6.11.2 Using BCC

A Data field with BCC encoding is constructed using steps (a) to (l) in 28.3.6.10.1 (Using BCC), then applying CSD for an HE MU PPDU as described in 28.3.10.2.2 (Cyclic shift for HE modulated fields).

28.3.6.11.3 Using LDPC

A Data field with LDPC encoding is constructed using steps (a) to (l) in 28.3.6.10.2 (Using LDPC), then applying CSD for an HE MU PPDU as described in 28.3.10.2.2 (Cyclic shift for HE modulated fields).

28.3.6.11.4 Combining to form an HE MU PPDU

The per-user data is combined as follows:

a) Spatial mapping: The Q matrix is applied as described in 28.3.11.14 (OFDM modulation). The combining of all user data of an RU is done in this block.

b) Phase rotation: Apply the appropriate phase rotations for each 20 MHz subchannel as described in 28.3.9 (Mathematical description of signals) and 21.3.7.5 (Definition of tone rotation).

c) IDFT: Compute the inverse discrete Fourier transform.

d) Insert GI and apply windowing: Prepend a GI determined by the TXVECTOR parameter GI_TYPE and apply windowing as described in 28.3.9 (Mathematical description of signals).

e) Analog and RF: Upconvert the resulting complex baseband waveform with each transmit chain to an RF signal according to the center frequency of the desired channel and transmit. Refer to 28.3.9 (Mathematical description of signals) and 28.3.10 (HE preamble) for details.

28.3.7 HE modulation and coding schemes (HE-MCSs)

The HE-MCS is a compact representation of the modulation and coding used in the Data field of the PPDU. For an HE SU PPDU and an HE extended range SU PPDU it is carried in the HE-SIG-A field. For an HE MU PPDU it is carried in the HE-SIG-B field. For an HE trigger-based PPDU, it is carried in the User Info fields of the Trigger frame.

The HE-SIG-B-MCS is a compact representation of the modulation and coding used in the HE-SIG-B field of the PPDU. For an HE MU PPDU, it is carried in the HE-SIG-A field. HE-SIG-B-MCS consists of indices 0 to 5 and each HE-SIG-B-MCS represents the same modulation and coding as the HE-MCS with the same index.

Rate dependent parameters for the full set of HE-MCSs are shown in Table 28-47 (HE-MCSs for mandatory 26-tone RU, NSS = 1) to Table 28-102 (HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, NSS = 8) (in 28.5 (Parameters for HE-MCSs)). These tables give rate-dependent parameters for HE-MCSs with indices 0 to 11, with number of spatial streams from 1 to 8, RU options of 26-tone, 52-tone, 106-tone, 242-tone, 484-tone and 996-tone, and bandwidth options of 20 MHz, 40 MHz, 80 MHz, and either 160 MHz or 80+80 MHz. HE-MCSs with indices 10 and 11 (1024-QAM) are optionally applied to the Data field of an HE PPDU with RUs equal to or larger than 242-tone. The HE extended range SU PPDU only supports a single 242-tone or 106-tone RU. The 242-tone RU can only be transmitted with the <HE-MCS, NSS> tuples <MCS 0, 1>, <MCS 1, 1> and <MCS 2, 1>. The 106-tone RU can only be transmitted with the <HE-MCS, NSS> tuple <MCS 0, 1>. The 106-tone RU location within the 20 MHz tone plan is fixed as the one that is higher in frequency.

DCM is an optional modulation scheme used for the HE-SIG-B field and the Data field in an HE PPDU. It is indicated in the HE-SIG-A field for the HE-SIG-B field in an HE MU PPDU and for the Data field in HE SU PPDU, HE trigger-based PPDU and HE extended range SU PPDU and indicated in the HE-SIG-B field for the Data field in an HE MU PPDU. It is only applied for the HE-MCSs with indices 0, 1, 3 and 4.

28.3.8 Timing-related parameters

Refer to Table 19-6 (Timing-related constants) and Table 21-5 (Timing-related constants) for timing-related parameters for non-HE PPDU formats.

Table 28-9 (Timing-related constants) defines the timing-related parameters for HE PPDU formats..

Table 28-9— Timing-related constants

Parameter	Values	Description
$\Delta_{F,\text{ Pre-HE}}$	312.5 kHz	Subcarrier frequency spacing for the pre-HE modulated fields.
$\Delta_{F,\text{ HE}}$	78.125 kHz	Subcarrier frequency spacing for the HE modulated fields.
$T_{DFT,\text{Pre-HE}}$	3.2 µs	IDFT/DFT period for the pre-HE modulated fields.
$T_{DFT,\text{HE}}$	12.8 µs	IDFT/DFT period for the HE Data field.
$T_{GI,\text{LegacyPreamble}}$	0.8 µs	Guard interval duration for the legacy preamble, RL-SIG, HE-SIG-A and HE-SIG-B
$T_{GI,\text{L-LTF}}$	1.6 µs	Guard interval duration for the L-LTF field.

Table 28-9— Timing-related constants *(continued)*

$T_{GI,\text{HE-LTF}}$	$T_{GI1,Data}$, $T_{GI2,Data}$ or $T_{GI4,Data}$ depending on the GI used for data	Guard interval duration for the HE-LTF field, same as $T_{GI,Data}$
$T_{GI,Data}$	$T_{GI1,Data}$, $T_{GI2,Data}$ or $T_{GI4,Data}$ depending on the GI used for data	Guard interval duration for the HE-Data field
$T_{GI1,Data}$	0.8 μs	Base guard interval duration for the HE-Data field.
$T_{GI2,Data}$	1.6 μs	Double guard interval duration for the HE-Data field.
$T_{GI4,Data}$	3.2 μs	Quadruple guard interval duration for the HE-Data field.
T_{SYM1}	13.6 μs = $T_{DFT,\text{HE}} + T_{GI1,Data} = 1.0625 \times T_{DFT,HE}$	OFDM symbol duration with base GI
T_{SYM2}	14.4 μs = $T_{DFT,\text{HE}} + T_{GI2,Data} = 1.125 \times T_{DFT,HE}$	OFDM symbol duration with double GI
T_{SYM4}	16 μs = $T_{DFT,\text{HE}} + T_{GI4,Data} = 1.25 \times T_{DFT,\text{HE}}$	OFDM symbol duration with quadruple GI
T_{SYM}	T_{SYM1}, T_{SYM2}, or T_{SYM4} depending on the GI used (see Table 28-14 (Tone scaling factor and guard interval duration values for HE PPDU fields))	Symbol interval
$T_{\text{L-STF}}$	8 μs = $10 \times T_{DFT,\text{Pre-HE}}/4$	Non-HT Short Training field duration
$T_{\text{L-LTF}}$	8 μs = $2 \times T_{DFT,\text{Pre-HE}} + T_{GI,\text{L-LTF}}$	Non-HT Long Training field duration
$T_{\text{L-SIG}}$	4 μs	Non-HT SIGNAL field duration
$T_{\text{RL-SIG}}$	4 μs	Repeated non-HT SIGNAL field duration
$T_{\text{HE-SIG-A}}$	8 μs = 2 × 4 μs	HE-SIG-A field duration in an HE SU PPDU, HE MU PPDU and HE trigger-based PPDU
$T_{\text{HE-SIG-A-R}}$	16 μs = 4 × 4 μs	HE-SIG-A field duration in an HE extended range SU PPDU
$T_{\text{HE-STF-T}}$	8 μs = 5 × 1.6 μs	HE-STF field duration for an HE trigger-based PPDU
$T_{\text{HE-STF-NT}}$	4 μs = 5 × 0.8 μs	HE-STF field duration for an HE SU PPDU, HE extended range SU PPDU and HE MU PPDU
$T_{\text{HE-LTF-1X}}$	3.2 μs	Duration of each 1x HE-LTF OFDM symbol without GI
$T_{\text{HE-LTF-2X}}$	6.4 μs	Duration of each 2x HE-LTF OFDM symbol without GI
$T_{\text{HE-LTF-4X}}$	12.8 μs	Duration of each 4x HE-LTF OFDM symbol without GI
$T_{\text{HE-LTF}}$	$T_{\text{HE-LTF-1X}}$, $T_{\text{HE-LTF-2X}}$ or $T_{\text{HE-LTF-4X}}$ depending upon the LTF duration used	Duration of each OFDM symbol without GI in the HE-LTF field
$T_{\text{HE-LTF-SYM}}$	sum of $T_{\text{HE-LTF}}$ and $T_{GI,\text{HE-LTF}}$	Duration of each OFDM symbol including GI in the HE-LTF field
$T_{\text{HE-SIG-B}}$	4 μs = $T_{DFT,\text{Pre-HE}} + T_{GI,\text{LegacyPreamble}}$	Duration of each OFDM symbol in the HE-SIG-B field

Table 28-9— Timing-related constants *(continued)*

$N_{service}$	16	Number of bits in the SERVICE field
N_{tail}	6 for BCC encoder, 0 for LDPC encoder	Number of tail bits per encoder
T_{SYML}	4 μs	Symbol duration including GI prior to the HE-STF field
T_{PE}	0, 4 μs, 8 μs, 12 μs or 16 μs depending on the actual extension duration used	Duration of the Packet Extension field

Table 28-10 (Tone allocation related constants for Data field in a non-OFDMA HE PPDU) defines tone allocation related parameters for a non-OFDMA HE PPDU.

Table 28-10—Tone allocation related constants for Data field in a non-OFDMA HE PPDU

Parameter	CBW20	CBW40	CBW80	CBW80+80	CBW160	Description
N_{SD}	234	468	980	980	1960	Number of complex data numbers per frequency segment
N_{SP}	8	16	16	16	32	Number of pilot values per frequency segment
N_{ST}	242	484	996	996	1992	Total number of subcarriers per frequency segment
N_{SR}	122	244	500	500	1012	Highest data subcarrier index per frequency segment
N_{Seg}	1	1	1	2	1	Number of frequency segments
N_{DC}	3	5	5	5	23	Number of null tones at DC per segment
$N_{Guard,Left}$	6	12	12	12	12	Number of guard tones at the lower side of the spectrum
$N_{Guard,Right}$	5	11	11	11	11	Number of guard tones at the higher end of the spectrum
NOTE: $N_{ST} = N_{SD} + N_{SP}$						

Table 28-11 (Tone allocation related constants for RUs in an OFDMA HE PPDU) defines tone allocation related parameters for a OFDMA HE PPDU.

Table 28-11—Tone allocation related constants for RUs in an OFDMA HE PPDU

Parameter	RU Size (tones)							Description
	26	52	106	242	484	996	2×996	
N_{SD}	24	48	102	234	468	980	1960	Number of complex data numbers per RU
N_{SP}	2	4	4	8	16	16	32	Number of pilot values per RU
N_{ST}	26	52	106	242	484	996	1992	Total number of subcarriers per RU
NOTE: $N_{ST} = N_{SD} + N_{SP}$								

Table 28-12 (Frequently used parameters) defines parameters used frequently in Clause 28.

Table 28-12—Frequently used parameters

Symbol	Explanation
N_{CBPS}, $N_{CBPS,u}$	Number of coded bits per symbol for user u, $u = 0, ..., N_{user,total} - 1$. For an HE SU PPDU, $N_{CBPS} = N_{CBPS,0}$ For an HE MU PPDU, N_{CBPS} is undefined
N_{CBPSS}, $N_{CBPSS,u}$	Number of coded bits per symbol per spatial stream. For the Data field, $N_{CBPSS,r,u}$ equals the number of coded bits per symbol per spatial stream for user u, $u = 0, ..., N_{user,total} - 1$. For the Data field of an HE SU PPDU, $N_{CBPSS} = N_{CBPSS,0}$ For the Data field of an HE MU PPDU, N_{CBPSS} is undefined
N_{DBPS}, $N_{DBPS,u}$	Number of data bits per symbol for user u, $u = 0, ..., N_{user,total} - 1$. For an HE SU PPDU, $N_{DBPS} = N_{DBPS,0}$ For an HE MU PPDU, N_{DBPS} is undefined
N_{BPSCS}, $N_{BPSCS,u}$	Number of coded bits per subcarrier per spatial stream for user u, $u = 0, ..., N_{user,total} - 1$. For an HE SU PPDU, $N_{BPSCS} = N_{BPSCS,0}$ For an HE MU PPDU, N_{BPSCS} is undefined
N_{RX}	Number of receive chains
N_{RU}	For pre-HE modulated fields, $N_{RU} = 1$. For HE modulated fields, N_{RU} represents the number of RUs in the transmission (equal to the TXVECTOR parameter NUM_RUS).

Table 28-12—Frequently used parameters *(continued)*

$N_{user,r}$	For pre-HE modulated fields, $N_{user,r} = 1$. For HE modulated fields, $N_{user,r}$ represents the total number of users in the r-th RU of the transmission (summing over all RUs equals to the TXVECTOR parameter NUM_USERS_TOTAL).
N_{STS}, $N_{STS,r,u}$	For pre-HE modulated fields, $N_{STS,r,u} = 1$ (see NOTE). For HE modulated fields, $N_{STS,r,u}$ represents the number of space-time streams at r-th RU for user u, $u = 0, ..., N_{user,r} - 1$. In case of STBC, $N_{STS,r,u} = 2$ For an HE SU PPDU, $N_{STS} = N_{STS,0,0}$ For an HE MU PPDU, $N_{STS} = max_{r=0}^{N_{RU}-1} N_{STS,r,total}$
$N_{STS,r,total}$	For HE modulated fields, $N_{STS,r,total}$ is the total number of space-time streams at the r-th RU in a PPDU. $N_{STS,r,total} = \sum_{u=0}^{N_{user,r}-1} N_{STS,r,u}$ For pre-HE modulated fields, $N_{STS,r,total}$ is undefined when the TXVECTOR parameter BEAM_CHANGE is 1 and $N_{STS,r,total} = N_{STS}$ when BEAM_CHANGE is 0. Note that $N_{STS,r,total} = N_{STS}$ for an HE SU PPDU.
N_{SS}, $N_{SS,r,u}$, $N_{SS,u}$	Number of spatial streams. For the Data field, $N_{SS,r,u}$ is the number of spatial streams at r-th RU for user u, $u = 0, ..., N_{user,r} - 1$ and $N_{SS,u}$ is the number of spatial streams for user u, $u = 0, ..., N_{user,total} - 1$. For the Data field of an HE SU PPDU, $N_{SS} = N_{SS,0,0}$ For the Data field of an HE MU PPDU, $N_{SS} = max_{r=0}^{N_{RU}-1} N_{SS,r,total}$
$N_{SS,r,total}$	For HE modulated fields, $N_{SS,r,total}$ is the total number of spatial streams at r-th RU in a PPDU. $N_{SS,r,total} = \sum_{u=0}^{N_{user,r}-1} N_{SS,r,u}$ For pre-HE modulated fields, $N_{SS,r,total}$ is undefined. Note that $N_{SS,r,total} = N_{SS}$ for an HE SU PPDU.
N_{TX}	Number of transmit chains
$N_{HE\text{-}LTF}$	The number of OFDM symbols in the HE-LTF field (see 28.3.10.10 (HE-LTF))
$N_{HE\text{-}SIG\text{-}B}$	The number of OFDM symbols in the HE-SIG-B field
K_r	Set of subcarrier indices in the r-th RU

Table 28-12—Frequently used parameters *(continued)*

R, R_u	R_u is the coding rate for user u, $u = 0, ..., N_{user,total} - 1$. For an HE SU PPDU, $R = R_0$ For an HE MU PPDU, R is undefined
$M_{r,u}$	For pre-HE modulated fields, $M_{r,u} = 0$. For HE modulated fields, $M_{r,0} = 0$ for $u = 0$ and $M_{r,u} = \sum_{u'=0}^{u-1} N_{STS,r,u'}$ for u, $u = 1, ..., N_{user,r} - 1$.
NOTE—For pre-HE modulated fields, u and r are zeros only since $N_{user,r} = 1$ and $N_{RU} = 1$.	

28.3.9 Mathematical description of signals

For a description of the conventions used for the mathematical description of the signals, see 17.3.2.5 (Mathematical conventions in the signal descriptions). In addition, the following notational conventions are used in Clause 28:

$[Q]_{m,n}$ indicates the element in row m and column n of matrix, where $1 \le m \le N_{row}$ and $1 \le n \le N_{col}$

N_{row} and N_{col} are the number of rows and columns, respectively, of the matrix Q.

$[Q]_{m:n}$ indicates a matrix consisting of columns m to n of matrix Q.

For a description on subcarrier indices over which the signal is transmitted for non-HT, HT and VHT PPDUs, see 22.3.7 (Mathematical description of signals).

For a 20 MHz non-OFDMA HE PPDU transmission, the 20 MHz is divided into 256 subcarriers. The signal is transmitted on subcarriers –122 to –2 and 2 to 122, with 0 being the center (DC) subcarrier.

For a 20 MHz OFDMA HE PPDU transmission, the 20 MHz is divided into 256 subcarriers. The signal is transmitted on subcarriers –122 to –4 and 4 to 122, with 0 being the center (DC) subcarrier.

For a 40 MHz non-OFDMA and OFDMA HE PPDU transmission, the 40 MHz is divided into 512 subcarriers. The signal is transmitted on subcarriers –244 to –3 and 3 to 244.

For an 80 MHz non-OFDMA HE PPDU transmission, the 80 MHz is divided into 1024 subcarriers. The signal is transmitted on subcarriers –500 to –3 and 3 to 500.

For an 80 MHz OFDMA HE PPDU transmission, the 80 MHz is divided into 1024 subcarriers. The signal is transmitted on subcarriers –500 to –4 and 4 to 500.

For a 160 MHz HE PPDU transmission or a noncontiguous 80+80 MHz transmission, and each half 80 MHz bandwidth is divided into 1024 subcarriers, and the subcarriers on which the signal is transmitted in each 80 MHz bandwidth is identical to an 80 MHz HE PPDU transmission, depending on non-OFDMA or OFDMA transmission within the corresponding 80 MHz.

The transmitted signal is described in complex baseband signal notation. The actual transmitted signal on transmit chain i_{TX} and frequency segment i_{Seg} is related to the complex baseband signal by the relation shown in Equation (28-1).

$$r_{RF}^{(i_{Seg},\, i_{TX})}(t) = \mathrm{Re}\left\{ \frac{1}{\sqrt{N_{Seg}}} r_{PPDU}^{(i_{Seg},\, i_{TX})}(t) \exp\left(j2\pi f_c^{(i_{Seg})} t\right) \right\}, \quad i_{Seg} = 0, \ldots, N_{Seg} - 1; \; i_{TX} = 1, \ldots, N_{TX} \quad (28\text{-}1)$$

where

N_{Seg} represents the number of frequency segments in the transmit signal as defined in Table 28-10 (Tone allocation related constants for Data field in a non-OFDMA HE PPDU)

$r_{PPDU}^{(i_{Seg},\, i_{TX})}$ represents the complex baseband signal of frequency segment i_{Seg} and transmit chain i_{TX}

$f_c^{(i_{Seg})}$ represents the center frequency of frequency segment i_{Seg}

The transmitted RF signal is derived by up-converting the complex baseband signal, which consists of several fields. The timing boundaries for the various fields are shown in Figure 28-18 (Timing boundaries for HE PPDU fields), where $N_{\text{HE-LTF}}$ is the number of HE-LTF symbols and is defined in Table 28-12 (Frequently used parameters), $N_{\text{HE-SIG-B}}$ is the number of symbols in the HE-SIG-B field, and N_{SYM} is the number of symbols in the Data field.

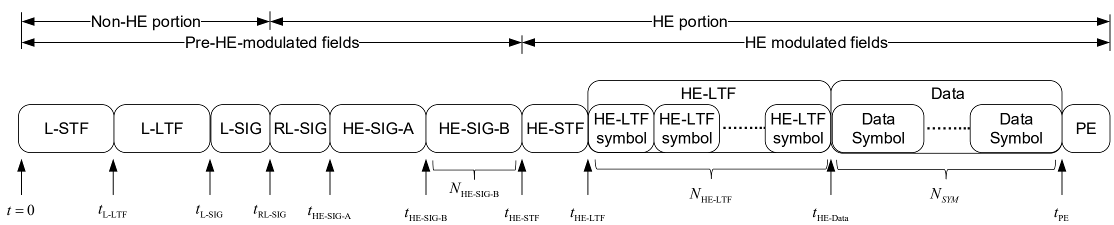


Figure 28-18—Timing boundaries for HE PPDU fields

The time offset, t_{Field}, determines the starting time of the corresponding field relative to the start of L-STF ($t = 0$).

The signal transmitted on frequency segment i_{Seg} of transmit chain i_{TX} shall be as shown in Equation (28-2).

$$\begin{aligned} r_{PPDU}^{(i_{Seg},\, i_{TX})}(t) = {} & r_{\text{L-STF}}^{(i_{Seg},\, i_{TX})}(t) + r_{\text{L-LTF}}^{(i_{Seg},\, i_{TX})}(t - t_{\text{L-LTF}}) \\ & + r_{\text{L-SIG}}^{(i_{Seg},\, i_{TX})}(t - t_{\text{L-SIG}}) + r_{\text{RL-SIG}}^{(i_{Seg},\, i_{TX})}(t - t_{\text{RL-SIG}}) + r_{\text{HE-SIG-A}}^{(i_{Seg},\, i_{TX})}(t - t_{\text{HE-SIG-A}}) + r_{\text{HE-SIG-B}}^{(i_{Seg},\, i_{TX})}(t - t_{\text{HE-SIG-B}}) \\ & + r_{\text{HE-STF}}^{(i_{Seg},\, i_{TX})}(t - t_{\text{HE-STF}}) + r_{\text{HE-LTF}}^{(i_{Seg},\, i_{TX})}(t - t_{\text{HE-LTF}}) + r_{\text{HE-Data}}^{(i_{Seg},\, i_{TX})}(t - t_{\text{HE-Data}}) + r_{\text{HE-PE}}^{(i_{Seg},\, i_{TX})}(t - t_{\text{HE-PE}}) \end{aligned} \tag{28-2}$$

where

$r_{\text{HE-SIG-B}}^{(i_{Seg},\, i_{TX})}(t - t_{\text{HE-SIG-B}})$ is only applicable to an HE MU PPDU

$0 \le i_{Seg} \le N_{Seg} - 1$

$1 \le i_{TX} \le N_{TX}$

$t_{\text{L-LTF}} = T_{\text{L-STF}}$

$t_{\text{L-SIG}} = t_{\text{L-LTF}} + T_{\text{L-LTF}}$

$t_{\text{RL-SIG}} = t_{\text{L-SIG}} + T_{\text{L-SIG}}$

$t_{\text{HE-SIG-A}} = t_{\text{RL-SIG}} + T_{\text{RL-SIG}}$

$$t_{\text{HE-SIG-B}} = \begin{cases} t_{\text{HE-SIG-A}} + T_{\text{HE-SIG-A}}, & \text{for an HE MU PPDU} \\ undefined, & \text{otherwise} \end{cases}$$

$$t_{\text{HE-STF}} = \begin{cases} t_{\text{HE-SIG-A}} + T_{\text{HE-SIG-A}}, & \text{for an HE SU PPDU and HE trigger-based PPDU} \\ t_{\text{HE-SIG-A}} + T_{\text{HE-SIG-A-R}}, & \text{for an HE extended range SU PPDU} \\ t_{\text{HE-SIG-B}} + N_{\text{HE-SIG-B}} T_{\text{HE-SIG-B}}, & \text{for an HE MU PPDU} \end{cases}$$

where $N_{HE\text{-}SIG\text{-}B}$ is the number of OFDM symbols in the HE-SIG-B field

$$t_{\text{HE-LTF}} = \begin{cases} t_{\text{HE-STF}} + T_{\text{HE-STF-T}}, & \text{for an HE trigger-based PPDU} \\ t_{\text{HE-STF}} + T_{\text{HE-STF-NT}}, & \text{otherwise} \end{cases}$$

$$t_{\text{HE-Data}} = \begin{cases} t_{\text{HE-LTF}} + N_{\text{HE-LTF}} \cdot (T_{\text{HE-LTF-1X}} + T_{\text{GI,HE-LTF}}), & \text{for 1x HE-LTF} \\ t_{\text{HE-LTF}} + N_{\text{HE-LTF}} \cdot (T_{\text{HE-LTF-2X}} + T_{\text{GI,HE-LTF}}), & \text{for 2x HE-LTF} \\ t_{\text{HE-LTF}} + N_{\text{HE-LTF}} \cdot (T_{\text{HE-LTF-4X}} + T_{\text{GI,HE-LTF}}), & \text{for 4x HE-LTF} \end{cases}$$

$$t_{\text{HE-PE}} = t_{\text{HE-Data}} + N_{SYM} T_{SYM}$$

In an HE SU PPDU, HE MU PPDU and HE extended range SU PPDU, for each field excluding the PE field, $r_{Field}^{(i_{Seg}, i_{TX})}(t)$ is defined in Equation (28-3) as the summation of one or more subfields. Each subfield is defined to be an inverse discrete Fourier transform.

$$r_{Field}^{(i_{Seg}, i_{TX})}(t) = w_{T_{Field}}(t) \sum_{r=0}^{N_{RU}-1} \frac{\alpha_r \beta_r^{Field}}{\sqrt{N_{Norm, r}}} \sum_{k \in K_r} \eta_{Field, k} \sum_{u=0}^{N_{user, r}-1} \sum_{m=1}^{N_{STS, r, u}} \left[Q_k^{(i_{Seg})} \right]_{i_{TX}, (M_{r,u}+m)} \Upsilon_{k, BW}$$
$$X_{k, r, u}^{i_{Seg}, m} \exp(j 2\pi k \Delta_{F, Field}(t - T_{GI, Field} - T_{CS, \text{HE}}(M_{r,u} + m))) \quad (28\text{-}3)$$

In an HE trigger-based PPDU, transmitted by user-u in the r-th RU, each field, $r_{Field}^{(i_{Seg}, i_{TX})}(t)$, is defined in Equation (28-4).

$$r_{Field}^{(i_{Seg}, i_{TX})}(t) = \frac{\beta_r^{Field}}{\sqrt{N_{Norm, r}}} w_{T_{Field}}(t) \sum_{k \in K_r} \eta_{Field, k} \sum_{m=1}^{N_{STS, r, u}} \left[Q_k^{(i_{Seg})} \right]_{i_{TX}, (M_{r,u}+m)} \Upsilon_{k, BW}$$
$$X_{k, r, u}^{(i_{Seg}, m)} \exp(j 2\pi k \Delta_{F, Field}(t - T_{GI, Field} - T_{CS, \text{HE}}(M_{r,u} + m))) \quad (28\text{-}4)$$

In the remainder of this subclause, pre-HE modulated fields refer to the L-STF, L-LTF, L-SIG, RL-SIG, HE-SIG-A, and HE-SIG-B fields, while HE modulated fields refer to the HE-STF, HE-LTF, Data, and PE fields, as shown in Figure 28-18 (Timing boundaries for HE PPDU fields). The total power of the time domain HE modulated field signals summed over all transmit chains should not exceed the total power of the time domain pre-HE modulated field signals summed over all transmit chains. For notational simplicity, the parameter BW is omitted from some bandwidth dependent terms.

In Equation (28-3) the following notations are used:

$N_{Norm,r}$ If the TXVECTOR parameter BEAM_CHANGE is 1, then for pre-HE modulated fields, $N_{Norm,r} = N_{TX}$. If the TXVECTOR parameter BEAM_CHANGE is 0, then for pre-HE modulated fields $N_{Norm,r} = N_{STS,r,total}$, where $N_{STS,r,total}$ is given in Table 28-12 (Frequently used parameters). For HE modulated fields $N_{Norm,r} = N_{STS,r,total}$.

$w_{T_{Field}}(t)$ is a windowing function. An example function, $w_{T_{Field}}(t)$, is given in 18.3.2.5 (Mathematical conventions in the signal descriptions).

K_r For pre-HE modulated fields, K_r is the set of subcarriers indices from $-N_{SR}$ to N_{SR} as defined in Table 28-13 (Highest data subcarrier index NSR for pre-HE modulated fields) excluding DC subcarriers. For HE modulated fields in a non-OFDMA HE PPDU, K_r is the set of subcarriers indices from $-N_{SR}$ to N_{SR} as defined in Table 28-10 (Tone allocation related constants for Data field in a non-OFDMA HE PPDU) excluding DC subcarriers. For HE modulated fields in an OFDMA HE PPDU, K_r is the set of subcarrier indices for the tones in the r-th RU as defined in Table 28-3 (Subcarrier indices for RUs in a 20 MHz HE PPDU), Table 28-4 (Subcarrier indices for RUs in a 40 MHz HE PPDU) and Table 28-5 (Subcarrier indices for RUs in an 80 MHz HE PPDU) excluding DC subcarriers.

Table 28-13—Highest data subcarrier index N_{SR} for pre-HE modulated fields

Field	N_{SR} as a function of bandwidth			
	20 MHz	**40 MHz**	**80 MHz**	**160 MHz**
L-STF	26	58	122	250
L-LTF	26	58	122	250
L-SIG	28	60	124	252
RL-SIG	28	60	124	252
HE-SIG-A	28	60	124	252
HE-SIG-B	28	60	124	252

$\eta_{Field,k}$ is the power boost factor of the k-th subcarrier of a given field within an OFDM symbol, which is $\sqrt{2}$ all the subcarriers of the L-STF, L-LTF, HE-STF and HE-LTF fields in the HE extended range SU PPDU. For the L-SIG and RL-SIG fields,

$$\eta_{Field,k} = \begin{cases} \sqrt{2}, k = -28, -27, 27, 28 & \text{for an HE extended range SU PPDU} \\ 1, & \text{otherwise} \end{cases}$$

and 1 otherwise.

α_r is the power boost factor for the r-th RU in an HE PPDU. For a DL HE MU PPDU, a STA shall support α_r in the range [0.7, $\sqrt{2}$] and a STA may support α_r in the range [0.5, 2].For an HE SU PPDU, HE extended range SU PPDU and HE trigger-based PPDU, α_r is always set to 1.

β_r^{Field} is the power normalization factor and is defined in Equation (28-5)

$$\beta_r^{Field} = \begin{cases} \dfrac{\varepsilon_{Field}}{\sqrt{N_{Field}^{\text{Tone}}}}, \text{ for pre-HE modulated fields} \\ \dfrac{1}{\sqrt{K_r^{Field}}}, \text{ for HE trigger-based PPDU HE fields} \\ \sqrt{\dfrac{|K_r|}{|K_r^{Field}|}} \Big/ \sqrt{\displaystyle\sum_{r=0}^{N_{RU}-1} \alpha_r^2 |K_r|}, \text{ otherwise} \end{cases} \quad (28\text{-}5)$$

$|K_r|$ is the cardinality of the set of subcarriers K_r.

$|K_r^{Field}|$ is the cardinality of the set of subcarriers modulated with data within K_r for the HE-STF and Data fields. For the HE-LTF field,

$$|K_r^{\text{HE-LTF}}| = \begin{cases} |K_r|, \text{ for a 4x HE-LTF} \\ |K_r|/2, \text{ for a 2x HE-LTF} \\ |K_r|/4, \text{ for a 1x HE-LTF} \end{cases}$$

N_{Field}^{Tone} Table 28-14 (Tone scaling factor and guard interval duration values for HE PPDU fields) summarizes the various values of N_{Field}^{Tone} as a function of bandwidth per frequency segment. In the case of an HE OFDMA PPDU, the N_{Field}^{Tone} value of HE-STF, HE-LTF and HE-Data fields is variable, and is determined by which RUs of the current full bandwidth are transmitted in the PPDU.

Table 28-14—Tone scaling factor and guard interval duration values for HE PPDU fields

Field	N_{Field}^{Tone} as a function of bandwidth, and RU size per frequency segment				Guard interval duration
	20 MHz	40 MHz	80 MHz	160 MHz	
L-STF	12	24	48	96	-
L-LTF	52	104	208	416	$T_{GI2,\text{L-LTF}}$
L-SIG in an HE PPDU	56	112	224	448	$T_{GI,\text{LegacyPreamble}}$
L-SIG in a non-HT duplicate PPDU	-	104	208	416	
RL-SIG	56	112	224	448	$T_{GI,\text{LegacyPreamble}}$
HE-SIG-A	56	112	224	448	$T_{GI,\text{LegacyPreamble}}$
HE-SIG-B	56	112	224	448	$T_{GI,\text{LegacyPreamble}}$
HE-STF not in an HE trigger-based PPDU	14	30	62	124	-
HE-STF in an HE trigger-based PPDU	30	60	124	248	-

Table 28-14—Tone scaling factor and guard interval duration values for HE PPDU fields

HE-LTF 1x Duration	60	122	250	500	$T_{GI,\text{HE-LTF1}}$
HE-LTF 2x Duration	122	242	498	996	$T_{GI,\text{HE-LTF2}}$
HE-LTF 4x Duration	242	484	996	1992	$T_{GI,\text{HE-LTF4}}$
HE-Data	242	484	996	1992	$T_{GI,Data}$
NON_HT_DUP_OFDM-Data	-	104	208	416	$T_{GI,\text{LegacyPreamble}}$

NOTE—in the case of an HE OFDMA PPDU, the N_{Field}^{Tone} value of HE-STF, HE-LTF and HE-Data fields is variable, and is determined by which RUs of the current full bandwidth are transmitted in the PPDU.

$$\varepsilon_{Field} = \begin{cases} \sqrt{\dfrac{N_{\text{L-LTF}}^{\text{Tone}}}{N_{\text{L-SIG}}^{\text{Tone}}}}, \text{ For the L-STF and L-LTF fields} \\ 1, \text{ otherwise} \end{cases}$$

$Q_k^{(i_{Seg})}$ is the spatial mapping matrix for the subcarrier k in frequency segment i_{Seg}. For HE modulated fields, $Q_k^{(i_{Seg})}$ is a matrix with N_{TX} rows and $N_{STS,r,total}$ columns. If the TXVECTOR parameter BEAM_CHANGE is 1, then for pre-HE modulated fields $Q_k^{(i_{Seg})}$ is a column vector with N_{TX} elements with element i_{TX} being $\exp(-j2\pi k\Delta_{F,\text{ Pre-HE}} T_{CS}^{i_{TX}})$, where $T_{CS}^{i_{TX}}$ represents the cyclic shift for the transmitter chain whose values are defined in 28.3.10.2.1 (Cyclic shift for pre-HE modulated fields); otherwise it is identical to the spatial mapping $Q_k^{(i_{Seg})}$ for HE modulated fields.

$\Delta_{F,\,Field}$ is the subcarrier frequency spacing. For pre-HE modulated fields, $\Delta_{F,\,Field} = \Delta_{F,\text{ Pre-HE}}$ given in Table 28-9 (Timing-related constants). For HE modulated fields, $\Delta_{F,\,Field} = \Delta_{F,\text{ HE}}$ given in Table 28-9 (Timing-related constants).

$X_{k,r,u}^{(i_{Seg},m)}$ is the frequency-domain symbol in subcarrier k of user u in the r-th RU for frequency segment i_{Seg} of space-time stream m. Some of the $X_{k,r,u}^{(i_{Seg},m)}$ within $-N_{SR} \le k \le N_{SR}$ have a value of zero. Examples of such cases include the DC tones, guard tones on each side of the transmit spectrum, the null subcarriers in an HE OFDMA PPDU, as well as the unmodulated tones of L-STF, HE-STF, and HE-LTF fields. Note that the multiplication matrices $A_{\text{HE-LTF}}^k$ are included in the calculation of $X_{k,r,u}^{(i_{Seg},m)}$ for the HE-STF and HE-LTF fields. When the TXVECTOR parameter BEAM_CHANGE is 0, the first column of the multiplication matrices $A_{\text{HE-LTF}}^k$ are included in the calculation of $X_{k,r,u}^{(i_{Seg},m)}$ for the pre-HE modulated fields.

$T_{GI,\,Field}$ is the guard interval duration used for each OFDM symbol in the field. The value for each field is as defined in Table 28-9 (Timing-related constants).

$T_{CS,\text{ HE}}(l)$ For pre-HE modulated fields, $T_{CS,\text{ HE}}(l) = 0$. For HE modulated fields, $T_{CS,\text{ HE}}(l)$ represents the cyclic shift per space-time stream, whose value is defined in 28.3.10.2.2 (Cyclic shift for HE modulated fields).

$\Upsilon_{k,BW}$ is used to represent tone rotation. BW in $\Upsilon_{k,BW}$ is determined by the TXVECTOR parameter CH_BANDWIDTH as defined in Table 28-15 (CH_BANDWIDTH and for pre-HE modulated fields). In HE modulated fields, $\Upsilon_{k,BW} = 1$ in all the subcarriers. In pre-HE modulated fields, $\Upsilon_{k,BW}$ is defined as in 21.3.7.5 (Definition of tone rotation) when TXVECTOR parameter BEAM_CHANGE is set to 1 and $\Upsilon_{k,BW} = 1$ for all the tones when TXVECTOR parameter BEAM_CHANGE is set to 0. When the TXVECTOR parameter BEAM_CHANGE is not present (such as in an HE MU PPDU and HE trigger-based PPDU), BEAM_CHANGE is assumed to be set to 1.

Table 28-15—CH_BANDWIDTH and $\Upsilon_{k,BW}$ for pre-HE modulated fields

CH_BANDWIDTH	$\Upsilon_{k,\mathrm{BW}}$
CBW20	$\Upsilon_{k,20}$
CBW40	$\Upsilon_{k,40}$
CBW80	$\Upsilon_{k,80}$
CBW160	$\Upsilon_{k,160}$
CBW80+80	$\Upsilon_{k,80}$ per frequency segment

28.3.10 HE preamble

28.3.10.1 Introduction

The HE portion of HE format preamble consists of pre-HE modulated fields and HE modulated fields. The HE modulated fields consist of HE-STF, HE-LTF and Data fields. The pre-HE modulated fields for the various HE PPDU formats are the following:

- RL-SIG and HE-SIG-A fields of an HE SU PPDU
- RL-SIG, HE-SIG-A and HE-SIG-B fields of an HE MU PPDU
- RL-SIG, HE-SIG-A and repeated HE-SIG-A fields of an HE extended range SU PPDU
- RL-SIG and HE-SIG-A fields of an HE trigger-based PPDU

28.3.10.2 Cyclic shift

28.3.10.2.1 Cyclic shift for pre-HE modulated fields

When the TXVECTOR parameter BEAM_CHANGE is 1, the cyclic shift value $T_{CS}^{i_{TX}}$ for the L-STF, L-LTF, L-SIG, RL-SIG and HE-SIG-A fields of the PPDU for transmit chain i_{TX} out of a total of N_{TX} are defined in Table 21-10 (Cyclic shift values for L-STF, L-LTF, L-SIG, and VHT-SIG-A fields of the PPDU). In UL MU transmission the cyclic shift value $T_{CS}^{i_{TX}}$ is based on the transmit chain index of each STA.

When the TXVECTOR parameter BEAM_CHANGE is 0, the cyclic shift value $T_{CS}^{i_{TX}}$ for the L-STF, L-LTF, L-SIG, RL-SIG, and HE-SIG-A fields is not specified.

28.3.10.2.2 Cyclic shift for HE modulated fields

The cyclic shift values defined in this subclause apply to the HE-STF, HE-LTF and Data fields of the HE PPDU when the TXVECTOR parameter BEAM_CHANGE is 1, and apply to the entire PPDU when the TXVECTOR parameter BEAM_CHANGE is 0.

Throughout the HE modulated fields of the preamble, cyclic shifts are applied to prevent unintended beamforming when correlated signals are transmitted in multiple space-time streams. The same cyclic shift is also applied to these streams during the transmission of the Data field of the HE PPDU. For the *r*-th RU, the cyclic shift value $T_{CS,\mathrm{HE}}(n)$ for the HE modulated fields for space-time stream *n* out of $N_{STS,r,total}$ total space-time streams is shown in Table 21-11 (Cyclic shift values for the VHT modulated fields of a PPDU).

28.3.10.3 L-STF

If the TXVECTOR parameter BEAM_CHANGE is 1, the time domain representation of the L-STF field shall be as specified in Equation (28-6). The equation applies to all contiguous signals up to 160 MHz and non contiguous 80+80 MHz.

$$r_{\text{L-STF}}^{(i_{Seg} i_{TX})}(t) = \frac{\varepsilon}{\sqrt{N_{TX} \cdot N_{\text{L-STF}}^{\text{Tone}}}} w_{T_{\text{L-STF}}}(t) \sum_{i_{BW} \in \Omega_{20\text{MHz}}} \sum_{k=-26}^{26} \eta_{\text{L-STF},k} \begin{pmatrix} \Upsilon_{(k-K_{\text{Shift}}(i_{BW})),\,\text{BW}} S_{k,20} \\ \cdot \exp(j2\pi(k-K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F,\text{Pre-HE}}(t-T_{CS}^{i_{TX}})) \end{pmatrix} \tag{28-6}$$

where

ε is a power scaling factor with the value $\varepsilon = \sqrt{\frac{N_{\text{Tone}}^{\text{L-LTF}}}{N_{\text{Tone}}^{\text{L-SIG}}}}$

$\eta_{\text{L-STF},k}$ is a PPDU format dependent scaling factor for the L-STF field on tone index *k* with the following value

$$\eta_{\text{L-STF},k} = \begin{cases} \sqrt{2}, & \text{for an HE extended range SU PPDU} \\ 1, & \text{otherwise} \end{cases} \tag{28-7}$$

$N_{20\text{MHz}}$ is defined in 22.3.8.3.4 (L-SIG definition)

$K_{Shift}(i) = (N_{20\text{MHz}} - 1 - 2i) \cdot 32$

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain i_{TX} with a value given in 28.3.10.2.1 (Cyclic shift for pre-HE modulated fields).

$N_{\text{L-STF}}^{\text{Tone}}$ has the value given in Table 28-14 (Tone scaling factor and guard interval duration values for HE PPDU fields).

$\Omega_{20\text{MHz}}$ is a set of 20 MHz channels that contains the channels where pre-HE modulated fields are located and the channel indices are within 0 to $N_{20\text{MHz}} - 1$ in an HE trigger-based PPDU or HE MU PPDU with preamble puncturing, or equal to $\{0, 1, \ldots, N_{20\text{MHz}} - 1\}$ otherwise.

$S_{k,20}$ is defined as $S_{-26,26}$ in Equation (19-8).

If the TXVECTOR parameter BEAM_CHANGE is 0, the time domain representation of the L-STF field of contiguous 20 MHz, 40 MHz, 80 MHz and 160 MHz transmission shall be as specified in Equation (28-8). The equation applies to all contiguous signals up to 160 MHz and non contiguous 80+80 MHz.

$$r_{\text{L-STF}}^{(i_{Seg} i_{TX})}(t) = \frac{\varepsilon}{\sqrt{N_{STS} \cdot N_{\text{L-STF}}^{\text{Tone}}}} w_{T_{\text{L-STF}}}(t) \sum_{i_{BW}=0}^{N_{20\text{MHz}}-1} \sum_{k=-26}^{26} \sum_{m=1}^{N_{STS}} \eta_{\text{L-STF},k} \begin{pmatrix} \left[Q_{4(k-K_{\text{Shift}}(i_{BW}))}^{(i_{Seg})}\right]_{i_{TX},m} \left[A_{\text{HE-LTF}}^{4(k-K_{\text{Shift}}(i_{BW}))}\right]_{m,1} S_{k,20} \\ \cdot \exp(j2\pi(k-K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F,\text{Pre-HE}}(t-T_{CS,\text{HE}}(m))) \end{pmatrix} \tag{28-8}$$

where

$T_{CS,\text{HE}}(m)$ represents the cyclic shift for space time stream m as defined in 28.3.10.2.2 (Cyclic shift for HE modulated fields)

$Q_k^{(i_{Seg})}$ is the spatial mapping/steering matrix for subcarrier k, in frequency segment i_{Seg} on the data symbols over tone spacing $\Delta_{F,\text{HE}}$ as defined in Table 28-9 (Timing-related constants). Refer to the descriptions in 22.3.10.11.1 (Transmission in VHT format) for examples of $Q_k^{(i_{Seg})}$.

$A_{\text{HE-LTF}}^k$ is defined in Equation (28-55)

28.3.10.4 L-LTF

If the TXVECTOR parameter BEAM_CHANGE is 1, the time domain representation of the L-LTF field shall be as specified in Equation (28-9). The equation applies to all contiguous signals up to 160 MHz and non contiguous 80+80 MHz.

$$r_{\text{L-LTF}}^{(i_{Seg} i_{TX})}(t) = \frac{\varepsilon}{\sqrt{N_{TX} \cdot N_{\text{L-LTF}}^{\text{Tone}}}} w_{T_{\text{L-LTF}}}(t) \sum_{i_{BW} \in \Omega_{20\text{MHz}}} \sum_{k=-26}^{26} \eta_{\text{L-LTF},k} \begin{pmatrix} \Upsilon_{(k-K_{\text{Shift}}(i_{BW})),\text{BW}} L_{k,20} \\ \cdot \exp(j2\pi(k-K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F,\text{Pre-HE}}(t-T_{GI,\text{L-LTF}}-T_{CS}^{i_{TX}})) \end{pmatrix} \tag{28-9}$$

$\eta_{\text{L-LTF},k}$ is a PPDU format dependent scaling factor for the L-LTF field on tone index k with the same value as $\eta_{\text{L-STF},k}$.

$N_{20\text{MHz}}$ is defined in 21.3.7.3 (Channel frequencies)

$K_{Shift}(i) = (N_{20\text{MHz}} - 1 - 2i) \cdot 32$

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain i_{TX} with a value given in 28.3.10.2.1 (Cyclic shift for pre-HE modulated fields).

$N_{\text{L-LTF}}^{\text{Tone}}$ has the value given in Table 28-14 (Tone scaling factor and guard interval duration values for HE PPDU fields).

$L_{k,20}$ is defined as $L_{-26,26}$ in Equation (18-8).

If the TXVECTOR parameter BEAM_CHANGE is 0, the time domain representation of the L-LTF field of contiguous 20 MHz, 40 MHz, 80 MHz and 160 MHz transmission shall be as specified in Equation (28-10). The equation applies to all contiguous signals up to 160 MHz and non contiguous 80+80 MHz.

$$r_{\text{L-LTF}}^{(i_{Seg} i_{TX})}(t) = \frac{\varepsilon}{\sqrt{N_{STS} \cdot N_{\text{L-LTF}}^{\text{Tone}}}} w_{T_{\text{L-LTF}}}(t) \sum_{i_{BW}=0}^{N_{20\text{MHz}}} \sum_{k=-26}^{26} \sum_{m=1}^{N_{STS}} \eta_{\text{L-LTF},k} \left(\begin{array}{l} \left[Q_{4(k-K_{\text{Shift}}(i_{BW}))}^{(i_{Seg})}\right]_{i_{TX},m} \left[A_{\text{HE-LTF}}^{4(k-K_{\text{Shift}}(i_{BW}))}\right]_{m,1} L_{k,20} \\ \cdot \exp(j2\pi(k-K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F,\text{Pre-HE}}(t-T_{GI,\text{LegacyPreamble}}-T_{CS,\text{HE}}(m))) \end{array} \right) \tag{28-10}$$

where

$T_{CS,\text{HE}}(m)$ represents the cyclic shift for space time stream m as defined in 28.3.10.2.2 (Cyclic shift for HE modulated fields)

$Q_k^{(i_{Seg})}$ is defined in 28.3.9 (Mathematical description of signals)

$A_{\text{HE-LTF}}^{k}$ is defined in Equation (28-55)

28.3.10.5 L-SIG

The L-SIG field is used to communicate rate and length information. The structure of the L-SIG field is defined in Figure 17-5 (SIGNAL field bit assignment).

In an HE PPDU, the RATE field shall be set to the value representing 6 Mb/s in the 20 MHz channel spacing column of Table 17-6 (Contents of the SIGNAL field). In a non-HT duplicate PPDU, the RATE field is defined in 17.3.4.2 (RATE field) using the L_DATARATE parameter in the TXVECTOR.

The LENGTH field shall be set to the value given by Equation (28-11).

$$\text{Length} = \left\lceil \frac{\text{TXTIME}-SignalExtension-20}{4} \right\rceil \times 3 - 3 - m \tag{28-11}$$

where

TXTIME (in μs) is defined in 28.4.2 (TXTIME and PSDU_LENGTH calculation).

m is 1 for an HE MU PPDU and HE extended range SU PPDU, and 2 otherwise

SignalExtension is 0 μs when the TXVECTOR parameter NO_SIG_EXTN is true and is aSignalExtension as defined in Table 19-25 (HT PHY characteristics) when TXVECTOR parameter NO_SIG_EXTN is false

The LSB of the binary expression of the Length value shall be mapped to B5. In a non-HT duplicate PPDU, the LENGTH field is defined in 17.3.4.3 (LENGTH field) using the L_LENGTH parameter in the TXVECTOR.

The Reserved (R) field shall be set to 0.

The Parity (P) field has the even parity of bits 0-16.

The SIGNAL TAIL field shall be set to 0.

The L-SIG field shall be encoded, interleaved, and mapped following the steps described in 17.3.5.6 (Convolutional encoder), 17.3.5.7 (Data interleaving), and 17.3.5.8 (Subcarrier modulation mapping). The stream of 48 complex numbers generated by these steps is denoted by $d_k, k = 0, \ldots, 47$. Pilots shall be inserted as described in 17.3.5.9 (Pilot subcarriers). Extra 4 BPSK modulated tones are added. The 4 extra tones [–28, –27, 27, 28] of L-SIG in 20 MHz HE PPDU is [–1, –1, –1, 1].

If the TXVECTOR parameter BEAM_CHANGE is 1, the time domain waveform of the L-SIG field shall be as given by Equation (28-12).

$$r_{\text{L-SIG}}^{(i_{Seg} i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{\text{L-SIG}}^{\text{Tone}}}} w_{T_{\text{L-SIG}}}(t) \sum_{i_{BW} \in \Omega_{20\text{MHz}}} \sum_{k=-28}^{28} \begin{pmatrix} \Upsilon_{(k - K_{\text{Shift}}(i_{BW})),\ \text{BW}} \eta_{\text{L-SIG},\,k}(D_{k,\,20} + p_0 P_k) \\ \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F,\ \text{Pre-HE}}(t - T_{GI,\ \text{LegacyPreamble}} - T_{CS}^{i_{TX}})) \end{pmatrix} \quad (28\text{-}12)$$

where

$\eta_{\text{L-SIG},\,k}$ is a PPDU dependent scaling factor for the L-SIG field on the subcarrier k defined as follows:

$$\eta_{\text{L-SIG},\,k} = \begin{cases} \sqrt{2}, & k = \pm 28, \pm 27 \text{ for an HE extended range SUPPDU} \\ 1, & \text{otherwise} \end{cases}$$

$N_{20\text{MHz}}$ is defined in 21.3.7.3 (Channel frequencies)

$K_{Shift}(i) = (N_{20\text{MHz}} - 1 - 2i) \cdot 32$

$$D_{k,\,20} = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ -1, k = -28, -27, 27 \\ 1, k = 28 \\ d_{M_{20}^r(k)}, \text{otherwise} \end{cases}$$

$$M_{20}^r(k) = \begin{cases} k + 26, -26 \le k \le -22 \\ k + 25, -20 \le k \le -8 \\ k + 24, -6 \le k \le -1 \\ k + 23, 1 \le k \le 6 \\ k + 22, 8 \le k \le 20 \\ k + 21, 22 \le k \le 26 \end{cases}$$

P_k is defined in 17.3.5.10 (OFDM modulation)

P_0 is the first pilot value in the sequence defined in 17.3.5.10 (OFDM modulation)

$N_{\text{L-SIG}}^{\text{Tone}}$ is defined in Table 28-14 (Tone scaling factor and guard interval duration values for HE PPDU fields)

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain i_{TX} with a value given in 28.3.10.2.1 (Cyclic shift for pre-HE modulated fields).

NOTE—$M_{20}^r(k)$ is a "reverse" function of the function $M(k)$ defined in 17.3.5.10 (OFDM modulation).

If the TXVECTOR parameter BEAM_CHANGE is 0, the time domain waveform of the L-SIG field shall be as given by Equation (28-13).

$$r_{\text{L-SIG}}^{(i_{Seg} i_{TX})}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{\text{L-SIG}}^{\text{Tone}}}} w_{T_{\text{L-SIG}}}(t) \sum_{i_{BW}=0}^{N_{20\text{MHz}}} \sum_{k=-28}^{28} \sum_{m=1}^{N_{STS}} \left(\begin{array}{l} \left[Q_{4(k-K_{\text{Shift}}(i_{BW}))}^{(i_{Seg})}\right]_{i_{TX},m} \left[A_{\text{HE-LTF}}^{4(k-K_{\text{Shift}}(i_{BW}))}\right]_{m,1} \eta_{\text{L-SIG},k}(D_{k,20} + p_0 P_k) \\ \cdot \exp(j2\pi(k-K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F,\text{Pre-HE}}(t - T_{GI,\text{LegacyPreamble}} - T_{CS,\text{HE}}(m))) \end{array} \right) \tag{28-13}$$

where

$T_{CS,\text{HE}}(m)$ represents the cyclic shift for space time stream m as defined in 28.3.10.2.2 (Cyclic shift for HE modulated fields)

$Q_k^{(i_{Seg})}$ is defined in 28.3.9 (Mathematical description of signals)

$A_{\text{HE-LTF}}^k$ is defined in Equation (28-55)

28.3.10.6 RL-SIG

The RL-SIG field is used to identify an HE PPDU.

If the TXVECTOR parameter BEAM_CHANGE is 1, the time domain waveform of the RL-SIG field shall be as given by Equation (28-14).

$$r_{\text{RL-SIG}}^{(i_{Seg} i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{\text{RL-SIG}}^{\text{Tone}}}} w_{T_{\text{RL-SIG}}}(t) \sum_{i_{BW} \in \Omega_{20\text{MHz}}} \sum_{k=-28}^{28} \eta_{\text{L-SIG},k} \left(\begin{array}{l} \Upsilon_{(k-K_{\text{Shift}}(i_{BW})),\text{BW}}(D_{k,20} + p_1 P_k) \\ \cdot \exp(j2\pi(k-K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F,\text{Pre-HE}}(t - T_{GI,\text{LegacyPreamble}} - T_{CS}^{i_{TX}})) \end{array} \right) \tag{28-14}$$

If the TXVECTOR parameter BEAM_CHANGE is 0, the time domain waveform of the RL-SIG field shall be as given by Equation (28-15).

$$r_{\text{L-SIG}}^{(i_{Seg} i_{TX})}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{\text{RL-SIG}}^{\text{Tone}}}} w_{T_{\text{RL-SIG}}}(t) \sum_{i_{BW}=0}^{N_{20\text{MHz}}-1} \sum_{k=-28}^{28} \eta_{\text{L-SIG},k} \sum_{m=1}^{N_{STS}} \left(\begin{array}{l} \left[Q_{4(k-K_{\text{Shift}}(i_{BW}))}^{(i_{Seg})}\right]_{i_{TX},m} \left[A_{\text{HE-LTF}}^{4(k-K_{\text{Shift}}(i_{BW}))}\right]_{m,1} (D_{k,20} + p_1 P_k) \\ \cdot \exp(j2\pi(k-K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F,\text{Pre-HE}}(t - T_{GI,\text{LegacyPreamble}} - T_{CS,\text{HE}}(m))) \end{array} \right) \tag{28-15}$$

28.3.10.7 HE-SIG-A

28.3.10.7.1 General

The HE-SIG-A field carries information required to interpret HE PPDUs.

28.3.10.7.2 Content

The HE-SIG-A field for an HE SU PPDU or an HE extended range SU PPDU contains the fields listed in Table 28-16 (HE-SIG-A field of an HE SU PPDU and HE extended range SU PPDU).

Table 28-16—HE-SIG-A field of an HE SU PPDU and HE extended range SU PPDU

Two Parts of HE-SIG-A	Bit	Field	Number of bits	Description
HE-SIG-A1	B0	Format	1	Differentiate an HE SU PPDU from an HE trigger-based PPDU: Set to 0 for HE trigger-based PPDU Set to 1 for HE SU PPDU This field is reserved and set to 1 for an HE extended range SU PPDU.
	B1	Beam Change	1	Set to 1 indicates that the pre-HE-STF portion of the PPDU is spatially mapped differently from HE-LTF1. Set to 0 indicates that the pre-HE-STF portion of the PPDU is spatially mapped the same way as HE-LTF1 on each tone.
	B2	UL/DL	1	Indicates whether the PPDU is sent UL or DL: Set to 0 for DL Set to 1 for UL This field indicates DL for TDLS, mesh and IBSS. NOTE—The TDLS peer can identify the TDLS frame by To DS and From DS fields in the MAC header of the MPDU.
	B3-B6	MCS	4	For an HE SU PPDU: Set to n for MCSn, where n = 0, 1, 2, …., 11 Values 12-15 are reserved For HE extended range SU PPDU with Bandwidth field set to 0 (242-tone RU): Set to n for MCSn, where n = 0, 1, 2 Values 3-15 are reserved For HE extended range SU PPDU with Bandwidth field set to 1 (right 106-tone RU in P20): Set to 0 for MCS 0 Values 1-15 are reserved
	B7	DCM	1	Indicates whether or not DCM is applied to the Data field for the MCS indicated. Set to 1 to indicate that DCM is applied to the Data field Set to 0 to indicate that DCM is not applied to the Data field. DCM is only applied for MCS0, MCS1, MCS3 and MCS4. DCM is only applied for 1 and 2 spatial streams. DCM is not applied when STBC is used.
	B8-B13	BSS Color	6	The BSS Color field is an identifier of the BSS

Table 28-16—HE-SIG-A field of an HE SU PPDU and HE extended range SU PPDU *(contin-*

	B14	Reserved	1	Reserved and set to 1
	B15-B18	Spatial Reuse	4	Set to SR Disallowed to disallow SRP-based spatial reuse (see 27.9 (Spatial reuse operation) and 27.11.6 (SPATIAL_REUSE)). NOTE—This part needs further development. Set to SR_Delay to delay the starting time of spatial reuse transmission (see 27.9.2.1 (General) and 27.11a (TXVECTOR parameters SPATIAL_REUSE for an HE PPDU)).
	B19-B20	Bandwidth	2	For an HE SU PPDU: Set to 0 for 20 MHz Set to 1 for 40 MHz Set to 2 for 80 MHz Set to 3 for 160 MHz and 80+80 MHz For an HE extended range SU PPDU: Set to 0 for 242-tone RU Set to 1 for right 106-tone RU within the primary 20 MHz
	B21-B22	GI+LTF Size	2	Indicates the GI duration and HE-LTF size. Set to 0 to indicate a 1x HE-LTF and 0.8 µs GI Set to 1 to indicate a 2x HE-LTF and 0.8 µs GI Set to 2 to indicate a 2x HE-LTF and 1.6 µs GI Set to 3 to indicate — a 4x HE-LTF and 0.8 µs GI when both the DCM and STBC fields are 1. Neither DCM nor STBC shall be applied when both the DCM and STBC are set to 1. — a 4x HE-LTF and 3.2 µs GI otherwise
	B23-B25	Nsts	3	Indicates the number of space time streams. For an HE SU PPDU: Set to the number of space time streams minus 1 For an HE extended range SU PPDU: Set to 0 for one space time stream when STBC field is set to 0 Set to 1 for two space time streams when STBC field is set to 1 Values 2-7 are reserved
HE-SIG-A2 (HE SU PPDU) or HE-SIG-A3 (HE extended range SU PPDU)	B0-B6	TXOP Duration	7	Set to 127 to indicate no duration information. Set to value other than 127 to indicate duration information for NAV setting and protection of the TXOP. NOTE—The encoding of TXOP Duration field is the same as the TXOP_DURATION parameter in Table 28-1 (TXVECTOR and RXVECTOR parameters).

Table 28-16—HE-SIG-A field of an HE SU PPDU and HE extended range SU PPDU *(contin-*

	B7	Coding	1	Indicates whether BCC or LDPC is used: Set to 0 to indicate BCC Set to 1 to indicate LDPC
	B8	LDPC Extra Symbol Segment	1	Indicates the presence of the extra OFDM symbol for LDPC. Set to 1 if an extra OFDM symbol for LDPC is present Set to 0 if an extra OFDM symbol for LDPC is present Reserved and set to 1 when the Coding field is 0.
	B9	STBC	1	Set to 1 if space time block coding is used Set to 0 otherwise
	B10	TxBF	1	Set to 1 if a Beamforming steering matrix is applied to the waveform in an SU transmission Set to 0 otherwise
	B11-B12	Pre-FEC Padding Factor	2	Indicates the pre-FEC padding factor value as defined in Table 28-39 (Pre-FEC Padding Factor subfield encoding).
	B13	PE Disambiguity	1	Indicate PE Disambiguity as defined in 28.3.12 (Packet extension).
	B14	Reserved	1	Reserved and set to 1
	B15	Doppler	1	Set to 0 if Doppler mode is not used Set to 1 if Doppler mode is used
	B16-B19	CRC	4	CRC for bits 0-41 of the HE-SIG-A field (see 28.3.10.7.3 (CRC computation)).
	B20-B25	Tail	6	Used to terminate the trellis of the convolutional decoder. Set to 0.
NOTE—Integer fields are transmitted in unsigned binary format, LSB first, where the LSB is in the lowest numbered bit position.				

The HE-SIG-A field of an HE MU PPDU contains the fields listed in Table 28-17 (HE-SIG-A field of an HE MU PPDU).

Table 28-17—HE-SIG-A field of an HE MU PPDU

Two Parts of HE-SIG-A	Bit	Field	Number of bits	Description
HE-SIG-A1	B0	UL/DL	1	Indicates whether the PPDU is sent UL or DL: Set to 0 for DL Set to 1 for UL This field indicates DL for TDLS, mesh and IBSS. NOTE—The TDLS peer can identify the TDLS frame by To DS and From DS fields in the MAC header of the MPDU.
	B1-B3	SIGB MCS	3	Indicates the MCS of the HE-SIG-B field: Set to 0 for MCS 0 Set to 1 for MCS 1 Set to 2 for MCS 2 Set to 3 for MCS 3 Set to 4 for MCS 4 Set to 5 for MCS 5 The values 6 and 7 are reserved
	B4	SIGB DCM	1	Set to 1 indicates that the HE-SIG-B is modulated with dual sub-carrier modulation for the MCS. Set to 0 indicates that the HE-SIB-B is not modulated with dual sub-carrier modulation for the MCS. DCM is only applicable to MCS0, MCS1, MCS3, and MCS4.
	B5-B10	BSS Color	6	The BSS Color field is an identifier of the BSS
	B11-B14	Spatial Reuse	4	Set to SR Disallowed to disallow SRP-based spatial reuse (see 27.9 (Spatial reuse operation) and 27.11.6 (SPATIAL_REUSE)). NOTE—This part needs further development. Set to SR_Restricted to restrict the spatial reuse transmission (see 27.9.2.1 (General) and 27.11a (TXVECTOR parameters SPATIAL_REUSE for an HE PPDU)).

Table 28-17—HE-SIG-A field of an HE MU PPDU *(continued)*

	B15-B17	Bandwidth	3	Set to 0 for full 20 MHz Set to 1 for full 40 MHz Set to 2 for full 80 MHz Set to 3 for full 160 MHz and 80+80 MHz Set to 4 for preamble puncturing in 80 MHz, where in the preamble only the secondary 20 MHz is punctured Set to 5 for preamble puncturing in 80 MHz, where in the preamble only one of the two 20 MHz sub-channels in secondary 40 MHz is punctured Set to 6 for preamble puncturing in 160 MHz or 80+80 MHz, where in the primary 80 MHz of the preamble only the secondary 20 MHz is punctured Set to 7 for preamble puncturing in 160 MHz or 80+80 MHz, where in the primary 80 MHz of the preamble the primary 40 MHz is present.
	B18-B21	Number Of HE-SIG-B Symbols Or MU-MIMO Users	4	If the SIGB Compression field is 0, indicates the number of OFDM symbols in the HE-SIG-B field minus 1. If the SIGB Compression field is 1, indicates the number of MU-MIMO users minus 1.
	B22	SIGB Compression	1	Set to 1 for full BW MU-MIMO. Set to 0 otherwise.
	B23-B24	GI+LTF Size	2	Indicates the GI duration and HE-LTF size: Set to 0 to indicate a 4x HE-LTF and 0.8 µs GI Set to 1 to indicate a 2x HE-LTF and 0.8 µs GI Set to 2 to indicate a 2x HE-LTF and 1.6 µs GI Set to 3 to indicate a 4x HE-LTF and 3.2 µs GI
	B25	Doppler	1	Set to 0 if Doppler mode is not used Set to 1 if Doppler mode is used
HE-SIG-A2	B0-B6	TXOP Duration	7	Set to 127 to indicate no duration information. Set to value other than 127 to indicate duration information for NAV setting and protection of the TXOP. NOTE—The encoding of TXOP Duration field is the same as the TXOP_DURATION parameter in Table 28-1 (TXVECTOR and RXVECTOR parameters).
	B7	Reserved	1	Reserved and set to 1
	B8-B10	Number of HE-LTF Symbols	3	Indicates the number of HE-LTF symbols: Set to 0 for 1 HE-LTF symbol Set to 1 for 2 HE-LTF symbols Set to 2 for 4 HE-LTF symbols Set to 3 for 6 HE-LTF symbols Set to 4 for 8 HE-LTF symbols Other values are reserved.
	B11	LPDC Extra Symbol	1	Indication of the presence of the extra OFDM symbol for LDPC.

Table 28-17—HE-SIG-A field of an HE MU PPDU *(continued)*

	B12	STBC	1	In an HE MU PPDU where each RU includes no more than 1 user, set to 1 to indicate all RUs are STBC encoded in the payload, set to 0 to indicate all RUs are not STBC encoded in the payload. STBC is not applied in MU-MIMO RUs. STBC doesn't apply to HE-SIG-B.
	B13-B14	Pre-FEC Padding Factor	2	Indicates the pre-FEC padding factor value as defined in Table 28-39 (Pre-FEC Padding Factor subfield encoding).
	B15	PE Disambiguity	1	Indicate PE Disambiguity as defined in 28.3.12 (Packet extension).
	B16-B19	CRC	4	CRC for bits 0-41 of the HE-SIG-A field (see 28.3.10.7.3 (CRC computation)).
	B20-B25	Tail	6	Used to terminate the trellis of the convolutional decoder. Set to 0.
NOTE—Integer fields are transmitted in unsigned binary format, LSB first, where the LSB is in the lowest numbered bit position.				

When the Bandwidth field is set to 5 or 7, the HE-SIG-B field may indicate which 20 MHz sub-channel(s) in the preamble of secondary 40 MHz channel are punctured by its RU allocation signaling; when the Bandwidth field is set to 6 or 7, the HE-SIG-B field may indicate which 20 MHz sub-channel(s) in the preamble of secondary 80 MHz channel are punctured by its RU allocation signaling. See 28.3.10.8 (HE-SIG-B) for the RU allocation signaling.

It is optional for an HE STA to receive a preamble-punctured HE MU PPDU with the Bandwidth field in HE-SIG-A setting to a values 4 to 7. Whether or not an HE STA is capable of receiving preamble-punctured HE MU PPDU with the Bandwidth field of HE-SIG-A field setting to 4, 5, 6, 7 are indicated by the Preamble Puncturing Receive Capable subfield in the HE Capabilities field (see 9.4.2.218 (HE Capabilities element)).

The HE-SIG-A field for an HE trigger-based PPDU contains the fields listed in Table 28-18 (HE-SIG-A field of an HE trigger-based PPDU).

Table 28-18—HE-SIG-A field of an HE trigger-based PPDU

Two Parts of HE-SIG-A	Bit	Field	Number of bits	Description
HE-SIG-A1	B0	Format	1	Differentiate an HE SU PPDU from an HE trigger-based PPDU: Set to 0 for HE trigger-based PPDU Set to 1 for HE SU PPDU
	B1-B6	BSS Color	6	The BSS Color field is an identifier of the BSS

Table 28-18—HE-SIG-A field of an HE trigger-based PPDU *(continued)*

B7-B10	Spatial Reuse 1	4	If the Bandwidth field indicates 20 MHz, 40 MHz, or 80 MHz: Spatial Reuse field for the first 20 MHz subband (see NOTE 1) If the Bandwidth field indicates 160/80+80 MHz: Spatial Reuse field for first 40 MHz subband of the 160 MHz operating band. (see NOTE 1) Set to 0 (SR disallowed Entry) to disallow SRP-based spatial reuse (see 27.9 (Spatial reuse operation) and 27.11.6 (SPATIAL_REUSE)). Set to value 1 to 14 corresponding to SRP value (see Table 28-19 (Spatial Reuse subfield encoding)) for SRP-based SR operation. The value 15 is reserved.
B11-B14	Spatial Reuse 2	4	If the Bandwidth field indicates 20 MHz, 40 MHz, or 80 MHz: Spatial Reuse field for the second 20 MHz subband (see NOTE 1) When operating 20 MHz, this field is set to same value as Spatial Reuse 1 field. When operating 40 MHz in 2.4 GHz band, this field is set to same value as Spatial Reuse 1 field If the Bandwidth field indicates 160/80+80 MHz: Spatial Reuse field for second 40 MHz subband of the 160 MHz operating band. (see NOTE 1) Set to 0 (SR disallowed Entry) to disallow SRP-based spatial reuse (see 27.9 (Spatial reuse operation) and 27.11.6 (SPATIAL_REUSE)). Set to value 1 to 14 corresponding to SRP value (see Table 28-19 (Spatial Reuse subfield encoding)) for SRP-based SR operation. The value 15 is reserved.

Table 28-18—HE-SIG-A field of an HE trigger-based PPDU *(continued)*

B15-B18	Spatial Reuse 3	4	If the Bandwidth field indicates 20 MHz, 40 MHz or 80 MHz: Spatial Reuse field for the third 20 MHz subband (see NOTE 1) When operating in 20 MHz or 40 MHz, this field is set to same value as Spatial Reuse 1 field. If the Bandwidth field indicates 160/80+80 MHz: Spatial Reuse field for third 40 MHz subband of the 160 MHz operating band. (see NOTE 1) When operating in 80+80 MHz, this field is set to same value as Spatial Reuse 1 field. Set to 0 (SR disallowed Entry) to disallow SRP-based spatial reuse (see 27.9 (Spatial reuse operation) and 27.11.6 (SPATIAL_REUSE)). Set to value 1 to 14 corresponding to SRP value (see Table 28-19 (Spatial Reuse subfield encoding)) for SRP-based SR operation. The value 15 is reserved.
B19-B22	Spatial Reuse 4	4	If the Bandwidth field indicates 20 MHz, 40 MHz or 80 MHz: Spatial Reuse field for the fourth 20 MHz subband (see NOTE 1) When operating in 20 MHz, this field is set to same value as Spatial Reuse 1 field. When operating in 40 MHz, this field is set to same value as Spatial Reuse 2 field. If the Bandwidth field indicates 160/80+80 MHz: Spatial Reuse field for fourth 40 MHz subband of the 160 MHz operating band. (see NOTE 1) When operating in 80+80 MHz, this field is set to same value as Spatial Reuse 2 field Set to 0 (SR disallowed Entry) to disallow SRP-based spatial reuse (see 27.9 (Spatial reuse operation) and 27.11.6 (SPATIAL_REUSE)). Set to value 1 to 14 corresponding to SRP value (see Table 28-19 (Spatial Reuse subfield encoding)) for SRP-based SR operation. The value 15 is reserved.
B23	Reserved	1	Reserved and set to 1. NOTE—Unlike other Reserved fields in HE-SIG-A of the HE trigger-based PPDU, B23 does not have a corresponding bit in the Trigger frame.
B24-B25	Bandwidth	2	For HE trigger-based PPDU: Set to 0 for 20 MHz Set to 1 for 40 MHz Set to 2 for 80 MHz Set to 3 for 160 MHz and 80+80 MHz

Table 28-18—HE-SIG-A field of an HE trigger-based PPDU *(continued)*

HE-SIG-A2	B0-B6	TXOP Duration	7	Set to 127 to indicate no duration information. Set to value other than 127 to indicate duration information for NAV setting and protection of the TXOP. NOTE—The encoding of TXOP Duration field is the same as the TXOP_DURATION parameter in Table 28-1 (TXVECTOR and RXVECTOR parameters).
	B7-B15	Reserved	9	Reserved and set to value indicated in the Trigger frame
	B16-B19	CRC	4	CRC of bits 0-41 of the HE-SIG-A field. See 28.3.10.7.3 (CRC computation).
	B20-B25	Tail	6	Used to terminate the trellis of the convolutional decoder. Set to 0.

NOTE 1—The four Spatial Reuse fields, 1, 2, 3, and 4, are arranged in increasing order of frequency and correspond to:

— For 20 MHz one Spatial Reuse field corresponding to the entire 20 MHz (other 3 fields indicate identical values)

— For 40 MHz two Spatial Reuse fields for each 20 MHz sub-band (other 2 fields indicate identical values)

— For 80 MHz four Spatial Reuse fields for each 20 MHz sub-band

- For an OFDMA transmission of a given BW, each of the Spatial Reuse fields that corresponds to a 20 MHz sub-band is also applicable to the 242-tone RU which is most closely aligned in frequency (in the tone-plan of that BW) with the aforementioned 20 MHz sub-band. The correspondence from an Spatial Reuse field to a 242-tone RU also holds for any RU within the 242-tone RU. The above also implies that a 20 MHz OBSS STA uses the Spatial Reuse field corresponding to its 20 MHz channel, a 40 MHz OBSS STA located on the lower frequency half of the 80 MHz BSS uses Spatial Reuse 1 field, Spatial Reuse 2 field values and a 40 MHz OBSS STA located on the upper frequency half of the 80 MHz BSS uses Spatial Reuse 3 field, Spatial Reuse 4 field values

— For 160 MHz and 80+80 MHz four Spatial Reuse fields for each 40 MHz sub-band

- For an OFDMA transmission of a given BW, each of the Spatial Reuse fields that corresponds to a 40 MHz sub-band is also applicable to the 484-tone RU which is most closely aligned in frequency (in the tone-plan of that BW) with the aforementioned 40 MHz sub-band. The correspondence from an Spatial Reuse field to a 484-tone RU also holds for any RU within the 484-tone RU.

NOTE 2—Integer fields are transmitted in unsigned binary format, LSB first, where the LSB is in the lowest numbered bit position.

Table 28-19 (Spatial Reuse subfield encoding) defines the encoding for the Spatial Reuse 1, Spatial Reuse 2, Spatial Reuse 3 and Spatial Reuse 4 subfields.

Table 28-19—Spatial Reuse subfield encoding

Value	Meaning
0	SR disallow
1	SRP = –80 dBm
2	SRP = –74 dBm
3	SRP = –68 dBm

Table 28-19—Spatial Reuse subfield encoding *(continued)*

Value	Meaning
4	SRP = –62 dBm
5	SRP = –56 dBm
6	SRP = –50 dBm
7	SRP = –47 dBm
8	SRP = –44 dBm
9	SRP = –41 dBm
10	SRP = –38 dBm
11	SRP = –35 dBm
12	SRP = –32 dBm
13	SRP = –29 dBm
14	SRP = –26 dBm
15	Reserved

SRP = TX PWR_{AP} + Acceptable Receiver Interference $level_{AP}$

Adjustment range for parameters (referenced to the antenna connector and normalized to 20 MHz bandwidth):

— TX $PWR_{AP} \geq -10$ dBm

— Acceptable Receiver Interference $Level_{AP}$: –82dBm to –36 dBm

If SRP is below < –80 dBm, set Spatial Reuse to 1, if SRP is above –26 dBm, set Spatial Reuse to 14. Same table is used for AP and STA.

28.3.10.7.3 CRC computation

The CRC computation defined in this subclause applies to HE-SIG-A, the Common field of HE-SIG-B and the User Specific field of HE-SIG-B.

The CRC is calculated over bits 0 to 41 of the HE-SIG-A field and over bits 0 to L of the HE-SIG-B field ($L = x$ for each HE-SIG-B common block field where $x = N \times 8$ when the Center 26-tone RU subfield is present, and $x = N \times 8 - 1$ otherwise, and $L = 20$ for the HE-SIG-B user specific fields). Refer to Table 28-20 (Common Block field) for N and the conditions under which the Center 26-tone RU subfield is present.

The value of the CRC field shall be the 1s complement of

$$crc(D) = (M(D) + I(D))D^8 mod\ G(D)$$

where

$$M(D) = \sum_{i=0}^{L} m_{L-i} D^i$$

where

$$I(D) = \sum_{i = L-7}^{L} D^i$$

$G(D)$ is defined in Equation (19-18)

The CRC field is transmitted from *c4* to *c7* with *c7* first.

Figure 19-8 (HT-SIG CRC calculation) shows the operation of the CRC, where the serial input are from m_L to m_0, and the output is stopped at *c4*.

28.3.10.7.4 Encoding and modulation

For an HE SU PPDU, HE MU PPDU and HE trigger-based PPDU, the HE-SIG-A field is composed of two parts, HE-SIG-A1 and HE-SIG-A2, each containing 26 data bits. HE-SIG-A1 is transmitted before HE-SIG-A2. The HE-SIG-A symbols shall be BCC encoded at rate, R = 1/2, interleaved, mapped to a BPSK constellation, and have pilots inserted following the steps described in 17.3.5.6 (Convolutional encoder), 28.3.11.8 (BCC interleavers), 17.3.5.8 (Subcarrier modulation mapping), and 17.3.5.9 (Pilot subcarriers), respectively. The constellation mappings of HE-SIG-A in HE SU PPDU, HE MU PPDU and HE trigger-based PPDU are shown in Figure 28-19 (Data tone constellation of HE-SIG-A symbols). The first and second half of the stream of 104 complex numbers generated by these steps (before pilot insertion) is divided into two groups of 52 complex numbers, where respectively, the first 52 complex numbers form the first symbol of HE-SIG-A and the second 52 complex numbers form the second symbol of HE-SIG-A. If the TXVECTOR parameter BEAM_CHANGE is 1, the time domain waveform for the HE-SIG-A field of an HE SU PPDU, HE MU PPDU and HE trigger-based PPDU shall be as specified in Equation (28-16).

$$r_{\text{HE-SIG-A}}^{(i_{Seg} i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{\text{HE-SIG-A}}^{\text{Tone}}}} \sum_{n=0}^{1} w_{T_{SYML}}(t - nT_{SYML}) \sum_{i_{BW} \in \Omega_{20\text{MHz}}} \sum_{k=-28}^{28} \begin{pmatrix} \Upsilon_{(k - K_{\text{Shift}}(i_{BW})), \text{BW}}(D_{k,n,20} + p_{n+2}P_k) \\ \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F,\text{ Pre-HE}}(t - nT_{SYML} - T_{GI,\text{ LegacyPreamble}} - T_{CS}^{i_{TX}})) \end{pmatrix} \tag{28-16}$$

$N_{20\text{MHz}}$ is defined in 21.3.7.3 (Channel frequencies)

$$K_{\text{Shift}}(i) = (N_{20\text{MHz}} - 1 - 2i) \cdot 32$$

$$D_{k,n,20} = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ d_{M_{20}^r(k), n}, \text{ otherwise} \end{cases}$$

$$M_{20}^r(k) = \begin{cases} k + 28, -28 \le k \le -22 \\ k + 27, -20 \le k \le -8 \\ k + 26, -6 \le k \le -1 \\ k + 25, 1 \le k \le 6 \\ k + 24, 8 \le k \le 20 \\ k + 23, 22 \le k \le 28 \end{cases}$$

P_k and p_n are defined in 17.3.5.10 (OFDM modulation)

$N_{\text{HE-SIG-A}}^{\text{Tone}}$ is defined in Table 28-14 (Tone scaling factor and guard interval duration values for HE PPDU fields)

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain i_{TX} with a value given in 28.3.10.2.1 (Cyclic shift for pre-HE modulated fields).

If the TXVECTOR parameter BEAM_CHANGE is 0, the time domain waveform of the HE-SIG-A field shall be as given by Equation (28-17).

$$r_{\text{HE-SIG-A}}^{(i_{Seg} i_{TX})}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{\text{HE-SIG-A}}^{\text{Tone}}}} \sum_{n=0}^{1} w_{T_{SYML}}(t - nT_{SYML}) \sum_{i_{BW}=0}^{N_{20\text{MHz}}-1} \sum_{k=-28}^{28} \sum_{m=1}^{N_{STS}} \left(\left[Q_{4(k - K_{\text{Shift}}(i_{BW}))}^{(i_{Seg})} \right]_{i_{TX}, m} \left[A_{\text{HE-LTF}}^{4(k - K_{\text{Shift}}(i_{BW}))} \right]_{m,1} (D_{k,n,20} + p_{n+2} P_k) \cdot \exp(j 2\pi (k - K_{\text{Shift}}(i_{\text{BW}})) \Delta_{F,\text{ Pre-HE}} (t - nT_{SYML} - T_{\text{GI, LegacyPreamble}} - T_{CS,HE}(m))) \right) \quad (28\text{-}17)$$

where

$T_{CS,\text{ HE}}(m)$ represents the cyclic shift for space time stream m as defined in 28.3.10.2.2 (Cyclic shift for HE modulated fields)

$Q_k^{(i_{Seg})}$ is defined in 28.3.9 (Mathematical description of signals)

$A_{\text{HE-LTF}}^{k}$ is defined in Equation (28-55)

For an HE extended range SU PPDU, the HE-SIG-A field is composed of four parts, i.e. HE-SIG-A1, HE-SIG-A2, HE-SIG-A3 and HE-SIG-A4, each part containing 26 data bits. These four parts are transmitted sequentially from HE-SIG-A1 to HE-SIG-A4. HE-SIG-A1 and HE-SIG-A2 have the same data bits. HE-SIG-A3 and HE-SIG-A4 have same data bits. The data bits of HE-SIG-A1 and HE-SIG-A3 shall be BCC encoded at rate, $R = 1/2$, interleaved, mapped to a BPSK constellation, and have pilots inserted. HE-SIG-A2 shall be BCC encoded at rate, $R = 1/2$, mapped to a QBPSK constellation without interleaving and have pilots inserted. The constellation mappings of the HE-SIG-A field in an HE extended range SU PPDU is shown in Figure 28-19 (Data tone constellation of HE-SIG-A symbols). The QBPSK constellation on HE-SIG-A2 is used to differentiate between an HE extended range SU PPDU and an HE MU PPDU when $m = 1$ in Equation (28-11), which indicates HE MU PPDU or HE extended range SU PPDU. HE-SIG-A4 shall be BCC encoded at rate, $R = 1/2$, mapped to a BPSK constellation without interleaving and have pilots inserted. BCC encoding, Data interleaving, constellation mapping and pilot insertion follow the steps described in 17.3.5.6 (Convolutional encoder), 28.3.11.8 (BCC interleavers), 17.3.5.8 (Subcarrier modulation mapping), and 17.3.5.9 (Pilot subcarriers), respectively.

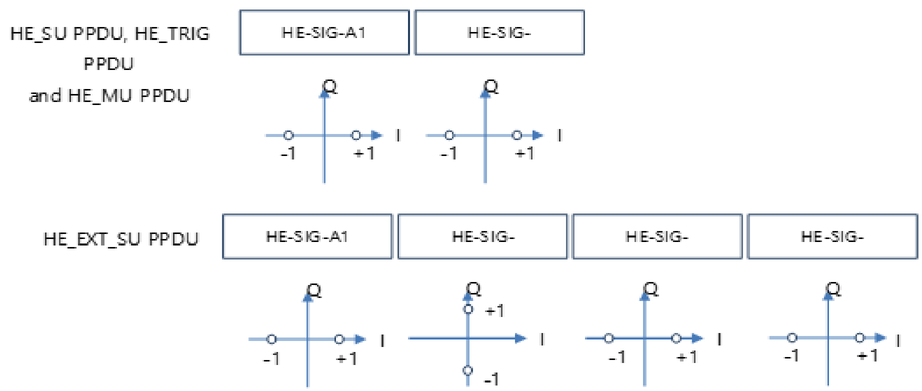


Figure 28-19—Data tone constellation of HE-SIG-A symbols

If the TXVECTOR parameter BEAM_CHANGE is 1, the time domain waveform for the HE-SIG-A field in an HE extended range SU PPDU, shall be as specified in Equation (28-18).

$$r_{\text{HE-SIG-A}}^{(i_{Seg} i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{\text{HE-SIG-A}}^{\text{Tone}}}} \sum_{n=0}^{3} w_{T_{\text{SYML}}}(t - nT_{SYML}) \sum_{i_{BW}=0}^{N_{\text{20MHz}}-1} \sum_{k=-28}^{28} \left(\begin{array}{l} \Upsilon_{(k-K_{\text{Shift}}(i_{BW})),\,\text{BW}}(R_n D_{k,n,20} + p_{n+2} P_k) \\ \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F,\,\text{Pre-HE}}(t - nT_{SYML} - T_{GI,\,\text{LegacyPreamble}} - T_{CS}^{i_{TX}})) \end{array} \right) \tag{28-18}$$

where

R_n is a phase rotation vector defined as $[1, j, 1, 1]$

If the TXVECTOR parameter BEAM_CHANGE is 0, the time domain waveform for the HE-SIG-A field in an HE extended range SU PPDU, shall be as specified in Equation (28-19).

$$r_{\text{HE-SIG-A}}^{(i_{Seg} i_{TX})}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{\text{HE-SIG-A}}^{\text{Tone}}}} \sum_{n=0}^{3} w_{T_{SYML}}(t - nT_{SYML}) \sum_{i_{BW}=0}^{N_{\text{20MHz}}-1} \sum_{k=-28}^{28} \sum_{m=1}^{N_{STS}} \left(\begin{array}{l} \left[Q_{4(k-K_{\text{Shift}}(i_{BW}))}^{(i_{Seg})}\right]_{i_{TX},\,m} \left[A_{\text{HE-LTF}}^{4(k-K_{\text{Shift}}(i_{BW}))}\right]_{m,\,1} (R_n D_{k,n,20} + p_{n+2} P_k) \\ \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F,\,\text{Pre-HE}}(t - nT_{SYML} - T_{\text{GI, LegacyPreamble}} - T_{CS,\,HE}(m))) \end{array} \right) \tag{28-19}$$

28.3.10.8 HE-SIG-B

28.3.10.8.1 Encoding and modulation

The HE-SIG-B field is separately encoded on each 20 MHz band. The encoding structure in one such 20 MHz band is shown in Figure 28-20 (HE-SIG-B field encoding structure in each 20 MHz). It consists of a

Common Block field followed by a User Specific field which together are referred to as the HE-SIG-B content channel.

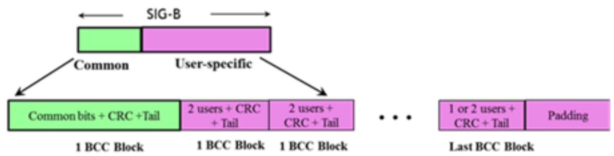


Figure 28-20—HE-SIG-B field encoding structure in each 20 MHz

The Common Block field of an HE-SIG-B content channel contains information regarding the resource unit allocation such as the RU assignment in frequency domain, the RUs allocated for MU-MIMO and the number of users in MU-MIMO allocations. The Common Block field is described in detail in 28.3.10.8.4 (HE-SIG-B common content).

The User Specific field of an HE-SIG-B content channel consists of one or more User Block fields. Each User Block field is made up of two user fields that contain information for two STAs to decode their payloads. The last User Block field may contain information for one or two STAs depending on the number of users indicated by the RU allocation signaling and the signaling of the center 26-tone RU. See 28.3.10.8.5 (HE-SIG-B per-user content) for a description of the contents of the User Block field.

When the SIGB Compression field in the HE-SIG-A field of an HE MU PPDU is set to 1 (indicating full bandwidth MU-MIMO transmission), the Common Block field is not present and the content channel consists of only the User Specific field.

28.3.10.8.2 Frequency domain mapping

The 20 MHz PPDU contains one content channel in which the Common Block field and User Specific field are carried as shown in Figure 28-21 (HE-SIG-B content channel for a 20 MHz PPDU). The Common Block field contains the RU allocation signaling for RUs that occur within the 242-tone RU boundary.

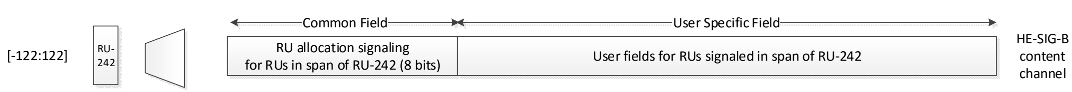


Figure 28-21—HE-SIG-B content channel for a 20 MHz PPDU

The 40 MHz PPDU contains two content channels, each occupying a 20 MHz segment. Each content channel contains a Common Block field followed by User Specific field as shown in Figure 28-22 (HE-SIG-B content channel for a 40 MHz PPDU). The content channels are ordered in increasing order of the absolute frequency i.e., the first content channel carries Common Block field and User Specific field corresponding to RUs whose subcarrier indices fall between [–244: –3] and the second content channel carries Common Block field and User Specific field corresponding to RUs whose subcarrier indices fall between [3:244]. If a 484-tone RU is signaled, both content channels will carry Common Block field and User Specific field corresponding to the 484-subcarrier RU.

Figure 28-22—HE-SIG-B content channel for a 40 MHz PPDU

The 80 MHz PPDU contains two content channels each of which are duplicated once as shown in Figure 28-23 (Default mapping of the two HE-SIG-B channels and their duplication in an 80 MHz PPDU). The arrangement of the content channels are in increasing order of the absolute frequency where HE-SIG-B content channel 1 occupies the tones in the 20 MHz segment with the lowest subcarrier indices followed by the HE-SIG-B content channel 2 in the adjacent 20 MHz segment. This structure of the first content channel occupying the lower subcarrier index followed by the second content channel is repeated with content duplication in the remaining two 20 MHz segments, respectively. The first content channel appearing in the 20 MHz segments carries a Common Block field and User Specific field corresponding to RUs whose subcarriers indices overlap those segments. The Common Block field of content channel 1 contains the following: an RU allocation signaling field for RUs with subcarrier indices in the range [–500:–259], followed by a second RU allocation signaling field for RUs with subcarrier indices between [17:258] and 1 bit to indicate the presence of the user field corresponding to the center 26-tone RU that spans subcarriers [–16:–4, 4:16]. The second content channel carries a Common Block field and User Specific field corresponding to RUs whose subcarrier indices fall in those segments. The Common Block field of content channel 2 contains the following: an RU allocation signaling field for RUs whose subcarrier indices fall in the range [–258:–17], followed by a second RU allocation signaling field for RUs with subcarrier indices between [259:500] and 1 bit to indicate presence of the user field corresponding to the center 26-tone RU that spans subcarriers [–16:–4, 4:16]. The same value for the bit signaling presence of the center 26-tone RU is carried in both content channels. The user fields in the User Specific field that follow the common field are arranged in the same order as the RU allocation signaling. When assigned, the user field corresponding to the center 26-tone RU that spans subcarriers [–16:–4, 4:16] is carried as the last user field in the HE-SIG-B content channel 1. When RUs greater than 242 subcarriers are signaled in the RU allocation signaling in a portion of the bandwidth, the signaling is carried in both content channels placed in the order of the absolute subcarrier index.

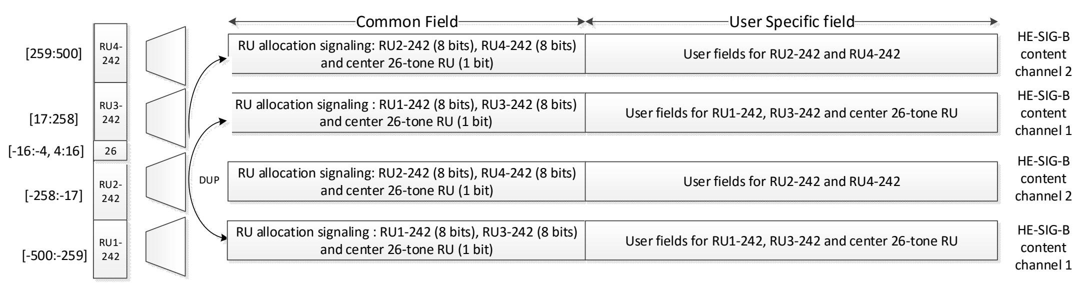


Figure 28-23—Default mapping of the two HE-SIG-B channels and their duplication in an 80 MHz PPDU

The 160 MHz PPDU contains two content channels each of which are duplicated four times as shown in Figure 28-24 (Default mapping of the two HE-SIG-B channels and their duplication in a 160 MHz PPDU). The arrangement of the content channels are in increasing order of the absolute frequency. The first content channel occupies the tones in the 20 MHz segment with the lowest subcarrier indices and the second content channel in the adjacent 20 MHz segment. This pattern of arranging HE-SIG-B content channel 1 and HE-SIG-B content channel 2 is duplicated over the other segments. The HE-SIG-B content channel 1 and HE-SIG-B content channel 2 carries RU allocation signaling at 242-tone RU granularity that overlap with the 20 MHz segments in which the content channels are carried (including duplication). The signaling for the presence of the User field corresponding to a center 26-tone RU in the 80 MHz segment with the lower subcarrier index is carried in HE-SIG-B content channel 1 as a 1-bit Center 26-tone RU field after the RU Allocation field in the Common field. Similarly, signaling for the center 26-tone RU in the 80 MHz segment with the higher subcarrier index is carried in HE-SIG-B content channel 2 as 1-bit Center 26-tone RU field after the RU Allocation field in the Common field. When assigned, the User field corresponding to the center 26-tone RU in the 80 MHz segments is carried as the last user field in their respective content channels. When RUs greater than 242 subcarriers are signaled in the RU Allocation field in a portion of the bandwidth, the signaling is carried in both content channels placed in the order of the absolute subcarrier index.

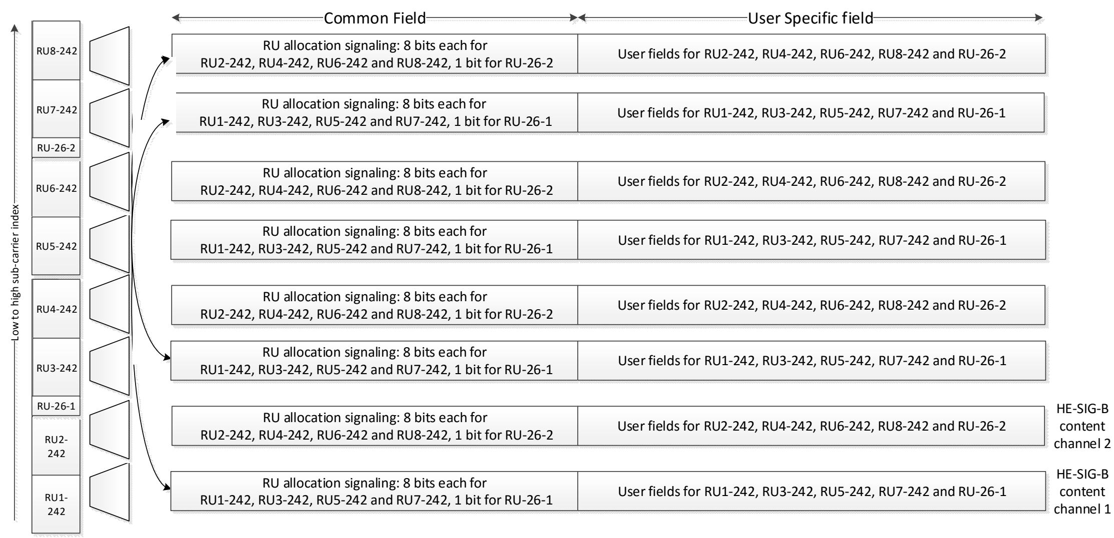


Figure 28-24—Default mapping of the two HE-SIG-B channels and their duplication in a 160 MHz PPDU

When the SIGB Compression field in the HE-SIG-A field of an HE MU PPDU is set to 0, for an MU-MIMO allocation of RU size greater than 242 subcarriers, the User fields are dynamically split between HE-SIG-B content channel 1 and HE-SIG-B content channel 2 and the split is decided by the AP (on a per case basis). See 28.3.10.8.4 (HE-SIG-B common content) and 28.3.10.8.5 (HE-SIG-B per-user content) for more details.

When preamble puncturing is present as indicated by values 4 to 7 in the Bandwidth field of HE-SIG-A field of an HE MU PPDU (see Table 28-17 (HE-SIG-A field of an HE MU PPDU)), the frequency domain structure of HE-SIG-B is the same as defined for the full bandwidth, i.e. the HE-SIG-B field frequency domain structure is solely dependent on the total bandwidth.

28.3.10.8.3 Time domain encoding

In each 20 MHz band, the bits in the Common Block field shall have CRC and tail bits added and then be BCC encoded at rate R = ½. The CRC bits are computed as described in 28.3.10.7.3 (CRC computation). Padding bits are not added after the common block.

In the User Specific field, in any 20 MHz band, the bits corresponding to two STAs (i.e. two User fields) are encoded together. Specifically, the STAs scheduled in the HE MU PPDU are split into groups of two. Each group of two User fields shall have CRC and tail bits added. If the number of User fields in the content channel is odd, CRC and tail bits are added after the last User field, which is not grouped. Padding bits are appended right after the tail bits corresponding to the last User Block field in each content channel to round up to the next multiple of number of data bits per HE-SIG-B symbol, as described in 17.3.5.4 (Pad bits (PAD)). Further padding bits are appended to each content channel so that the number of OFDM symbols after encoding and modulation in the content channel equals the Number Of HE-SIG-B Symbols Or MU-MIMO Users field in the HE-SIG-A field for an HE MU PPDU. Thus, padding ensures that the content channels in different 20 MHz bands end at the same OFDM symbol. For both the Common Block and User Specific fields, the information bits, tail bits and padding bits (if present) are BCC encoded at rate R = ½ using the encoder described in 17.3.5.6 (Convolutional encoder). When the code rate of the HE-SIG-B MCS is not equal to ½, the convolutional encoder output bits for each field are concatenated, then the concatenated bit streams are punctured as described in 17.3.5.6 (Convolutional encoder).

The coded bits are interleaved as in 28.3.11.8 (BCC interleavers). The interleaved bits are mapped to constellation points from the MCS specified in HE-SIG-A and have pilots inserted following the steps described in 17.3.5.8 (Subcarrier modulation mapping) and 17.3.5.9 (Pilot subcarriers), respectively.Each HE-SIG-B symbol shall have 52 data tones.

The guard interval used for HE-SIG-B shall be 0.8 μs.

The number of OFDM symbols in the HE-SIG-B field, denoted by $N_{SYM,\text{HE-SIG-B}}$, shall be signaled by the Number Of HE-SIG-B Symbols Or MU-MIMO Users field in the HE-SIG-A field of an HE MU PPDU (see 28.3.10.7.2 (Content)).

For the c-th content channel (c = 1 or 2), denote the sample on the k-th data subcarrier of the n-th symbol by $d_{k,n,c}$. The time domain waveform for the HE-SIG-B follows Equation (28-20).

$$r_{\text{HE-SIG-B}}^{(i_{Seg} i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{\text{HE-SIG-B}}^{\text{Tone}}}} \sum_{n=0}^{N_{SYM,\text{HE-SIG\_B}}} w_{T_{\text{HE-SIG-B}}}(t - nT_{SYML}) \sum_{i_{BW} \in \Omega_{20\text{MHz}}} \sum_{k=-N_{SR}}^{N_{SR}} \left(\begin{array}{l} \Upsilon_{(k - K_{\text{Shift}}(i_{BW})),\,\text{BW}} \Gamma_{M_{20}^r(k)} (D_{k,n,i_{BW}}^{i_{Seg}} + p_{n+4} P_k) \\ \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F,\,\text{Pre-HE}}(t - nT_{SYML} - T_{GI,\,\text{LegacyPreamble}} - T_{CS}^{i_{TX}})) \end{array} \right) \quad (28\text{-}20)$$

where

$\Gamma_{M_{20}^r(k)}$ is the phase rotation value for HE-SIG-B field PAPR reduction. When the HE-SIG-B field is modulated with MCS=0 and DCM=1, $\Gamma_{M_{20}^r(k)} = 1$. For all other modulation schemes of HE-SIG-B field,

$$\Gamma_{M_{20}^r(k)} = \begin{cases} 1 & 0 \le M_{20}^r(k) < 26 \\ (-1)^{M_{20}^r(k)} & 26 \le M_{20}^r(k) < 52 \end{cases}$$

$N_{20\text{MHz}}$ and $K_{\text{Shift}}(i)$ are defined in 21.3.8.2.4 (L-SIG definition)

$$D_{k,n,i_{BW}}^{i_{Seg}} = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ d_{M_{20}^r(k),\, n,\, (i_{BW} mod\ 2) + 1}, \text{ otherwise} \end{cases}$$

$$M^r_{20}(k) = \begin{cases} k+28, & -28 \le k \le -22 \\ k+27, & -20 \le k \le -8 \\ k+26, & -6 \le k \le -1 \\ k+25, & 1 \le k \le 6 \\ k+24, & 8 \le k \le 20 \\ k+23, & 22 \le k \le 28 \end{cases}$$

P_k and p_n are defined in 17.3.5.10 (OFDM modulation)

$N_{SYM,\text{HE-SIG-B}}$ his the number of OFDM symbols in the HE-SIG-B field

28.3.10.8.4 HE-SIG-B common content

The Common Block field in the HE-SIG-B field carries the RU allocation subfields. Depending on the PPDU bandwidth, the Common Block field can contain multiple RU Allocation subfields. The format of the Common Block field is defined in Table 28-20 (Common Block field).

Table 28-20—Common Block field

Subfield	Number of bits	Description
RU Allocation	N x 8	Indicates the RU assignment in the frequency domain. It also indicates the number of user fields in each RU. For RUs of size greater than or equal to 106-tones that support MU-MIMO, it indicates the number of users multiplexed using MU-MIMO. N = 1 for a 20 MHz and a 40 MHz HE MU PPDU N = 2 for an 80 MHz HE MU PPDU N = 4 for a 160 MHz or 80+80 MHz HE MU PPDU
Center 26-tone RU	1	This field is present only for full bandwidth 80 MHz, 160 MHz and 80+80 MHz. For full bandwidth 80 MHz: Set to 1 to indicate that the center 26-tone RU is allocated in the Common Block fields of both HE-SIG-B content channels with the same value. Set to 0, otherwise. For full bandwidth 160 MHz or 80+80 MHz: Set to 1 to indicate that the center 26-tone RU is allocated for one individual 80 MHz in the Common Block fields of both HE-SIG-B content channels. Set to 0, otherwise.
CRC	4	See 28.3.10.7.3 (CRC computation)
Tail	6	Used to terminate the trellis of the convolutional decoder. Set to 0
NOTE—Integer fields are transmitted in unsigned binary format, LSB first, where the LSB is in the lowest numbered bit position.		

An RU Allocation subfield in the Common Block field of HE-SIG-B consists of 8 bits that indicates the following for a 20 MHz PPDU BW:

- The RU assignment in the frequency domain: indexes the size of the RUs and their placement in the frequency domain.
- The number of user fields in a 20 MHz BW within the HE-SIG-B content channel: the number of users multiplexed in the RUs indicated by the arrangement; for RUs of size greater than or equal to 106 tones that support MU-MIMO, it indicates the number of users multiplexed using MU-MIMO.

The mapping of the 8-bit RU Allocation subfield to the RU assignment and the number of user fields per RU is defined in the Table 28-21 (RU allocation signaling: arrangement and number of MU-MIMO allocations). In the table, the number of entries column refers to the number of 8-bit indices that refer to the same RU assignment in the frequency domain but differ in the number of users fields per RU. The RU assignment and the number of user fields per RU together indicate the number of user-fields in the User specific field of HE-SIG-B. Signaling for the center 26-tone RU in BW ≥ 80 MHz follows the RU Allocation subfields. For full BW 80 MHz, 1 bit is added to indicate if center 26-tone RU is allocated in the Common Block fields of both HE-SIG-B content channels with same value. For full BW 160 MHz, 1 bit is added to indicate if center 26-tone RU is allocated for one individual 80 MHz in common block fields of both HE-SIG-B content channels.

Table 28-21—RU allocation signaling: arrangement and number of MU-MIMO allocations

<table>
<tr><th>8 bits indices (B7 B6 B5 B4 B3 B2 B1 B0)</th><th>#1</th><th>#2</th><th>#3</th><th>#4</th><th>#5</th><th>#6</th><th>#7</th><th>#8</th><th>#9</th><th>Number of entries</th></tr>
<tr><td>00000000</td><td>26</td><td>26</td><td>26</td><td>26</td><td>26</td><td>26</td><td>26</td><td>26</td><td>26</td><td>1</td></tr>
<tr><td>00000001</td><td>26</td><td>26</td><td>26</td><td>26</td><td>26</td><td>26</td><td>26</td><td colspan="2">52</td><td>1</td></tr>
<tr><td>00000010</td><td>26</td><td>26</td><td>26</td><td>26</td><td>26</td><td colspan="2">52</td><td>26</td><td>26</td><td>1</td></tr>
<tr><td>00000011</td><td>26</td><td>26</td><td>26</td><td>26</td><td>26</td><td colspan="2">52</td><td colspan="2">52</td><td>1</td></tr>
<tr><td>00000100</td><td>26</td><td>26</td><td colspan="2">52</td><td>26</td><td>26</td><td>26</td><td>26</td><td>26</td><td>1</td></tr>
<tr><td>00000101</td><td>26</td><td>26</td><td colspan="2">52</td><td>26</td><td>26</td><td>26</td><td colspan="2">52</td><td>1</td></tr>
<tr><td>00000110</td><td>26</td><td>26</td><td colspan="2">52</td><td>26</td><td colspan="2">52</td><td>26</td><td>26</td><td>1</td></tr>
<tr><td>00000111</td><td>26</td><td>26</td><td colspan="2">52</td><td>26</td><td colspan="2">52</td><td colspan="2">52</td><td>1</td></tr>
<tr><td>00001000</td><td colspan="2">52</td><td>26</td><td>26</td><td>26</td><td>26</td><td>26</td><td>26</td><td>26</td><td>1</td></tr>
<tr><td>00001001</td><td colspan="2">52</td><td>26</td><td>26</td><td>26</td><td>26</td><td>26</td><td colspan="2">52</td><td>1</td></tr>
<tr><td>00001010</td><td colspan="2">52</td><td>26</td><td>26</td><td>26</td><td colspan="2">52</td><td>26</td><td>26</td><td>1</td></tr>
<tr><td>00001011</td><td colspan="2">52</td><td>26</td><td>26</td><td>26</td><td colspan="2">52</td><td colspan="2">52</td><td>1</td></tr>
<tr><td>00001100</td><td colspan="2">52</td><td colspan="2">52</td><td>26</td><td>26</td><td>26</td><td>26</td><td>26</td><td>1</td></tr>
<tr><td>00001101</td><td colspan="2">52</td><td colspan="2">52</td><td>26</td><td>26</td><td>26</td><td colspan="2">52</td><td>1</td></tr>
<tr><td>00001110</td><td colspan="2">52</td><td colspan="2">52</td><td>26</td><td colspan="2">52</td><td>26</td><td>26</td><td>1</td></tr>
<tr><td>00001111</td><td colspan="2">52</td><td colspan="2">52</td><td>26</td><td colspan="2">52</td><td colspan="2">52</td><td>1</td></tr>
</table>

Table 28-21—RU allocation signaling: arrangement and number of MU-MIMO allocations

$00010y_2y_1y_0$	52		52		-	106				8
$00011y_2y_1y_0$	106				-	52		52		8
$00100y_2y_1y_0$	26	26	26	26	26	106				8
$00101y_2y_1y_0$	26	26	52		26	106				8
$00110y_2y_1y_0$	52		26	26	26	106				8
$00111y_2y_1y_0$	52		52		26	106				8
$01000y_2y_1y_0$	106				26	26	26	26	26	8
$01001y_2y_1y_0$	106				26	26	26	52		8
$01010y_2y_1y_0$	106				26	52		26	26	8
$01011y_2y_1y_0$	106				26	52		52		8
$0110y_1y_0z_1z_0$	106				-	106				16
01110000	52		52		-	52		52		1
01110001	242-tone RU empty									1
01110010	484-tone RU with zero HE-SIG-B User Specific field in the corresponding HE-SIG-B Content Channel									1
01110011	996-tone RU with zero HE-SIG-B User Specific field in the corresponding HE-SIG-B Content Channel									1
$011101x_1x_0$	Reserved									4
$011111x_1x_0$	Reserved									8
$10y_2y_1y_0z_2z_1z_0$	106				26	106				64
$11000y_2y_1y_0$	242									8
$11001y_2y_1y_0$	484									8
$11010y_2y_1y_0$	996									8

Table 28-21—RU allocation signaling: arrangement and number of MU-MIMO allocations

$11011y_2y_1y_0$	2×996	8
$111x_4x_3x_2x_1x_0$	Reserved	32
$y_2y_1y_0$ = 000-111 indicates number of STAs multiplexed in the only 106-tone RU or the left 106-tone RU if there are two 106-tone RUs. The binary vector $y_2y_1y_0$ is indexed as [y[3]y[2]y[1]] indicates $2^2 \times y[3] + 2^1 \times y[2] + y[1] + 1$ STAs multiplexed in the RU. $z_2z_1z_0$ = 000-111 indicates number of STAs multiplexed in the right 106-tone RU if there are two 106-tone RUs. The binary vector $z_2z_1z_0$ is indexed as [z[3]z[2]z[1]] indicates $2^2 \times z[3] + 2^1 \times z[2] + z[1] + 1$ STAs multiplexed in the RU. Similarly, y_1y_0 = 00-11 indicates number of STAs multiplexed in the left 106-tone RU. The binary vector y_1y_0 is indexed as [y[2]y[1]] indicates $2^1 \times y[2] + y[1] + 1$ STAs multiplexed in the RU. Similarly, z_1z_0 = 00-11 indicates the number of STAs multiplexed in the right 106-tone RU. The binary vector z_1z_0 is indexed as [z[2]z[1]] indicates $2^1 \times z[2] + z[1] + 1$ STAs multiplexed in the RU. #1 to #9 (from left to the right) is ordered in increasing order of the absolute frequency. x_1x_0 = 00-11, $x_4x_3x_2x_1x_0$ = 00000-11111. '-' means no STA in that RU.		

The number of RU Allocation subfields in the Common Block field depends on the PPDU bandwidth

- In the default mode when the SIGB Compression field in the HE-SIG-A field of an HE MU PPDU is set to 0, for a 20 MHz and a 40 MHz PPDU, each HE-SIG-B content channel contains one RU Allocation field in the Common field followed by multiple User fields. The position of the User field in the User Specific field together with the 8-bit RU Allocation field indicates the RU assignment to the user.
- In the default mode for an 80 MHz PPDU, each HE-SIG-B content channel contains two RU Allocation subfields for a total of 16 bits of RU allocation signaling, one each for the RUs in the two 20 MHz segments of the HE-SIG-B content channel. The position of the User field in the User Specific field together with the 8-bit RU Allocation field indicates the RU assignment to the user. The User fields corresponding to the first RU Allocation field are followed by the User fields indicated by the second RU Allocation field in the User Specific field.
- In the default mode for a 160 MHz PPDU, each HE-SIG-B content channel contains four RU Allocation subfields for a total of 32 bits of RU allocation signaling, one each for the RUs in the four 20 MHz segments of the HE-SIG-B content channel. The position of the User field in the Use Specific field together with the 8-bit RU Allocation field indicates the RU assignment to the user. The User fields for each of the 20 MHz segments in the content channel are arranged by the order in which their RU Allocation fields appear in the Common field.

28.3.10.8.5 HE-SIG-B per-user content

The User Specific field consists of multiple User fields. The User fields follow the Common field of HE-SIG-B. The RU Allocation field in the Common field and the position of the User field in the HE-SIG-B User Specific field together identify the RU used to transmit a STA's data. Multiple RU allocations addressed to a single STA shall not be allowed in 802.11ax. Therefore, the signaling that enables STAs to decode its data is carried in only one user field. An example for the mapping of the 8-bit RU allocation subfield and the position of the user field to an STA's data is illustrated in Figure 28-25 (Illustration for the mapping of the 8-bit RU allocation subfield and the position of the User field to the STA's assignment). The

RU allocation signaling indicates an arrangement of 106-tone RU followed by five 26-tone RUs and that the 106-tone RU contains three user-fields, i.e., the 106-tone RU supports multiplexing of three users using MU-MIMO. The eight user fields in the HE-SIG-B user-specific field thus map to the 6 RUs, with the first three user fields indicating MU-MIMO allocations in the first 106-tone RU followed by user fields corresponding to the each of the five 26-tone RUs.

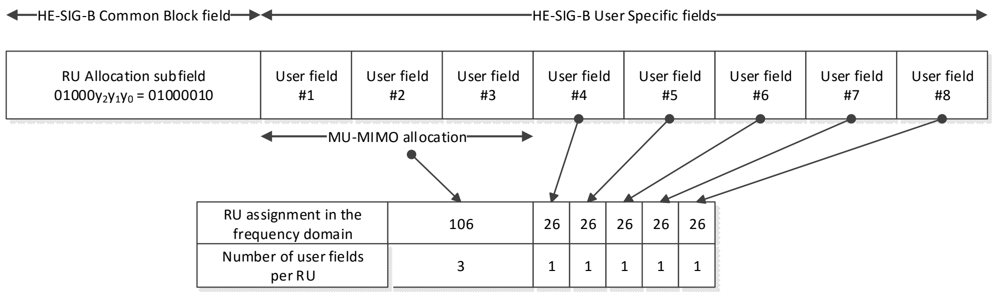


Figure 28-25—Illustration for the mapping of the 8-bit RU allocation subfield and the position of the User field to the STA's assignment

The contents of the User field differ based on whether the field addresses a single STA in an RU or a STA in an MU-MIMO allocation in an RU. Irrespective of whether the allocation is for a STA in an SU or an MU-MIMO allocation, the size of the user field is the same.

The HE-SIG-B user field for an SU allocation contain the subfields shown in Table 28-22 (Fields of the HE-SIG-B user field for an non-MU-MIMO allocation).

Table 28-22—Fields of the HE-SIG-B user field for an non-MU-MIMO allocation

Bit	Field	Number of bits	Description
B0-B10	STA-ID	11	The STA-ID refers to the AID described in 9.4.1.8 (AID field). The 11 LSBs of the AID field are used to address the STAs in this field. For RUs that carry a broadcast allocation: — For single BSS AP, the STAID for broadcast will be 0 — For Multiple BSS AP, the STAID for broadcast to a specific BSS will follow the group addressed AID assignment in the TIM according to the existing Multi-BSSID TIM operation — For multiple BSS AP, the STAID for broadcast to all BSS of the AP is set to 2047 And further: — STAID value 2046 is used to indicate that the RU carries no data — When a STA transmits on the uplink using the HE MU PPDU format, the STA-ID field is populated by the AID of the transmitter assigned by the AP
B11-B13	NSTS	3	Number of spatial streams. Set to the number of space time streams minus 1.
B14	Tx Beam-forming	1	Use of transmit beamforming. Set to 1 if a beamforming steering matrix is applied to the waveform in an SU transmission. Set to 0 otherwise.
B15-B18	MCS	4	Modulation and coding scheme Set to *n* for MCS*n*, where *n* = 0, 1 ,2 …., 11 Values 12 to 15 are reserved

Table 28-22—Fields of the HE-SIG-B user field for an non-MU-MIMO allocation *(continued)*

B19	DCM	1	Indicates whether or not dual carrier modulation is used. Set to 1 to indicate that the payload of the HE MU PPDU is modulated with dual carrier modulation for the MCS. Set to 0 indicates that the payload of the PPDU is not modulated with dual carrier modulation for the MCS.
B20	Coding	1	Indicates whether BCC or LDPC is used. Set to 0 for BCC Set to 1 for LDPC
NOTE—Integer fields are transmitted in unsigned binary format, LSB first, where the LSB is in the lowest numbered bit position.			

The HE-SIG-B user field for an STA in MU-MIMO allocation contain the subfields shown in Table 28-23 (Fields of the HE-SIG-B user field for an MU-MIMO allocation).

Table 28-23—Fields of the HE-SIG-B user field for an MU-MIMO allocation

Bit	Field	Number of bits	Description
B0-B10	STA-ID	11	The STA-ID refers to the AID described in 9.4.1.8 (AID field). The 11 LSBs of the AID field are used to address STAs in this field.
B11-B14	Spatial Configuration	4	Indication for the number of spatial streams for a STA in an MU-MIMO allocation. See Table 28-24 (Spatial Configuration subfield encoding).
B15-B18	MCS	4	Modulation and coding scheme. Set to n for MCS*n*, where *n* = 0, 1, 2,…..11 Values 12 to 15 are reserved
B19	DCM	1	Indicates whether or not dual carrier modulation is used. Set to 1 to indicate that the payload of the HE MU PPDU is modulated with dual carrier modulation for the MCS. Set to 0 indicates that the payload of the PPDU is not modulated with dual carrier modulation for the MCS.
B20	Coding	1	Indicates whether BCC or LDPC is used. Set to 0 for BCC Set to 1 for LDPC
NOTE—Integer fields are transmitted in unsigned binary format, LSB first, where the LSB is in the lowest numbered bit position.			

A user field for an MU-MIMO allocation includes a Spatial Configuration subfield consisting of 4 bits that indicates the number of spatial streams for each STA and the total number of spatial streams in the MU-MIMO allocation. The subfield shown in Table 28-24 (Spatial Configuration subfield encoding) is constructed by using the entries corresponding to the value of number of users (N_{user}) multiplexed using MU-MIMO in an RU. When MU-MIMO is used in an RU of size less than or equal to 242 subcarriers, the number of users (N_{user}) in an MU-MIMO allocation is equal to the number of user fields per RU signaled for the RU in the RU allocation subfield of an HE-SIG-B Common block field. When MU-MIMO is used in RUs of size greater than 242 subcarriers, the number of users (N_{user}) in an MU-MIMO allocation is computed as the sum of the number of user-fields per RU indicated for the RU by the 8-bit RU allocation subfield in each HE-SIG-B content channel. For a given value of N_{user}, the four bits of the spatial configuration subfield are used as follows: A STA with a STA-ID that matches the 11-bit ID signaled in the user field for an MU-MIMO allocation derives the number of spatial streams allocated to it using the row corresponding to the signaled 4-bit spatial configuration subfield and the column corresponding to the position of the user field in the user-specific field. The starting stream index for the STA is computed by summing the Nsts in the columns prior to the column indicated by the STA's user-field position. In the case of load balancing for RUs of size greater than 242 subcarriers where user fields corresponding to the same MU-MIMO allocations are split into two HE-SIG-B content channels, the user-field positions are logically continuous with the first user field corresponding to the same RU in the second HE-SIG-B content channel updating its position (and therefore, column index) from that of the last user field in the first HE-SIG-B content channel.

Table 28-24—Spatial Configuration subfield encoding

N_{user}	B3...B0	Nsts [1]	Nsts [2]	Nsts [3]	Nsts [4]	Nsts [5]	Nsts [6]	Nsts [7]	Nsts [8]	Total Nsts	Number of entries
2	0000-0011	1-4	1							2-5	10
	0100-0110	2-4	2							4-6	
	0111-1000	3-4	3							6-7	
	1001	4	4							8	
3	0000-0011	1-4	1	1						3-6	13
	0100-0110	2-4	2	1						5-7	
	0111-1000	3-4	3	1						7-8	
	1001-1011	2-4	2	2						6-8	
	1100	3	3	2						8	
4	0000-0011	1-4	1	1	1					4-7	11
	0100-0110	2-4	2	1	1					6-8	
	0111	3	3	1	1					8	
	1000-1001	2-3	2	2	1					7-8	
	1010	2	2	2	2					8	

Table 28-24—Spatial Configuration subfield encoding *(continued)*

5	0000-0011	1-4	1	1	1	1				5-8	6
	0100-0101	2-3	2	1	1	1				7-8	
6	0000-0010	1-3	1	1	1	1	1			6-8	4
	0011	2	2	1	1	1	1			8	
7	0000-0001	1-2	1	1	1	1	1	1		7-8	2
8	0000	1	1	1	1	1	1	1	1	8	1

When the SIGB Compression field in the HE-SIG-A field of an HE MU PPDU is set to 1 (indicating full bandwidth MU-MIMO transmission), the number of STAs in the MU-MIMO group is indicated in the SIGB Number of Symbols/Number of MU-MIMO Users field in the HE-SIG-A field. When the SIGB Compression field in the HE-SIG-A field of an HE MU PPDU is set to 1, for bandwidths larger than 20 MHz, the User fields are split equitably between two HE-SIG-B content channels, i.e., for a k user MU-MIMO PPDU, $1, \ldots, \lceil k/2 \rceil$ User fields are carried in HE-SIG-B content channel 1 and $\lceil k/2 \rceil + 1, \ldots, k$ User fields in HE-SIG-B content channel 2.

The total number of spatial streams (total N_{STS}) is computed by summing all columns for the row signaled by the spatial configuration subfield and is indicated in Table 28-24 (Spatial Configuration subfield encoding) under the column Total Nsts.

28.3.10.9 HE-STF

The main purpose of the HE-STF field is to improve automatic gain control estimation in a MIMO transmission. The duration of the HE-STF field for HE PPDUs except HE trigger-based PPDUs is $T_{\text{HE-STF-NT}}$ (periodicity of 0.8 μs with 5 periods) and the duration of the HE-STF field for an HE trigger-based PPDU is $T_{\text{HE-STF-T}}$ (periodicity of 1.6 μs with 5 periods). The tone indices for HE-STF field for HE PPDUs except HE trigger-based PPDUs is defined in Equation (28-21).

$$
\begin{aligned}
& i_{STF} \bmod 16 = 0, \lfloor N_{DC}/2 \rfloor < |i_{STF}| \le N_{SR} \\
& i_{STF} : \text{HE-STF tone index}
\end{aligned}
\tag{28-21}
$$

The tone indices for HE-STF fields for an HE trigger-based PPDU are defined in Equation (28-22).

$$
\begin{aligned}
& i_{STF} \bmod 8 = 0, \lfloor N_{DC}/2 \rfloor < |i_{STF}| \le N_{SR} \\
& i_{STF} : \text{HE-STF tone index}
\end{aligned}
\tag{28-22}
$$

For the HE-STF field, the M sequence is defined by Equation (28-23).

$$
M = \{-1, -1, -1, 1, 1, 1, -1, 1, 1, 1, -1, 1, 1, -1, 1\} \tag{28-23}
$$

The HE-STF field is constructed from the M sequence(s) multiplied by $(1 + j)/\sqrt{2}$ or $(-1 - j)/\sqrt{2}$ and extra coefficients selected out of $(1 + j)/\sqrt{2}$ or $(-1 - j)/\sqrt{2}$ at tone indices which are null but shall have the HE-STF coefficients after mapping M sequences to each 20 MHz subchannel.

For a 20 MHz transmission, the frequency domain sequence for HE PPDUs except HE trigger-based PPDUs is given by Equation (28-24).

$$HES_{-112:16:112} = \{M\} \cdot (1+j)/\sqrt{2}$$
$$HES_0 = 0 \tag{28-24}$$

where $HES_{a:b:c}$ means coefficients of the HE-STF on every b tone indices from a to c tone indices and coefficients on other tone indices are set to zero.

For a 40 MHz transmission, the frequency domain sequence for HE PPDUs except HE trigger-based PPDUs is given by Equation (28-25).

$$HES_{-240:16:240} = \{M, 0, -M\} \cdot (1+j)/\sqrt{2} \tag{28-25}$$

For an 80 MHz transmission, the frequency domain sequence for HE PPDUs except HE trigger-based PPDUs is given by Equation (28-26).

$$HES_{-496:16:496} = \{M, 1, -M, 0, -M, 1, -M\} \cdot (1+j)/\sqrt{2} \tag{28-26}$$

For a 160 MHz transmission, the frequency domain sequence for HE PPDUs except HE trigger-based PPDUs is given by Equation (28-27).

$$HES_{-1008:16:1008} = \{M, 1, -M, 0, -M, 1, -M, 0, -M, -1, M, 0, -M, 1, -M\} \cdot (1+j)/\sqrt{2} \tag{28-27}$$

For an 80+80 MHz transmission, the primary 80 MHz segment for HE PPDUs except HE trigger-based PPDUs shall use the HE-STF pattern for the 80 MHz defined in Equation (28-26).

For an 80+80 MHz transmission, the frequency domain sequence of the secondary 80 MHz segment for HE PPDUs except HE trigger-based PPDUs is given by Equation (28-28).

$$HES_{-496:16:496} = \{-M, -1, M, 0, -M, 1, -M\} \cdot (1+j)/\sqrt{2} \tag{28-28}$$

For a 20 MHz transmission, the frequency domain sequence for HE trigger-based PPDUs is given by Equation (28-29).

$$HES_{-120:8:120} = \{M, 0, -M\} \cdot (1+j)/\sqrt{2} \tag{28-29}$$

For a 40 MHz transmission, the frequency domain sequence for HE trigger-based PPDUs is given by Equation (28-30).

$$HES_{-248:8:248} = \{M, -1, -M, 0, M, -1, M\} \cdot (1+j)/\sqrt{2}$$
$$HES_{\pm 248} = 0 \tag{28-30}$$

For an 80 MHz transmission, the frequency domain sequence for HE trigger-based PPDUs is given by Equation (28-31).

$$HES_{-504:8:504} = \{M, -1, M, -1, -M, -1, M, 0, -M, 1, M, 1, -M, 1, -M\} \cdot (1+j)/\sqrt{2}$$
$$HES_{\pm 504} = 0 \tag{28-31}$$

For a 160 MHz transmission, the frequency domain sequence for HE trigger-based PPDUs is given by Equation (28-32).

$$\begin{aligned} HES_{-1016:8:1016} &= \{M, -1, M, -1, -M, -1, M, 0, -M, 1, M, 1, -M, 1, -M, 0 \\ &\qquad -M, 1, -M, 1, M, 1, -M, 0, -M, 1, M, 1, -M, 1, -M\} \cdot (1+j)/\sqrt{2} \\ HES_{\pm 8} &= 0, HES_{\pm 1016} = 0 \end{aligned} \quad (28\text{-}32)$$

For an 80+80 MHz transmission, the primary 80 MHz segment for HE trigger-based PPDUs shall use the HE-STF pattern for the 80 MHz defined in Equation (28-31).

For an 80+80 MHz transmission, the frequency domain sequence of the secondary 80 MHz segment for HE trigger-based PPDUs is given by Equation (28-33).

$$\begin{aligned} HES_{-504:8:504} &= \{-M, 1, -M, 1, M, 1, -M, 0, -M, 1, M, 1, -M, 1, -M\} \cdot (1+j)/\sqrt{2} \\ HES_{\pm 504} &= 0 \end{aligned} \quad (28\text{-}33)$$

For an OFDMA transmission, the coefficients in Equation (28-24) to Equation (28-33) are set to zero if those values are corresponding to tone indices for which no RUs are defined (see 28.3.9 (Mathematical description of signals)).

The time domain representation of the signal for an HE PPDU that is not an HE trigger-based PPDU on frequency segment i_{Seg} of transmit chain i_{TX} shall be as specified in Equation (28-34).

$$\begin{aligned} r_{\text{HE-STF}}^{(i_{Seg} i_{TX})}(t) &= w_{T_{\text{HE-STF-NT}}}(t) \cdot \sum_{r=0}^{N_{RU}-1} \frac{\alpha_r \beta_r}{\sqrt{N_{STS,r,total}}} \\ &\sum_{k \in K_r} \eta_{\text{HE-STF},k} \sum_{u=0}^{N_{user,r}-1} \sum_{m=1}^{N_{STS,r,u}} \left(\left[Q_k^{(i_{Seg})} \right]_{i_{TX}, M_{r,u}+m} HES_k \cdot \exp(j2\pi k \Delta_{F,\text{HE}}(t - T_{CS,HE}(M_{r,u}+m))) \right) \end{aligned} \quad (28\text{-}34)$$

where

α_r is the power boost factor for the r-th RU. A STA shall support α_r in the range [0.7, $\sqrt{2}$]. A STA may support α_r in the range [0.5, 2].

$\eta_{\text{HE-STF},k}$ is an HE PPDU format dependent scaling factor, defined by

$$\eta_{\text{HE-STF},k} = \begin{cases} \sqrt{2}, & \text{for an HE extended range SU PPDU} \\ 1, & \text{otherwise} \end{cases}$$

β_r is the per-RU power normalization factor and defined by

$$\beta_r = \left(\sqrt{\frac{|K_r|}{\left|K_r^{\text{HE-STF}}\right|}} \right) \Big/ \left(\sqrt{\sum_{r=1}^{N_{RU}} \alpha_r^2 |K_r|} \right)$$

$|K_r|$ is the cardinality of the set of subcarriers K_r.

$K_r^{\text{HE-STF}}$ is the set of subcarriers that have non-zero values within K_r in the HE-STF field

$T_{CS,\text{HE}}(M_{r,u}+m)$ represents the cyclic shift for space time stream $M_{r,u}+m$ as defined in 28.3.10.2.2 (Cyclic shift for HE modulated fields)

$Q_k^{(i_{Seg})}$ is defined in 28.3.9 (Mathematical description of signals)

$w_{T_{\text{HE-STF-NT}}}$ is the windowing function for HE-STF field in the non-HE trigger-based PPDU

The time domain representation of the signal for an HE trigger-based PPDU transmitted by user u in the r-th RU on frequency segment i_{Seg} of transmit chain i_{TX} shall be as specified in Equation (28-35).

$$r_{\text{HE-STF}}^{(i_{Seg} i_{TX})}(t) = \frac{1}{\sqrt{\left|K_r^{\text{HE-STF}}\right| N_{STS,r,total}}} w_{T_{\text{HE-STF-T}}}(t) \sum_{k \in K_r} \sum_{m=1}^{N_{STS,r,u}} \left(\left[Q_k^{(i_{Seg})} \right]_{i_{TX},(M_{r,u}+m)} HES_k \cdot \exp(j2\pi k \Delta_{F,\text{HE}}(t - T_{CS,HE}(M_{r,u}+m))) \right) \tag{28-35}$$

where

$w_{T_{\text{HE-STF-T}}}$ is the windowing function for HE-STF field in the HE trigger-based PPDU

28.3.10.10 HE-LTF

The HE-LTF field provides a means for the receiver to estimate the MIMO channel between the set of constellation mapper outputs (or, if STBC is applied, the STBC encoder outputs) and the receive chains. In an HE SU PPDU, HE extended range SU PPDU and HE MU PPDU, the transmitter provides training for $N_{STS,r,total}$ space-time streams (spatial mapper inputs) used for the transmission of the PSDU(s) in the r-th RU. In an HE trigger-based PPDU, the transmitter of user u in the r-th RU provides training for $N_{STS,r,u}$ space-time streams used for the transmission of the PSDU. For each tone in the r-th RU, the MIMO channel that can be estimated is an $N_{RX} \times N_{STS,r,total}$ matrix. An HE transmission has a preamble that contains HE-LTF symbols, where the data tones of each HE-LTF symbol are multiplied by entries belonging to a matrix $P_{\text{HE-LTF}}$, to enable channel estimation at the receiver. The pilot subcarriers of each HE-LTF symbol are multiplied by the entries of a matrix $R_{\text{HE-LTF}}$ defined in the following text. The multiplication of the pilot subcarriers in the HE-LTF symbol by the $R_{\text{HE-LTF}}$ matrix instead of the $P_{\text{HE-LTF}}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the HE-LTF. In an HE SU PPDU, HE extended range SU PPDU and HE MU PPDU with a single RU (the RU having an MU-MIMO allocation or an SU allocation), the number of HE-LTF symbols, $N_{\text{HE-LTF}}$, is a function of the total number of space-time streams N_{STS} as shown in Table 28-12 (Frequently used parameters). In an HE trigger-based PPDU, $N_{\text{HE-LTF}}$ is indicated in the Trigger frame that triggers the transmission of the PPDU. In an HE MU PPDU, $N_{\text{HE-LTF}}$ is indicated in the HE-SIG-A field. In an HE MU PPDU with more than one RU and in an HE trigger-based PPDU, $N_{\text{HE-LTF}}$ may take any value among one, two, four, six or eight, which is greater than or equal to the maximum value of the initial number of HE-LTF symbols for each RU r, which is calculated as a function of $N_{STS,r,total}$, separately based on Table 28-12 (Frequently used parameters).

An HE PPDU supports 3 HE-LTF modes, which are 1x HE-LTF, 2x HE-LTF and 4x HE-LTF. It is optional to support the 1x HE-LTF mode in an HE SU PPDU, HE extended range SU PPDU and HE MU PPDU. It is mandatory to support transmission of 1x HE-LTF in an UL MU-MIMO PPDU over the full bandwidth, for a STA declaring support for UL MU-MIMO. The 1x HE-LTF mode is disallowed in an HE MU PPDU and in an HE trigger-based PPDU with more than one RUs, and is also disallowed in an HE MU PPDU with one RU whenever the RU has an MU-MIMO allocation. In an HE SU PPDU, HE MU PPDU and HE extended range SU PPDU, the combination of HE-LTF modes and GI duration is indicated in HE-SIG-A field. In an HE trigger-based PPDU, the combination of HE-LTF modes and GI duration is indicated in the Trigger frame that triggers the transmission of the PPDU. The mandatory combinations of HE-LTF modes and GI duration are:

— 2x HE-LTF, $T_{GI1,Data}$

— 2x HE-LTF, $T_{GI2,Data}$

— 4x HE-LTF, $T_{GI4,Data}$

The optional combinations of HE-LTF mode and GI duration are:

— 1x HE-LTF, $T_{GI1,Data}$ in an HE SU PPDU or HE extended SU PPDU

— 1x HE-LTF, $T_{GI1,Data}$ in a non-OFDMA, MU-MIMO HE MU PPDU

— 1x HE-LTF, $T_{GI2,Data}$ in a non-OFDMA, MU-MIMO HE trigger-based PPDU

The duration of each HE-LTF symbol excluding GI is $T_{\text{HE-LTF}}$ is defined in Equation (28-36). In an HE SU PPDU, HE MU PPDU or HE extended range SU PPDU, the HE-LTF symbol duration is indicated in HE-SIG-A field. In an HE trigger-based PPDU, the HE-LTF symbol duration is indicated in the Trigger frame that triggers the transmission of the PPDU.

$$T_{\text{HE-LTF}} = \begin{cases} T_{\text{HE-LTF-1X}}, \text{ if 1x HE-LTF} \\ T_{\text{HE-LTF-2X}}, \text{ if 2x HE-LTF} \\ T_{\text{HE-LTF-4X}}, \text{ if 4x HE-LTF} \end{cases} \tag{28-36}$$

where $T_{\text{HE-LTF-1X}}$, $T_{\text{HE-LTF-2X}}$, $T_{\text{HE-LTF-4X}}$ are defined in Table 28-9 (Timing-related constants).

In a 20 MHz transmission, the 1x HE-LTF sequence transmitted and located on subcarriers [−122:122] is given by Equation (28-37).

$$\begin{aligned} &HELTF_{-122,122} = \\ &\quad \{0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, \\ &\quad 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, \\ &\quad -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, \\ &\quad 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, 0, 0, 0, \\ &\quad 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, \\ &\quad 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, \\ &\quad 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, \\ &\quad -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0\} \end{aligned} \tag{28-37}$$

In a 20 MHz transmission, the 2x HE-LTF sequence transmitted and located on subcarriers [−122:122] is given by Equation (28-38).

$$\begin{aligned} &HELTF_{-122,122} = \\ &\quad \{-1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, \\ &\quad 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, \\ &\quad 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, \\ &\quad 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, \\ &\quad 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, 0, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, \\ &\quad 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, \\ &\quad 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, \\ &\quad 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, \\ &\quad 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1\} \end{aligned} \tag{28-38}$$

In a 20 MHz transmission, the 4x HE-LTF sequence transmitted and located on subcarriers [–122:122] is given by Equation (28-39).

$$
\begin{array}{l}
HELTF_{-122,122} = \\
\{-1, -1, +1, -1, +1, -1, +1, +1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, -1, -1, +1, \\
+1, -1, -1, -1, -1, +1, +1, -1, +1, -1, +1, +1, +1, +1, -1, +1, -1, -1, +1, +1, -1, +1, +1, \\
+1, +1, -1, -1, +1, -1, -1, -1, +1, +1, +1, +1, -1, +1, +1, -1, -1, -1, -1, +1, -1, -1, +1, \\
+1, -1, +1, -1, -1, -1, -1, +1, -1, +1, -1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1, -1, -1, \\
+1, -1, -1, +1, +1, +1, -1, +1, +1, +1, -1, +1, -1, +1, -1, -1, -1, -1, -1, +1, +1, +1, -1, \\
-1, -1, +1, -1, +1, +1, +1, 0, 0, 0, -1, +1, -1, +1, -1, +1, +1, -1, +1, +1, +1, -1, -1, +1, \\
-1, -1, +1, -1, +1, -1, +1, +1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, -1, -1, +1, +1, \\
-1, -1, -1, -1, -1, -1, +1, -1, +1, -1, -1, -1, -1, +1, -1, +1, +1, -1, -1, +1, -1, -1, -1, \\
-1, +1, +1, -1, +1, +1, +1, +1, +1, +1, +1, -1, +1, +1, -1, -1, -1, -1, +1, -1, -1, +1, +1, \\
-1, +1, -1, -1, -1, -1, +1, -1, +1, -1, -1, +1, +1, +1, +1, -1, -1, +1, +1, +1, +1, +1, -1, \\
+1, +1, -1, -1, -1, +1, -1, -1, -1, +1, -1, +1, -1, +1, +1\}
\end{array}
\tag{28-39}
$$

In a 40 MHz transmission, the 1x HE-LTF sequence transmitted and located on subcarriers [–244:244] is given by Equation (28-40).

$$
\begin{array}{l}
HELTF_{-244,244} = \\
\{+1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, \\
0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, \\
0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, \\
0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, \\
-1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, \\
0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, \\
0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, \\
0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, 0, 0, 0, 0, +1, \\
0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, \\
+1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, \\
0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, \\
0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, \\
0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, \\
+1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, \\
0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, \\
0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1\}
\end{array}
\tag{28-40}
$$

In a 40 MHz transmission, the 2x HE-LTF sequence transmitted and located on subcarriers [–244:244] is given by Equation (28-41).

$$
\begin{array}{l}
HELTF_{-244,244} = \\
\quad \{+1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, \\
\quad 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, \\
\quad 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, \\
\quad 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, \\
\quad 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, \\
\quad 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, \\
\quad 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, \\
\quad 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, \\
\quad 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, 0, 0, 0, 0, 0, 0, -1, 0, -1, 0, \\
\quad -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, \\
\quad -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, +1, 0, \\
\quad +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, \\
\quad -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, +1, 0, +1, 0, \\
\quad +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, \\
\quad +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, \\
\quad -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, \\
\quad +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, \\
\quad -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1\}
\end{array}
\tag{28-41}
$$

In a 40 MHz transmission, the 4x HE-LTF sequence transmitted and located on subcarriers [–244:244] is given by Equation (28-42).

$$
\begin{array}{l}
HELTF_{-244,244} = \\
\quad \{+1, -1, -1, -1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, -1, +1, +1, -1, +1, -1, -1, -1, \\
\quad +1, +1, -1, -1, -1, -1, -1, -1, -1, +1, -1, -1, +1, +1, -1, +1, -1, -1, -1, -1, -1, +1, -1, \\
\quad +1, +1, +1, -1, -1, +1, +1, +1, -1, -1, +1, +1, +1, +1, -1, +1, +1, -1, -1, +1, -1, +1, -1, \\
\quad +1, -1, -1, +1, -1, +1, +1, +1, -1, -1, +1, +1, +1, -1, -1, -1, -1, +1, -1, -1, +1, +1, -1, \\
\quad +1, -1, -1, -1, -1, -1, +1, -1, +1, +1, +1, -1, -1, +1, +1, +1, +1, +1, +1, +1, +1, -1, +1, \\
\quad +1, -1, -1, +1, -1, +1, +1, +1, +1, +1, -1, +1, -1, -1, -1, +1, +1, -1, -1, -1, -1, -1, -1, \\
\quad -1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, -1, +1, +1, -1, +1, -1, -1, -1, +1, +1, -1, -1, \\
\quad -1, -1, -1, -1, -1, +1, -1, -1, +1, +1, -1, +1, -1, -1, -1, -1, -1, +1, -1, +1, +1, +1, -1, \\
\quad -1, +1, +1, +1, -1, -1, -1, -1, -1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, -1, +1, +1, -1, \\
\quad +1, -1, -1, -1, +1, +1, -1, -1, -1, +1, +1, +1, +1, -1, +1, +1, -1, -1, +1, -1, +1, +1, +1, \\
\quad +1, +1, -1, +1, -1, -1, -1, +1, +1, -1, -1, -1, +1, 0, 0, 0, 0, 0, -1, +1, +1, +1, +1, -1, +1, \\
\quad +1, -1, -1, +1, -1, +1, -1, +1, -1, -1, +1, -1, +1, +1, +1, -1, -1, +1, +1, +1, +1, +1, +1, \\
\quad +1, -1, +1, +1, -1, -1, +1, -1, +1, +1, +1, +1, +1, -1, +1, -1, -1, -1, +1, +1, -1, -1, -1, \\
\quad +1, +1, -1, -1, -1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, -1, +1, +1, -1, +1, -1, -1, -1, \\
\quad +1, +1, -1, -1, -1, +1, +1, +1, +1, -1, +1, +1, -1, -1, +1, -1, +1, +1, +1, +1, +1, -1, +1, \\
\quad -1, -1, -1, +1, +1, -1, -1, -1, +1, -1, -1, -1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, -1, \\
\quad +1, +1, -1, +1, -1, -1, -1, +1, +1, -1, -1, -1, +1, -1, -1, -1, -1, +1, -1, -1, +1, +1, -1, \\
\quad +1, -1, +1, -1, +1, +1, -1, +1, -1, -1, -1, +1, +1, -1, -1, -1, -1, -1, -1, -1, +1, -1, -1, \\
\quad +1, +1, -1, +1, -1, -1, -1, -1, -1, +1, -1, +1, +1, +1, -1, -1, +1, +1, +1, -1, +1, -1, -1, \\
\quad -1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, -1, +1, +1, -1, +1, -1, -1, -1, +1, +1, -1, -1, \\
\quad -1, +1, +1, +1, +1, -1, +1, +1, -1, -1, +1, -1, +1, +1, +1, +1, +1, -1, +1, -1, -1, -1, +1, \\
\quad +1, -1, -1, -1, -1\}
\end{array}
\tag{28-42}
$$

In an 80 MHz transmission, the 1x HE-LTF sequence transmitted and located on subcarriers [−500:500] is given by Equation (28-43).

$$
\begin{aligned}
&HELTF_{-500,500} = \\
&\{-1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, \\
&0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, \\
&0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, \\
&0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, \\
&-1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, \\
&0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, \\
&0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, \\
&0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, \\
&-1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, \\
&0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, \\
&0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, \\
&0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, \\
&+1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, \\
&0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, \\
&0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, \\
&0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, \\
&-1, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, \\
&+1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, \\
&0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, \\
&0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, \\
&0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, \\
&+1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, \\
&0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, \\
&0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, \\
&0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, \\
&-1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, \\
&0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, \\
&0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, \\
&0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, \\
&-1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, \\
&0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, \\
&0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, \\
&0, 0, 0, +1, 0, 0, 0, +1\}
\end{aligned}
\tag{28-43}
$$

In an 80 MHz transmission, the 2x HE-LTF sequence transmitted and located on subcarriers [−500:500] is given by Equation (28-44).

$$
\begin{gathered}
HELTF_{-500,500} = \\
\{+1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, \\
0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, \\
0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, \\
0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, \\
0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, \\
0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, \\
0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, \\
0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, \\
0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, \\
0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, \\
0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, \\
0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, \\
0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, \\
0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, \\
0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, \\
0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, \\
0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, \\
0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, 0, 0, 0, 0, 0, 0, \\
+1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, \\
-1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, \\
+1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, \\
+1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, \\
+1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, \\
+1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, \\
+1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, \\
+1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, \\
-1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, \\
+1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, \\
-1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, \\
+1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, \\
-1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, \\
-1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, \\
-1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, \\
-1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, \\
-1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, \\
+1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1\}
\end{gathered}
\qquad (28\text{-}44)
$$

In an 80 MHz transmission, the 4x HE-LTF sequence transmitted and located on subcarriers [−500:500] is given by Equation (28-45).

$$
\begin{array}{l}
HELTF_{-500,500} = \\
\{+1, +1, -1, +1, -1, +1, -1, -1, -1, +1, -1, -1, -1, +1, +1, -1, +1, +1, +1, +1, +1, -1, \\
-1, +1, +1, +1, +1, -1, +1, -1, +1, -1, -1, +1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, \\
-1, +1, +1, +1, -1, -1, -1, -1, -1, -1, +1, +1, +1, +1, +1, +1, -1, +1, +1, +1, -1, +1, +1, \\
-1, -1, -1, +1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, +1, +1, +1, +1, -1, -1, +1, +1, +1, \\
-1, +1, +1, -1, -1, -1, +1, -1, +1, +1, -1, +1, +1, -1, +1, -1, -1, +1, +1, +1, +1, -1, -1, \\
+1, +1, +1, +1, +1, -1, +1, +1, -1, -1, -1, +1, -1, -1, -1, +1, -1, +1, -1, +1, +1, -1, +1, \\
-1, +1, -1, +1, +1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1, \\
-1, +1, -1, +1, -1, +1, +1, -1, -1, +1, -1, -1, -1, +1, +1, -1, +1, +1, +1, +1, -1, -1, -1, \\
+1, +1, +1, +1, -1, +1, +1, +1, +1, +1, +1, +1, -1, +1, +1, +1, -1, +1, +1, -1, -1, -1, +1, \\
-1, +1, -1, -1, +1, +1, -1, +1, -1, +1, +1, +1, +1, +1, -1, -1, +1, +1, +1, -1, +1, +1, -1, \\
-1, -1, +1, -1, +1, +1, -1, +1, +1, -1, +1, -1, -1, +1, -1, +1, -1, +1, -1, +1, +1, +1, -1, \\
+1, +1, +1, -1, -1, +1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1, -1, +1, -1, +1, -1, +1, +1, \\
-1, -1, +1, -1, -1, -1, +1, +1, -1, +1, +1, +1, +1, -1, -1, -1, +1, +1, +1, +1, -1, +1, -1, \\
-1, -1, -1, -1, -1, +1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, -1, +1, +1, -1, -1, +1, \\
-1, +1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, -1, -1, +1, \\
-1, -1, +1, -1, +1, +1, +1, +1, +1, +1, -1, -1, +1, +1, +1, +1, +1, -1, +1, +1, -1, -1, -1, \\
+1, -1, -1, -1, +1, -1, +1, -1, +1, +1, -1, +1, -1, +1, -1, +1, +1, +1, -1, +1, +1, +1, -1, \\
-1, +1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1, -1, +1, -1, +1, -1, +1, +1, -1, -1, +1, -1, \\
-1, -1, +1, +1, -1, +1, +1, +1, +1, -1, -1, -1, +1, +1, +1, +1, -1, -1, +1, +1, +1, +1, +1, \\
+1, -1, +1, +1, +1, -1, +1, +1, -1, -1, -1, +1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, +1, \\
+1, +1, +1, -1, -1, +1, +1, +1, -1, +1, +1, -1, -1, -1, +1, -1, +1, +1, -1, +1, +1, -1, +1, \\
-1, -1, -1, +1, -1, +1, -1, -1, -1, -1, +1, +1, +1, -1, -1, +1, 0, 0, 0, 0, 0, +1, -1, -1, -1, \\
-1, -1, -1, +1, -1, +1, +1, -1, -1, +1, +1, -1, +1, -1, +1, +1, -1, -1, +1, -1, +1, -1, -1, \\
-1, +1, +1, -1, +1, +1, +1, -1, +1, +1, +1, +1, +1, +1, +1, -1, +1, -1, -1, +1, -1, -1, +1, \\
-1, +1, +1, +1, -1, -1, +1, -1, -1, -1, +1, +1, -1, -1, -1, -1, -1, +1, -1, -1, -1, -1, -1, \\
+1, +1, -1, -1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, +1, +1, -1, +1, -1, +1, -1, -1, \\
-1, -1, -1, +1, +1, +1, -1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, +1, -1, -1, +1, -1, \\
+1, -1, -1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, -1, -1, \\
+1, -1, -1, +1, -1, +1, +1, +1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, +1, +1, -1, -1, +1, \\
-1, -1, -1, +1, -1, -1, -1, -1, -1, -1, -1, +1, -1, +1, +1, -1, +1, +1, -1, +1, -1, -1, -1, \\
+1, +1, -1, +1, +1, +1, -1, -1, +1, +1, +1, +1, +1, -1, +1, -1, -1, -1, -1, +1, +1, -1, -1, \\
-1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, +1, +1, -1, +1, -1, +1, -1, -1, -1, -1, -1, +1, \\
+1, +1, -1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, +1, -1, -1, +1, -1, +1, -1, +1, +1, \\
+1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, +1, -1, -1, -1, \\
-1, -1, -1, -1, +1, -1, +1, +1, -1, +1, +1, -1, +1, -1, -1, -1, +1, +1, -1, +1, +1, +1, -1, \\
-1, +1, +1, +1, +1, +1, -1, +1, +1, +1, +1, +1, -1, -1, +1, +1, +1, +1, +1, -1, +1, +1, -1, \\
-1, -1, +1, -1, -1, -1, +1, -1, +1, -1, +1, +1, +1, +1, +1, -1, -1, -1, +1, +1, +1, +1, -1, \\
+1, +1, -1, -1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, -1, -1, -1, -1, -1, -1, +1, +1, -1, \\
-1, -1, +1, -1, -1, +1, +1, +1, -1, +1, -1, -1, +1, -1, -1, +1, -1, +1, -1, +1, -1, +1, -1, \\
-1, +1, +1, -1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, +1, -1, -1, -1, -1, -1, -1, -1, \\
+1, -1, +1, +1, -1, +1, +1, -1, +1, -1, -1, -1, +1, +1, -1, +1, +1, +1, -1, -1, +1, +1, +1, \\
+1, +1, -1, +1, -1, -1, -1, -1, +1, +1, -1, -1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, \\
+1, +1, -1, +1, -1, +1, -1, -1, -1, -1, -1, +1, +1, +1, -1, -1, -1, -1, +1, -1, -1, +1, +1, \\
+1, -1, +1, +1, -1, -1, +1, -1, +1, -1, +1\}
\end{array}
\tag{28-45}
$$

In a 160 MHz transmission, the 1x HE-LTF sequence is given by Equation (28-46).

$$HELTF_{-1012,1012} = \{LTF_{80\text{MHz\_primary\_1x}}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, LTF_{80\text{MHz\_secondary\_1x}}\} \tag{28-46}$$

where

$LTF_{80\text{MHz\_primary\_1x}} = \{LTF_{80\text{MHz\_left\_1x}}, 0, LTF_{80\text{MHz\_right\_1x}}\}$ and shall be used in the primary 80 MHz frequency segment

$LTF_{80\text{MHz\_secondary\_1x}} = \{LTF_{80\text{MHz\_left\_1x}}, 0, -LTF_{80\text{MHz\_right\_1x}}\}$ and shall be used in the secondary 80 MHz frequency segment

$LTF_{80\text{MHz\_left\_1x}}$ = {−1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0}

$LTF_{80\text{MHz\_right\_1x}}$ = {0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1}

In a 160 MHz transmission, the 2x HE-LTF sequence is given by Equation (28-47).

$$HELTF_{-1012,1012} = \{LTF_{80\text{MHz\_primary\_2x}}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, LTF_{80\text{MHz\_secondary\_2x}}\} \tag{28-47}$$

where

$$LTF_{\mathrm{80MHz\_primary\_2x}} = \{LTF_{\mathrm{80MHz\_part1\_2x}}, LTF_{\mathrm{80MHz\_part2\_2x}}, LTF_{\mathrm{80MHz\_part3\_2x}}, LTF_{\mathrm{80MHz\_part4\_2x}}, LTF_{\mathrm{80MHz\_part5\_2x}}\} \quad (28\text{-}48)$$

$$LTF_{\mathrm{80MHz\_secondary\_2x}} = \{LTF_{\mathrm{80MHz\_part1\_2x}}, -LTF_{\mathrm{80MHz\_part2\_2x}}, LTF_{\mathrm{80MHz\_part3\_2x}}, LTF_{\mathrm{80MHz\_part4\_2x}}, -LTF_{\mathrm{80MHz\_part5\_2x}}\} \quad (28\text{-}49)$$

$$\begin{aligned} LTF_{\mathrm{80MHz\_part1\_2x}} = \{ & +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, \\ & -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, \\ & +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, \\ & +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, \\ & -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, \\ & -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, \\ & +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, \\ & +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, \\ & +1, 0, -1, 0, +1, 0\} \end{aligned}$$

$$\begin{aligned} LTF_{\mathrm{80MHz\_part2\_2x}} = \{ & +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, \\ & +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, \\ & +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, \\ & -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, \\ & -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, \\ & +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, \\ & +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, \\ & -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, \\ & +1, 0, +1, 0, +1, 0\} \end{aligned}$$

$$\begin{aligned} LTF_{\mathrm{80MHz\_part3\_2x}} = \{ & +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, 0, 0, 0, 0, 0, 0, +1, 0, -1, 0, -1, 0, +1, \\ & 0, +1, 0, -1, 0, +1\} \end{aligned}$$

$$\begin{aligned} LTF_{\mathrm{80MHz\_part4\_2x}} = \{ & 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, \\ & 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, \\ & 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, \\ & 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, \\ & 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, \\ & 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, \\ & 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, \\ & 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, \\ & 0, +1, 0, +1, 0, -1\} \end{aligned}$$

$$\begin{aligned} LTF_{\mathrm{80MHz\_part5\_2x}} = \{ & 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, \\ & 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, \\ & 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, \\ & 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, \\ & 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, \\ & 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, \\ & 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, \\ & 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, \\ & 0, -1, 0, +1, 0, +1\} \end{aligned}$$

In a 160 MHz transmission, the 4x HE-LTF sequence is given by Equation (28-50).

$$\begin{aligned} HELTF_{-1012,1012} = \{ & LTF_{\mathrm{80MHz\_primary\_4x}}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, \\ & 0, 0, 0, 0, LTF_{\mathrm{80MHz\_secondary\_4x}}\} \end{aligned} \quad (28\text{-}50)$$

where

$$LTF_{\mathrm{80MHz\_primary\_4x}} = \{LTF_{\mathrm{80MHz\_left\_4x}}, 0, LTF_{\mathrm{80MHz\_right\_4x}}\} \tag{28-51}$$

$$LTF_{\mathrm{80MHz\_secondary\_4x}} = \{LTF_{\mathrm{80MHz\_left\_4x}}, 0, -LTF_{\mathrm{80MHz\_right\_4x}}\} \tag{28-52}$$

$$\begin{aligned}
LTF_{\mathrm{80MHz_left_4x}} = \{&+1, +1, -1, +1, -1, +1, -1, -1, -1, +1, -1, -1, -1, +1, +1, -1, +1, +1, +1, +1, +1, -1,\\
&-1, +1, +1, +1, +1, -1, +1, -1, +1, -1, -1, +1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, -1,\\
&+1, +1, +1, -1, -1, -1, -1, -1, -1, +1, +1, +1, +1, +1, +1, -1, +1, +1, +1, -1, +1, +1, -1, -1,\\
&-1, +1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, +1, +1, +1, +1, -1, -1, +1, +1, +1, -1, +1, +1,\\
&-1, -1, -1, +1, -1, +1, +1, -1, +1, +1, -1, +1, -1, -1, +1, +1, +1, +1, -1, -1, +1, +1, +1, +1,\\
&+1, -1, +1, +1, -1, -1, -1, +1, -1, -1, -1, +1, -1, +1, -1, +1, +1, -1, +1, -1, +1, -1, +1, +1,\\
&+1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1, -1, +1, -1, +1, -1, +1,\\
&+1, -1, -1, +1, -1, -1, -1, +1, +1, -1, +1, +1, +1, +1, -1, -1, -1, +1, +1, +1, +1, -1, +1, +1,\\
&+1, +1, +1, +1, +1, -1, +1, +1, +1, -1, +1, +1, -1, -1, -1, +1, -1, +1, -1, -1, +1, +1, -1, +1,\\
&-1, +1, +1, +1, +1, +1, -1, -1, +1, +1, +1, -1, +1, +1, -1, -1, -1, +1, -1, +1, +1, -1, +1, +1,\\
&-1, +1, -1, -1, +1, -1, +1, -1, +1, -1, +1, +1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, -1,\\
&-1, +1, +1, -1, -1, -1, -1, +1, -1, +1, -1, +1, +1, -1, -1, +1, -1, -1, -1, +1, +1, -1, +1, +1,\\
&+1, +1, -1, -1, -1, +1, +1, +1, +1, -1, +1, -1, -1, -1, -1, -1, -1, +1, -1, -1, -1, +1, -1, -1,\\
&+1, +1, +1, -1, +1, -1, +1, +1, -1, -1, +1, -1, +1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1, +1,\\
&-1, -1, +1, +1, +1, -1, +1, -1, -1, +1, -1, -1, +1, -1, +1, +1, +1, +1, +1, +1, -1, -1, +1, +1,\\
&+1, +1, +1, -1, +1, +1, -1, -1, -1, +1, -1, -1, -1, +1, -1, +1, -1, +1, +1, -1, +1, -1, +1, -1,\\
&+1, +1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1, -1, +1, -1, +1,\\
&-1, +1, +1, -1, -1, +1, -1, -1, -1, +1, +1, -1, +1, +1, +1, +1, -1, -1, -1, +1, +1, +1, +1, -1,\\
&-1, +1, +1, +1, +1, +1, +1, -1, +1, +1, +1, -1, +1, +1, -1, -1, -1, +1, -1, +1, -1, -1, +1, +1,\\
&-1, +1, -1, +1, +1, +1, +1, +1, -1, -1, +1, +1, +1, -1, +1, +1, -1, -1, -1, +1, -1, +1, +1, -1,\\
&+1, +1, -1, +1, -1, -1, -1, +1, -1, +1, -1, -1, -1, -1, +1, +1, +1, -1, -1, +1, 0, 0\}
\end{aligned}$$

$$\begin{aligned}
LTF_{\mathrm{80MHz_right_4x}} = \{&0, 0, +1, -1, -1, -1, -1, -1, -1, +1, -1, +1, +1, -1, -1, +1, +1, -1, +1, -1, +1, +1,\\
&-1, -1, +1, -1, +1, -1, -1, -1, +1, +1, -1, +1, +1, +1, -1, +1, +1, +1, +1, +1, +1, +1, -1, +1,\\
&-1, -1, +1, -1, -1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, +1, +1, -1, -1, -1, -1, -1, +1,\\
&-1, -1, -1, -1, -1, +1, +1, -1, -1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, +1, +1, -1, +1,\\
&-1, +1, -1, -1, -1, -1, -1, +1, +1, +1, -1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, +1, -1,\\
&-1, +1, -1, +1, -1, -1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1,\\
&-1, -1, +1, -1, -1, +1, -1, +1, +1, +1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, +1, +1, -1, -1,\\
&+1, -1, -1, -1, +1, -1, -1, -1, -1, -1, -1, -1, +1, -1, +1, +1, -1, +1, +1, -1, +1, -1, -1, -1,\\
&+1, +1, -1, +1, +1, +1, -1, -1, +1, +1, +1, +1, +1, -1, +1, -1, -1, -1, -1, +1, +1, -1, -1, -1,\\
&-1, -1, +1, -1, -1, +1, +1, +1, -1, +1, +1, +1, -1, +1, -1, +1, -1, -1, -1, -1, -1, +1, +1, +1,\\
&-1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, +1, -1, -1, +1, -1, +1, -1, +1, +1, +1, -1, +1,\\
&-1, -1, +1, +1, -1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, +1, -1, -1, -1, -1, -1, -1, -1,\\
&+1, -1, +1, +1, -1, +1, +1, -1, +1, -1, -1, -1, +1, +1, -1, +1, +1, +1, -1, -1, +1, +1, +1, +1,\\
&+1, -1, +1, +1, +1, +1, +1, -1, -1, +1, +1, +1, +1, +1, -1, +1, +1, -1, -1, -1, +1, -1, -1, -1,\\
&+1, -1, +1, -1, +1, +1, +1, +1, +1, -1, -1, -1, +1, +1, +1, +1, -1, +1, +1, -1, -1, -1, +1, -1,\\
&-1, +1, +1, -1, +1, -1, +1, -1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1, +1, -1, -1, +1, +1, +1,\\
&-1, +1, -1, -1, +1, -1, -1, +1, -1, +1, -1, +1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, +1, +1,\\
&-1, -1, +1, -1, -1, -1, +1, -1, -1, -1, -1, -1, -1, -1, +1, -1, +1, +1, -1, +1, +1, -1, +1, -1,\\
&-1, -1, +1, +1, -1, +1, +1, +1, -1, -1, +1, +1, +1, +1, +1, -1, +1, -1, -1, -1, -1, +1, +1, -1,\\
&-1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, +1, +1, -1, +1, -1, +1, -1, -1, -1, -1, -1, +1,\\
&+1, +1, -1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, +1, -1, -1, +1, -1, +1, -1, +1\}
\end{aligned}$$

For an 80+80 MHz transmission, the primary 80 MHz frequency segment shall use the 80 MHz 1x HE-LTF sequence, $HELTF_{-500,500} = LTF_{\mathrm{80MHz\_primary\_1x}}$, and the secondary 80 MHz frequency segment shall use the 80 MHz 1x HE-LTF sequence, $HELTF_{-500,500} = LTF_{\mathrm{80MHz\_secondary\_1x}}$.

For an 80+80 MHz transmission, the primary 80 MHz frequency segment shall use the 80 MHz 2x HE-LTF sequence, $HELTF_{-500,500} = LTF_{80\text{MHz\_primary\_2x}}$, and secondary 80 MHz frequency segment shall use the 80 MHz 2x HE-LTF sequence, $HELTF_{-500,500} = LTF_{80\text{MHz\_secondary\_2x}}$.

For an 80+80 MHz transmission, the primary 80 MHz frequency segment shall use the 80 MHz 4x HE-LTF sequence, $HELTF_{-500,500} = LTF_{80\text{MHz\_primary\_4x}}$, and secondary 80 MHz frequency segment shall use the 80 MHz 4x HE-LTF sequence, $HELTF_{-500,500} = LTF_{80\text{MHz\_secondary\_4x}}$.

In an UL MU-MIMO transmission not using single stream pilots, the generation of the HE-LTF sequence per frequency segment is to mask the non-zero elements in the common HE-LTF sequence repeatedly by a distinct orthogonal code as defined by Equation (28-53).

$$HELTF_k' = HELTF_k \cdot \left[P_{8\times 8}\right]_{M_{r,u}+m,\left(\left(\left\lceil \frac{k}{N_{\text{HE-LTF-Mode}}}\right\rceil - 1\right) \bmod 8\right)+1} \tag{28-53}$$

Where $HELTF_k$ is the k-th element of the common HE-LTF sequence generated by one of the equations from (Equation (28-38) to Equation (28-56) depending on the bandwidth and the HE-LTF mode (excluding the 1x HE-LTF which shall not be masked). $\left[P_{8\times 8}\right]$ is defined in Equation (22-46). $M_{r,u}+m$ is the row of the $\left[P_{8\times 8}\right]$ corresponding to the spatial time stream of user u in the r-th RU. Depending on the HE-LTF modes, $N_{\text{HE-LTF-Mode}}$ is defined in Equation (28-54).

$$N_{\text{HE-LTF-Mode}} = \begin{cases} 2, \text{ for 2x HE-LTF} \\ 1, \text{ for 4x HE-LTF} \end{cases} \tag{28-54}$$

The generation of the time domain HE-LTF symbols per frequency segment in an HE SU PPDU, HE MU PPDU, HE extended range SU PPDU, HE trigger-based PPDU is shown in Figure 28-26 (Generation of HE-LTF symbols per frequency segment in an HE SU PPDU, HE MU PPDU, HE extended range SU PPDU and HE trigger-based PPDU) where $A^k_{\text{HE-LTF}}$ is given by Equation (28-55).

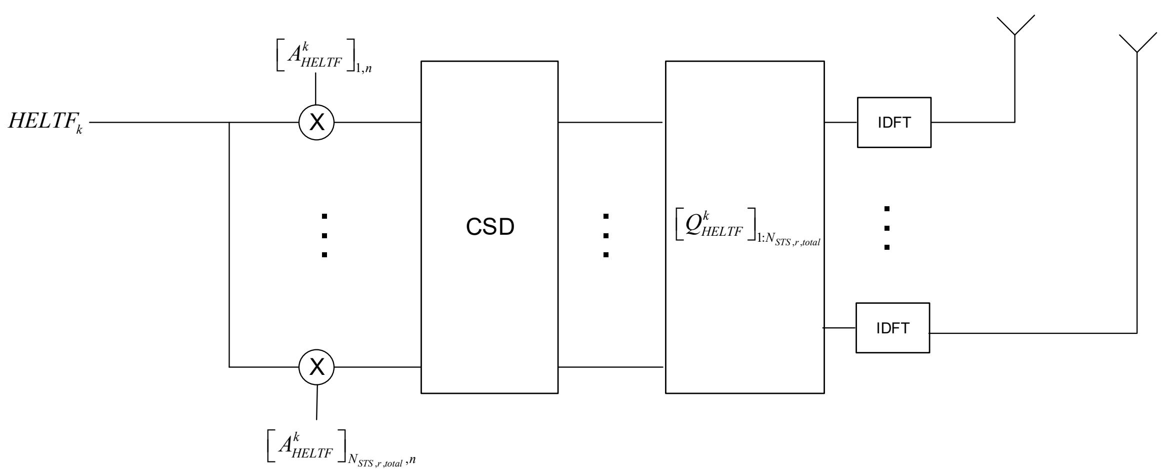


Figure 28-26—Generation of HE-LTF symbols per frequency segment in an HE SU PPDU, HE MU PPDU, HE extended range SU PPDU and HE trigger-based PPDU

The generation of time domain symbol of 1x HE-LTF is equivalent to modulating every 4 tones in an OFDM symbol of 12.8 µs excluding GI, and then only transmit the first ¼ of the OFDM symbol in the time domain, as shown in Figure 28-27 (Generation of 1x HE-LTF symbols per frequency segment).

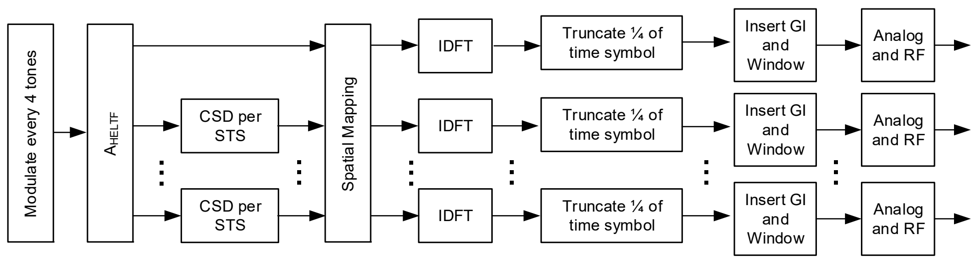


Figure 28-27—Generation of 1x HE-LTF symbols per frequency segment

The generation of time domain symbol of 2x HE-LTF is equivalent to modulating every other tone in an OFDM symbol of 12.8 µs excluding GI, and then only transmit the first half of the OFDM symbol in time domain, as shown in Figure 28-28 (Generation of 2x HE-LTF symbols per frequency segment).

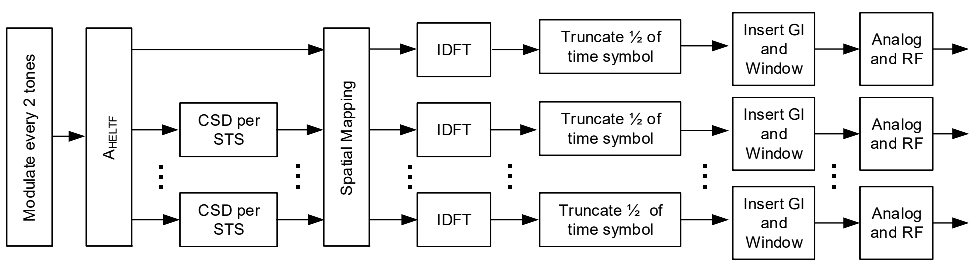


Figure 28-28—Generation of 2x HE-LTF symbols per frequency segment

$A^k_{\text{HE-LTF}}$ is given by Equation (28-55).

$$A^k_{\text{HE-LTF}} = \begin{cases} R_{\text{HE-LTF}}, \text{ if } k \in K_{\text{Pilot}} \text{ and single stream pilots are used} \\ P_{\text{HE-LTF}}, \text{ otherwise} \end{cases} \tag{28-55}$$

where

K_{Pilot} is the set of subcarrier indices for the pilot subcarriers as defined in 28.3.3.4 (Pilot subcarriers).

$R_{\text{HE-LTF}}$ is a $N_{\text{HE-LTF}} \times N_{\text{HE-LTF}}$ matrix whose elements are defined in Equation (28-56).

$$[R_{\text{HE-LTF}}]_{m,n} = [P_{\text{HE-LTF}}]_{1,n},\ 1 \le m, n \le N_{\text{HE-LTF}} \tag{28-56}$$

$P_{\text{HE-LTF}}$ is defined in Equation (28-57).

$$P_{\text{HE-LTF}} = \begin{cases} P_{4\times4}, N_{\text{HE-LTF}} \le 4 \\ P_{6\times6}, N_{\text{HE-LTF}} = 5, 6 \\ P_{8\times8}, N_{\text{HE-LTF}} = 7, 8 \end{cases} \tag{28-57}$$

where $P_{4 \times 4}$ is defined in Equation (19-27), $P_{6 \times 6}$ is defined in Equation (21-45), and $P_{8 \times 8}$ is defined in Equation (22-46).

When the 1x HE-LTF is used for non-OFDMA UL MU-MIMO, neither masking by orthogonal code nor single stream pilot are not used.

In an HE SU PPDU, HE MU PPDU and HE extended range SU PPDU, the time domain representation of the waveform transmitted on frequency segment i_{Seg} of transmit chain i_{TX} shall be as described by Equation (28-58).

$$r_{\text{HE-LTF}}^{(i_{Seg} i_{TX})}(t) = \frac{1}{\sqrt{\sum_{r=0}^{N_{RU}-1} \alpha_r^2 |K_r|}} \sum_{n=0}^{N_{\text{HE-LTF}}-1} w_{T_{\text{HE-LTF}}}(t - nT_{\text{HE-LTF}}) \sum_{r=0}^{N_{RU}-1} \frac{\alpha_r \sqrt{|K_r|}}{\sqrt{N_{STS,r,total} |K_r^{\text{HE-LTF}}|}}$$
$$\sum_{k \in K_r} \eta_{\text{HE-LTF},k} \sum_{u=0}^{N_{user,r}-1} \sum_{m=1}^{N_{STS,r,u}} \left(\begin{array}{l} \left[Q_k^{(i_{Seg})}\right]_{i_{TX},(M_{r,u}+m)} \left[A_{\text{HE-LTF}}^k\right]_{(M_{r,u}+m),(n+1)} HELTF_k'' \\ \cdot \exp(j2\pi k \Delta_{F,\text{HE}}(t - nT_{\text{HE-LTF}} - T_{GI} - T_{CS,\text{HE}}(M_{r,u}+m))) \end{array} \right) \quad (28\text{-}58)$$

In an HE trigger-based PPDU, the time domain representation of the waveform of user u in the r-th RU, transmitted on frequency segment i_{Seg} of transmit chain i_{TX} shall be as described by Equation (28-59).

$$r_{\text{HE-LTF}}^{(i_{Seg} i_{TX})}(t) = \frac{1}{\sqrt{N_{STS,r,total} |K_r^{\text{HE-LTF}}|}} \sum_{n=0}^{N_{\text{HE-LTF}}-1} w_{T_{\text{HE-LTF}}}(t - nT_{\text{HE-LTF}})$$
$$\sum_{k \in K_r} \sum_{m=1}^{N_{STS,r,u}} \left(\begin{array}{l} \left[Q_k^{(i_{Seg})}\right]_{i_{TX},(M_{r,u}+m)} \left[A_{\text{HE-LTF}}^k\right]_{(M_{r,u}+m),(n+1)} HELTF_k'' \\ \cdot \exp(j2\pi k \Delta_{F,\text{HE}}(t - nT_{\text{HE-LTF}} - T_{GI} - T_{CS,\text{HE}}(M_{r,u}+m))) \end{array} \right) \quad (28\text{-}59)$$

where

$HELTF_k'' = HELTF_k$ if single stream pilots are used or when the 1x HE-LTF is used for non-OFDMA UL MU-MIMO, and $HELTF_k'' = HELTF_k'$ if single stream pilots are not used.

α_r is the power boost factor for the r-th RU. A STA shall support α_r in the range [0.7, $\sqrt{2}$]. A STA may support α_r in the range [0.5, 2].

$\eta_{\text{HE-LTF},k}$ is an HE PPDU format dependent scaling factor, defined by

$$\eta_{\text{HE-LTF},k} = \begin{cases} \sqrt{2}, & \text{for an HE extended range SU PPDU} \\ 1, & \text{otherwise} \end{cases}$$

$N_{\text{HE-LTF}}^{\text{Tone}}$ is defined in Table 28-14 (Tone scaling factor and guard interval duration values for HE PPDU fields)

$T_{CS,\text{HE}}(M_{r,u}+m)$ represents the cyclic shift for space time stream $M_{r,u}+m$ as defined in 28.3.10.2.2 (Cyclic shift for HE modulated fields)

$Q_k^{(i_{Seg})}$ is defined in 28.3.9 (Mathematical description of signals)

$A_{\text{HE-LTF}}^k$ is defined in Equation (28-55)

K_r is the set of subcarrier indices for the tones in the r-th RU as defined in 28.3.9 (Mathematical description of signals)

When a 1x, 2x or 4x HE-LTF is transmitted, it is recommended that the spatial mapping matrix applied to HE-STF and beyond is chosen such that it preserves the smoothness of the physical channel, achieved by limiting the variation of each element's real and imaginary values in the spatial mapping matrix across successive tones within one RU.

28.3.11 Data field

28.3.11.1 General

The number of OFDM symbols in the Data field is determined by the Length field in L-SIG (see Equation (28-11)), the preamble duration and the settings of the GI+LTF Size, Pre-FEC Padding Factor and PE Disambiguity fields in the HE-SIG-A field (see 28.3.10.7 (HE-SIG-A)). Data symbols in an HE PPDU shall use a DFT period of 12.8 µs and subcarrier spacing of 78.125 kHz. Data symbols in an HE PPDU shall support guard interval durations of 0.8 µs, 1.6 µs and 3.2 µs. HE PPDUs shall have single stream pilots in the Data field. In UL MU-MIMO transmissions, all streams use the same pilot sequence.

When BCC encoding is used, the Data field shall consist of the SERVICE field, the PSDU, the tail bits, the post-FEC padding bits and the packet extension. When LDPC encoding is used, the Data field shall consist of the SERVICE field, the PSDU, the post-FEC padding bits and the packet extension. No tail bits are present when LDPC encoding is used.

The Data field of the HE PPDU contains data for one or more users.

28.3.11.2 Pre-FEC padding process

A two-step padding process is applied on all HE PPDUs. A pre-FEC padding with both MAC and PHY padding is applied before conducting FEC coding, and a post-FEC PHY padding is applied on the FEC encoded bits.

The pre-FEC padding may pad toward 4 possible boundaries in the last one (in the case of non STBC), or two (in the case of STBC) OFDM symbols of an HE PPDU, the 4 possible boundaries partition the FEC output bit stream of the last OFDM symbol(s) into 4 symbol segments. The 4 possible boundaries are represented by a pre-FEC padding factor parameter.

Figure 28-29 (HE PPDU padding process in the last OFDM symbol (non STBC) when a = 1) illustrates these 4 possible symbol segments in the last OFDM symbol of a non STBC case, and the general padding process assuming the desired pre-FEC padding boundary, pre-FEC padding factor, is 1. In the case of STBC, the FEC output bits and post-FEC padding bits are modulated into the last two OFDM symbols by STBC encoding, each with the same number of effective symbol segments.

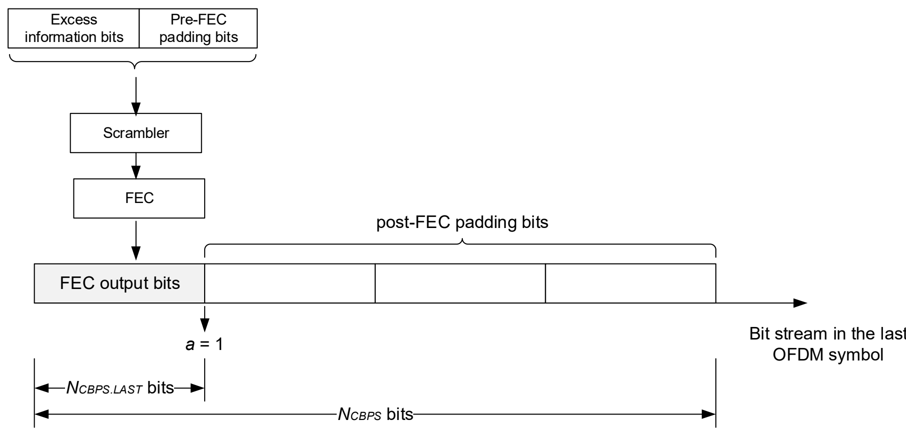


Figure 28-29—HE PPDU padding process in the last OFDM symbol (non STBC) when *a* = 1

The pre-FEC padding process is described in this subclause, and the encoding and post-FEC padding process are described in 28.3.11.5 (Coding). While this subclause describes the pre-FEC padding processing of an SU transmission, its extension to MU transmission is described in 28.3.11.5.4 (Encoding process for an HE MU PPDU).

In an HE SU PPDU transmission, the transmitter first computes the number of excess bits in the last OFDM symbol(s). Specifically, for HE SU PPDU, the number of excess bits is calculated based on Equation (28-60).

$$N_{Excess} = mod(8 \cdot \text{APEP\_LENGTH} + N_{Tail} + N_{service}, m_{STBC} \cdot N_{DBPS}) \quad (28\text{-}60)$$

where

m_{STBC} is 2 when STBC is used, and 1 otherwise
APEP_LENGTH is the TXVECTOR parameter APEP_LENGTH

Based on N_{Excess}, compute the initial number of symbol segments in the last OFDM symbol(s), pre-FEC padding factor value or a_{init}, as shown in Equation (28-61).

$$a_{init} = \begin{cases} 4, & \text{if } N_{Excess} = 0 \\ \min\left(\left\lceil \dfrac{N_{Excess}}{m_{STBC} \cdot N_{DBPS,SHORT}} \right\rceil, 4\right), & \text{otherwise} \end{cases} \quad (28\text{-}61)$$

where

$N_{DBPS,SHORT} = N_{CBPS,SHORT} \cdot R$, in which R is the coding rate, and
$N_{CBPS,SHORT} = N_{SD,SHORT} \cdot N_{SS} \cdot N_{BPSCS}$;

The parameter $N_{SD,SHORT}$ values for different RU sizes are as shown in Table 28-25 (NSD,SHORT values).

Table 28-25—$N_{SD,SHORT}$ values

RU Size	$N_{SD,SHORT}$	
	DCM = 0	DCM = 1
26-tone	6	2
52-tone	12	6
106-tone	24	12
242-tone	60	30
484-tone	120	60
996-tone	240	120
2×996-tone	492	246

Given the a_{init} values, the initial number of data bits per symbol and the initial number of coded bits per symbol in the last OFDM symbol(s) are defined in Equation (28-62).

$$N_{DBPS,\,LAST,\,init} = \begin{cases} a_{init} N_{DBPS,\,SHORT}, \text{ if } a_{init} < 4 \\ N_{DBPS}, \text{ if } a_{init} = 4 \end{cases}$$
$$N_{CBPS,\,LAST,\,init} = \begin{cases} a_{init} N_{CBPS,\,SHORT}, \text{ if } a_{init} < 4 \\ N_{CBPS}, \text{ if } a_{init} = 4 \end{cases} \tag{28-62}$$

For an HE SU PPDU, the number of pre-FEC pad bits is calculated using Equation (28-63).

$$\begin{aligned} N_{PAD,\,\text{Pre-FEC}} = {} & (N_{SYM.init} - m_{STBC})N_{DBPS} + m_{STBC}N_{DBPS,\,LAST,\,init} \\ & - 8 \cdot \text{APEP\_LENGTH} - N_{Tail} - N_{service} \end{aligned} \tag{28-63}$$

where $N_{SYM,init}$ is defined as in Equation (28-65) for BCC encoding, and Equation (28-70) for LDPC encoding.

Among the pre-FEC padding bits, the MAC delivers a PSDU that fills the available octets in the Data field of the HE PPDU, toward the desired pre-FEC padding boundary, represented by a_{init} value, in the last OFDM symbol(s). The number of pre-FEC pad bits added by MAC will always be a multiple of eight. The PHY then determines the number of remaining pad bits to add and appends them to the PSDU. The number of pre-FEC pad bits added by PHY will always be 0 to 7. The procedure is defined in Equation (28-64).

$$\begin{aligned} N_{PAD,\,\text{Pre-FEC,MAC}} &= \left\lfloor \frac{N_{PAD,\,\text{Pre-FEC}}}{8} \right\rfloor \cdot 8 \\ N_{PAD,\,\text{Pre-FEC,PHY}} &= N_{PAD,\,\text{Pre-FEC}} \bmod 8 \end{aligned} \tag{28-64}$$

28.3.11.3 SERVICE field

The SERVICE field of HE PPDU is as shown in Table 28-26 (SERVICE field).

Table 28-26—SERVICE field

Bits	Field	Description
B0-B6	Scrambler Initialization	Set to 0
B7-B15	Reserved	Set to 0

28.3.11.4 Scrambler

The SERVICE field, PSDU, and PHY padding of the Data field shall be scrambled by the scrambler defined in 17.3.5.5 (PHY DATA scrambler and descrambler). The Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) TXVECTOR parameters CH_BANDWIDTH_IN_NON_HT and DYN_BANDWIDTH_IN_NON_HT are not present and therefore the initial state of the scrambler is set to a nonzero pseudorandom seed. A different nonzero pseudorandom seed may be used for each user in an HE MU PPDU.

28.3.11.5 Coding

The Data field shall be encoded using either the binary convolutional code (BCC) defined in 28.3.11.5.1 (Binary convolutional coding and puncturing) or the low density parity check (LDPC) code defined in 28.3.11.5.2 (LDPC coding). The encoder is selected by the Coding field in HE-SIG-A in an HE SU PPDU or an HE extended range SU PPDU, or HE-SIG-B per-user subfield(s) in an HE MU PPDU, as defined in 28.3.10.7 (HE-SIG-A) and 28.3.10.8 (HE-SIG-B) respectively.

When conducting BCC FEC encoding for an HE PPDU, the number of encoders is always 1.

LDPC is the only FEC coding scheme in the HE PPDU Data field for a 484-, 996-, and 2×996-tone RU. LDPC is the only FEC coding scheme in the HE PPDU Data field for MCS10 and MCS11 in a 242- 484-, 996- and 2×996-tone RU. Support of BCC code is limited to less than or equal to four spatial streams and MCS0 to MCS9 (per user in case of MU-MIMO), and is mandatory (for both transmit and receive) for RU sizes less than or equal to a 242-tone RU(#838). Support of LDPC code (for both transmit and receive) is mandatory for HE STAs declaring support for at least one of HE 40/80/160/80+80 SU PPDU bandwidths, for HE STAs declaring support for more than 4 spatial streams, or for HE STAs declaring support for MCS10 and MCS11, according to HE capabilities field as defined in 9.4.2.218 (HE Capabilities element). Otherwise, support of LDPC code for either transmit or receive is optional.

28.3.11.5.1 Binary convolutional coding and puncturing

The information bits and pre-FEC padding bits of user u are encoded by a rate R = ½ convolutional encoder defined in 17.3.5.6 (Convolutional encoder). After encoding, the encoded data is punctured by the method defined in 17.3.5.6 (Convolutional encoder) (except for rate 5/6), to achieve the rate selected by the modulation and coding scheme. In the case that rate 5/6 coding is selected, the puncturing scheme will be the same as described in 21.3.10.5.3 (Binary convolutional coding and puncturing).

The initial number of OFDM symbols in the Data field with BCC encoding in an HE SU PPDU is calculated using Equation (28-65).

$$N_{SYM,init} = m_{STBC} \cdot \left\lceil \frac{8 \cdot \text{APEP\_LENGTH} + N_{Tail} + N_{service}}{m_{STBC} N_{DBPS}} \right\rceil \tag{28-65}$$

For an HE SU PPDU with BCC encoding,

$$N_{SYM} = N_{SYM,init} \tag{28-66}$$

and

$$a = a_{init} \tag{28-67}$$

The number of data bits per symbol in the last OFDM symbol(s) of an HE SU PPDU is $N_{DBPS,LAST} = N_{DBPS,LAST,init}$.

The number of coded bits per symbol in the last OFDM symbol(s) of an HE SU PPDU is given by Equation (28-68).

$$N_{CBPS,LAST} = \begin{cases} a \cdot N_{CBPS,SHORT}, & \text{if } a < 4 \\ N_{CBPS}, & \text{if } a = 4 \end{cases} \tag{28-68}$$

28.3.11.5.2 LDPC coding

For an HE SU PPDU using LDPC coding to encode the Data field, the LDPC code and encoding process described in 19.3.11.7 (LDPC codes) shall be used with the following modifications. First, all bits in the Data field including the scrambled SERVICE, PSDU, and pre-FEC pad bits are encoded, i.e., $N_{pld} = N_{service} + 8 \times \text{APEP\_LENGTH} + N_{PAD,Pre\text{-}FEC}$. Thus, N_{pld} for HE PPDUs shall be computed using Equation (28-69) instead of Equation (20-35).

$$N_{pld} = (N_{SYM,init} - m_{STBC})N_{DBPS} + m_{STBC}N_{DBPS,LAST,init} \tag{28-69}$$

where

$$N_{SYM.init} = m_{STBC} \cdot \left\lceil \frac{8 \cdot \text{APEP\_LENGTH} + N_{service}}{m_{STBC} \cdot N_{DBPS}} \right\rceil \tag{28-70}$$

Following the calculation of N_{pld}, N_{avbits} shall be computed using Equation (28-71) instead of Equation (20-36).

$$N_{avbits} = (N_{SYM,init} - m_{STBC}) \cdot N_{CBPS} + m_{STBC} \cdot N_{CBPS,LAST,init} \tag{28-71}$$

In addition, in step d) of LDPC encoding process as described in 19.3.11.7.5 (LDPC PPDU encoding process), if the following condition is met:

$(N_{punc} > 0.1 \times N_{CW} \times L_{LDPC} \times (1 - R))$ AND $\left(N_{shrt} < 1.2 \times N_{punc} \times \frac{R}{1 - R}\right)$ is true OR if

$N_{punc} > 0.3 \times N_{CW} \times L_{LDPC} \times (1 - R)$ is true,

then the LDPC Extra Symbol Segment field of HE-SIG-A shall be set to 1, and increment N_{avbits} by the following Equation (28-72) instead of Equations (19-39), followed by recomputing N_{punc} as in Equation (19-40):

$$N_{avbits} = \begin{cases} N_{avbits} + m_{STBC} \cdot (N_{CBPS} - 3N_{CBPS,SHORT}), & \text{if } a_{init} = 3 \\ N_{avbits} + m_{STBC} \cdot N_{CBPS,SHORT}, & \text{otherwise} \end{cases} \tag{28-72}$$

and then update a and N_{SYM} values by the following Equation (28-73):

$$\begin{cases} N_{SYM} = N_{SYM,init} + m_{STBC} \text{ and } a = 1, & \text{if } a_{init} = 4 \\ N_{SYM} = N_{SYM,init} \text{ and } a = a_{init} + 1, & \text{otherwise} \end{cases} \tag{28-73}$$

If in step d) of LDPC encoding process as described in 19.3.11.7.5 (LDPC PPDU encoding process), the above mentioned condition is not met, then the LDPC Extra Symbol Segment field in HE-SIG-A shall be set to 0, and

$$\begin{aligned} N_{SYM} &= N_{SYM,init} \\ a &= a_{init} \end{aligned} \tag{28-74}$$

With the final pre-FEC padding factor value a, update the N_{CBPS} of the last symbol as:

$$N_{CBPS,LAST} = \begin{cases} a \cdot N_{CBPS,SHORT}, & \text{if } a < 4 \\ N_{CBPS}, & \text{if } a = 4 \end{cases} \tag{28-75}$$

For completeness, the number of data bits of the last symbol $N_{DBPS,LAST} = N_{DBPS,LAST,init}$.

LDPC codes used in HE MU PPDUs shall also follow the definitions in 19.3.11.7 (LDPC codes). Refer to 28.3.11.5.4 (Encoding process for an HE MU PPDU) for a description of the LDPC encoding process for HE MU PPDUs.

28.3.11.5.3 Post-FEC padding

The number of post-FEC padding bits in each of the last m_{STBC} symbol(s) is computed by:

$$N_{PAD,POST\text{-}FEC} = N_{CBPS} - N_{CBPS,LAST} \tag{28-76}$$

The last m_{STBC} symbols shall consist of $N_{CBPS.LAST}$ bits from the FEC output followed by $N_{PAD.POST\text{-}FEC}$ post-FEC padding bits. The values of the post-FEC padding bits are not specified and are left up to implementation.

28.3.11.5.4 Encoding process for an HE MU PPDU

For an HE MU PPDU, all the users shall use a common pre-FEC padding factor value and a common N_{SYM} value. The padding process is described as follows.

First compute initial pre-FEC padding factor value ($a_{init,u}$) for each user u using Equation (28-61), and the initial number of OFDM symbols ($N_{SYM,init,u}$) for each user u using Equation (28-65) if user u is BCC encoded, or Equation (28-70) if user u is LDPC encoded. Among all the users, derive the user index with the longest encoded packet duration, as in Equation (28-77).

$$u_{\max} = \arg\max_{u=0}^{N_u - 1}(N_{SYM,init,u} - m_{STBC} + 0.25 m_{STBC} a_{init,u}) \tag{28-77}$$

where m_{STBC} is the common STBC setting among all the users, as described in 28.3.11.7 (Segment parser).

Then the common a_{init} and $N_{SYM,init}$ values among all the users are derived by Equation (28-78):

$$\begin{aligned} N_{SYM.init} &= N_{SYM,\,init,\,u_{\max}} \\ a_{init} &= a_{init,\,u_{\max}} \end{aligned} \tag{28-78}$$

Update each user's initial number of coded bits in its last symbol as below:

$$\begin{aligned} N_{DBPS,\,last,\,init,\,u} &= \begin{cases} a_{init}N_{DBPS,\,short,\,u}, \text{ if } a_{init} < 4 \\ N_{DBPS,\,u}, \text{ if } a_{init} = 4 \end{cases} \\ N_{CBPS,\,last,\,init,\,u} &= \begin{cases} a_{init}N_{CBPS,\,short,\,u}, \text{ if } a_{init} < 4 \\ N_{CBPS,\,u}, \text{ if } a_{init} = 4 \end{cases} \end{aligned} \tag{28-79}$$

For each user with LDPC encoding, the number of pre-FEC padding bits is computed as in Equation (28-80):

$$\begin{aligned} N_{PAD,\,\text{Pre-FEC},\,u} = {} & (N_{SYM,\,init} - m_{STBC})N_{DBPS,\,u} + m_{STBC}N_{DBPS,\,last,\,init,\,u} \\ & - 8 \cdot \text{APEP\_LENGTH}_u - N_{service} \end{aligned} \tag{28-80}$$

For each user with LDPC encoding, the parameters $N_{pld,u}$ and $N_{avbits,u}$ are computed using Equation (28-81) and Equation (28-82) respectively:

$$N_{pld,\,u} = (N_{SYM,\,init} - m_{STBC})N_{DBPS,\,u} + m_{STBC}N_{DBPS,\,last,\,init,\,u} \tag{28-81}$$

$$N_{avbits,\,u} = (N_{SYM,\,init} - m_{STBC})N_{CBPS,\,u} + m_{STBC}N_{CBPS,\,last,\,init,\,u} \tag{28-82}$$

For each user with LDPC encoding continue LDPC encoding process as in 19.3.11.7.5 (LDPC PPDU encoding process) starting with the parameters $N_{pld,u}$ and $_{avbits,u}$. If there is at least one user with LDPC encoding, where step d) of its LDPC encoding process of 19.3.11.7.5 (LDPC PPDU encoding process), meets the following condition:

$$(N_{punc,\,u} > 0.1 \times N_{CW,\,u} \times L_{LDPC,\,u} \times (1 - R_u)) \text{ AND } \left(N_{shrt,\,u} < 1.2 \times N_{punc,\,u} \times \frac{R_u}{1 - R_u}\right) \text{ is true OR if}$$

$$N_{punc,\,u} > 0.3 \times N_{CW,\,u} \times L_{LDPC,\,u} \times (1 - R_u) \text{ is true,}$$

where $N_{punc,u}$, $N_{CW,u}$, $L_{LDPC,u}$ and $N_{shrt,u}$ are the LDPC encoding parameters for user u, as defined in 19.3.11.7.5 (LDPC PPDU encoding process), and R_u is the coding rate of user u, then the LDPC Extra Symbol Segment field in HE-SIG-A shall be set to 1, and all the users with LDPC encoding shall increment N_{avbits} and recomputed N_{punc}, by the following two equations once:

$$N_{avbits,\,u} = \begin{cases} N_{avbits,\,u} + m_{STBC} \cdot (N_{CBPS} - 3N_{CBPS,\,short,\,u}), \text{ if } a_{init} = 3 \\ N_{avbits,\,u} + m_{STBC} \cdot N_{CBPS,\,last,\,u}, \text{ otherwise} \end{cases} \tag{28-83}$$

$$N_{punc,\,u} = \max(0, (N_{CW,\,u} \times L_{LDPC,\,u}) - N_{avbits,\,u} - N_{shrt,\,u}) \tag{28-84}$$

Update the common pre-FEC padding factor and N_{SYM} values for all users by the following equation:

$$\begin{cases} N_{SYM} = N_{SYM,\,init} + m_{STBC} \text{ and } a = 1, \text{ if } a_{init} = 4 \\ N_{SYM} = N_{SYM,\,init} \text{ and } a = a_{init} + 1, \text{ otherwise} \end{cases} \quad (28\text{-}85)$$

If among all the users with LDPC encoding, in step d) of 19.3.11.7.5 (LDPC PPDU encoding process), the above mentioned condition is not met, or if all the users in the HE MU PPDU are BCC encoded, then the LDPC Extra Symbol Segment field in HE-SIG-A shall be set to 0, and:

$$a = a_{init}, N_{SYM} = N_{SYM,\,init} \quad (28\text{-}86)$$

Note that users with BCC encoding shall also use the common N_{SYM} and pre-FEC padding parameters as in Equation (28-86).

For the users with LDPC encoding, $N_{DBPS.LAST.u} = N_{DBPS.LAST.init.u}$.

For the users with BCC encoding, update the N_{DBPS} of the last symbol as

$$N_{DBPS,\,last,\,u} = \begin{cases} a \cdot N_{DBPS,\,short,\,u}, \text{ if } a < 4 \\ N_{DBPS,\,u}, \text{ if } a = 4 \end{cases}$$

For each user with either LDPC or BCC encoding, update the N_{CBPS} of the last symbol as

$$N_{CBPS,\,last,\,u} = \begin{cases} a \cdot N_{CBPS,\,short,\,u}, \text{ if } a < 4 \\ N_{CBPS,\,u}, \text{ if } a_{init} = 4 \end{cases}$$

For the users with BCC encoding, the number of pre-FEC padding bits is shown in Equation (28-87).

$$N_{PAD,\,\text{Pre-FEC},\,u} = (N_{SYM} - m_{STBC})N_{DBPS,\,u} + m_{STBC}N_{DBPS,\,last,\,u} - 8 \cdot \text{APEP\_LENGTH}_u - N_{Tail} - N_{service} \quad (28\text{-}87)$$

For each user with either LDPC or BCC encoding, the number of post-FEC padding bits in each of the last m_{STBC} symbol(s) is computed as in Equation (28-88):

$$N_{PAD,\,\text{Post-FEC},\,u} = N_{CBPS,\,u} - N_{CBPS,\,last,\,u} \quad (28\text{-}88)$$

Among the pre-FEC padding bits, the MAC delivers a PSDU that fills the available octets in the Data field of the HE PPDU, toward the desired pre-FEC padding boundary, represented by a_{init}, in the last OFDM symbol(s). The PHY then determines the number of pad bits to add and appends them to the PSDU. The number of pre-FEC pad bits added by PHY will always be 0 to 7. The procedure is defined in Equation (28-89) and Equation (28-90).

$$N_{PAD,\,\text{Pre-FEC},\,MAC} = 8 \cdot \left\lfloor \frac{N_{PAD,\,\text{Pre-FEC}}}{8} \right\rfloor \quad (28\text{-}89)$$

$$N_{PAD,\,\text{Pre-FEC},\,PHY} = N_{PAD,\,\text{Pre-FEC}} \bmod 8 \quad (28\text{-}90)$$

28.3.11.5.5 Encoding process for an HE trigger-based PPDU

The AP indicates the common N_{SYM}, pre-FEC padding factor, STBC indication and LDPC Extra Symbol Segment fields in the Trigger frame.

For an HE trigger-based PPDU with BCC encoding, follow the HE SU PPDU padding and encoding process as introduced in 28.3.11.2 (Pre-FEC padding process), 28.3.11.5.1 (Binary convolutional coding and puncturing), and 28.3.11.5.3 (Post-FEC padding), with initial parameters setting to $N_{SYM.init} = N_{SYM}$, and $a_{init} = a$, where N_{SYM} and a are the common number of symbols and pre-FEC padding factor indicated in the Trigger frame, respectively.

For an HE trigger-based PPDU with LDPC encoding, follow the HE SU PPDU padding and encoding process as introduced in 28.3.11.2 (Pre-FEC padding process), 28.3.11.5.2 (LDPC coding), and 28.3.11.5.3 (Post-FEC padding), with the following exceptions:

When the LDPC Extra Symbol Segment field in the Trigger frame is 1, set the initial parameters following Equation (28-91):

$$\begin{cases} a_{init} = 4 \text{ and } N_{SYM,init} = N_{SYM} - m_{STBC}, & \text{if } a = 1 \\ a_{init} = a - 1 \text{ and } N_{SYM,init} = N_{SYM}, & \text{otherwise} \end{cases} \tag{28-91}$$

where N_{SYM} and a are the common number of symbols and pre-FEC padding factor indicated in the Trigger frame respectively, and m_{STBC} is 2 if the Trigger frame indicates STBC and 1 otherwise. Then continue with the LDPC encoding process as in 20.3.11.7.5 (LDPC PPDU encoding process), during which in step d) of 20.3.11.7.5 (LDPC PPDU encoding process), always increment N_{avbits} as in Equation (28-72), and always recompute N_{punc} as in Equation (19-40).

When the LDPC Extra Symbol Segment field in the Trigger frame is 0, set initial parameters to $N_{SYM,init} = N_{SYM}$, and $a_{init} = a$, where N_{SYM} and a are the common number of symbols and pre-FEC padding factor indicated in the Trigger frame respectively. Then continue with the LDPC encoding process as in 20.3.11.7.5 (LDPC PPDU encoding process), during which in step d) of 20.3.11.7.5 (LDPC PPDU encoding process), N_{avbits} and N_{punc} are not changed, and $a = a_{init}$.

28.3.11.6 Stream parser

After coding, scrambling, puncturing and post-FEC padding, the data bit streams at the output of the FEC encoder are processed in groups of N_{CBPS} bits. Each of these groups is re-arranged into N_{SS} blocks of N_{CBPSS} bits ($N_{SS,u}$ blocks of $N_{CBPSS,u}$ bits in the case of an HE MU transmission). This operation is referred to as “stream parsing” and is described in this subclause.

The description is given in terms of an SU transmission. For MU transmissions, the rearrangements are carried out in the same way per user.

The number of bits assigned to a single axis (real or imaginary) in a constellation point in a spatial stream is denoted by Equation (28-92).

$$s = max\left(1, \frac{N_{BPSCS}}{2}\right) \tag{28-92}$$

The sum of these over all streams is $S = N_{SS} \cdot s$.

Consecutive blocks of s bits are assigned to different spatial streams in a round robin fashion.

For the N_{CBPS} bits of each OFDM symbol, S bits from the output of the encoder are divided among all spatial streams, s bits per stream.

Note that for all RU sizes the coded bits of each OFDM symbol are always evenly allocated to N_{SS} spatial streams.

The following equations are an equivalent description to the above procedure. Bit i at the output of the encoder is assigned to input bit k of spatial stream i_{SS} where

$$i = (i_{SS} - 1)s + S \cdot \left\lfloor \frac{k}{s} \right\rfloor + (k \bmod s)$$

$$i_{SS} = 1, 2, \ldots, N_{SS}$$

$$i = 0, 1, \ldots, N_{CBPS} - 1$$

$$k = 0, 1, \ldots, N_{CBPSS} - 1$$

28.3.11.7 Segment parser

The description in this subclause is for an SU transmission. For an MU transmissions, the rearrangements are carried out in the same way but per user.

For a 20 MHz, 40 MHz, 80 MHz, 160 MHz and 80+80 MHz transmission with a 26-, 52-, 106-, 242-, 484- or 996-tone RU, the segment parser is bypassed and the output bits of each stream parser are as specified in Equation (28-93).

$$y_{k,l} = x_k \tag{28-93}$$

where

x_k	is bit k of a block of N_{CBPSS} bits, $k = 0$ to $N_{CBPSS} - 1$
l	is the frequency subblock index and $l = 0$ for a 26-, 52-, 106-, 242-, 484- and 996-tone RU.
$y_{k,l}$	is bit k of the frequency subblock l

For a 160 MHz and 80+80 MHz transmission with a 2×996-tone RU, the output bits of each stream parser are first divided into blocks of N_{CBPSS} bits ($N_{CBPSS,u}$ bits in the case of an MU transmission). Then, each block is further divided into two frequency subblocks of $N_{CBPSS}/2$ bits as shown in Equation (28-94).

$$y_{k,l} = x_m \tag{28-94}$$

$$m = 2s \cdot \left\lfloor \frac{k}{s} \right\rfloor + l \cdot s + (k \bmod s), \quad k = 0, 1, \ldots, \frac{N_{CBPSS}}{2} - 1 \tag{28-95}$$

and

x_m	is bit m of a block of N_{CBPSS} bits and $m = 0, ..., N_{CBPSS} - 1$
l	is the frequency subblock index and $l = 0, 1$
$y_{k,l}$	is bit k of the frequency subblock l
s	is defined in Equation (28-92)

28.3.11.8 BCC interleavers

For ease of explanation, the operation of the interleaver is described only for the SU case. For user u of an MU transmission, the interleaver operates in the same way on the output bits for the user from the stream parser by replacing N_{SS}, N_{CBPSS}, N_{CBPS}, and N_{BPSCS} with $N_{SS,u}$, $N_{CBPSS,u}$, $N_{CBPS,u}$ and $N_{BPSCS,u}$, respectively. That is, the operation of the interleaver is the same as if the transmission were an SU one, consisting of bits from only that user.

The BCC interleaver operation is specified in 21.3.10.8 (BCC interleaver). When DCM is used with BPSK modulation in a 106-tone RU or a 242-tone RU with $N_{SS} = 1$, after the $2 \times N_{DBPS}$ coded bits in each OFDM symbol, 1 padding bit is added before the bits are interleaved. (The interleaver parameters, N_{COL}, N_{ROW}, and N_{ROT}, for the Data field depend on the RU size and whether or not DCM is used and are defined in the RU size column of Table 28-27 (BCC interleaver parameters).

Table 28-27—BCC interleaver parameters

DCM	Parameter	RU size (tones)				HE-SIG-A/ HE-SIG-B (tones)
		26	52	106	242	56
Not used	N_{COL}	8	16	17	26	13
	N_{ROW}	$3 \times N_{BPSCS}$	$3 \times N_{BPSCS}$	$6 \times N_{BPSCS}$	$9 \times N_{BPSCS}$	$4 \times N_{BPSCS}$
	N_{ROT} $(2 \le N_{SS} \le 4)$	2	11	29	58	-
Used	N_{COL}	4	8	17	13	13
	N_{ROW}	$3 \times N_{BPSCS}$	$3 \times N_{BPSCS}$	$3 \times N_{BPSCS}$	$9 \times N_{BPSCS}$	$2 \times N_{BPSCS}$
	N_{ROT} $(N_{SS} = 2)$	2	2	11	29	-

The interleaver parameters, N_{COL} and N_{ROW}, for the HE-SIG-A and HE-SIG-B fields are defined in the HE-SIG-A/HE-SIG-B column of Table 28-27 (BCC interleaver parameters).

NOTE—DCM is not used on the HE-SIG-A field.

28.3.11.9 Constellation mapping

The mapping between the input bits of the constellation mapper and complex constellation points for BPSK, QPSK, 16-QAM, 64-QAM and 256-QAM is as defined in 21.3.10.9 (Constellation mapping).

1024-QAM is optional for SU and MU for RUs equal to or larger than 242 subcarriers. For 1024-QAM, the mapping of the bits at the output of the interleaver to the complex constellation points is defined in Figure 28-30 (Constellation bit encoding for 1024-QAM (1st quadrant)), Figure 28-31 (Constellation bit encoding for 1024-QAM (2nd quadrant)), Figure 28-32 (Constellation bit encoding for 1024-QAM (3rd quadrant)) and Figure 28-33 (Constellation bit encoding for 1024-QAM (4th quadrant)).

Figure 28-30—Constellation bit encoding for 1024-QAM (1st quadrant)

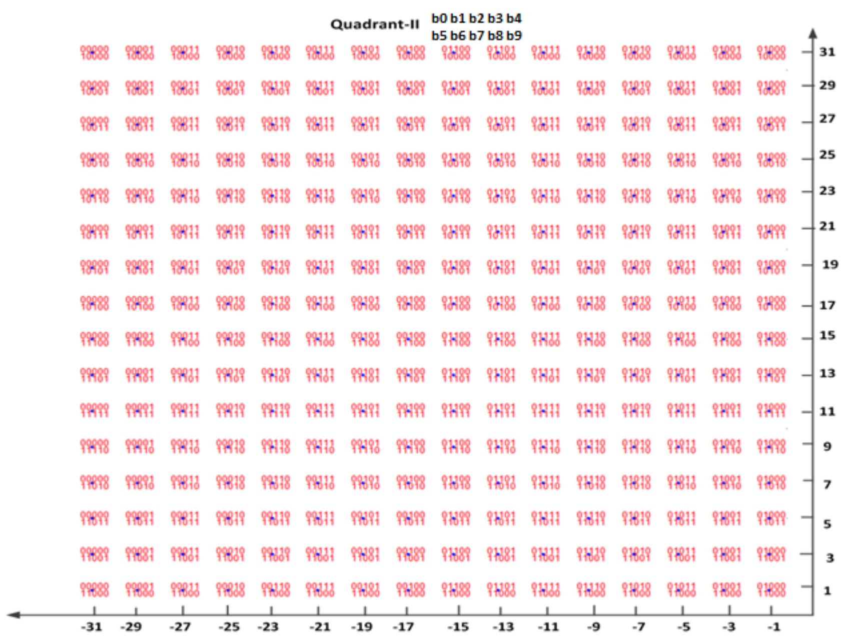


Figure 28-31—Constellation bit encoding for 1024-QAM (2nd quadrant)

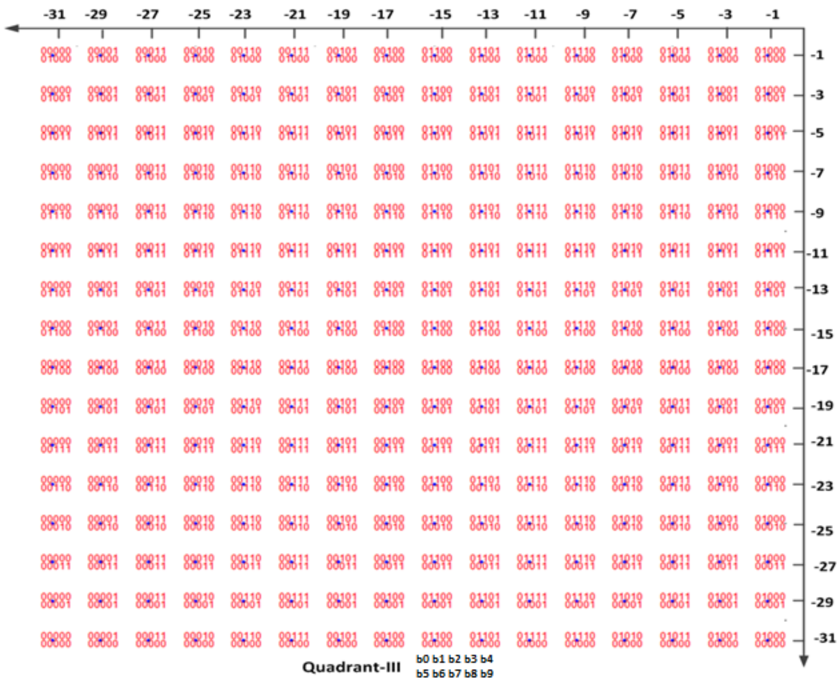


Figure 28-32—Constellation bit encoding for 1024-QAM (3rd quadrant)

Figure 28-33—Constellation bit encoding for 1024-QAM (4th quadrant)

The normalization factor K_{mod} for 1024 QAM is $1/\sqrt{682}$.

Dual subcarrier modulation (DCM) is an optional modulation scheme for the HE-SIG-B and Data fields. DCM can be applied to an HE SU PPDU and an HE extended range SU PPDU. In an HE MU PPDU, DCM can be applied only to RUs containing data for 1 user.

DCM is only applied to MCS0, MCS 1, MCS 3 and MCS 4. DCM is applied only with $N_{SS} = 1$ or $N_{SS} = 2$ (in the case of single user RU in an HE MU PPDU, $N_{SS,r,u} = 1$ or $N_{SS,r,u} = 2$). DCM is not applied with MU-MIMO or with STBC.

When DCM is employed, bit sequences are mapped to a pair symbols $(d_k, d_{q(k)})$ where k is in the range of $0 \le k \le N_{SD} - 1$ and $q(k)$ is in the range of $N_{SD} \le q(k) \le 2N_{SD} - 1$ in order to exploit frequency diversity for a and $0 \le k \le N_{SD}/2 - 1$ and $q(k)$ is in the range of $N_{SD}/2 \le q(k) \le N_{SD} - 1$ for a 2×996-tone RU. To maximize the frequency diversity, the indices of a pair of DCM subcarriers $(k, q(k))$ is $q(k) = k + N_{SD}$. The N_{SD} here refers to the N_{SD} with DCM = 1, which is half the value of N_{SD} with DCM = 0.

For BPSK modulation with DCM, the input stream is broken into groups of N_{CBPS} or $N_{CBPS,u}$ bits $(B_0, B_1, \ldots, B_{N_{CBPS,u} - 1})$. Each bit B_k is BPSK modulated to a sample d_k. This generates the samples for the lower half of the data subcarriers. For the upper half of the subcarriers, the samples are generated as $d_{k + N_{SD}} = d_k \times e^{j(k + N_{SD})\pi}, k = 0, 1, \ldots, N_{SD} - 1$. The N_{SD} here refers to the N_{SD} with DCM = 1, which is half the value of N_{SD} with DCM = 0.

For QPSK modulation with DCM, the input stream is broken into groups of N_{CBPS} or $N_{CBPS,u}$ bits $(B_0, B_1, \ldots, B_{N_{CBPS,u} - 1})$. Each pair of bits (B_{2k}, B_{2k+1}) is QPSK modulated to a symbol d_k. This generates the constellation points for the lower half the data subcarriers in the RU. For the upper half of the data sub-carriers in the RU, $d_{k + N_{SD}} = conj(d_k)$.

For 16-QAM modulation with DCM, the input stream is broken into groups of N_{CBPS} or $N_{CBPS,u}$ bits $(B_0, B_1, \ldots, B_{N_{CBPS,u} - 1})$. A group of 4 bits $(B_{4k}, B_{4k+1}, B_{4k+2}, B_{4k+3})$ is 16-QAM modulated to a sample d_k as described in 18.3.5.8. This is the sample on subcarrier k in the lower half. In the upper half, the sample $d_{k + N_{SD}}$ on subcarrier $k + N_{SD}$ is obtained by 16-QAM modulating a permutation of the bits $(B_{4k}, B_{4k+1}, B_{4k+2}, B_{4k+3})$. Specifically, $d_{k + N_{SD}}$ is obtained by applying the 16-QAM modulation procedure in 18.3.5.8 to the bit group $(B_{4k+1}, B_{4k}, B_{4k+3}, B_{4k+2})$. he N_{SD} here refers to the N_{SD} with DCM = 1, which is half the value of N_{SD} with DCM = 0.

28.3.11.10 Space-time block coding

This subclause defines a set of optional robust transmission techniques that are applicable only when using STBC coding. For an HE PPDU, STBC is allowed only with single spatial stream and two space-time streams, and its application is as indicated by the STBC bit in HE-SIG-A. In an HE MU PPDU, STBC coding is used in all RUs or not used in any of the RUs. If in an RU, DL MU-MIMO is applied, STBC shall not be used in any RU in the HE MU PPDU.

The STBC encoding process is as described in 22.3.10.9.4 (Space-time block coding), with $N_{SS,0} = 1$ and $N_{STS,0} = 2$.

28.3.11.11 LDPC tone mapper

The LDPC tone mapping shall be performed on all LDPC encoded streams mapped in an RU as described in this subclause. LDPC tone mapping shall not be performed on streams that are encoded using BCC. When DCM is applied to LDPC encoded streams, $D_{\mathrm{TM\_DCM}}$ shall be applied on both the lower half data subcarriers in an RU and the upper half data subcarriers of the RU. The LDPC tone-mapping distance parameters D_{TM} and D_{TM_DCM} are constant for each RU size and the values for different RU sizes are given in Table 28-28 (LDPC tone mapping distance for each RU size).

Table 28-28—LDPC tone mapping distance for each RU size

Parameter	RU Size (tones)						
	26	52	106	242	484	996	2×996
D_{TM}	1	3	6	9	12	20	20
D_{TM_DCM}	1	1	3	9	9	14	14

NOTE—The LDPC tone mapping parameters D_{TM} and D_{TM_DCM} are applied for each frequency subblock, $l = 0$ and $l = 1$.

For an HE PPDU without DCM, the LDPC tone mapping for the LDPC encoded stream for user u in the r-th RU is done by permuting the stream of complex numbers generated by the constellation mappers (see 28.3.11.9 (Constellation mapping)) as defined by Equation (28-96).

$$d''_{t(k), i, n, l, r, u} = d'_{k, i, n, l, r, u} \tag{28-96}$$

where

$$k = \begin{cases} 0, 1, \ldots, N_{SD} - 1 \text{ for a 26-, 52-, 106-, 242-, 484- and 996-tone RU} \\ 0, 1, \ldots, N_{SD}/2 - 1 \text{ for a 2x996-tone RU} \end{cases}$$

$$i = 1, \ldots, N_{SS, r, u}$$

$$n = 0, 1, \ldots, N_{SYM} - 1$$

$$l = \begin{cases} 0 \text{ for a 26-, 52-, 106-, 242-, 484- and 996-tone RU} \\ 0, 1 \text{ for a 2x996-tone RU} \end{cases}$$

$$u = 0, \ldots, N_{user, r} - 1$$

$$r = 0, \ldots, N_{RU} - 1$$

N_{SD} is the number of data tones in the r-th RU

$$t(k) = \begin{cases} D_{TM}\left(k \bmod \dfrac{N_{SD}}{D_{TM}}\right) + \left\lfloor \dfrac{k \cdot D_{TM}}{N_{SD}} \right\rfloor, \text{ for a 26-, 52-, 106-, 242-, 484- and 996-tone RU} \\ D_{TM}\left(k \bmod \dfrac{N_{SD}/2}{D_{TM}}\right) + \left\lfloor \dfrac{k \cdot D_{TM}}{N_{SD}/2} \right\rfloor, \text{ for a 2x996-tone RU} \end{cases}$$

For an HE PPDU with DCM, the LDPC tone mapping for the LDPC encoded stream corresponding to user u in the r-th RU is done by permuting the stream of complex numbers generated by the constellation mappers (see 25.3.10.7) as defined by Equation (28-97).

$$d''_{t(k), i, n, l, r, u} = d'_{k, i, n, l, r, u} \tag{28-97}$$

where

$$k = \begin{cases} 0, 1, \ldots, 2N_{SD} - 1 \text{ for a 26-, 52-, 106-, 242-, 484- and 996-tone RU} \\ 0, 1, \ldots, N_{SD} - 1 \text{ for a 2x996-tone RU} \end{cases}$$

$$i = 1, \ldots, N_{SS, r, u}$$

$$n = 0, 1, \ldots, N_{SYM} - 1$$

$$l = \begin{cases} 0 \text{ for a 26-, 52-, 106-, 242-, 484- and 996-tone RU} \\ 0, 1 \text{ for a 2x996-tone RU} \end{cases}$$

$$u = 0, \ldots, N_{user, r} - 1$$

$$r = 0, \ldots, N_{RU} - 1$$

N_{SD} is the number of data tones in the r-th RU when DCM is applied

For a 26-, 52-, 106-, 242-, 484- and 996-tone RU,

$$t(k) = \begin{cases} D_{TM\_DCM}\left(k \bmod \dfrac{N_{SD}}{D_{TM\_DCM}}\right) + \left\lfloor \dfrac{k \cdot D_{TM\_DCM}}{N_{SD}} \right\rfloor, \text{ for } k < N_{SD} \\ D_{TM\_DCM}\left((k - N_{SD}) \bmod \dfrac{N_{SD}}{D_{TM\_DCM}}\right) + \left\lfloor \dfrac{(k - N_{SD}) \cdot D_{TM\_DCM}}{N_{SD}} \right\rfloor + N_{SD}, \text{ for } k \geq N_{SD} \end{cases}$$

For a 2x996-tone RU,

$$t(k) = \begin{cases} D_{TM\_DCM}\left(k \bmod \dfrac{N_{SD}/2}{D_{TM\_DCM}}\right) + \left\lfloor \dfrac{k \cdot D_{TM\_DCM}}{N_{SD}/2} \right\rfloor, \text{ for } 0 \leq k < N_{SD}/2 - 1 \\ D_{TM\_DCM}\left((k - N_{SD}/2) \bmod \dfrac{N_{SD}/2}{D_{TM\_DCM}}\right) + \left\lfloor \dfrac{(k - N_{SD}/2) \cdot D_{TM\_DCM}}{N_{SD}/2} \right\rfloor + N_{SD}/2, \text{ for } N_{SD}/2 \leq k \leq N_{SD} - 1 \end{cases}$$

D_{TM_DCM} is the LDPC tone mapping distance for the r-th RU when DCM is applied.

NOTE—LDPC tone mapper for a 26-, 52-, 106-, 242-, 484- and 996-tone RU is defined as one segment. LDPC tone mapping is performed separately for the upper and lower 80 MHz frequency segments of a 2×996-tone RU as indicated by the frequency subblock index l in Error! Reference source not found. and Error! Reference source not found.

Since LDPC tone mapping is not performed on BCC-coded streams, for BCC-coded streams, Equation (28-98) applies.

$$d''_{k, i, n, l, r, u} = d'_{k, i, n, l, r, u} \tag{28-98}$$

where

$$k = \begin{cases} 0, 1, \ldots, N_{SD} - 1 \text{ for a 26-, 52-, 106-, 242-, 484- and 996-tone RU} \\ 0, 1, \ldots, N_{SD}/2 - 1 \text{ for a 2x996-tone RU} \end{cases}$$

$$i = 1, \ldots, N_{SS, r, u}$$

$$n = 0, 1, \ldots, N_{SYM} - 1$$

$$l = \begin{cases} 0 \text{ for a 26-, 52-, 106-, 242-, 484- and 996-tone RU} \\ 0, 1 \text{ for a 2x996-tone RU} \end{cases}$$

$$u = 0, \ldots, N_{user, r} - 1$$

$$r = 0, \ldots, N_{RU} - 1$$

28.3.11.12 Segment deparser

For a 26-, 52-, 106-, 242-, 484- and 996-tone RU, the segment deparsing is not performed and $d^{(i_{Seg})}_{k, i, n, l, r, u}$ is specified in Equation (28-99).

$$d^{(i_{Seg})}_{k, i, n, l, r, u} = d''_{k, i, n, 0, r, u}, \quad \text{if } 0 \le k \le N_{SD} - 1, \; i_{Seg} = 0 \tag{28-99}$$

For a 2×996-tone RU in a 160 MHz HE PPDU, the two frequency subblocks at the output of the LDPC tone mapper are combined into one frequency segment as specified in Equation (28-100).

$$d^{(i_{Seg})}_{k, i, n, l, r, u} = \begin{cases} d''_{k, i, n, 0, r, u}, & \text{if } 0 \le k \le \dfrac{N_{SD}}{2} - 1 \\ d''_{k - \frac{N_{SD}}{2}, i, n, l, r, u}, & \text{if } \dfrac{N_{SD}}{2} \le k \le N_{SD} - 1 \end{cases}, \; i_{Seg} = 0 \tag{28-100}$$

For a 2×996-tone RU in an 80+80 MHz HE PPDU, the segment deparsing is not performed and $d^{(i_{Seg})}_{k, i, n, l, r, u}$ is specified in Equation (28-101).

$$d^{(i_{Seg})}_{k, i, n, r, u} = d''_{k, i, n, i_{Seg}, r, u}, \quad \text{if } 0 \le k \le N_{SD} - 1, \; i_{Seg} = 0, 1 \tag{28-101}$$

NOTE—As per Table 21-7 (center frequency for frequency segment iSeg = 0), $f_c^{(0)}$ is always less than $f_c^{(1)}$ in case of 80+80 MHz HE PPDU. Hence, $d''_{k, i, n, 0, r, u}$ (frequency subblock 0) is always transmitted in the frequency segment lower in frequency, while $d''_{k, i, n, 1, r, u}$ (frequency subblock 1) is always transmitted in the frequency segment higher in frequency.

28.3.11.13 Pilot subcarriers

For a user transmitting on the *i*-th 26-tone RU in a given PPDU BW, two pilot subcarriers shall be inserted in subcarriers $k \in K_{R26_i}$, where K_{R26_i} is given by the *i*-th pilot index set in the row of given PPDU BW of Table 28-29 (Pilot indices for a 26-tone RU).

Table 28-29—Pilot indices for a 26-tone RU

PPDU BW	K_{R26_i}
20 MHz, *i* = 1:9	−116/−102, −90/−76, −62/−48, −36/−22, −10/10, 22/36, 48/62, 76/90, 102/116

Table 28-29—Pilot indices for a 26-tone RU *(continued)*

40 MHz, i = 1:18	−238/−224, −212/−198, −184/−170, −158/−144, −130/−116, −104/−90, −78/−64, −50/−36, −24/−10, 10/24, 36/50, 64/78, 90/104, 116/130, 144/158, 170/184, 198/212, 224/238
80 MHz, i = 1:37	−494/−480, −468/−454, −440/−426, −414/−400, −386/−372, −360/−346, −334/−320, −306/−292, −280/−266, −252/−238, −226/−212, −198/−184, −172/−158, −144/−130, −118/−104, −92/−78, −64/−50, −38/−24, −10/10, 24/38, 50/64, 78/92, 104/118, 130/144, 158/172, 184/198, 212/226, 238/252, 266/280, 292/306, 320/334, 346/360, 372/386, 400/414, 426/440, 454/468, 480/494
160 MHz, i = 1:74	{pilot subcarrier indices in 80 MHz −512, pilot subcarrier indices in 80 MHz +512}

The pilot mapping P_n^k for the subcarrier k for symbol n shall be as specified in Equation (28-102).

$$\begin{aligned} P_n^{K_{R26_i}} &= \{\Psi_{n \bmod 2}, \Psi_{(n+1) \bmod 2}\} \\ P_n^{k \notin K_{R26_i}} &= 0 \end{aligned} \tag{28-102}$$

where

Ψ_m is defined in Table 28-30 (The 2 pilot values for a 26-tone RU)

Table 28-30—The 2 pilot values for a 26-tone RU

Ψ_0	Ψ_1
1	−1

For a user transmitting on the i-th 52-tone RU in a given PPDU BW, four pilot subcarriers shall be inserted in subcarriers $k \in K_{R52_i}$, where K_{R52_i} is given by the i-th pilot index set in the row of given PPDU BW of Table 28-31 (Pilot indices for 52-tone RU transmission).

Table 28-31—Pilot indices for 52-tone RU transmission

PPD BW	K_{R52_i}
20 MHz, i = 1:4	−116/−102/−90/−76, −62/−48/−36/−22, 22/36/48/62, 76/90/102/116
40 MHz, i = 1:8	−238/−224/−212/−198, −184/−170/−158/−144, −104/−90/−78/−64, −50/−36/−24/−10, 10/24/36/50, 64/78/90/104, 144/158/170/184, 198/212/224/238
80 MHz, i = 1:16	−494/−480/−468/−454, −440/−426/−414/−400, −360/−346/−334/−320, −306/−292/−280/−266, −252/−238/−226/−212, −198/−184/−172/−158, −118/−104/−92/−78, −64/−50/−38/−24, 24/38/50/64, 78/92/104/118, 158/172/184/198, 212/226/238/252, 266/280/292/306, 320/334/346/360, 400/414/426/440, 454/468/480/494
160 MHz, i = 1:32	{pilot subcarrier indices in 80 MHz −512, pilot subcarrier indices in 80 MHz +512}

The pilot mapping P_n^k for the subcarrier k for symbol n shall be as specified in Equation (28-103).

$$P_n^{K_{R52_i}} = \{\Psi_{n \bmod 4}, \Psi_{(n+1) \bmod 4}, \Psi_{(n+2) \bmod 4}, \Psi_{(n+3) \bmod 4}\}$$
$$P_n^{k \notin K_{R52_i}} = 0 \quad (28\text{-}103)$$

where

Ψ_m is defined in Table 28-32 (The 4 pilot values in a 52- and 106-tone RU)

Table 28-32—The 4 pilot values in a 52- and 106-tone RU

Ψ_0	Ψ_1	Ψ_2	Ψ_3
1	1	1	–1

For a user transmitting on the *i*-th 106-tone RU in a given PPDU BW, four pilot subcarriers shall be inserted in subcarriers $k \in K_{R106_i}$, where K_{R106_i} is given by the *i*-th pilot index set in the row of given PPDU BW of Table 28-33 (Pilot indices for 106-tone RU transmission).

Table 28-33—Pilot indices for 106-tone RU transmission

PPD BW	K_{R106_i}
20 MHz, *i* = 1:2	–116/–90/–48/–22, 22/48/90/116
40 MHz, *i* = 1:4	–238/–212/–170/–144, –104/–78/–36/–10, 10/36/78/104, 144/170/212/238
80 MHz, *i* = 1:8	–494/–468/–426/–400, –360/–334/–292/–266, –252/–226/–184/–158, –118/–92/–50/–24, 24/50/92/118, 158/184/226/252, 266/292/334/360, 400/426/468/494
160 MHz, *i* = 1:16	{pilot subcarrier indices in 80 MHz –512, pilot subcarrier indices in 80 MHz +512}

The pilot mapping P_n^k for the subcarrier *k* for symbol *n* shall be as specified in Equation (28-104).

$$P_n^{K_{R106_i}} = \{\Psi_{n \bmod 4}, \Psi_{(n+1) \bmod 4}, \Psi_{(n+2) \bmod 4}, \Psi_{(n+3) \bmod 4}\}$$
$$P_n^{k \notin K_{R106_i}} = 0 \quad (28\text{-}104)$$

where

Ψ_m is defined in Table 28-32 (The 4 pilot values in a 52- and 106-tone RU)

For a user transmitting on the *i*-th 242-tone RU in a given PPDU BW, eight pilot subcarriers shall be inserted in subcarriers $k \in K_{R242_i}$, where K_{R242_i} is given by the *i*-th pilot index set in the row of given PPDU BW of Table 28-34 (Pilot indices for 242-tone RU transmission).

Table 28-34—Pilot indices for 242-tone RU transmission

PPD BW	K_{R242_i}
20 MHz, *i* = 1	–116/–90/–48/–22/22/48/90/116
40 MHz, *i* = 1:2	–238/–212/–170/–144/–104/–78/–36/–10, 10/36/78/104/144/170/212/238
80 MHz, *i* = 1:4	–494/–468/–426/–400/–360/–334/–292/–266,–252/–226/–184/–158/–118/–92/–50/–24, 24/50/92/118/158/184/226/252, 266/292/334/360/400/426/468/494
160 MHz, *i* = 1:8	{pilot subcarrier indices in 80 MHz –512, pilot subcarrier indices in 80 MHz +512}

The pilot mapping P_n^k for the subcarrier *k* for symbol *n* shall be as specified in Equation (28-105).

$$P_n^{K_{R242_i}} = \{\Psi_{n \bmod 8}, \Psi_{n+1 \bmod 8}, \Psi_{n+2 \bmod 8}, \Psi_{n+3 \bmod 8}, \Psi_{(n+4) \bmod 8}, \Psi_{(n+5) \bmod 8}, \Psi_{(n+6) \bmod 8}, \Psi_{(n+7) \bmod 8}\}$$
$$P_n^{k \notin K_{R242_i}} = 0 \tag{28-105}$$

where

Ψ_m is defined in Table 28-35 (The 8 pilot values in a 242-tone RU)

Table 28-35—The 8 pilot values in a 242-tone RU

Ψ_0	Ψ_1	Ψ_2	Ψ_3	Ψ_4	Ψ_5	Ψ_6	Ψ_7
1	1	1	–1	–1	1	1	1

For a 484-tone RU transmission, the pilot mapping for 8 pilots in 242-tone RU is replicated in the two 242-RUs of the 484-tone RU transmission. Specifically, for a user transmitting on the *i*-th 484-tone RU in a given PPDU BW, sixteen pilot subcarriers shall be inserted in subcarriers $k \in K_{R484_i}$, where K_{R484_i} is given by the *i*-th pilot index set in the row of given PPDU BW of Table 28-36 (Pilot indices for 484-tone RU transmission).

Table 28-36—Pilot indices for 484-tone RU transmission

PPD BW	K_{R484_i}

Table 28-36—Pilot indices for 484-tone RU transmission *(continued)*

40 MHz, i = 1	–238/–212/–170/–144/–104/–78/–36/–10/10/36/78/104/144/170/212/238
80 MHz, i = 1:2	–494/–468/–426/–400/–360/–334/–292/–266/–252/–226/–184/–158/–118/–92/–50/–24, 24/50/92/118/158/184/226/252/266/292/334/360/400/426/468/494
160 MHz, i = 1:4	{pilot subcarrier indices in 80 MHz −512, pilot subcarrier indices in 80 MHz +512}

The pilot mapping P_n^k for the subcarrier k for symbol n shall be as specified in Equation (28-106).

$$\begin{aligned} P_n^{K_{R484_i}} = \{&\Psi_{n \bmod 8}, \Psi_{n+1 \bmod 8}, \Psi_{n+2 \bmod 8}, \Psi_{n+3 \bmod 8}, \\ &\Psi_{(n+4) \bmod 8}, \Psi_{(n+5) \bmod 8}, \Psi_{(n+6) \bmod 8}, \Psi_{(n+7) \bmod 8}, \\ &\Psi_{(n+8) \bmod 8}, \Psi_{(n+9) \bmod 8}, \Psi_{(n+10) \bmod 8}, \Psi_{(n+11) \bmod 8}, \\ &\Psi_{(n+12) \bmod 8}, \Psi_{(n+13) \bmod 8}, \Psi_{(n+14) \bmod 8}, \Psi_{(n+15) \bmod 8}\} \\ P_n^{k \notin K_{R484_i}} = 0& \end{aligned} \tag{28-106}$$

where

Ψ_m is defined in Table 28-35 (The 8 pilot values in a 242-tone RU)

For a 996-tone RU transmission, the pilot mapping for its 16 pilots is the same as the mapping for 484-tone RU transmission. Specifically, for a user transmitting on the i-th 996-tone RU in a given PPDU BW, sixteen pilot subcarriers shall be inserted in subcarriers $k \in K_{R996_i}$, where K_{R996_i} is given by the i-th pilot index set in the row of given PPDU BW of Table 28-37 (Pilot indices for 996-tone RU transmission).

Table 28-37—Pilot indices for 996-tone RU transmission

PPD BW	K_{R996_i}
80 MHz, i = 1	–468/–400/–334/–266/–226/–158/–92/–24/24/92/158/226/266/334/400/468
160 MHz, i = 1:2	{for i = 1 pilot subcarrier indices in 80 MHz −512, for i = 2 pilot subcarrier indices in 80 MHz +512}

The pilot mapping P_n^k for the subcarrier k for symbol n shall be as specified in Equation (28-107).

$$\begin{aligned} P_n^{K_{R996_i}} = \{&\Psi_{n \bmod 8}, \Psi_{(n+1) \bmod 8}, \Psi_{(n+2) \bmod 8}, \Psi_{(n+3) \bmod 8}, \\ &\Psi_{(n+4) \bmod 8}, \Psi_{(n+5) \bmod 8}, \Psi_{(n+6) \bmod 8}, \Psi_{(n+7) \bmod 8}, \\ &\Psi_{(n+8) \bmod 8}, \Psi_{(n+9) \bmod 8}, \Psi_{(n+10) \bmod 8}, \Psi_{(n+11) \bmod 8}, \\ &\Psi_{(n+12) \bmod 8}, \Psi_{(n+13) \bmod 8}, \Psi_{(n+14) \bmod 8}, \Psi_{(n+15) \bmod 8}\} \\ P_n^{k \notin K_{R996_i}} = 0& \end{aligned} \tag{28-107}$$

where

Ψ_m is defined in Table 28-35 (The 8 pilot values in a 242-tone RU)

For a 160 MHz transmission (equivalently two 996-tone RU transmissions), the 80 MHz (equivalently 996-tone RU) pilot mapping is replicated in the two 80 MHz subchannels of the 160 MHz transmission. Specifically, 32 pilot subcarriers shall be inserted in subcarriers $k \in K_{\mathrm{R2x996}_i}$, where K_{R2x996_i} is given by $\{-980, -912, -846, -778, -738, -670, -604, -536, -488, -420, -354, -286, -246, -178, -112, -44, 44, 112, 178, 246, 286, 354, 420, 488, 536, 604, 670, 738, 778, 846, 912, 980\}$. The pilot mapping P_n^k for the subcarrier k for symbol n shall be as specified in Equation (28-108).

$$
\begin{aligned}
P_n^{K_{R2x996_i}} = \{ & \Psi_{n \bmod 8}, \Psi_{(n+1) \bmod 8}, \Psi_{(n+2) \bmod 8}, \Psi_{(n+3) \bmod 8}, \\
& \Psi_{(n+4) \bmod 8}, \Psi_{(n+5) \bmod 8}, \Psi_{(n+6) \bmod 8}, \Psi_{(n+7) \bmod 8}, \\
& \Psi_{(n+8) \bmod 8}, \Psi_{(n+9) \bmod 8}, \Psi_{(n+10) \bmod 8}, \Psi_{(n+11) \bmod 8}, \\
& \Psi_{(n+12) \bmod 8}, \Psi_{(n+13) \bmod 8}, \Psi_{(n+14) \bmod 8}, \Psi_{(n+15) \bmod 8}, \\
& \Psi_{n \bmod 8}, \Psi_{(n+1) \bmod 8}, \Psi_{(n+2) \bmod 8}, \Psi_{(n+3) \bmod 8}, \\
& \Psi_{(n+4) \bmod 8}, \Psi_{(n+5) \bmod 8}, \Psi_{(n+6) \bmod 8}, \Psi_{(n+7) \bmod 8}, \\
& \Psi_{(n+8) \bmod 8}, \Psi_{(n+9) \bmod 8}, \Psi_{(n+10) \bmod 8}, \Psi_{(n+11) \bmod 8}, \\
& \Psi_{(n+12) \bmod 8}, \Psi_{(n+13) \bmod 8}, \Psi_{(n+14) \bmod 8}, \Psi_{(n+15) \bmod 8} \} \\
P_n^{k \notin K_{R2x996_i}} = {} & 0
\end{aligned}
\tag{28-108}
$$

where

Ψ_m is defined in Table 28-35 (The 8 pilot values in a 242-tone RU)

For a noncontiguous 80+80 MHz transmission, each frequency segment shall follow the 80 MHz pilot subcarrier allocation and values defined for 996-tone RU in 80 MHz transmission as specified in Equation (28-107).

The above pilot mapping shall be copied to all space-time streams before the space-time stream cyclic shifts are applied.

28.3.11.14 OFDM modulation

The time domain waveform of the Data field of an HE PPDU that is not an HE trigger-based PPDU, from transmit chain i_{TX}, $1 \le i_{TX} \le N_{TX}$ and frequency segment i_{Seg}, shall be as defined in Equation (28-109).

$$
\begin{aligned}
r_{\text{HE-Data}}^{(i_{Seg} i_{TX})}(t) = {} & \frac{1}{\sqrt{\sum_{r=1}^{N_{RU}} \alpha_r^2 |K_r|}} \sum_{n=0}^{N_{SYM}-1} w_{T_{\text{HE-Data}}}(t - nT_{SYM}) \sum_{r=0}^{N_{RU}-1} \frac{\alpha_r}{\sqrt{N_{STS,r,total}}} \\
& \sum_{k \in K_r} \sum_{u=0}^{N_{user,r}-1} \sum_{m=1}^{N_{STS,r,u}} \left(\begin{array}{l} \left[Q_k^{(i_{Seg})} \right]_{i_{TX}, (M_{r,u}+m)} (\tilde{D}_{k,m,n,r}^{(i_{Seg},u)} + p_{n+2+N_{\text{HE-SIG-A}}+N_{\text{HE-SIG-B}}} P_n^k) \\ \cdot \exp(j 2\pi k \Delta_{F,\text{HE}}(t - nT_{SYM} - T_{GI,Data} - T_{CS,\text{HE}}(M_{r,u}+m))) \end{array} \right)
\end{aligned}
\tag{28-109}
$$

where

p_n is defined in 17.3.5.10 (OFDM modulation)

P_n^k is defined in 28.3.11.13 (Pilot subcarriers)

$T_{CS,\,\mathrm{HE}}(M_{r,\,u}+m)$ represents the cyclic shift for space time stream $M_{r,u}+m$ as defined in 28.3.10.2.2 (Cyclic shift for HE modulated fields)

$T_{GI,\,Data}$ is the guard interval duration as defined in Table 28-9 (Timing-related constants)

$\tilde{D}_{k,\,m,\,n,\,r}^{(i_{Seg},\,u)}$ is the transmitted constellation for user u in the r-th RU at subcarrier k, space-time stream m, and Data field OFDM symbol n and is defined by Equation (28-110).

$$\tilde{D}_{k,\,m,\,n,\,r}^{(i_{Seg},\,u)} = \begin{cases} 0, k \in K_{\mathrm{Pilot}} \\ \tilde{d}_{M_r(k),\,m,\,n,\,r,\,u}^{(i_{Seg})}, \text{otherwise} \end{cases} \quad (28\text{-}110)$$

where

K_{Pilot} is the set of subcarrier indices of pilot subcarriers, as defined in 28.3.3.4 (Pilot subcarriers)

$M_r(k)$ is defined in Equation (28-111)

$$M_r(k) = k - K_{r,\,\min} - \left|\{k' : K_{r,\,\min} \le k' < k\} \cap K_{\mathrm{Pilot}}\right| \quad (28\text{-}111)$$

where

$K_{r,min}$ is the minimum value of the set K_r

$|\Phi|$ is the cardinality of a set Φ

NOTE – $M_r(k)$ translates a subcarrier index k ($-N_{SR} \le k \le N_{SR}$) into the index of data symbols in a transmission over an RU ($0 \le M_r(k) \le N_{SD,r}$). The subcarrier index k for the data tone is first offset by the minimum value of subcarrier index $K_{r,min}$ (for the lower edge tone) in this RU, and then subtracted by the number of pilot subcarriers falling in between the data tone and the edge tone.

In a noncontiguous 80+80 MHz transmission, each frequency segment shall follow the 80 MHz HE subcarrier mapping as specified in 28.3.9 (Mathematical description of signals).

The time domain waveform of the Data field of an HE trigger-based PPDU for user u in the r-th RU from transmit chain i_{TX}, $1 \le i_{TX} \le N_{TX}$ shall be as defined in Equation (28-112).

$$\begin{aligned} r_{\text{HE-Data}}^{(i_{Seg} i_{TX})}(t) &= \frac{1}{\sqrt{|K_r|}} \sum_{n=0}^{N_{SYM}-1} w_{T_{\text{HE-Data}}}(t - nT_{SYM}) \frac{1}{\sqrt{N_{STS,\,r,\,total}}} \\ &\sum_{k \in K_r} \sum_{m=1}^{N_{STS,\,r,\,u}} \left(\left[Q_k^{(i_{Seg})}\right]_{i_{TX},\,(M_{r,\,u}+m)} (\tilde{D}_{k,\,m,\,n,\,r}^{(i_{Seg},\,u)} + p_{n+4} P_n^k) \cdot \exp(j 2\pi k \Delta_{F,\,\mathrm{HE}}(t - nT_{SYM} - T_{GI,\,Data} - T_{CS,\,HE}(M_{r,\,u}+m))) \right) \end{aligned} \quad (28\text{-}112)$$

where

$Q_k^{(i_{Seg})}$ is a spatial mapping/steering matrix with N_{TX} rows and $N_{STS,r,total}$ columns for subcarrier k in frequency segment i_{Seg}. $Q_k^{(i_{Seg})}$ may be frequency dependent, and the dimension may be variant in each RU. Refer to the descriptions in 22.3.10.11.1 (Transmission in VHT format) for examples of $Q_k^{(i_{Seg})}$.

28.3.11.15 Dual carrier modulation

Dual carrier modulation (DCM) modulates the same information on a pair of sub-carriers. DCM is an optional modulation scheme for the HE-SIG-B and Data fields. DCM is only applied to BPSK, QPSK and 16-QAM modulations.

The constellation mapper for DCM is defined in 28.3.11.9 (Constellation mapping). The LDPC tone mapper for DCM is defined in 28.3.11.11 (LDPC tone mapper). The BCC interleaver for DCM is defined in 28.3.11.8 (BCC interleavers).

28.3.12 Packet extension

An HE PPDU may have a Packet Extension (PE) field appended at the end of the PPDU, with possible durations being 0 µs, 4 µs, 8 µs, 12 µs, or 16 µs. The PE field, when present, shall be transmitted with the same average power as the Data field, and its content is arbitrary.

The PE field is applied for the recipient of the PPDU to obtain longer processing time at the end of an HE PPDU, and its duration is determined by both the pre-FEC padding factor value in the last OFDM symbol(s) of the Data field, and the maximum PE duration requested by the recipient for the signal bandwidth (or RU size), the number of spatial streams, and the constellation size of the current PPDU, which is based on the PPE Thresholds field in HE Capabilities element (see 9.4.2.218 (HE Capabilities element)).

For an HE PPDU, the maximum PE durations as defined by the PPE Thresholds field in the HE Capabilities element (see 9.4.2.218 (HE Capabilities element)) are 0 µs, 8 µs and 16 µs.

— A 0 µs maximum PE duration means no PE is present.
— A 8 µs maximum PE duration means that a PE field of 0 µs, 0 µs, 4 µs, and 8 µs are appended at the end of the PPDU, corresponding to a pre-FEC padding factor of 1, 2, 3 and 4, respectively, as shown in Figure 28-34 (PE field when maximum PE duration is 8 µs (non STBC)).
— A 16 µs maximum PE duration means that a PE field of 4 µs, 8 µs, 12 µs, and 16 µs are appended at the end of the PPDU, corresponding to a pre-FEC padding factor of 1, 2, 3 and 4, respectively, as shown in Figure 28-35 (PE field when maximum PE duration is 16 µs (non STBC)).

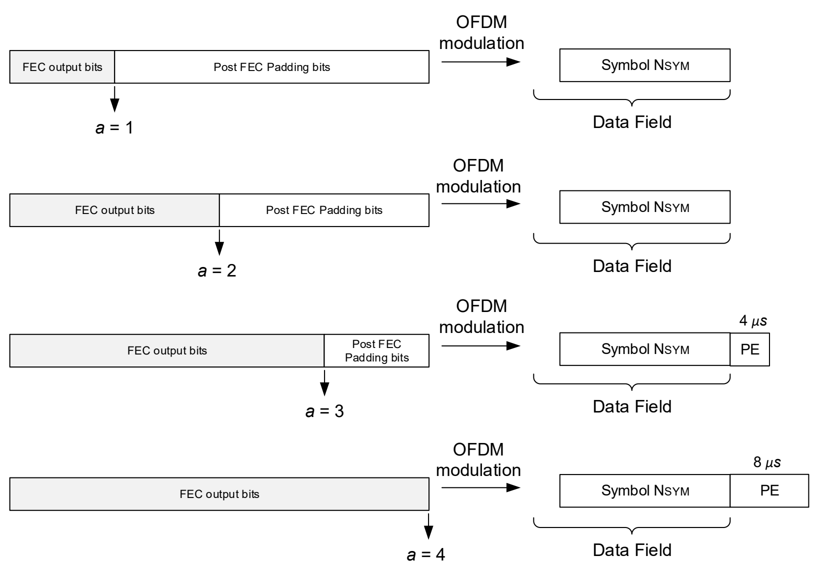


Figure 28-34—PE field when maximum PE duration is 8 µs (non STBC)

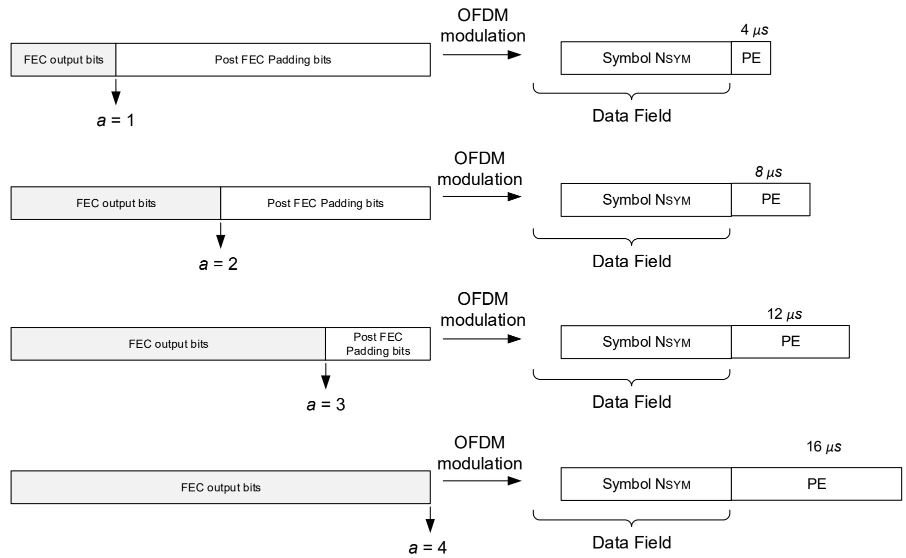


Figure 28-35—PE field when maximum PE duration is 16 μs (non STBC)

For an HE MU PPDU, the AP computes the PE duration, $T_{PE,u}$, for each user u, according to the common pre-FEC padding factor value among all users as described in 28.3.11.5.4 (Encoding process for an HE MU PPDU), the Maximum PE Duration capabilities, the RU size, the number of spatial streams and constellation size for user u. The AP shall choose the largest PE duration among all the users as the common PE duration of the current HE MU PPDU as:

$$T_{PE} = \max_u(T_{PE,u}) \tag{28-113}$$

and then append the PE field at the end of the current HE MU PPDU, with duration T_{PE}.

For an HE trigger-based PPDU, the AP indicates the packet extension duration information for all users in the Packet Extension subfield in the Common Info field of the Trigger frame. The first two bits in the Packet Extension subfield indicate the pre-FEC padding factor and the third bit indicates the PE-Disambiguity. Each user, when responding to the Trigger frame with an HE trigger-based PPDU, shall append PE field at the end of the current HE trigger-based PPDU, with a duration T_{PE}. The value of T_{PE} can be calculated using Equation (28-114).

$$T_{PE} = \left\lfloor \frac{\left(\frac{\text{LENGTH} + m + 3}{3} \times 4 - T_{\text{RL-SIG}} - T_{\text{HE-SIG-A}} - T_{\text{HE-PREAMBLE}}\right) - N_{SYM}T_{SYM}}{4} \right\rfloor \times 4 \tag{28-114}$$

where

$$N_{SYM} = \left\lfloor \left(\frac{\text{LENGTH} + m + 3}{3} \times 4 - T_{\text{RL-SIG}} - T_{\text{HE-SIG-A}} - T_{\text{HE-PREAMBLE}}\right) / T_{SYM} \right\rfloor - b_{\text{PE-Disambiguity}}$$

LENGTH is the value indicated by Length subfield of the Common Info field in the Trigger frame

$b_{\text{PE-Disambiguity}}$ is B2 of the Packet Extension subfield of the Common Info field in the Trigger frame

$T_{\text{HE-PREAMBLE}} = T_{\text{HE-STF-T}} + N_{\text{HE-LTF}} T_{\text{HE-LTF},SYM}$

$T_{\text{HE-STF-T}}$, $T_{\text{HE-LTF},SYM}$, $T_{\text{RL-SIG}}$ and $T_{\text{HE-SIG-A}}$ are defined in Table 28-9 (Timing-related constants)

Editor's Note: The HE-SIG-A bits definition below should be moved into 28.3.10.7 (HE-SIG-A)

The 3-bit Packet Extension field in HE-SIG-A are defined as in Table 28-38 (Packet Extension field in HE-SIG-A).

Table 28-38—Packet Extension field in HE-SIG-A

Name	bits	Definition
Pre-FEC Padding Factor	B0-B1	Indicates the pre-FEC padding factor value of the current PPDU
PE Disambiguity	B2	Indicates PE disambiguity

The Pre-FEC Padding Factor subfield of the Packet Extension field is encoded as shown in Table 28-39 (Pre-FEC Padding Factor subfield encoding).

Table 28-39—Pre-FEC Padding Factor subfield encoding

Pre-FEC padding factor value	Pre-FEC Padding Factor subfield encoding
1	b01
2	b10
3	b11
4	b00

The PE Disambiguity subfield of the Packet Extension field shall be set to 1 if the condition in Equation (28-115) is met, otherwise it shall be set to 0.

$$T_{PE} + 4 \times \left(\left\lceil \frac{\mathrm{TXTIME} - SignalExtension - 20}{4} \right\rceil - \left(\frac{\mathrm{TXTIME} - SignalExtension - 20}{4} \right) \right) \geq T_{SYM} \tag{28-115}$$

where

T_{PE} is the PE field duration

T_{SYM} is the symbol duration of the Data field as defined in 28.3.8 (Timing-related parameters)

TXTIME (in µs) is defined in 28.4.2 (TXTIME and PSDU_LENGTH calculation)

SignalExtension is 0 µs when TXVECTOR parameter NO_SIG_EXTN is true and is aSignalExtension as defined in Table 19-25 (HT PHY characteristics) when TXVECTOR parameter NO_SIG_EXTN is false

The receiver computes N_{SYM} and T_{PE} using Equation (28-116) and Equation (28-117), respectively.

$$N_{SYM} = \left\lfloor \left(\frac{\mathrm{L\_LENGTH} + m + 3}{3} \times 4 - T_{\text{HE-PREAMBLE}} \right) / T_{SYM} \right\rfloor - b_{\text{PE-Disambiguity}} \tag{28-116}$$

$$T_{PE} = \left\lfloor \frac{\left(\frac{\text{L\_LENGTH} + m + 3}{3} \times 4 - T_{\text{HE-PREAMBLE}}\right) - N_{SYM}T_{SYM}}{4} \right\rfloor \times 4 \qquad (28\text{-}117)$$

where

$$T_{\text{HE-PREAMBLE}} = \begin{cases} T_{\text{RL-SIG}} + T_{\text{HE-SIG-A}} + T_{\text{HE-STF-T}} + N_{\text{HE-LTF}}T_{\text{HE-LTF},\,SYM}, \text{ for an HE trigger-based PPDU} \\ T_{\text{RL-SIG}} + T_{\text{HE-SIG-A}} + T_{\text{HE-STF-NT}} + N_{\text{HE-LTF}}T_{\text{HE-LTF},\,SYM}, \text{ for an HE SU PPDU} \\ T_{\text{RL-SIG}} + T_{\text{HE-SIG-A}} + N_{\text{HE-SIG-B}}T_{\text{HE-SIG-B}} + T_{\text{HE-STF-NT}} + N_{\text{HE-LTF}}T_{\text{HE-LTF},\,SYM}, \text{ for an HE MU PPDU} \\ T_{\text{RL-SIG}} + T_{\text{HE-SIG-A}} + T_{\text{HE-SIG-A-R}} + T_{\text{HE-STF-NT}} + N_{\text{HE-LTF}}T_{\text{HE-LTF},\,SYM}, \text{ for an HE extended range SU PPDU} \end{cases}$$

$T_{\text{RL-SIG}}$, $T_{\text{HE-STF-T}}$, $T_{\text{HE-STF-NT}}$, $T_{\text{HE-LTF,SYM}}$, $T_{\text{HE-SIG-A}}$, $T_{\text{HE-SIG-A-R}}$, $T_{\text{HE-SIG-B}}$ are defined in Table 28-9 (Timing-related constants)

$N_{\text{HE-SIG-B}}$, $N_{\text{HE-LTF}}$ are defined in Table 28-12 (Frequently used parameters)

$b_{\text{PE-Disambiguity}}$ is PE Disambiguity subfield in the Packet Extension subfield of the HE-SIG-A field

28.3.13 Non-HT duplicate transmission

When the TXVECTOR parameter FORMAT is NON_HT and the TXVECTOR parameter NON_HT_MODULATION is NON_HT_DUP_OFDM, the transmitted PPDU is a non-HT duplicate. Non-HT duplicate transmission is used to transmit to non-HT OFDM STAs, HT STAs, VHT STAs and HE STAs that may be present in a part of a 40 MHz, 80 MHz, or 160 MHz channel (see Table 21-2 (Interpretation of FORMAT, NON_HT Modulation and CH_BANDWIDTH parameters)). The RL-SIG, HE-SIG-A, HE-SIG-B, HE-STF, and HE-LTF fields are not transmitted. The L-STF, L-LTF, and L-SIG fields shall be transmitted in the same way as in the HE transmission when the TXVECTOR parameter BEAM_CHANGE is 0, with the exceptions for the Rate and Length fields which shall follow 17.3.4 (SIGNAL field).

In a 40 MHz non-HT duplicate transmission, the Data field shall be as defined by Equation (28-60).

For 80 MHz and 160 MHz non-HT duplicate transmissions, the Data field shall be as defined by Equation (21-101).

In a noncontiguous 80+80 MHz non-HT duplicate transmission, data transmission in each frequency segment shall be as defined for an 80 MHz non-HT duplicate transmission in Equation (21-101).

28.3.14 Transmit requirements for an HE trigger-based PPDU

28.3.14.1 Introduction

HE trigger-based PPDU transmissions are preceded by a Trigger frame from the AP. Since multiple transmitters take part in an HE trigger-based PPDU transmission, it requires transmission time, frequency, sampling symbol clock, and power pre-correction by the participating STAs to mitigate the synchronization related issues at the AP. Frequency and sampling clock pre-corrections are needed to prevent inter-carrier interference. Power pre-correction is required to control interference among participating STAs HE trigger-based PPDU transmission. An AP can schedule in the same HE trigger-based PPDU transmission both Class A and Class B devices. A STA participating in HE trigger-based PPDU transmissions shall support power pre-correction described in 28.3.14.2 (Power pre-correction) and shall meet pre-correction accuracy requirements described in 28.3.14.3 (Pre-correction accuracy requirements).

28.3.14.2 Power pre-correction

An AP indicates in the AP Tx Power subfield of the Common Info field in Trigger frame the combined transmit power of all the transmit antennas used to transmit the Trigger frame normalized to 20 MHz bandwidth. An AP indicates in the Target RSSI subfield of the User Info field in Trigger frame the target receive signal power averaged over the AP's antennas for the HE trigger-based PPDU.

Each STA that is scheduled in the Trigger frame calculates UL transmit power, Tx_{pwr}^{STA}, of the HE trigger-based PPDU for the assigned MCS using Equation (28-118).

$$Tx_{pwr}^{STA} = PL_{DL} + Target_{RSSI} \tag{28-118}$$

where PL_{DL} represents DL pathloss and $Target_{RSSI}$ represents target receive signal power averaged over the AP's antennas for the HE trigger-based PPDU. $Target_{RSSI}$ is dBm value of Target RSSI subfield of User Info field in Trigger frame, the encoding of which is specified in Table 9-25g (Target RSSI subfield encoding). Note that an encoded value of 127 in Target RSSI subfield indicates to the STA to transmit an HE trigger-based PPDU at its maximum transmit power for the assigned MCS.

Each STA computes PL_{DL} using Equation (28-119).

$$PL_{DL} = Tx_{pwr}^{AP} - DL_{RSSI} \tag{28-119}$$

where Tx_{pwr}^{AP} represents AP's combined transmit power of all the transmit antennas used to transmit the Trigger frame normalized to 20 MHz bandwidth and DL_{RSSI} represents measured received power from the legacy preamble portion of the Trigger frame at the STA, also normalized to 20 MHz bandwidth. Tx_{pwr}^{AP} is dBm value of AP Tx Power subfield of the Common Info field in Trigger frame, the encoding of which is specified in Table 9-25e (AP Tx Power subfield encoding). DL_{RSSI} is an average of the received power over the antennas on which the average PL_{DL} is being computed.

A STA that applies beamforming (BF) in the UL should take the BF gain into account when calculating the transmit power needed to meet the target RSSI.

The UL transmit power of HE trigger-based PPDU is further subject to a STA's minimum and maximum transmit power limit due to hardware capability, regulatory requirements and local maximum transmit power levels (see 11.8.5 (Specification of regulatory and local maximum transmit power levels)) as well as non-802.11 in-device coexistence requirements.

Each STA that is scheduled in the Trigger frame transmits UL Power headroom HR_{STA} in the HE trigger-based PPDU to assist in the AP's MCS selection. The UL power headroom for the assigned MCS is defined in Equation (28-120).

$$HR_{STA} = Tx_{pwr}^{Max} - Tx_{pwr}^{STA} \tag{28-120}$$

where Tx_{pwr}^{Max} and Tx_{pwr}^{STA} represent maximum UL transmit power of HE trigger-based PPDU for the assigned MCS and current UL transmit power of HE trigger-based PPDU for the assigned MCS, respectively. HR_{STA} is dB value of UL Headroom in HE trigger-based PPDU, the encoding of which is specified in 9.2.4.6.4.6 (UL power headroom). Note that the MSB bit of the UL Headroom subfield being set to 1 indicates that the STA is transmitting the HE trigger-based PPDU at its minimum Tx_{pwr}^{STA} for the assigned MCS.

28.3.14.3 Pre-correction accuracy requirements

A STA that transmits an HE trigger-based PPDU shall support per chain max(P–32, –10 dBm) as the minimum transmit power, with P the maximum power the STA can transmit at the antenna connector of that chain using MCS 0 while meeting the TX EVM and spectral mask requirements. A STA transmitting at and above the minimum power shall support the EVM requirements for MCS 7.

A STA that transmits an HE trigger-based PPDU shall support the absolute transmit power requirements and the RSSI measurement accuracy requirements defined in Table 28-40 (Transmit power and RSSI measurement accuracy). The absolute transmit power accuracy is applicable for the entire range of transmit

Table 28-40—Transmit power and RSSI measurement accuracy

Parameter	Minimum Requirement		Comments
	Class A	Class B	
Absolute transmit power accuracy	±3 dB	±9 dB	Accuracy of achieving a specified transmit power
RSSI measurement accuracy	±3 dB	±5 dB	The difference between the RSSI and the received power Requirements are valid from minimum Rx to maximum Rx input power
Relative transmit power accuracy	-	±3 dB	Accuracy of achieving a change in transmit power for consecutive HE trigger-based PPDU The relative transmit power accuracy is applicable only to Class B devices.

power that the STA is capable of. The RSSI accuracy requirements shall be applied to receive signal level range from –82 dBm to –20 dBm in 2.4 GHz and –82 dBm to –30 dBm in 5 GHz. The requirements are for nominal (room) temperature conditions. The RSSI shall be measured during the reception of the PHY legacy preamble

A STA that transmits an HE trigger-based PPDU shall pre-compensate for carrier frequency offset (CFO) error and symbol clock error. After compensation, the absolute value of residual CFO error with respect to the PPDU carrying the associated Trigger frame shall not exceed 350 Hz for data subcarriers when measured as the 10% point of CCDF of CFO errors in AWGN at a received power of –60 dBm in the primary 20 MHz. The residual CFO error measurement shall be made on the HE trigger-based PPDU following the HE-SIG-A field. The symbol clock error shall be pre-compensated by the same ppm amount as CFO error.

A STA that transmits an HE trigger-based PPDU shall have timing accuracy of ±0.4 µs relative to the actual ending time of the PPDU carrying the Trigger frame. This requirement does not include round trip delay.

28.3.15 SU-MIMO and DL MU-MIMO beamforming

28.3.15.1 General

For SU-MIMO and DL MU-MIMO beamforming in RU r, the receive signal vector in subcarrier k (where subcarrier k is one of the subcarriers in RU r, $k \in K_r$) at beamformee u, $\boldsymbol{y}_{k,u} = [y_{k,0}, y_{k,1}, \ldots, y_{k,N_{RX_u}-1}]^T$, is shown in Equation (28-121), where $\boldsymbol{x}_k = [\boldsymbol{x}_{k,0}^T, \boldsymbol{x}_{k,1}^T, \ldots, \boldsymbol{x}_{k,N_{user,r}-1}^T]^T$ denotes the transmit signal vector in subcarrier k for all N_{user} beamformees, with $\boldsymbol{x}_{k,u} = [x_{k,0}, x_{k,1}, \ldots, x_{k,N_{STS,r,u}-1}]^T$ being the transmit signal for beamformee u.

$$\boldsymbol{y}_{k,u} = \boldsymbol{H}_{k,u} \times [Q_{k,0}, Q_{k,1}, \ldots, Q_{k,N_{user}-1}] \times \boldsymbol{x}_k + \boldsymbol{n} \tag{28-121}$$

where

$\boldsymbol{H}_{k,u}$	is the channel matrix from the beamformer to beamformee u in subcarrier k with dimensions $N_{RX_u} \times N_{TX}$
N_{RX_u}	is the number of receive antennas at beamformee u
$Q_{k,u}$	is a steering matrix for beamformee u in subcarrier k with dimensions $N_{TX} \times N_{STS,r,u}$
$N_{user,r}$	is the number of HE MU PPDU recipients (see Table 28-12 (Frequently used parameters)) in RU r
$\boldsymbol{n}$	is a vector of additive noise and may include interference

The DL MU-MIMO steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \ldots, Q_{k,N_{user,r}-1}]$ can be determined by the beamformer using the beamforming feedback for subcarrier k from beamformee u, where $u = 0, 1, \ldots, N_{user,r}-1$. The feedback report format is described in 9.4.1.63 (HE Compressed Beamforming Report field) and 9.4.1.64 (HE MU Exclusive Beamforming Report field). The steering matrix that is computed (or updated) using new beamforming feedback from some or all of participating beamformees might replace the existing steering matrix Q_k for the next DL MU-MIMO data transmission.

For SU-MIMO beamforming, the steering matrix Q_k can be determined from the beamforming feedback matrix V_k that is sent back to the beamformer by the beamformee using the compressed beamforming feedback matrix format as defined in 19.3.12.3.6 (Compressed beamforming feedback matrix). The feedback report format is described in 9.4.1.63 (HE Compressed Beamforming Report field).

28.3.15.2 Beamforming feedback matrix *V*

Upon receipt of an HE NDP PPDU, the beamformee computes a set of matrices for feedback to the beamformer as described in 21.3.11.2 (Beamforming Feedback Matrix V). The eligible beamformees shall remove the space-time stream CSD in Table 21-11 (Cyclic shift values for the VHT modulated fields of a PPDU) from the measured channel before computing a set of matrices for feedback to the beamformer.

The beamforming feedback matrix, $V_{k,u}$, found by the beamformee u for subcarrier k in RU r shall be compressed in the form of angles using the method described in 19.3.12.3.6 (Compressed beamforming feedback matrix). The angles, $\phi(k,v)$ and $\psi(k,u)$, are quantized according to Table 9-68 (Quantization of angles). The number of bits for quantization is set by the beamformer, i.e., HE AP. The number of bits for quantization, tone grouping factor, and the number of columns in the HE Compressed beamforming feedback are set by the beamformee, i.e., non-AP STA, only if the NDP Announcement frame contains only one STA Info field. The compressed beamforming feedback matrix as defined in 19.3.12.3.6 (Compressed beamforming feedback matrix) is the only Clause 28 beamforming feedback matrix defined.

The beamformee shall generate the beamforming feedback matrices with the number of rows (*Nr*) equal to the N_{STS} of the NDP.

After receiving the angle information, $\phi(k,v)$ and $\psi(k,u)$, the beamformer reconstructs $V_{k,u}$ using Equation (19-79). For SU-MIMO beamforming, the beamformer uses $V_{k,0}$, matrix to determine the steering matrix Q_k. For MU-MIMO beamforming, the beamformer may calculate a steering matrix $Q_k = [Q_{k,0}, Q_{k,1}, \ldots, Q_{k,N_{user,r}-1}]$ using $V_{k,u}$ and $SNR_{k,u}$ ($0 \le u \le N_{user,r}-1$) in order to suppress crosstalk between participating beamformees. The method used by the beamformer to calculate the steering matrix Q_k is implementation specific.

28.3.15.3 CQI-only feedback

Whenever the HE NDP Announcement frame is requesting a CQI-only feedback, upon receipt of the HE NDP, the beamformee computes HE CQI-only feedback as described in 9.4.1.64. The CQI-only feedback $CQI_{s,r,u}$, in RU *r* for space time stream s shall be estimated using the method described in 9.4.1.65 (HE CQI-only Report field). The CQI values to be fed back are derived from quantized SNRs according to Table 9-76h (Average SNR of RU index k for space-time stream i subfield). The beamformee shall transmit the HE CQI-only feedback for space-time stream $1, \ldots, Nc$ for each of the RU indices for which the CQI-only report is being requested by the beamformer. After receiving the CQI information, the beamformer may use it to identify the best range of RUs for compressed beamforming feedback or for RU assignment during subsequent MU transmissions. The actual use is implementation specific.

28.3.16 HE preamble format for sounding PPDUs

NDP is the only HE sounding format.

The format of an HE NDP PPDU is shown in Figure 28-36 (HE NDP PPDU format).

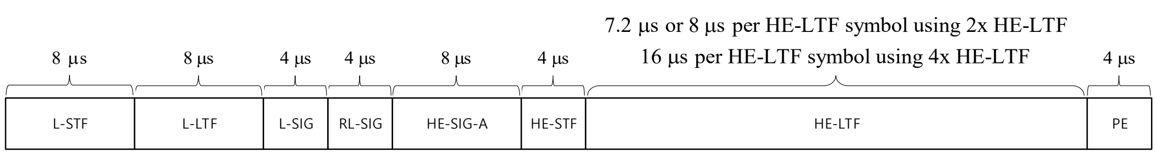


Figure 28-36—HE NDP PPDU format

NOTE—The number of HE-LTF symbols in the HE NDP is determined by the Nsts field in HE SIG-A.

The HE NDP PPDU has the following properties:

— Uses the HE SU PPDU format but without the Data field
— Has a Packet Extension field that is 4 us in duration

28.3.17 Receiver specification

28.3.17.1 General

For tests in this subclause, the input levels are measured at the antenna connectors and are referenced as the average power per receive antenna. The number of spatial streams under test shall be equal to the number of utilized transmitting STA antenna (output) ports and also equal to the number of utilized Device Under Test input ports. Each output port of the transmitting STA shall be connected through a cable to one input port of the Device Under Test.

28.3.17.2 Receiver minimum input sensitivity

The packet error rate (PER) shall be less than 10% for a PSDU with the rate-dependent input levels listed in Table 28-41 (Receiver minimum input level sensitivity). The PSDU length shall be 2048 octets for BPSK modulation with DCM or 4096 octets for all other modulations. The test in this subclause and the minimum sensitivity levels specified in Table 28-41 (Receiver minimum input level sensitivity) apply only to non-STBC modes, 800 ns GI, BCC for 20 MHz bandwidth and LDPC for bandwidth greater than 20 MHz, and HE SU PPDUs.

Table 28-41—Receiver minimum input level sensitivity

Modulation		Rate (R)	Minimum sensitivity (20 MHz PPDU) (dBm)	Minimum sensitivity (40 MHz PPDU) (dBm)	Minimum sensitivity (80 MHz PPDU) (dBm)	Minimum sensitivity (160 MHz or 80+80 MHz PPDU) (dBm)
Without DCM	With DCM					
N/A	BPSK	1/2	–82	–79	–76	–73
BPSK	QPSK	1/2	–82	–79	–76	–73
QPSK	16-QAM	1/2	–79	–76	–73	–70
QPSK	16-QAM	3/4	–77	–74	–71	–68
16-QAM	N/A	1/2	–74	–71	–68	–65
16-QAM	N/A	3/4	–70	–67	–64	–61
64-QAM	N/A	2/3	–66	–63	–60	–57
64-QAM	N/A	3/4	–65	–62	–59	–56
64-QAM	N/A	5/6	–64	–61	–58	–55
256-QAM	N/A	3/4	–59	–56	–53	–50
256-QAM	N/A	5/6	–57	–54	–51	–48
1024-QAM	N/A	3/4	–54	–51	–48	–45
1024-QAM	N/A	5/6	–52	–49	–46	–43

28.3.17.3 Adjacent channel rejection

Adjacent channel rejection for *W* MHz (where *W* is 20, 40, 80, or 160) shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 28-41 (Receiver minimum input level sensitivity) and raising the power of the interfering signal of W MHz bandwidth until 10% PER is caused for a PSDU length of 2048 octets for BPSK modulation with DCM or 4096 octets for all other modulations. The difference in power between the signals in the interfering channel and the desired channel is the corresponding adjacent channel rejection. The center frequency of the adjacent channel shall be placed *W* MHz away from the center frequency of the desired signal.

Adjacent channel rejection for 80+80 MHz channels shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table xx-a (Receiver minimum input level sensitivity). Then, an interfering signal of 80 MHz bandwidth is introduced, where the center frequency of the interfering signal is placed 80 MHz away from the center frequency of the frequency segment lower in the frequency of the desired signal. The power of interfering signal is raised until 10% PER is caused for a PSDU length of 2048 octets for BPSK modulation with DCM or 4096 octets for all other modulations. Let ΔP_1 be the difference between the interfering and desired signal. Next, the interfering signal of 80 MHz bandwidth is moved to the frequency where the center frequency of the interfering signal is 80 MHz away from the center frequency of the frequency segment higher in frequency of the desired signal. The power of the interfering is raised until 10% PER is caused for a PSDU length of 2048 octets for BPSK modulation with DCM or 4096 octets for all other modulations. Let ΔP_2 be the power difference between the interfering and desired signal. The smaller value between ΔP_1 and ΔP_2 is the corresponding adjacent channel rejection.

The interfering signal in the adjacent channel shall be a signal compliant with the HE PHY, unsynchronized with the signal in the channel under test, and shall have a minimum duty cycle of 50%. The corresponding rejection shall be no less than specified in Table 28-42 (Minimum required adjacent and nonadjacent channel rejection levels).

The test in this subclause and the adjacent sensitivity levels specified in Table 28-42 (Minimum required adjacent and nonadjacent channel rejection levels) apply only to non-STBC modes, 800 ns GI, BCC for 20 MHz bandwidth and LDPC for greater than 20 MHz bandwidth, and HE SU PPDUs.

Table 28-42—Minimum required adjacent and nonadjacent channel rejection levels

Modulation		Rate (R)	Adjacent channel rejection (dB)		Nonadjacent channel rejection (dB)	
Without DCM	With DCM		20/40/80/ 160 MHz Channel	80+80 MHz Channel	20/40/80/ 160 MHz Channel	80+80 MHz Channel
N/A	BPSK	1/2	16	13	32	29
BPSK	QPSK	1/2	16	13	32	29
QPSK	16-QAM	1/2	13	10	29	26
QPSK	16-QAM	3/4	11	8	27	24
16-QAM	N/A	1/2	8	5	24	21
16-QAM	N/A	3/4	4	1	20	17
64-QAM	N/A	2/3	0	–3	16	13
64-QAM	N/A	3/4	–1	–4	15	12
64-QAM	N/A	5/6	–2	–5	14	11
256-QAM	N/A	3/4	–7	–10	9	6
256-QAM	N/A	5/6	–9	–12	7	4
1024-QAM	N/A	3/4	–12	–15	4	1
1024-QAM	N/A	5/6	–14	–17	2	–1

The measurement of adjacent channel rejection for 160 MHz operation in regulatory domain is required only if such a frequency band plan is permitted in the regulatory domain.

28.3.17.4 Nonadjacent channel rejection

Nonadjacent channel rejection for W MHz channels (where W is 20, 40, 80, or 160) shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 28-41 (Receiver minimum input level sensitivity), and raising the power of the interfering signal of W MHz bandwidth until a 10% PER occurs for a PSDU length of 2048 octets for BPSK modulation with DCM or 4096 octets for all other modulations. The difference in power between the signals in the interfering channel and the desired channel is the corresponding nonadjacent channel rejection. The nonadjacent channel rejection shall be met with any nonadjacent channels located at least 2×W MHz away from the center frequency of the desired signal.

Nonadjacent channel rejection for 80+80 MHz channels shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 28-41 (Receiver minimum input level sensitivity). Then, an interfering signal of 80 MHz bandwidth is introduced, where the center frequency of the interfering signal is placed at least 160 MHz away from the center frequency of the frequency segment lower in the frequency of the desired signal. The center frequency of the interfering signal shall also be at least 160 MHz away from the center frequency of the frequency segment higher in frequency of the desired signal. The power of interfering signal is raised until 10% PER is caused for a PSDU length of 2048 octets for BPSK modulation with DCM or 4096 octets for all other modulations. Let ΔP_1 be the difference between the interfering and desired signal. Next, the interfering signal of 80 MHz bandwidth is moved to the frequency where the center frequency of the interfering signal is at least 160 MHz away from the center frequency of the frequency segment higher in frequency of the desired signal. The center frequency of the interfering signal shall also be at least 160 MHz away from the center frequency of the frequency segment lower in frequency of the desired signal. The power of the interfering is raised until 10% PER is caused for a PSDU length of 2048 octets for BPSK modulation with DCM or 4096 octets for all other modulations. Let ΔP_2 be the power difference between the interfering and desired signal. The smaller value between ΔP_1 and ΔP_2 is the corresponding nonadjacent channel rejection.

The interfering signal in the nonadjacent channel shall be a signal compliant with the HE PHY, unsynchronized with the signal in the channel under test, and shall have a minimum duty cycle of 50%. The corresponding rejection shall be no less than specified in Table 28-42 (Minimum required adjacent and nonadjacent channel rejection levels).

The test in this subclause and the nonadjacent sensitivity levels specified in Table 28-42 (Minimum required adjacent and nonadjacent channel rejection levels) apply only to non-STBC modes, 800 ns GI, BCC for 20 MHz bandwidth and LDPC for greater than 20 MHz bandwidth, and HE SU PPDUs.

The measurement of nonadjacent channel rejection for 160 MHz operation in regulatory domain is required only if such a frequency band plan is permitted in the regulatory domain.

28.3.17.5 Receiver maximum input level

The receiver shall provide a maximum PER of 10% at a PSDU length of 2048 octets for BPSK modulation with DCM or 4096 octets for all other modulations, for a maximum input level of –30 dBm in 5 GHz band and –20 dBm in 2.4 GHz band, measured at each antenna for any baseband HE modulation.

28.3.17.6 CCA sensitivity

28.3.17.6.1 General

The thresholds in this subclause are compared with the signal level at each receiving antenna.

28.3.17.6.2 CCA sensitivity for operating classes requiring CCA-ED

For the operating classes requiring CCA-Energy Detect (CCA-ED), the PHY shall also indicate a medium busy condition when CCA-ED detects a channel busy condition. For improved spectrum sharing, CCA-ED is required in some bands. The behavior class indicating CCA-ED is given in Table D-2 (Behavior limits). The operating classes requiring the corresponding CCA-ED behavior class are given in E.1 (Country information and operating classes). The PHY of a STA that is operating within an operating class that requires CCA-ED shall operate with CCA-ED. CCA-ED shall detect a channel busy condition when the received signal strength exceeds the CCA-ED threshold as given by dot11OFDMEDThreshold for the primary 20 MHz channel, dot11OFDMEDThreshold for the secondary 20 MHz channel (if present), dot11OFDMEDThreshold +3 dB for the secondary 40 MHz channel (if present), and dot11OFDMEDThreshold + 6 dB for the secondary 80 MHz channel (if present). The CCA-ED thresholds for the operating classes requiring CCA-ED are subject to the criteria in D.2.5 (CCA-ED threshold).

NOTE—The requirement to detect a channel busy condition as stated in 21.3.18.5.3 (CCA sensitivity for signals occupying the primary 20 MHz channel) and 21.3.18.5.4 (CCA sensitivity for signals not occupying the primary 20 MHz channel) is a mandatory energy detect requirement on all Clause 21 (Very High Throughput (VHT) PHY specification) receivers. Support for CCA-ED is an additional requirement that relates specifically to the sensitivities described in D.2.5 (CCA-ED threshold).

28.3.17.6.3 CCA sensitivity for signals occupying the primary 20 MHz channel

The PHY shall issue a PHY-CCA.indication(BUSY, {primary}) primitive if one of the conditions listed in Table 28-43 (Conditions for CCA BUSY on the primary 20 MHz) is met in an otherwise idle 20 MHz, 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz operating channel width. With >90% probability, the PHY shall detect the start of a PPDU that occupies at least the primary 20 MHz channel under the conditions listed in Table 28-43 (Conditions for CCA BUSY on the primary 20 MHz) within a period of aCCATime (see 21.4.4 (VHT PHY)) and hold the CCA signal busy (PHY-CCA.indication(BUSY, channel-list) primitive) for the duration of the PPDU, unless it receives a CCARESET.request primitive before the end of the PPDU for instance during spatial reuse operation as described in 27.9 (Spatial reuse operation).

Table 28-43—Conditions for CCA BUSY on the primary 20 MHz

Operating Channel Width	Conditions
20 MHz, 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz	The start of a 20 MHz NON_HT PPDU in the primary 20 MHz channel as defined in 17.3.10.6 (CCA requirements). The start of an HT PPDU under the conditions defined in 19.3.19.5 (CCA sensitivity). The start of a 20 MHz VHT PPDU in the primary 20 MHz channel at or above –82 dBm. The start of a 20 MHz HE PPDU in the primary 20 MHz channel at or above –82 dBm.
40 MHz, 80 MHz, 160 MHz, or 80+80 MHz	The start of a 40 MHz non-HT duplicate, VHT PPDU or HE PPDU in the primary 40 MHz channel at or above –79 dBm. The start of an HT PPDU under the conditions defined in 19.3.19.5 (CCA sensitivity).
80 MHz, 160 MHz, or 80+80 MHz	The start of an 80 MHz non-HT duplicate, VHT PPDU or HE PPDU in the primary 80 MHz channel at or above –76 dBm.
160 MHz or 80+80 MHz	The start of a 160 MHz or 80+80 MHz non-HT duplicate, VHT PPDU or HE PPDU at or above –73 dBm.

The receiver shall issue a PHY-CCA.indication(BUSY, {primary}) primitive for any signal that exceeds a threshold equal to 20 dB above the minimum modulation and coding rate sensitivity (–82 + 20 = –62 dBm) in the primary 20 MHz channel within a period of aCCATime after the signal arrives at the receiver's antenna(s); then the receiver shall not issue a PHY-CCA.indication(BUSY,{secondary}), PHYCCA.indication(BUSY,{secondary40}), PHY-CCA.indication(BUSY,{secondary80}), or PHYCCA.indication(IDLE) primitive while the threshold continues to be exceeded.

28.3.17.6.4 CCA sensitivity for signals not occupying the primary 20 MHz channel

The PHY shall issue a PHY-CCA.indication(BUSY, {secondary}) primitive if the conditions for issuing PHY-CCA.indication(BUSY, {primary}) primitive are not present and one of the following conditions are present in an otherwise idle 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz operating channel width:

- Any signal within the secondary 20 MHz channel at or above a threshold of –62 dBm within a period of aCCATime after the signal arrives at the receiver’s antenna(s); then the PHY shall not issue a PHY-CCA.indication(BUSY,{secondary40}), PHY-CCA.indication(BUSY,{secondary80}), or PHY-CCA.indication(IDLE) primitive while the threshold continues to be exceeded.
- A 20 MHz NON_HT, HT_MF, HT_GF, VHT PPDU or HE PPDU detected in the secondary 20 MHz channel at or above max(–72 dBm, OBSS_PD) with >90% probability within a period aCCAMidTime (see 28.4.3 (HE PHY)).

The PHY shall issue a PHY-CCA.indication(BUSY, {secondary40}) primitive if the conditions for issuing a PHY-CCA.indication(BUSY, {primary}) and PHY-CCA.indication(BUSY, {secondary}) primitive are not present and one of the following conditions are present in an otherwise idle 80 MHz, 160 MHz, or 80+80 MHz operating channel width:

- Any signal within the secondary 40 MHz channel at or above a threshold of –59 dBm within a period of aCCATime after the signal arrives at the receiver’s antenna(s); then the PHY shall not issue a PHY-CCA.indication(BUSY, {secondary80}) primitive or PHY-CCA.indication(IDLE) primitive while the threshold continues to be exceeded.
- A 40 MHz non-HT duplicate, HT_MF, HT_GF, VHT PPDU or HE PPDU detected in the secondary 40 MHz channel at or above max(–72 dBm, OBSS_PD) with >90% probability within a period aCCAMidTime (see 28.4.3 (HE PHY)).
- A 20 MHz non-HT, HT_MF, HT_GF, VHT PPDU or HE PPDU detected in any 20 MHz sub-channel of the secondary 40 MHz channel at or above max(–72 dBm, OBSS_PD) with >90% probability within a period aCCAMidTime.

The PHY shall issue a PHY-CCA.indication(BUSY, {secondary80}) primitive if the conditions for PHYCCA.indication(BUSY, {primary}), PHY-CCA.indication(BUSY, {secondary}), and PHYCCA.indication(BUSY, {secondary40}) primitive are not present and one of the following conditions are present in an otherwise idle 160 MHz or 80+80 MHz operating channel width:

- Any signal within the secondary 80 MHz channel at or above –56 dBm.
- An 80 MHz non-HT duplicate, VHT PPDU or HE PPDU detected in the secondary 80 MHz channel at or above max(–69 dBm, OBSS_PD) with >90% probability within a period aCCAMidTime (see 28.4.3 (HE PHY)).
- A 40 MHz non-HT duplicate, HT_MF, HT_GF, VHT or HE PPDU detected in any 40 MHz sub-channel of the secondary 80 MHz channel at or above max(–72 dBm, OBSS_PD) with >90% probability within a period aCCAMidTime.
- A 20 MHz NON_HT, HT_MF, HT_GF, VHT or HE PPDU detected in any 20 MHz sub-channel of the secondary 80 MHz channel at or above max(–72 dBm, OBSS_PD) with >90% probability within a period aCCAMidTime.

28.3.18 Transmit specification

28.3.18.1 Transmit spectral mask

The bandwidth of the spectral mask applied to an HE PPDU shall be determined by the bandwidth indicated in the Bandwidth subfield of the HE-SIG-A field. All HE PPDU formats shall be compliant with the transmit spectral mask described in this section.

NOTE 1—In the presence of additional regulatory restrictions, the device has to meet both the regulatory requirements and the mask defined in this subclause.

NOTE 2—Transmit spectral mask figures in this subclause are not drawn to scale.

NOTE 3—For rules regarding TX center frequency leakage levels, see 28.3.18.4.2 (Transmit center frequency leakage). The spectral mask requirements in this subclause do not apply to the RF LO.

For a 20 MHz mask PPDU of HE format, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 19.5 MHz, –20 dBr at 10.25 MHz frequency offset, –28 dBr at 20 MHz frequency offset, and –40 dBr at 30 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 9.75 and 10.25 MHz, 10.25 and 20 MHz, and 20 and 30 MHz shall be linearly interpolated in dB domain from the requirements for 9.75 MHz, 10.25 MHz, 20 MHz, and 30 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectral mask and –53 dBm/MHz at any frequency offset. Figure 28-37 (Example transmit spectral mask for a 20 MHz mask PPDU) shows an example of the resulting overall spectral mask when the –40 dBr spectrum level is above –53 dBm/MHz.

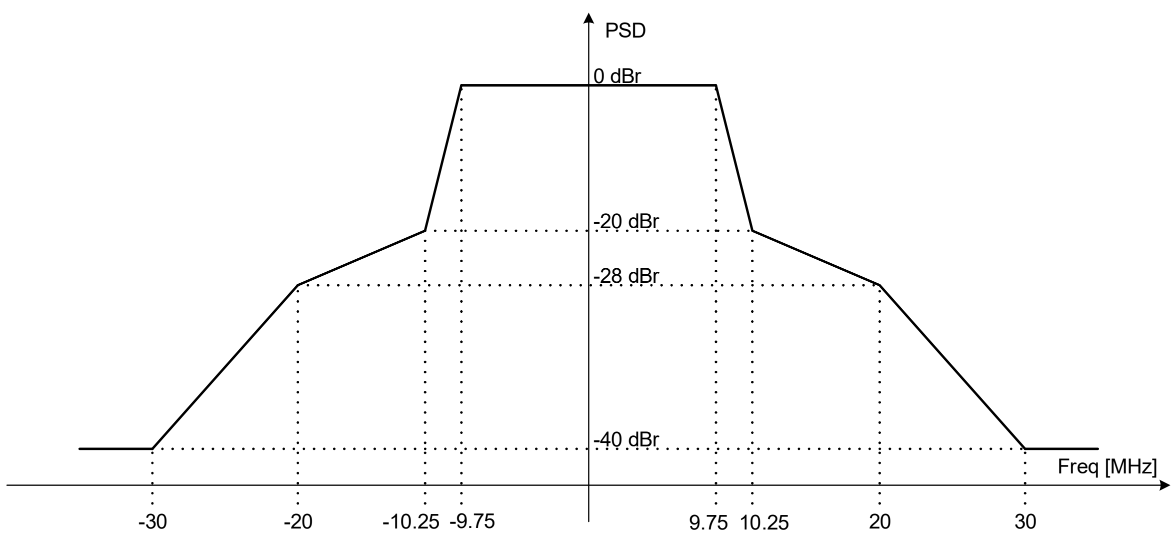


Figure 28-37—Example transmit spectral mask for a 20 MHz mask PPDU

For a 40 MHz mask PPDU of HE format, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 39 MHz, –20 dBr at 20.5 MHz frequency offset, –28 dBr at 40 MHz frequency offset, and –40 dBr at 60 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 19.5 and 20.5 MHz, 20.5 and 40 MHz, and 40 and 60 MHz shall be linearly interpolated in dB domain from the requirements for 19.5 MHz, 20.5 MHz, 40 MHz, and 60 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectral mask and –56 dBm/MHz at any frequency offset greater than 19.5 MHz. Figure 28-38

(Example transmit spectral mask for a 40 MHz mask PPDU) shows an example of the resulting overall spectral mask when the –40 dBr spectrum level is above –56 dBm/MHz.

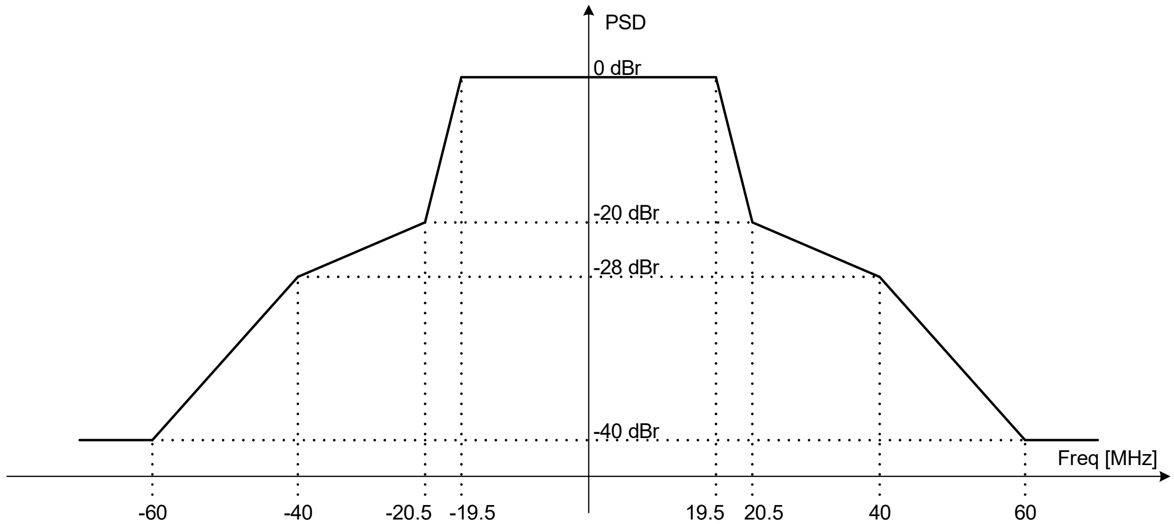


Figure 28-38—Example transmit spectral mask for a 40 MHz mask PPDU

For an 80 MHz mask PPDU of HE format, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 79 MHz, –20 dBr at 40.5 MHz frequency offset, –28 dBr at 80 MHz frequency offset, and –40 dBr at 120 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 39.5 and 40.5 MHz, 40.5 and 80 MHz, and 80 and 120 MHz shall be linearly interpolated in dB domain from the requirements for 39.5 MHz, 40.5 MHz, 80 MHz, and 120 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectrum mask and –59 dBm/MHz at any frequency offset. Figure 28-39 (Example transmit spectral mask for a 80 MHz mask PPDU) shows an example of the resulting overall spectral mask when the –40 dBr spectrum level is above –59 dBm/MHz.

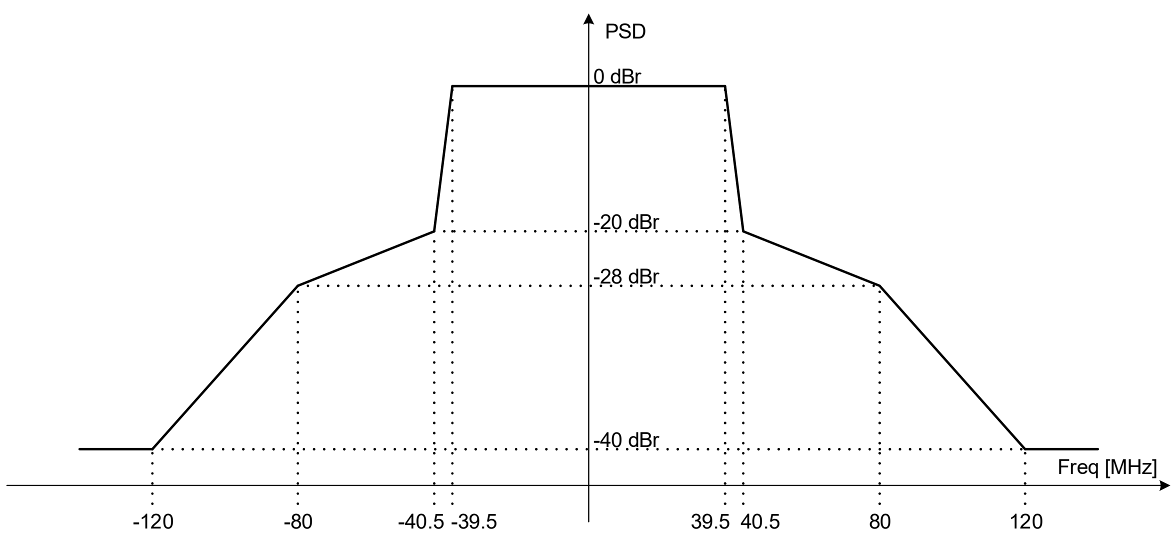


Figure 28-39—Example transmit spectral mask for a 80 MHz mask PPDU

For a 160 MHz mask PPDU of HE format, the interim transmit spectral mask shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth of 159 MHz, –20 dBr at 80.5 MHz frequency offset, –28 dBr at 160 MHz frequency offset, and –40 dBr at 240 MHz frequency offset and above. The interim transmit spectral mask for frequency offsets in between 79.5 and 80.5 MHz, 80.5 and 160 MHz, and 160 and 240 MHz shall be linearly interpolated in dB domain from the requirements for 79.5 MHz, 80.5 MHz, 160 MHz, and 240 MHz frequency offsets. The transmit spectrum shall not exceed the maximum of the interim transmit spectrum mask and –59 dBm/MHz at any frequency offset. Figure 28-40 (Example transmit spectral mask for a 160 MHz mask PPDU) shows an example of the resulting overall spectral mask when the –40 dBr spectrum level is above –59 dBm/MHz.

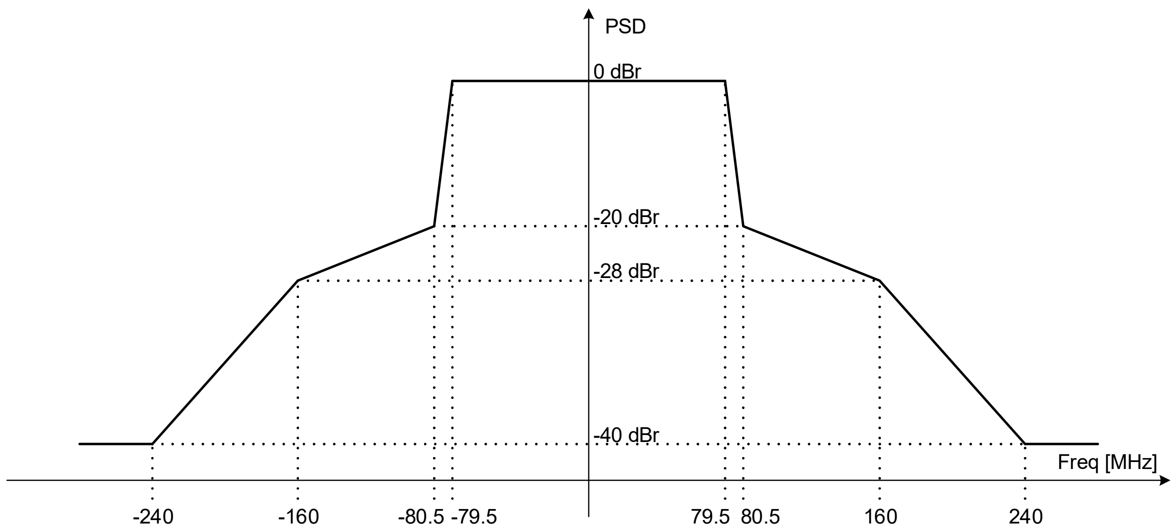


Figure 28-40—Example transmit spectral mask for a 160 MHz mask PPDU

For an 80+80 MHz mask PPDU of HE format, the overall transmit spectral mask is constructed in the following manner. First, the 80 MHz interim spectral mask is placed on each of the two 80 MHz segments. Then, for each frequency at which both of the 80 MHz interim spectral masks have values greater than –40 dBr and less than –20 dBr, the sum of the two interim mask values (summed in linear domain) shall be taken as the overall spectral mask value. Next, for each frequency at which neither of the two 80 MHz interim masks have values greater than or equal to –20 dBr and less than or equal to 0 dBr, the higher value of the two interim masks shall be taken as the overall interim spectral value. Finally, for any frequency region where the mask value has not been defined yet, linear interpolation (in dB domain) between the nearest two frequency points with the interim spectral mask value defined shall be used to define the interim spectral mask value. The transmit spectrum shall not exceed the maximum of the interim transmit spectrum mask and –59 dBm/MHz at any frequency offset. Figure 28-41 (Example transmit spectral mask for a 80+80 MHz mask PPDU) shows an example of a transmit spectral mask for a noncontiguous transmission using two 80 MHz channels where the center frequency of the two 80 MHz channels are separated by 160 MHz and the −40 dBr spectrum level is above −59 dBm/MHz.

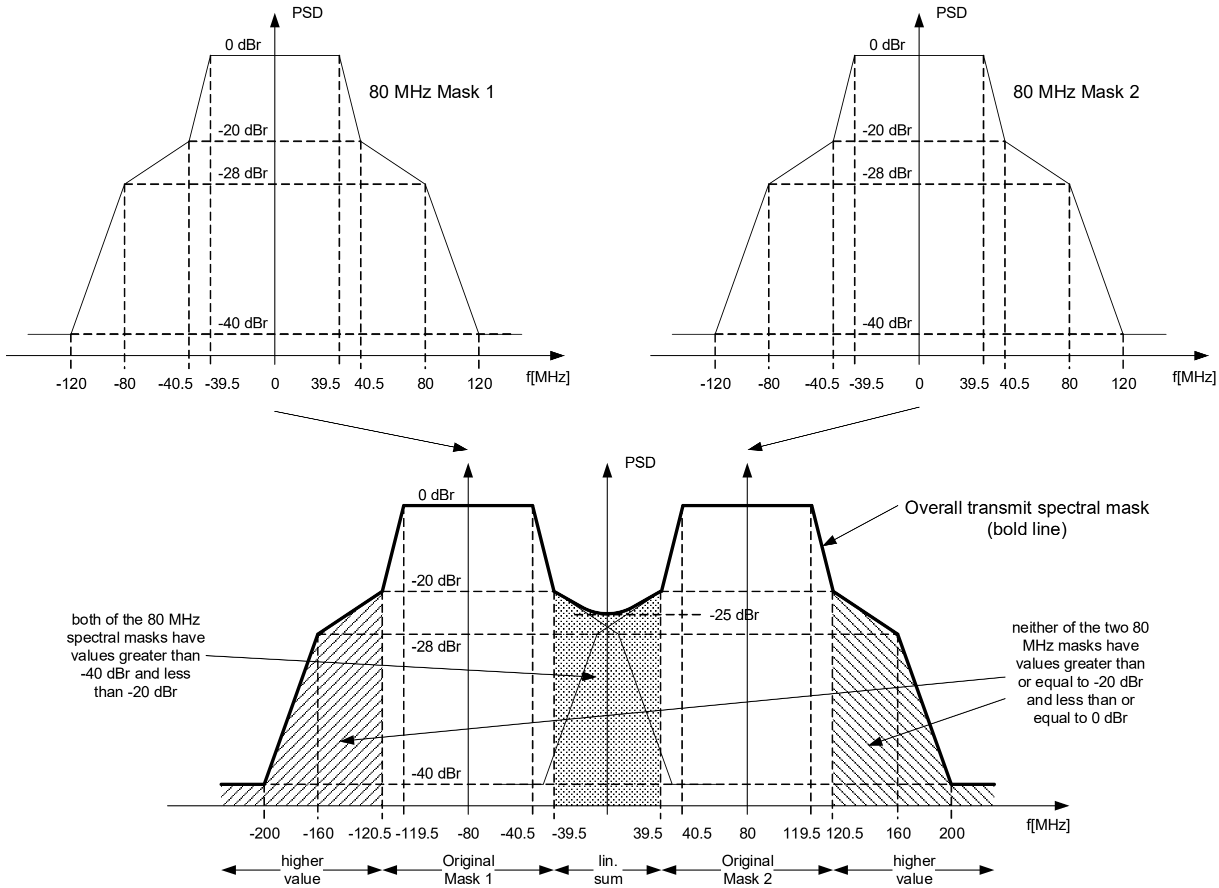


Figure 28-41—Example transmit spectral mask for a 80+80 MHz mask PPDU

Different center frequency separation between the two 80 MHz frequency segments of the spectral mask as well as different peak levels of each 80 MHz frequency segment of the spectral mask are possible, in which case a similar procedure in determining the spectral mask as in Figure 28-41 (Example transmit spectral mask for a 80+80 MHz mask PPDU) is followed.

The transmit spectral mask for noncontiguous transmissions using two nonadjacent 80 MHz channels is applicable only in regulatory domains that allow for such transmissions.

Measurements shall be made using a 25 kHz resolution bandwidth and a 7.5 kHz video bandwidth.

When channel puncturing happens in an HE MU PPDU, the HE MU PPDU is still treated as an 80 MHz or 160 MHz (80+80 MHz) PPDU, therefore the spectral mask is the same as those defined for the total channel width.

28.3.18.2 Spectral flatness

Spectral flatness measurements shall be conducted using BPSK modulated HE PPDUs. Demodulate the HE PPDUs according to the following (or equivalent) procedure:

a) Start of PPDU shall be detected.

b) Transition from L-STF to L-LTF shall be detected and fine timing shall be established.

c) Coarse and fine frequency offsets shall be estimated.

d) Symbols in a PPDU shall be manipulated to account for both frequency error and sampling offset drift.

e) For each HE-LTF symbol, transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, and compensate the subcarrier values according to the estimated phase.

f) For each of the data OFDM symbols: transform the symbol into subcarrier received values.

The spectral flatness test shall be performed over at least 20 HE PPDUs. The PPDUs under test shall be at least 16 data OFDM symbols long.

Evaluate spectral flatness using the subcarrier received values or the magnitude of the channel estimation of the occupied subcarriers of the transmission HE PPDUs. Non-occupied subcarriers of the transmitted HE PPDUs shall be ignored during averaging and testing. Resource unit power boosting and beamforming should not be used when measuring spectral flatness.

Let $E_{i,avg}$ denote the magnitude of the channel estimation on subcarrier i or the average constellation energy of a BPSK modulated subcarrier i in an HE data symbol. In a contiguous HE transmission having a bandwidth listed in Table 28-44 (Maximum transmit spectral flatness deviations), $E_{i,avg}$ of each of the subcarriers with indices listed as tested subcarrier indices shall not deviate by more than the specified maximum deviation in Table 28-44 (Maximum transmit spectral flatness deviations) from the average of $E_{i,avg}$ over subcarrier indices listed as averaging subcarrier indices. Averaging of $E_{i,avg}$ is done in the linear domain.

Table 28-44—Maximum transmit spectral flatness deviations

Bandwidth of transmission (MHz)	Averaging subcarrier indices (inclusive)	Tested subcarrier indices (inclusive)	Maximum deviation (dB)
20	–84 to –2 and +2 to +84	–84 to –2 and +2 to +84	±4
		–122 to –85 and +85 to +122	+4/–6
40	–168 to –3 and +3 to +168	–168 to –3 and +3 to +168	±4
		–244 to –169 and +169 to +244	+4/–6
80	–344 to –3 and +3 to +3441	–344 to –3 and +3 to +344	±4
		–500 to –345 and +345 to +500	+4/–6
160	–696 to –515, –509 to –166, +166 to +509, and +515 to +696	–696 to –515, –509 to –166, +166 to +509, and +515 to +696	±4
		–1012 to –697, –165 to –12, +12 to +165, and +697 to +1012	+4/–6

In an 80+80 MHz transmission, each segment shall meet the spectral flatness requirement for an 80 MHz transmission.

For the spectral flatness test, the transmitting STA shall be configured to use a spatial mapping matrix Q_k (see 28.3.11.14 (OFDM modulation)) with flat frequency response. Each output port under test of the transmitting STA shall be connected through a cable to one input port of the testing instrumentation. The requirements apply to 20 MHz, 40 MHz, 80 MHz, and 160 MHz contiguous transmissions as well as 80+80 MHz transmissions.

28.3.18.3 Transmit center frequency and symbol clock frequency tolerance

Transmit center frequency and the symbol clock frequency for all transmit antennas and frequency segments shall be derived from the same reference oscillator. The symbol clock frequency and transmit center frequency maximum tolerance shall be ±20 ppm. HE trigger-based PPDU format is subject to additional requirements as defined in 28.3.14 (Transmit requirements for an HE trigger-based PPDU).

28.3.18.4 Modulation accuracy

28.3.18.4.1 Introduction to modulation accuracy tests

Transmit modulation accuracy specifications are described in 28.3.18.4.2 (Transmit center frequency leakage) and 28.3.18.4.3 (Transmitter constellation error). The test method is described in 28.3.18.4.4 (Transmitter modulation accuracy (EVM) test).

28.3.18.4.2 Transmit center frequency leakage

The TX LO leakage requirement for all transmission modes shall be the following. The power measured at the location of the RF LO using resolution BW 78.125 kHz shall not exceed the maximum of –32 dB relative to the total transmit power and –20 dBm, or equivalently max(P–32, –20), where P is the transmit power per antenna in dBm. The transmit center frequency leakage is specified per antenna.

For an 80+80 MHz transmission where the RF LO falls outside both frequency segments, the RF LO shall additionally met the spectral mask requirements as defined in 28.3.18.1 (Transmit spectral mask).

28.3.18.4.3 Transmitter constellation error

The relative constellation RMS error, calculated by first averaging over subcarriers, frequency segments, HE PPDUs, and spatial streams (see Equation (28-122)) shall not exceed a data-rate dependent value according to Table 28-45 (Allowed relative constellation error versus constellation size and coding rate). The number of spatial streams under test shall be equal to the number of utilized transmitting STA antenna (output) ports and also equal to the number of utilized testing instrumentation input ports. In the test, $N_{SS} = N_{STS}$ (no STBC) shall be used. Each output port of the transmitting STA shall be connected through a cable to one input port of the testing instrumentation. The requirements apply to 20 MHz, 40 MHz, 80 MHz, and 160 MHz contiguous transmissions as well as 80+80 MHz noncontiguous transmissions.

28.3.18.4.4 Transmitter modulation accuracy (EVM) test

The transmit modulation accuracy test shall be performed by instrumentation capable of converting the transmitted signals into a stream of complex samples at sampling rate greater than or equal to the bandwidth of the signal being transmitted except that for a noncontiguous transmissions each frequency segment may be tested independently.

In this case, transmit modulation accuracy of each segment shall meet the required value in Table 28-45 (Allowed relative constellation error versus constellation size and coding rate) using only the occupied data subcarriers within the corresponding segment.

LO leakage that can potentially show up in center frequency of the HE PPDU tone plan and its ±3 tone neighbors shall be excluded from the computation of the transmitter modulation accuracy test. The potential LO leakage tones for 20 MHz operating devices are the center of primary 20 MHz of the HE PPDU tone plan and ±3 tones. The potential LO leakage tones for 40MHz operating devices are the center of the

Table 28-45—Allowed relative constellation error versus constellation size and coding rate

Modulation		Coding rate	Relative constellation error in an HE SU PPDU, HE extended rate SU PPDU and HE MU PPDU (dB)	Relative constellation error in an HE trigger-based PPDU (dB)	Relative constellation error in HE trigger-based PPDU when transmit power is less than or equal to the maximum power of MCS7 (dB)
Without DCM	With DCM				
N/A	BPSK	1/2	–5	–13	–27
BPSK	QPSK	1/2	–5	–13	–27
QPSK	16-QAM	1/2	–10	–13	–27
QPSK	16-QAM	3/4	–13	–13	–27
16-QAM	N/A	1/2	–16	–16	–27
16-QAM	N/A	3/4	–19	–19	–27
64-QAM	N/A	2/3	–22	–22	–27
64-QAM	N/A	3/4	–25	–25	–27
64-QAM	N/A	5/6	–27	–27	–27
256-QAM	N/A	3/4	–30	–30	–30
256-QAM	N/A	5/6	–32	–32	–32
1024-QAM	N/A	3/4	–35	–35	–35
1024-QAM	N/A	5/6	–35	–35	–35

NOTE—The maximum power of MCS7 can be measured by setting the Target RSSI subfield as defined in Table 9-25g (Target RSSI subfield encoding) in the Trigger frame to 127 for the same data-carrying subcarriers which EVM test is conducted.

primary 40 MHz of the PPDU tone plan and ±3 tones. For 80 MHz capable devices that transmits 20 MHz or 40 MHz PPDU, the potential LO leakage tone exist outside the PPDU bandwidth and should not affect the transmitter modulation accuracy test.

The instrument shall have sufficient accuracy in terms of I/Q branch amplitude and phase balance, DC offsets, phase noise, and analog to digital quantization noise. A possible embodiment of such a setup is converting the signals to a low IF frequency with a microwave synthesizer, sampling the signal with a digital oscilloscope and decomposing it digitally into quadrature components. The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or equivalent procedure:

a) Start of PPDU shall be detected.

b) Transition from L-STF to L-LTF shall be detected and fine timing shall be established.

c) Coarse and fine frequency offsets shall be estimated.

d) Symbols in a PPDU shall be derotated according to estimated frequency offset. Sampling offset drift shall be also compensated. Note that amplitude drift shall not be compensated by the testing instrument.

e) For each HE-LTF symbol, transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, and derotate the subcarrier values according to the estimated phase.

f) Estimate the complex channel response coefficient for each of the subcarriers and each of the transmit streams.

g) For each of the data OFDM symbols: transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, and compensate the subcarrier values according to the estimated phase, group the results from all of the receiver chains in each subcarrier to a vector, and multiply the vector by a zero-forcing equalization matrix generated from the estimated channel.

h) For each data-carrying subcarrier in each spatial stream of RU under test, find the closest constellation point and compute the Euclidean distance from it.

i) Compute the average across PPDUs of the RMS of all errors per PPDU as given by Equation (28-122).

$$Error_{RMS} = \qquad (28\text{-}122)$$

$$\frac{1}{N_f}\sum_{i_f=1}^{N_f}\sqrt{\frac{\sum_{i_s=1}^{N_{SYM}}\sum_{i_{ss}=1}^{N_{SS}}\sum_{i_{sc}=1}^{N_{ST}}\left(I_e(i_f,i_s,i_{ss},i_{sc})-I_0(i_f,i_s,i_{ss},i_{sc})\right)^2+\left(Q_e(i_f,i_s,i_{ss},i_{sc})-Q_0(i_f,i_s,i_{ss},i_{sc})\right)^2}{N_{SYM}N_{SS}N_{ST}P_0}}$$

where

$I_0(i_f, i_s, i_{ss}, i_{sc})$ $Q_0(i_f, i_s, i_{ss}, i_{sc})$ denotes the ideal symbol point in the complex plane in i_{sc}-th data tone of the RU under test, spatial stream i_{ss}, and the OFDM symbol of frame i_f.

$I_e(i_f, i_s, i_{ss}, i_{sc})$ $Q_e(i_f, i_s, i_{ss}, i_{sc})$ denotes the equalized observed symbol point in the complex plane of the i_{sc}-th data tone of the RU under test, spatial stream i_{ss}, and the OFDM symbol of frame i_f.

P_0 is the average power of constellation

N_f is the number of tested frames

N_{ST} is the number of data tones of the occupied RU

N_{SS} is the number of spatial streams of the data

N_{SYM} is the number of data OFDM symbols

NOTE 1—In the case the transmit modulation accuracy test is performed simultaneously for the two frequency segments of the 80+80 MHz transmissions with 2×996-subcarrier RU.

The test shall be performed over at least 20 PPDUs (N_f as defined in Equation (28-122)). When the occupied RU has 26 tones, the PPDUs under test shall be at least 32 data OFDM symbols long. For occupied RUs that have more than 26 tones, the PPDUs under test shall be at least 16 data OFDM symbols long. Random data shall be used for the symbols.

For an HE trigger-based PPDU, additional transmit modulation accuracy test for the unoccupied subcarriers of the PPDU shall be performed. The transmit modulation accuracy of unoccupied subcarriers of the PPDU test shall be performed by instrumentation capable of converting the transmitted signals into a stream of complex samples at sampling rate greater than or equal to the bandwidth of the signal being transmitted except that for noncontiguous transmissions, only the frequency segment with occupied subcarriers is tested. The transmit modulation accuracy of unoccupied subcarriers of the PPDU shall meet the relative constellation error staircase mask for each modulation and code rate using the unoccupied subcarriers within the corresponding segment.

The instrument shall have sufficient accuracy in terms of I/Q branch amplitude and phase balance, DC offsets, phase noise, and analog to digital quantization noise. A possible embodiment of such a setup is converting the signals to a low IF frequency with a microwave synthesizer, sampling the signal with a digital oscilloscope and decomposing it digitally into quadrature components. The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or equivalent procedure:

a) Start of PPDU shall be detected.

b) Transition from L-STF to L-LTF shall be detected and fine timing shall be established.

c) Coarse and fine frequency offsets shall be estimated.

d) Symbols in a PPDU shall be derotated according to estimated frequency offset. Sampling offset drift shall be also compensated. Note that amplitude drift shall not be compensated by the testing instrument.

e) For each of the data OFDM symbols, transform the symbol into subcarrier received values and estimate the power of each subcarrier.

f) Compute the average unoccupied subcarrier error vector magnitude for each unoccupied 26-tone RU and average across PPDUs of the RMS of all errors per PPDU as given by Equation (28-123).

$$UnusedToneError_{RMS}(k) = \frac{1}{N_f}\sum_{i_f=1}^{N_f}\sqrt{\frac{\sum_{i_s}^{N_{SYM}}\sum_{i_{RU}\in\Omega_k}(I_u(i_f, i_s, i_{RU}))^2 + (Q_u(i_f, i_s, i_{RU}))^2}{N_{SYM}\cdot 26\cdot P_S}} \tag{28-123}$$

where

$I_u(i_f, i_s, i_{RU})$ $Q_u(i_f, i_s, i_{RU})$ denotes unequalized observed symbol point in the complex plane in unoccupied 26-tone RU i_{RU} and OFDM symbol is of frame i_f.

Ω_k is a set of subcarriers for k-th 26-tone RU as defined in Table 28-3 (Subcarrier indices for RUs in a 20 MHz HE PPDU), Table 28-4 (Subcarrier indices for RUs in a 40 MHz HE PPDU) and Table 28-5 (Subcarrier indices for RUs in an 80 MHz HE PPDU)

P_S is the average data subcarrier power of the occupied RU under test and is given by Equation (28-124)

$$P_S = \frac{1}{N_{SYM}N_{ST}}\sum_{i_s=1}^{N_{SYM}}\sum_{i_{sc}=1}^{N_{ST}}(I_u(i_f, i_s, i_{SC}))^2 + (Q_u(i_f, i_s, i_{SC}))^2 \tag{28-124}$$

N_f is the number of tested frames

N_{SYM} is the number of data OFDM symbols

N_{ST} is the number of data tones of the occupied RU

g) For all MCS, for an occupied RU bandwidth of r in units of a 26-tone RU as defined by Equation (28-125)

$$r = \begin{cases} 1, \text{ if 26-tone RU} \\ 2, \text{ if 52-tone RU} \\ 4, \text{ if 106-tone RU} \\ 9, \text{ if 242-tone RU} \\ 18, \text{ if 484-tone RU} \\ 37, \text{ if 996-tone RU} \end{cases} \tag{28-125}$$

the average unoccupied subcarrier error vector magnitude for each unoccupied 26-tone RU as calculated in step e) shall meet the staircase mask requirement in Equation (28-126).

$$UnusedToneError_{RMS}(m) \le \begin{cases} \max(UsedToneError_{RMS} - 2, -35\text{ dB}),\ 1 \le m \le r \\ \max(UsedToneError_{RMS} - 12, -35\text{ dB}),\ r+1 \le m \le 2r \\ \max(UsedToneError_{RMS} - 22, -35\text{ dB}),\ 2r \le m \le 3r \\ -35\text{ dB, otherwise} \end{cases} \tag{28-126}$$

where

m defines the gap in the units of 26-tone RU to the occupied RU from either side and is a positive integer with $m = 1$ being the adjacent 26-tone RU.

$UsedToneError_{RMS}$ is the relative constellation error for the HE trigger based PPDU defined in Table 28-45 (Allowed relative constellation error versus constellation size and coding rate)

h) Compute the maximum average unoccupied subcarrier error vector magnitude as given by Equation (28-127).

$$UnusedToneError_{\text{MAX-RMS}} = \max_{\forall k}(UnusedToneError_{RMS}(k)) \tag{28-127}$$

The test shall be performed over at least 20 PPDUs (N_f as defined in Equation (28-122)). The PPDUs under test shall be at least 16 data OFDM symbols long. The unequalized observed symbol of potential LO leakage subcarrier locations shall be treated as zero during unoccupied subcarriers transmit modulation accuracy test. Random data shall be used for the symbols.

28.3.18.5 Time of Departure accuracy

The Time of Departure accuracy test evaluates TIME_OF_DEPARTURE against aTxPHYTxStartRMS and aTxPHYTxStartRMS against TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH as defined in Annex P with the following test parameters:

— MULTICHANNEL_SAMPLING_RATE is:

$20 \times 10^6\left(1 + \left\lceil \frac{f_H - f_L}{20\text{ MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW20

$40 \times 10^6\left(1 + \left\lceil \frac{f_H - f_L}{40\text{ MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW40

$80 \times 10^6\left(1 + \left\lceil \frac{f_H - f_L}{80\text{ MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW80

$160 \times 10^6\left(1 + \left\lceil \frac{f_H - f_L}{160\text{ MHz}} \right\rceil\right)$ sample/s, for a CH_BANDWIDTH parameter equal to CBW160 or CBW80+80

where

f_H is the nominal center frequency in Hz of the highest channel in the channel set

f_L is the nominal center frequency in Hz of the lowest channel in the channel set, the channel set is the set of channels upon which frames providing measurements are transmitted, the channel set comprises channels uniformly spaced across.

— FIRST_TRANSITION_FIELD is L-STF.

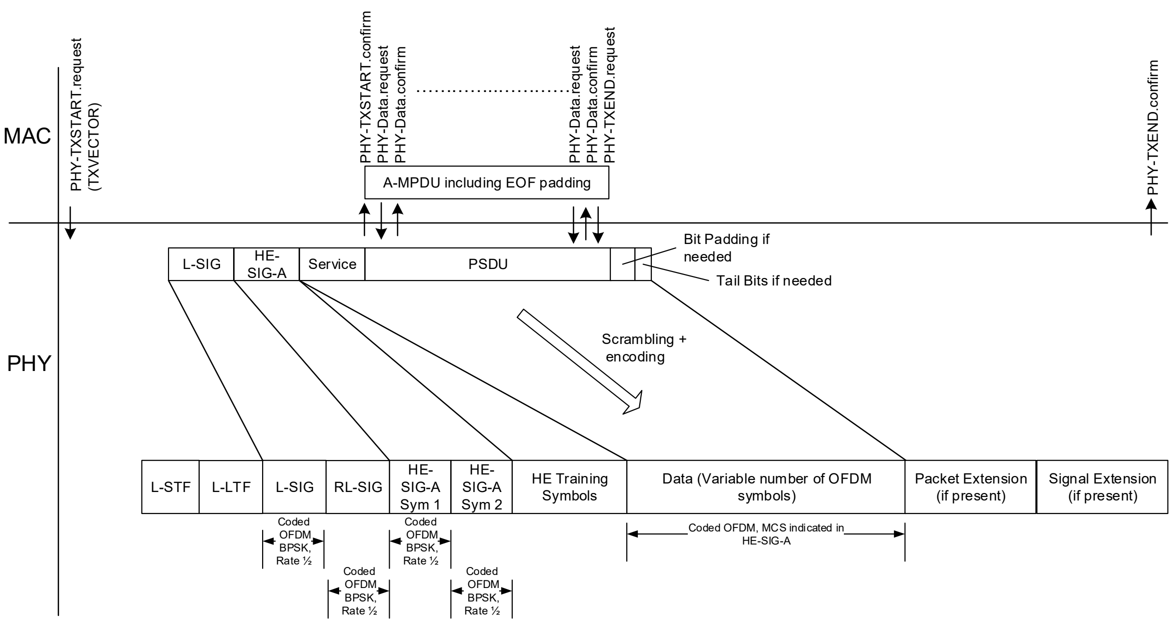
— SECOND_TRANSITION_FIELD is L-LTF.

— TRAINING_FIELD is L-LTF windowed in a manner which should approximate the windowing described in 17.3.2.5 (Mathematical conventions in the signal descriptions) with TTR = 100 ns.
— TIME_OF_DEPARTURE_ACCURACY_TEST_THRESH is 80 ns.

NOTE—The indicated windowing applies to the time of departure accuracy test equipment, and not the transmitter or receiver.

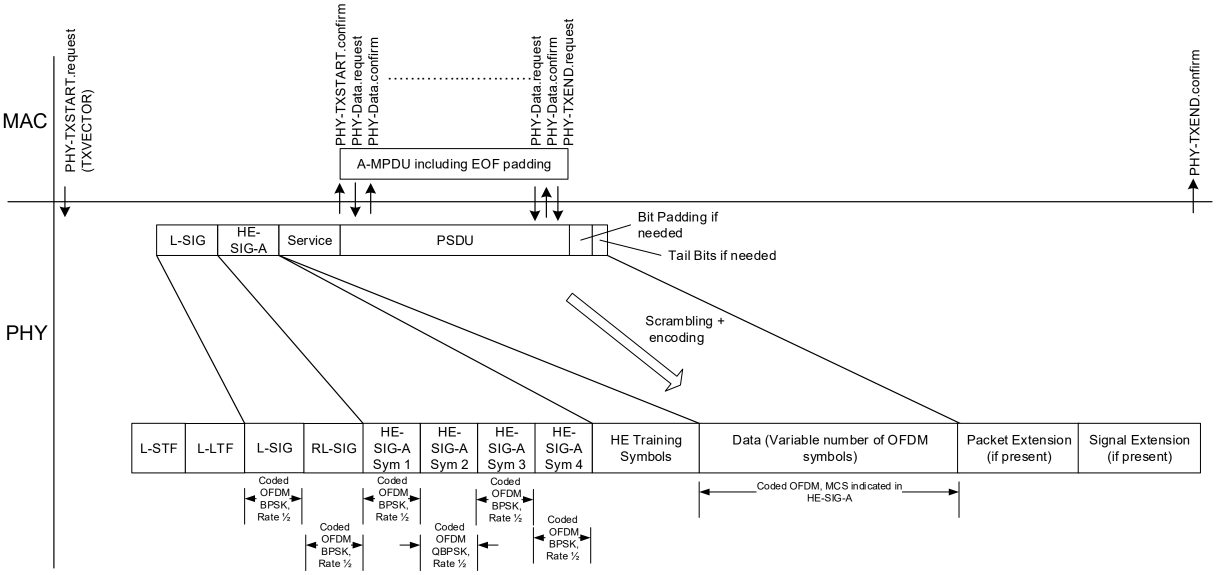
28.3.19 HE transmit procedure

There are five options for the transmit PHY procedure. The first four options, for which typical transmit procedures are shown in Figure 28-42 (PHY transmit procedure for an HE SU PPDU), Figure 28-44 (PHY transmit procedure for an HE MU PPDU), Figure 28-43 (PHY transmit procedure for an HE extended range SU PPDU) and Figure 28-45 (PHY transmit procedure for an HE trigger-based PPDU), are selected if the FORMAT field of the PHY-TXSTART.request(TXVECTOR) primitive is equal to HE_SU, HE_MU, HE_EXT_SU, or HT_TRIG, respectively. These transmit procedures do not describe the operation of optional features, such as DCM.



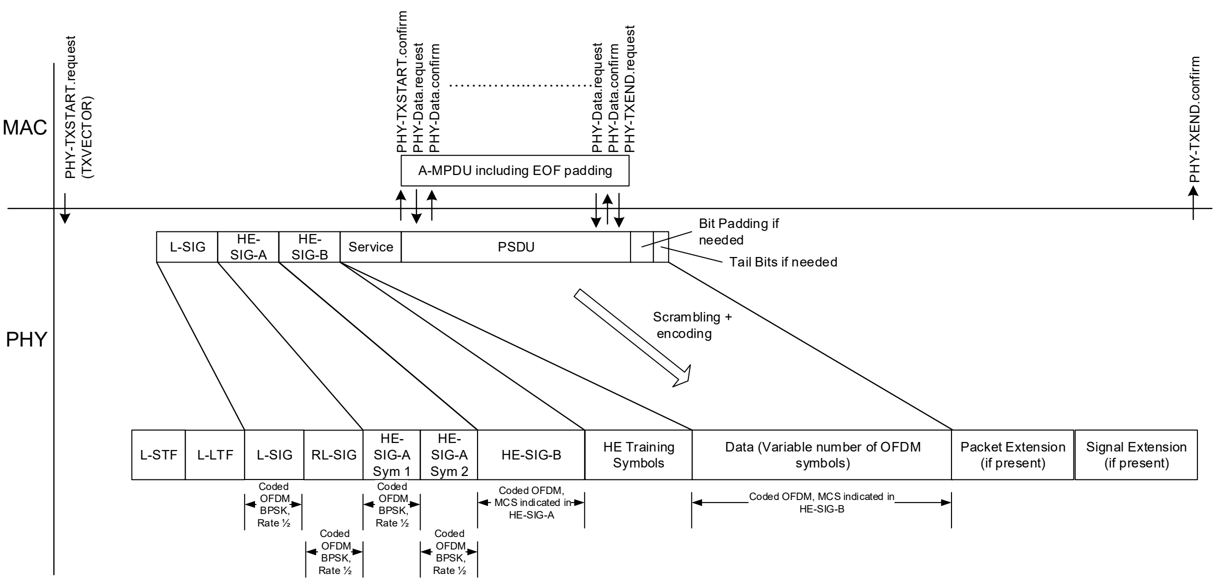
NOTE—This procedure does not describe the operation of optional features, such as DCM.

Figure 28-42—PHY transmit procedure for an HE SU PPDU



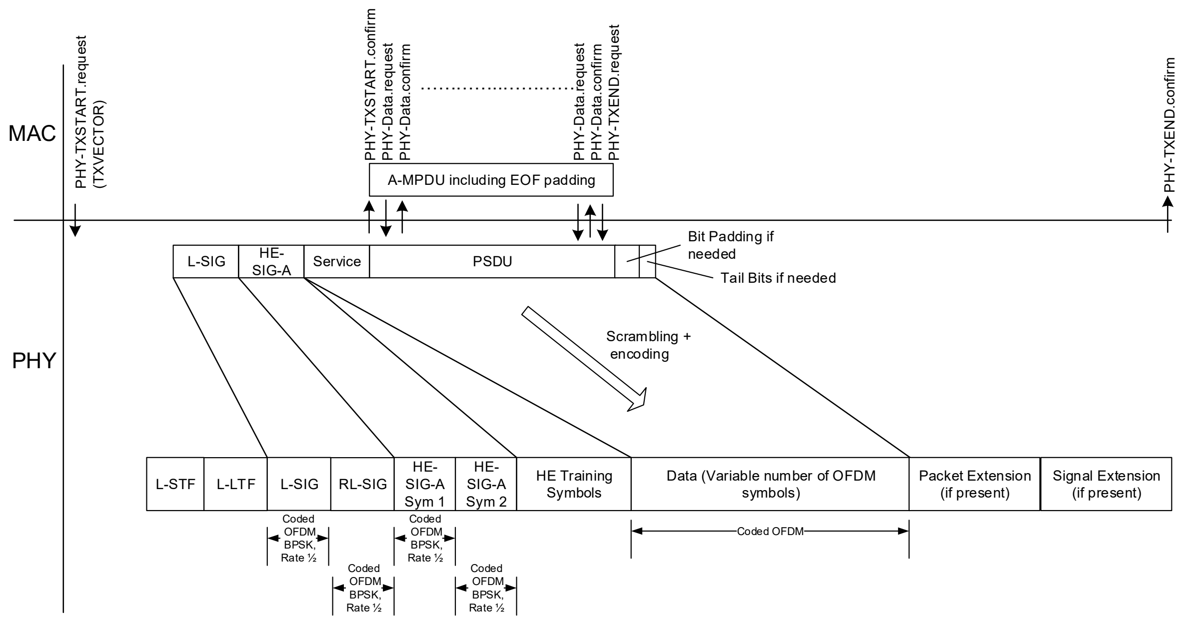
NOTE—This procedure does not describe the operation of optional features, such as DCM.

Figure 28-43—PHY transmit procedure for an HE extended range SU PPDU



NOTE—This procedure does not describe the operation of optional features, such as DCM.

Figure 28-44—PHY transmit procedure for an HE MU PPDU



NOTE—This procedure does not describe the operation of optional features, such as DCM.

Figure 28-45—PHY transmit procedure for an HE trigger-based PPDU

The fifth option is to follow the transmit procedure in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) if the FORMAT parameter of the PHYTXSTART.request(TXVECTOR) primitive is NON_HT and the NON_HT_MODULATION parameter is set to NON_HT_DUP_OFDM except that the signal referred to in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) is instead generated simultaneously on each of the 20 MHz channels that are indicated by the CH_BANDWIDTH parameter as defined in 28.3.10 (HE preamble) and 28.3.13 (Non-HT duplicate transmission).

NOTE 1—For an HE MU PPDU the A-MPDU is per user in the MAC sublayer and the HE Training Symbols, and Data are per user in the PHY in Figure 28-44 (PHY transmit procedure for an HE MU PPDU), with the number HE Training Symbols depending on the maximum total number of space-time streams across all RUs.

NOTE 2—The transmit procedure for NON_HT, HT_MF, HT_GF, and VHT format are specified in 26.2.x (Support for NON-HT, HT, and VHT formats).

In all options, in order to transmit data, the MAC generates a PHY-TXSTART.request primitive, which causes the PHY entity to enter the transmit state. Further, the PHY is set to operate at the appropriate frequency through station management via the PLME, as specified in 28.4 (HE PLME). Other transmit parameters, such as HE-MCS Coding types and transmit power, are set via the PHY-SAP using the PHYTXSTART.request(TXVECTOR) primitive, as described in 28.2.2 (TXVECTOR and RXVECTOR parameters). The remainder of the clause applies to the first four options.

The PHY indicates the state of the primary channel and other channels (if any) via the PHY-CCA.indication primitive (see 22.3.18.5 (CCA sensitivity) and 7.3.5.12 (PHY-CCA.indication)). Transmission of the PPDU shall be initiated by the PHY after receiving the PHY-TXSTART.request(TXVECTOR) primitive. The TXVECTOR elements for the PHY-TXSTART.request primitive are specified in Table 28-1 (TXVECTOR and RXVECTOR parameters).

Transmission of the PHY preamble may start if TIME_OF_DEPARTURE_REQUESTED is false, and shall start immediately if TIME_OF_DEPARTURE_REQUESTED is true, based on the parameters passed in the PHY-TXSTART.request primitive.

If all of the following conditions are met:

— if dot11TODImplemented and dot11TODActivated are true or if dot11TimingMsmtActivated is true,
— the TXVECTOR parameter TIME_OF_DEPARTURE_REQUESTED is true,

then the PHY shall issue a PHY-TXSTART.confirm(TXSTATUS) primitive to the MAC, forwarding the TIME_OF_DEPARTURE corresponding to the time when the first frame energy is sent by the transmitting port and TIME_OF_DEPARTURE_ClockRate parameter within the TXSTATUS vector. If dot11TimingMsmtActivated is true, then the PHY shall forward the value of TX_START_OF_FRAME_OFFSET in TXSTATUS vector.

After the PHY preamble transmission is started, the PHY entity immediately initiates data scrambling and data encoding. The encoding method for the Data field is based on the FEC_CODING, CH_BANDWIDTH, NUM_STS, STBC, MCS, and NUM_USERS parameter of the TXVECTOR, as described in 28.3.4 (HE PPDU formats).

The SERVICE field and PSDU are encoded as described in 28.3.5 (Transmitter block diagram). The data shall be exchanged between the MAC and the PHY through a series of PHY-DATA.request(DATA) primitives issued by the MAC, and PHY-DATA.confirm primitives issued by the PHY. PHY padding bits are appended to the PSDU to make the number of bits in the coded PSDU an integral multiple of the number of coded bits per OFDM symbol.

Transmission can be prematurely terminated by the MAC through the PHY-TXEND.request primitive. PSDU transmission is terminated by receiving a PHY-TXEND.request primitive. Each PHYTXEND.request primitive is acknowledged with a PHY-TXEND.confirm primitive from the PHY.

A packet extension and/or a signal extension may be present in the PPDU. When no packet extension and signal extension are present, the PHY-TXEND.confirm primitive is generated at the end of last symbol of the PPDU. When a packet extension and/or a signal extension present, the PHY-TXEND.confirm primitive is generated at the end of the packet extension or signal extension.

In the PHY, the GI with GI duration indicated in GI_TYPE parameter of the TXVECTOR is inserted in every data OFDM symbol as a countermeasure against delay spread.

When the PPDU transmission is completed the PHY entity enters the receive state.

A typical state machine implementation of the transmit PHY for an HE PPDU transmission is provided in Figure 28-46 (PHY transmit state machine for an HE PPDU). Request (.request) and confirmation(.confirm) primitives are issued once per state as shown. This state machine does not describe the operation of optional features, such as DCM.

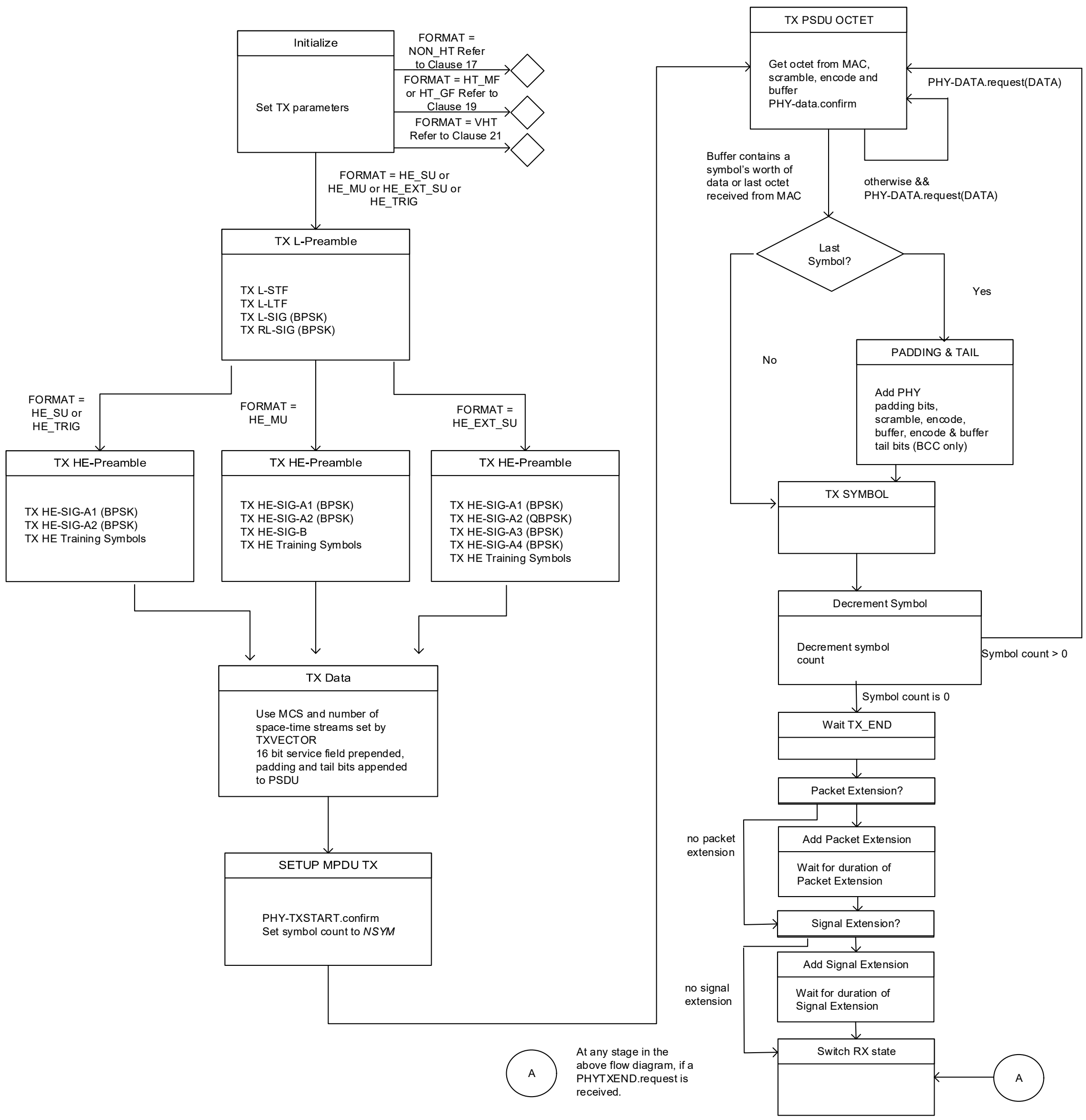
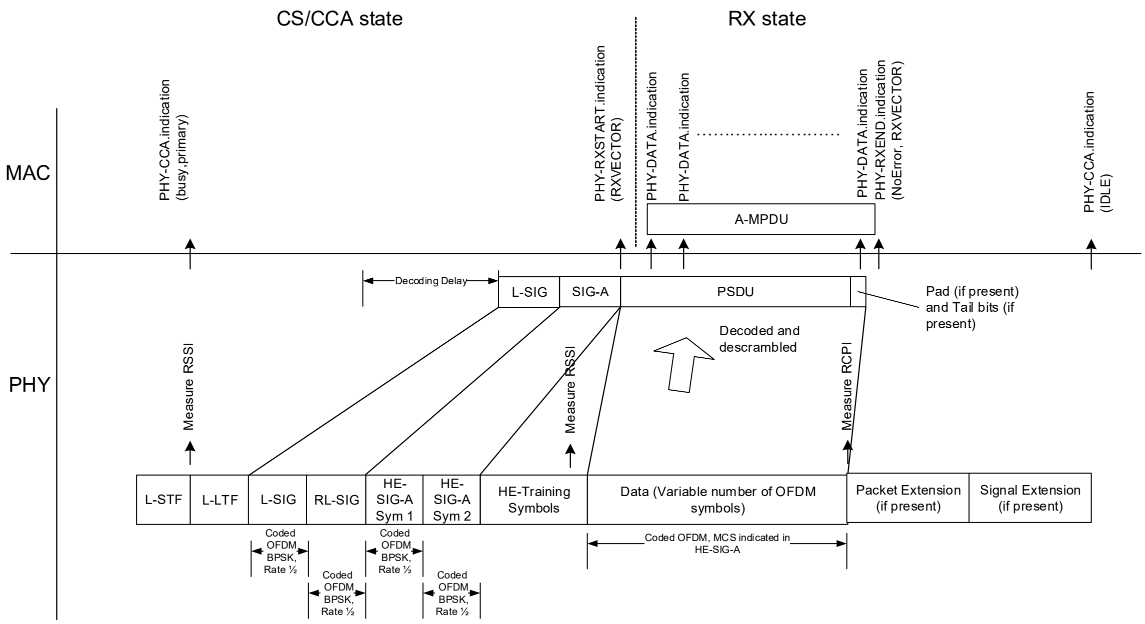


Figure 28-46—PHY transmit state machine for an HE PPDU

28.3.20 HE receive procedure

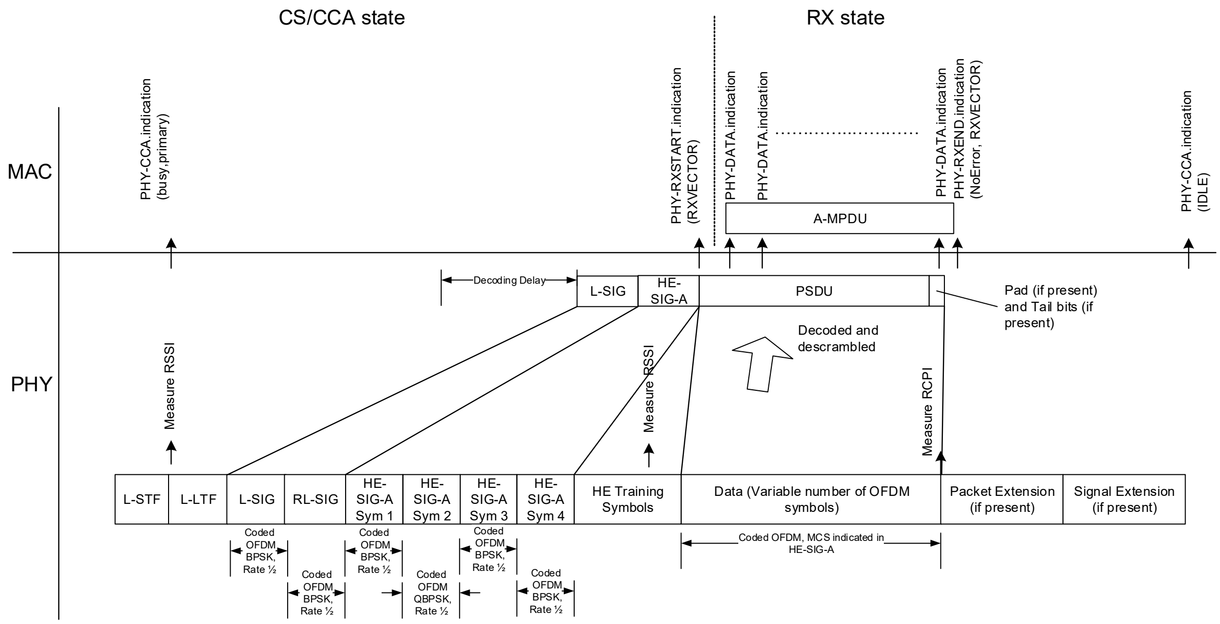
Typical PHY receive procedures are shown in Figure 28-47 (PHY receive procedure for an HE SU PPDU), Figure 28-48 (PHY receive procedure for an HE extended range SU PPDU), Figure 28-49 (PHY receive procedure for an HE MU PPDU), and Figure 28-50 (PHY receive procedure for an HE trigger-based PPDU) respectively. A typical state machine implementation of the receive PHY is given in Figure 28-51 (PHY receive state machine). This receive procedure and state machine do not describe the operation of optional features, such as DCM. If the detected format indicates a Non-HT PPDU, refer to the receive procedure and state machine in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification). If the detected format indicates an HT PPDU format, refer to the receive procedure and state machine in Clause 19

(High Throughput (HT) PHY specification). If the detected format indicates a VHT PPDU format, refer to the receive procedure and state machine in Clause 21 (Very High Throughput (VHT) PHY specification).Through station management (via the PLME) the PHY is set to the appropriate frequency, as specified in 28.4 (HE PLME). The PHY has also been configured with cell identification information and STA identification information (i.e., BSS Color value and STA ID in the cell) so that it can receive data intended for the STA in the specific cell. Other receive parameters, such as RSSI and indicated DATARATE, may be accessed via the PHY-SAP.



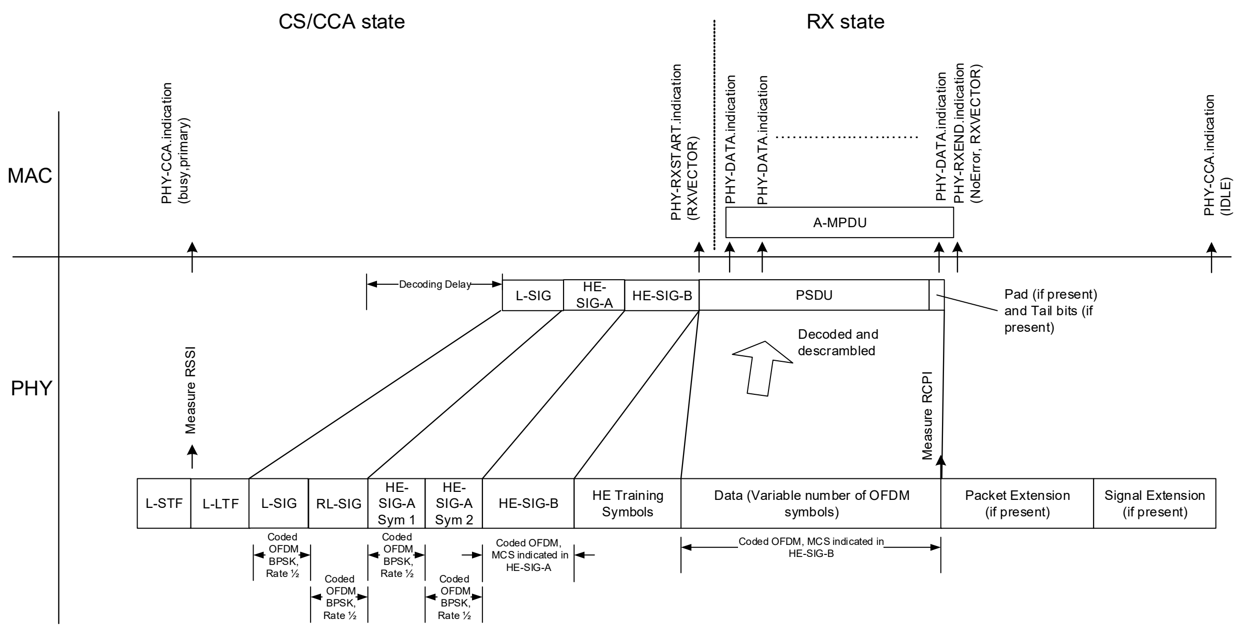
NOTE—This procedure does not describe the operation of optional features, such as DCM.

Figure 28-47—PHY receive procedure for an HE SU PPDU



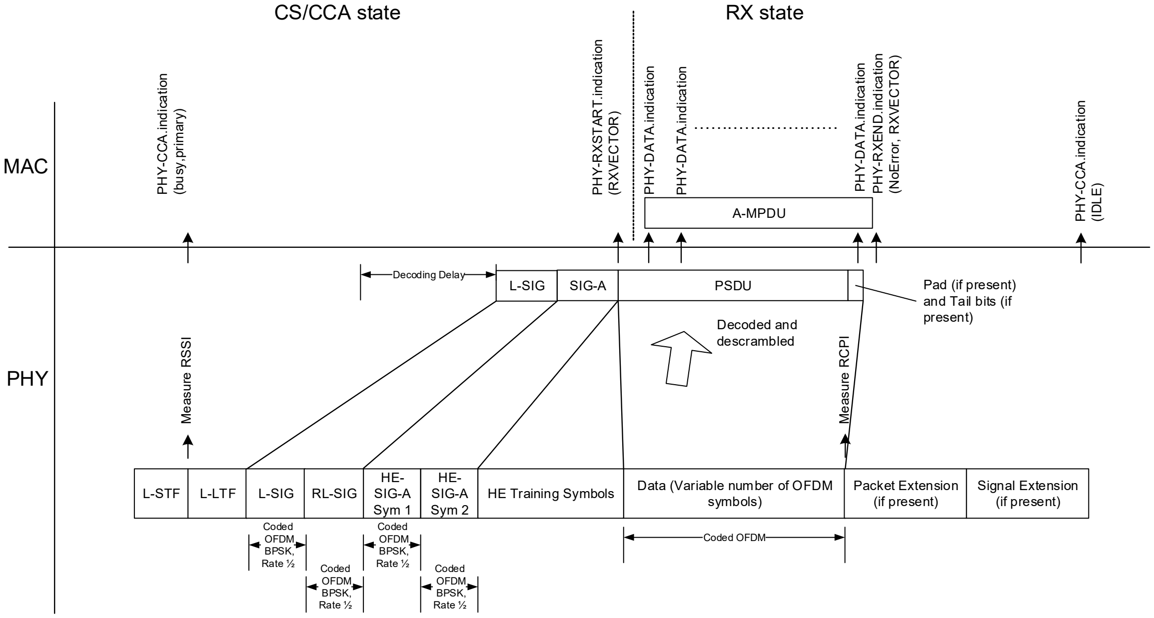
NOTE—This procedure does not describe the operation of optional features, such as DCM.

Figure 28-48—PHY receive procedure for an HE extended range SU PPDU



NOTE—This procedure does not describe the operation of optional features, such as DCM.

Figure 28-49—PHY receive procedure for an HE MU PPDU



NOTE—This procedure does not describe the operation of optional features, such as DCM.

Figure 28-50—PHY receive procedure for an HE trigger-based PPDU

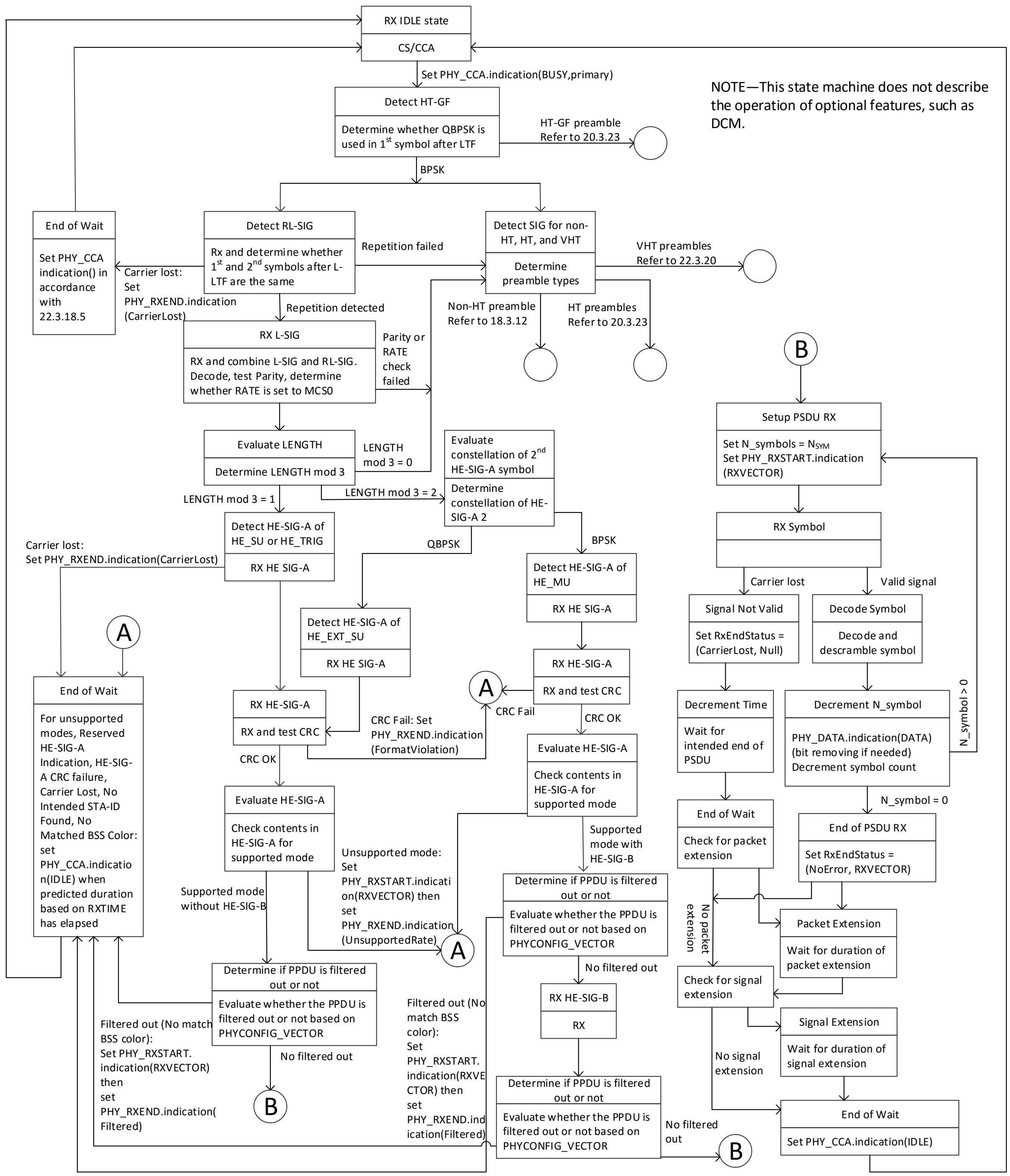


Figure 28-51—PHY receive state machine

Upon receiving the transmitted PHY preamble overlapping the primary 20 MHz channel in a greater than or equal to 20 MHz BSS, the PHY measures a receive signal strength. This activity is indicated by the PHY to the MAC via a PHY-CCA.indication primitive. A PHY-CCA.indication(BUSY, channel-list) primitive is also issued as an initial indication of reception of a signal as specified in 22.3.18.5 (CCA sensitivity). The channel-list parameter of the PHYCCA.indication primitive is absent when the operating channel width is

20 MHz. The channel-list parameter is present and includes the element primary when the operating channel width is 40 MHz, 80 MHz, 160 MHz, or 80+80 MHz.

The PHY shall not issue a PHY-RXSTART.indication primitive in response to a PPDU that does not overlap the primary channel, except when the PHY at an AP receives the HE-trigger based PPDU. In such case, the PHY shall issue a PHY-RXSTART.indication primitive in response to a PPDU transmission either at the primary or at the secondary channel.

The PHY includes the most recently measured RSSI value in the PHY-RXSTART.indication(RXVECTOR) primitive issued to the MAC.

After the PHY-CCA.indication(BUSY, channel-list) primitive is issued, the PHY entity shall begin receiving the training symbols and searching for the preambles for NON-HT, HT, VHT, and HE PPDUs, respectively. If the constellation used in the first symbol after the first long training field is QBPSK, the PHY entity shall continue to detect the received signal using the receive procedure for HT-GF depicted in Clause 19. Otherwise, for detecting the HE preamble, the PHY entity shall search for L-SIG and RL-SIG in order to set the maximum duration of the data stream. If RL-SIG is detected, the PHY entity should check the parity bit and RATE fields in L-SIG and RL-SIG. If either the check of the parity bit is invalid or the RATE field is not set to MCS0 in NON-HT, a PHY-RXSTART.indication primitive is not issued. If the check of the parity bit is valid and the RATE field is set to MCS0 but the LENGTH field value in L-SIG is a multiple of 3, a PHY-RXSTART.indication primitive is not issued. In both cases, the PHY should continue to detect the received signal using non-HT, HT, and VHT receive procedure in Clauses 17, 19, and 21, respectively.

If a valid parity bit and the RATE with MCS0 are indicated in L-SIG and RL-SIG and the LENGTH field value in L-SIG and RL-SIG meet the condition that the remainder is 1 after LENGTH divided by 3, the PHY entity should begin receiving the sequence of HE-SIG-A, HE-STF, and HE-LTF for HE SU PPDU and HE trigger-based PPDU as shown in Figure 28-47 (PHY receive procedure for an HE SU PPDU) and Figure 28-50 (PHY receive procedure for an HE trigger-based PPDU), respectively. After RL-SIG, the PHY entity shall receive two symbols of HE-SIG-A immediately followed by HE-STF. The PHY entity shall check CRC of HE-SIG-A. If the CRC check is valid, the PHY entity shall report TXOP, BSS Color and check Format field, and continue to receive HE-STF. The PHY entity shall report to the MAC entity the predicted duration of the TXOP in HE-SIG-A. The PHY entity shall check the BSS color in HE-SIG-A. If the BSS color doesn't contain an intended value, the PHY entity shall set PHY_RXSTART.indication(RXVECTOR) then set PHY_RXEND.indication(Filtered). The PHY entity shall check Format field in HE-SIG-A. If the Format field indicates an HE SU PPDU, the PHY entity shall receive HE-STF for 4 µs after HE-SIG-A. If the Format field indicates an HE trigger-based PPDU, the PHY entity shall receive HE-STF for 8 µs after HE-SIG-A. The PHY entity shall maintain PHY-CCA.indication(BUSY, channellist) primitive for the predicted duration of the transmitted PPDU, as defined by RXTIME in Equation (28-128), for all supported modes, unsupported modes, Reserved HE-SIG-A Indication, and invalid HE-SIG-A CRC. Reserved HE-SIG-A Indication is defined as an HE-SIG-A with Reserved bits equal to 0. If the HE-SIG-A indicates an unsupported mode, the PHY shall issue a PHY-RXEND.indication(UnsupportedRate)primitive. If the HE-SIG-A indicates an invalid CRC or Reserved HE-SIG-A Indication, the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation)primitive.

If a valid parity bit of L-SIG and RL-SIG is indicated and the LENGTH field value in L-SIG and RL-SIG meet the condition that the remainder is 2 after LENGTH divided by 3, the PHY entity should detect the signal constellations in the second symbol after RL-SIG. If the constellation is QBPSK, the PHY entity shall continue receiving the sequence of HE-SIG-A, HE-STF, and HE-LTF for an HE extended range SU PPDU shown in Figure 28-48 (PHY receive procedure for an HE extended range SU PPDU). After RL-SIG, the PHY entity shall receive four symbols of HE-SIG-A immediately followed by HE-STF. The PHY entity shall check CRC of HE-SIG-A. If the CRC check is valid, the PHY entity shall report TXOP, BSS Color, and continue to receive HE-STF. The PHY entity shall report to the MAC entity the predicted duration of the TXOP in HE-SIG-A. The PHY entity shall check the BSS color in HE-SIG-A. If the BSS color doesn't contain an intended value, the PHY entity shall set PHY_RXSTART.indication(RXVECTOR) then set PHY_RXEND.indication(Filtered). The PHY entity shall receive HE-STF for 4 µs after HE-SIG-A. The PHY entity shall maintain PHY-CCA.indication(BUSY, channellist) primitive for the predicted duration of the transmitted PPDU, as defined by RXTIME in Equation (28-128), for all supported modes, unsupported modes, Reserved HE-SIG-A Indication, and invalid HE-SIG-A CRC. Reserved HE-SIG-A Indication is defined as an HE-SIG-A with Reserved bits equal to 0. If the HE-SIG-A indicates an unsupported mode, the PHY shall issue a PHY-RXEND.indication(UnsupportedRate)primitive. If the HE-SIG-A indicates an invalid CRC or Reserved HE-SIG-A Indication, the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation) primitive.

If a valid parity bit of L-SIG and RL-SIG is indicated and the LENGTH field value in L-SIG and RL-SIG meet the condition that the remainder is 2 after LENGTH divided by 3, the PHY entity should detect the signal constellations in the second symbol after RL-SIG. If the constellation is BPSK, the PHY entity shall continue receiving the sequence of HE-SIG-A, HE-SIG-B, HE-STF, and HE-LTF for an HE MU PPDU shown in Figure 28-49 (PHY receive procedure for an HE MU PPDU). After RL-SIG, the PHY entity shall receive two symbols of HE-SIG-A immediately followed by HE-SIG-B. The PHY entity shall check CRC of HE-SIG-A. If the CRC check is valid, the PHY entity shall report TXOP, BSS Color, and continue to receive HE-SIG-B. The PHY entity shall report to the MAC entity the predicted duration of the TXOP in HE-SIG-A. The PHY entity shall check the BSS color in HE-SIG-A. If the BSS color doesn't contain an intended value, the PHY entity shall set PHY_RXSTART.indication(RXVECTOR) then set PHY_RXEND.indication(Filtered). After HE-SIG-A, the PHY entity shall receive HE-SIG-B for the number of symbols predicted from HE-SIG-A. If the common field presents in HE-SIG-B, the PHY entity shall check the CRC of the common field. If the CRC in the common field is valid or the common field is not present, the PHY entity shall search for intended STA-ID in each user-specific subfield with a valid CRC. If no CRC is valid or no intended STA-ID is detected, the PHY entity shall set PHY_RXSTART.indication(RXVECTOR) then set PHY_RXEND.indication(Filtered). If a complete allocation of an intended STA-ID is detected in block with valid CRC, the PHY entity shall continue receiving HE-STF for 4 µs after HE-SIG-B for the detected and intended STA. The PHY entity shall maintain PHY-CCA.indication(BUSY, channellist) primitive for the predicted duration of the transmitted PPDU, as defined by RXTIME in Equation (28-128), for all supported modes, unsupported modes, Reserved HE-SIG-A Indication, and invalid HE-SIG-A CRC. Reserved HE-SIG-A Indication is defined as an HE-SIG-A with Reserved bits equal to 0. If the HE-SIG-A indicates an unsupported mode, the PHY shall issue a PHY-RXEND.indication(UnsupportedRate)primitive. If the HE-SIG-A indicates an invalid CRC or Reserved HE-SIG-A Indication, the PHY shall issue the error condition PHY-RXEND.indication(FormatViolation)primitive.

If signal loss occurs during reception prior to completion of the PSDU reception, the error condition PHYRXEND. indication(CarrierLost) shall be reported to the MAC. After waiting for the end of the PPDU as determined by Equation (28-128) the PHY shall set the PHY-CCA.indication (IDLE) primitive and return to the RX IDLE state.

$$\mathrm{RXTIME}(\mu s) = 20 + T_{\mathrm{HE\_PREAMBLE}} + N_{SYM}T_{SYM} + T_{PE} + SignalExtension \qquad (28\text{-}128)$$

where

$T_{\mathrm{HE\_PREAMBLE}}$, N_{SYM} and T_{PE} are defined in Equation (28-116) and Equation (28-117)

SignalExtension is 0 µs when TXVECTOR parameter NO_SIG_EXTN is true and is aSignalExtension as defined in Table 19-25 (HT PHY characteristics) when TXVECTOR parameter NO_SIG_EXTN is false.

Except in an HE NDP PPDU, a Data field follows the HE-STF and HE-LTF fields. The number of symbols in the Data field and the packet extension duration are computed from Equation (28-116) and Equation (28-117), respectively.

The received PSDU bits are assembled into octets, decoded, and present to the MAC using a series of PHY-DATA.indication(DATA) primitive exchanges. Any final bits that cannot be assembled into a complete octet are considered pad bits and discarded. After the reception of the final bit of the last PSDU octet, and possible padding and tail bits, the PHY entity shall check whether packet extension and/or signal extension is applied. If packet extension and/or signal extension is applied, the PHY entity shall wait until the packet extension and/or signal extension expires before returning to the RX IDLE state, as shown in Figure 28-51 (PHY receive state machine).

The receiving procedures are subject to further changes depending on the decisions of spatial reuse and 20 MHz only devices.

28.4 HE PLME

28.4.1 PLME_SAP sublayer management primitives

Table 25-1 (HE PHY MIB attributes (11ax)) lists the MIB attributes that may be accessed by the PHY entities and the intralayer of higher level LMEs. These attributes are accessed via the PLME-GET, PLME-SET, PLME-RESET, and PLME-CHARACTERISTICS primitives defined in 6.5 (PLME SAP interface).

28.4.2 TXTIME and PSDU_LENGTH calculation

The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated for an HE PPDU using Equation (28-129).

$$\mathrm{TXTIME} = 20 + T_{\mathrm{HE\_PREAMBLE}} + N_{SYM}T_{SYM} + T_{PE} + SignalExtension \quad (28\text{-}129)$$

where

$T_{\mathrm{HE\_PREAMBLE}}$ is defined as in Equation (28-116) and Equation (28-117), and *SignalExtension* is 0 μs when TXVECTOR parameter NO_SIG_EXTN is true and is aSignalExtension as defined in Table 19-25 (HT PHY characteristics) when TXVECTOR parameter NO_SIG_EXTN is false

For an HE NDP PPDU, there is no Data field and $N_{SYM} = 0$.

For an HE SU PPDU and HE extended range SU PPDU using BCC encoding, the total number of OFDM symbols in the Data field is given by Equation (28-66).

For an HE SU PPDU and HE extended range SU PPDU using LDPC encoding, the total number of OFDM symbols in the Data field, N_{SYM}, is given in 28.3.11.5.2 (LDPC coding).

For an HE MU PPDU (including both MU-MIMO and OFDMA), the total number of OFDM symbols in the Data field, N_{SYM}, is given in 28.3.11.5.4 (Encoding process for an HE MU PPDU).

For an HE trigger-based PPDU, the total number of OFDM symbols in the Data field, N_{SYM}, is given in 28.3.11.5.5 (Encoding process for an HE trigger-based PPDU).

T_{PE} is given by Equation (28-113).

The value of the PSDU_LENGTH parameter returned in the PLME-TXTIME.confirm primitive for an HE SU PPDU and HE extended range SU PPDU is calculated using Equation (28-130).

$$\text{PSDU\_LENGTH} = \left\lfloor \frac{(N_{SYM,init} - m_{STBC})N_{DBPS} + m_{STBC}N_{DBPS,last,init} - N_{service} - N_{tail}}{8} \right\rfloor \quad (28\text{-}130)$$

where

$N_{SYM,init}$ is given by Equation (28-65) for BCC encoding and by Equation (28-70) for LDPC encoding
m_{STBC} is 2 when STBC is used, and 1 otherwise
N_{DBPS} is given in 28.5 (Parameters for HE-MCSs)
$N_{DBPS,last,init}$ is given by Equation (28-62)

The value of the PSDU_LENGTH parameter for user *u* returned in the PLME-TXTIME.confirm primitive and in the RXVECTOR for an HE MU PPDU is calculated using Equation (28-131).

$$\text{PSDU\_LENGTH}_u = \left\lfloor \frac{(N_{SYM,init} - m_{STBC})N_{DBPS,u} + m_{STBC}N_{DBPS,last,init,u} - N_{service} - N_{tail}}{8} \right\rfloor \quad (28\text{-}131)$$

$N_{SYM,init}$ is given by Equation (28-78)
$N_{DBPS,last,init,u}$ is given by Equation (28-79)

The value of the PSDU_LENGTH parameter returned in the PLME-TXTIME.confirm primitive for an HE NDP PPDU is 0.

28.4.3 HE PHY

The static HE PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, shall be as shown in Table 20-25 (HT PHY characteristics) unless otherwise listed in Table 28-46 (HE PHY characteristics). The definitions for these characteristics are given in 6.5 (PLME SAP interface).

Table 28-46—HE PHY characteristics

Characteristic	Value
aTxPHYDelay	Implementation dependent
aRxPHYDelay	Implementation dependent
aCCAMidTIme	25 µs
aPPDUMaxTime	5.484 ms
aPSDUMaxLength	6 500 631 octets

28.5 Parameters for HE-MCSs

The rate-dependent parameters for 26-tone RU, 52-tone RU, 106-tone RU, 242-tone RU and non-OFDMA 20 MHz, 484-tone RU and non-OFDMA 40 MHz, 996-tone RU and non-OFDMA 80 MHz, non-OFDMA 160 MHz and 80+80 MHz N_{SS} = 1, …, 8 are given in Table 28-47 (HE-MCSs for mandatory 26-tone RU, NSS = 1) through Table 28-102 (HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, NSS = 8). Support for HE-MCS 8, 9, 10, and 11 (when valid) is optional in all cases. HE-MCS 10 and 11 (1024-QAM) are applicable only to RU sizes equal to or larger than 242 tones.

Dual sub-carrier modulation (DCM) is an optional modulation scheme for any OFDMA and non OFDMA transmissions. DCM is only applied to MCS 0, MCS 1, MCS 3 and MCS 4. DCM is applied only with

N_{SS} = 1 or N_{SS} = 2 (in the case of single user RU in an HE MU PPDU, $N_{SS,r,u}$ = 1 or $N_{SS,r,u}$ = 2). An HE STA shall support single spatial stream HE-MCSs within the range HE-MCS 0 to HE-MCS 7 for all channel widths for which it has indicated support regardless of the Tx or Rx Highest Supported Long GI Data Rate subfield values in the Supported HE-MCS and NSS Set field. When more than one spatial stream is supported, the Tx or Rx Highest Supported Long GI Data Rate subfield values in the Supported HE-MCS and NSS Set field may result in a reduced HE-MCS range (cut-off) for N_{SS} = 2, …, 8. Support for OFDMA 26-tone RU, 52-tone RU, 106-tone RU, 242-tone RU and 996-tone RU with N_{SS} = 1 is mandatory. Support for non-OFDMA 20 MHz, 40 MHz, and 80 MHz with N_{SS} = 1 is mandatory. Support for more than one spatial stream is optional in all cases. Support for OFDMA and non-OFDMA 160 MHz and 80+80 MHz with N_{SS} = 1, …, 8 is optional.

Table 28-47 (HE-MCSs for mandatory 26-tone RU, NSS = 1) to Table 28-102 (HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, NSS = 8) define HE-MCSs not only for SU transmission but also for user u at r-th RU of an MU transmission. In the case of HE-MCSs for MU transmissions, the parameters, N_{SS}, R, N_{BPSCS}, N_{CBPS}, and N_{DBPS} are replaced with $N_{SS,u}$, R_u, $N_{BPSCS,u}$, $N_{CBPS,u}$, and $N_{DBPS,u}$, respectively.

Table 28-47—HE-MCSs for mandatory 26-tone RU, N_{SS} = 1

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 μs GI	1.6 μs GI	3.2 μs GI
0	1	BPSK	1/2	1	12	12	6	0.4	0.4	0.4
	0		1/2		24	24	12	0.9	0.8	0.8
1	1	QPSK	1/2	2	12	24	12	0.9	0.8	0.8
	0		1/2		24	48	24	1.8	1.7	1.5
2	N/A		3/4		24	48	36	2.6	2.5	2.3
3	1	16-QAM	1/2	4	12	48	24	1.8	1.7	1.5
	0		1/2		24	96	48	3.5	3.3	3.0
4	1		3/4		12	48	36	2.6	2.5	2.3
	0		3/4		24	96	72	5.3	5.0	4.5
5	N/A	64-QAM	2/3	6	24	144	96	7.1	6.7	6.0
6			3/4				108	7.9	7.5	6.8
7			5/6				120	8.8	8.3	7.5
8		256-QAM	3/4	8		192	144	10.6	10.0	9.0
9			5/6				160	11.8	11.1	10.0

Table 28-48—HE-MCSs for mandatory 26-tone RU, N_{SS} = 2

HE-MCS Index	DCM	Modula-tion	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 µs GI	1.6 µs GI	3.2 µs GI
0	1	BPSK	1/2	1	12	24	12	0.9	0.8	0.8
	0		1/2		24	48	24	1.8	1.7	1.5
1	1	QPSK	1/2	2	12	48	24	1.8	1.7	1.5
	0		1/2		24	96	48	3.5	3.3	3.0
2	N/A		3/4		24	96	72	5.3	5.0	4.5
3	1	16-QAM	1/2	4	12	96	48	3.5	3.3	3.0
	0		1/2		24	192	96	7.1	6.7	6.0
4	1		3/4		12	96	72	5.3	5.0	4.5
	0		3/4		24	192	144	10.6	10.0	9.0
5	N/A	64-QAM	2/3	6	24	288	192	14.1	13.3	12.0
6			3/4				216	15.9	15.0	13.5
7			5/6				240	17.6	16.7	15.0
8		256-QAM	3/4	8		384	288	21.2	20.0	18.0
9			5/6				320	23.5	22.2	20.0

Table 28-49—HE-MCSs for mandatory 26-tone RU, N_{SS} = 3

HE-MCS Index	DCM	Modula-tion	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 µs GI	1.6 µs GI	3.2 µs GI
0	N/A	BPSK	1/2	1	24	72	36	2.6	2.5	2.3
1		QPSK	1/2	2		144	72	5.3	5.0	4.5
2			3/4				108	7.9	7.5	6.8
3		16-QAM	1/2	4		288	144	10.6	10.0	9.0
4			3/4				216	15.9	15.0	13.5
5		64-QAM	2/3	6		432	288	21.2	20.0	18.0
6			3/4				324	23.8	22.5	20.3
7			5/6				360	26.5	25.0	22.5
8		256-QAM	3/4	8		576	432	31.8	30.0	27.0
9			5/6				480	35.3	33.3	30.0

Table 28-50—HE-MCSs for mandatory 26-tone RU, N_{SS} = 4

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps) 0.8 µs GI	Data rate (Mbps) 1.6 µs GI	Data rate (Mbps) 3.2 µs GI
0	N/A	BPSK	1/2	1	24	96	24	3.5	3.3	3.0
1		QPSK	1/2	2		192	96	7.1	6.7	6.0
2			3/4				144	10.6	10.0	9.0
3		16-QAM	1/2	4		384	192	14.1	13.3	12.0
4			3/4				288	21.2	20.0	18.0
5		64-QAM	2/3	6		576	384	28.2	26.7	24.0
6			3/4				432	31.8	30.0	27.0
7			5/6				480	35.3	33.3	30.0
8		256-QAM	3/4	8		768	576	42.4	40.0	36.0
9			5/6				640	47.1	44.4	40.0

Table 28-51—HE-MCSs for mandatory 26-tone RU, N_{SS} = 5

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps) 0.8 µs GI	Data rate (Mbps) 1.6 µs GI	Data rate (Mbps) 3.2 µs GI
0	N/A	BPSK	1/2	1	24	120	60	4.4	4.2	3.8
1		QPSK	1/2	2		240	120	8.8	8.3	7.5
2			3/4				180	13.2	12.5	11.3
3		16-QAM	1/2	4		480	240	17.6	16.7	15.0
4			3/4				360	26.5	25.0	22.5
5		64-QAM	2/3	6		720	480	35.3	33.3	30.0
6			3/4				540	39.7	37.5	33.8
7			5/6				600	44.1	41.7	37.5
8		256-QAM	3/4	8		960	720	52.9	50.0	45.0
9			5/6				800	58.8	55.6	50.0

Table 28-52—HE-MCSs for mandatory 26-tone RU, N_{SS} = 6

HE-MCS Index	DCM	Modula-tion	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 µs GI	1.6 µs GI	3.2 µs GI
0	N/A	BPSK	1/2	1	24	144	72	5.3	5.0	4.5
1		QPSK	1/2	2		288	144	10.6	10.0	9.0
2			3/4				216	15.9	15.0	13.5
3		16-QAM	1/2	4		576	288	21.2	20.0	18.0
4			3/4				432	31.8	30.0	27.0
5		64-QAM	2/3	6		864	576	42.4	40.0	36.0
6			3/4				648	47.6	45.0	40.5
7			5/6				720	52.9	50.0	45.0
8		256-QAM	3/4	8		1 152	864	63.5	60.0	54.0
9			5/6				960	70.6	66.7	60.0

Table 28-53—HE-MCSs for mandatory 26-tone RU, N_{SS} = 7

HE-MCS Index	DCM	Modula-tion	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 µs GI	1.6 µs GI	3.2 µs GI
0	N/A	BPSK	1/2	1	24	168	84	6.2	5.8	5.3
1		QPSK	1/2	2		336	168	12.4	11.7	10.5
2			3/4				252	18.5	17.5	15.8
3		16-QAM	1/2	4		672	336	24.7	23.3	21.0
4			3/4				504	37.1	35.0	31.5
5		64-QAM	2/3	6		1 008	672	49.4	46.7	42.0
6			3/4				756	55.6	52.5	47.3
7			5/6				840	61.8	58.3	52.5
8		256-QAM	3/4	8		1 344	1 008	74.1	70.0	63.0
9			5/6				1 120	82.4	77.8	70.0

Table 28-54—HE-MCSs for mandatory 26-tone RU, N_{SS} = 8

HE-MCS Index	DCM	Modula-tion	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps) 0.8 µs GI	Data rate (Mbps) 1.6 µs GI	Data rate (Mbps) 3.2 µs GI
0	N/A	BPSK	1/2	1	24	192	96	7.1	6.7	6.0
1		QPSK	1/2	2		384	192	14.1	13.3	12.0
2			3/4				288	21.2	20.0	18.0
3		16-QAM	1/2	4		768	384	28.2	26.7	24.0
4			3/4				576	42.4	40.0	36.0
5		64-QAM	2/3	6		1 152	768	56.5	53.3	48.0
6			3/4				864	63.5	60.0	54.0
7			5/6				960	70.6	66.7	60.0
8		256-QAM	3/4	8		1 536	1 152	84.7	80.0	72.0
9			5/6				1 280	94.1	88.9	80.0

Table 28-55—HE-MCSs for mandatory 52-tone RU, N_{SS} = 1

HE-MCS Index	DCM	Modula-tion	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps) 0.8 µs GI	Data rate (Mbps) 1.6 µs GI	Data rate (Mbps) 3.2 µs GI
0	1	BPSK	1/2	1	24	24	12	0.9	0.8	0.8
	0		1/2		48	48	24	1.8	1.7	1.5
1	1	QPSK	1/2	2	24	48	24	1.8	1.7	1.5
	0		1/2		48	96	48	3.5	3.3	3.0
2	N/A		3/4		48	96	72	5.3	5.0	4.5
3	1	16-QAM	1/2	4	24	96	48	3.5	3.3	3.0
	0		1/2		48	192	96	7.1	6.7	6.0
4	1		3/4		24	96	72	5.3	5.0	4.5
	0		3/4		48	192	144	10.6	10.0	9.0
5	N/A	64-QAM	2/3	6	48	288	192	14.1	13.3	12.0
6			3/4				216	15.9	15.0	13.5
7			5/6				240	17.6	16.7	15.0
8		256-QAM	3/4	8		384	288	21.2	20.0	18.0
9			5/6				320	23.5	22.2	20.0

Table 28-56—HE-MCSs for mandatory 52-tone RU, N_{SS} = 2

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps) 0.8 µs GI	1.6 µs GI	3.2 µs GI
0	1	BPSK	1/2	1	24	48	24	1.8	1.7	1.5
	0		1/2		48	96	48	3.5	3.3	3.0
1	1	QPSK	1/2	2	24	96	48	3.5	3.3	3.0
	0		1/2		48	192	96	7.1	6.7	6.0
2	N/A		3/4		48	192	144	10.6	10.0	9.0
3	1	16-QAM	1/2	4	24	192	96	7.1	6.7	6.0
	0		1/2		48	384	192	14.1	13.3	12.0
4	1		3/4		24	192	144	10.6	10.0	9.0
	0		3/4		48	384	288	21.2	20.0	18.0
5	N/A	64-QAM	2/3	6	48	576	384	28.2	26.7	24.0
6			3/4				432	31.8	30.0	27.0
7			5/6				480	35.3	33.3	30.0
8		256-QAM	3/4	8		768	576	42.4	40.0	36.0
9			5/6				640	47.1	44.4	40.0

Table 28-57—HE-MCSs for mandatory 52-tone RU, N_{SS} = 3

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps) 0.8 µs GI	1.6 µs GI	3.2 µs GI
0	N/A	BPSK	1/2	1	48	144	72	5.3	5.0	4.5
1		QPSK	1/2	2		288	144	10.6	10.0	9.0
2			3/4				216	15.9	15.0	13.5
3		16-QAM	1/2	4		576	288	21.2	20.0	18.0
4			3/4				432	31.8	30.0	27.0
5		64-QAM	2/3	6		864	576	42.4	40.0	36.0
6			3/4				648	47.6	45.0	40.5
7			5/6				720	52.9	50.0	45.0
8		256-QAM	3/4	8		1 152	864	63.5	60.0	54.0
9			5/6				960	70.6	66.7	60.0

Table 28-58—HE-MCSs for mandatory 52-tone RU, N_{SS} = 4

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps) 0.8 µs GI	1.6 µs GI	3.2 µs GI
0	N/A	BPSK	1/2	1	48	192	96	7.1	6.7	6.0
1		QPSK	1/2	2		384	192	14.1	13.3	12.0
2			3/4				288	21.2	20.0	18.0
3		16-QAM	1/2	4		768	384	28.2	26.7	24.0
4			3/4				576	42.4	40.0	36.0
5		64-QAM	2/3	6		1 152	768	56.5	53.3	48.0
6			3/4				864	63.5	60.0	54.0
7			5/6				960	70.6	66.7	60.0
8		256-QAM	3/4	8		1 536	1 152	84.7	80.0	72.0
9			5/6				1 280	94.1	88.9	80.0

Table 28-59—HE-MCSs for mandatory 52-tone RU, N_{SS} = 5

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps) 0.8 µs GI	1.6 µs GI	3.2 µs GI
0	N/A	BPSK	1/2	1	48	240	120	8.8	8.3	7.5
1		QPSK	1/2	2		480	240	17.6	16.7	15.0
2			3/4				360	26.5	25.0	22.5
3		16-QAM	1/2	4		960	480	35.3	33.3	30.0
4			3/4				720	52.9	50.0	45.0
5		64-QAM	2/3	6		1 440	960	70.6	66.7	60.0
6			3/4				1080	79.4	75.0	67.5
7			5/6				1 200	88.2	83.3	75.0
8		256-QAM	3/4	8		1 920	1 440	105.9	100.0	90.0
9			5/6				1 600	117.6	111.1	100.0

Table 28-60—HE-MCSs for mandatory 52-tone RU, N_{SS} = 6

HE-MCS Index	DCM	Modula-tion	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 μs GI	1.6 μs GI	3.2 μs GI
0	N/A	BPSK	1/2	1	48	288	144	10.6	10.0	9.0
1		QPSK	1/2	2		576	288	21.2	20.0	18.0
2			3/4				432	31.8	30.0	27.0
3		16-QAM	1/2	4		1 152	576	42.4	40.0	36.0
4			3/4				864	63.5	60.0	54.0
5		64-QAM	2/3	6		1 728	1 152	84.7	80.0	72.0
6			3/4				1 296	95.3	90.0	81.0
7			5/6				1 440	105.9	100.0	90.0
8		256-QAM	3/4	8		2 304	1 728	127.1	120.0	108.0
9			5/6				1 920	141.2	133.3	120.0

Table 28-61—HE-MCSs for mandatory 52-tone RU, N_{SS} = 7

HE-MCS Index	DCM	Modula-tion	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 μs GI	1.6 μs GI	3.2 μs GI
0	N/A	BPSK	1/2	1	48	336	168	12.4	11.7	10.5
1		QPSK	1/2	2		672	336	24.7	23.3	21.0
2			3/4				504	37.1	35.0	31.5
3		16-QAM	1/2	4		1 344	672	49.4	46.7	42.0
4			3/4				1 008	74.1	70.0	63.0
5		64-QAM	2/3	6		2 016	1 344	98.8	93.3	84.0
6			3/4				1 512	111.2	105.0	94.5
7			5/6				1 680	123.5	116.7	105.0
8		256-QAM	3/4	8		2 688	2 016	148.2	140.0	126.0
9			5/6				2 240	164.7	155.6	140.0

Table 28-62—HE-MCSs for mandatory 52-tone RU, N_{SS} = 8

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps) 0.8 µs GI	1.6 µs GI	3.2 µs GI
0	N/A	BPSK	1/2	1	48	384	192	14.1	13.3	12.0
1		QPSK	1/2	2		768	384	28.2	26.7	24.0
2			3/4				576	42.4	40.0	36.0
3		16-QAM	1/2	4		1 536	768	56.5	53.3	48.0
4			3/4				1 152	84.7	80.0	72.0
5		64-QAM	2/3	6		2 304	1 536	112.9	106.7	96.0
6			3/4				1 728	127.1	120.0	108.0
7			5/6				1 920	141.2	133.3	120.0
8		256-QAM	3/4	8		3 072	2 304	169.4	160.0	144.0
9			5/6				2 560	188.2	177.8	160.0

Table 28-63—HE-MCSs for mandatory 106-tone RU, N_{SS} = 1

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps) 0.8 µs GI	1.6 µs GI	3.2 µs GI
0	1	BPSK	1/2	1	51	51	25	1.8	1.7	1.6
	0		1/2		102	102	51	3.8	3.5	3.2
1	1	QPSK	1/2	2	51	102	51	3.8	3.5	3.2
	0		1/2		102	204	102	7.5	7.1	6.4
2	N/A		3/4		102	204	153	11.3	10.6	9.6
3	1	16-QAM	1/2	4	51	204	102	7.5	7.1	6.4
	0		1/2		102	408	204	15.0	14.2	12.8
4	1		3/4		51	204	153	11.3	10.6	9.6
	0		3/4		102	408	306	22.5	21.3	19.1
5	N/A	64-QAM	2/3	6	102	612	408	30.0	28.3	25.5
6			3/4		102		459	33.8	31.9	28.7
7			5/6		102		510	37.5	35.4	31.9
8		256-QAM	3/4	8	102	816	612	45.0	42.5	38.3
9			5/6		102		680	50.0	47.2	42.5

Table 28-64—HE-MCSs for mandatory 106-tone RU, N_{SS} = 2

HE-MCS Index	DCM	Modula-tion	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 µs GI	1.6 µs GI	3.2 µs GI
0	1	BPSK	1/2	1	51	102	51	3.8	3.5	3.2
	0		1/2		102	204	102	7.5	7.1	6.4
1	1	QPSK	1/2	2	51	204	102	7.5	7.1	6.4
	0		1/2		102	408	204	15.0	14.2	12.8
2	N/A		3/4		102	408	306	22.5	21.3	19.1
3	1	16-QAM	1/2	4	51	408	204	15.0	14.2	12.8
	0		1/2		102	816	408	30.0	28.3	25.5
4	1		3/4		51	408	306	22.5	21.3	19.1
	0		3/4		102	816	612	45.0	42.5	38.3
5	N/A	64-QAM	2/3	6	102	1 224	816	60.0	56.7	51.0
6			3/4		102		918	67.5	63.8	57.4
7			5/6		102		1 020	75.0	70.8	63.8
8		256-QAM	3/4	8	102	1 632	1 224	90.0	85.0	76.5
9			5/6		102		1 360	100.0	94.4	85.0

Table 28-65—HE-MCSs for mandatory 106-tone RU, N_{SS} = 3

HE-MCS Index	DCM	Modula-tion	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 µs GI	1.6 µs GI	3.2 µs GI
0	N/A	BPSK	1/2	1	102	306	153	11.3	10.6	9.6
1		QPSK	1/2	2		612	306	22.5	21.3	19.1
2			3/4				459	33.8	31.9	28.7
3		16-QAM	1/2	4		1 224	612	45.0	42.5	38.3
4			3/4				918	67.5	63.8	57.4
5		64-QAM	2/3	6		1 836	1 224	90.0	85.0	76.5
6			3/4				1 337	101.3	95.6	86.1
7			5/6				1 530	112.5	106.3	95.6
8		256-QAM	3/4	8		2 448	1 836	135.0	127.5	114.8
9			5/6				2 048	150.0	141.7	127.5

Table 28-66—HE-MCSs for mandatory 106-tone RU, N_{SS} = 4

HE-MCS Index	DCM	Modula-tion	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 μs GI	1.6 μs GI	3.2 μs GI
0	N/A	BPSK	1/2	1	102	408	204	15.0	14.2	12.8
1		QPSK	1/2	2		816	408	30.0	28.3	25.5
2			3/4				612	45.0	42.5	38.3
3		16-QAM	1/2	4		1 632	816	60.0	56.7	51.0
4			3/4				1 224	90.0	85.0	76.5
5		64-QAM	2/3	6		2 448	1 632	120.0	113.3	102.0
6			3/4				1 836	135.0	127.5	114.8
7			5/6				2 040	150.0	141.7	127.5
8		256-QAM	3/4	8		3 264	2 448	180.0	170.0	153.0
9			5/6				2 720	200.0	188.9	170.0

Table 28-67—HE-MCSs for mandatory 106-tone RU, N_{SS} = 5

HE-MCS Index	DCM	Modula-tion	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 μs GI	1.6 μs GI	3.2 μs GI
0	N/A	BPSK	1/2	1	102	510	255	18.8	17.7	15.9
1		QPSK	1/2	2		1 020	510	37.5	35.4	31.9
2			3/4				765	56.3	53.1	47.8
3		16-QAM	1/2	4		2 040	1 020	75.0	70.8	63.8
4			3/8				1 530	112.5	106.3	95.6
5		64-QAM	2/3	6		3 060	2 040	150.0	141.7	127.5
6			3/4				2 295	168.8	159.4	143.4
7			5/6				2 550	187.5	177.1	159.4
8		256-QAM	3/4	8		4 080	3 060	225.0	212.5	191.3
9			5/6				3 400	250.0	236.1	212.5

Table 28-68—HE-MCSs for mandatory 106-tone RU, N_{SS} = 6

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 µs GI	1.6 µs GI	3.2 µs GI
0	N/A	BPSK	1/2	1	102	612	306	22.5	21.3	19.1
1		QPSK	1/2	2		1 224	612	45.0	42.5	38.3
2			3/4				918	67.5	63.8	57.4
3		16-QAM	1/2	4		2 448	1 224	90.0	85.0	76.5
4			3/4				1 836	135.0	127.5	114.8
5		64-QAM	2/3	6		3 672	2 448	180.0	170.0	153.0
6			3/4				2 754	202.5	191.3	172.1
7			5/6				3 060	225.0	212.5	191.3
8		256-QAM	3/4	8		4 896	3 672	270.0	255.0	229.5
9			5/6				4 080	300.0	283.3	255.0

Table 28-69—HE-MCSs for mandatory 106-tone RU, N_{SS} = 7

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 µs GI	1.6 µs GI	3.2 µs GI
0	N/A	BPSK	1/2	1	102	714	357	26.3	24.8	22.3
1		QPSK	1/2	2		1 428	714	52.5	49.6	44.6
2			3/4				1 071	78.8	74.4	66.9
3		16-QAM	1/2	4		2 856	1 428	105.0	99.2	89.3
4			3/4				2 142	157.5	148.8	133.9
5		64-QAM	2/3	6		4 284	2 856	210.0	198.3	178.5
6			3/4				3 213	236.3	223.1	200.8
7			5/6				3 570	262.5	247.9	223.1
8		256-QAM	3/4	8		5 712	4 284	315.0	297.5	267.8
9			5/6				4 760	350.0	330.6	297.5

Table 28-70—HE-MCSs for mandatory 106-tone RU, N_{SS} = 8

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps) 0.8 µs GI	1.6 µs GI	3.2 µs GI
0	N/A	BPSK	1/2	1	102	816	408	30.0	28.3	25.5
1		QPSK	1/2	2		1632	816	60.0	56.7	51.0
2			3/4				1 224	90.0	85.0	76.5
3		16-QAM	1/2	4		3264	1 632	120.0	113.3	102.0
4			3/4				2 448	180.0	170.0	153.0
5		64-QAM	2/3	6		4896	3 264	240.0	226.7	204.0
6			3/4				3 672	270.0	225.0	229.5
7			5/6				4 080	300.0	283.3	255.0
8		256-QAM	3/4	8		6528	4 896	360.0	340.0	306.0
9			5/6				5 440	400.0	377.8	340.0

Table 28-71—HE-MCSs for mandatory 242-tone RU and mandatory non-OFDMA 20 MHz, N_{SS} = 1

HE-MCS Index	DCM	Modula-tion	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 μs GI	1.6 μs GI	3.2 μs GI
0	1	BPSK	1/2	1	117	117	58	4.3	4.0	3.6
	0		1/2		234	234	117	8.6	8.1	7.3
1	1	QPSK	1/2	2	117	234	117	8.6	8.1	7.3
	0		1/2		234	468	234	17.2	16.3	14.6
2	N/A		3/4		234	468	351	25.8	24.4	21.9
3	1	16-QAM	1/2	4	117	468	234	17.2	16.3	14.6
	0		1/2		234	936	468	34.4	32.5	29.3
4	1		3/4		117	468	351	25.8	24.4	21.9
	0		3/4		234	936	702	51.6	48.8	43.9
5	N/A	64-QAM	2/3	6	234	1 404	936	68.8	65.0	58.5
6			3/4				1 053	77.4	73.1	65.8
7			5/6				1 170	86.0	81.3	73.1
8		256-QAM	3/4	8		1 872	1 404	103.2	97.5	87.8
9			5/6				1 560	114.7	108.3	97.5
10		1024-QAM	3/4	10		2 340	1 755	129.0	121.9	109.7
11			5/6				1 950	143.4	135.4	121.9

Table 28-72—HE-MCSs for mandatory 242-tone RU and mandatory non-OFDMA 20 MHz, N_{SS} = 2

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 µs GI	1.6 µs GI	3.2 µs GI
0	1	BPSK	1/2	1	117	234	117	8.6	8.1	7.3
	0		1/2		234	468	234	17.2	16.3	14.6
1	1	QPSK	1/2	2	117	468	234	17.2	16.3	14.6
	0		1/2		234	936	468	34.4	32.5	29.3
2	N/A		3/4		234	936	702	51.6	48.8	43.9
3	1	16-QAM	1/2	4	117	936	468	34.4	32.5	29.3
	0		1/2		234	1 872	936	68.8	65.0	58.5
4	1		3/4		117	936	702	51.6	48.8	43.9
	0		3/4		234	1 872	1 404	103.2	97.5	87.8
5	N/A	64-QAM	2/3	6	234	2 808	1 872	137.6	130.0	117.0
6			3/4				2 106	154.9	146.3	131.6
7			5/6				2 340	172.1	162.5	146.3
8		256-QAM	3/4	8		3 744	2 808	206.5	195.0	175.5
9			5/6				3 120	229.4	216.7	195.0
10		1024-QAM	3/4	10		4 680	3 510	258.1	243.8	219.4
11			5/6				3 900	286.8	270.8	243.8

Table 28-73—HE-MCSs for mandatory 242-tone RU and mandatory non-OFDMA 20 MHz, N_{SS} = 3

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps) 0.8 µs GI	1.6 µs GI	3.2 µs GI
0	N/A	BPSK	1/2	1	234	702	351	25.8	24.4	21.9
1		QPSK	1/2	2		1 404	702	51.6	48.8	43.9
2			3/4				1 053	77.4	73.1	65.8
3		16-QAM	1/2	4		2 808	1 404	103.2	97.5	87.8
4			3/4				2 106	154.9	146.3	131.6
5		64-QAM	2/3	6		4 212	2 808	206.5	195.0	175.5
6			3/4				3 159	232.3	219.4	197.4
7			5/6				3 510	258.1	243.8	219.4
8		256-QAM	3/4	8		5 616	4 212	309.7	292.5	263.3
9			5/6				4 680	344.1	325.0	292.5
10		1024-QAM	3/4	10		7 020	5 265	387.1	365.6	329.1
11			5/6				5 850	430.1	406.3	365.6

Table 28-74—HE-MCSs for mandatory 242-tone RU and mandatory non-OFDMA 20 MHz, N_{SS} = 4

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps) 0.8 µs GI	1.6 µs GI	3.2 µs GI
0	N/A	BPSK	1/2	1	234	936	468	34.4	32.5	29.3
1		QPSK	1/2	2		1 872	936	68.8	65.0	58.5
2			3/4				1 404	103.2	97.5	87.8
3		16-QAM	1/2	4		3 744	1 872	137.6	130.0	117.0
4			3/4				2 808	206.5	195.0	175.5
5		64-QAM	2/3	6		5 616	3 744	275.3	260.0	234.0
6			3/4				4 212	309.7	292.5	263.3
7			5/6				4 680	344.1	325.0	292.5
8		256-QAM	3/4	8		7 488	5 616	412.9	390.0	351.0
9			5/6				6 240	458.8	433.3	390.0
10		1024-QAM	3/4	10		9 360	7 020	516.2	487.5	438.8
11			5/6				7 800	573.5	541.7	487.5

Table 28-75—HE-MCSs for mandatory 242-tone RU and mandatory non-OFDMA 20 MHz, N_{SS} = 5

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 μs GI	1.6 μs GI	3.2 μs GI
0	N/A	BPSK	1/2	1	234	1 170	585	43.0	40.6	36.6
1		QPSK	1/2	2		2 340	1 170	86.0	81.3	73.1
2			3/4				1 755	129.0	121.9	109.7
3		16-QAM	1/2	4		4 680	2 340	172.1	162.5	146.3
4			3/4				3 510	258.1	243.8	219.4
5		64-QAM	2/3	6		7 020	4 680	344.1	325.0	292.5
6			3/4				5 265	387.1	365.6	329.1
7			5/6				5 850	430.1	406.3	365.6
8		256-QAM	3/4	8		9 360	7 020	516.2	487.5	438.8
9			5/6				7 800	573.5	541.7	487.5
10		1024-QAM	3/4	10		11 700	8 775	645.2	609.4	548.4
11			5/6				9 750	716.9	677.1	609.4

Table 28-76—HE-MCSs for mandatory 242-tone RU and mandatory non-OFDMA 20 MHz, N_{SS} = 6

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 μs GI	1.6 μs GI	3.2 μs GI
0	N/A	BPSK	1/2	1	234	1 404	702	51.6	48.8	43.9
1		QPSK	1/2	2		2 808	1 404	103.2	97.5	87.8
2			3/4				2 106	154.9	146.3	131.6
3		16-QAM	1/2	4		5 616	2 808	206.5	195.0	175.5
4			3/4				4 212	309.7	292.5	263.3
5		64-QAM	2/3	6		8 424	5 616	412.9	390.0	351.0
6			3/4				6 318	464.6	438.8	394.9
7			5/6				7 020	516.2	487.5	438.8
8		256-QAM	3/4	8		11 232	8 424	619.4	585.0	526.5
9			5/6				9 360	688.2	650.0	585.0
10		1024-QAM	3/4	10		14 040	10 530	774.3	731.3	658.1
11			5/6				11 700	860.3	812.5	731.3

Table 28-77—HE-MCSs for mandatory 242-tone RU and mandatory non-OFDMA 20 MHz, N_{SS} = 7

HE-MCS Index	DCM	Modula-tion	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 µs GI	1.6 µs GI	3.2 µs GI
0	N/A	BPSK	1/2	1	234	1 638	819	60.2	56.9	51.2
1		QPSK	1/2	2		3 276	1 638	120.4	113.8	102.4
2			3/4				2 457	180.7	170.6	153.6
3		16-QAM	1/2	4		6 552	3 276	240.9	227.5	204.8
4			3/4				4 914	361.3	341.3	307.1
5		64-QAM	2/3	6		9 828	6 552	481.8	455.0	409.5
6			3/4				7 371	542.0	511.9	460.7
7			5/6				8 190	602.2	568.8	511.9
8		256-QAM	3/4	8		13 104	9 828	722.6	682.5	614.3
9			5/6				10 920	802.9	758.3	682.5
10		1024-QAM	3/4	10		16 380	12 285	903.3	853.1	767.8
11			5/6				13 650	1 003.7	947.9	853.1

Table 28-78—HE-MCSs for mandatory 242-tone RU and mandatory non-OFDMA 20 MHz, N_{SS} = 8

HE-MCS Index	DCM	Modula-tion	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 µs GI	1.6 µs GI	3.2 µs GI
0	N/A	BPSK	1/2	1	234	1 872	936	68.8	65.0	58.5
1		QPSK	1/2	2		3 744	1 872	137.6	130.0	117.0
2			3/4				2 808	206.5	195.0	175.5
3		16-QAM	1/2	4		7 488	3 744	275.3	260.0	234.0
4			3/4				5 616	412.9	390.0	351.0
5		64-QAM	2/3	6		11 232	7 488	550.6	520.0	468.0
6			3/4				8 424	619.4	585.0	526.5
7			5/6				9 360	688.2	650.0	585.0
8		256-QAM	3/4	8		14 976	11 232	825.9	780.0	702.0
9			5/6				12 480	917.6	866.7	780.0
10		1024-QAM	3/4	10		18 720	14 040	1 032.4	975.0	877.5
11			5/6				15 600	1 147.1	1 083.3	975.0

Table 28-79—HE-MCSs for mandatory 484-tone RU and mandatory non-OFDMA 40 MHz, N_{SS} = 1

HE-MCS Index	DCM	Modula-tion	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 µs GI	1.6 µs GI	3.2 µs GI
0	1	BPSK	1/2	1	234	234	117	8.6	8.1	7.3
	0		1/2		468	468	234	17.2	16.3	14.6
1	1	QPSK	1/2	2	234	468	234	17.2	16.3	14.6
	0		1/2		468	936	468	34.4	32.5	29.3
2	N/A		3/4		468	936	702	51.6	48.8	43.9
3	1	16-QAM	1/2	4	234	936	468	34.4	32.5	29.3
	0		1/2		468	1 872	936	68.8	65.0	58.5
4	1		3/4		234	936	702	51.6	48.8	43.9
	0		3/4		468	1 872	1 404	103.2	97.5	87.8
5	N/A	64-QAM	2/3	6	468	2 808	1 872	137.6	130.0	117.0
6			3/4				2 106	154.9	146.3	131.6
7			5/6				2 340	172.1	162.5	146.3
8		256-QAM	3/4	8		3 744	2 808	206.5	195.0	175.5
9			5/6				3 120	229.4	216.7	195.0
10		1024-QAM	3/4	10		4 680	3 510	258.1	243.8	219.4
11			5/6				3 900	286.8	270.8	243.8

Table 28-80—HE-MCSs for mandatory 484-tone RU and mandatory non-OFDMA 40 MHz, N_{SS} = 2

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps) 0.8 µs GI	1.6 µs GI	3.2 µs GI
0	1	BPSK	1/2	1	234	468	234	17.2	16.3	14.6
	0		1/2		468	936	468	34.4	32.5	29.3
1	1	QPSK	1/2	2	234	936	468	34.4	32.5	29.3
	0		1/2		468	1 872	936	68.8	65.0	58.5
2	N/A		3/4		468	1 872	1 404	103.2	97.5	87.8
3	1	16-QAM	1/2	4	234	1 872	936	68.8	65.0	58.5
	0		1/2		468	3 744	1 872	137.6	130.0	117.0
4	1		3/4		234	1 872	1 404	103.2	97.5	87.8
	0		3/4		468	3 744	2 808	206.5	195.0	175.5
5	N/A	64-QAM	2/3	6	468	5 616	3 744	275.3	260.0	234.0
6			3/4				4 212	309.7	292.5	263.3
7			5/6				4 680	344.1	325.0	292.5
8		256-QAM	3/4	8		7 488	5 616	412.9	390.0	351.0
9			5/6				6 240	458.8	433.3	390.0
10		1024-QAM	3/4	10		9 360	7 020	516.2	487.5	438.8
11			5/6				7 800	573.5	541.7	487.5

Table 28-81—HE-MCSs for mandatory 484-tone RU and mandatory non-OFDMA 40 MHz, N_{SS} = 3

HE-MCS Index	DCM	Modula-tion	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 µs GI	1.6 µs GI	3.2 µs GI
0	N/A	BPSK	1/2	1	468	1 404	702	51.6	48.8	43.9
1		QPSK	1/2	2		2 808	1 404	103.2	97.5	87.8
2			3/4				2 106	154.9	146.3	131.6
3		16-QAM	1/2	4		5 616	2 808	206.5	195.0	175.5
4			3/4				4 212	309.7	292.5	263.3
5		64-QAM	2/3	6		8 424	5 616	412.9	390.0	351.0
6			3/4				6 318	464.6	438.8	394.9
7			5/6				7 020	516.2	487.5	438.8
8		256-QAM	3/4	8		11 232	8 424	619.4	585.0	526.5
9			5/6				9 360	688.2	650.0	585.0
10		1024-QAM	3/4	10		14 040	10 530	774.3	731.3	658.1
11			5/6				11 700	860.3	812.5	731.3

Table 28-82—HE-MCSs for mandatory 484-tone RU and mandatory non-OFDMA 40 MHz, N_{SS} = 4

HE-MCS Index	DCM	Modula-tion	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 µs GI	1.6 µs GI	3.2 µs GI
0	N/A	BPSK	1/2	1	468	1 872	936	68.8	65.0	58.5
1		QPSK	1/2	2		3 744	1 872	137.6	130.0	117.0
2			3/4				2 808	206.5	195.0	175.5
3		16-QAM	1/2	4		7 488	3 744	275.3	260.0	234.0
4			3/4				5 616	412.9	390.0	351.0
5		64-QAM	2/3	6		11 232	7 488	550.6	520.0	468.0
6			3/4				8 424	619.4	585.0	526.5
7			5/6				9 360	688.2	650.0	585.0
8		256-QAM	3/4	8		14 976	11 232	825.9	780.0	702.0
9			5/6				12 480	917.6	866.7	780.0
10		1024-QAM	3/4	10		18 720	14 040	1 032.4	975.0	877.5
11			5/6				15 600	1 147.1	1 083.3	975.0

Table 28-83—HE-MCSs for mandatory 484-tone RU and mandatory non-OFDMA 40 MHz, N_{SS} = 5

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 µs GI	1.6 µs GI	3.2 µs GI
0	N/A	BPSK	1/2	1	468	2 340	1 170	86.0	81.3	73.1
1		QPSK	1/2	2		4 680	2 340	172.1	162.5	146.3
2			3/4				3 510	258.1	243.8	219.4
3		16-QAM	1/2	4		9 360	4 680	344.1	325.0	292.5
4			3/8				7 020	516.2	487.5	438.8
5		64-QAM	2/3	6		14 040	9 360	688.2	650.0	585.0
6			3/4				10 530	774.3	731.3	658.1
7			5/6				11 700	860.3	812.5	731.3
8		256-QAM	3/4	8		18 720	14 040	1 032.4	975.0	877.5
9			5/6				15 600	1 147.1	1 083.3	975.0
10		1024-QAM	3/4	10		23 400	17 550	1 290.4	1 218.8	1 096.9
11			5/6				19 500	1 433.8	1 354.2	1 218.8

Table 28-84—HE-MCSs for mandatory 484-tone RU and mandatory non-OFDMA 40 MHz, N_{SS} = 6

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 µs GI	1.6 µs GI	3.2 µs GI
0	N/A	BPSK	1/2	1	468	2 808	1404	103.2	97.5	87.8
1		QPSK	1/2	2		5 616	2808	206.5	195.0	175.5
2			3/4				4212	309.7	292.5	263.3
3		16-QAM	1/2	4		11 232	5616	412.9	390.0	351.0
4			3/4				8424	619.4	585.0	526.5
5		64-QAM	2/3	6		16 848	11 232	825.9	780.0	702.0
6			3/4				12 636	929.1	877.5	789.8
7			5/6				14 040	1 032.4	975.0	877.5
8		256-QAM	3/4	8		22 464	16 848	1 238.8	1 170.0	1 053.0
9			5/6				18 720	1 376.5	1 300.0	1 170.0
10		1024-QAM	3/4	10		28 080	21 060	1 548.5	1 462.5	1 316.3
11			5/6				23 400	1 720.6	1 625.0	1 462.5

Table 28-85—HE-MCSs for mandatory 484-tone RU and mandatory non-OFDMA 40 MHz, N_{SS} = 7

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps) 0.8 µs GI	1.6 µs GI	3.2 µs GI
0	N/A	BPSK	1/2	1	468	3 276	1 638	120.4	113.8	102.4
1		QPSK	1/2	2		6 552	3 276	240.9	227.5	204.8
2			3/4				4 914	361.3	341.3	307.1
3		16-QAM	1/2	4		13 104	6 552	481.8	455.0	409.5
4			3/4				9 828	722.6	682.5	614.3
5		64-QAM	2/3	6		19 656	13 104	963.5	910.0	819.0
6			3/4				14 742	1 084.0	1 023.8	921.4
7			5/6				16 380	1 204.4	1 137.5	1 023.8
8		256-QAM	3/4	8		26 208	19 656	1 445.3	1 365.0	1 228.5
9			5/6				21 840	1 605.9	1 516.7	1 365.0
10		1024-QAM	3/4	10		32 760	24 570	1 806.6	1 706.3	1 535.6
11			5/6				27 300	2 007.4	1 895.8	1 706.3

Table 28-86—HE-MCSs for mandatory 484-tone RU and mandatory non-OFDMA 40 MHz, N_{SS} = 8

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps) 0.8 µs GI	1.6 µs GI	3.2 µs GI
0	N/A	BPSK	1/2	1	468	3 744	1 872	137.6	130.0	117.0
1		QPSK	1/2	2		7 488	3 744	275.3	260.0	234.0
2			3/4				5 616	412.9	390.0	351.0
3		16-QAM	1/2	4		14 976	7 488	550.6	520.0	468.0
4			3/4				11 232	825.9	780.0	702.0
5		64-QAM	2/3	6		22 464	14 976	1 101.2	1 040.0	936.0
6			3/4				16 848	1 238.8	1 170.0	1 053.0
7			5/6				18 720	1 376.5	1 300.0	1 170.0
8		256-QAM	3/4	8		29 952	22 464	1 651.8	1 560.0	1 404.0
9			5/6				24 960	1 835.3	1 733.3	1 560.0
10		1024-QAM	3/4	10		37 440	28 080	2 064.7	1 950.0	1 755.0
11			5/6				31 200	2 294.1	2 166.7	1 950.0

Table 28-87—HE-MCSs for mandatory 969-tone RU and mandatory non-OFDMA 80 MHz, N_{SS} = 1

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps) 0.8 μs GI	1.6 μs GI	3.2 μs GI
0	1	BPSK	1/2	1	490	490	245	18.0	17.0	15.3
	0		1/2		980	980	490	36.0	34.0	30.6
1	1	QPSK	1/2	2	490	980	490	36.0	34.0	30.6
	0		1/2		980	1960	980	72.1	68.1	61.3
2	N/A		3/4		980	1960	1 470	108.1	102.1	91.9
3	1	16-QAM	1/2	4	490	1960	980	72.1	68.1	61.3
	0		1/2		980	3920	1 960	144.1	136.1	122.5
4	1		3/4		490	1960	1 470	108.1	102.1	91.9
	0		3/4		980	3920	2 940	216.2	204.2	183.8
5	N/A	64-QAM	2/3	6	980	5 880	3 920	288.2	272.2	245.0
6			3/4				4 410	324.3	306.3	275.6
7			5/6				4 900	360.3	340.3	306.3
8		256-QAM	3/4	8		7 840	5 880	432.4	408.3	367.5
9			5/6				6 533	480.4	453.7	408.3
10		1024-QAM	3/4	10		9 800	7 350	540.4	510.4	459.4
11			5/6				8 166	600.4	567.1	510.4

Table 28-88—HE-MCSs for mandatory 969-tone RU and mandatory non-OFDMA 80 MHz, N_{SS} = 2

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps) 0.8 µs GI	1.6 µs GI	3.2 µs GI
0	1	BPSK	1/2	1	490	980	490	36.0	34.0	30.6
	0		1/2		980	1 960	980	72.1	68.1	61.3
1	1	QPSK	1/2	2	490	1 960	980	72.1	68.1	61.3
	0		1/2		980	3 920	1 960	144.1	136.1	122.5
2	N/A		3/4		980	3 920	2 940	216.2	204.2	183.8
3	1	16-QAM	1/2	4	490	3 920	1 960	144.1	136.1	122.5
	0		1/2		980	7 840	3 920	288.2	272.2	245.0
4	1		3/4		490	3 920	2 940	216.2	204.2	183.8
	0		3/4		980	7 840	5 880	432.4	408.3	367.5
5	N/A	64-QAM	2/3	6	980	11 760	7 840	576.5	544.4	490.0
6			3/4				8 820	648.5	612.5	551.3
7			5/6				9 800	720.6	680.6	612.5
8		256-QAM	3/4	8		15 680	11 760	864.7	816.7	735.0
9			5/6				13 066	960.7	907.4	816.6
10		1024-QAM	3/4	10		19 600	14 700	1 080.9	1 020.8	918.8
11			5/6				16 333	1 201.0	1 134.3	1 020.8

Table 28-89—HE-MCSs for mandatory 969-tone RU and mandatory non-OFDMA 80 MHz, N_{SS} = 3

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps) 0.8 μs GI	1.6 μs GI	3.2 μs GI
0	N/A	BPSK	1/2	1	980	2 940	1 470	108.1	102.1	91.9
1		QPSK	1/2	2		5 880	2 940	216.2	204.2	183.8
2			3/4				4 410	324.3	306.3	275.6
3		16-QAM	1/2	4		11 760	5 880	432.4	408.3	367.5
4			3/4				8 820	648.5	612.5	551.3
5		64-QAM	2/3	6		17 640	11 760	864.7	816.7	735.0
6			3/4				13 230	972.8	918.8	826.9
7			5/6				14 700	1 080.9	1 020.8	918.8
8		256-QAM	3/4	8		23 520	17 640	1 297.1	1 225.0	1 102.5
9			5/6				19 600	1 441.2	1 361.1	1 225.0
10		1024-QAM	3/4	10		29 400	22 050	1 621.3	1 531.3	1 378.1
11			5/6				24 500	1 801.5	1 701.4	1 531.3

Table 28-90—HE-MCSs for mandatory 969-tone RU and mandatory non-OFDMA 80 MHz, N_{SS} = 4

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps) 0.8 μs GI	1.6 μs GI	3.2 μs GI
0	N/A	BPSK	1/2	1	980	3 920	1 960	144.1	136.1	122.5
1		QPSK	1/2	2		7 840	3 920	288.2	272.2	245.0
2			3/4				5 880	432.4	408.3	367.5
3		16-QAM	1/2	4		15 680	7 840	576.5	544.4	490.0
4			3/4				11 760	864.7	816.7	735.0
5		64-QAM	2/3	6		23 520	15 680	1 152.9	1 088.9	980.0
6			3/4				17 640	1 297.1	1 225.0	1 102.5
7			5/6				19 600	1 441.2	1 361.1	1 225.0
8		256-QAM	3/4	8		31 360	23 520	1 729.4	1 633.3	1 470.0
9			5/6				26 133	1 921.5	1 814.8	1 633.3
10		1024-QAM	3/4	10		39 200	29 400	2 161.8	2 041.7	1 837.5
11			5/6				32 666	2 401.9	2 268.5	2 041.6

Table 28-91—HE-MCSs for mandatory 969-tone RU and mandatory non-OFDMA 80 MHz, N_{SS} = 5

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 μs GI	1.6 μs GI	3.2 μs GI
0	N/A	BPSK	1/2	1	980	4 900	2 450	180.1	170.1	153.1
1		QPSK	1/2	2		9 800	4 900	360.3	340.3	306.3
2			3/4				7 350	540.4	510.4	459.4
3		16-QAM	1/2	4		19 600	9 800	720.6	680.6	612.5
4			3/8				14 700	1 080.9	1 020.8	918.8
5		64-QAM	2/3	6		29 400	19 600	1 441.2	1 361.1	1 225.0
6			3/4				22 050	1 621.3	1 531.3	1 378.1
7			5/6				24 500	1 801.5	1 701.4	1 531.3
8		256-QAM	3/4	8		39 200	29 400	2 161.8	2 041.7	1 837.5
9			5/6				32 666	2 401.9	2 268.5	2 041.6
10		1024-QAM	3/4	10		49 000	36 750	2 702.2	2 552.1	2 296.9
11			5/6				40 833	3 002.4	2 835.6	2 552.1

Table 28-92—HE-MCSs for mandatory 969-tone RU and mandatory non-OFDMA 80 MHz, N_{SS} = 6

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 μs GI	1.6 μs GI	3.2 μs GI
0	N/A	BPSK	1/2	1	980	5 880	2 940	216.2	204.2	183.8
1		QPSK	1/2	2		11 760	5 880	432.4	408.3	367.5
2			3/4				8 820	648.5	612.5	551.3
3		16-QAM	1/2	4		23 520	11 760	864.7	816.7	735.0
4			3/4				17 640	1 297.1	1 225.0	1 102.5
5		64-QAM	2/3	6		35 280	23 520	1 729.4	1 633.3	1 470.0
6			3/4				26 460	1 945.6	1 837.5	1 653.8
7			5/6				29 400	2 161.8	2 041.7	1 837.5
8		256-QAM	3/4	8		47 040	35 280	2 594.1	2 450.0	2 205.0
9			5/6				39 200	2 882.4	2 722.2	2 450.0
10		1024-QAM	3/4	10		58 800	44 100	3 242.6	3 062.5	2 756.3
11			5/6				49 000	3 602.9	3 402.8	3 062.5

Table 28-93—HE-MCSs for mandatory 969-tone RU and mandatory non-OFDMA 80 MHz, N_{SS} = 7

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 μs GI	1.6 μs GI	3.2 μs GI
0	N/A	BPSK	1/2	1	980	6 860	3 430	252.2	238.2	214.4
1		QPSK	1/2	2		13 720	6 860	504.4	476.4	428.8
2			3/4				10 290	756.6	714.6	643.1
3		16-QAM	1/2	4		27 440	13 720	1 008.8	952.8	857.5
4			3/4				20 580	1 513.2	1 429.2	1 286.3
5		64-QAM	2/3	6		41 160	27 440	2 017.6	1 905.6	1 715.0
6			3/4				30 870	2 269.9	2 143.8	1 929.4
7			5/6				34 300	2 522.1	2 381.9	2 143.8
8		256-QAM	3/4	8		54 880	41 160	3 026.5	2 858.3	2 572.5
9			5/6				45 733	3 362.7	3 175.9	2 858.3
10		1024-QAM	3/4	10		68 600	51 450	3 783.1	3 572.9	3 215.6
11			5/6				57 166	4 203.4	3 969.9	3 572.9

Table 28-94—HE-MCSs for mandatory 969-tone RU and mandatory non-OFDMA 80 MHz, N_{SS} = 8

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 μs GI	1.6 μs GI	3.2 μs GI
0	N/A	BPSK	1/2	1	980	7 840	3 920	288.2	272.2	245.0
1		QPSK	1/2	2		15 680	7 840	576.5	544.4	490.0
2			3/4				11 760	864.7	816.7	735.0
3		16-QAM	1/2	4		31 360	15 680	1 152.9	1 088.9	980.0
4			3/4				23 520	1 729.4	1 633.3	1 470.0
5		64-QAM	2/3	6		47 040	31 360	2 305.9	2 177.8	1 960.0
6			3/4				35 280	2 594.1	2 450.0	2 205.0
7			5/6				39 200	2 882.4	2 722.2	2 450.0
8		256-QAM	3/4	8		62 720	47 040	3 458.8	3 266.7	2 940.0
9			5/6				52 266	3 843.1	3 629.6	3 266.6
10		1024-QAM	3/4	10		78 400	58 800	4 323.5	4 083.3	3 675.0
11			5/6				65 333	4 803.9	4 537.0	4 083.3

Table 28-95—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, N_{SS} = 1

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 μs GI	1.6 μs GI	3.2 μs GI
0	1	BPSK	1/2	1	980	980	490	36.0	34.0	30.6
	0		1/2		1 960	1 960	980	72.1	68.1	61.3
1	1	QPSK	1/2	2	980	1 960	980	72.1	68.1	61.3
	0		1/2		1 960	3 920	1 960	144.1	136.1	122.5
2	N/A		3/4		1 960	3 920	2 940	216.2	204.2	183.8
3	1	16-QAM	1/2	4	980	3 920	1 960	144.1	136.1	122.5
	0		1/2		1 960	7 840	3 920	288.2	272.2	245.0
4	1		3/4		980	3 920	2 940	216.2	204.2	183.8
	0		3/4		1 960	7 840	5 880	432.4	408.3	367.5
5	N/A	64-QAM	2/3	6	1 960	11 760	7 840	576.5	544.4	490.0
6			3/4				8 820	648.5	612.5	551.3
7			5/6				9 800	720.6	680.6	612.5
8		256-QAM	3/4	8		15 680	11 760	864.7	816.7	735.0
9			5/6				13 066	960.7	907.4	816.6
10		1024-QAM	3/4	10		19 600	14 700	1 080.9	1 020.8	918.8
11			5/6				16 333	1 201.0	1 134.2	1 020.8

Table 28-96—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, N_{SS} = 2

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 μs GI	1.6 μs GI	3.2 μs GI
0	1	BPSK	1/2	1	980	1 960	980	72.1	68.1	61.3
	0		1/2		1 960	3 920	1 960	144.1	136.1	122.5
1	1	QPSK	1/2	2	980	3 920	1 960	144.1	136.1	122.5
	0		1/2		1 960	7 840	3 920	288.2	272.2	245.0
2	N/A		3/4		1 960	7 840	5 880	432.4	408.3	367.5
3	1	16-QAM	1/2	4	980	7 840	3 920	288.2	272.2	245.0
	0		1/2		1 960	15 680	7 840	576.5	544.4	490.0
4	1		3/4		980	7 840	5 880	432.4	408.3	367.5
	0		3/4		1 960	15 680	11 760	864.7	816.7	735.0
5	N/A	64-QAM	2/3	6	1 960	23 520	15 680	1 152.9	1 088.9	980.0
6			3/4				17 640	1 297.1	1 225.0	1 102.5
7			5/6				19 600	1 441.2	1 361.1	1 225.0
8		256-QAM	3/4	8		31 360	23 520	1 729.4	1 633.3	1 470.0
9			5/6				26 133	1 921.5	1 814.8	1 633.3
10		1024-QAM	3/4	10		39 200	29 400	2 161.8	2 041.7	1 837.5
11			5/6				32 666	2 401.9	2 268.5	2 041.6

Table 28-97—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, N_{SS} = 3

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 μs GI	1.6 μs GI	3.2 μs GI
0	N/A	BPSK	1/2	1	1 960	5 880	2 940	216.2	204.2	183.8
1		QPSK	1/2	2		11 760	5 880	432.4	408.3	367.5
2			3/4				8 820	648.5	612.5	551.3
3		16-QAM	1/2	4		23 520	11 760	864.7	816.7	735.0
4			3/4				17 640	1 297.1	1 225.0	1 102.5
5		64-QAM	2/3	6		35 280	23 520	1 729.4	1 633.3	1 470.0
6			3/4				26 460	1 945.6	1 837.5	1 653.8
7			5/6				29 400	2 161.8	2 041.7	1 837.5
8		256-QAM	3/4	8		47 040	35 280	2 594.1	2 450.0	2 205.0
9			5/6				39 200	2 882.4	2 722.2	2 450.0
10		1024-QAM	3/4	10		58 800	44 100	3 242.6	3 062.5	2 756.3
11			5/6				49 000	3 602.9	3 402.8	3 062.5

Table 28-98—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, N_{SS} = 4

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 μs GI	1.6 μs GI	3.2 μs GI
0	N/A	BPSK	1/2	1	1 960	7 840	3 920	288.2	272.2	245.0
1		QPSK	1/2	2		15 680	7 840	576.5	544.4	490.0
2			3/4				11 760	864.7	816.7	735.0
3		16-QAM	1/2	4		31 360	15 680	1 152.9	1 088.9	980.0
4			3/4				23 520	1 729.4	1 633.3	1 470.0
5		64-QAM	2/3	6		47 040	31 360	2 305.9	2 177.8	1 960.0
6			3/4				35 280	2 594.1	2 450.0	2 205.0
7			5/6				39 200	2 882.4	2 722.2	2 450.0
8		256-QAM	3/4	8		62 720	47 040	3 458.8	3 266.7	2 940.0
9			5/6				52 266	3 843.1	3 629.6	3 266.6
10		1024-QAM	3/4	10		78 400	58 800	4 323.5	4 083.3	3 675.0
11			5/6				65 333	4 803.9	4 537.0	4 083.3

Table 28-99—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, N_{SS} = 5

HE-MCS Index	DCM	Modula-tion	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 μs GI	1.6 μs GI	3.2 μs GI
0	N/A	BPSK	1/2	1	1 960	9 800	4 900	360.3	340.3	306.3
1		QPSK	1/2	2		19 600	9 800	720.6	680.6	612.5
2			3/4				14 700	1 080.9	1 020.8	918.8
3		16-QAM	1/2	4		39 200	19 600	1 441.2	1 361.1	1 225.0
4			3/4				29 400	2 161.8	2 041.7	1 837.5
5		64-QAM	2/3	6		58 800	39 200	2 882.4	2 722.2	2 450.0
6			3/4				44 100	3 242.6	3 062.5	2 756.3
7			5/6				49 000	3 602.9	3 402.8	3 062.5
8		256-QAM	3/4	8		78 400	58 800	4 323.5	4 083.3	3 675.0
9			5/6				65 333	4 803.9	4 537.0	4 083.3
10		1024-QAM	3/4	10		98 000	73 500	5 404.4	5 104.2	4 593.8
11			5/6				81 666	6 004.9	5 671.3	5 104.1

Table 28-100—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, N_{SS} = 6

HE-MCS Index	DCM	Modula-tion	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 μs GI	1.6 μs GI	3.2 μs GI
0	N/A	BPSK	1/2	1	1 960	11 760	5 880	432.4	408.3	367.5
1		QPSK	1/2	2		23 520	11 760	864.7	816.7	735.0
2			3/4				17 640	1 297.1	1 225.0	1 102.5
3		16-QAM	1/2	4		47 040	23 520	1 729.4	1 633.3	1 470.0
4			3/4				35 280	2 594.1	2 450.0	2 205.0
5		64-QAM	2/3	6		70 560	47 040	3 458.8	3 266.7	2 940.0
6			3/4				52 920	3 891.2	3 675.0	3 307.5
7			5/6				58 800	4 323.5	4 083.3	3 675.0
8		256-QAM	3/4	8		94 080	70 560	5 188.2	4 900.0	4 410.0
9			5/6				78 400	5 764.7	5 444.4	4 900.0
10		1024-QAM	3/4	10		11 7600	88 200	6 485.3	6 125.0	5 512.5
11			5/6				98 000	7 205.9	6 805.6	6 125.0

Table 28-101—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, N_{SS} = 7

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 µs GI	1.6 µs GI	3.2 µs GI
0	N/A	BPSK	1/2	1	1 960	13 720	6 860	504.4	476.4	428.8
1		QPSK	1/2	2		27 440	13 720	1 008.8	952.8	857.5
2			3/4				20 580	1 513.2	1 429.2	1 286.3
3		16-QAM	1/2	4		54 880	27 440	2 017.6	1 905.6	1 715.0
4			3/4				41 160	3 026.5	2 858.3	2 572.5
5		64-QAM	2/3	6		82 320	54 880	4 035.3	3 811.1	3 430.0
6			3/4				61 740	4 539.7	4 287.5	3 858.8
7			5/6				68 600	5 044.1	4 763.9	4 287.5
8		256-QAM	3/4	8		109 760	82 320	6 052.9	5 716.7	5 145.0
9			5/6				91 466	6 725.4	6 351.8	5 716.6
10		1024-QAM	3/4	10		137 200	102 900	7 566.2	7 145.8	6 431.3
11			5/6				114 333	8 406.8	7 939.8	7 145.8

Table 28-102—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, N_{SS} = 8

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
								0.8 µs GI	1.6 µs GI	3.2 µs GI
0	N/A	BPSK	1/2	1	1 960	15 680	7 840	576.5	544.4	490.0
1		QPSK	1/2	2		31 360	15 680	1 152.9	1 088.9	980.0
2			3/4				23 520	1 729.4	1 633.3	1 470.0
3		16-QAM	1/2	4		62 720	31 360	2 305.9	2 177.8	1 960.0
4			3/4				47 040	3 458.8	3 266.7	2 940.0
5		64-QAM	2/3	6		94 080	62 720	4 611.8	4 355.6	3 920.0
6			3/4				70 560	5 188.2	4 900.0	4 410.0
7			5/6				78 400	5 764.7	5 444.4	4 900.0
8		256-QAM	3/4	8		125 440	94 080	6 917.6	6 533.3	5 880.0
9			5/6				104 533	7 686.3	7 259.2	6 533.3
10		1024-QAM	3/4	10		156 800	117 600	8 647.1	8 166.7	7 350.0
11			5/6				130 666	9 607.8	9 074.0	8 166.6

Annex B

(normative)

Protocol Implementation Conformance Statement (PICS) proforma

B.4 PICS proforma—IEEE Std 802.11-<year>

Change B.4.3 as follows:

B.4.3 IUT configuration

Item	IUT configuration	References	Status	Support
	What is the configuration of the IUT?			
* CFOFDM	Orthogonal frequency division multiplexing (OFDM) PHY	—	O.2 CFHT5G:M CFTVHT:M CFHEW:M	Yes ☐ No ☐
...				
*CFHT	High throughput (HT) PHY	9.4.2.56 (HT Capabilities element)	O.2 CFVHT:M CFHEW:M	Yes ☐ No ☐
...				
*CFESM	Extended spectrum management	10.21.3 (Operation with operating classes)	O CFVHT OR CFTVHT:M	Yes ☐ No ☐
*CFHE	High Efficiency WLAN (HEW) operation	9.4.2.218 (HE Capabilities element)	O CFHEW20:M CFHEW80:M	Yes ☐ No ☐
CFHEW2G4	HEW operation in 2.4 GHz band	Clause 28 (High Efficiency (HE) PHY specification)	CFHEW:O.6	Yes ☐ No ☐
CFHEW5G	HEW Operation in 5 GHz band	Clause 28 (High Efficiency (HE) PHY specification)	CFHEW:O.6	Yes ☐ No ☐
CFHEW20	HEW operation with 20 MHz only	Clause 28 (High Efficiency (HE) PHY specification)	CFIndSTA and CFHEW:M	Yes ☐ No ☐

B.4.3 IUT configuration *(continued)*

Item	IUT configuration	References	Status	Support
CFHEW80	HEW Operation with capability of 80 MHz or higher channel width	Clause 28 (High Efficiency (HE) PHY specification)	CFAP and CFHEW and CFVHT:M CFIndSTA and CFHEW and CFVHT:M	Yes ☐ No ☐

B.4.4 MAC protocol

Change B.4.4.1 as follows:

B.4.4.1 MAC protocol capabilities

Item	Protocol capability	References	Status	Support
	Are the following MAC protocol capabilities supported?			
PC6	Fragmentation	10.3 (DCF), 10.5 (Fragmentation)	~~M~~	~~Yes ☐ No ☐~~
PC6.1	Static fragmentation	10.3 (DCF), 10.5 (Fragmentation)	M	Yes ☐ No ☐
PC6.1	Dynamic fragmentation	10.3 (DCF), 10.5 (Fragmentation)		
PC6.2.1	Dynamic fragmentation level 0		CFHEW:M	Yes ☐ No ☐
PC6.2.2	Dynamic fragmentation level 1	27.3.3.2 (Level 1 dynamic fragmentation)	CFHEW:O	Yes ☐ No ☐
PC6.2.3	Dynamic fragmentation level 2	27.3.3.3 (Level 2 dynamic fragmentation)	CFHEW:O	Yes ☐ No ☐
PC6.2.4	Dynamic fragmentation level 3	27.3.3.4 (Level 3 dynamic fragmentation)	CFHEW:O	Yes ☐ No ☐
PC7	Defragmentation	10.3 (DCF), 10.6 (Defragmentation)	M	Yes ☐ No ☐

Change B.4.4.2 as follows:

B.4.4.2 MAC frames

Item	MAC frame	References	Status	Support
	Is transmission of the following MAC frames supported?	9 (Frame formats)		
FT42	Transmission of Operating Mode Notification frame and Operating Mode Notification element	9.6.23.4 (Operating Mode Notification frame format), 9.4.2.166 (Operating Mode Notification element), 11.42 (Notification of operating mode changes)	O	Yes ☐ No ☐ N/A ☐
FT43	Trigger frame		CFHEW:M	Yes ☐ No ☐ N/A ☐
	Is reception of the following MAC frames supported?	9 (Frame formats)		
FR41	VHT NDP Announcement	9 (Frame formats)	VHTM4.2:M TVHTM4.2:M	Yes ☐ No ☐ N/A ☐
FR42	Beamforming Report Poll	9 (Frame formats)	VHTM4.2:O VHTM4.4:M TVHTM4.2:O TVHTM4.4:M	Yes ☐ No ☐ N/A ☐
FR43	Reception of Operating Mode Notification frame and Operating Mode Notification element	9.6.23.4 (Operating Mode Notification frame format), 9.4.2.166 (Operating Mode Notification element), 11.42 (Notification of operating mode changes)	CFVHT:M CFTVHT:M	Yes ☐ No ☐ N/A ☐
FR44	Trigger frame	9 (Frame formats)	CFHEW:M	Yes ☐ No ☐ N/A ☐

Change B.4.4.10 as follows:

B.4.10 QoS base functionality

Item	Protocol capability	References	Status	Support
...				
QB4	Block acknowledgments (block ack)			
...				
QB4.4	Multi-TID Block Ack	9.3.1.9.4 (Multi-TID BlockAck variant)	CFQoS:O CFHT OR CFTVHT:M	Yes ☐ No ☐ N/A ☐
QB4.5	Multi-STA BlockAck	9.3.1.9.7 (Multi-STA BlockAck variant)		
QB4.5.1	Transmission of Multi-STA BlockAck	9.3.1.9.7 (Multi-STA BlockAck variant)	CFAP and CFHEW: M	Yes ☐ No ☐ N/A ☐
QB4,5,2	Reception of Multi-STA BlockAck	9.3.1.9.7 (Multi-STA BlockAck variant)	CFIndSTA and CFHEW: M	Yes ☐ No ☐ N/A ☐
...				

Insert a new subclause B.4.27 as follows:

B.4.27 High Efficiency WLAN (HEW) features

B.4.27.1 HEW MAC features

Item	Protocol capability	References	Status	Support
	Are the following MAC protocol features supported?			
HEWM1	HEW capabilities signaling			
HEWM1.1	HE Capabilities element	9.4.2.218 (HE Capabilities element)	CFHEW:M	Yes ☐ No ☐ N/A ☐
HEWM1.2	Signaling of STA capabilities in Probe Request, (Re)Association Request frames	9.3.3.6 (Association Request frame format), 9.3.3.8 (Reassociation Request frame format), 9.3.3.10 (Probe Request frame format), 9.4.2.218 (HE Capabilities element)	(CFHEW AND CFIndepSTA): M	Yes ☐ No ☐ N/A ☐

B.4.27.1 HEW MAC features *(continued)*

Item	Protocol capability	References	Status	Support
HEWM1.3	Signaling of STA and BSS capabilities in Beacon, Probe Response, (Re)Association Response frames	9.3.3.3 (Beacon frame format), 9.3.3.7 (Association Response frame format), 9.3.3.9 (Reassociation Response frame format), 9.3.3.11 (Probe Response frame format), 9.4.2.218 (HE Capabilities element)	(CFVHT AND CFAP):M	Yes ☐ No ☐ N/A ☐
HEWM2	Signaling of HE operation	9.4.2.219 (HE Operation element)	(CFHEW AND CFAP):M	Yes ☐ No ☐ N/A ☐
HEWM3	A-MPDU with multiple TIDs	27.10.4 (A-MPDU with multiple TIDs)	CFHEW:O	Yes ☐ No ☐ N/A ☐
HEWM4	HE variant HT Control			
HEWM4.1	UL MU Response Scheduling	9.2.4.6.4.2 (UL MU response scheduling)	CFHEW:O	Yes ☐ No ☐ N/A ☐
HEWM4.2	Operating Mode	9.2.4.6.4.3 (Operating Mode)	CFHEW:O	Yes ☐ No ☐ N/A ☐
HEWM4.3	HE Link Adaptation	9.2.4.6.4.4 (HE link adaptation)	CFHEW:O	Yes ☐ No ☐ N/A ☐
HEWM4.4	Buffer Status Report	9.2.4.6.4.5 (Buffer Status Report (BSR))	CFHEW:O	Yes ☐ No ☐ N/A ☐
HEWM4.5	UL Power Headroom	9.2.4.6.4.6 (UL power headroom)	CFHEW:M	Yes ☐ No ☐ N/A ☐
HEWM5	Trigger			
HEWM5.1	Basic Trigger	9.3.1.23.1 (Basic Trigger variant)	CFHEW:M	Yes ☐ No ☐ N/A ☐
HEWM5.2	Beamforming Report Poll	9.3.1.23.2 (Beamforming Report Poll variant)	CFHEW:M	Yes ☐ No ☐ N/A ☐
HEWM5.3	MU-BAR	9.3.1.23.3 (MU-BAR variant)	CFHEW:O	Yes ☐ No ☐ N/A ☐
HEWM5.4	MU-RTS transmission	9.3.1.23.4 (MU-RTS variant)	CFHEW:O	Yes ☐ No ☐ N/A ☐

B.4.27.1 HEW MAC features *(continued)*

Item	Protocol capability	References	Status	Support
HEWM5.5	MU-RTS reception	9.3.1.23.4 (MU-RTS variant)	CFHEW:M	Yes ☐ No ☐ N/A ☐
HEWM5.6	BSRP	9.3.1.23.5 (BSRP variant)	CFHEW:O	Yes ☐ No ☐ N/A ☐
HEWM6	Transmit beamforming			
HEWM6.1	SU beamformer capable	9.4.2.218 (HE Capabilities element)	CFHEW:O	Yes ☐ No ☐ N/A ☐
HEWM6.2	SU beamformee capable	9.4.2.218 (HE Capabilities element)	CFHEW:O	Yes ☐ No ☐ N/A ☐
HEWM6.3	MU beamformer capable	9.4.2.218 (HE Capabilities element)	CFAP AND CFHEWM6.1: O	Yes ☐ No ☐ N/A ☐
HEWM6.4	MU beamformee capable	9.4.2.218 (HE Capabilities element)	CFIndepSTA and VHTM7.2: O	Yes ☐ No ☐ N/A ☐
HEWM6.5	Transmission of HE NDP	27.6 (HE sounding protocol)	HEWM6.1:M	Yes ☐ No ☐ N/A ☐
HEWM6.6	Reception of HE NDP	27.6 (HE sounding protocol)	HEWM6.2:M	Yes ☐ No ☐ N/A ☐
HEWM6.7	Transmission of Trigger frame	27.6 (HE sounding protocol)	HEWM6.1:O	Yes ☐ No ☐ N/A ☐
HEWM6.8	Reception of Trigger frame	27.6 (HE sounding protocol)	HEWM6.7:M	Yes ☐ No ☐ N/A ☐
HEWM7	Sounding protocol			
HEWM7.1	HE Sounding Protocol as SU beamformer	27.6 (HE sounding protocol)	HEWM6.1:M	Yes ☐ No ☐ N/A ☐
HEWM7.2	HE Sounding Protocol as SU beamformee	27.6 (HE sounding protocol)	HEWM6.2:M	Yes ☐ No ☐ N/A ☐
HEWM7.3	HE Sounding Protocol as MU beamformer	27.6 (HE sounding protocol)	HEWM6.4:M	Yes ☐ No ☐ N/A ☐
HEWM7.4	HE Sounding Protocol as MU beamformee	27.6 (HE sounding protocol)	HEWM6.5:M	Yes ☐ No ☐ N/A ☐
HEWM8	NAV update	27.2.2 (Updating two NAVs)		
HEWM8.1	Update basic NAV	27.2.2 (Updating two NAVs)	CFHEW:M	Yes ☐ No ☐ N/A ☐

B.4.27.1 HEW MAC features *(continued)*

Item	Protocol capability	References	Status	Support
HEWM8.2	Update IntraBSS NAV	27.2.2 (Updating two NAVs)	CFAP AND CFHEW: O CFIndSTA AND CFHEW: M	Yes ☐ No ☐ N/A ☐
HEWM9	OFDMA-based random access	27.5.2.6 (UL OFDMA-based random access)	CFHEW: O	Yes ☐ No ☐ N/A ☐
HEWM10	TWT operation	27.7 (TWT operation)	CFHEW: O	Yes ☐ No ☐ N/A ☐

B.4.27.2 HEW PHY features

Item	Protocol capability	References	Status	Support
	Are the following PHY protocol features supported?			
HEWP1	PHY operating modes			
HEWP1.1	Operation according to Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification) (Orthogonal frequency division multiplexing (OFDM) PHY specification), Clause 19 (High Throughput (HT) PHY specification) (High Throughput) and/or Clause 21 (Very High Throughput (VHT) PHY specification)	28.1.1 (Introduction to the HE PHY)	CFHEW5G and (CFAP or CFHEW80):M	Yes ☐ No ☐ N/A ☐
HEWP1.2	Operation according Clause 19 (High Throughput (HT) PHY specification) (High Throughput) in 5GHz	28.1.1 (Introduction to the HE PHY)	CFHEW5G and CFHEW20: M	Yes ☐ No ☐ N/A ☐
HEWP1.3	Operation according Clause 19 (High Throughput (HT) PHY specification) (High Throughput) in 2.4 GHz	28.1.1 (Introduction to the HE PHY)	CFHEW2G4: M	Yes ☐ No ☐ N/A ☐
HEWP2	HE PPDU format	28.1.4 (PPDU formats)		
HEWP2.1	HE SU PPDU	28.1.4 (PPDU formats)		Yes ☐ No ☐ N/A ☐
HEWP2.2	HE extended range SU PPDU	28.1.4 (PPDU formats)		Yes ☐ No ☐ N/A ☐
HEWP2.3	HE MU PPDU	28.1.4 (PPDU formats)		Yes ☐ No ☐ N/A ☐
HEWP2.4	HE trigger-based PPDU	28.1.4 (PPDU formats)		Yes ☐ No ☐ N/A ☐
HEWP3	BSS bandwidth			

B.4.27.2 HEW PHY features *(continued)*

Item	Protocol capability	References	Status	Support
HEWP3.1	20 MHz operation	27.16 (HE BSS operation)	CFHEW: M	Yes ☐ No ☐ N/A ☐
HEWP3.2	40 MHz operation	27.16 (HE BSS operation)	CFHEW80 and CFHEW5G:M CFHEW2G4:O	Yes ☐ No ☐ N/A ☐
HEWP3.3	80 MHz operation	27.16 (HE BSS operation)	CFHEW80 and CFHEW5G:M	Yes ☐ No ☐ N/A ☐
HEWP3.4	160 MHz operation	27.16 (HE BSS operation)	CFHEW80 and CFHEW5G:O HEWP3.5:M	Yes ☐ No ☐ N/A ☐
HEWP3.5	80+80 MHz operation	27.16 (HE BSS operation)	CFHEW80 and CFHEW5G:O	Yes ☐ No ☐ N/A ☐
HEWP4	PHY timing information			
HEWP4.1	Values in 20 MHz channel	28.3.8 (Timing-related parameters)	HEWP4.1:M	Yes ☐ No ☐ N/A ☐
HEWP4.2	Values in 40 MHz channel	28.3.8 (Timing-related parameters)	HEWP4.2:M	Yes ☐ No ☐ N/A ☐
HEWP4.3	Values in 80 MHz channel	28.3.8 (Timing-related parameters)	HEWP4.3:M	Yes ☐ No ☐ N/A ☐
HEWP4.4	Values in 160 MHz channel	28.3.8 (Timing-related parameters)	HEWP4.4:M	Yes ☐ No ☐ N/A ☐
HEWP4.5	Values in 80+80 MHz channel	28.3.8 (Timing-related parameters)	HEWP4.5:M	Yes ☐ No ☐ N/A ☐
HEWP5	STBC	28.3.11.10 (Space-time block coding)	CFHEW:O	Yes ☐ No ☐ N/A ☐
HEWP6	Tone allocation			
HEWP6.1	26-tone RU mapping		CFHEW:M	Yes ☐ No ☐ N/A ☐
HEWP6.2	52-tone RU mapping		CFHEW:M	Yes ☐ No ☐ N/A ☐
HEWP6.3	106-tone RU mapping		CFHEW:M	Yes ☐ No ☐ N/A ☐
HEWP6.4	242-tone RU mapping		CFHEW80:M CFHEW20:O	Yes ☐ No ☐ N/A ☐
HEWP6.5	484-tone RU mapping		CFHEW80 and HEWP3.2:M	Yes ☐ No ☐ N/A ☐
HEWP6.6	996-tone RU mapping		CFHEW80 and HEWP3.3:M CFHEW80 and HEWP3.4:M	Yes ☐ No ☐ N/A ☐
HEWP6.7	2x996-tone RU mapping		CFHEW80 and HEWP3.4:M	Yes ☐ No ☐ N/A ☐
HEWP7	Coding			

B.4.27.2 HEW PHY features *(continued)*

Item	Protocol capability	References	Status	Support
HEWP10.1	BCC with less than 4 spatial streams		(HEWP6.1 or HEWP6.2 or HEWP6.3 or HEWP6.4):M (HEWP3.1 and HEWP2.1):M	Yes ☐ No ☐ N/A ☐
HEWP10.2	LDPC with more than 4 spatial streams		CFHEW80:M CFHEW20:O	Yes ☐ No ☐ N/A ☐
HEWP10.3	LDPC with less or equal to 4 spatial streams		(HEWP6.5 or HEWP6.6 or HEWP6.7):M ((HEWP3.2 or HEWP3.3 or HEWP3.4 or HEWP3.5) and HEWP2.1):M (HEWP6.1 or HEWP6.2 or HEWP6.3 or HEWP6.4):O (HEWP3.1 and HEWP2.1):O CFHEW20: O	Yes ☐ No ☐ N/A ☐
HEWP11	STBC		CFHEW: O	Yes ☐ No ☐ N/A ☐
HEWP12	Coding and modulation schemes			
HEWP12.1	For 26-, 52-, 106-, 242-, 484- and 996-tone mapping			
HEWP12.1.1	HE-MCS with Index 0-7 and $N_{SS} = 1$	28.5 (Parameters for HE-MCSs)	CFHEW: M	Yes ☐ No ☐ N/A ☐
HEWP12.1.2	HE-MCS with Index 0-8 and $N_{SS} = 1$	28.5 (Parameters for HE-MCSs)	HEWP12.1.1:O	Yes ☐ No ☐ N/A ☐
HEWP12.1.3	HE-MCS with Index 0-9 and $N_{SS} = 1$	28.5 (Parameters for HE-MCSs)	HEWP12.1.2:O	Yes ☐ No ☐ N/A ☐
HEWP12.1.4	HE-MCS with Index 0-7 and $N_{SS} = 2$	28.5 (Parameters for HE-MCSs)	CFHEW:O	Yes ☐ No ☐ N/A ☐
HEWP12.1.5	HE-MCS with Index 0-8 and $N_{SS} = 2$	28.5 (Parameters for HE-MCSs)	HEWP12.1.4:O	Yes ☐ No ☐ N/A ☐
HEWP12.1.6	HE-MCS with Index 0-9 and $N_{SS} = 2$	28.5 (Parameters for HE-MCSs)	HEWP12.1.5:O	Yes ☐ No ☐ N/A ☐
HEWP12.1.7	HE-MCS with Index 0-7 and $N_{SS} = 3$	28.5 (Parameters for HE-MCSs)	CFHEW:O	Yes ☐ No ☐ N/A ☐

B.4.27.2 HEW PHY features *(continued)*

Item	Protocol capability	References	Status	Support
HEWP12.1.8	HE-MCS with Index 0-8 and N_{SS} = 3	28.5 (Parameters for HE-MCSs)	HEWP12.1.7:O	Yes ☐ No ☐ N/A ☐
HEWP12.1.9	HE-MCS with Index 0-9 and N_{SS} = 3	28.5 (Parameters for HE-MCSs)	HEWP12.1.8:O	Yes ☐ No ☐ N/A ☐
HEWP12.1.10	HE-MCS with Index 0-7 and N_{SS} = 4	28.5 (Parameters for HE-MCSs)	CFHEW:O	Yes ☐ No ☐ N/A ☐
HEWP12.1.11	HE-MCS with Index 0-8 and N_{SS} = 4	28.5 (Parameters for HE-MCSs)	HEWP12.1.10:O	Yes ☐ No ☐ N/A ☐
HEWP12.1.12	HE-MCS with Index 0-9 and N_{SS} = 4	28.5 (Parameters for HE-MCSs)	HEWP12.1.11:O	Yes ☐ No ☐ N/A ☐
HEWP12.1.13	HE-MCS with Index 0-7 and N_{SS} = 5	28.5 (Parameters for HE-MCSs)	CFHEW:O	Yes ☐ No ☐ N/A ☐
HEWP12.1.14	HE-MCS with Index 0-8 and N_{SS} = 5	28.5 (Parameters for HE-MCSs)	HEWP12.1.13:O	Yes ☐ No ☐ N/A ☐
HEWP12.1.15	HE-MCS with Index 0-9 and N_{SS} = 5	28.5 (Parameters for HE-MCSs)	HEWP12.1.14:O	Yes ☐ No ☐ N/A ☐
HEWP12.1.16	HE-MCS with Index 0-7 and N_{SS} = 6	28.5 (Parameters for HE-MCSs)	CFHEW:O	Yes ☐ No ☐ N/A ☐
HEWP12.1.17	HE-MCS with Index 0-8 and N_{SS} = 6	28.5 (Parameters for HE-MCSs)	HEWP12.1.16:O	Yes ☐ No ☐ N/A ☐
HEWP12.1.18	HE-MCS with Index 0-9 and N_{SS} = 6	28.5 (Parameters for HE-MCSs)	HEWP12.1.17:O	Yes ☐ No ☐ N/A ☐
HEWP12.1.19	HE-MCS with Index 0-7 and N_{SS} = 7	28.5 (Parameters for HE-MCSs)	CFHEW:O	Yes ☐ No ☐ N/A ☐
HEWP12.1.20	HE-MCS with Index 0-8 and N_{SS} = 7	28.5 (Parameters for HE-MCSs)	HEWP12.1.19:O	Yes ☐ No ☐ N/A ☐
HEWP12.1.21	HE-MCS with Index 0-9 and N_{SS} = 7	28.5 (Parameters for HE-MCSs)	HEWP12.1.20:O	Yes ☐ No ☐ N/A ☐
HEWP12.1.22	HE-MCS with Index 0-7 and N_{SS} = 8	28.5 (Parameters for HE-MCSs)	CFHEW:O	Yes ☐ No ☐ N/A ☐
HEWP12.1.23	HE-MCS with Index 0-8 and N_{SS} = 8	28.5 (Parameters for HE-MCSs)	HEWP12.1.22:O	Yes ☐ No ☐ N/A ☐
HEWP12.1.24	HE-MCS with Index 0-9 and N_{SS} = 8	28.5 (Parameters for HE-MCSs)	HEWP12.1.23:O	Yes ☐ No ☐ N/A ☐

B.4.27.2 HEW PHY features *(continued)*

Item	Protocol capability	References	Status	Support
HEWP12.2	For 242-, 484- and 996-tone plan			
HEWP12.2.1	HE-MCS with Index 0-10 and $N_{SS} = 1$	28.5 (Parameters for HE-MCSs)	CFHEW80: O	Yes ☐ No ☐ N/A ☐
HEWP12.2.2	HE-MCS with Index 0-11 and $N_{SS} = 1$	28.5 (Parameters for HE-MCSs)	HEWP12.2.1:O	Yes ☐ No ☐ N/A ☐
HEWP12.2.3	HE-MCS with Index 0-10 and $N_{SS} = 2$	28.5 (Parameters for HE-MCSs)	CFHEW80: O	Yes ☐ No ☐ N/A ☐
HEWP12.2.4	HE-MCS with Index 0-11 and $N_{SS} = 2$	28.5 (Parameters for HE-MCSs)	HEWP12.2.3:O	Yes ☐ No ☐ N/A ☐
HEWP12.2.5	HE-MCS with Index 0-10 and $N_{SS} = 3$	28.5 (Parameters for HE-MCSs)	CFHEW80: O	Yes ☐ No ☐ N/A ☐
HEWP12.2.6	HE-MCS with Index 0-11 and $N_{SS} = 3$	28.5 (Parameters for HE-MCSs)	HEWP12.2.5:O	Yes ☐ No ☐ N/A ☐
HEWP12.2.7	HE-MCS with Index 0-10 and $N_{SS} = 4$	28.5 (Parameters for HE-MCSs)	CFHEW80: O	Yes ☐ No ☐ N/A ☐
HEWP12.2.8	HE-MCS with Index 0-11 and $N_{SS} = 4$	28.5 (Parameters for HE-MCSs)	HEWP12.2.7:O	Yes ☐ No ☐ N/A ☐
HEWP12.2.9	HE-MCS with Index 0-10 and $N_{SS} = 5$	28.5 (Parameters for HE-MCSs)	CFHEW80: O	Yes ☐ No ☐ N/A ☐
HEWP12.2.10	HE-MCS with Index 0-11 and $N_{SS} = 5$	28.5 (Parameters for HE-MCSs)	HEWP12.2.9:O	Yes ☐ No ☐ N/A ☐
HEWP12.2.11	HE-MCS with Index 0-10 and $N_{SS} = 6$	28.5 (Parameters for HE-MCSs)	CFHEW80: O	Yes ☐ No ☐ N/A ☐
HEWP12.2.12	HE-MCS with Index 0-11 and $N_{SS} = 6$	28.5 (Parameters for HE-MCSs)	HEWP12.2.11: O	Yes ☐ No ☐ N/A ☐
HEWP12.2.13	HE-MCS with Index 0-10 and $N_{SS} = 7$	28.5 (Parameters for HE-MCSs)	CFHEW80: O	Yes ☐ No ☐ N/A ☐
HEWP12.2.14	HE-MCS with Index 0-11 and $N_{SS} = 7$	28.5 (Parameters for HE-MCSs)	HEWP12.2.13: O	Yes ☐ No ☐ N/A ☐
HEWP12.2.15	HE-MCS with Index 0-10 and $N_{SS} = 8$	28.5 (Parameters for HE-MCSs)	CFHEW80: O	Yes ☐ No ☐ N/A ☐
HEWP12.2.16	HE-MCS with Index 0-11 and $N_{SS} = 8$	28.5 (Parameters for HE-MCSs)	HEWP12.2.15: O	Yes ☐ No ☐ N/A ☐

Annex C

(normative)

ASN.1 encoding of the MAC and PHY MIB

C.3 MIB Detail

Change the dot11smt object as follows:

```
dot11smt OBJECT IDENTIFIER ::= { ieee802dot11 1 }
…
-- dot11STACivicLocationConfigTable::= { dot11smt 37 }
-- dot11HEStationConfigTable::= { dot11smt <ANA> }
-- dot11PPEThresholdsMappingsTable::= { dot11smt <ANA> }
…
```

Change Dot11StationConfigEntry as follows:

```
Dot11StationConfigEntry ::= SEQUENCE
    {
        …,
        dot11FutureChannelGuidanceActivated                    TruthValue,
        dot11HEOptionImplemented                               TruthValue,
    }
…
```

Insert the following after the dot11FutureChannelGuidanceActivated OBJECT-TYPE element in the Dot11StationConfig TABLE:

```
dot11HEOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
    "This is a capability variable.
    Its value is determined by device capabilities.

    This attribute indicates whether the entity is HE Capable."
::= { dot11StationConfigEntry <ANA>}
```

Insert the following after the dot11S1GStationConfig TABLE:

```
-- ********************************************************************
-- * dot11HEStationConfig TABLE
-- ********************************************************************

dot11HEStationConfigTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11HEStationConfigEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Station Configuration attributes. In tabular form to allow for multiple
        instances on an agent."
    ::= { dot11smt <ANA> }

dot11HEStationConfigEntry OBJECT-TYPE
    SYNTAX Dot11HEStationConfigEntry
    MAX-ACCESS not-accessible
```

```
    STATUS current
    DESCRIPTION
       "An entry (conceptual row) in the dot11HEStationConfig Table.

       ifIndex - Each IEEE 802.11 interface is represented by an ifEntry. Inter-
       face tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex }
    ::= { dot11HEStationConfigTable 1 }

Dot11HEStationConfigEntry ::=
    SEQUENCE {
       dot11HEULMUResponseSchedulingOptionImplemented        TruthValue,
       dot11ULMUMIMOOptionImplemented                        TruthValue,
       dot11OFDMARandomAccessOptionImlemented                TruthValue,
       dot11HEControlFieldOptionImplemented                  TruthValue,
       dot11OMIOptionImplemented                             TruthValue,
       dot11HEMCSFeedbackOptionImplemented                   TruthValue,
       dot11HEDynamicFragmentationImplemented                TruthValue,
       dot11AMPDUwithMultipleTIDOptionImplemented            TruthValue,
       dot11MPDUAskedforAckInMultiTIDAMPDU                   TruthValue,
       dot11DurationRTSThreshold                             Unsigned32,
       dot11PPEThresholdsRequired                            TruthValue,
       dot11IntraPPDUPowerSaveOptionActivated                TruthValue,
       dot11AMSDUFragmentationOptionImplemented              TruthValue
       }

dot11HEULMUResponseSchedulingOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a capability variable.
       Its value is determined by device capabilities.

       This attribute, when true, indicates that the station implementation is
       capable of receiving frames with an UL MU response scheduling A-Control
       field. The capability is disabled, otherwise."
    DEFVAL { false }
    ::= { dot11HEStationConfigEntry 1}

dot11ULMUMIMOOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a capability variable.
       Its value is determined by device capabilities.

       This attribute, when true, indicates that the station implementation is
       capable of a full bandwidth UL MU-MIMO transmission. The capability is
       disabled, otherwise."
    DEFVAL { false }
    ::= { dot11HEStationConfigEntry 2}

dot11OFDMARandomAccessOptionImlemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
       "This is a capability variable.
       Its value is determined by device capabilities.

       This attribute, when true, indicates that the station implementation is
       capable of an OFDMA random access operation. The capability is disabled,
```

```
      otherwise."
   DEFVAL { false }
   ::= { dot11HEStationConfigEntry 3}

dot11HEControlFieldOptionImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by device capabilities.

      This attribute, when true, indicates that the station implementation is
      capable of receiving the HE variant HT Control field. The capability is
      disabled, otherwise."
   DEFVAL { false }
   ::= { dot11HEStationConfigEntry 4}

dot11OMIOptionImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by device capabilities.

      This attribute, when true, indicates that the station implementation is
      capable of generating frames with an OMI A-Control field. The capability
      is disabled, otherwise."
   DEFVAL { false }
   ::= { dot11HEStationConfigEntry 5}

dot11HEMCSFeedbackOptionImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by device capabilities.

      This attribute indicates the MCS feed back capability supported by the
      station implementation."
   DEFVAL { false }
   ::= { dot11HEStationConfigEntry 6}

dot11HEDynamicFragmentationImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
      "This is a capability variable.
      Its value is determined by device capabilities.

      This attribute, when true, indicates that the STA implementation is
      capable of receiving dynamic fragments. The capability is disabled,
      otherwise"
   DEFVAL { false }
   ::= { dot11HEStationConfigEntry 7}

dot11AMPDUwithMultipleTIDOptionImplemented OBJECT-TYPE
   SYNTAX TruthValue
   MAX-ACCESS read-only
   STATUS current
   DESCRIPTION
```

```
        "This is a capability variable.
        Its value is determined by device capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of generating an A-MPDU that contains QoS Data frames with two or
        more different TID values. The capability is disabled, otherwise."
    DEFVAL { false }
    ::= { dot11HEStationConfigEntry 8}

dot11MPDUAskedforAckInMultiTIDAMPDU OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by device capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of receiving a multi-TID A-MPDU that can solicit either Ack or
        BlockAck, or both. The capability is disabled, otherwise."
    DEFVAL { false }
    ::= { dot11HEStationConfigEntry 9}

dot11DurationRTSThreshold OBJECT-TYPE
    SYNTAX Unsigned32 (0..1023)
    UNITS "32 microseconds"
    MAX-ACCESS read-write
    STATUS current
    DESCRIPTION
        "This is a control variable.
        It is written by an external management entity or by the MAC upon receiv-
        ing duration-based RTS threshold notification frame.
        Changes take effect as soon as practical in the implementation.

        This attribute indicates the duration of the transmission or TXOP above
        which an RTS/CTS handshake is performed. Value zero means the RTS should
        be always used for TxOP transmission. Value 1023 means this feature is
        disabled"
    DEFVAL { 1023 }
    ::= { dot11HEStationConfigEntry 10}

dot11PPEThresholdsRequired OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by device capabilities.
        This attribute, when true, indicates that Post-FEC Padding and Packet
        Extension Thresholds exist and are provided in dot11PPEThreshold-
        sTable(#1313)."
    DEFVAL { false }
    ::= { dot11HEStationConfigEntry 11}

dot11IntraPPDUPowerSaveOptionActivated OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable.
        Its value is determined by device capabilities.

        This attribute, when true, indicates that the station implementation is
        capable of Intra PPDU Power Save operation. The capability is disabled,
```

```
        otherwise."
    DEFVAL { false }
    ::= { dot11HEStationConfigEntry 12}

dot11AMSDUFragmentationOptionImplemented OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-only
    STATUS current
    DESCRIPTION
        "This is a capability variable. Its value is determined by device
         capabilities.

         This attribute, when true, indicates that the STA implementation is
         capable of receiving dynamic fragments of A-MSDUs. The capability is
         disabled, otherwise"
    DEFVAL { false }
::= { dot11HEStationConfigEntry 13}

-- **********************************************************************
-- * End of dot11HEStationConfigTable TABLE
-- **********************************************************************

-- ************************************************************************
-- * dot11PPEThresholdsMappings TABLE
-- ************************************************************************
dot11PPEThresholdsMappingsTable OBJECT-TYPE
    SYNTAX SEQUENCE OF Dot11PPEThresholdsMappingsEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "Conceptual table for PPE Thresholds Mappings. The MIB supports the
         ability to share separate PPE Thresholds for each NSS/RU pair. The
         Thresholds Mappings Table contains one entry for each NSS/RU pair
         and contains two fields for each entry: PPET8 and PPET16. The PPE
         Thresholds mappings are logically WRITE-ONLY. Attempts to read the
         entries in this table return unsuccessful status and values of null or 0.
         The default value for all PPET8 fields is NONE."
    REFERENCE "IEEE Std 802.11-<year>, 27.12 (HE PPDU post FEC padding and packet
        extension)"
::= { dot11smt <ANA>}

dot11PPEThresholdsMappingsEntry OBJECT-TYPE
    SYNTAX Dot11PPEThresholdsMappingsEntry
    MAX-ACCESS not-accessible
    STATUS current
    DESCRIPTION
        "An Entry (conceptual row) in the PPE Thresholds Mappings Table.
         ifIndex - Each IEEE Std 802.11 interface is represented by an ifEntry.
         Interface tables in this MIB module are indexed by ifIndex."
    INDEX { ifIndex, dot11PPEThresholdsMappingIndex }
::= { dot11PPEThresholdsMappingsTable 1 }

Dot11PPEThresholdsMappingsEntry ::= SEQUENCE {
    dot11PPEThresholdsMappingIndex                           Unsigned32,
    dot11PPEThresholdsMappingNSS                             Integer,
    dot11PPEThresholdsMappingRUIndex                         Integer,
    dot11PPEThresholdsMappingPPET8                           Integer,
    dot11PPEThresholdsMappingPPET16                          Integer,
    dot11PPEThresholdsMappingStatus                          RowStatus}

dot11PPEThresholdsMappingIndex OBJECT-TYPE
    SYNTAX Unsigned32
    MAX-ACCESS not-accessible
    STATUS current
```

```
    DESCRIPTION
    "The auxiliary variable used to identify instances of the columnar objects
     in the PPE Thresholds Mappings Table."
::= { dot11PPEThresholdsMappingsEntry 1 }

dot11PPEThresholdsMappingNSS OBJECT-TYPE
    SYNTAX Integer
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "The NSS value portion of the NSS/RU pair for which the values from this
         Thresholds mapping entry are to be used."
::= { dot11PPEThresholdsMappingsEntry 2 }

dot11PPEThresholdsMappingRUIndex OBJECT-TYPE
    SYNTAX Integer
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "The index of the RU value portion of the NSS/RU pair for which the values
         from this Thresholds mapping entry are to be used. The index values
         map to an RU as follows: RU Index of 0 is 996 tones, 1 is 448 tones,
         2 is 996 tones, 3 is 2x996 tones."
::= { dot11PPEThresholdsMappingsEntry 3 }

dot11PPEThresholdsMappingPPET8 OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "An index that determines a constellation value at or above which a
         Post FEC Padding and Packet Extension value of at least 8 us is
         required for the given NSS/RU pair corresponding to the row of the
         entry. The index values are mapped as follows: 0 is BPSK, 1 is QPSK,
         2 is 16-QAM, 3 is 64-QAM, 4 is 256-QAM, 5 is 1024-QAM,
         6 is reserved, 7 is the special value of NONE."
::= { dot11PPEThresholdsMappingsEntry 4 }

dot11PPEThresholdsMappingPPET16 OBJECT-TYPE
    SYNTAX TruthValue
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "An index that determines a constellation value at or above which a
         Post FEC Padding and Packet Extension value of 16 us is required for
         the given NSS/RU pair corresponding to the row of the entry. The index
         values are mapped as follows: 0 is BPSK, 1 is QPSK, 2 is 16-QAM,
         3 is 64-QAM, 4 is 256-QAM, 5 is 1024-QAM, 6 is reserved,
         7 is the special value of NONE."
::= { dot11PPEThresholdsMappingsEntry 5 }

dot11PPEThresholdsMappingStatus OBJECT-TYPE
    SYNTAX RowStatus
    MAX-ACCESS read-create
    STATUS current
    DESCRIPTION
        "The status column used for creating, modifying, and deleting instances
         of the columnar objects in the PPE Thresholds mapping Table."
    DEFVAL { active }
::= { dot11PPEThresholdsMappingsEntry 6 }

-- **********************************************************************
-- * End of dot11PPEThresholdsMappings TABLE
-- **********************************************************************
```

Insert the following compliance objects after the dot11S1GComplianceGroup object:

```
dot11HEComplianceGroup OBJECT-GROUP
    OBJECTS {
        dot11HEULMUResponseSchedulingOptionImplemented,
        dot11ULMUMIMOOptionImplemented,
        dot11OFDMARandomAccessOptionImlemented,
        dot11HEControlFieldOptionImplemented,
        dot11OMIOptionImplemented,
        dot11HEMCSFeedbackOptionImplemented,
        dot11HEDynamicFragmentationImplemented,
        dot11AMPDUwithMultipleTIDOptionImplemented,
        dot11MPDUAskedforAckInMultiTIDAMPDU,
        dot11DurationRTSThreshold,
        dot11PPEThresholdsRequired,
        dot11IntraPPDUPowerSaveOptionActivated,}
    STATUS current
    DESCRIPTION
        "Attributes that configure the HE Group for IEEE 802.11."
::= { dot11Groups <ANA> }
```

Insert the following after dot11S1GCompliance:

```
-- ******************************************************************
-- * Compliance Statements - HE
-- ******************************************************************
dot11HECompliance MODULE-COMPLIANCE
    STATUS current
    DESCRIPTION
        "This object class provides the objects from the IEEE 802.11
        MIB used to operate at high efficiency."
    MODULE -- this module
    MANDATORY-GROUPS { dot11HEComplianceGroup }
-- OPTIONAL-GROUPS { }
    ::= { dot11Compliances <ANA> }
```

Annex G

(normative)

Frame exchange sequences

Insert a new subclause as follows:

G.5 HE sequences

ht-txop-sequence = L-sig-protected-sequence |
ht-nav-protected-sequence |
dual-cts-protected-sequence |
1{initiator-sequence};

Only Trigger frame sequence is defined here. It can be used for all Trigger frame variants.

(* Trigger frame is sent by the AP to initiate non-AP UL transmission. A PPDU containing a trigger is either a non-A MPDU trigger frame, or an A MPDU containing carrying trigger frame *)

He-mu-sequence = MU-RTS-CTS-protected-sequence | HE-mu-sequence-no-protection

MU-RTS-CTS-protected-sequence = {**MU-RTS** + **CTS**} + *HE-mu-sequence-no-protection*

HE-mu-sequence-no-protection = *dl-mu-sequence* | *ul-mu-sequence* | *cascading-mu-sequence*

(**Trigger**) | (**Trigger** +*a-mpdu* + *mu-user-respond* + *a-mpdu-end*)
1{**Data**[+*HTC*]+*QoS*+(*no-ack* | *block-ack*)+*a-mpdu*}
+ *a-mpdu-end*;
[+*mu-user-respond* other-users];