25.3 Fragmentation

25.3.1 General

An HE STA can dynamically fragment individually addressed 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.

25.3.2 Procedure at the originator

A dynamic fragment is an MPDU, the payload of which carries a portion of an MSDU or MMPDU, which generation follows the rules defined in 10.5 (Fragmentation), except for:

— Reception of dynamic fragments is not mandatory. An HE STA declares its capability of receiving dynamic fragments by setting the HE Fragmentation Support field of the HE Capabilities element it transmits to a nonzero value as described below.

— The length of each fragment is not required to be equal for all fragments. The length of each fragment may be of any nonzero value. Other conditions may be TBD.

An HE STA may transmit to a receiver STA an individually addressed (A)-MPDU that contains:

— One dynamic fragment of an MSDU or MMPDU in a VHT single MPDU if the receiver STA has indicated a nonzero value in the HE Fragmentation Support field of its HE Capabilities element
  - The originator STA shall follow the rules defined in 10.13.8 (Transport of VHT single MPDUs) for generating the VHT single MPDU

— Up to one dynamic fragment for each MSDU in an A-MPDU if the receiver STA has indicated a value of 2 in the HE Fragmentation Support field of its HE Capabilities element
  - The originator STA shall follow the rules defined in 10.24.7 (HT-immediate block ack extensions) for generating the A-MPDU

— Up to four dynamic fragments for each MSDU in an A-MPDU if the receiver STA has indicated a value of 3 in the HE Fragmentation Support field of its HE Capabilities element
  - 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 (HT-immediate block ack extensions) for generating the A-MPDU with the following exceptions:
    - The A-MPDU should contain MPDUs whose range of the Sequence Number subfields does not exceed 16. Other conditions may be TBD.

An HE STA shall not transmit a PSDU that contains dynamic fragments of an MSDU or MMPDU whose number is greater than the maximum number of fragments or that are carried in an A-MPDU format that is not supported by the receiver STA, as determined by the value of the HE Fragmentation Support field of the HE Capabilities element sent by the receiver STA.

25.3.3 Procedure at the receiver

An HE STA that transmits an HE Capabilities element with a nonzero value in the HE Fragmentation Support subfield shall set dot11DynamicFragmentation to true. Otherwise, the HE STA may set dot11DynamicFragmentation to false.

Defragmentation of dynamic fragments shall follow the rules defined in 10.6 (Defragmentation), except for:

— The receiver STA may support the concurrent reception of dynamic fragments of TBD number of MSDUs/MMPDUs under TBD conditions

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NOTE—The receiver STA is still subject to the Receive Timer rules for each fo the MSDUs/MMPDUs as defined in 9.6 (Defragmentation).

Upon reception of a PSDU that carries one or more dynamic fragments, the receiver STA responds with:

— An Ack frame when the received fragment is contained in a VHT single 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

— A BlockAck frame when the received fragments, up to one fragment for each MSDU, are contained in the A-MPDU that solicits the immediate response and is sent by an HE STA whose HE Fragmentation Support subfield in its HE Capabilities element is 2
  - The receiver STA shall follow the rules defined in 10.24.7 (HT-immediate block ack extensions) for generating the BlockAck frame, except that the STA shall:
    - Set to 1 each bit of the Block Ack Bitmap field that corresponds to a Sequence Number subfield of a successfully received fragment contained in the soliciting A-MPDU
    - Update the corresponding block acknowledgement record when an MSDU that is received in fragments is successfully reconstructed (see 10.6 (Defragmentation)).

— A BlockAck frame when the received fragments, one or more fragments for each MSDU, are contained in an A-MPDU that solicits the immediate response and is sent by an HE STA whose HE Fragmentation Support subfield in its HE Capabilities element is 3
  - The receiver 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 Fragment Number subfield in the Block Ack Starting Sequence Control subfield of the BlockAck frame
    - Set to 1 each bit in location 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:
      $B = SC - SSN$, where SC and SSN are treated as 14-bit unsigned integers
      SC is the value of the Sequence Control 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 acknowledgement record when an MSDU that is received in fragments is successfully reconstructed (see 10.6 (Defragmentation)).

25.4 Block acknowledgement

25.4.1 Selection of BlockAck and BlockAckReq variants

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. A Multi-STA BlockAck frame with BA Information for multiple AIDs shall have RA field set to the broadcast address.

An HE STA that supports Multi-STA BA 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 1 then the BA Start Sequence Control, TID and BA Bitmap of the BA information field are processed according the procedure given in 10.24.7 (HT-immediate block ack extensions).

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— If the ACK type field is 0, the field indicates an ACK of either a single MPDU or all MPDUs carried in the eliciting PPDU that was transmitted by the STA.

25.5 MU operation

25.5.1 HE DL MU operation

25.5.1.1 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 more than one RUs (see 26.3.9.8.3 (Time domain encoding)), unless the STA set the DL OFDMA Capable subfield of the HE Capabilities element to 1.

An AP shall not transmit to a STA a HE MU PPDU with the HE-SIG-B allocating spatial streams to more than one recipient STA, unless the STA set the DL MU MIMO Capable subfield of the HE Capabilities element to 1.

The transmission for all the STAs in an HE MU PPDU in either DL OFDMA or DL MU MIMO shall end at the same time, indicated by the L-SIG field as described in 26.3.9.5 (L-SIG).

The padding procedure for each A-MPDU in an HE MU PPDU is the same as for an A-MPDU in a VHT PPDU and defined in 10.13.6 (A-MPDU padding for VHT PPDU).

25.5.1.2 HE MU PPDU payload

The content of each individual A-MPDU in an HE MU PPDU is based on the rules specified in 10.13.1 (A-MPDU contents).

The frame type and address type (unicast, groupcast) of MPDUs may be different across A-MPDUs within a same HE MU PPPDU.

A groupcast frame in a groupcast 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.

25.5.2 UL MU operation

25.5.2.1 General

The UL MU operation allows an AP to solicit immediate simultaneous response frames from one or more non-AP STAs. Non-AP STAs transmit their response frames in HE trigger-based PPDU format, in either UL MU OFDMA UL MU-MIMO, or both.

An HE STA with dot11ULMUOFDMAOptionImplemented set to true shall set the UL MU OFDMA Capable subfield of the HE Capabilities element it transmits to 1; otherwise, the STA shall set it to 0.

An HE STA with dot11ULMUMIMOOptionImplemented set to true shall set the UL MU MIMO Capable subfield of the HE Capabilities element it transmits to 1; otherwise, the STA shall set it to 0.

A non-AP STA with dot11ULMUOFDMAOptionImplemented or dot11ULMUMIMOOptionImplemented equal to true is referred to as an UL MU capable STA.

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25.5.2.2 Rules for soliciting UL MU frames

25.5.2.2.1 General

An AP shall not send to a STA a frame soliciting the transmission of a PPDU with the TXVECTOR parameter FORMAT set to HE_TRIG, unless the STA is UL MU Capable.

An AP may transmit a PPDU that elicits an HE trigger-based PPDU from one or more UL MU capable STAs by including in the PPDU at least one of:

— A Trigger frame that includes one or more per-User Info field addressed to the recipient STA(s).
  • For recipient STAs that are associated with the AP, the per-User Info field is addressed to a recipient STA if the value of the AID subfield of the Per-User Info field is equal to the AID of the STA.
  • For recipient STAs that are not associated with the AP, TBD

— An "Trigger Information TBD contained in the MAC Header" of individually addressed MPDUs contained in the PPDU

— The following two frames shall not be present at the same time in an A-MPDU

— A Trigger frame with a per-User Info field addressed to a STA

— an MPDU addressed to the same STA that includes "Trigger Information Field info in MAC header TBD"

If a Trigger frame is aggregated with other frames in an A-MPDU, the Trigger frame shall be the first frame in the A-MPDU.

25.5.2.2.2 Allowed settings of the Trigger frame fields

If dot11MultiBSSIDActivated is true and at least two of the Trigger frame recipient STAs are associated with two different BSSIDs, then the TA shall be set to a common address TBD; in all other cases the TA shall be set to the BSSID of the AP to which all recipient STAs are associated.

An AP shall not set any subfields of the Commin Info field to a value that is not supported by all the recipient STAs of the Trigger frame.

An AP shall not set any subfields of a Per User Info field to a value that is not supported by the recipient STAs of the Per User Info field.

If a Trigger frame is transmitted in a broadcast RU of a HE MU PPDU, then the Trigger frame shall not include any Per User Info fields addressed to a STA that is identified as recipient of another RU or spatial stream of the same HE MU PPDU.

25.5.2.2.3 AP access procedures for UL MU operation

An UL OFDMA MPDU/A-MPDU is the acknowledgement of the Trigger frame. When the AP receives MPDU correctly from at least one STA indicated by trigger frame, the frame exchange initiated by the trigger frame is successful.

25.5.2.3 STA behavior

A STA shall not transmit an HE trigger-based PPDU unless is it explicitly enabled by an AP in one of the operation modes described in this section.

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The inter frame space between a PPDU that contains a Trigger frame and the triggered 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 a Trigger Frame with a Per User Info field addressed to the STA, or the PPDU contains an MPDU addressed to the STA which carries a "Trigger Information Field info in MAC header TBD". The Per User Info field is addressed to a STA if the AID subfield is equal to the AID of the STA, if the STA is associated with the AP. If the STA is not associated with the AP, TBD.

— The UL MU CS Condition described in 25.5.2.4 (UL MU CS mechanism) indicates the medium is idle, or the CS Required subfield in a Trigger frame is 0.

A STA transmitting an HE trigger-based PPDU shall set the TXVECTOR parameter as follows:

— The L_LENGTH parameter shall be set to the value indicated by the L-SIG Length field of the eliciting Trigger frame or of the "Trigger Information Field info in MAC header TBD".

— The CP_LTF_TYPE parameter shall be set to the value indicated by the CP-LTF subfield of the Common Info field of the eliciting Trigger frame

— The SIG-A_CONT parameter shall be set to the value indicated by the SIG-A subfield of the Common Info field of the eliciting Trigger frame [TBD, depending on how the TXVECTOR is defined we may spell out all the subfields of SIG-A]

— The DCM parameter shall be set to the value indicated by the DCM subfield of the per-User Info field of the eliciting Trigger frame

— The CODING_TYPE parameter shall be set to the value indicated by the Coding Type subfield of the Per User Info field of the eliciting Trigger frame

— The RU parameter shall be set to the value indicated by the RU Allocation field of the trigger frame

— The NSTS parameter shall be set to TBD

The MAC padding procedure is descried in 10.42.2.1.2

The content of each individual A-MPDU in an HE MU PPDU is based on the rules specified in 10.13.1 (A-MPDU contents) and the additional rules described in this clause.

If the Trigger Type value of a Trigger frame is not equal to 0, the STA shall include in the reponse A-MPDU at least one MPDU of the required type. If the STA does not have a frame of the required type, the STA should transmit QoS Null frame.

NOTE--The frame type of MPDUs may be different across A-MPDUs within a same HE trigger-based PPPDU

25.5.2.4 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 is described in and virtual CS is defined in 10.3.2.1 (CS mechanism).

When two NAVs are supported by a STA, 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.

When only one NAV is supported by a STA, if the NAV is considered and the NAV counter is nonzero, then virtual CS is busy. Otherwise, the virtual CS is idle.

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Editor's Note: The previous sentence is only needed if support for two NAVs is optional. Mandatory or optional support for two NAVs is still TBD.

A NAV is considered in virtual CS for a STA that is polled from a Trigger frame for UL MU transmission unless one of the following conditions is met:

- The NAV was set by a frame originating from the AP sending the Trigger frame
- The response generated by the STA contains an Ack frame or a BlockAck frame and the duration of the HE trigger-based PPDU is less than a TBD value
- The NAV was set by a frame originating from an intra-BSS STA
- The CS Required subfield in the Trigger frame is 0
- Other condition TBD

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) 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 UL RUs in the Trigger frame are considered idle; if the STA detects that the 20 MHz channels containing the allocated UL RUs are not all idle, then the STA shall not transmit anything in the allocated UL RUs.

If the CS Required subfield in a Trigger frame is set to 0, the STA may transmit an HE trigger-based PPDU without the carrier sense.

The AP shall set the CS Required subfield to 1 except under the following conditions:

- All HE trigger-based PPDU(s) solicited by the Trigger frame containing ACK/BA and the length of the HE trigger-based PPDU is below a TBD threshold.
- Other conditions are TBD.

25.5.2.5 HE buffer status feedback operation for UL MU

The buffer status report from HE STAs may be utilized to support the efficient UL MU operation. An AP may poll HE STAs for buffer status reports using the frame carrying the trigger information. The frame may be a broadcast Trigger frame, a unicast Trigger frame, a Trigger frame for random access, or a Data type of frame carrying the trigger information. An AP may request an HE STA to send its buffer status information by TBD indication in the Trigger frame or in the HE A-Control field in a Data type of frame. In this case, an AP may indicate TBD granularity of the Queue Size for an HE STA to report (signaling method TBD). Upon reception of the frame including the TBD indication in the Trigger frame or in the HE A-Control field, the HE STA may respond with the frame including the Queue Size subfield in a QoS Control field or TBD HE A-Control field. To report the buffer status for a given TID, an HE STA shall set the Queue Size subfield in a QoS Data or a QoS Null frame to the amount of queued traffic present in the output queue belonging to the TID.

25.5.2.6 UL OFDMA-based random access

UL OFDMA-based distributed random access is a random access mechanism for HE STAs that randomly select resource units (RUs) assigned by an AP for transmission of UL PPDUs. The HE AP indicates a TBD parameter in the Trigger frame for HE STAs to initiate random access following the Trigger frame transmission.

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25.5.2.6.1 Random access procedure

In this sub-section, the random access procedure is described with respect to UL OFDMA contention parameters. The procedure is also illustrated in Figure 25-1 (Illustration of the UL OFDMA-based random access procedure). An HE STA that uses the random access procedure maintains an internal counter termed as OBO counter. The OFDMA contention window (OCW) is an integer with an initial value of OCWmin. Other parameters for random access are TBD.

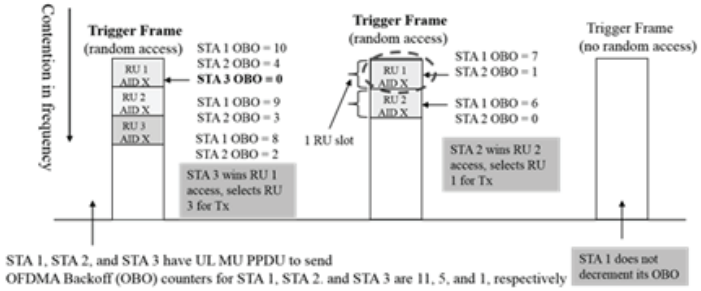


Figure 25-1—Illustration of the UL OFDMA-based random access procedure

An HE AP indicates the value of OCWmin for the random access operation. The method of indication of the OCWmin value is TBD.

The random access procedure initiates with an HE STA receiving a Trigger frame for random access.

For an initial UL PPDU transmission, when an HE STA obtains the value of OCWmin from the HE AP, 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.

If the OBO counter for an HE STA is smaller than the number of RUs assigned to AID value TBD 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 TBD in a Trigger frame. For instance, as shown in Figure 25-1 (Illustration of the UL OFDMA-based random access procedure), HE STA 1 and HE STA 2 decrement their non-zero OBO counters by 1 in every RU assigned to AID value TBD for random access within the Trigger frame.

If the OBO counter for an HE STA is a zero value or if the OBO counter decrements to 0, it randomly selects any one of the assigned RUs for random access and transmits its UL PPDU in the selected RU. Otherwise, the STA resumes with its OBO counter in the next Trigger frame for random access.

25.5.3 HE MU cascading operation

A TXOP can include both DL MU and UL MU transmissions.

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A 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 a DL MU PPDU in the same TXOP, as illustrated in Figure 25-2 (An example of cascading sequence of MU PPDUs).

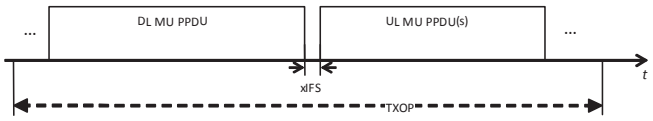


Figure 25-2—An example of cascading sequence of MU PPDUs

The cascading sequence has only one DL transmitter. The cascading sequence may have different UL transmitters within each HE trigger-base PPDU. The cascading sequence may have a different set of transmitters in HE trigger-based PPDUs as compared to the DL HE MU PPDU that follows the HE trigger-based PPDUs within the same TXOP.

25.6 HE sounding protocol

The HE sounding protocol is initiated by an AP sending an NDP Announcement frame (TBD) followed by an HE NDP transmitted a SIFS after the end of the PPDU carrying the NDP Announcement (TBD).

An HE AP may use the Trigger frame to solicit HE beamforming feedback from a STA provided that the UL MU Capable field of the most recently received HE Capabilities element from that STA is 1 (see 25.5.2 (UL MU operation)).

An HE AP may solicit beamforming feedback from multiple STAs sequentially through SU transmission.

An example of the HE sounding protocol using MU operation to solicit feedback is shown in Figure 25-3 (An example of the HE sounding protocol using MU operation).

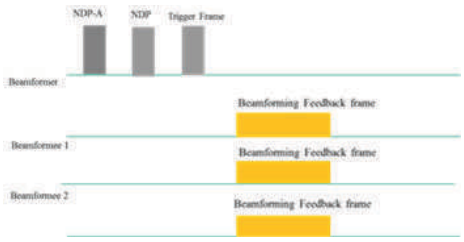


Figure 25-3—An example of the HE sounding protocol using MU operation

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25.7 TWT operation

25.8 Receive operating mode

25.8.1 General

An HE STA can change its operating mode setting either using the procedure described in 10.41 (Notificaion of operating mode changes), or the procedure describes in this subclause. Receive operating mode (ROM) indication is a procedure for a first HE STA to indicate the maximum operating channel width and the maximum number of spatial streams it can receive to a second HE STA.

When the first HE STA chooses to indicate its ROM setting, this can be signaled using the ROM subfield in the HE variant HT Control field sent in a frame of type Data. The ROM subfield is set to indicate that the first HE STA supports receiving frames with a bandwidth up to and including the value indicated by the Channel Width subfield and with a number of spatial streams up to and including the value indicated by the Rx NSS subfield (see [HE variant HT Control field]). The dot11ROMIOptionImplemented defines whether the HE AP implements the reception of the ROM setting and the AP transmits according to the ROM setting to the transmitter of the ROM setting. An HE AP shall set dot11ROMIOptionImplemented to true.

ROM indication allows an HE STA to adapt the maximum operating channel width or the maximum number of spatial streams it can receive. In doing so, an HE STA may save power by changing to a ROM setting that consumes less power, or by changing to a ROM setting that supports higher throughput operation. Unlike 11.41 (Notification of operating mode changes), ROM indication can be signaled in the MAC header of a Data frame as opposed to a management frame exchange. Hence, there is minimal impact on channel efficiency.

25.8.2 Rules for ROM indication

An HE STA may transmit an individually address frame of type Data that contains the ROM subfield to indicate that the transmitting HE STA supports receiving frames with a bandwidth up to and including the value indicated by the Channel Width subfield and with a number of spatial streams up to and including the value indicated by the Rx NSS subfield of the ROM subfield.

The transmitting HE STA shall support for receiving frames with a bandwidth up to and including the value indicated by the Channel Width subfield and with a number of spatial streams up to and including the value indicated by the Rx NSS subfield of the ROM subfield indicated in the eliciting frame immediately after receiving a successful acknowledgement from the responding HE STA.

If there is a change to the current maximum operating channel width or the maximum number of spatial streams, the transmitting HE shall adjust to the most recently sent ROM settings within a time TBD [Outage Time] following the receipt of an immediate acknowledgement response. The transmitting HE STA shall support receiving frames with a bandwidth up to and including the most recent value indicated by the Channel Width subfield and with a number of spatial streams up to and including the most recent value indicated by the Rx NSS subfield of the ROM subfield.

NOTE—In the event of transmission failures, the transmitting HE STA can attempt recovery procedure as defined in 9.19.2.4 (Multiple frame transmission in an EDCA TXOP), and can defer from changing to the new ROM settings indicated in the eliciting frame until a successful acknowledgement from the responding STA is received.

The responding HE STA shall use the value indicated by the Channel Width subfield most recently received from the transmitting HE STA as the current maximum operating channel width that the transmitting HE STA indicated as supported for receiving frames.

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The responding HE STA shall use the value indicated by the Rx NSS subfield most recently received from the transmitting HE STA as the current maximum number of spatial streams that the transmitting HE STA indicated as supported for receiving frames.

The responding HE STA shall not transmit a subsequent PPDU to the transmitting HE STA that uses a bandwith or a number of spatial stream not indicated as currently supported by the transmitting HE STA.

If there is a change to the current maximum operating channel width or the maximum number of spatial stream that the transmistting STA is capable of receiving, the responding HE STA shall not sent any PPDU to the transmitting HE STA within a time TBD [Outage Time] following the transmission of an immediate acknowledgement response.

25.9 Spatial reuse operation

25.9.1 General

The objective of the HE spatial reuse operation is to improve the system level performance and the utilization of the spectrum resources in dense deployment scenarios by early identification of signals from overlapping basic service sets (OBSSs) and interference management.

25.9.2 Color code based CCA rules

An STA determines whether a detected frame is an inter-BSS or an intra-BSS frame by using BSS color or MAC address in the MAC header. The detected frame is intra-BSS frame if one of the following conditions is true:

— The BSS color in the detected PPDUis same as the BSS color announced by its associated AP,

— The RA or TA of the detected frame is same as the BSSID or its bandwidth signaling variant of its associated AP

— Its associated AP is identified by TBD Multiple BSSID element and the RA or TA of the detected frame is same as one of the BSSID or its bandwidth signaling variant defined by TBD Multiple BSSID element

If the detected frame is an inter-BSS frame, under TBD condition, uses TBD OBSS PD level that is greater than the minimum receives sensitivity level.

A STA should regard an inter-BSS PPDU with a valid PHY header and that has receiving power/RSSI below the OBSS PD level used by the receiving STA and that meets additional TBD conditions, as not having been received at all (e.g., should not update its NAV), except that the medium condition shall indicate BUSY during the period of time that is taken by the receiving STA to validate that the PPDU is from an inter-BSS, but not longer than the time indicated as the length of the PPDU payload.

A STA should revise the NAV depending on TBD conditions at the recipient of the ongoing OBSS frame.

25.9.3 Adaptive CCA and transmit power control

When the color code based CCA rule is used, as described in Error! Reference source not found., an HE STA is allowed to adjust the OBSS_PD threshold in conjunction with transmit power control to improve the system level performance and the utilization of the spectrum resources.

To further improve the possibilities of spatial reuse, an STA is allowed to adjust the setting of one or more following parameters, CCA ED level, 802.11 signal detect CCA or TXPWR threshold values. The constraints on selecting threshold values are TBD.

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25.10 A-MPDU operation

25.10.1 General

A-MPDU operation for an HE PPDU is as defined in 10.13 (A-MPDU operation), except for A-MPDU padding, which is defined in 25.10.2 (A-MPDU padding) and except for an A-MPDU that includes QoS Data frames from from two or more different TSs, the rules for which are defined in 25.10.3 (A-MPDU with multiple TIDs).

25.10.2 A-MPDU padding

The A-MPDU padding per each HE STA in an HE MU PPDU follows the same procedure as for VHT STA11ac procedure as defined in Section 10.13.6 (A-MPDU padding for VHT PPDU).

A non-AP STA that transmits an HE trigger-based PPDU shall construct the PSDU carried in the HE trigger-based PPDU as follows.

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 fullfilled:

— The A-MPDU content constraints (see 10.13.1 (A-MPDU contents)) 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

And provided that

— 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.

Then, padding shall be 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 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 VHT single MPDU (see 10.13.7 (Setting the EOF field of the MPDU delimiter)).

25.10.3 A-MPDU with multiple TIDs

An HE STA with dot11AMPDUwithMultipleTIDOptionImplemented set to true shall set the A-MPDU with Multiple TIDs Capable subfield of the HE Capabilities element it transmits to 1; otherwise, the HE STA shall set it to 0.

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An HE AP shall not send A-MPDU with multiple TIDs to an HE non-AP STA that associates with the AP, unless the HE non-AP STA is A-MPDU With Multiple TIDs capable.

An HE non-AP STA shall not send an A-MPDU with multiple TIDs to its associated HE AP, unless the HE AP is A-MPDU With Multiple TIDs capable.

In an HE MU PPDU, an HE STA may aggregate the frames in an A-MPDU with multiple TIDs as defined in Table 9-426a (Multiple TID A-MPDU contents in the data enabled immediate response context) or Table 9-426b (Multiple TID A-MPDU contents in the data enabled no immediate response context). An A-MPDU with multiple TIDs shall not be transmitted in an SU PPDU.

Multi-STA BlockAck frame shall be used to acknowledge the Multi-TID A-MPDU in MU PPDU. The value of TID field in Multi-STA BlockAck frame is TBD.

25.11 TXVECTOR parameters STA_ID_LIST, UPLINK_FLAG and BSS_COLOR for an HE PPDU

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 STA's AID. If an RU is intended for a group of STAs then the STA_ID_LIST element is set as follows:

— For a single BSS AP, if the RU is intended for all STAs in the BSS, the STA_ID_LIST element is set to 0;

— For a multiple BSS AP, if the RU is intended for all STAs in one of its BSSs, the STA_ID_LIST element is set to the group addressed AID assignment in the TIM according to the existing Multi-BSSID TIM operation;

— For a multiple BSS AP, if the RU is intended for all STAs on all its BSSs, the STA_ID_LIST element is set to 2047.

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

— 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, shall set the TXVECTOR parameter UPLINK_FLAG to 0

NOTE—The (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.

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 9.X.Y (Spatial Reuse) or reduce power consumption as described in 25.13.1 (Intra-PPDU power save for HE non-AP STAs).

An HE AP shall select a value in the range 1 to TBD to include in the BSS Color subfield of the HE Operation elements that it transmits and shall maintain that single value of the BSS Color subfield for the duration of the existence of the BSS. An HE AP transmitting an HE PPDU shall set the TXVECTOR parameter BSS_COLOR to the value indicated in the BSS Color subfield of its HE Operation element.

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A non-AP HE STA transmitting an HE PPDU shall set the TXVECTOR parameter BSS_COLOR to the value indicated in the BSS Color subfield of the HE Operation element received from the AP with which it is associated.

The virtual APs which are defined by TBD Multiple BSSID element shall select a same BSS Color.

25.12 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 9.4.2.213 (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 asetermined by the post-FEC padding a-factor (see 26.3.10 (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.

25.13 Power management

25.13.1 Intra-PPDU power save for HE non-AP STAs

An HE non-AP STA that is in awake state (see 11.2.2.2 (STA Power Management modes)) and 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 received PPDU when one of the following conditions is met:

— The PPDU is an HE MU PPDU with:
  - The value of the RXVECTOR parameter BSS_COLOR equal to the BSS color of the BSS with which the STA is associated and,
  - The value of the RXVECTOR parameter UL_FLAG is equal to 0 and,
  - The values obtained from the RXVECTOR parameter STA_ID_LIST do not match 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 with:
  - The value of the RXVECTOR parameter BSS_COLOR equal to the BSS color of the BSS with which the STA is associated and,
  - The value of the RXVECTOR parameter UL_FLAG is equal to 1

— The PPDU is an HE trigger-based PPDU with:
  - The value of the RXVECTOR parameter BSS_COLOR equal to the BSS color of the BSS with which the STA is associated

An HE STA that is in intra-PPDU power save mode and has entered doze state shall continue to operate its NAV timer and consider the medium busy during doze state and shall transition into awake state at the end of the PPDU.

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NOTE—The STA can contend for access to the medium immediately on the expiry of the NAV timer.

25.13.2 Power save with UL OFDMA-based random access

This section illustrates the power save mechanisms for HE STAs using random access procedure (see 25.5.2.6.1 (Random access procedure)).

An HE AP may indicate values of one or multiple Trigger frame start time(s) for random access in the Beacon. The power save operation with the indication of one value of Trigger frame start time in a Beacon for random access is shown in Figure 25-4 (Illustration of Trigger frame (TF) Start Time in Beacon frame for power save operation with random access operation).

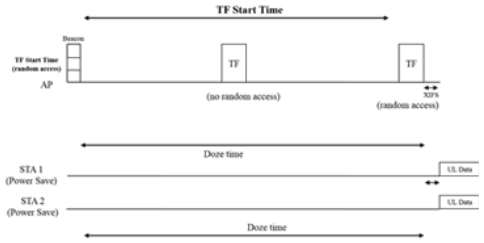


Figure 25-4—Illustration of Trigger frame (TF) Start Time in Beacon frame for power save operation with random access operation

When an HE STA receives a Beacon with the value of Trigger frame start time for random access, it may enter the doze state till the expiration of the value indicated in the Beacon.

If random acces is enabled by a sequence of Trigger frames, 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 that 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.

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26. High Efficiency (HE) PHY specification

26.1 Introduction

26.1.1 Introduction to the HE PHY

Clause 26 specifies the PHY entity for a high efficiency (HE) orthogonal frequency division multiplexing (OFDM) system. In addition to the requirements in Clause 26, an HE STA shall be capable of transmitting and receiving PPDUs that are compliant with the mandatory PHY specifications defined in Clause 20 and Clause 22.

The HE PHY is based on the VHT PHY defined in Clause 22, which in turn is based on the HT PHY defined in Clause 20, which in turn is further based on the OFDM PHY defined in Clause 18. 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 divisional 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.

NOTE—An HE SU PPDU includes individually addressed and group addressed transmissions.

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. Tones of one or more secondary channels in 80 MHz and 160 (80+80) MHz could be nulled when using OFDMA PPDU transmission. The modes of non-contiguous channel bonding are TBD. The non-contiguous channels within primary or secondary 80 MHz only exists at AP side.

The HE PHY provides support for 800 ns, 1600 ns, and 3200 ns 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 data subcarriers are modulated using binary phase shift keying (BPSK), quadrature phase shift keying (QPSK), 16-quadrature amplitude modulation (16-QAM), 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 shall support the following Clause 26 features:

— Binary convolutional coding for RU sizes less than or equal to 242 tones (transmit and receive)

— LDPC as the only coding scheme for RU sizes of 484 tones, 996 tones (transmit and receive)

— LDPC when declaring support for at least one of HE 80/160/80+80 SU-PPDU bandwidths, or declaring support for more than 4 spatial streams (transmit and receive)

— A combination of 2x LTF with 0.8 μs GI duration on both LTF and data

— A combination of 2x LTF with 1.6 μs GI duration on both LTF and data

— A combination of 4x LTF with 3.2 μs GI duration on both LTF and data

An HE STA may support the following Clause 26 features:

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— Other combinations of LTF durations and GI durations

— LDPC (transmit and receive) for RU sizes less than or equal to 242 tones

— LDPC (transmit and receive) when declaring support for less than or equal to 4 spatial streams

— Dual carrier modulation (transmit and receive)

NOTE—Once mandatory vs optional TBDs are decided, above text will have additions.

26.1.2 Scope

The services provided to the MAC by the HE PHY consist of the following protocol functions:

a) A function that defines a method of mapping the PSDUs into a framing format (PPDU) suitable for sending and receiving PSDUs between two or more 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 22 (Very High Throughput (VHT) PHY specification), Clause 20 (High Throughput (HT) PHY specification) and Clause 18 (Orthogonal frequency division multiplexing (OFDM) PHY specification) PHYs.

26.1.3 HE PHY functions

26.1.3.1 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 26.3 (HE PHY) and 26.4 (HE PLME). The HE PHY service is provided to the MAC through the PHY service primitives defined in Clause 7 (PHY service specification). The HE PHY service interface is described in 26.2 (HE PHY service interface).

26.1.3.2 PHY management entity (PLME)

The PLME performs management of the local PHY functions in conjunction with the MLME.

26.1.3.3 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.

26.1.4 PPDU formats

The structure of the PPDU transmitted by an HE STA is determined by the TXVECTOR parameters as defined in Table 26-1 (TXVECTOR and RXVECTOR parameters).

The FORMAT parameter determines the overall structure of the PPDU:

— 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.

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— HE MU PPDU format (HE_MU) carries one or more PSDUs to one or more users. It is similar to the SU format, except that an HE-SIG-B field is present. Support for the HE MU PPDU format is mandatory.

— HE extended range SU PPDU format (HE_EXT_SU) carries a single PSDU. It is similar to the SU format, except that the HE-SIG-A field is repeated. Support for the HE extended range SU PPDU format is TBD (mandatory or optional).

— 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 TBD (mandatory or optional).

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26.2 HE PHY service interface

26.2.1 Introduction

26.2.2 TXVECTOR and RXVECTOR parameters

The parameters in Table 26-1 (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 26-1—TXVECTOR and RXVECTOR parameters

Parameter	Condition	Value	TXVECTOR	RXVECTOR
FORMAT		Determines the format of the PPDU. Enumerated type: NON_HT indicates Clause 18 (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 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
PE_DURATION	FORMAT is HE_SU or HE_MU or 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.	Y	Y
BEAM_CHANGE	FORMAT is HE_SU	Indicates beam change between pre-HE and HE modulated fields. 1 indicates that the beam is changed between the two portions. NOTE—BEAM_CHANGE shall be set to 1 if $N_{SS} > 2$ or the PPDU is the first PPDU in a TXOP.		
	Otherwise	Set to 1		

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Table 26-1—TXVECTOR and RXVECTOR parameters *(continued)*

BSS_COLOR	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Set to a value of the AP's choosing within the range 0 to TBD (see 25.11 (STA ID, Uplink Flag and BSS Color in HE PPDUs)).	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 25.11 (STA ID, Uplink Flag and BSS Color in HE PPDUs)).	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 25.11 (STA ID, Uplink Flag and BSS Color in HE PPDUs)).	M U	Y
	Otherwise	Not present	N	N

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, HE extended range SU PPDU and HE trigger-based PPDU and present per user for an HE MU PPDU. 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.

26.3 HE PHY

26.3.1 Introduction

26.3.2 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 26-1 (HE SU PPDU format). This PPDU is used for SU transmission and in this format the HE-SIG-A field is not repeated.

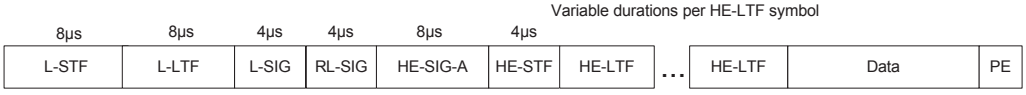


Figure 26-1—HE SU PPDU format

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The format of the HE MU PPDU is defined as in Figure 26-2 (HE MU PPDU format). This format is used for MU transmission that is not a response of a Trigger frame. An HE-SIG-B field is present in this format.

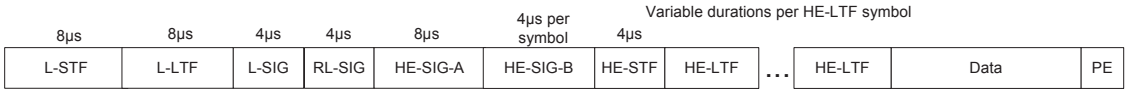


Figure 26-2—HE MU PPDU format

The format of the HE extended range SU PPDU is defined as in Figure 26-3 (HE extended range SU PPDU format). This format is used for SU transmission and in this format the HE-SIG-A field is repeated.

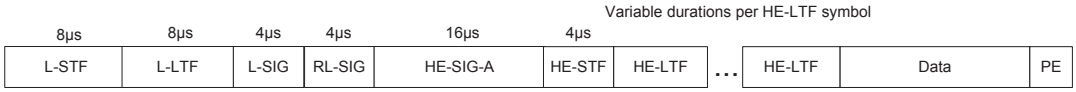


Figure 26-3—HE extended range SU PPDU format

The format of the HE extended range SU PPDU is defined as in Figure 26-4 (HE trigger-based PPDU format). This format is used for SU transmission and in this format the HE-SIG-A field is repeated.

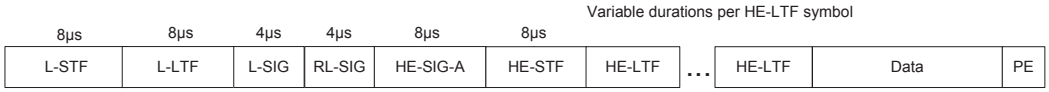


Figure 26-4—HE trigger-based PPDU format

The fields of the HE PPDU formats are summarized in Figure 26-2 (HE PPDU fields).

Table 26-2—HE PPDU fields

Field	Description
L-STF	Non-HT Short Training field
L-LTF	Non-HT Long Training field
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

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Table 26-2—HE PPDU fields *(continued)*

Data	The Data field carrying the PSDU(s)
Data	The Data field carries 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. In the HE NDP PPDU the Data field is not present. The number of OFDM symbols in the HE-LTF field, $N_{HE\text{-}LTF}$, is 1, 2, 4, 6, or 8 and the duration of each symbol in the HE-LTF field is 3.2 μs, 6.4 μs, or 12.8 μs plus the GI duration. 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.

DL HE NDP is one DL HE sounding format.

The format of a HE NDP PPDU is shown in Figure 26-5 (HE NDP PPDU format).

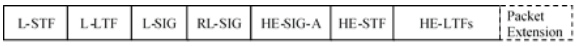


Figure 26-5—HE NDP PPDU format

NOTE 1—The number of HE-LTF OFDM symbols, $N_{HE\text{-}LTF}$ in the NDP is a function of the total number of space-time streams N_{STS} as shown in Table 26-6 (Frequently used parameters).

NOTE 2—The combination of HE-LTF modes and GI duration is indicated in HE-SIG-A field.

NOTE 3—The duration of each HE-LTF OFDM symbol, $T_{HE\text{-}LTF}$, is defined in Table 26-3 (Timing-related constants).

NOTE 4—The presence and duration of PE are TBD.

The HE NDP PPDU has the following properties:

— It uses the HE SU PPDU format but without the Data field

— is an HE SU PPDU as implied by the value of L-Length field in L-SIG field

26.3.3 Transmitter block diagram

The generation of each field in a 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)

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l) Multiply by 1st column of PVHTLTF
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) Inverse discrete Fourier transform (IDFT)
s) Cyclic shift diversity (CSD) per chain insertion
t) Guard interval (GI) insertion
u) Windowing

Figure 26-6 (Transmitter block diagram for the L-SIG, RL-SIG and HE-SIG-A fields when the Beam Change field is 1) to Figure 26-13 (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 26-6 (Transmitter block diagram for the L-SIG, RL-SIG and HE-SIG-A fields when the Beam Change field is 1) shows the transmit process for the L-SIG, RL-SIG, and HE-SIG-A fields of a 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 other pre-HE-SIG-B fields of the HE PPDU when the Beam Change subfield in HE-SIG-A field is set to 1, with the following exceptions applied:

— The BCC encoder and interleaver 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.

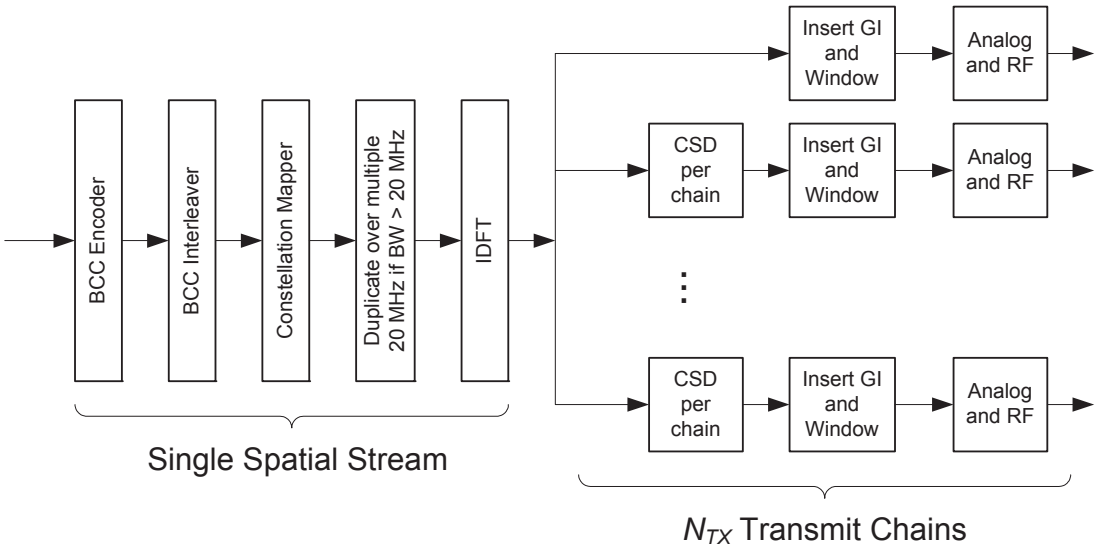


Figure 26-6—Transmitter block diagram for the L-SIG, RL-SIG and HE-SIG-A fields when the Beam Change field is 1

Figure 26-7 (Transmitter block diagram for the L-SIG, RL-SIG and HE-SIG-A fields when the Beam Change field is 0) shows the transmit process for the L-SIG, RL-SIG, and HE-SIG-A fields of a HE PPDU using one frequency segment, when the Beam Change subfield in HE-SIG-A field is set to 0. These transmit

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blocks are also used to generate the other pre-HE-SIG-B 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 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.

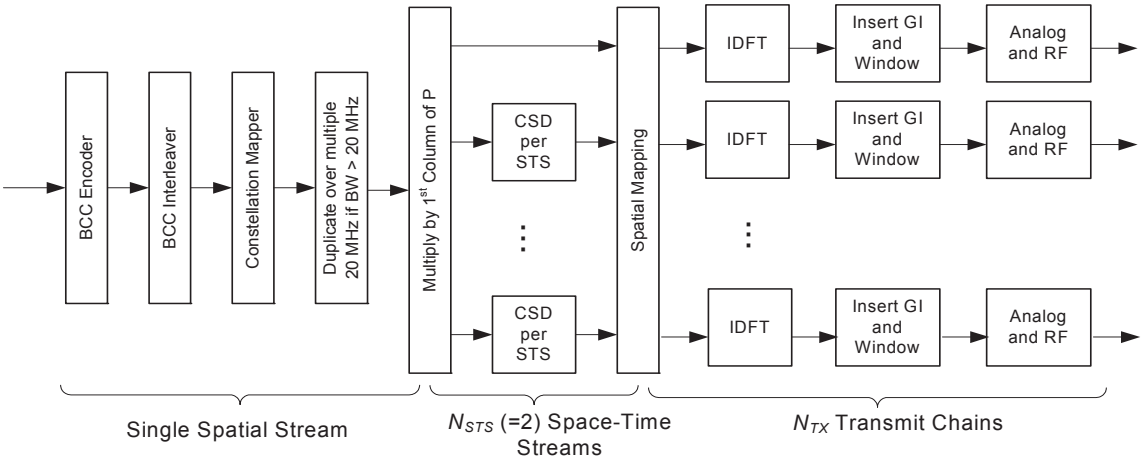


Figure 26-7—Transmitter block diagram for the L-SIG, RL-SIG and HE-SIG-A fields when the Beam Change field is 0

Figure 26-8 (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 26.3.9.8.1 (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. (TBD: MCS0-DCM)

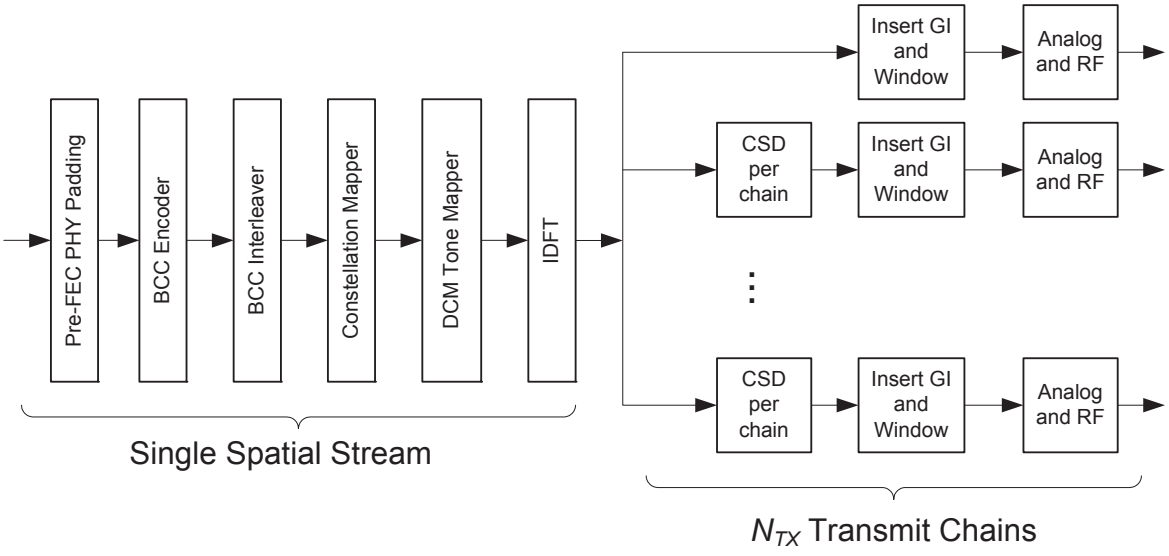


Figure 26-8—Transmitter block diagram for the HE-SIG-B field

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Figure 26-9 (Transmitter block diagram for the Data field of an HE SU transmission in a 26-, 52-, 106- or 242-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-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 26-29 (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 using single stream pilots). 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-STF field. (TBD: MCS0-DCM). This figure also applies to the data field with BCC encoding in a HE trigger-based PPDU.

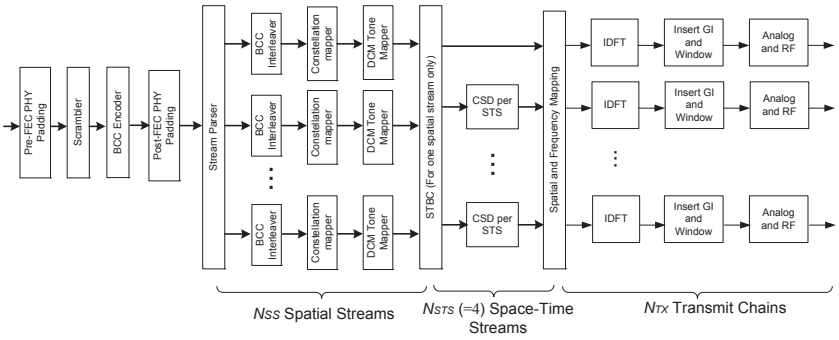


Figure 26-9—Transmitter block diagram for the Data field of an HE SU transmission in a 26-, 52-, 106- or 242-RU with BCC encoding

Figure 26-10 (Transmitter block diagram for the Data field of an HE SU transmission in 26-, 52-, 106-, 242-, 484- or 996-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-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

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DCM tone Mapper is applied only when the DCM indication for the RU is set to 1. (TBD: MCS0-DCM) This figure also applies to the data field with LDPC encoding in a HE trigger-based PPDU.

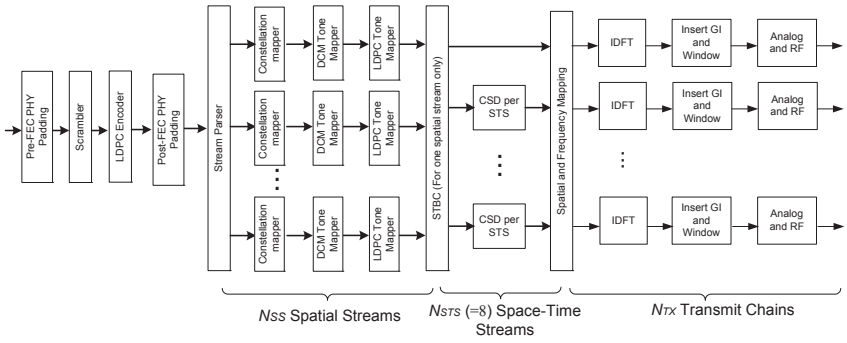


Figure 26-10—Transmitter block diagram for the Data field of an HE SU transmission in 26-, 52-, 106-, 242-, 484- or 996-RU with LDPC encoding

Figure 26-11 (Transmitter block diagram for the Data field of an HE downlink MU-MIMO transmission in 106-, 242-, 484- or 996-RU with LDPC encoding) shows the transmitter blocks used to generate the Data field of a HE downlink MU-MIMO transmission within a 106-, 242-, 484-, or 996-RU with LDPC encoding.

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This also includes the downlink MU-MIMO transmission in an RU that is part of a downlink or uplink OFDMA PPDU.

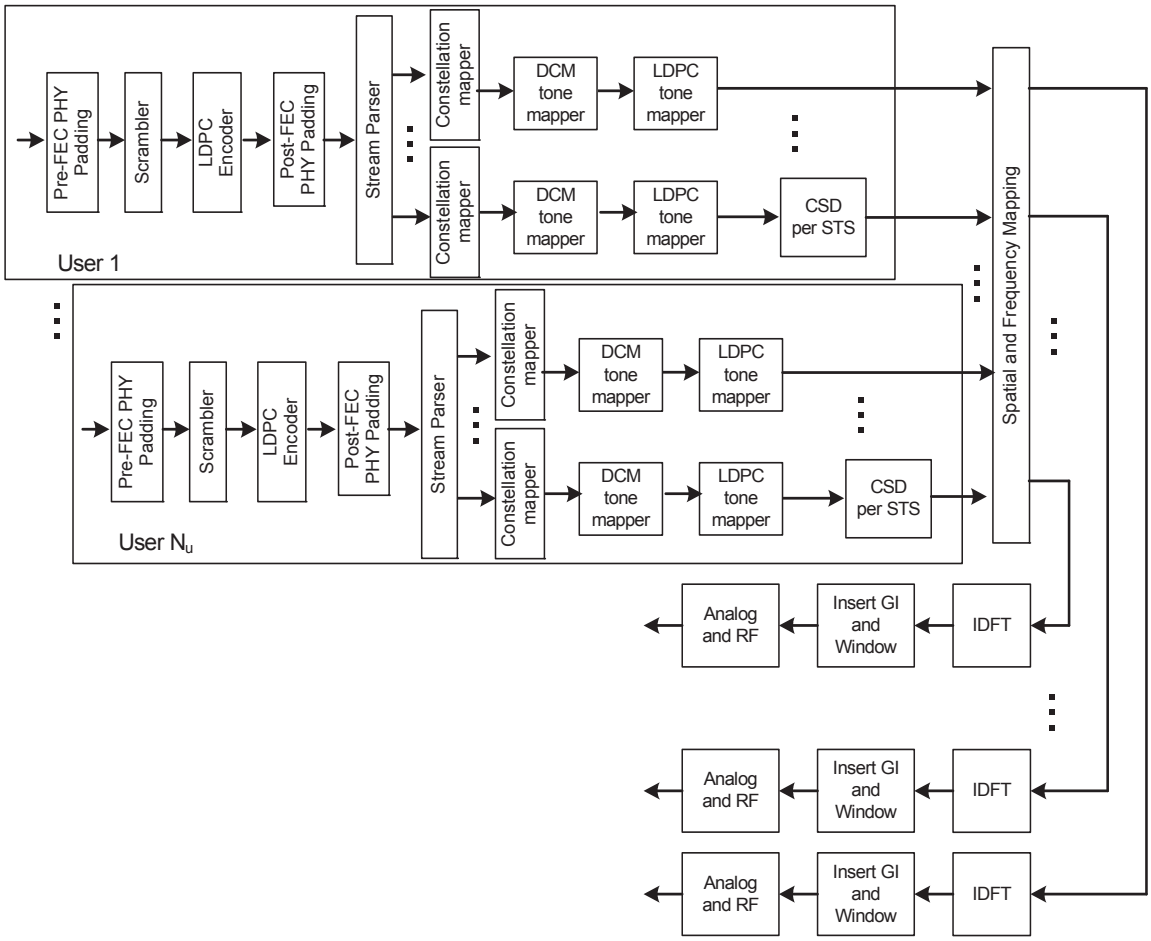


Figure 26-11—Transmitter block diagram for the Data field of an HE downlink MU-MIMO transmission in 106-, 242-, 484- or 996-RU with LDPC encoding

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Figure 26-12 (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.

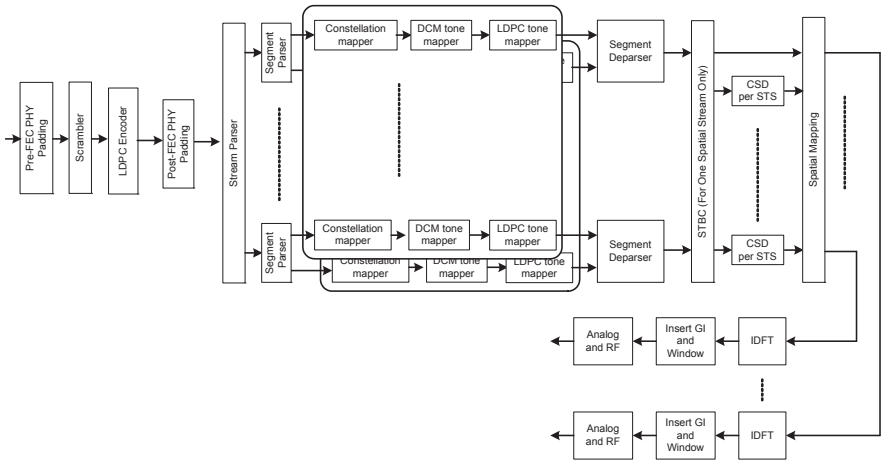


Figure 26-12—Transmitter block diagram for the Data field of an HE SU PPDU in 160 MHz with LDPC encoding

Figure 26-13 (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.

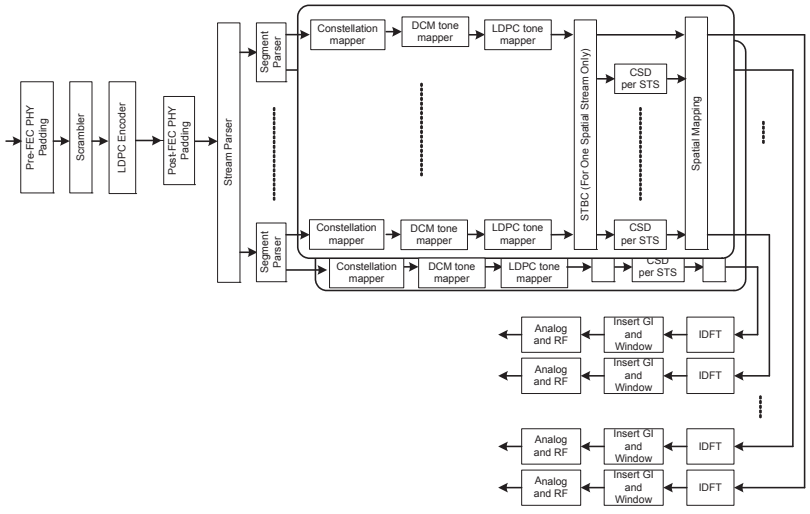


Figure 26-13—Transmitter block diagram for the Data field of an HE SU PPDU in 80+80 MHz with LDPC encoding

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26.3.4 Overview of the PPDU encoding process

26.3.5 HE modulation and coding schemes (HE-MCSs)

The HE-MCS is a value that determines the modulation and coding used in the HE-SIG-B field and the Data field of the PPDU. It is a compact representation that is carried in the HE-SIG-A field for the HE-SIG-B field in an HE MU PPDU and for the Data field in an HE SU PPDU and HE extended range SU PPDU and carried in the HE-SIG-B field for the Data field in an HE MU PPDU. Rate-dependent parameters for the full set of HE-MCSs are shown in Table 26-37 (HE-MCSs for TBD mandatory/optional 26-tone RU, NSS = 1) to Table 26-92 (HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, NSS = 8) (in 26.5 (1 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 can only be transmitted with MCS0, MCS1, MCS2 and only with 1 spatial stream on the primary 20 MHz channel.

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.

26.3.6 Timing-related parameters

Refer to Table 20-6 and Table 22-5 (Timing-related constants) for timing-related parameters for non-HE PPDU formats.

Table 26-3 (Timing-related constants) defines the timing-related parameters for HE PPDU formats..

Table 26-3— Timing-related constants

Parameter	Values	Description
$\Delta_{F,\text{ Pre-HE}}$	312.5 kHz	Subcarrier frequency spacing for the pre-HE portion.
$\Delta_{F,\text{ HE}}$	78.125 kHz	Subcarrier frequency spacing for the HE portion.
$T_{DFT,Pre\text{-}HE}$	3.2 μs	IDFT/DFT period for the pre-HE portion.
$T_{DFT,HE}$	12.8 μs	IDFT/DFT period for the HE portion.
$T_{GI,Pre\text{-}HE}$	0.8 μs	Guard interval duration for the legacy preamble, RL-SIG, HE-SIG-A and HE-SIG-B
$T_{GI,HE\text{-}LTF}$	$T_{GI1,Data}$, $T_{GI2,Data}$ 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.

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Table 26-3— Timing-related constants *(continued)*

$T_{GI4,Data}$	3.2 μs	Quadruple guard interval duration for the HE-Data field.
T_{SYM1}	13.6 μs = $T_{GI,HE\text{-}LTF} + T_{GI1,Data}$ = 1.0625 × $T_{DFT,HE}$	Normal GI symbol interval
T_{SYM2}	14.4 μs = $T_{GI,HE\text{-}LTF} + T_{GI2,Data}$ = 1.125 × $T_{DFT,HE}$	Double GI symbol interval
T_{SYM4}	16 μs = $T_{GI,HE\text{-}LTF} + T_{GI4,Data}$ = 1.25 × $T_{DFT,HE}$	Quadruple GI symbol interval
T_{SYM}	T_{SYM1}, T_{SYM2}, or T_{SYM4} depending on the GI used (see Table xx-x (Tone scaling factor and guard interval duration values for PHY fields))	Symbol interval
$T_{L\text{-}STF}$	8 μs = 10 × $T_{DFT,Pre\text{-}HE}$ /4	Non-HT Short Training field duration
$T_{L\text{-}STF}$	8 μs = 2 × $T_{DFT,Pre\text{-}HE} + T_{GI2,Data}$	Non-HT Long Training field duration
$T_{L\text{-}SIG}$	4 μs	Non-HT SIGNAL field duration
$T_{RL\text{-}SIG}$	4 μs	Repeated non-HT SIGNAL field duration
$T_{HE\text{-}SIG\text{-}A}$	8 μs = 2 × 4 μs	HE-SIG-A field duration in an HE SU PPDU, HE MU PPDU and HE trigger-based PPDU
$T_{HE\text{-}SIG\text{-}A\text{-}R}$	8 μs or 16 μs (TBD)	HE-SIG-A field duration in an HE extended range SU PPDU
$T_{HE\text{-}STF\text{-}T}$	8 μs = 5 × 1.6 μs	HE-STF field duration for an HE trigger-based PPDU
$T_{HE\text{-}STF\text{-}NT}$	4 μs = 5 × 0.8 μs	HE-STF field duration for an HE SU PPDU, HE extended range SU PPDU and HE MU PPDU
$T_{HE\text{-}LTF}$	$T_{HE\text{-}LTF\text{-}1X}$, $T_{HE\text{-}LTF\text{-}2X}$ or $T_{HE\text{-}LTF\text{-}4X}$ depending upon the LTF duration used	Duration of each HE-LTF field OFDM symbol without GI
$T_{HE\text{-}LTF\text{-}1X}$	3.2 μs	Duration of each 1x HE-LTF OFDM symbol without GI
$T_{HE\text{-}LTF\text{-}2X}$	6.4 μs	Duration of each 2x HE-LTF OFDM symbol without GI
$T_{HE\text{-}LTF\text{-}4X}$	12.8 μs	Duration of each 4x HE-LTF OFDM symbol without GI
$T_{HE\text{-}LTF\text{-}SYM}$	sum of $T_{HE\text{-}LTF}$ and $T_{GI,HE\text{-}LTF}$	Duration of each HE-LTF OFDM symbol including GI
$T_{HE\text{-}SIG\text{-}B}$	4 μs = $T_{DFT,Pre\text{-}HE} + T_{GI,Pre\text{-}HE}$	Duration of each HE-SIG-B field OFDM symbol
$N_{service}$	16	Number of bits in the SERVICE field
N_{tail}	6	Number of tail bits per BCC encoder
T_{SYML}	4 μs	Symbol duration including GI prior to the HE-STF field

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Table 26-4 (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 26-4—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 26-4 (Tone allocation related constants for Data field in a non-OFDMA HE PPDU) defines tone allocation related parameters for a OFDMA HE PPDU.

Table 26-5—Tone allocation related constants for RUs in an OFDMA HE PPDU

Parameter	RU Size (tones)						Description
	26	52	106	242	484	996	
N_{SD}	24	48	102	234	468	980	Number of complex data numbers per RU
N_{SP}	2	4	4	8	16	16	Number of pilot values per RU
N_{ST}	26	52	106	242	484	996	Total number of subcarriers per RU
NOTE: $N_{ST} = N_{SD} + N_{SP}$							

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Table 26-6 (Frequently used parameters) defines parameters used frequently in Clause 26.

Table 26-6—Frequently used parameters

Symbol	Explanation
N_{CBPS}, $N_{CBPS,r,u}$	Number of coded bits per symbol at r-th RU for user u, $r = 0, \ldots, N_{RU} - 1$, $u = 0, \ldots, N_{user,r} - 1$. For an HE SU PPDU, $N_{CBPS} = N_{CBPS,0}$ For an HE MU PPDU, N_{CBPS} is undefined
N_{CBPSS}, $N_{CBPSS,r,u}$	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 at r-th RU for user u, $r = 0, \ldots, N_{RU} - 1$, $u = 0, \ldots, N_{user,r} - 1$. For the Data field of an HE SU PPDU, $N_{CBPSS} = N_{CBPSS,0,0}$ For the Data field of an HE MU PPDU, N_{CBPSS} is undefined
N_{DBPS}, $N_{DBPS,r,u}$	Number of data bits per symbol at r-th RU for user u, $r = 0, \ldots, N_{RU} - 1$, $u = 0, \ldots, N_{user,r} - 1$. For an HE SU PPDU, $N_{DBPS} = N_{DBPS,0,0}$ For an HE MU PPDU, N_{DBPS} is undefined
N_{BPSCS}, $N_{BPSCS,u}$	Number of coded bits per subcarrier per spatial stream at r-th RU for user u, $r = 0, \ldots, N_{RU} - 1$, $u = 0, \ldots, N_{user,r} - 1$. For an HE SU PPDU, $N_{BPSCS} = N_{BPSCS,0,0}$ 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).
$N_{uset,r}$	For pre-HE modulated fields, $N_{uset,r} = 1$. For HE modulated fields, $N_{uset,r}$ represents the number of users at r-th RU in 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 2). For HE modulated fields, $N_{STS,r,u}$ the number of space-time streams at r-th RU for user u, $u = 0, \ldots, N_{user,r} - 1$. 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, $N_{STS,total}$ 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. Note that $N_{STS,r,total} = N_{STS}$ for an HE SU PPDU.

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Table 26-6—Frequently used parameters *(continued)*

N_{SS}, $N_{SS,r,u}$	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, $u = 0, ..., N_{user,r} - 1$ 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_{ES}, $N_{ES,r,u}$	The number of BCC encoders. This parameter should be 1 in all BCC cases in 11ax. For a Data field encoded using BCC, $N_{ES,r,u}$ is the number of BCC encoders at r-th RU for user u, $u = 0, ..., N_{user,r} - 1$. For the Data field encoded using LDPC, $N_{ES} = 1$ for an HE SU PPDU and $N_{ES,r,u} = 1$ for an HE MU PPDU at r-th RU for user u, $u = 0, ..., N_{user,r} - 1$. For the Data field of an HE SU PPDU, $N_{ES} = N_{ES,0,0}$ For the Data field of an HE MU PPDU, N_{ES} is undefined.
$N_{HE\text{-}LTF}$	The number of OFDM symbols in the HE-LTF field (see 26.3.9.10 (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
R, $R_{r,u}$	$R_{r,u}$ is the coding rate at r-th RU for user u, $u = 0, ..., N_{user,r} - 1$. For an HE SU PPDU, $R = R_{0,0}$ 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 1—Pre-HE modulated fields refer to the L-STF, L-LTF, L-SIG, RL-SIG, HE-SIG-A, HE-SIG-A-R, and HE-SIG-B fields, while HE modulated fields refer to the HE-STF, HE-LTF, and Data fields (see Timing boundaries for HE PPDU fields). NOTE 2—For pre-HE modulated fields, u and r are zeros only since $N_{user,r} = 1$ and $N_{RU} = 1$.	

26.3.7 OFDMA and SU tone allocation

Orthogonal Frequency Division Multiple Access (OFDMA) is the multi-user variant of the OFDM scheme where multiple-access is achieved by assigning subsets of subcarriers to different users, allowing

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simultaneous data transmission by several users. In OFDMA, the resources are allocated in two dimensional regions over time and frequency. 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 Figure 26 14. 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. In HE, the subcarriers that form a RU are physically adjacent (contiguous except at the middle of the band where nulls are placed at DC).

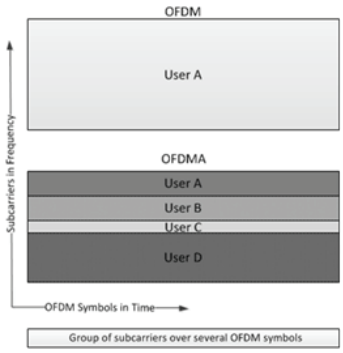


Figure 26-14—Illustration of OFDM and OFDMA concepts

Subchannelization defines subchannels that can be allocated to stations depending on their channel conditions and service requirements. Using subchannelization, an OFDMA system can potentially allocate different transmit powers to different allocations.

OFDMA is a method to add multiple access in OFDM systems and has been adopted by other wireless standards, and the HE amendment introduces OFDMA into 802.11 WLAN networks. The OFDMA parameters in HE satisfy general design criteria for OFDM systems as follows:

$$\begin{aligned} &T_{CP} \geq \tau_{RMS} \quad \text{(to prevent ISI due to delay spread)} \\ &T_{CP}\Delta f \ll 1 \quad \text{(for spectral efficiency improvement)} \end{aligned} \tag{26-1}$$

In OFDMA, an OFDM symbol is constructed of subcarriers, the number of which is a function of the FFT size. There are several subcarrier types: 1) Data subcarriers which are used for data transmission; defined in 26.3.7.1 (Resource unit, edge and DC tones), 2) Pilot subcarriers which are utilized for phase information and parameter tracking; defined in 26.3.7.3 (Pilot tones), and 3) unused subcarriers which are not used for data/pilot transmission. The unused subcarriers are the DC subcarrier (defined in 26.3.7.1 (Resource unit, edge and DC tones)), the Guard band subcarriers at the band edges (defined in 26.3.7.1 (Resource unit, edge and DC tones)), and the Null subcarriers (defined in 26.3.7.2 (Null subcarriers)).

26.3.7.1 Resource unit, edge and DC tones

The OFDMA structure consists of a 26-subcarrier resource unit (RU), 52-subcarrier RU, 106-subcarrier RU, 242-subcarrier RU, 484-subcarrier RU and 996-subcarrier RU. Resource allocations for single user (SU) consist of a 242 subcarrier RU, 484-subcarrier RU, 996-subcarrier RU and 2x996-subcarrier RU.

The 26-subcarrier RU and 52-subcarrier RU are used in the 20 MHz, 40 MHz, 80 MHz, 160 MHz and 80+80 MHz OFDMA HE PPDU formats. The 106-subcarrier RU is used in the 20 MHz, 40 MHz, 80 MHz, 160 MHz and 80+80 MHz OFDMA and MU-MIMO HE PPDU formats. The 242-subcarrier RU is used in

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the 40 MHz, 80 MHz, 160 MHz and 80+80 MHz OFDMA and MU-MIMO HE PPDU formats. The 484-subcarrier RU is used in the 80 MHz, 160 MHz and 80+80 MHz OFDMA and MU-MIMO HE PPDU formats. The 996-subcarrier RU is used in the 160 MHz and 80+80 MHz OFDMA and MU-MIMO HE PPDU formats.

The 242-subcarrier and larger RUs are used in the HE SU PPDU and non-OFDMA, MU-MIMO HE PPDU formats. The 242-subcarrier RU is used in the 20 MHz HE SU PPDU and MU-MIMO HE PPDU formats. The 484-subcarrier RU is used in the 40 MHz HE SU PPDU and MU-MIMO HE PPDU formats. The 996-subcarrier RU is used in the 80 MHz HE SU PPDU and MU-MIMO HE PPDU formats. The 2x996-subcarrier RU is used in the 160 MHz and 80+80 MHz HE SU PPDU and MU-MIMO HE PPDUs.

The maximum numbers of RUs in the 20 MHz, 40 MHz, 80 MHz, 160 MHZ and 80+80 MHz HE PPDU formats are defined in Table 26-7 (Total number of RUs for BWs). Cases of 1 RU indicate the HE SU and a HE MU-MIMO PPDU allocation.

Table 26-7—Total number of RUs for BWs

RU type	CBW20	CBW40	CBW80	CBW80+80 and CBW160
26-subcarrier RU	9	18	37	74
52-subcarrier RU	4	8	16	32
106-subcarrier RU	2	4	8	16
242-subcarrier RU	1-SU/MU-MIMO	2	4	8
484-subcarrier RU	N/A	1-SU/MU-MIMO	2	4
996-subcarrier RU	N/A	N/A	1-SU/MU-MIMO	2
2x996 subcarrier RU	N/A	N/A	N/A	1-SU/MU-MIMO

An OFDMA HE PPDU can carry a mixture of 26-subcarrier, 52-subcarrier and 106-subcarrier RUs within any of the 242-subcarrier RU boundaries.

Table 26-8—Subcarrier indices for RUs in a 20 MHz HE PPDU

RU type					
26-subcarrier RU	RU 1 [−120: −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-subcarrier RU	RU 1 [−121: −70]	RU 2 [−68: −17]	RU 3 [17: 68]	RU 4 [70: 121]	
106-subcarrier RU	RU 1 [−122: −17]		RU 2 [17: 122]		
242-subcarrier RU	RU 1 [−122: −2, 2:122]				

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Table 26-9—Subcarrier indices for RUs in a 40 MHz HE PPDU

RU type					
26-subcarrier 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-subcarrier 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-subcarrier RU	RU 1 [−243: −138]	RU 2 [−109: −4]	RU 3 [4: 109]	RU 4 [138: 243]	
242-subcarrier RU	RU 1 [−244: −3]		RU2 [3: 244]		
484-subcarrier RU	RU 1 [−244: −3, 3: 244]				

Table 26-10—Subcarrier indices for RUs in an 80 MHz HE PPDU

RU type					
26-subcarrier 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]	

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Table 26-10—Subcarrier indices for RUs in an 80 MHz HE PPDU

52-subcarrier 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-subcarrier 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-subcarrier RU	RU 1 [−500: −259]	RU 2 [−258: −17]	RU 3 [17: 258]	RU 4 [259: 500]	
484-subcarrier RU	RU 1 [−500: −17]		RU 2 [17, 500]		
996-subcarrier RU	RU 1 [−500: −3, 3: 500]				

A 26-subcarrier RU consists of 24 data subcarriers and 2 pilot subcarriers. The position of the pilots for the 26-subcarrier RU is defined in 26.3.7.3 (Pilot tones). The location of the 26-subcarrier RUs are fixed as defined in Table 26-8 (Subcarrier indices for RUs in a 20 MHz HE PPDU) and shown in Figure 26 15, Figure 26 16 and Figure 26 17 for the 20 MHz, 40 MHz and 80 MHz OFDMA HE PPDU formats, respectively. The same structure as used for the 80 MHz OFDMA HE PPDU is used for each 80 MHz frequency segment of the 160 MHz and 80+80 MHz OFDMA HE PPDU. The center 26-subcarrier RU in the 20 MHz and 80 MHz OFDMA HE PPDU (Figure 26-15 (RU locations in a 20 MHz HE PPDU) and Figure 26-17 (RU locations in an 80 MHz HE PPDU)) is located on subcarriers [–16: –4, 4: 16].

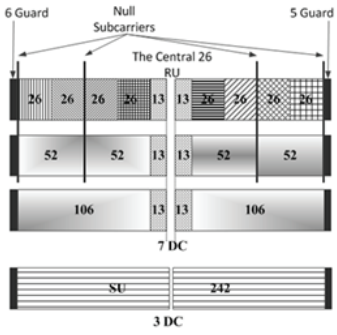


Figure 26-15—RU locations in a 20 MHz HE PPDU

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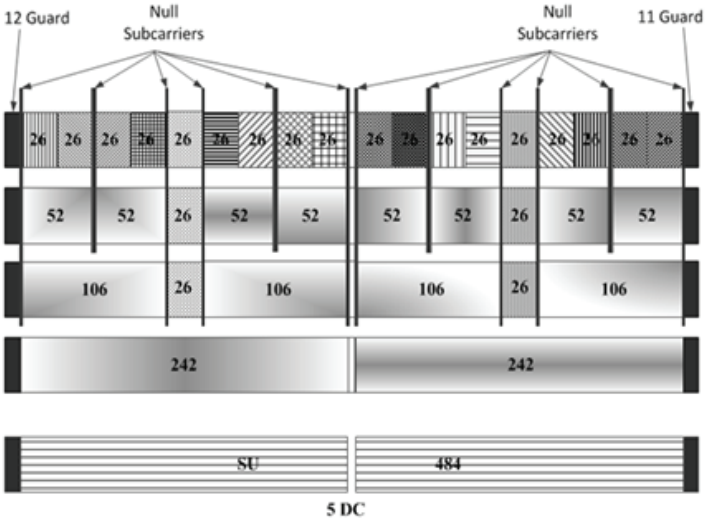


Figure 26-16—RU locations in a 40 MHz HE PPDU

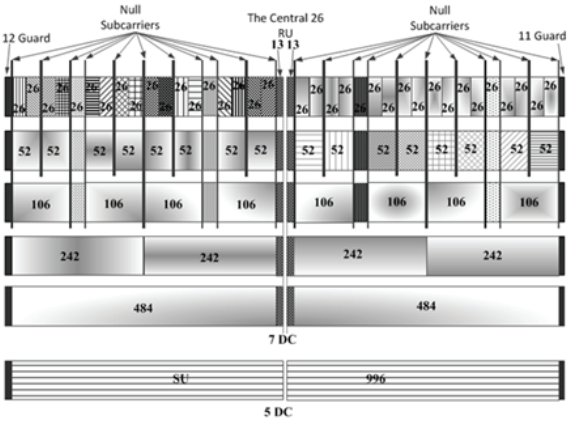


Figure 26-17—RU locations in an 80 MHz HE PPDU

A 52-subcarrier RU consists of 48 data subcarriers and 4 pilot subcarriers. The position of the pilots for the 52-subcarrier RU is defined in 26.3.7.3 (Pilot tones). The locations of the 52-subcarrier RUs are fixed as defined in Table 26-8 (Subcarrier indices for RUs in a 20 MHz HE PPDU), Table 26-9 (Subcarrier indices for RUs in a 40 MHz HE PPDU) and Table 26-10 (Subcarrier indices for RUs in an 80 MHz HE PPDU) and illustrated in Figure 26-15 (RU locations in a 20 MHz HE PPDU), Figure 26-16 (RU locations in a 40 MHz HE PPDU) and Figure 26-17 (RU locations in an 80 MHz HE PPDU) for the 20 MHz, 40 MHz and 80 MHz OFDMA HE PPDU formats, respectively. The same structure as used in the 80 MHz OFDMA HE PPDU format is used for each 80 MHz frequency segment of the 160 MHz and 80+80 MHz OFDMA HE PPDU formats.

A 106-subcarrier RU consists of 102 data subcarriers and 4 pilot subcarriers. The position of the pilots for the 106-subcarrier RU is defined in 26.3.7.3 (Pilot tones). The locations of the 106-subcarrier RUs are fixed as defined in Table 26-8 (Subcarrier indices for RUs in a 20 MHz HE PPDU), Table 26-9 (Subcarrier indices for RUs in a 40 MHz HE PPDU) and Table 26-10 (Subcarrier indices for RUs in an 80 MHz HE PPDU) and illustrated in Figure 26-15 (RU locations in a 20 MHz HE PPDU), Figure 26-16 (RU locations in a 40 MHz HE PPDU) and Figure 26-17 (RU locations in an 80 MHz HE PPDU) for the 20 MHz, 40 MHz and 80 MHz

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OFDMA HE PPDU formats, respectively. The same structure as used in the 80 MHz OFDMA HE PPDU formats is used for each 80 MHz frequency segment of the 160 MHz and 80+80 MHz OFDMA HE PPDU formats.

A 242-subcarrier RU consists of 234 data subcarriers and 8 pilot subcarriers. The position of pilots for the 242-subcarrier RU is defined in 26.3.7.3 (Pilot tones). The locations of the 242-subcarrier RUs are fixed as defined in Table 26-9 (Subcarrier indices for RUs in a 40 MHz HE PPDU) and Table 26-10 (Subcarrier indices for RUs in an 80 MHz HE PPDU) and illustrated in Figure 26-16 (RU locations in a 40 MHz HE PPDU) and Figure 26-17 (RU locations in an 80 MHz HE PPDU) for the 40 MHz, 80 MHz OFDMA HE PPDU formats, respectively. The same structure as used in the 80 MHz OFDMA HE PPDU formats is used for each 80 MHz frequency segment of the 160 MHz and 80+80 MHz OFDMA HE PPDU formats. A 20 MHz HE SU PPDU and MU-MIMO HE PPDU with a 242-subcarrier RU is shown in Figure 26-15 (RU locations in a 20 MHz HE PPDU).

A 484-subcarrier RU consists of 468 data subcarriers and 16 pilot subcarriers. The position of the pilots for the 484-subcarrier RU is defined in 26.3.7.3 (Pilot tones). The locations of the 484-subcarrier RUs are fixed as defined in Table 26-10 (Subcarrier indices for RUs in an 80 MHz HE PPDU) and illustrated in Figure 26-17 (RU locations in an 80 MHz HE PPDU) for the 80 MHz HE PPDU. The same structure as used for the 80 MHz OFDMA HE PPDU is used for each 80 MHz frequency segment of the 160 MHz and 80+80 MHz OFDMA HE PPDU. The 40 MHz HE SU PPDU and MU-MIMO HE PPDU with a 484-subcarrier RU is shown in Figure 26-16 (RU locations in a 40 MHz HE PPDU).

A 996-subcarrier RU consists of 980 data subcarriers and 16 pilot subcarriers. The position of the pilots for the 996-subcarrier RU is defined in 26.3.7.3 (Pilot tones). The locations of the 996-subcarrier RUs are fixed and located on subcarrier [−1012: −515, −509: −12] and [12: 509, 515: 1012] for each half of the BW, respectively, for 160/80+80 MHz HE OFDMA PPDUs.

The 20 MHz OFDMA HE PPDU has 7 DC subcarriers located at [−3:3]. The 20 MHz HE SU PPDU and 20 MHz MU-MIMO HE PPDU with a 242 subcarrier RU has 3 DC subcarriers located at [−1: 1]. The 40 MHz OFDMA HE PPDU, HE SU PPDU and a HE MU-MIMO PPDU with 484 subcarries have 5 DC subcarriers located at [−2: 2]. An 80 MHz HE OFDMA PPDU has 7 DC subcarriers located at [−3: 3]. The 80 MHz HE SU PPDU and 80 MHz HE MU-MIMO PPDU with 996 a subcarrier allocation have 5 DC subcarriers located at [−2: 2]. The same structure as used in the 80 MHz OFDMA HE PPDU is used for each 80 MHz frequency segment of the 160 MHz and 80+80 MHz OFDMA HE PPDU. The DC tones are located on subcarriers [−11: 11]. The same structure as used in the 80 MHz HE SU PPDU is used for each 80 MHz frequency segment of the 160 MHz and 80+80 MHz OFDMA HE PPDU.

The 20 MHz HE PPDU format has 11 guard subcarriers (6, 5) located at [−128: −123] and [123: 127] as shown in Figure 26-15 (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 26-16 (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 26-17 (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.

26.3.7.2 Null subcarriers

There are null subcarriers between the 26-, 52- and 106-subcarrier RU locations as illustrated in Figure 26-15 (RU locations in a 20 MHz HE PPDU), Figure 26-16 (RU locations in a 40 MHz HE PPDU) and

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Figure 26-17 (RU locations in an 80 MHz HE PPDU). The null subcarriers have zero energy. The indices of the null subcarrier are enumerated in Table 26-11 (Null subcarrier indices).

Table 26-11— 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

26.3.7.3 Pilot tones

If pilot tones are present in the HE-LTF field, the pilot tone locations in the HE-LTF field and Data field shall be the same. The pilot tone locations for 20 MHz, 40 MHz and 80 MHz bandwidth are as shown in Figure 26-18 (Pilot tone locations for 20 MHz), Figure 26-19 (Pilot tone locations for 40 MHz) and Figure 26-20 (Pilot tone locations for 80 MHz), respectively. All pilot tones are at the even indices enumerated in Table 26-12 (Pilot tone indices).

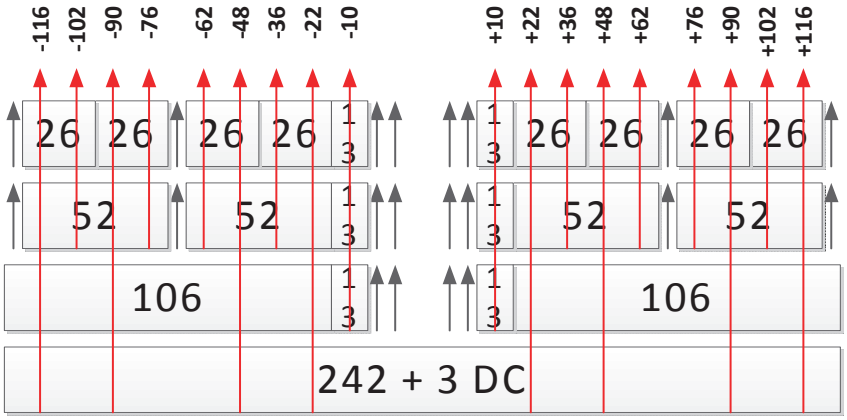


Figure 26-18—Pilot tone locations for 20 MHz

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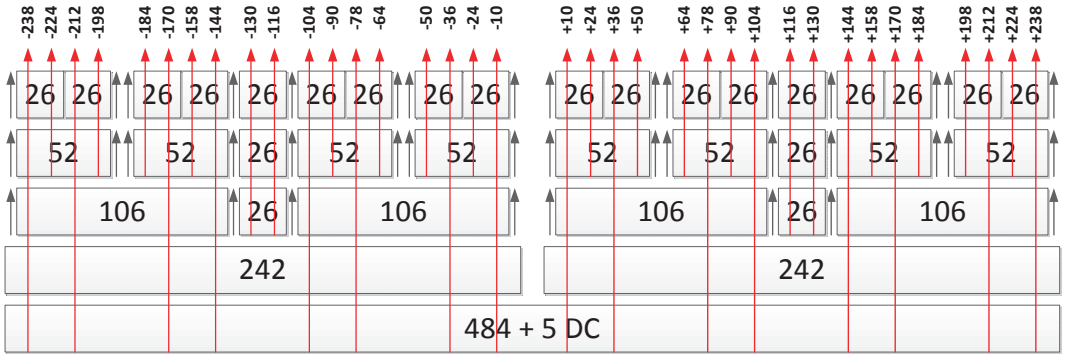


Figure 26-19—Pilot tone locations for 40 MHz

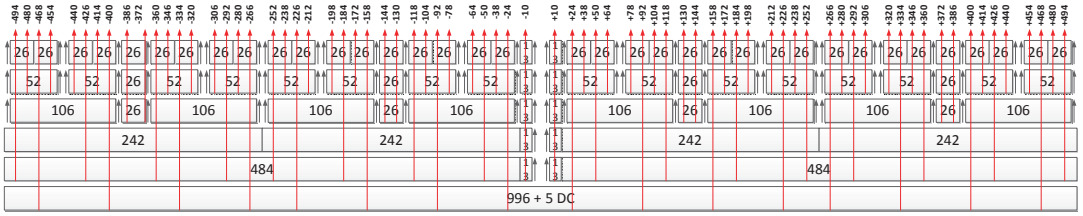


Figure 26-20—Pilot tone locations for 80 MHz

Table 26-12— Pilot tone indices

Channel Width	RU Size	Pilot Tone 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

The pilot tones locations for 160 MHz or 80+80 MHz shall use the same 80 MHz locations for both 80 MHz.

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26.3.8 Mathematical description of signals

For a description of the conventions used for the mathematical description of the signals, see 18.3.2.5 (Mathematical conventions in the signal descriptions). In addition, the following notational conventions are used in Clause 26:

$[Q]_{m,n}$ indicates the element in row m and column n of matrix, where $1 \le m \le N_{row}$, $1 \le n \le N_{col}$

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 HE Non-OFDMA 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 HE OFDMA 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 HE Non-OFDMA or OFDMA 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 HE Non-OFDMA 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 HE OFDMA 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 a 80 MHz HE PPDU transmission, depending on Non-OFDMA or OFDMA transmission within the correspond 80 MHz.

The transmitted signal is described in complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the relation shown in Equation 26-2.

$$r_{RF}^{(i_{Seg},i_{TX})}(t) = \mathrm{Re}\left\{ \frac{1}{\sqrt{N_{Seg}}} r_{PPDU}^{(i_{Seg},i_{TX})}(t) \exp\left(j2\pi f_c^{(i_{Seg})} t \right) \right\}, \quad i_{Seg} = 0,\ldots,N_{Seg}-1;\ i_{TX} = 1,\ldots,N_{TX} \tag{26-2}$$

where

N_{Seg} represents the number of frequency segments in the transmit signal, as defined in Table 26 3;

$r_{PPDU}^{(i_{Seg}, i_{TX})}$ represents the complex baseband signal of frequency segment i_{Seg} and transmit chain i_{TX};

$f_c^{(i_{Seg})}$ represents the center frequency of the portion of the PPDU transmitted in 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 26-21 (Timing boundaries for HE PPDU fields), where $N_{HE\text{-}LTF}$ is the number of HE-LTF symbols and is defined in Table 26-6

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(Frequently used parameters), $N_{HE\text{-}SIG\text{-}B}$ is the number of symbols in the HE-SIG-B field, and N_{SYM} is the number of symbols in the Data field.

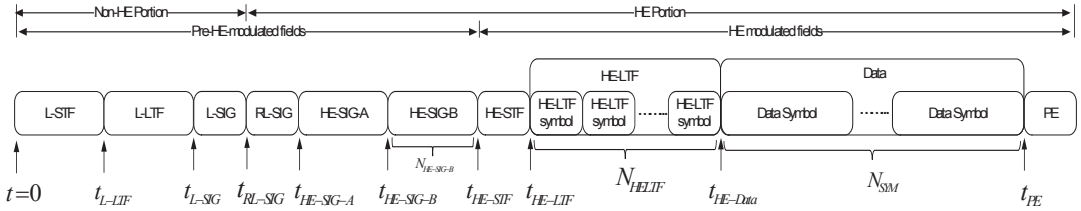


Figure 26-21—Timing boundaries for HE PPDU fields

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 (26 3).

$$\begin{aligned} r_{\text{PPDU}}^{(i_{Seg},i_{\text{TX}})}(t) = {} & r_{\text{L-STF}}^{(i_{Seg},i_{\text{TX}})}(t) + r_{\text{L-LTF}}^{(i_{Seg},i_{\text{TX}})}(t - t_{\text{L-LTF}}) \\ & + r_{\text{L-SIG}}^{(i_{Seg},i_{\text{TX}})}(t - t_{\text{L-SIG}}) + r_{\text{RL-SIG}}^{(i_{Seg},i_{\text{TX}})}(t - t_{\text{RL-SIG}}) \\ & + r_{\text{HE-SIG-A}}^{(i_{Seg},i_{\text{TX}})}(t - t_{\text{HE-SIG-A}}) + r_{\text{HE-SIG-B}}^{(i_{Seg},i_{\text{TX}})}(t - t_{\text{HE-SIG-B}}) \\ & + r_{\text{HE-STF}}^{(i_{Seg},i_{\text{TX}})}(t - t_{\text{HE-STF}}) + r_{\text{HE-LTF}}^{(i_{Seg},i_{\text{TX}})}(t - t_{\text{HE-LTF}}) \\ & + r_{\text{HE-Data}}^{(i_{Seg},i_{\text{TX}})}(t - t_{\text{HE-Data}}) + r_{\text{HE-PE}}^{(i_{Seg},i_{\text{TX}})}(t - t_{\text{HE-PE}}) \end{aligned} \tag{26-3}$$

where

$0 \le i_{Seg} \le N_{Seg} - 1$

$1 \le i_{TX} \le N_{TX}$

$t_{\text{L-LTF}} = T_{\text{L-STF}}$

$t_{\text{L-SIG}} = t_{\text{L-LTF}} + T_{\text{L-LTF}}$

$t_{\text{RL-SIG}} = t_{\text{L-SIG}} + T_{\text{L-SIG}}$

$t_{\text{HE-SIG-A}} = t_{\text{RL-SIG}} + T_{\text{RL-SIG}}$

$$t_{\text{HE-SIG-B}} = \begin{cases} t_{\text{HE-SIG-A}} + T_{\text{HE-SIG-A}}, & \text{for an HE MU PPDU} \\ undefined, & \text{otherwise} \end{cases}$$

$$t_{\text{HE-STF}} = \begin{cases} t_{\text{HE-SIG-A}} + T_{\text{HE-SIG-A}}, & \text{for an HE SU PPDU and HE trigger-based PPDU} \\ t_{\text{HE-SIG-A}} + T_{\text{HE-SIG-A-R}}, & \text{for an HE extended range SU PPDU} \\ t_{\text{HE-SIG-B}} + N_{\text{HE-SIG-B}} T_{\text{HE-SIG-B}}, & \text{for an HE MU PPDU} \end{cases}$$

where $N_{HE\text{-}SIG\text{-}B}$ is the number of OFDM symbols in the HE-SIG-B field

$$t_{\text{HE-LTF}} = \begin{cases} t_{\text{HE-STF}} + T_{\text{HE-STF-T}}, & \text{for an HE trigger-based PPDU} \\ t_{\text{HE-STF}} + T_{\text{HE-STF-NT}}, & \text{otherwise} \end{cases}$$

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$$t_{\text{HE-Data}} = \begin{cases} t_{\text{HE-LTF}} + N_{HELTF} \cdot (T_{\text{HE-LTF-1X}} + T_{\text{GI,HE-LTF}}), & \text{for 1x HE-LTF} \\ t_{\text{HE-LTF}} + N_{HELTF} \cdot (T_{\text{HE-LTF-2X}} + T_{\text{GI,HE-LTF}}), & \text{for 2x HE-LTF} \\ t_{\text{HE-LTF}} + N_{HELTF} \cdot (T_{\text{HE-LTF-4X}} + T_{\text{GI,HE-LTF}}), & \text{for 4x HE-LTF} \end{cases}$$

$$t_{PE} = t_{\text{HE-Data}} + N_{SYM} T_{SYM}$$

In an HE SU PPDU, HE MU PPDU and HE extended range SU PPDU, each field, $r_{Field}^{(i_{Seg}, i_{TX})}(t)$, is defined as the summation of one or more subfields, where each subfield is defined to be an inverse discrete Fourier transform as specified in EquationEquation 26-4.

$$r_{\text{Field}}^{(i_{Seg}, i_{\text{TX}})}(t) = \eta_{\text{Field}} w_{T_{\text{Field}}}(t) \sum_{r=0}^{N_{RU}-1} \frac{\alpha_r \beta_r}{\sqrt{N_{Norm,r}}} \sum_{k \in K_r} \sum_{u=0}^{N_{user,r}-1} \sum_{m=1}^{N_{STS,r,u}} \left[Q_k^{(i_{Seg})} \right]_{i_{TX},(M_{r,u}+m)} \Upsilon_{k,\text{BW}} X_{k,r,u}^{(i_{Seg},m)} \exp\left(j2\pi k \Delta_{F,\text{Field}} (t - T_{GI,Field} - T_{CS,HE}(M_{r,u}+m)) \right) \quad (26\text{-}4)$$

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 26-5.

$$r_{\text{Field}}^{(i_{Seg}, i_{\text{TX}})}(t) = \frac{\eta_{\text{Field}} \alpha_r \beta_r}{\sqrt{N_{Norm,r}}} w_{T_{\text{Field}}}(t) \sum_{k \in K_r} \sum_{m=1}^{N_{STS,r,u}} \left[Q_k^{(i_{Seg})} \right]_{i_{TX},(M_{r,u}+m)} \Upsilon_{k,\text{BW}} X_{k,r,u}^{(i_{Seg},m)} \exp\left(j2\pi k \Delta_{F,\text{Field}} (t - T_{GI,Field} - T_{CS,HE}(M_{r,u}+m)) \right) \quad (26\text{-}5)$$

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 26-21 (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 26-4 the following notions are used:

N_{Field}^{Tone} Table 26-13 (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 26-13—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	-

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Table 26-13—Tone scaling factor and guard interval duration values for HE PPDU fields

L-LTF	52	104	208	416	$T_{GI2,Data}$
L-SIG	56	112	224	448	$T_{GI,LegacyPreamble}$
RL-SIG	56	112	224	448	$T_{GI,LegacyPreamble}$
HE-SIG-A	56	112	224	448	$T_{GI,LegacyPreamble}$
HE-SIG-B	56	112	224	448	$T_{GI,LegacyPreamble}$
HE-STF not in HE_TRIG	14	30	62	126	-
HE-STF in HE_TRIG	30	60	124	248	-
HE-LTF 1x Duration	60	122	250	500	$T_{GI,HE\text{-}LTF1}$
HE-LTF 2x Duration	122	242	498	996	$T_{GI,HE\text{-}LTF2}$
HE-LTF 4x Duration	242	484	996	1992	$T_{GI,HE\text{-}LTF4}$
HE-Data	242	484	996	1992	$T_{GI,Data}$, $T_{GI2,Data}$ or $T_{GI4,Data}$
NON_HT_DUP_OFDM-Data	56	112	224	448	$T_{GI,LegacyPreamble}$

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.

$N_{Norm,r}$ 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 26-6 (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, Kr is the set of subcarriers indices from $-N_{SR}$ to N_{SR}. For HE modulated fields in a non-OFDMA HE PPDU, Kr is the set of subcarriers indices from $-N_{SR}$ to N_{SR}. 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.

η_{Field} is the power boost factor per OFDM symbol, which is $\sqrt{2}$ for the L-STF and L-LTF fields in the HE extended range SU PPDU, and 1 otherwise.

α_r is the power boost factor for the *r*-th RU, where $\alpha_r \in [TBD_1, TBD_2]$

β_r is the per-RU power normalization factor and is defined in Equation 26-6

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$$\beta_r = \begin{cases} \dfrac{1}{\sqrt{N_{Field}^{Tone}}}, & \text{Pre-HE modulated fields when BEAM\_CHANGE = 1} \\ \left(\sqrt{\dfrac{|K_r|}{|K_r^{Field}|}}\right) \Big/ \left(\sqrt{\sum_{r=1}^{N_{RU}} \alpha_r^2 |K_r|}\right), & \text{otherwise} \end{cases} \quad (26\text{-}6)$$

$|K_r|$ is the cardinality of the set of subcarriers K_r

K_r^{Field} is the set of subcarriers that have non-zero values within K_r in the HE-STF and Data fields, and defined in Equation 26-7 for the HE-LTF field.

$$K_r^{HELTF} = \begin{cases} |K_r|/4, & \text{for 1x HE-LTF} \\ |K_r|/2, & \text{for 2x HE-LTF} \\ |K_r|, & \text{for 4x HE-LTF} \end{cases} \quad (26\text{-}7)$$

$Q_k^{(i_{Seg})}$ 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 $N_{STS,total}$ 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 $\exp(-j2\pi k\Delta_{F,Pre-HE}T_{CS}^{i_{TX}})$, where $T_{CS}^{i_{TX}}$ represents the cyclic shift for the transmitter chain whose values are TBD; otherwise it is identical to the spatial mapping $Q_k^{(i_{Seg})}$ for HE modulation fields.

$\Delta_{F,Field}$ is the subcarrier frequency spacing. For pre-HE modulated fields, $\Delta_{F,Field} = \Delta_{F,Pre-HE}$ given in Table 26 3. For HE modulated fields, $\Delta_{F,Field} = \Delta_{F,HE}$ given in Table 26-3 (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 leftover tones 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_{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_{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 25-2 (Tone scaling factor and guard interval duration values for PHY fields).

$T_{CS,HE}(l)$ For pre-HE modulated fields, $T_{CS,HE}(l) = 0$. For HE modulated fields, $T_{CS,HE}(l)$ represents the cyclic shift per space-time stream, whose value is defined in Table 25-xx (Cyclic shift values for the HE modulated fields of a PPDU).

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$\Upsilon_{k,BW}$ is used to represent a rotation of the tones. In HE modulated fields, in all the subcarriers. In pre-HE modulated fields, BW in $\Upsilon_{k,BW}$ is determined by the TXVECTOR parameter CH_BANDWIDTH as defined in Table 26 14.

Table 26-14—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

For a 20 MHz PPDU transmission,

$$\Upsilon_{k,20} = 1 \quad (26\text{-}8)$$

For a 40 MHz PPDU transmission,

$$\Upsilon_{k,40} = TBD \quad (26\text{-}9)$$

For an 80 MHz PPDU transmission,

$$\Upsilon_{k,80} = TBD \quad (26\text{-}10)$$

For a noncontiguous 80+80 MHz PPDU transmission, each 80 MHz frequency segment shall use the phase rotation for 80 MHz PPDU transmissions as defined in Equation 26-10.

For a contiguous 160 MHz PPDU transmission,

$$\Upsilon_{k,160} = TBD \quad (26\text{-}11)$$

26.3.9 HE preamble

26.3.9.1 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 and HE-LTF fields. The pre-HE modulated fields depend on the structure of the PPDU and consist of 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

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— RL-SIG and HE-SIG-A fields of an HE trigger-based PPDU

26.3.9.2 Cyclic shift for pre-HE modulated fields

26.3.9.3 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 26-12. The equation applies to all contiguous signals up to 160 MHz and non contiguous 80+80 MHz.

$$r_{\text{L-STF}}^{(i_{seg},i_{TX})}(t) = \frac{\eta}{\sqrt{N_{\text{TX}} \cdot N_{\text{L-STF}}^{\text{Tone}}}} w_{\text{T}_{\text{L-STF}}}(t) \sum_{i_{BW}=0}^{N_{20MHz}-1} \sum_{k=-26}^{26} \left(\begin{array}{l} \Upsilon_{(k-K_{\text{Shift}}(i_{BW})),\text{BW}} S_{k,20} \\ \cdot \exp\left(j2\pi \left(k - K_{\text{Shift}}\left(i_{\text{BW}}\right)\right) \Delta_{F,\text{Pre-HE}} \left(t - T_{GI,\text{LegacyPreamble}} - T_{CS}^{i_{TX}} \right) \right) \end{array} \right) \quad (26\text{-}12)$$

where

η is an PPDU format dependent scaling factor, with the following value

$$\eta = \begin{cases} \sqrt{2}, & \text{HEextended range SU PPDU} \\ 1, & \text{otherwise} \end{cases} \quad (26\text{-}13)$$

N_{20MHz} is defined in 22.3.8.3.4 (L-SIG definition)

$K_{Shift}(i) = (N_{20MHz} - 1 - 2i) \cdot 32$

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmitter chain i_{TX} with a value given in 26.3.9.2 (Cyclic shift for Pre-HE modulated fields).

$\Upsilon_{k,\,BW}$ is defined by Equation (22-14), Equation (22-15), Equation (22-16) and Equation (22-17).

$N_{\text{L-STF}}^{\text{Tone}}$ has the value given in Table 22-8 (Tone scaling factor and guard interval duration values for PHY fields(11ac)).

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 26-14. The equation applies to all contiguous signals up to 160 MHz and non contiguous 80+80 MHz.

$$r_{\text{L-STF}}^{(i_{seg},i_{TX})}(t) = \frac{\eta}{\sqrt{N_{\text{TX}} \cdot N_{\text{L-STF}}^{\text{Tone}}}} w_{\text{T}_{\text{L-STF}}}(t) \sum_{i_{BW}=0}^{N_{20MHz}-1} \sum_{k=-26}^{26} \sum_{m=0}^{N_{STS,total}-1} \left(\begin{array}{l} \Upsilon_{(k-K_{\text{Shift}}(i_{BW})),\text{BW}} \left[Q_{4(k-K_{\text{Shift}}(i_{BW}))}^{(i_{seg})} \right]_{i_{TX},m} \left[A_{HELTF}^{4(k-K_{\text{Shift}}(i_{BW}))} \right]_{m,1} S_{k,20} \\ \cdot \exp\left(j2\pi \left(k - K_{\text{Shift}}\left(i_{\text{BW}}\right)\right) \Delta_{F,\text{Pre-HE}} \left(t - T_{GI,\text{LegacyPreamble}} - T_{CS}^{i_{TX}} \right) \right) \end{array} \right) \quad (26\text{-}14)$$

where

$T_{CS,\,HE}(n)$ is given in 26.3.9.2 (Cyclic shift for Pre-HE modulated fields)

$Q_k^{(i_{Seg})}$ is defined in <reference>

A_{HELTF}^{k} is defined in Equation (26-57)

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26.3.9.4 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 26-15. The equation applies to all contiguous signals up to 160 MHz and non contiguous 80+80 MHz.

$$r_{\text{L-LTF}}^{(i_{seg},i_{TX})}(t)=\frac{\eta}{\sqrt{N_{\text{TX}}\cdot N_{\text{L-LTF}}^{\text{Tone}}}}w_{\text{T}_{\text{L-LTF}}}(t)\sum_{i_{BW}=0}^{N_{20MHz}-1}\sum_{k=-26}^{26}\left(\begin{array}{l}\Upsilon_{(k-K_{\text{Shift}}(i_{BW})),\text{BW}}L_{k,20}\\ \cdot\exp\left(j2\pi\left(k-K_{\text{Shift}}\left(i_{\text{BW}}\right)\right)\Delta_{F,\text{Pre-HE}}\left(t-T_{GI,\text{LegacyPreamble}}-T_{CS}^{i_{TX}}\right)\right)\end{array}\right) \quad (26\text{-}15)$$

η is an PPDU format dependent scaling factor, as defined in Equation (26 13).

N_{20MHz} is defined in 21.3.7.3 (Channel frequencies)

$K_{Shift}(i) = (N_{20MHz} - 1 - 2i) \cdot 32$

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmitter chain i_{TX} with a value given in 26.3.9.2 (Cyclic shift for Pre-HE modulated fields).

$\Upsilon_{k,\,BW}$ is defined by Equation (22-14), Equation (22-15), Equation (22-16) and Equation (22-17).

$N_{\text{L-LTF}}^{\text{Tone}}$ has the value given in Table 22-8 (Tone scaling factor and guard interval duration values for PHY ields(11ac)).

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 (26 16). The equation applies to all contiguous signals up to 160 MHz and non contiguous 80+80 MHz.

$$r_{\text{L-LTF}}^{(i_{seg},i_{TX})}(t)=\frac{\eta}{\sqrt{N_{\text{TX}}\cdot N_{\text{L-LTF}}^{\text{Tone}}}}w_{\text{T}_{\text{L-LTF}}}(t)$$
$$\sum_{i_{BW}=0}^{N_{20MHz}-1}\sum_{k=-26}^{26}\sum_{m=0}^{N_{STS,total}-1}\left(\begin{array}{l}\Upsilon_{(k-K_{\text{Shift}}(i_{BW})),\text{BW}}\left[Q_{4(k-K_{\text{Shift}}(i_{BW}))}^{(i_{seg})}\right]_{i_{TX},m}\left[A_{HELTF}^{4(k-K_{\text{Shift}}(i_{BW}))}\right]_{m,1}L_{k,20}\\ \cdot\exp\left(j2\pi\left(k-K_{\text{Shift}}\left(i_{\text{BW}}\right)\right)\Delta_{F,\text{Pre-HE}}\left(t-T_{GI,\text{LegacyPreamble}}-T_{CS}^{i_{TX}}\right)\right)\end{array}\right) \quad (26\text{-}16)$$

where

$T_{CS,\,HE}(n)$ is given in 26.3.9.2 (Cyclic shift for Pre-HE modulated fields)

$Q_k^{(i_{Seg})}$ is defined in <reference>

A_{HELTF}^{k} is defined in Equation (26-57)

26.3.9.5 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 18-5 (SIGNAL field bit assignment).

In a HE PPDU, the RATE field shall be set to the value representing 6 Mb/s in the 20 MHz channel spacing column of Table 18-6 (Contents of the SIGNAL field). In a non-HT duplicate PPDU, the RATE field is defined in 18.3.4.2 (RATE field) using the L_DATARATE parameter in the TXVECTOR.

The LENGTH field shall be set to the value given by Equation 26-17.

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$$\text{Length} = \frac{\text{TXTIME} - 20}{4} \times 3 - 3 - m \quad (26\text{-}17)$$

where

TXTIME (in μs) is defined in 26.4.3 (TXTIME and PSDU_LENGTH calculation).

m is 1 for an HE MU PPDU and HE extended range SU PPDU, and 2 otherwise.

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 18.3.4.3 (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 18.3.5.6 (Convolutional encoder), 18.3.5.7 (Data interleaving), and 18.3.5.8 (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 18.3.5.9 (Pilot subcarriers). Extra 4 BPSK modulated tones are added, two at each edge of the subcarriers used by data and pilot tones. 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 26-18.

$$r_{\text{L-SIG}}^{(i_{Seg}, i_{TX})}(t) = \frac{1}{\sqrt{N_{L-SIG}^{\text{Tone}} N_{TX}}} w_{T_{L-SIG}}(t) \cdot \sum_{i_{BW}=0}^{N_{20MHz}-1} \sum_{k=-28}^{28} \left(\begin{array}{l} \Upsilon_{(k-K_{\text{Shift}}(i_{BW})),\text{BW}} \left(D_{k,20} + p_0 P_k \right) \\ \cdot \exp\left(j2\pi \left(k - K_{\text{Shift}}\left(i_{\text{BW}} \right) \right) \Delta_{F,\text{Pre-HE}} \left(t - T_{GI,\text{LegacyPreamble}} - T_{CS}^{i_{TX}} \right) \right) \end{array} \right) \quad (26\text{-}18)$$

where

N_{20MHz} is defined in 21.3.7.3 (Channel frequencies)

$K_{Shift}(i) = (N_{20MHz} - 1 - 2i) \cdot 32$

$$D_{k,20} = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ \pm 1(\text{TBD}), k = \pm 27, \pm 28 \\ d_{M_{20}^r(k)}, \text{otherwise} \end{cases}$$

$$M_{20}^r(k) = \begin{cases} k + 26, -26 \le k \le -22 \\ k + 25, -20 \le k \le -8 \\ k + 24, -6 \le k \le -1 \\ k + 23, 1 \le k \le 6 \\ k + 22, 8 \le k \le 20 \\ k + 21, 22 \le k \le 26 \end{cases}$$

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P_k is defined in 18.3.5.10 (OFDM modulation)

P_0 is the first pilot value in the sequence defined in 18.3.5.10 (OFDM modulation)

$N_{\text{L-SIG}}^{\text{Tone}}$ has the value given in <reference>

$\Upsilon_{k,\,BW}$ is defined by Equation 26-8, Equation 26-9, Equation 26-10 and Equation 26-11.

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmitter chain i_{TX} with a value given in 26.3.9.2 (Cyclic shift for pre-HE modulated fields).

NOTE—$M_{20}^{r}(k)$ is a "reverse" function of the function $M(k)$ defined in 18.3.5.10 (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 26-19.

$$r_{L-SIG}^{(i_{seg},i_{TX})}(t)=\frac{1}{\sqrt{N_{\text{L-SIG}}^{\text{Tone}}N_{STS,total}}}w_{T_{L-SIG}}(t)\cdot\sum_{i_{BW}=0}^{N_{20MHz}-1}\sum_{k=-28}^{28}\sum_{m=0}^{N_{STS,total}-1}\left(\begin{array}{l}\left[Q_{4(k-K_{\text{Shift}}(i_{BW}))}^{(i_{seg})}\right]_{i_{TX},m}\left[A_{HELTF}^{4(k-K_{\text{Shift}}(i_{BW}))}\right]_{m,1}\left(D_{k,20}+p_0P_k\right)\\ \cdot\exp\left(j2\pi\left(k-K_{\text{Shift}}\left(i_{BW}\right)\right)\Delta_{F,\text{Pre-HE}}\left(t-T_{GI,\text{LegacyPreamble}}-T_{CS,HE}(m)\right)\right)\end{array}\right) \quad (26\text{-}19)$$

where

$T_{CS,\,HE}(n)$ is given in 26.3.9.2 (Cyclic shift for pre-HE modulated fields)

$Q_k^{(i_{Seg})}$ is defined in <reference>

A_{HELTF}^{k} is defined in Equation 26-57

26.3.9.6 RL-SIG

The RL-SIG field is used to identify a HE PPDU.

The time domain waveform of the RL-SIG field is generated by repeating the time domain waveform of the L-SIG field, as defined in Equation 26-20.

$$r_{RL-SIG}^{(i_{Seg},i_{TX})}(t)=r_{L-SIG}^{(i_{Seg},i_{TX})}(t) \quad (26\text{-}20)$$

26.3.9.7 HE-SIG-A

26.3.9.7.1 General

The HE-SIG-A field carries information required to interpret HE PPDUs. The structure of the HE-SIG-A field for the first part (HE-SIG-A1) and for the second part (HE-SIG-A2) is TBD.

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26.3.9.7.2 Content

The HE-SIG-A field for an HE SU PPDU or an HE extended range SU PPDU contains the fields listed in Table 26-15 (Fields in the HE-SIG-A for an HE SU PPDU and HE extended range SU PPDU).

Table 26-15—Fields in the HE-SIG-A for an HE SU PPDU and HE extended range SU PPDU

Two Parts of HE-SIG-A	Bit	Field	Number of bits	Description
	TBD	UL/DL	1	Indicates whether the PPDU is sent UL or DL. This field indicates DL for TDLS. NOTE—The TDLS peer can identify the TDLS frame by To DS and From DS fields in the MAC header of the MPDU.
	TBD	Format	1	Differentiate between an HE SU PPDU and an HE trigger-based PPDU or between an HE extended range SU PPDU and an HE trigger-based PPDU
	TBD	BSS Color	6	The BSS Color field is an identifier of the BSS
	TBD	Spatial Reuse	TBD	TBD
	TBD	TXOP Duration	TBD	Indicates the remaining time in the current TXOP. Details TBD
	TBD	Bandwidth	2	Set to 0 for 20 MHz, 1 for 40 MHz, 2 for 80 MHz, 3 for 160 MHz and 80+80 MHz
	TBD	MCS	4	HE-MCS index
	TBD	CP+LTF Size	3	To indicate the CP length and HE-LTF size, the current combinations are 1x HE-LTF + 0.8 μs, 2x HE-LTF + 0.8 μs, 2x HE-LTF + 1.6 μs and 4x HE-LTF + 3.2 μs. Other combinations are TBD.
	TBD	Coding	2	Indication of BCC/LDPC and presence of the extra OFDM symbol for LDPC. Detailed indication is TBD.
	TBD	Nsts	3	Indicates the number of spatial streams: Set to 0 for 1 space time stream Set to 1 for 2 space time streams Set to 2 for 3 space time streams Set to 3 for 4 space time streams Set to 4 for 5 space time streams Set to 5 for 6 space time streams Set to 6 for 7 space time streams Set to 7 for 8 space time streams
	TBD	STBC	1	Set to 1 if space time block coding is used and set to 0 otherwise.
	TBD	TxBF	1	Set to 1 if a Beamforming steering matrix is applied to the waveform in an SU transmission, set to 0 otherwise

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Table 26-15—Fields in the HE-SIG-A for an HE SU PPDU and HE extended range SU PPDU

	TBD	DCM	1	Set to 1 indicates that the payload of the SU PPDU is modulated with dual sub-carrier modulation for the MCS. Set to 0 indicates that the payload of the PPDU is not modulated with dual sub-carrier modulation for the MCS.
	TBD	Packet Extension	3	The first two bits indicate the "a-factor" and the third bit indicates the PE-Disambiguity.
	TBD	Beam Change	1	Set to 1 indicates that the pre-HE-STF portion of the SU PPDU is spatially mapped differently from HE-LTF1. Set to 0 indicates that the pre-HE-STF portion of the SU PPDU is spatially mapped the same way as HE-LTF1 on each tone.
	TBD	CRC	4	CRC of bits 0-41 in HT-SIG-A. See 22.3.9.7.1 (CRC calculation for HE-SIG-A). The first bit to be transmitted is bit C3 as explained in 20.3.9.7.1 (CRC calculation for HE-SIG).
	TBD	Tail	6	Used to terminate the trellis of the convolutional decoder. Set to 0.

NOTE—The HE-SIG-A field contents for the HE extended range SU PPDU may be subject to change.

The HE-SIG-A field of an HE MU PPDU contains the fields listed in Table 26-16 (Fields in the HE-SIG-A for an HE MU PPDU).

Table 26-16—Fields in the HE-SIG-A for an HE MU PPDU

Two Parts of HE-SIG-A	Bit	Field	Number of bits	Description
	TBD	UL/DL	1	Indicates whether the PPDU is sent UL or DL. This field indicates DL for TDLS. NOTE—The TDLS peer can identify the TDLS frame by To DS and From DS fields in the MAC header of the MPDU.
	TBD	BSS Color	6	The BSS Color field is an identifier of the BSS
	TBD	Spatial Reuse	TBD	TBD
	TBD	TXOP Duration	TBD	Indicates the remaining time in the current TXOP. Details TBD
	TBD	Bandwidth	>= 2	Set to 0 for 20 MHz, 1 for 40 MHz, 2 for 80 MHz, 3 for 160 MHz and 80+80 MHz

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Table 26-16—Fields in the HE-SIG-A for an HE MU PPDU *(continued)*

	TBD	SIGB MCS	3	Indication the MCS of HE-SIG-B. Set to 0 for MCS0 Set to 1 for MCS1 Set to 2 for MCS2 Set to 3 for MCS3 Set to 4 for MCS4 Set to 5 for MCS5
	TBD	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.
	TBD	SIGB Number Of Symbols	4	Indciates the number of HE-SIG-B symbols.
	TBD	SIGB Compression	1	Set to 1 for full BW MU-MIMO. Set to 0 otherwise.
	TBD	Number of HE-LTF Symbols	3	Indicates the number of HE-LTF symbols.
	TBD	CP+LTF Size	3	To indicate the CP length and HE-LTF size, the current combinations are 1x HE-LTF + 0.8 μs, 2x HE-LTF + 0.8 μs, 2x HE-LTF + 1.6 μs and 4x HE-LTF + 3.2 μS. Other combinations are TBD.
	TBD	LPDC Extra Symbol	1	Indication of the presence of the extra OFDM symbol for LDPC.
	TBD	Packet Extension	3	The first two bits indicate the "a-factor" and the third bit indicates the PE-Disambiguity.
	TBD	CRC	4	CRC of bits 0-41 in HT-SIG-A. See 22.3.9.7.1 (CRC calculation for HE-SIG-A). The first bit to be transmitted is bit C3 as explained in 20.3.9.7.1 (CRC calculation for HE-SIG).
	TBD	Tail	6	Used to terminate the trellis of the convolutional decoder. Set to 0.

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The HE-SIG-A field for an HE trigger-based PPDU contains the fields listed in Table 26-17 (Fields in the HE-SIG-A for an HE trigger-based PPDU).

Table 26-17—Fields in the HE-SIG-A for an HE trigger-based PPDU

Two Parts of HE-SIG-A	Bit	Field	Number of bits	Description
	TBD	Format	1	Set to 0 for an HE SU PPDU Set to 1 for an HE trigger-based PPDU
	TBD	BSS Color	6	The BSS Color field is an identifier of the BSS
	TBD	Spatial Reuse	TBD	TBD
	TBD	TXOP Duration	TBD	Indicates the remaining time in the current TXOP. Details TBD
	TBD	Bandwidth	TBD	TBD
	TBD	Reserved	TBD	TBD
	TBD	CRC	4	CRC of bits 0-41 in HT-SIG-A. See 22.3.9.7.1 (CRC calculation for HE-SIG-A). The first bit to be transmitted is bit C3 as explained in 20.3.9.7.1 (CRC calculation for HE-SIG).
	TBD	Tail	6	Used to terminate the trellis of the convolutional decoder. Set to 0.

26.3.9.7.3 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 protects bits 0 to L of the HE-SIG ($L = 41$ for HE-SIG-A, or $L = x$ for each HE-SIG-B common block fields, or $L = x$ for HE-SIG-B user specific fields). 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

$$I(D) = \sum_{i=L-7}^{L} D^i$$

$G(D)$ and $crc(D)$ are defined in Equation (20-18)

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The CRC field is transmitted from *c5* to *c7* with *c7* first.

Figure 20-8 (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*.

26.3.9.7.4 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 18.3.5.6 (Convolutional encoder), 18.3.5.7 (Data interleaving), 18.3.5.8 (Subcarrier modulation mapping), and 18.3.5.9 (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 26 22. 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 26-21.

$$r_{\text{HE-SIG-A}}^{(i_{Seg},i_{TX})}(t)=\frac{1}{\sqrt{N_{HE-SIG-A}^{\text{Tone}}N_{TX}}}\sum_{n=0}^{1}w_{T_{SYML}}\left(t-nT_{SYML}\right)\cdot\sum_{i_{BW}=0}^{N_{20MHz}-1}\sum_{k=-28}^{28}\left(\begin{array}{l}\Upsilon_{\left(k-K_{\text{Shift}}(i_{BW})\right),\text{BW}}\left(D_{k,n,BW}+p_{n+2}P_k\right)\\ \cdot\exp\left(j2\pi\left(k-K_{\text{Shift}}\left(i_{\text{BW}}\right)\right)\Delta_{F,\text{Pre-HE}}\left(t-nT_{SYML}-T_{GI,LEgacy\,\text{Preamble}}-T_{CS}^{i_{TX}}\right)\right)\end{array}\right) \quad (26\text{-}21)$$

N_{20MHz} is defined in 21.3.7.3 (Channel frequencies)

$K_{Shift}(i) = (N_{20MHz} - 1 - 2i) \cdot 32$

$$D_{k,n,20} = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ d_{M_{20}^r(k),n}, \text{otherwise} \end{cases}$$

$$M_{20}^r(k) = \begin{cases} k+28, -28 \le k \le -22 \\ k+25, -20 \le k \le -8 \\ k+24, -6 \le k \le -1 \\ k+23, 1 \le k \le 6 \\ k+22, 8 \le k \le 20 \\ k+21, 22 \le k \le 28 \end{cases}$$

P_k and p_n are defined in 18.3.5.10 (OFDM modulation).

$N_{HE-SIG-A}^{Tone}$ has the value given in Error! Reference source not found.

$\Upsilon_{k,BW}$ is defined by Equation 26-8, Equation 26-9, Equation 26-10 and Equation 26-11.

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmitter chain i_{TX} with a value given in 26.3.9.2 (Cyclic shift for Pre-HE modulated fields).

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If the TXVECTOR parameter BEAM_CHANGE is 0, the time domain waveform of the HE-SIG-A field shall be as given by Equation 26-22.

$$r_{HE-SIG-A}^{(i_{seg},i_{TX})}(t)=\frac{1}{\sqrt{N_{\text{HE-SIG-A}}^{\text{Tone}}N_{STS,total}}}\sum_{n=0}^{1}w_{T_{SYML}}(t-nT_{SYML})$$
$$\cdot\sum_{i_{BW}=0}^{N_{20MHz}-1}\sum_{k=-28}^{28}\sum_{m=0}^{N_{STS,total}-1}\left(\begin{array}{l}\left[Q_{4(k-K_{\text{Shift}}(i_{BW}))}^{(i_{seg})}\right]_{i_{TX},m}\left[A_{HELTF}^{4(k-K_{\text{Shift}}(i_{BW}))}\right]_{m,1}(D_{k,20}+p_{n+2}P_k)\\ \cdot\exp\left(j2\pi(k-K_{\text{Shift}}(i_{BW}))\Delta_{F,\text{Pre-HE}}(t-nT_{SYML}-T_{GI,\text{LegacyPreamble}}-T_{CS,HE}(m))\right)\end{array}\right) \quad (26\text{-}22)$$

where

$T_{CS,HE}(n)$ is given in 26.3.9.2 (Cyclic shift for pre-HE modulated fields)

$Q_k^{(i_{Seg})}$ is defined in <reference>

A_{HELTF}^{k} is defined in Equation 26-57

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 and have pilots inserted. The constellation mappings of the HE-SIG-A field in an HE extended range SU PPDU is shown in Figure 26-22 (Data tone constellation of HE-SIG-A symbols). QBPSK constellation on HE-SIG-A2 is used to differentiate between an HE extended range SU PPDU and an HE MU PPDU. HE-SIG-A4 shall be BCC encoded at rate, R=1/2, mapped to a BPSK constellation and have pilots inserted. BCC encoding, Data interleaving, constellation mapping and pilot insertion follow the steps described in 18.3.5.6 (Convolutional encoder), 18.3.5.7 (Data interleaving), 18.3.5.8 (Subcarrier modulation mapping), and 18.3.5.9 (Pilot subcarriers), respectively.

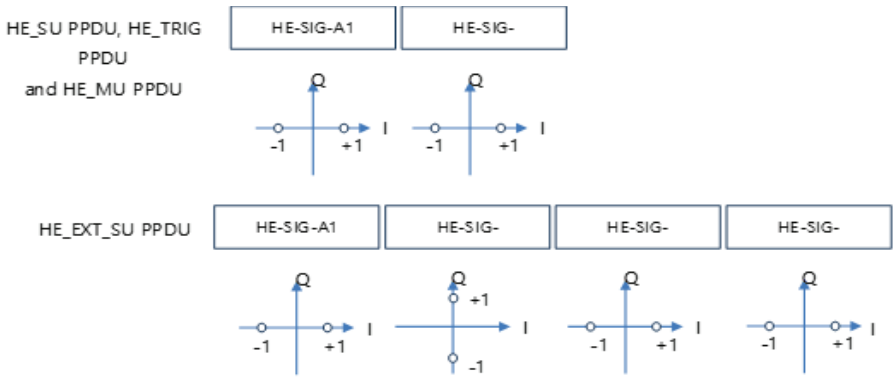


Figure 26-22—Data tone constellation of HE-SIG-A symbols

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 26-23.

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$$r_{\text{HE-SIG-A}}^{(i_{Seg},i_{TX})}(t)=\frac{1}{\sqrt{N_{HE-SIG-A}^{\text{Tone}}N_{TX}}}\sum_{n=0}^{3}w_{T_{SYML}}(t-nT_{SYML})$$
$$\cdot\sum_{i_{BW}=0}^{N_{20MHz}-1}\sum_{k=-28}^{28}\left(\begin{array}{l}\Upsilon_{(k-K_{\text{Shift}}(i_{BW})),\text{BW}}\left(R_nD_{k,n,BW}+p_{n+2}P_k\right)\\ \cdot\exp\left(j2\pi\left(k-K_{\text{Shift}}(i_{\text{BW}})\right)\Delta_{F,\text{Pre-HE}}\left(t-nT_{SYML}-T_{GI,LEgacy\,\text{Pr}eamble}-T_{CS}^{i_{TX}}\right)\right)\end{array}\right) \quad (26\text{-}23)$$

where

R 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 26-24.

$$r_{HE-SIG-A}^{(i_{seg},i_{TX})}(t)=\frac{1}{\sqrt{N_{\text{HE-SIG-A}}^{\text{Tone}}N_{STS,total}}}\sum_{n=0}^{3}w_{T_{SYML}}(t-nT_{SYML})$$
$$\cdot\sum_{i_{BW}=0}^{N_{20MHz}-1}\sum_{k=-28}^{28}\sum_{m=0}^{N_{STS,total}-1}\left(\begin{array}{l}\left[Q_{4(k-K_{\text{Shift}}(i_{BW}))}^{(i_{seg})}\right]_{i_{TX},m}\left[A_{HELTF}^{4(k-K_{\text{Shift}}(i_{BW}))}\right]_{m,1}\left(R_nD_{k,20}+p_{n+2}P_k\right)\\ \cdot\exp\left(j2\pi\left(k-K_{\text{Shift}}(i_{BW})\right)\Delta_{F,\text{Pre-HE}}\left(t-nT_{SYML}-T_{GI,\text{LegacyPreamble}}-T_{CS,HE}(m)\right)\right)\end{array}\right) \quad (26\text{-}24)$$

26.3.9.8 HE-SIG-B

26.3.9.8.1 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 26-23 (HE-SIG-B field encoding structure in each 20 MHz). It consists of a Common Block field followed by a User Specific field.

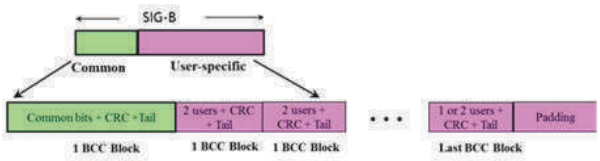


Figure 26-23—HE-SIG-B field encoding structure in each 20 MHz

The Common Block field contains information regarding the resource unit allocation such as the RU arrangement 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 26.3.9.8.4 (HE-SIG-B common content).

The User Specific field consists of multiple User Block fields. Each User Block field contains information for two STAs to decode their payloads. The last User Block field may contain information for only one STA, if the number of user fields indicated by the RU allocation signaling in the common block is odd. See 26.3.9.8.5 (HE-SIG-B per-user content) for a description of the contents of the User Block field.

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26.3.9.8.2 Frequency domain mapping

For 20 MHz and 40 MHz PPDUs, the Common Block field and the User field for a STA are transmitted in the same 20 MHz band as the STA's data as shown in Figure 26-24 (HE-SIG-B content channel for a 20 MHz PPDU) and Figure 26-25 (HE-SIG-B content channel for a 40 MHz PPDU).



Figure 26-24—HE-SIG-B content channel for a 20 MHz PPDU



Figure 26-25—HE-SIG-B content channel for a 40 MHz PPDU

For an 80 MHz PPDU, the default frequency mapping of the Common Block field and User Specific fields is shown in Figure 26-26 (Default mapping of the two HE-SIG-B channels and their duplication in an 80 MHz PPDU). The HE-SIG-B field content in the 1st and 3rd 20 MHz bands from the top are identical. The information carried in either of these bands is called HE-SIG-B content channel 1. HE-SIG-B content channel 1 carries signaling information for all STAs whose payloads occupy some tones in A242 or C242. Similarly, the HE-SIG-B contents on the 2nd and 4th 20 MHz bands are identical. The information carried in either of these bands is called HE-SIG-B content channel 2. HE-SIG-B content channel 2 carries signaling information for all STAs whose payloads occupy some tones in B242 or D242.



Figure 26-26—Default mapping of the two HE-SIG-B channels and their duplication in an 80 MHz PPDU

For a 160 MHz PPDU, the default frequency mapping of the Common Block field and User Specific fields is shown in Figure 26-27 (Default mapping of the two HE-SIG-B channels and their duplication in a 160 MHz PPDU). The HE-SIG-B content in the 1st, 3rd, 5th and 7th 20 MHz bands from top are all identical. The information carried in any of these bands is called HE-SIG-B content channel 1. HE-SIG-B content channel 1 carries signaling information for all STAs whose payloads occupy some tones in A1-242 or C1-242 or A2-242 or C2-242. Similarly, the HE-SIG-B contents in the 2nd, 4th, 6th and 8th 20 MHz bands from top are identical. The information carried in any of these bands is called HE-SIG-B content

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channel 2. HE-SIG-B content channel 2 carries signaling information for all STAs whose payloads occupy some tones in B1-242 or D1-242 or B2-242 or D2-242.

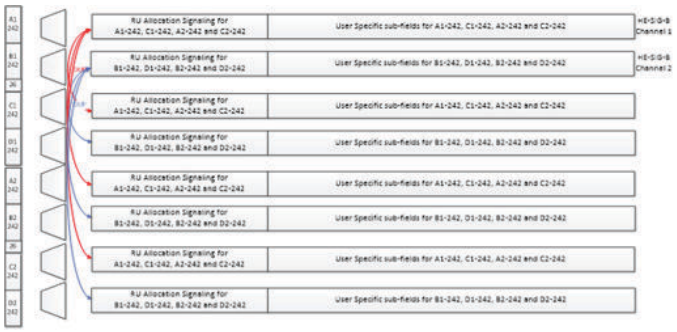


Figure 26-27—Default mapping of the two HE-SIG-B channels and their duplication in a 160 MHz PPDU

For MU-MIMO allocation of RU size > 20 MHz, the User Block subfields are dynamically split between the two HE-SIG-B content channels (1/2) and the split is decided by the AP (on a per case basis). See 25.3.9.2.5.2 and 25.3.9.2.5.3 for more details.

26.3.9.8.3 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. 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 and then BCC encoded at rate R = ½ using the encoder described in 18.3.5.6. If the number of users is even, padding bits are added to round up the number of symbols to the nearest integer. If the number of users is odd, the User Block field corresponding to the last user, who is not grouped, is encoded after adding tail and CRC bits and only then are any padding bits added. The padding bits added ensure that both content channels have the same number of symbols. The specific method of generating padding bits is TBD. When the code rate is not equal to ½, the convolutional encoder output bits for each field (including padding bits) are concatenated, then the concatenated bit streams are punctured continuously as described in 18.3.5.6 (Convolutional encoder).

The number of data tones in each symbol is N_{SD} = 52. The coded bits are interleaved as in 22.3.10.8, with the parameter N_{col} = 13 (as in Table 22-17, for 20 MHz). 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 18.3.5.7 (Data Interleaving), 18.3.5.8 (Subcarrier modulation mapping) and 18.3.5.9 (Pilot subcarriers) respectively.

The cyclic prefix used for HE-SIG-B shall be 0.8 μs. The number of symbols in HE-SIG-B, denoted by $N_{SYM,HE\text{-}SIG\text{-}B}$, shall be signaled in HE-SIG-A in the default mode (see Section 25.3.9.2.4). For the c-th content channel (c = 1 or 2), denote the sample on the k-th subcarrier of the n-th symbol by $d_{k,n,c}$. The time domain waveform for the HE-SIG-B follows Equation 26-25.

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$$r_{HE-SIG-B}^{(i_{Seg},i_{Tx})}(t)=\frac{1}{\sqrt{N_{HE-SIG-B}^{Tone}N_{Tx}}}\sum_{n=0}^{N_{sym,HE-SIG-B}}w_{T_{HE-SIG-B}}(t-nT_{SYML})\sum_{i_{BW}=0}^{N_{20MHz}-1}\sum_{k=-N_{SR}}^{N_{SR}}\Upsilon_{(k-K_{shift}(i_{BW})),BW}$$
$$\left(D^{i_{Seg}}{}_{k,n,i_{BW}}+p_{n+4}P_k\right)\exp\left(j2\pi(k-K_{shift}(i_{BW}))\Delta_{F,Pre-HE}(t-nT_{SYML}-T_{GI,LEgacy\,Preamble}-T_{CS}^{i_{TX}})\right) \quad (26\text{-}25)$$

where

N_{20MHz} and $K_{Shift}(i)$ are defined in 22.3.8.2.4 (L-SIG definition)

$$D_{k,n,i_{BW}}^{i_{Seg}}=\begin{cases}0,\ k=0,\pm7,\pm21\\ d_{M_{20}^r(k),n,(i_{BW}mod\,2)+1},\ \text{otherwise}\end{cases}$$

$$M_{20}^r(k)=\begin{cases}k+28,\ -28\le k\le -22\\ k+27,\ -20\le k\le -8\\ k+26,\ -6\le k\le -1\\ k+25,\ 1\le k\le 6\\ k+24,\ 8\le k\le 20\\ k+23,\ 22\le k\le 28\end{cases}$$

P_k and p_n are defined in 18.3.5.10 (OFDM modulation).

$\Upsilon_{k,BW}$ is defined by Equation 26-8, Equation 26-9, Equation 26-10 and Equation 26-11

$N_{sym,HE-SIG-B}$ his the number of symbols in HE-SIG-B

26.3.9.8.4 HE-SIG-B common content

The Common block field in the HE-SIG-B carries RU allocation subfields. Depending on the PPDU bandwidth, the Common block field can contain multiple RU allocation subfields.

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 arrangement in the frequency domain: indexes the size of the RUs and their placement in the frequency domain.

— Number of user fields in each RU in 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 arrangement and the number of user fields per RU is defined in the Table 26-18 (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 arrangement in the frequency domain but differ in the number of users fields per RU. The RU

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arrangement 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 unit in 80 MHz is [TBD].

Table 26-18—RU allocation signaling: Arrangement and number of MU-MIMO allocations

8 bits indices	#1	#2	#3	#4	#5	#6	#7	#8	#9	Number of entries
000 0 0000	26	26	26	26	26	26	26	26	26	1
000 0 0001	26	26	26	26	26	26	26	52		1
000 0 0010	26	26	26	26	26	52		26	26	1
000 0 0011	26	26	26	26	26	52		52		1
000 0 0100	26	26	52		26	26	26	26	26	1
000 0 0101	26	26	52		26	26	26	52		1
000 0 0110	26	26	52		26	52		26	26	1
000 0 0111	26	26	52		52	52		52		1
000 0 1000	52		26	26	26	26	26	26	26	1
000 0 1001	52		26	26	26	26	26	52		1
000 0 1010	52		26	26	26	52		26	26	1
000 0 1011	52		26	26	26	52		52		1
000 0 1100	52		52		26	26	26	26	26	1
000 0 1101	52		52		26	26	26	52		1
000 0 1110	52		52		26	52		26	26	1
000 0 1111	52		52		52	52		52		1
000 1 xxxx	Definition TBD									16
00100 yyy	26	26	26	26	26	106				8
00101 yyy	26	26	52		52	106				8
00110 yyy	52		26	26	26	106				8
00111 yyy	52		52		26	106				8
01000 yyy	106				26	26	26	26	26	8
01001 yyy	106				26	26	26	52		8
01010 yyy	106				26	52		26	26	8

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Table 26-18—RU allocation signaling: Arrangement and number of MU-MIMO allocations

01011 yyy	106	26	52	52	8
011 xxxxx	Definition TBD				32
10 yyy yyy	106	26	106		64
11 0 00yyy	242				8
11 0 01yyy	484				8
11 0 10yyy	996				8
11 0 11yyy	2×996				8
11 1 xxxx	Definition TBD				32

NOTE: yyy' = 000~111 indicates number of STAs multiplexed in an RU. Binary vector yyy 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.

The definition for entries with 'x' bits is TBD.

The number of RU allocation subfields in the HE-SIG-B common block field depends on the total PPDU bandwidth

— In the default mode, for 20 MHz and 40 MHz PPDU, each HE-SIG-B content channel contains one RU allocation subfield followed by multiple user fields. The position of the user-field in the user-specific field together with the 8-bit RU allocation subfield indicates the RU assignment to the user.

— In the default mode for the 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 user fields corresponding to the first RU allocation signaling field are followed by the user fields indicated by the second RU allocation signaling field in the user specific field.

In the default mode for the 160 MHz PPDU, each HE-SIG-B content channel contains four RU allocation signaling fields 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 user fields for each of the 20 MHz segments in the content channel are arranged by the order in which their RU allocation signaling fields appear in the common field.

26.3.9.8.5 HE-SIG-B per-user content

The user-specific field consists of multiple user fields. The user fields follow the common block field of HE-SIG-B. The RU allocation subfield in the Common block 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. 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 26-28 (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 arrangement 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

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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.

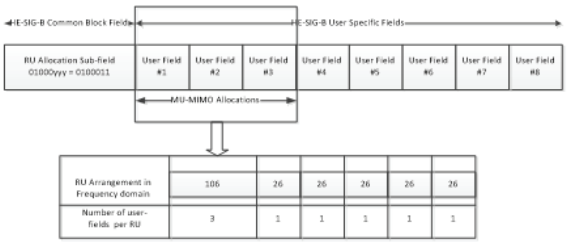


Figure 26-28—Illustration for the mapping of the 8-bit RU allocation subfield and the position of the user-field to the STA's assignment

The contents of the user field differ based on whether the field addresses a single-STA in an RU or a STA in a MU-MIMO allocation in an RU. Irrespective of whether the allocation is for a STA in a SU or an MU-MIMO allocation, the size of the user field is the same.

The HE-SIG-B user field for a SU allocation contain the subfields shown in Table 26-19 (Fields of the HE-SIG-B user field for a SU allocation).

Table 26-19—Fields of the HE-SIG-B user field for a SU allocation

Bit	Field	Number of bits	Description
TBD	STA-ID	11	The STA identifier that addresses a STA – reference to MAC section(?). 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 will have a special STAID value reserved.
TBD	NSTS	3	Number of spatial streams
TBD	Tx Beam-forming	1	Use of transmit beamforming
TBD	MCS	4	Modulation and Coding Scheme
TBD	DCM	1	Indication for use of dual carrier modulation
TBD	Coding	1	Indication for use of LDPC

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The HE-SIG-B user field for an STA in MU-MIMO allocation contain the subfields shown in Table 26-20 (Fields of the HE-SIG-B user field for a MU-MIMO allocation).

Table 26-20—Fields of the HE-SIG-B user field for a MU-MIMO allocation

Bit	Field	Number of bits	Description
TBD	STA-ID	11	The STA identifier that addresses an STA – reference to MAC section(?)
TBD	Spatial Configuration	4	Indication for the number of spatial streams for a STA in a MU-MIMO allocation. See Table 26-21 (Spatial Configuration subfield encoding).
TBD	MCS	4	Modulation and Coding Scheme
TBD	DCM	1	Use of dual carrier modulation
TBD	Coding	1	Use of LDPC

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 26-21 (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 ≤ 20 MHz, the number of users (Nuser) 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 20 MHz or greater, 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 Nuser, 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 > 20 MHz 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 user-field 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 26-21—Spatial Configuration subfield encoding

N_{user}	B0...B3	Nsts [1]	Nsts [2]	Nsts [3]	Nsts [4]	Nsts [5]	Nsts [6]	Nsts [7]	Nsts [8]	Total Nsts	Number of entries

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Table 26-21—Spatial Configuration subfield encoding *(continued)*

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	
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

26.3.9.9 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 THE-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 THE-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 26-26.

$$i_{STF} \bmod 16 = 0, \lfloor N_{DC}/2 \rfloor < |i_{STF}| \le N_{SR} \qquad \text{(26-26)}$$

i_{STF} : HE-STF tone index

The tone indices for HE-STF fields for an HE trigger-based PPDU are defined in Equation 26-27.

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$$i_{STF} \bmod 8 = 0, \lfloor N_{DC}/2 \rfloor < |i_{STF}| \le N_{SR}$$
$$i_{STF} : \text{HE-STF tone index} \quad (26\text{-}27)$$

For the HE-STF field, the *M* sequence is defined by Equation 26-28.

$$M = \{-1, -1, -1, 1, 1, 1, -1, 1, 1, 1, -1, 1, 1, -1, 1\} \quad (26\text{-}28)$$

The HE-STF field is constructed from the M sequence(s) by multiplying integer coefficient(s) to each 20 MHz subchannel and inserting appropriate coefficients into tone indices which are null after mapping M sequences.

For a 20 MHz transmission, the frequency domain sequence for HE PPDUs except HE trigger-based PPDUs is given by Equation 26-29.

$$HES_{-112:16:112} = \{M\} \cdot (1+j)/\sqrt{2}$$
$$HES_0 = 0 \quad (26\text{-}29)$$

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 26-30.

$$HES_{-240:16:240} = \{M, 0, -M\} \cdot (1+j)/\sqrt{2} \quad (26\text{-}30)$$

For an 80 MHz transmission, the frequency domain sequence for HE PPDUs except HE trigger-based PPDUs is given by Equation 26-31.

$$HES_{-496:16:496} = \{M, 1, -M, 0, -M, 1, -M\} \cdot (1+j)/\sqrt{2} \quad (26\text{-}31)$$

For a 20 MHz transmission, the frequency domain sequence for HE trigger-based PPDUs is given by Equation 26-32.

$$HES_{-120:8:120} = \{M, 0, -M\} \cdot (1+j)/\sqrt{2} \quad (26\text{-}32)$$

For a 40 MHz transmission, the frequency domain sequence for HE trigger-based PPDUs is given by Equation 26-33.

$$HES_{-248:8:248} = \{M, -1, -M, 0, M, -1, M\} \cdot (1+j)/\sqrt{2}$$
$$HES_{\pm 248} = 0 \quad (26\text{-}33)$$

For an 80 MHz transmission, the frequency domain sequence for HE trigger-based PPDUs is given by Equation 26-34.

$$HES_{-504:8:504} = \{M, -1, M, -1, -M, -1, M, 0, -M, 1, M, 1, -M, 1, -M\} \cdot (1+j)/\sqrt{2}$$
$$HES_{\pm 504} = 0 \quad (26\text{-}34)$$

For an OFDMA transmission, the coefficients in Equation (25-3) to (25-8) are set to zero if those values are corresponding to tone indices on which no RUs defined in 25.3.7.1 are assigned.

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The time domain representation of the signal for HE PPDUs except HE trigger-based PPDUs on frequency segment i_{Seg} of transmit chain i_{TX} shall be as specified in Equation 26-35.

$$r_{\text{HE-STF}}^{(i_{Seg},i_{TX})}(t) = w_{T_{\text{HE-STF-NT}}}(t)\cdot\eta_{EXT}\cdot\sum_{r=0}^{N_{RU}-1}\frac{\alpha_r\beta_r}{\sqrt{N_{STS,r,total}}} \cdot\sum_{k\in K_r}\sum_{u=0}^{N_{user,r}-1}\sum_{m=1}^{N_{STS,r,u}}\left(\begin{array}{l}\left[Q_k^{(i_{Seg})}\right]_{i_{TX},(M_{r,u}+m)} HES_k \\ \cdot\exp\left(j2\pi k\Delta_{F,\text{HE}}\left(t-T_{\text{CS,HE}}\left(M_{r,u}+m\right)\right)\right)\end{array}\right) \quad (26\text{-}35)$$

where

α_r is the power boost factor for the r-th RU, where $\alpha_r \in [TBD_1, TBD_2]$

η_{EXT} is an PPDU format dependent scaling factor, with the following value

$$\eta_{EXT} = \begin{cases}\sqrt{2}, & \text{HE extended range SU PPDU}\\ 1, & \text{otherwise}\end{cases}$$

β_r is the per-RU power normalization factor and defined by

$$\beta_r = \left(\sqrt{\frac{|K_r|}{|K_r^{\text{HE-STF}}|}}\right) \Big/ \left(\sqrt{\sum_{r=1}^{N_{RU}}\alpha_r|K_r|}\right)$$

$|K_r|$ 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

$T_{CS,HE}(n)$ is given in 26.3.9.2 (Cyclic shift for Pre-HE modulated fields)

$Q_k^{(i_{Seg})}$ is defined in 25.3.10.10.x (Transmission in HE format)

$w_{T_{\text{HE-STF-NT}}}$ is the windowing function for HE-STF field in the non-HE trigger-based PPDU.

The time domain representation of the signal for HE trigger-based PPDUs on frequency segment i_{Seg} of transmit chain i_{TX} shall be as specified in Equation 26-36.

$$r_{\text{HE-STF}}^{(i_{Seg},i_{TX})}(t) = \frac{\alpha_r\beta_r}{\sqrt{N_{STS,r,total}}} w_{T_{\text{HE-STF-T}}}(t) \cdot\sum_{k\in K_r}\sum_{m=1}^{N_{STS,r,u}}\left(\begin{array}{l}\left[Q_k^{(i_{Seg})}\right]_{i_{TX},(M_{r,u}+m)} HES_k \\ \cdot\exp\left(j2\pi k\Delta_{F,\text{HE}}\left(t-T_{\text{CS,HE}}\left(M_{r,u}+m\right)\right)\right)\end{array}\right) \quad (26\text{-}36)$$

where

$w_{T_{\text{HE-STF-T}}}$ is the windowing function for HE-STF field in the HE trigger-based PPDU.

26.3.9.10 HE-LTF

The HE Long Training field (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 MU PPDU or HE extended range SU PPDU, the transmitter

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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. A 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 $P_{HE\text{-}LTF}$, to enable channel estimation at the receiver. The pilot tones of each HE-LTF symbol are multiplied by the entries of a matrix $R_{HE\text{-}LTF}$ defined in the following text. The multiplication of the pilot tones in the HE-LTF symbol by the $R_{HE\text{-}LTF}$ matrix instead of the $P_{HE\text{-}LTF}$ matrix allows receivers to track phase and frequency offset during MIMO channel estimation using the HE-LTF. In an HE SU PPDU and HE extended range SU PPDU, the number of HE-LTF symbols, NHE-LTF, is a function of the total number of space-time streams N_{STS} as shown in <reference>. In an HE trigger-based PPDU, NHE-LTF is indicated in the Trigger frame that triggers the transmission of the PPDU. In an HE MU PPDU, NHE-LTF is indicated in the HE-SIG-A field. In an HE MU PPDU and HE trigger-based PPDU, NHE-LTF is selected to be not smaller than the maximum value of the functions for each $N_{STS,r,total}$. As a result the HE-LTF field consists of one, two, four, six or eight symbols.

A HE PPDU supports 3 HE-LTF modes, which are 1x HE-LTF, 2x HE-LTF, and 4x HE-LTF. It is optional to support 1x HE-LTF in an HE SU PPDU, HE extended range SU PPDU and HE MU PPDU. In an HE SU PPDU, HE MU PPDU or 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, $T_{GI,Data}$

— 2x HE-LTF, $T_{GI,Data2}$

— 4x HE-LTF, $T_{GI,Data4}$

The optional combinations of HE-LTF mode and GI duration are:

— 1x HE-LTF, $T_{GI,Data}$ in a HE SU PPDU or HE extended SU PPDU

— 1x HE-LTF, $T_{GI,Data}$ in a non-OFDMA, MU-MIMO HE MU PPDU

— 1x HE-LTF, $T_{GI,Data2}$ in a non-OFDMA, MU-MIMO HE trigger-based PPDU

The duration of each HE-LTF symbol is THE-LTF is defined in Equation 26-37. 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.

$$T_{HE-LTF} = \begin{cases} T_{HE-LTF-1X} & \text{if 1x HE-LTF} \\ T_{HE-LTF-2X} & \text{if 2x HE-LTF} \\ T_{HE-LTF-4X} & \text{if 4x HE-LTF} \end{cases} \quad (26\text{-}37)$$

where $T_{HE\text{-}LTF\text{-}1X}$, $T_{HE\text{-}LTF\text{-}2X}$, $T_{HE\text{-}LTF\text{-}4X}$ are defined in Table 26-3 (Timing-related constants).

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In a 20 MHz transmission, the 1x HE-LTF sequence transmitted is given by Equation 26-38.

$$HELTF_{-122,122} =$$
$$\{0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1,$$
$$0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -$$
$$1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0,$$
$$-1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, 0, 0, 0, 0,$$
$$-1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0,$$
$$0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0,$$
$$0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1,$$
$$0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0\} \quad (26\text{-}38)$$

In a 20 MHz transmission, the 2x HE-LTF sequence transmitted is given by Equation 26-39.

$$HELTF_{-122,122} =$$
$$\{-1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1,$$
$$0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1,$$
$$0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1,$$
$$0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1,$$
$$0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, 0, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1,$$
$$0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1,$$
$$0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1,$$
$$0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1,$$
$$0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1\} \quad (26\text{-}39)$$

In a 20 MHz transmission, the 4x HE-LTF sequence transmitted is given by Equation 26-40.

$$HELTF_{-122,122} =$$
$$\{-1, -1, +1, -1, +1, -1, +1, +1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, -1, -1, +1,$$
$$+1, -1, -1, -1, -1, +1, +1, -1, +1, -1, +1, +1, +1, +1, -1, +1, -1, -1, +1, +1, -1, +1, +1,$$
$$+1, +1, -1, -1, +1, -1, -1, -1, +1, +1, +1, +1, -1, +1, +1, -1, -1, -1, -1, +1, -1, -1, -1, +1,$$
$$+1, -1, +1, -1, -1, -1, -1, +1, -1, +1, -1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1, -1, -$$
$$1, +1, -1, -1, +1, +1, +1, -1, +1, +1, +1, -1, +1, -1, +1, -1, -1, -1, -1, -1, +1, +1, +1,$$
$$-1, -1, -1, +1, -1, +1, +1, +1, 0, 0, 0, -1, +1, -1, +1, -1, +1, +1, -1, +1, +1, +1, -1, -1,$$
$$+1, -1, -1, +1, -1, +1, -1, +1, +1, +1, -1, +1, +1, +1, -1, -1, -1, -1, -1, +1,$$
$$+1, -1, -1, -1, -1, -1, -1, +1, -1, +1, -1, -1, -1, -1, +1, -1, +1, +1, -1, -1, +1, -1, -$$
$$1, -1, -1, +1, +1, -1, +1, +1, +1, +1, +1, +1, +1, -1, +1, +1, -1, -1, -1, -1, +1, -1, -1,$$
$$+1, +1, -1, +1, -1, -1, -1, -1, +1, -1, +1, -1, -1, +1, +1, +1, +1, -1, -1, +1, +1, +1, +1,$$
$$+1, -1, +1, +1, -1, -1, -1, +1, -1, -1, -1, +1, -1, +1, -1, +1, +1\} \quad (26\text{-}40)$$

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In a 40 MHz transmission, the 1x HE-LTF sequence transmitted is given by Equation 26-41.

$HELTF_{-244,244}$ =

{+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, (26-41)
0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1,
0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −
1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0,
−1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0,
0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0,
0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1,
0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 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 40 MHz transmission, the 2x HE-LTF sequence transmitted is given by Equation 26-42.

$HELTF_{-244,244}$ =

{+1, 0, −1, 0, −1, 0, −1, 0, −1, 0, −1, 0, +1, 0, +1, 0, −1, 0, −1, 0, +1, 0, −1, 0, +1, 0, −1,
0, −1, 0, −1, 0, −1, 0, −1, 0, −1, 0, +1, 0, +1, 0, +1, 0, +1, 0, −1, 0, +1, 0, −1, 0, +1, 0, +1,
0, −1, 0, −1, 0, −1, 0, −1, 0, −1, 0, +1, 0, +1, 0, −1, 0, −1, 0, +1, 0, −1, 0, +1, 0, −1, 0, +1,
0, +1, 0, +1, 0, +1, 0, +1, 0, −1, 0, −1, 0, −1, 0, −1, 0, +1, 0, −1, 0, +1, 0, −1, 0, +1, 0, +1,
0, +1, 0, +1, 0, +1, 0, −1, 0, +1, 0, −1, 0, −1, 0, +1, 0, −1, 0, +1, 0, −1, 0, −1, 0, +1, 0, +1,
0, +1, 0, +1, 0, +1, 0, −1, 0, −1, 0, +1, 0, +1, 0, −1, 0, +1, 0, −1, 0, +1, 0, +1, 0, +1, 0, +1,
0, +1, 0, +1, 0, −1, 0, −1, 0, −1, 0, −1, 0, +1, 0, −1, 0, +1, 0, −1, 0, −1, 0, −1, 0, −1, 0, −1,
0, −1, 0, −1, 0, +1, 0, +1, 0, −1, 0, −1, 0, +1, 0, −1, 0, +1, 0, −1, 0, +1, 0, +1, 0, +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, − (26-42)
1, 0, −1, 0, −1, 0, +1, 0, +1, 0, −1, 0, −1, 0, +1, 0, −1, 0, +1, 0, −1, 0, −1, 0, −1, 0, −1, 0,
−1, 0, −1, 0, +1, 0, −1, 0, +1, 0, +1, 0, −1, 0, +1, 0, −1, 0, +1, 0, +1, 0, +1, 0, +1, 0, +1, 0,
+1, 0, +1, 0, −1, 0, −1, 0, +1, 0, +1, 0, −1, 0, +1, 0, −1, 0, +1, 0, −1, 0, −1, 0, −1, 0, −1, 0,
−1, 0, +1, 0, −1, 0, +1, 0, +1, 0, −1, 0, +1, 0, −1, 0, +1, 0, +1, 0, +1, 0, +1, 0, +1, 0, +1, 0,
+1, 0, −1, 0, −1, 0, +1, 0, +1, 0, −1, 0, +1, 0, −1, 0, −1, 0, −1, 0, −1, 0, −1, 0, −1, 0, −1, 0,
+1, 0, +1, 0, −1, 0, −1, 0, +1, 0, −1, 0, +1, 0, −1, 0, −1, 0, −1, 0, −1, 0, −1, 0, −1, 0, +1, 0,
−1, 0, +1, 0, +1, 0, −1, 0, +1, 0, −1, 0, +1, 0, +1, 0, −1, 0, −1, 0, −1, 0, −1, 0, −1, 0, +1, 0,
+1, 0, −1, 0, −1, 0, +1, 0, −1, 0, +1, 0, −1, 0, +1, 0, +1, 0, +1, 0, +1, 0, +1, 0, −1, 0, +1, 0,
−1, 0, −1, 0, +1, 0, −1, 0, +1, 0, −1, 0, +1}

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In a 40 MHz transmission, the 4x HE-LTF sequence transmitted is given by Equation 26-43.

$HELTF_{-244,244}$ =

{+1, −1, −1, −1, −1, +1, −1, −1, +1, +1, −1, +1, −1, +1, −1, +1, +1, −1, +1, −1, −1, −1,
+1, +1, −1, −1, −1, −1, −1, −1, −1, +1, −1, −1, +1, +1, −1, +1, −1, −1, −1, −1, −1, +1, −1,
+1, +1, +1, −1, −1, +1, +1, +1, −1, −1, +1, +1, +1, +1, −1, +1, +1, −1, −1, +1, −1, +1, −1,
+1, −1, −1, +1, −1, +1, +1, +1, −1, −1, +1, +1, +1, −1, −1, −1, −1, +1, −1, −1, +1, +1, −1,
+1, −1, −1, −1, −1, −1, +1, −1, +1, +1, +1, −1, −1, +1, +1, +1, +1, +1, +1, +1, +1, −1, +1,
+1, −1, −1, +1, −1, +1, +1, +1, +1, +1, −1, +1, −1, −1, −1, +1, +1, −1, −1, −1, −1, −1, −1,
−1, −1, +1, −1, −1, +1, +1, −1, +1, −1, +1, −1, +1, +1, −1, +1, −1, −1, −1, +1, +1, −1, −1,
−1, −1, −1, −1, −1, +1, −1, −1, +1, +1, −1, +1, −1, −1, −1, −1, −1, +1, −1, +1, +1, +1, −1,
−1, +1, +1, +1, −1, −1, −1, −1, −1, −1, +1, −1, −1, +1, +1, −1, +1, −1, +1, −1, +1, +1, −1,
+1, −1, −1, −1, +1, +1, −1, −1, −1, +1, +1, +1, +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, (26-43)
+1, −1, −1, +1, −1, +1, −1, +1, −1, −1, +1, −1, +1, +1, +1, −1, −1, +1, +1, +1, +1, +1, +1,
+1, −1, +1, +1, −1, −1, +1, −1, +1, +1, +1, +1, +1, −1, +1, −1, −1, −1, +1, +1, −1, −1, −1,
+1, +1, −1, −1, −1, −1, +1, −1, −1, +1, +1, −1, +1, −1, +1, −1, +1, +1, −1, +1, −1, −1, −1,
+1, +1, −1, −1, −1, +1, +1, +1, +1, −1, +1, +1, −1, −1, +1, −1, +1, +1, +1, +1, +1, −1, +1,
−1, −1, −1, +1, +1, −1, −1, −1, +1, −1, −1, −1, −1, +1, −1, −1, +1, +1, −1, +1, −1, +1, −1,
+1, +1, −1, +1, −1, −1, −1, +1, +1, −1, −1, −1, +1, −1, −1, −1, −1, +1, −1, −1, +1, +1, −1,
+1, −1, +1, −1, +1, +1, −1, +1, −1, −1, −1, +1, +1, −1, −1, −1, −1, −1, −1, −1, +1, −1, −1,
+1, +1, −1, +1, −1, −1, −1, −1, −1, +1, −1, +1, +1, +1, −1, −1, +1, +1, +1, −1, +1, −1, −1,
−1, −1, +1, −1, −1, +1, +1, −1, +1, −1, +1, −1, +1, +1, −1, +1, −1, −1, −1, +1, +1, −1, −1,
−1, +1, +1, +1, +1, −1, +1, +1, −1, −1, +1, −1, +1, +1, +1, +1, +1, −1, +1, −1, −1, −1, +1,
+1, −1, −1, −1, −1}

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In an 80 MHz transmission, the 1x HE-LTF sequence transmitted is given by Equation 26-44.

$$
\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{26-44}
$$

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In an 80 MHz transmission, the 2x HE-LTF sequence transmitted is given by Equation 26-45.

$HELTF_{-500,500}$ =

{+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, 0, 0, 0, 0, 0, 0, (26-45)
+1, 0, −1, 0, −1, 0, +1, 0, +1, 0, −1, 0, +1, 0, −1, 0, −1, 0, −1, 0, +1, 0, +1, 0, +1, 0, +1, 0,
−1, 0, +1, 0, +1, 0, +1, 0, −1, 0, +1, 0, −1, 0, −1, 0, −1, 0, −1, 0, +1, 0, +1, 0, +1, 0, −1, 0,
+1, 0, +1, 0, −1, 0, −1, 0, +1, 0, −1, 0, −1, 0, +1, 0, −1, 0, −1, 0, +1, 0, −1, 0, +1, 0, +1, 0,
+1, 0, −1, 0, +1, 0, +1, 0, +1, 0, +1, 0, −1, 0, +1, 0, −1, 0, −1, 0, −1, 0, −1, 0, +1, 0, −1, 0,
+1, 0, +1, 0, −1, 0, −1, 0, −1, 0, +1, 0, −1, 0, +1, 0, +1, 0, +1, 0, −1, 0, +1, 0, +1, 0, +1, 0,
+1, 0, −1, 0, −1, 0, −1, 0, +1, 0, +1, 0, +1, 0, +1, 0, −1, 0, −1, 0, −1, 0, −1, 0, +1, 0, −1, 0,
+1, 0, +1, 0, −1, 0, +1, 0, +1, 0, +1, 0, −1, 0, −1, 0, −1, 0, −1, 0, −1, 0, +1, 0, −1, 0, −1, 0,
+1, 0, −1, 0, +1, 0, +1, 0, −1, 0, +1, 0, −1, 0, −1, 0, +1, 0, −1, 0, −1, 0, −1, 0, +1, 0, +1, 0,
−1, 0, −1, 0, −1, 0, +1, 0, −1, 0, −1, 0, +1, 0, −1, 0, +1, 0, +1, 0, +1, 0, −1, 0, +1, 0, +1, 0,
+1, 0, −1, 0, +1, 0, −1, 0, +1, 0, +1, 0, −1, 0, +1, 0, −1, 0, −1, 0, −1, 0, −1, 0, +1, 0, −1, 0,
−1, 0, −1, 0, +1, 0, −1, 0, +1, 0, +1, 0, −1, 0, +1, 0, +1, 0, +1, 0, −1, 0, −1, 0, +1, 0, +1, 0,
+1, 0, −1, 0, −1, 0, −1, 0, +1, 0, +1, 0, +1, 0, +1, 0, −1, 0, +1, 0, +1, 0, +1, 0, −1, 0, +1, 0,
−1, 0, −1, 0, −1, 0, −1, 0, +1, 0, +1, 0, +1, 0, −1, 0, +1, 0, −1, 0, −1, 0, −1, 0, +1, 0, −1, 0,
−1, 0, −1, 0, −1, 0, +1, 0, −1, 0, −1, 0, −1, 0, +1, 0, −1, 0, +1, 0, +1, 0, −1, 0, +1, 0, +1, 0,
−1, 0, +1, 0, −1, 0, −1, 0, +1, 0, −1, 0, −1, 0, −1, 0, +1, 0, +1, 0, −1, 0, −1, 0, −1, 0, +1, 0,
−1, 0, −1, 0, +1, 0, −1, 0, +1, 0, +1, 0, +1, 0, −1, 0, +1, 0, +1, 0, +1, 0, −1, 0, −1, 0, −1, 0,
−1, 0, −1, 0, +1, 0, +1, 0, +1, 0, −1, 0, +1, 0, −1, 0, −1, 0, −1, 0, +1, 0, −1, 0, −1, 0, −1, 0,
+1, 0, +1, 0, +1, 0, +1, 0, −1, 0, +1, 0, +1, 0, +1, 0, −1, 0, +1, 0, +1}

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In an 80 MHz transmission, the 4x HE-LTF sequence transmitted is given by Equation 26-46.

$$HELTF_{-500,500} =$$
$$\{+1, +1, -1, +1, -1, +1, -1, -1, -1, +1, -1, -1, -1, +1, +1, -1, +1, +1, +1, +1, +1, -1, -$$
$$1, +1, +1, +1, +1, -1, +1, -1, +1, -1, -1, +1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1,$$
$$-1, +1, +1, +1, -1, -1, -1, -1, -1, -1, +1, +1, +1, +1, +1, +1, -1, +1, +1, +1, -1, +1, +1,$$
$$-1, -1, -1, +1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, +1, +1, +1, +1, -1, -1, +1, +1, +1,$$
$$-1, +1, +1, -1, -1, -1, +1, -1, +1, +1, -1, +1, +1, -1, +1, -1, -1, +1, +1, +1, +1, -1, -1,$$
$$+1, +1, +1, +1, +1, -1, +1, +1, -1, -1, -1, +1, -1, -1, -1, +1, -1, +1, -1, +1, +1, -1, +1,$$
$$-1, +1, -1, +1, +1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1,$$
$$-1, +1, -1, +1, -1, +1, +1, -1, -1, +1, -1, -1, -1, +1, +1, -1, +1, +1, +1, +1, -1, -1, -1,$$
$$+1, +1, +1, +1, -1, +1, +1, +1, +1, +1, +1, +1, -1, +1, +1, +1, -1, +1, +1, -1, -1, -1, +1,$$
$$-1, +1, -1, -1, +1, +1, -1, +1, -1, +1, +1, +1, +1, +1, -1, -1, +1, +1, +1, -1, +1, +1, -1,$$
$$-1, -1, +1, -1, +1, +1, -1, +1, +1, -1, +1, -1, -1, +1, -1, +1, -1, +1, -1, +1, +1, +1, -1,$$
$$+1, +1, +1, -1, -1, +1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1, -1, +1, -1, +1, -1, +1, +1,$$
$$-1, -1, +1, -1, -1, -1, +1, +1, -1, +1, +1, +1, +1, -1, -1, -1, +1, +1, +1, -1, +1, -1, -1,$$
$$-1, -1, -1, -1, -1, +1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, -1, +1, +1, -1, -1, +1,$$
$$-1, +1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, -1, -1, +1,$$
$$-1, -1, +1, -1, +1, +1, +1, +1, +1, +1, -1, -1, +1, +1, +1, +1, +1, -1, +1, +1, -1, -1, -1,$$
$$+1, -1, -1, -1, +1, -1, +1, -1, +1, +1, -1, +1, -1, +1, -1, +1, +1, +1, -1, +1, +1, +1, -1,$$
$$-1, +1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1, -1, +1, -1, +1, -1, +1, +1, -1, -1, +1, -1,$$
$$-1, -1, +1, +1, -1, +1, +1, +1, +1, -1, -1, -1, +1, +1, +1, +1, -1, -1, +1, +1, +1, +1, +1,$$
$$+1, -1, +1, +1, +1, -1, +1, +1, -1, -1, -1, +1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, +1,$$
$$+1, +1, +1, -1, -1, +1, +1, +1, -1, +1, +1, -1, -1, -1, +1, -1, +1, +1, -1, +1, +1, -1, +1,$$
$$-1, -1, -1, +1, -1, +1, -1, -1, -1, -1, +1, +1, +1, -1, -1, +1, 0, 0, 0, 0, 0, +1, -1, -1, -$$ (26-46)
$$1, -1, -1, -1, +1, -1, +1, +1, -1, -1, +1, +1, -1, +1, -1, +1, +1, -1, -1, +1, -1, +1, -1,$$
$$-1, -1, +1, +1, -1, +1, +1, +1, -1, +1, +1, +1, +1, +1, +1, +1, -1, +1, -1, -1, +1, -1, -1,$$
$$+1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, +1, +1, -1, -1, -1, -1, -1, +1, -1, -1, -1, -1,$$
$$-1, +1, +1, -1, -1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, +1, +1, -1, +1, -1, +1, -1,$$
$$-1, -1, -1, -1, +1, +1, +1, -1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, +1, -1, -1, +1,$$
$$-1, +1, -1, -1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, -1,$$
$$-1, +1, -1, -1, +1, -1, +1, +1, +1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, +1, +1, -1, -1,$$
$$+1, -1, -1, -1, +1, -1, -1, -1, -1, -1, -1, -1, +1, -1, +1, +1, -1, +1, +1, -1, +1, -1, -1,$$
$$-1, +1, +1, -1, +1, +1, +1, -1, -1, +1, +1, +1, +1, +1, -1, +1, -1, -1, -1, -1, +1, +1, -1,$$
$$-1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, +1, +1, -1, +1, -1, +1, -1, -1, -1, -1, -1,$$
$$+1, +1, +1, -1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, +1, -1, -1, +1, -1, +1, -1, +1,$$
$$+1, +1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, +1, -1, -1,$$
$$-1, -1, -1, -1, -1, +1, -1, +1, +1, -1, +1, +1, -1, +1, -1, -1, -1, +1, +1, -1, +1, +1, +1,$$
$$-1, -1, +1, +1, +1, +1, +1, -1, +1, +1, +1, +1, +1, -1, -1, +1, +1, +1, +1, +1, -1, +1, +1,$$
$$-1, -1, -1, +1, -1, -1, -1, +1, -1, +1, -1, +1, +1, +1, +1, +1, -1, -1, -1, +1, +1, +1, +1,$$
$$-1, +1, +1, -1, -1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, -1, -1, -1, -1, -1, -1, +1, +1,$$
$$-1, -1, -1, +1, -1, -1, +1, +1, +1, -1, +1, -1, -1, +1, -1, -1, +1, -1, +1, -1, +1, -1, +1,$$
$$-1, -1, +1, +1, -1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, +1, -1, -1, -1, -1, -1, -1,$$
$$-1, +1, -1, +1, +1, -1, +1, +1, -1, +1, -1, -1, -1, +1, +1, -1, +1, +1, +1, -1, -1, +1, +1,$$
$$+1, +1, +1, -1, +1, -1, -1, -1, -1, +1, +1, -1, -1, -1, -1, -1, +1, -1, -1, +1, +1, +1, -1,$$
$$+1, +1, +1, -1, +1, -1, +1, -1, -1, -1, -1, -1, +1, +1, +1, -1, -1, -1, -1, +1, -1, -1, +1,$$
$$+1, +1, -1, +1, +1, -1, -1, +1, -1, +1, -1, +1\}$$

In a 160 MHz transmission, the 1x HE-LTF sequence transmitted is given by Equation 26-47.

$$HELTF_{-1012,\,1012} = \{1\text{x LTF}_{\text{80MHz\_primary}}, \text{zeros}(1, 23), 1\text{x LTF}_{\text{80MHz\_secondary}}\} \quad (26\text{-}47)$$

where

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$1x\ LTF_{80MHz\_primary} = \{L\text{-}LTF_{80MHz\_1x}, 0, R\text{-}LTF_{80MHz\_1x}\}$
$1x\ LTF_{80MHz\_secondary} = \{L\text{-}LTF_{80MHz\_1x}, 0, (-1)*R\text{-}LTF_{80MHz\_1x}\}$

In a 160 MHz transmission, the 2x HE-LTF sequence transmitted is given by Equation 26-48.

$$HELTF_{-1012,1012} = \{2x\ LTF_{80MHz\_primary}, zeros(1, 23), 2x\ LTF_{80MHz\_secondary}\} \quad (26\text{-}48)$$

where

$2x\ LTF_{80MHz\_primary} =$
$\{\{1^{st}\ 242\text{-RU}\}, \{2^{nd}\ 242\text{-RU}\}, \{central\ 26\text{-RU}\}, \{3^{rd}\ 242\text{-RU}\}, \{4^{th}\ 242\text{-RU}\}\}$ (26-49)
$2x\ LTF_{80MHz\_secondary} =$
$\{\{1^{st}\ 242\text{-RU}\}, (-1)*\{2^{nd}\ 242\text{-RU}\}, \{central\ 26\text{-RU}\}, \{3^{rd}\ 242\text{-RU}\}, (-1)*\{4^{th}\ 242\text{-RU}\}\}$ (26-50)

In a 160 MHz transmission, the 4x HE-LTF sequence transmitted is given by Equation (26 51).

$$HELTF_{-1012,1012} = \{4x\ LTF_{80MHz\_primary}, zeros(1, 23), 4x\ LTF_{80MHz\_secondary}\} \quad (26\text{-}51)$$

where

$$4x\ LTF_{80MHz\_primary} = \{L\text{-}LTF_{80MHz\_4x}, 0, R\text{-}LTF_{80MHz\_4x}\} \quad (26\text{-}52)$$

$$4x\ LTF_{80MHz\_secondary} = \{L\text{-}LTF_{80MHz\_4x}, 0, (-1)*R\text{-}LTF_{80MHz\_4x}\} \quad (26\text{-}53)$$

For a noncontiguous 80+80 MHz transmission, the 1x HE-LTF sequence is given by Equation 26-54.

$$HELTF_{80+80MHz} = \{1x\ LTF_{80MHz\_primary}, zeros(1, 23), 1x\ LTF_{80MHz\_secondary}\} \quad (26\text{-}54)$$

For a noncontiguous 80+80 MHz transmission, the 2x HE-LTF sequence is given by Equation 26-55.

$$HELTF_{80+80MHz} = \{2x\ LTF_{80MHz\_primary}, zeros(1, 23), 2x\ LTF_{80MHz\_secondary}\} \quad (26\text{-}55)$$

For a noncontiguous 80+80 MHz transmission, the 4x HE-LTF sequence is given by Equation 26-56.

$$HELTF_{80+80MHz} = \{4x\ LTF_{80MHz\_primary}, zeros(1, 23), 4x\ LTF_{80MHz\_secondary}\} \quad (26\text{-}56)$$

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 using single stream pilots is shown in Figure 26-29 (Generation of HE-LTF symbols per frequency segment in an HE SU PPDU, HE MU PPDU,

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HE extended range SU PPDU, and HE trigger-based PPDU using single stream pilots) where A^{k}_{HELTF} is given by Equation 26-57.

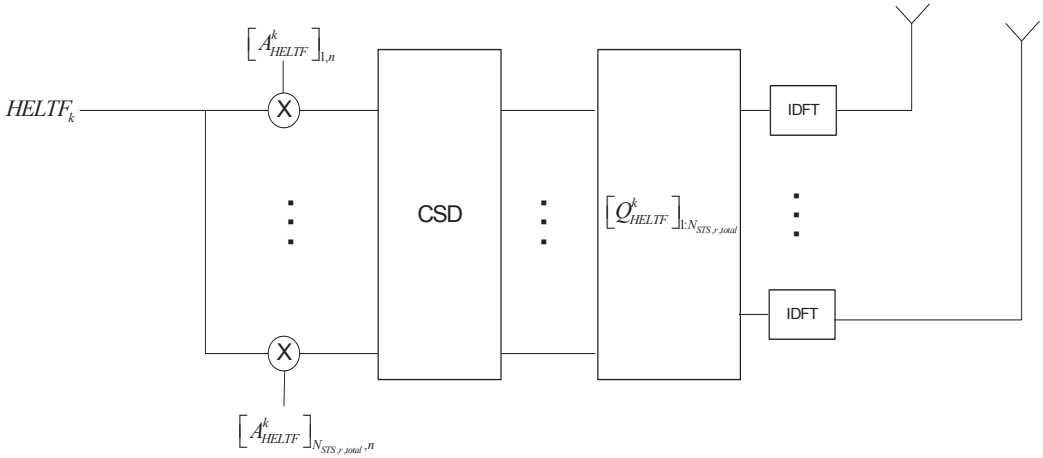


Figure 26-29—Generation of HE-LTF symbols per frequency segment in an HE SU PPDU, HE MU PPDU, HE extended range SU PPDU, and HE trigger-based PPDU using single stream pilots

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 26-30 (Generation of 1x HE-LTF symbols per frequency segment).

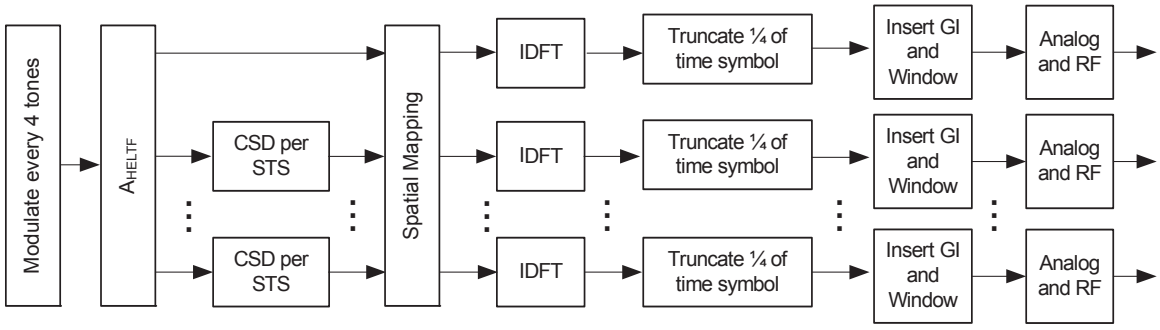


Figure 26-30—Generation of 1x HE-LTF symbols per frequency segment

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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 26-31 (Generation of 2x HE-LTF symbols per frequency segment).

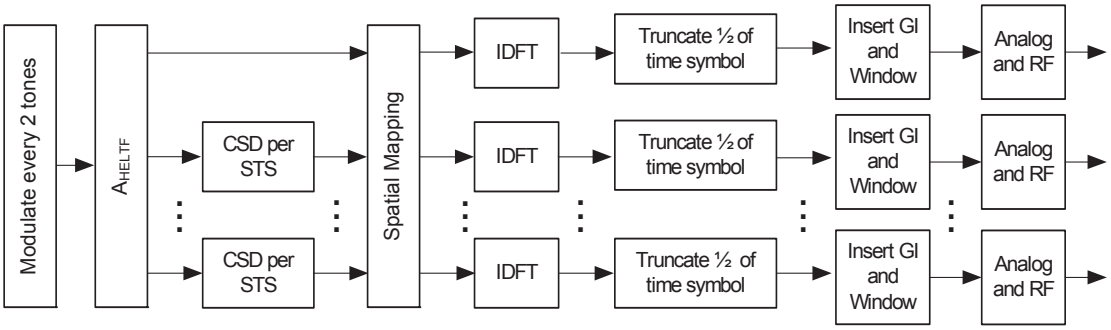


Figure 26-31—Generation of 2x HE-LTF symbols per frequency segment

A^{k}_{HELTF} is given by Equation 26-57.

$$A^{k}_{HELTF} = \begin{cases} R_{HELTF}, & \text{if } k \in K_{\text{Pilot}} \\ P_{HELTF}, & \text{otherwise} \end{cases} \tag{26-57}$$

where

K_{Pilot} is the set of subcarrier indices for the pilot tones as defined in 25.x (xx).

R_{HELTF} is a $N_{HELTF} \times N_{HELTF}$ matrix whose elements are defined in EEquation 26-58.

$$[R_{HELTF}]_{m,\,n} = [P_{HELTF}]_{1,\,n},\ 1 \le m, n \le N_{HELTF} \tag{26-58}$$

P_{HELTF} is defined in Equation 26-59.

$$P_{HELTF} = \begin{cases} P_{4\times 4}, N_{HELTF} \le 4 \\ P_{6\times 6}, N_{HELTF} = 6 \\ P_{8\times 8}, N_{HELTF} = 8 \end{cases} \tag{26-59}$$

where $P_{4\times 4}$ is defined in Equation (20-17), $P_{6\times 6}$ is defined in Equation (22-45), and $P_{8\times 8}$ is defined in Equation (22-46).

In an HE SU PPDU, HE MU PPDU, HE extended range SU PPDU and HE trigger-based PPDU using single stream pilots, the time domain representation of the waveform transmitted on frequency segment i_{Seg} of transmit chain i_{TX} shall be as described by Equation (26 60).

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$$r_{HE-LTF}^{(i_{seg},i_{TX})}(t)=\frac{\eta_{HE-LTF}\cdot\eta_{EXT}}{\sqrt{\sum_{r=1}^{N_{RU}}\alpha_r^2\left|K_r\right|}}\sum_{n=0}^{N_{HELTF}-1}w_{T_{HE-LTF}}\left(t-nT_{HE-LTF}\right)\sum_{r=0}^{N_{RU}-1}\frac{\alpha_r}{\sqrt{N_{STS,r,total}}}$$
$$\cdot\sum_{k\in K_r}\sum_{u=0}^{N_{user,r}-1}\sum_{m=1}^{N_{STS,r,u}}\left(\begin{array}{l}\left[Q_k^{(i_{seg})}\right]_{i_{TX},\left(M_{r,u}+m\right)}\left[A_{HELTF}^k\right]_{\left(M_{r,u}+m\right),(n+1)}HELTF_k\\ \cdot\exp\left(j2\pi k\Delta_{F,HE}\left(t-nT_{HE-LTF}-T_{GI}-T_{CS,HE}\left(M_{r,u}+m\right)\right)\right)\end{array}\right) \quad (26\text{-}60)$$

where

α_r is the power boost factor for the *r*-th RU, where $\alpha_r \in [TBD_1, TBD_2]$

η_{EXT} is an PPDU format dependent scaling factor, with the following value

$$\eta_{EXT}=\begin{cases}\sqrt{2}, & \text{HE extended range SU PPDU}\\ 1, & \text{otherwise}\end{cases}$$

$N_{\text{HE-LTF}}^{\text{Tone}}$ has the value given in Table 25-xx (Tone scaling factor and guard interval duration values for PHY fields)

$T_{CS,HE}(n)$ is given in 26.3.9.2 (Cyclic shift for Pre-HE modulated fields)

$Q_k^{(i_{Seg})}$ is defined in 25.xx (Transmission in HE format)

A_{HELTF}^k is defined in Equation 26-57

K_r is the set of subcarrier indices for the tones in the *r*-th RU as defined in 25.x

$\eta_{\text{HE-LTF}}$ is the power scaling factor as defined in (25-xx)

$$\eta_{\text{HE-LTF}}=\begin{cases}2 & \text{for 1x HE-LTF}\\ \sqrt{2} & \text{for 2x HE-LTF}\\ 1 & \text{for 4x HE-LTF}\end{cases}$$

26.3.10 Data field

26.3.10.1 General

The number of OFDM symbols in the Data field is determined by the Length field in L-SIG (see Equation (25-x)), the preamble duration and the setting of the CP+LTF Size field in HE-SIG-A (see 26.3.9.7 (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. The Data field in UL MU transmissions shall immediately follow the HE-LTF section.

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 (bits for SU and bits for each user u in MU). 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.

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26.3.10.2 Pre-FEC encoding 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 a HE PPDU, the 4 possible boundaries participate the FEC output bit stream of the last OFDM symbol(s) into 4 symbol segments. The 4 possible boundaries are represented by a parameter a, called *a-factor*.

Figure 26-32 (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, *a-factor*, is 1. In the case of STBC, the FEC output bits and post-FEC padding bits as shown in Figure 26-33 (HE PPDU padding process in the last OFDM symbol (STBC) when a = 1), are modulated into the last two OFDM symbols by STBC encoding, each with the same number of effective symbol segments, *a-factor*, being 1.

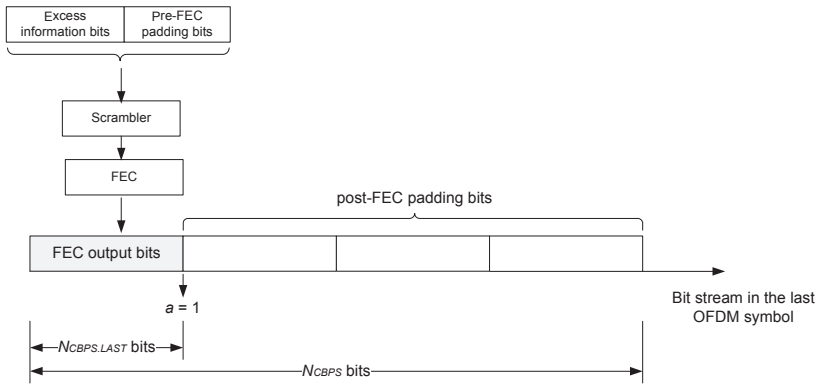


Figure 26-32—HE PPDU padding process in the last OFDM symbol (non STBC) when *a* = 1

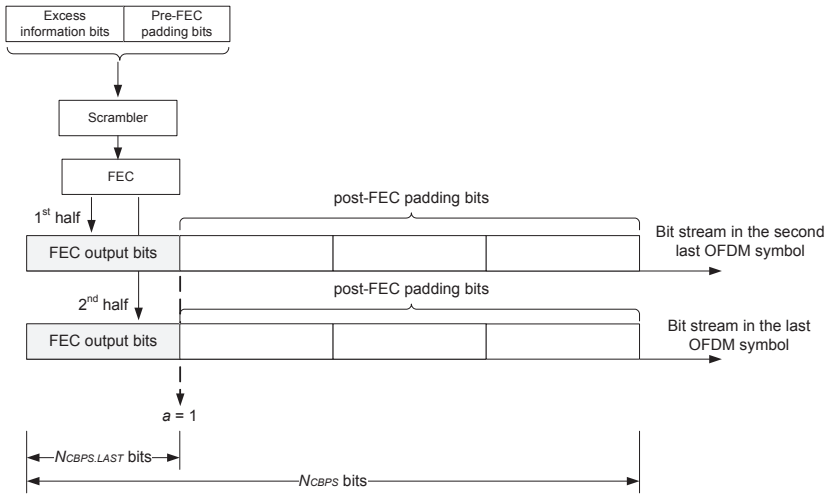


Figure 26-33—HE PPDU padding process in the last OFDM symbol (STBC) when *a* = 1

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The pre-FEC padding process is described in this subclause, and the encoding and post-FEC padding process are described in 26.3.10.3. While this subclause describes the pre-FEC padding processing of an SU transmission, its extension to MU transmission is described in 25.3.10.3.4 (Encoding Process for HE MU PPDUs).

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 with BCC encoding, the number of excess bits is calculated based on Equation 26-61.

$$N_{Excess} = mod(8 \cdot \text{APEP\_LENGTH} + N_{Tail} + N_{service}, m_{STBC} \cdot N_{DBPS}) \quad (26\text{-}61)$$

where

m_{STBC} is 2 when STBC is used, and 1 otherwise;

APEP_LENGTH is the TXVECTOR parameter APEP_LENGTH.

For a HE SU PPDU with LDPC encoding, the number of excess bits is calculated based on Equation 26-62:

$$N_{Excess} = mod(8 \cdot \text{APEP\_LENGTH} + N_{service}, m_{STBC} \cdot N_{DBPS}) \quad (26\text{-}62)$$

Then based on N_{Excess}, compute the initial number of symbol segments in the last OFDM symbol(s), a-factor value or a_{init}, as shown in Equation 26-63.

$$a_{init} = \begin{cases} 4, & \text{if } N_{Excess} = 0 \\ \left\lceil \dfrac{N_{Excess}}{m_{STBC} \cdot N_{DBPS,SHORT}} \right\rceil, & \text{otherwise} \end{cases} \quad (26\text{-}63)$$

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 26-22 (NSD,SHORT values).

Table 26-22—$N_{SD,SHORT}$ values

RU Size	$N_{SD,SHORT}$	
	DCM = 0	DCM = 1
26	6	2 (TBD)
52	12	6 (TBD)
106	24	12 (TBD)
242	60	30 (TBD)

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Table 26-22—$N_{SD,SHORT}$ values

484	120	60 (TBD)
996	240	120 (TBD)
996x2	492	246 (TBD)

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 26-64.

$$N_{DBPS.LAST.init} = \begin{cases} a_{init}.N_{DBPS.SHORT}, & \text{if } a_{init} < 4 \\ N_{DBPS,} & \text{if } a_{init} = 4 \end{cases}$$
$$N_{CBPS.LAST.init} = \begin{cases} a_{init}.N_{CBPS.SHORT}, & \text{if } a_{init} < 4 \\ N_{CBPS,} & \text{if } a_{init} = 4 \end{cases} \quad (26\text{-}64)$$

For a HE SU PPDU with BCC encoding, the number of pre-FEC pad bits is calculated using Equation 26-65.

$$N_{PAD,PRE-FEC} = (N_{SYM.init} - m_{STBC}).N_{DBPS} + m_{STBC}.N_{DBPS.Last.init} - 8.APEP\_LENGTH - N_{Tail} - N_{service} \quad (26\text{-}65)$$

where $N_{SYM.init}$ is defined as in Equation (26 68) for BCC encoding, and Equation (26 73) for LDPC encoding.

For a HE SU PPDU with LDPC encoding, the number of pre-FEC pad bits is calculated using Equation 26-66.

$$N_{PAD,PRE-FEC} = (N_{SYM.init} - m_{STBC}).N_{DBPS} + m_{STBC}.N_{DBPS.Last.init} - 8.APEP\_LENGTH - N_{service} \quad (26\text{-}66)$$

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 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 26-67.

$$N_{PAD,PRE-FEC,MAC} = \left\lfloor \frac{N_{PAD,PRE-FEC}}{8} \right\rfloor \cdot 8$$
$$N_{PAD,PRE-FEC,PHY} = N_{PAD,PRE-FEC} \bmod 8 \quad (26\text{-}67)$$

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26.3.10.3 SERVICE field

The SERVICE field of HE PPDU is as shown in Table 26-23 (SERVICE field).

Table 26-23—SERVICE field

Bits	Field	Description
B0-B6	Scrambler Initialization	Set to 0
B7-B15	Reserved	Set to 0

26.3.10.4 Coding

The Data field shall be encoded using either the binary convolutional code (BCC) defined in 26.3.10.3.1 or the low density parity check (LDPC) code defined in 25.3.10.3.2 (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 a HE MU PPDU, as defined in 26.3.9.7 (HE-SIG-A) and 26.3.9.8 (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-RU, a 996-RU or a 996x2-RU. Support of BCC code is limited to less than or equal to four spatial streams (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-RU. 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, or for HE STAs declaring support for more than 4 spatial streams, according to HE capabilities field as defined in 9.4.2.213 (HE Capabilities element). Otherwise, support of LDPC code for either transmit or receive is optional.

26.3.10.4.1 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 18.3.5.6 (Convolutional encoder). After encoding, the encoded data is punctured by the method defined in 18.3.5.6 (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 20.3.11.6 (Binary convolutional coding and puncturing).

The initial number of OFDM symbols in the Data field with BCC encoding in a HE SU PPDU is calculated as in Equation 26-68.

$$N_{SYM,\,init} = m_{STBC} \cdot \left\lceil \frac{8 \cdot \text{APEP\_LENGTH} + N_{Tail} N_{ES} + N_{service}}{m_{STBC} N_{DBPS}} \right\rceil \quad (26\text{-}68)$$

For a HE SU PPDU with BCC encoding,

$$N_{SYM} = N_{SYM.init} \quad (26\text{-}69)$$

and

$$a = a_{init} \quad (26\text{-}70)$$

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The number of coded bits per symbol in the last OFDM symbol(s) of a HE SU PPDU is

$$N_{CBPS,LAST} = \begin{cases} a \cdot N_{CBPS,SHORT}, & \text{if } a < 4 \\ N_{CBPS}, & \text{if } a = 4 \end{cases} \quad (26\text{-}71)$$

26.3.10.4.2 LDPC coding

For a HE SU PPDU using LDPC coding to encode the Data field, the LDPC code and encoding process described in 20.3.11.7 (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. Thus, N_{pld} for HE PPDUs shall be computed using Equation 26-72 instead of Equation (20-35).

$$N_{pld} = (N_{SYM.init} - m_{STBC}).N_{DBPS} + m_{STBC}.N_{DBPS.LAST.init} \quad (26\text{-}72)$$

where

$$N_{SYM.init} = m_{STBC}.\left\lceil \frac{8.APEP\_LENGTH + N_{service}}{m_{STBC}.N_{DBPS}} \right\rceil \quad (26\text{-}73)$$

Following the calculation of N_{pld}, N_{avbits} shall be computed using Equation 26-74 instead of Equation (20-36).

$$N_{avbits} = (N_{SYM,init} - m_{STBC}) \cdot N_{CBPS} + m_{STBC} \cdot N_{CBPS,LAST,init} \quad (26\text{-}74)$$

In addition, in step d) of LDPC encoding process as described in clause 20.3.11.7.5 (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 OFDM Symbol field of HE-SIG-A shall be set to 1, and increment N_{avbits} by the following Equation 26-75 instead of Equations (20-39), followed by recomputing N_{punc} as in Equation (20-40):

$$N_{avbits} = \begin{cases} N_{avbits} + m_{STBC}.\left(N_{CBPS} - 3.N_{CBPS.SHORT}\right), & \text{if } a_{init} = 3 \\ N_{avbits} + m_{STBC}.N_{CBPS.SHORT}, & \text{otherwise} \end{cases} \quad (26\text{-}75)$$

and then update a and N_{SYM} values by the following Equation 26-76:

$$\begin{cases} N_{SYM} = N_{SYM.init} + m_{STBC}, \text{ and } a = 1, & \text{if } a_{init} = 4 \\ N_{SYM} = N_{SYM.init}, \text{ and } a = a_{init} + 1, & \text{otherwise} \end{cases} \quad (26\text{-}76)$$

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If in step d) of LDPC encoding process as described in clause 20.3.11.7.5 (LDPC PPDU encoding process), the above mentioned condition is not met, then the LDPC Extra OFDM Symbol field of HE-SIG-A shall be set to 0, and:

$$a = a_{init}, N_{SYM} = N_{SYM, init} \tag{26-77}$$

With the final *a-factor* value a, update the N_{CBPS} of the last symbol as:

$$N_{CBPS.LAST} = \begin{cases} a \cdot N_{CBPS.SHORT}, & \text{if } a < 4 \\ N_{CBPS}, & \text{if } a = 4 \end{cases} \tag{26-78}$$

LDPC codes used in HE MU PPDUs shall also follow the definitions in 20.3.11.7 (LDPC codes). Refer to 25.3.10.3.4 (Encoding process for HE MU PPDUs) for a description of the LDPC encoding process for HE MU PPDUs.

26.3.10.4.3 Post-FEC padding

The number of post-FEC padding bits in each of the last m_{STBC} symbol(s) is computed by:

$$N_{PAD.POST\text{-}FEC} = N_{CBPS} - N_{CBPS.LAST} \tag{26-79}$$

$N_{PAD.POST\text{-}FEC}$ bits with arbitrary 0 or 1 values (TBD) are appended after the FEC output bits in each of the last m_{STBC} OFDM symbols.

26.3.10.4.4 Encoding process for an HE MU PPDU

For an HE MU PPDU, all the users shall use a common *a-factor* value and a common N_{SYM} value. The padding process is described as follows.

First compute initial *a-factor* value ($a_{init,u}$) for each user u using Equation 26-63, and the initial number of OFDM symbols ($N_{init,u}$) for each user u using Equation 26-68 if user u is BCC encoded, or Equation 26-73 if user u is LDPC encoded. Among all the users, derive the user index with the longest encoded packet duration, as in Equation 26-80.

$$u_{\max} = \arg\max_{u=0}^{N_U-1}(N_{SYM.init.u} - m_{STBC} + 0.25.m_{STBC}.a_{init.u}) \tag{26-80}$$

where m_{STBC} is the common STBC setting among all the users, as described in 26.3.10.8.

Then the common a_{init} and N_{init} values among all the users are derived by Equation 26-81:

$$\begin{aligned} N_{SYM.init} &= N_{SYM.init.u_{\max}} \\ a_{init} &= a_{init.u_{\max}} \end{aligned} \tag{26-81}$$

Update each user's initial number of coded bits in its last symbol as below:

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$$N_{DBPS.LAST.init.u} = \begin{cases} a_{init}.N_{DBPS.SHORT.u}, & \text{if } a_{init} < 4 \\ N_{DBPS.u}, & \text{if } a_{init} = 4 \end{cases}$$
$$N_{CBPS.LAST.init.u} = \begin{cases} a_{init}.N_{CBPS.SHORT.u}, & \text{if } a_{init} < 4 \\ N_{CBPS.u}, & \text{if } a_{init} = 4 \end{cases} \quad (26\text{-}82)$$

For each user with LDPC encoding, the number of pre-FEC padding bits is computed as in Equation 26-83:

$$N_{PAD,PRE-FEC,u} = (N_{SYM.init} - m_{STBC}).N_{DBPS.u} + m_{STBC}.N_{DBPS.LAST.init.u} - 8APEP\_LENGTH_u - N_{service} \quad (26\text{-}83)$$

For each user with LDPC encoding, the parameters $N_{pld,u}$ and $N_{avbits,u}$ are computed using Equation 26-84 and Equation 26-85 respectively:

$$N_{pld,u} = (N_{SYM.init} - m_{STBC}).N_{DBPS,u} + m_{STBC}.N_{DBPS.LAST.init,u} \quad (26\text{-}84)$$

$$N_{avbits,u} = (N_{SYM.init} - m_{STBC}).N_{CBPS,u} + m_{STBC}.N_{CBPS.LAST.init,u} \quad (26\text{-}85)$$

Each user with LDPC encoding continue LDPC encoding process as in clause 20.3.11.7.5 (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 clause 20.3.11.7.5 (LDPC PPDU encoding process), meets the following condition:

$(N_{punc,u} > 0.1 \times N_{CW,u} \times L_{LDPC,u} \times (1 - R_u))$ AND $\left(N_{shrt,u} < 1.2 \times N_{punc,u} \times \frac{R_u}{1 - R_u}\right)$ is true OR if

$N_{punc,u} > 0.3 \times N_{CW,u} \times L_{LDPC,u} \times (1 - R_u)$ 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 20.3.11.7.5 (LDPC PPDU encoding process), and R_u is the coding rate of user u, then the LDPC Extra symbol bit 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:

$$N_{avbits,u} = \begin{cases} N_{avbits,u} + m_{STBC}.\left(N_{CBPS,u} - 3.N_{CBPS.SHORT,u}\right), & \text{if } a_{init} = 3 \\ N_{avbits,u} + m_{STBC}.N_{CBPS.SHORT,u}, & \text{otherwise} \end{cases} \quad (26\text{-}86)$$

$$N_{punc,u} = \max\left(0,\ (N_{CW,u} \times L_{LDPC,u}) - N_{avbits,u} - N_{shrt,u}\right) \quad (26\text{-}87)$$

Update the common *a-factor* and N_{SYM} values for all users by the following equation:

$$\begin{cases} N_{SYM} = N_{SYM.init} + m_{STBC}, \text{ and } a = 1, & \text{if } a_{init} = 4 \\ N_{SYM} = N_{SYM.init}, \text{ and } a = a_{init} + 1, & \text{otherwise} \end{cases} \quad (26\text{-}88)$$

Note that users with BCC encoding shall also use the common N_{SYM} and a parameters as in Equation 26-76.

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If among all the users with LDPC encoding, in step d) of clause 20.3.11.7.5 (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 bit in HE-SIG-A shall be set to 0, and:

$$a = a_{init}, N_{SYM} = N_{SYM, init} \tag{26-89}$$

Update the N_{CBPS} and N_{DBPS} of the last symbol for each user as:

$$N_{DBPS.LAST.u} = \begin{cases} a.N_{DBPS.SHORT.u}, & \text{if } a < 4 \\ N_{CBPS.u}, & \text{if } a = 4 \end{cases}$$
$$N_{CBPS.LAST.u} = \begin{cases} a.N_{CBPS.SHORT.u}, & \text{if } a < 4 \\ N_{CBPS.u}, & \text{if } a = 4 \end{cases} \tag{26-90}$$

For the users with BCC encoding, the number of pre-FEC padding bits is shown in Equation (26 91).

$$N_{PAD,PRE-FEC,u} = (N_{SYM} - m_{STBC}).N_{DBPS.u} + m_{STBC}.N_{DBPS.LAST.u} - 8APEP\_LENGTH_u - N_{Tail} - N_{service} \tag{26-91}$$

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 26-92:

$$N_{PAD,POST-FEC,u} = m_{STBC}.(N_{CBPS,u} - N_{CBPS.LAST,u}) \tag{26-92}$$

26.3.10.4.5 Encoding process for an HE trigger-based PPDU

The AP indicates the common N_{SYM}, *a-factor*, STBC indication and LDPC Extra Symbol 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 25.3.10.1.1 (pre-FEC padding process), 26.3.10.4.1 (Binary convolutional coding and puncturing), and 26.3.10.4.3 (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 *a-factor* parameters 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 26.3.10.2 (Pre-FEC encoding process), 26.3.10.4.2 (LDPC coding), and 26.3.10.4.3 (Post-FEC padding), with the following exceptions:

When the Trigger frame indicates LDPC Extra Symbol = 1, set the initial parameters following Equation 26-93:

$$\begin{cases} a_{init} = 4, \ N_{SYM.init} = N_{SYM} - m_{STBC}, & \text{if } a = 1 \\ a_{init} = a - 1, \ N_{SYM.init} = N_{SYM}, & \text{otherwise} \end{cases} \tag{26-93}$$

where N_{SYM} and a are the common number of symbols and *a-factor* parameters indicated in the Trigger frame respectively, and m_{STBC} is 2 if the Trigger frame indicates STBC and 1 otherwise. Then continue with

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the LDPC encoding process as in clause 20.3.11.7.5 (LDPC PPDU encoding process), during which in step d) of clause 20.3.11.7.5 (LDPC PPDU encoding process), always increment N_{avbits} as in Equation 26-75, and always recompute N_{punc} as in Equation (20-40), followed by updating $a = a_{init} + 1$ if $a_{init} < 4$, or $a = 1$ if $a_{init} = 4$.

When the Trigger frame indicates LDPC Extra Symbol = 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 a-factor parameters indicated in the Trigger frame respectively. Then continue with the LDPC encoding process as in clause 20.3.11.7.5 (LDPC PPDU encoding process), during which in step d) of clause 20.3.11.7.5 (LDPC PPDU encoding process), N_{avbits} and N_{punc} are not changed, and $a = a_{init}$.

26.3.10.5 Stream parser

After coding, 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 a HE MU transmission). This operation is referred to as "stream parsing" and is described in this section.

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 26-94.

$$s = max(1, \frac{N_{BPSCS}}{2}) \quad (26\text{-}94)$$

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.

Let

$$N_{\text{Block}} = \left\lfloor \frac{N_{CBPS}}{S} \right\rfloor \quad (26\text{-}95)$$

For the $N_{\text{Block}}.S$ 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 in all the different RU sizes, $N_{CBPS} = N_{\text{Block}}.S$, therefore 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

$$i = \left(i_{SS} - 1\right)s + S \cdot \left\lfloor \frac{k}{s} \right\rfloor + k \bmod s, \quad k = 0,1,\ldots, N_{Block} \cdot s - 1$$

where

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$i_{SS} = 1,\ 2,\ \ldots,\ N_{SS}$

$i = 0,\ 1,\ \ldots,\ N_{CBPS} - 1$

$k = 0,\ 1,\ \ldots,\ N_{CBPS} - 1$

26.3.10.6 Segment parser

For a 160 MHz and 80+80 MHz HE SU PPDU, a 160 MHz and 80+80 MHz HE MU PPDU, and a HE trigger-based PPDU with the RU spanning the entire PPDU bandwidth, the output bits of each stream parser are segment parsed as specified in 22.3.10.7.

26.3.10.7 BCC interleavers

Editor's Note: There is some duplication here. I think we need to delete the Table 25-24 and its reference sentence.

The BCC interleaver parameters are defined in Table 26-24 (BCC interleaver and LDPC tone mapper parameter).

Table 26-24—BCC interleaver and LDPC tone mapper parameter

RU Size (tones)	BCC		LDPC
	N_{col}	N_{rot}	D_{TM}
26	8	2	1
52	16	11	3
106	17	29	6
242	26	58	9
484	-	-	12
996	-	-	20

For ease of explanation, the operation of the interleaver is described only for the SU case. For user u in the r-th RU 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_{CBPSSI}, and N_{BPSCS} with $N_{SS,r,u}$, $N_{CBPSS,r,u}$, $N_{CBPSSI,r,u}$ and $N_{BPSCS,r,u}$, 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.

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The BCC interleaver operation is specified in 22.3.10.8 (BCC interleaver). The values of the interleaver parameters, N_{COL}, N_{ROW}, and N_{ROT} are selected based on the RU size of the user, and are given in Table 26-25 (BCC interleaver parameters).

Table 26-25—BCC interleaver parameters

Parameter	RU Size (tones)			
	26	52	106	242
N_{COL}	8	16	17	26
N_{ROW}	$3 \times N_{BPSCS}$	$3 \times N_{BPSCS}$	$6 \times N_{BPSCS}$	$9 \times N_{BPSCS}$
N_{ROT} ($N_{SS} \leq 4$)	2	11	29	58

26.3.10.8 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 22.3.10.9 (constellation mapping).

1024-QAM is used as an optional feature for SU and MU using resource units equal to or larger than 242 tones in 11ax. For 1024-QAM, the constellation mapping is TBD.

Dual sub-carrier modulation (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.

When DCM is employed, bit sequences are mapped to a pair symbols $(d_k, d_{q(k)})$ where k is in the range of $0 \leq k \leq \frac{N_{SD}}{2} - 1$ and $q(k)$ is in the range of $\frac{N_{SD}}{2} \leq k \leq N_{SD} - 1$ in order to exploit frequency diversity. To maximize the frequency diversity, the indices of a pair of DCM subcarriers $(k, q(k))$ is $q(k) = k + N_{SD}/2$.

For QPSK modulation with DCM, the input stream is broken into groups of N_{CBPS} or $N_{CBPS,ru}$ bits $(B_0, B_1, \ldots, B_{N_{CBPS,ru}-1})$. 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 subcarriers in the RU, $d_{q(k)} = conj(d_k)$.

For BPSK and 16-QAM modulation with DCM, the constellation mapping is TBD.

26.3.10.9 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 (TBD: undecided whether in HE-SIG-A for HE_MU). 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 clause 22.3.10.9.4 (Space-time block coding), with $N_{SS,0} = 1$ and $N_{STS,0} = 2$.

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26.3.10.10 LDPC tone mapper

The LDPC tone mapper parameters are defined in Table 26-24 (BCC interleaver and LDPC tone mapper parameter).

The LDPC tone mapping shall be performed on all LDPC encoded streams mapped in a 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, DTM_DCM shall be applied on both the lower half data subcarriers in a RU and the upper half data subcarriers of the RU. The LDPC tone-mapping distance parameter D_{TM} and D_{TM_DCM} are constant for each RU size and the values for different RU sizes are given in Table 26-26 (LDPC tone mapping distance for each RU size).

Table 26-26—LDPC tone mapping distance for each RU size

Parameter	RU Size (tones)						
	26	52	106	242	484	996	2x996
D_{TM}	1	3	6	9	12	20	20
D_{TM_DCM}	1	1	3	9	9	14	20

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 26.3.10.7) to

$$d''_{t(k),i,n,l,r,u} = d'_{k,i,n,l,r,u};\ k = 0,1,\ldots,N_{SD}-1 \text{ for a RU of 26, 52, 106, 242, 484, and 996 tones}$$
$$k = 0,1,\ldots,\frac{N_{SD}}{2}-1 \text{ for a RU of } 996\times 2 \text{ to}nes$$
$$i = 1,\ldots,N_{SS,r,u}$$
$$n = 0,1,\ldots,N_{SYM}-1$$
$$l = 0 \text{ for a RU of 26, 52, 106, 242, 494, and 996 tones}$$
$$l = 0,1 \text{ for a RU of } 996\times 2 \text{ tones}$$
$$u = 0,\ldots,N_{user,r}-1$$
$$r = 0,\ldots,N_{RU}-1 \qquad \text{(26-96)}$$

where N_{SD} is the number of data tones in the r-th RU.

$$t(k) = \begin{cases} D_{TM}\left(k \bmod \frac{N_{SD}}{D_{TM}}\right) + \left\lfloor \frac{k\cdot D_{TM}}{N_{SD}} \right\rfloor, & \text{for a RU of 26, 52, 106, 242, 484, and 996 tones} \\ D_{TM}\left(k \bmod \frac{N_{SD}/2}{D_{TM}}\right) + \left\lfloor \frac{k\cdot D_{TM}}{N_{SD}/2} \right\rfloor, & \text{for a RU of } 996\times 2 \text{ tones} \end{cases} \qquad \text{(26-97)}$$

For a 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) to

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$$d''_{t(k),i,n,l,r,u} = \begin{cases} d'_{k,i,n,l,r,u}; \\ d'_{k',i,n,l,r,u}; \end{cases} \quad (26\text{-}98)$$

where

$k = 0,1,...,\frac{N_{SD}}{2} - 1$

$k' = k - \frac{N_{SD}}{2}, for\, k = \frac{N_{SD}}{2}, \frac{N_{SD}}{2} + 1, ..., N_{SD}\text{-}1$

$i = 1, \ldots, N_{SS,r,u}$

$n = 0,1, \ldots, N_{SYM} - 1$

$l = 0$ for a RU of 26, 52, 106, 242, 494, and 996 tones

$l = 0,1$ for a RU of 996×2 tones

$u = 0, \ldots, N_{user,r} - 1$

$r = 0, \ldots, N_{RU} - 1$

N_{SD} is the number of data tones in the *r*-th RU and

$$t(k) = \begin{cases} D_{TM\_DCM}\left(k \bmod \frac{N_{SD}/2}{D_{TM\_DCM}}\right) + \left\lfloor \frac{k \cdot D_{TM\_DCM}}{N_{SD}/2} \right\rfloor, & \text{for a RU of 26, 52, 106, 242, 484, and 996 tones} \\ D_{TM\_DCM}\left(k' \bmod \frac{N_{SD}/2}{D_{TM\_DCM}}\right) + \left\lfloor \frac{k' \cdot D_{TM\_DCM}}{N_{SD}/2} \right\rfloor + \frac{N_{SD}}{2}, & \text{for a RU of 26, 52, 106, 242, 484, and 996 tones} \\ D_{TM\_DCM}\left(k \bmod \frac{N_{SD}/2}{D_{TM\_DCM}}\right) + \left\lfloor \frac{k \cdot D_{TM\_DCM}}{N_{SD}/2} \right\rfloor, & \text{for a RU of } 996 \times 2 \text{ tones} \end{cases} \quad (26\text{-}99)$$

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 segement. LDPC tone mapping is performed separately for the upper and lower 80 MHz frequency segments of a 2x996-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, the following applies:

$d''_{k,i,n,l,r,u} = d'_{k,i,n,l,r,u}$; $k = 0,1,...,N_{SD} - 1$ for a RU of 26, 52, 106, 242, 484, and 996 tones

$k = 0,1,...,\frac{N_{SD}}{2} - 1$ for a RU of 996×2 to*nes*

$i = 1, \ldots, N_{SS,r,u}$

$n = 0,1, \ldots, N_{SYM} - 1$

$l = 0$ for a RU of 26, 52, 106, 242, 494, and 996 tones

$l = 0,1$ for a RU of 996×2 tones

$u = 0, \ldots, N_{user,r} - 1$

$r = 0, \ldots, N_{RU} - 1$ (26-100)

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26.3.10.11 Segment deparser

In a transmission over a RU of 26, 52, 106, 242, 484 and 996 subcarriers, the segment deparsing is not performed (see EEquation 26-90).

For a 160 MHz HE SU PPDU, or a 160 MHz HE MU PPDU or HE trigger-based PPDU with the RU spanning the entire PPDU bandwidth, the two frequency subblocks at the output of the LDPC tone mapper are combined into one frequency segment as specified in Equation 26-89.

In an 80+80 MHz HE PPDU transmission, the segment deparsing is not performed (see Equation 26-91).

26.3.10.12 Pilot subcarriers

For a user transmitting on the *i*-th 26-tone RU in a given PPDU BW, two pilot tones shall be inserted in subcarriers $k \in K_{R26_i}$, where K_{R26_i} is given by *i*-th pilot index set in the row of given PPDU BW of Table 26-27 (Pilot indices for 26-tone RU transmission).

Table 26-27—Pilot indices for 26-tone RU transmission

PPD 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
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 tone indices in 80 MHz −512, pilot tone indices in 80 MHz +512}

The pilot mapping P_k^k for subcarrier *k* for symbol *n* shall be as specified in Equation 26-101.

$$P_n^{K_{\mathrm{R26}_i}} = \{\Psi_{i,n \bmod 2}, \Psi_{i,(n+1) \bmod 2}\}$$
$$P_n^{k \notin K_{\mathrm{R26}_i}} = 0 \qquad (26\text{-}101)$$

where

$\Psi_{i,m}$ is TBD for Pilot values for *i*-th 26-tone RU in a given PPDU BW.

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For a user transmitting on the *i*-th 52-tone RU in a given PPDU BW, four pilot tones shall be inserted in subcarriers $k \in K_{R52_i}$, where K_{R52_i} is given by *i*-th pilot index set in the row of given PPDU BW of Table 26-28 (Pilot indices for 52-tone RU transmission).

Table 26-28—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 tone indices in 80 MHz −512, pilot tone indices in 80 MHz +512}

The pilot mapping P_k^k for subcarrier *k* for symbol *n* shall be as specified in Equation 26-102.

$$P_n^{K_{R52_i}} = \{\Psi_{i,n \bmod 4}, \Psi_{i,(n+1) \bmod 4}, \Psi_{i,(n+2) \bmod 4}, \Psi_{i,(n+3) \bmod 4}\}$$
$$P_n^{k \notin K_{R52_i}} = 0 \qquad (26\text{-}102)$$

where

$\Psi_{i,m}$ is TBD for pilot values for the *i*-th 52-tone RU in a given PPDU BW.

For a user transmitting on the *i*-th 106-tone RU in a given PPDU BW, four pilot tones shall be inserted in subcarriers $k \in K_{R106_i}$, where K_{R106_i} is given by *i*-th pilot index set in the row of given PPDU BW of Table 26-29 (Pilot indices for 106-tone RU transmission).

Table 26-29—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 tone indices in 80 MHz −512, pilot tone indices in 80 MHz +512}

The pilot mapping P_k^k for subcarrier *k* for symbol *n* shall be as specified in Equation 26-103.

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$$P_n^{K_{\mathrm{R106}_i}} = \{\Psi_{i,n \bmod 4}, \Psi_{i,(n+1) \bmod 4}, \Psi_{i,(n+2) \bmod 4}, \Psi_{i,(n+3) \bmod 4}\}\}$$
$$P_n^{k \notin K_{\mathrm{R106}_i}} = 0 \quad (26\text{-}103)$$

where

$\Psi_{i,m}$ is TBD for pilot values for the *i*-th 106-tone RU in a given PPDU BW.

For a user transmitting on the *i*-th 242-tone RU in a given PPDU BW, eight pilot tones shall be inserted in subcarriers $k \in K_{R242_i}$, where K_{R242_i} is given by *i*-th pilot index set in the row of given PPDU BW of Table 26-30 (Pilot indices for 242-tone RU transmission).

Table 26-30—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 tone indices in 80 MHz −512, pilot tone indices in 80 MHz +512}

The pilot mapping P_k^k for subcarrier *k* for symbol *n* shall be as specified in Equation 26-104.

$$P_n^{K_{\mathrm{R242}_i}} = \{\Psi_{i,n \bmod 8}, \Psi_{i,(n+1) \bmod 8}, \Psi_{i,(n+2) \bmod 8}, \Psi_{i,(n+3) \bmod 8}, \Psi_{i,(n+4) \bmod 8}, \Psi_{i,(n+5) \bmod 8}, \Psi_{i,(n+6) \bmod 8}, \Psi_{i,(n+7) \bmod 8}\}$$
$$P_n^{k \notin K_{\mathrm{R242}_i}} = 0 \quad (26\text{-}104)$$

where

$\Psi_{i,m}$ is TBD for pilot values for the *i*-th 242-tone RU in a given PPDU BW.

For a user transmitting on the *i*-th 484-tone RU in a given PPDU BW, sixteen pilot tones shall be inserted in subcarriers $k \in K_{R484_i}$, where K_{R484_i} is given by *i*-th pilot index set in the row of given PPDU BW of Table 26-31 (Pilot indices for 484-tone RU transmission).

Table 26-31—Pilot indices for 484-tone RU transmission

PPD BW	K_{R484_i}
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 tone indices in 80 MHz −512, pilot tone indices in 80 MHz +512}

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The pilot mapping P_k^k for subcarrier *k* for symbol *n* shall be as specified in Equation 26-105.

$$P_n^{K_{\mathrm{R484}_i}} = \{\Psi_{i,n \bmod 8}, \Psi_{i,(n+1) \bmod 8}, \Psi_{i,(n+2) \bmod 8}, \Psi_{i,(n+3) \bmod 8}, \Psi_{i,(n+4) \bmod 8}, \Psi_{i,(n+5) \bmod 8}, \Psi_{i,(n+6) \bmod 8}, \Psi_{i,(n+7) \bmod 8}, \cdots$$
$$\Psi_{i,(n+8) \bmod 8}, \Psi_{i,(n+9) \bmod 8}, \Psi_{i,(n+10) \bmod 8}, \Psi_{i,(n+11) \bmod 8}, \Psi_{i,(n+12) \bmod 8}, \Psi_{i,(n+13) \bmod 8}, \Psi_{i,(n+14) \bmod 8}, \Psi_{i,(n+15) \bmod 8}\}$$
$$P_n^{k \notin K_{\mathrm{R484}_i}} = 0 \qquad (26\text{-}105)$$

where

$\Psi_{i,m}$ is TBD for pilot values for the *i*-th 484-tone RU in a given PPDU BW.

For a user transmitting on the *i*-th 996-tone RU in a given PPDU BW, sixteen pilot tones shall be inserted in subcarriers $k \in K_{R996_i}$, where K_{R996_i} is given by *i*-th pilot index set in the row of given PPDU BW of Table 26-32 (Pilot indices for 996-tone RU transmission).

Table 26-32—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	{pilot tone indices in 80 MHz −512, pilot tone indices in 80 MHz +512}: −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_k^k for subcarrier *k* for symbol *n* shall be as specified in Equation 26-106.

$$P_n^{K_{\mathrm{R996}_i}} = \{\Psi_{i,n \bmod 8}, \Psi_{i,(n+1) \bmod 8}, \Psi_{i,(n+2) \bmod 8}, \Psi_{i,(n+3) \bmod 8}, \Psi_{i,(n+4) \bmod 8}, \Psi_{i,(n+5) \bmod 8}, \Psi_{i,(n+6) \bmod 8}, \Psi_{i,(n+7) \bmod 8}, \cdots$$
$$\Psi_{i,(n+8) \bmod 8}, \Psi_{i,(n+9) \bmod 8}, \Psi_{i,(n+10) \bmod 8}, \Psi_{i,(n+11) \bmod 8}, \Psi_{i,(n+12) \bmod 8}, \Psi_{i,(n+13) \bmod 8}, \Psi_{i,(n+14) \bmod 8}, \Psi_{i,(n+15) \bmod 8}\}$$
$$P_n^{k \notin K_{\mathrm{R996}_i}} = 0 \qquad (26\text{-}106)$$

where

$\Psi_{i,m}$ is TBD for pilot values for the *i*-th 996-tone RU in a given PPDU BW.

For a 160 MHz transmission, the 80 MHz pilot mapping is replicated in the two 80 MHz subchannels of the 160 MHz transmission. Specifically, thirty-two pilot tones 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 Pnk for subcarrier *k* for symbol *n* shall be as specified in Equation 26-107.

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$$
\begin{aligned}
P_n^{K_{\mathrm{R2x996}}} &= \{\Psi_{i,n \bmod 8}, \Psi_{i,(n+1) \bmod 8}, \Psi_{i,(n+2) \bmod 8}, \Psi_{i,(n+3) \bmod 8}, \Psi_{i,(n+4) \bmod 8}, \Psi_{i,(n+5) \bmod 8}, \Psi_{i,(n+6) \bmod 8}, \Psi_{i,(n+7) \bmod 8}, \cdots \\
&\quad \Psi_{i,(n+8) \bmod 8}, \Psi_{i,(n+9) \bmod 8}, \Psi_{i,(n+10) \bmod 8}, \Psi_{i,(n+11) \bmod 8}, \Psi_{i,(n+12) \bmod 8}, \Psi_{i,(n+13) \bmod 8}, \Psi_{i,(n+14) \bmod 8}, \Psi_{i,(n+15) \bmod 8}, \cdots \\
&\quad \Psi_{i,n \bmod 8}, \Psi_{i,(n+1) \bmod 8}, \Psi_{i,(n+2) \bmod 8}, \Psi_{i,(n+3) \bmod 8}, \Psi_{i,(n+4) \bmod 8}, \Psi_{i,(n+5) \bmod 8}, \Psi_{i,(n+6) \bmod 8}, \Psi_{i,(n+7) \bmod 8}, \cdots \\
&\quad \Psi_{i,(n+8) \bmod 8}, \Psi_{i,(n+9) \bmod 8}, \Psi_{i,(n+10) \bmod 8}, \Psi_{i,(n+11) \bmod 8}, \Psi_{i,(n+12) \bmod 8}, \Psi_{i,(n+13) \bmod 8}, \Psi_{i,(n+14) \bmod 8}, \Psi_{i,(n+15) \bmod 8}\} \\
P_n^{k \notin K_{\mathrm{R2x996}}} &= 0
\end{aligned}
\tag{26-107}
$$

where

$\Psi_{i,\,m}$ is TBD for pilot values for the *i*-th 996-tone RU in a given PPDU BW.

For a noncontiguous 80+80 MHz transmission, each frequency segment shall follow the 80 MHz pilot tone allocation and values defined for 996-tone RU in 80 MHz transmission as specified in Equation 26-106 and TBD pilot values for 996-tone RU in 80 MHz PPDU BW.

The above pilot mapping shall be copied to all space-time streams before the space-time stream cyclic shifts are applied.

26.3.10.13 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}, $1 \le i_{TX} \le N_{TX}$, shall be as defined in Equation 26-108.

$$
\begin{aligned}
r_{\text{HE-Data}}^{(i_{seg}, i_{TX})}(t) = {} & \frac{1}{\sqrt{\sum_{r=1}^{N_{RU}} \alpha_r^2 \left| K_r \right|}} \sum_{n=0}^{N_{SYM}-1} w_{T_{HE-Data}}\left(t - nT_{SYM}\right) \sum_{r=0}^{N_{RU}-1} \frac{\alpha_r}{\sqrt{N_{STS,r,total}}} \\
& \cdot \sum_{k \in K_r} \sum_{u=0}^{N_{user,r}-1} \sum_{m=1}^{N_{STS,r,u}} \left(\begin{array}{l} \left[Q_k^{(i_{seg})} \right]_{i_{TX}, (M_{r,u}+m)} \left(\tilde{D}_{k,m,n,r}^{(i_{Seg},u)} + p_{n+2+N_{HE-SIG-A}+N_{HE-SIG-B}} P_n^k \right) \\ \cdot \exp\left(j2\pi k \Delta_{F,HE} \left(t - nT_{SYM} - T_{\text{GI,Data}} - T_{CS,HE}\left(M_{r,u}+m\right) \right) \right) \end{array} \right)
\end{aligned}
\tag{26-108}
$$

where

p_n is defined in 18.3.5.10 (OFDM modulation)

P_n^k is defined in Error! Reference source not found.

$\tilde{D}_{k,\,m,\,n,\,BW}^{(i_{Seg,\,r,\,u})}$ 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 in Error! Reference source not found..

$N_{\text{HE-Data}}^{\text{Tone}}$ has the value given in Error! Reference source not found.

$T_{CS,\,HE}(n)$ is given in 26.3.9.2 (Cyclic shift for Pre-HE modulated fields)

$T_{\text{GI,Data}}$ is the guard interval duration as defined in Table 26-3 (Timing-related constants)

$$
\tilde{D}_{k,m,n,r}^{(i_{Seg},u)} = \begin{cases} 0, k \in K_{\text{Pilot}} \\ \tilde{d}_{M_r(k),m,n,r,u}^{(i_{Seg})}, \text{otherwise} \end{cases}
\tag{26-109}
$$

where

K_{Pilot} is the set of subcarrier indices of pilot tones, as defined in 26.3.7.3 (Pilot tones)

$M_r(k)$ is defined in Equation 26-110

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$$M_r(k) = k - K_{r,\min} - \left| \left\{ k' : K_{r,\min} \le k' < k \right\} \cap K_{\text{Pilot}} \right| \quad (26\text{-}110)$$

where

$K_{r,min}$ is the minimum value of the set K_r.

$|\Phi|$ is the cardinality of a set Φ

NOTE – Mr(k) translates a subcarrier index k ($-N_{SR} \le k \le N_{SR}$) into the index of data symbols in a transmission over a 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 tones 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 26.3.7 (OFDMA and SU tone allocation).

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 26-111.

$$r_{\text{HE-Data}}^{(i_{seg}, i_{TX})}(t) = \frac{\alpha_r}{\sqrt{\sum_{r=1}^{N_{RU}} \alpha_r^2 |K_r|}} \sum_{n=0}^{N_{SYM}-1} w_{T_{HE-Data}}(t - nT_{SYM}) \frac{1}{\sqrt{N_{STS,r,total}}} \cdot \sum_{k \in K_r} \sum_{m=1}^{N_{STS,r,u}} \left(\left[Q_k^{(i_{seg})} \right]_{i_{TX}, (M_{r,u}+m)} \left(\tilde{D}_{k,m,n,r}^{(i_{Seg},u)} + p_{n+4} P_n^k \right) \cdot \exp\left(j2\pi k \Delta_{F,HE} \left(t - nT_{SYM} - T_{\text{GI,Data}} - T_{CS,HE} \left(M_{r,u} + m \right) \right) \right) \right) \quad (26\text{-}111)$$

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 $Q_k^{(i_{Seg})}$.

26.3.10.14 Dual carrier modulation

Dual sub-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 26.3.10.8 (Constellation mapping). The DCM tone mapper is TBD.

26.3.10.15 Packet extension

A 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 (PE content TBD).

The PE field is applied for the recipient of the PPDU to obtain longer processing time at the end of a HE PPDU, and its duration is determined by both the *a-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

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number of spatial streams, and the constellation size of the current PPDU, which is based on the Maximum PE capabilities as defined in HE capabilities field (8.4.2.1 (HE Capabilities Element)).

For a HE PPDU, the maximum PE durations as defined by the Maximum PE capabilities in HE capabilities (8.4.2.1 (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-factor* being 1, 2, 3 and 4, respectively, as shown in Figure 26-34 (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-factor* being 1, 2, 3 and 4, respectively, as shown in Figure 26-35 (PE field when maximum PE duration is 16 µs (non STBC)).

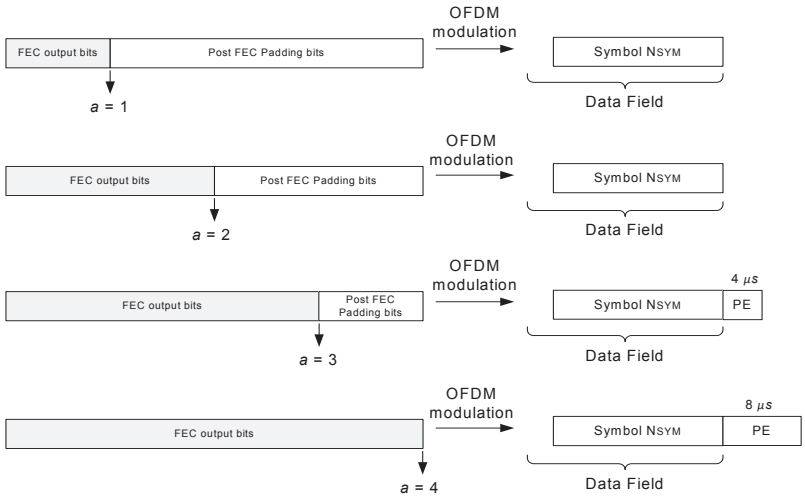


Figure 26-34—PE field when maximum PE duration is 8 µs (non STBC)

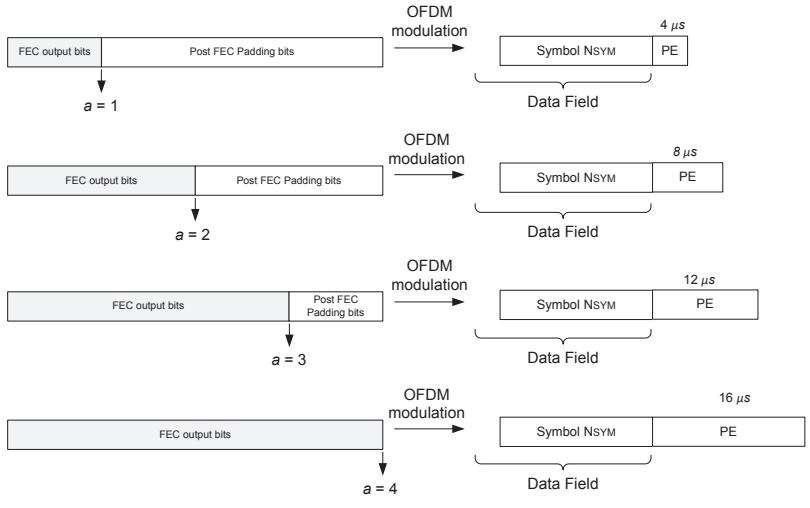


Figure 26-35—PE field when maximum PE duration is 16 µs (non STBC)

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For an HE MU PPDU, the AP computes the PE duration, $T_{PE,u}$, for each user u, according to the common a-factor value among all users as described in 26.3.10.4.4 (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:

$$T_{PE} = \max_{u}\left(T_{PE,u}\right) \tag{26-112}$$

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 common PE duration, T_{PE}, for all the users in the Trigger frame. Each user, when responding 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 TPE is TBD.

Editor's Note: The HE-SIG-A bits definition below should be moved into 26.3.9.7 (HE-SIG-A)

The 3-bit Packet Extension field in HE-SIG-A are defined as in Table 26-33 (Packet Extension field in HE-SIG-A).

Table 26-33—Packet Extension field in HE-SIG-A

Name	bits	Definition
a-factor	B0-B1	Indicates a-factor value of current PPDU
PE Disambiguity	B2	Indicates PE disambiguity

The a-factor subfield of the Packet Extension field is encoded as shown in Table 26-34 (a-factor subfield encoding).

Table 26-34—a-factor subfield encoding

a-factor value	a-factor subfield encoding
1	b01
2	b10
3	b11
4	b00

The PE Disabmbituity subfield of the Packet Extension field shall be set to 1 if the condition in Equation (26 113) is met, otherwise it shall be set to 0.

$$T_{PE} + 4 \times \left(\left\lceil \frac{\text{TXTIME} - 20}{4} \right\rceil - \left(\frac{\text{TXTIME} - 20}{4} \right) \right) \geq T_{SYM} \tag{26-113}$$

where

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T_{PE} is the PE field duration

T_{SYM} is the symbol duration of the Data field as defined in 26.3.6 (Timing-related parameters)

TXTIME (in μs) is defined in 26.4.3 (TXTIME and PSDU_LENGTH calculation).

Based on PE disambiguity field and a-factor field, the recipient shall compute N_{SYM} and T_{PE} listed in 26.3.15.

26.3.11 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, HE STAs that may be present in a part of a 40 MHz, 80 MHz, or 160 MHz channel (see Error! Reference source not found.). 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 18.3.4 (SIGNAL field).

In a 40 MHz non-HT duplicate transmission, the Data field shall be as defined by Equation 26-61.

For 80 MHz and 160 MHz non-HT duplicate transmissions, the Data field shall be as defined by Error! Reference source not found..

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 Error! Reference source not found..

26.3.12 MU-MIMO

26.3.12.1 Introduction

DL MU MIMO is specified in 22.3.11 for full band transmission. In this amendment, MU-MIMO is also applicable on a subset of active RUs within PPDU bandwidth in both DL and UL. The non-AP STAs in the same MU-MIMO group are allocated the same resource unit. The combination of SU-MIMO and MU-MIMO on different RU for different non-AP STA in one PPDU is supported.

26.3.12.2 Minimum RU size in MU MIMO transmission

Both DL and UL MU MIMO shall transmit on the RU of at least 106 tones.

26.3.12.3 DL MU-MIMO

26.3.12.3.1 Introduction

For 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 26-114, 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.

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$$\boldsymbol{y}_{k,u} = \boldsymbol{H}_{k,u} \times [Q_{k,0}, Q_{k,1}, \ldots, Q_{k,N_{user}-1}] \times \boldsymbol{x}_k + \boldsymbol{n} \quad (26\text{-}114)$$

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} is the number of VHT MU PPDU recipients (see Table 26-6 (Frequently used parameters))

$\boldsymbol{n}$ 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 TBD. 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. The beamformee group for the DL MU transmission is signaled in HE-SIG-B (see 26.3.9.8.3 (Time domain encoding) and 26.3.12.3.4 (Resource indication and STA self identification)).

26.3.12.3.2 Beamforming feedback

TBD

26.3.12.3.3 Maximum number of total spatial streams in a VHT MU PPDU

A DL MU-MIMO capable STA shall support reception of DL MU PPDUs with the total number of space-time streams across the N_{user} users being less than or equal to its DL MU-MIMO STS Capability in the HE Capabilities.

26.3.12.3.4 Resource indication and STA self identification

AP shall transmit HE MU PPDU. The UL/DL field in the HE-SIG-A shall be set TBD (for DL). 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 26-18 (RU allocation signaling: Arrangement and number of MU-MIMO allocations). If the value of SIGB Compression field in HE-SIG-A is 1, there is no RU allocation signaling in HE-SIG-B common field. The number of STAs in the MU MIMO group is indicated in the TBD field in HE-SIG-A. the number of spatial streams $N_{SS,r,u}$ is indicated by NSTS field in user specific block as defined in Table 26 19 and Table 26 20.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 26-21 (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, $N_{SS,r,u}$,

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$u = 1, \ldots, N_{user,r}$, could be 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 HE DL 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.

26.3.12.4 UL MU-MIMO

26.3.12.4.1 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 at multiple transmitters.

For UL MU-MIMO transmissions, support for both single stream pilots and the masking the LTF sequence of each spatial stream by a distinct orthogonal code is mandatory at the transmitter side (non-AP STA).

26.3.12.4.2 Resource indication and STA self identification

UL MU-MIMO transmissions are preceded by a Trigger frame from the AP. Similar as UL OFDMA cases, the Trigger frame indicates the transmitting STAs in the common part about when to transmit the UL MU-MIMO PPDUs, the duration of the payload, and packet-extension. The CP length for UL OFDMA/MU-MIMO transmissions shall also be explicitly indicated by AP in the Trigger frame. The value of CP length for all users addressed by the Trigger frame shall be the same. The Trigger frame shall use 1 bit to indicate whether the UL MU-MIMO 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. The allocated RU and spatial streams are carried in the fields of RU allocation info and SS allocation of Per User Info field, where Address field is set as the AID of designated MU MIMO STA. Details TBD.

If a STA finds that there is no Per 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.

26.3.12.4.3 Pre-corrections in UL MU-MIMO

Since multiple transmitters take part in an UL MU-MIMO transmission, it requires time, frequency, sampling 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 done through power control described in Error! Reference source not found.. The Trigger frame serves as a reference DL frame for the STAs to do the aforementioned pre-

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corrections to the UL PPDUs. The accuracy requirements on these pre-corrections are specified in section x.x.x.

26.3.12.4.4 Power control in UL MU-MIMO

TBD

26.3.12.4.5 Maximum number of spatial streams in UL MU-MIMO PPDUs

An UL MU-MIMO capable STA shall support transmission of UL MU PPDUs with the number of space-time streams being less than or equal to its UL MU-MIMO STS Capability in HE Capabilities.

26.3.12.4.6 Requirements for STAs transmitting HE trigger-based PPDUs

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 MCS0 while meeting the TX EVM and spectral mask requirements. A STA transmitting at and above the minimum power shall support the EVM requirements for MCS7 (TBD whether support for higher MCS).

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 26-35 (Transmit power and RSSI measurement accuracy).

Table 26-35—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	±2 dB	±5 dB	Difference between the actual RSSI and the measured RSSI Requirements are valid from minimum Rx to maximum Rx input power

A STA that transmits an HE trigger-based PPDU shall pre-compensate for carrier frequency offset (CFO) error and timing drift. 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 20MHz. The residual CFO error measurement shall be made on the HE trigger-based PPDU following the HE-SIG-A field.

A STA that transmits an HE trigger-based PPDU shall have timing accuracy of ±0.4 μs relative to the PPDU carrying the Trigger frame. This requirement does not include round trip delay.

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26.3.13 Transmit specification

26.3.13.1 Transmit spectral mask

26.3.13.2 Spectral flatness

26.3.13.3 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.

26.3.13.4 Modulation accuracy

26.3.13.4.1 Introduction to modulation accuracy tests

26.3.13.4.2 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.

26.3.13.4.3 Transmitter constellation error

26.3.14 HE transmit procedure

26.3.15 HE receive procedure

26.4 HE PLME

26.4.1 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).

26.4.2 PHY MIB

TBD

26.4.3 TXTIME and PSDU_LENGTH calculation

The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated for a HE PPDU using Equation 26-115 for an HE SU PPDU and HE trigger-based PPDU, Equation 26-116 for an HE MU PPDU and Equation 26-117 for an HE extended range SU PPDU.

$$\text{TXTIME} = T_{\text{LEG\_PREAMBLE}} + T_{\text{L-SIG}} + T_{\text{RL-SIG}} + T_{\text{HE-SIG-A}} + T_{\text{HE\_PREAMBLE}} + N_{SYM}T_{SYM} + T_{PE} \quad (26\text{-}115)$$

$$\text{TXTIME} = T_{LEG\_PREAMBLE} + T_{L-SIG} + T_{RL-SIG} + T_{HE-SIG-A} + N_{HE-SIG-B}T_{HE-SIG-B} + T_{HE\_PREAMBLE} + N_{SYM}T_{SYM} + T_{PE} \quad (26\text{-}116)$$

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$$\text{TXTIME} = T_{LEG\_PREAMBLE} + T_{L-SIG} + T_{RL-SIG} + T_{HE-SIG-A} + T_{HE-SIG-A-R} + T_{HE\_PREAMBLE} + N_{SYM} T_{SYM} + T_{PE} \quad (26\text{-}117)$$

where

$T_{\text{LEG\_PREAMBLE}} = T_{L-STF} + T_{L-LTF}$

$$T_{\text{HE\_PREAMBLE}} = \begin{cases} T_{\text{HE-STF-T}} + N_{HELTF} T_{\text{HE-LTF,SYM}}, & \text{for an HE trigger-based PPDU} \\ T_{\text{HE-STF-NT}} + N_{HELTF} T_{\text{HE-LTF,SYM}}, & \text{otherwise} \end{cases}$$

$T_{L\text{-}STF}$, $T_{L\text{-}LTF}$, $T_{HE\text{-}STF\text{-}T}$, $T_{HE\text{-}STF\text{-}NT}$, $T_{HE\text{-}LTF,SYM}$, $T_{L\text{-}SIG}$, $T_{RL\text{-}SIG}$, $T_{HE\text{-}SIG\text{-}A}$, $T_{HE\text{-}SIG\text{-}A\text{-}R}$, $T_{HE\text{-}SIG\text{-}B}$, and T_{SYM} are defined in Table 26-3 (Timing-related constants)

$N_{HE\text{-}SIG\text{-}B}$ and $N_{HE\text{-}LTF}$ are defined in Table 26-6 (Frequently used parameters)

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 26-118.

$$N_{SYM} = m_{STBC} \times \left\lceil \frac{8 \cdot \text{APEP\_LENGTH} + N_{service} + N_{tail} \cdot N_{ES}}{m_{STBC} \cdot N_{DBPS}} \right\rceil \quad (26\text{-}118)$$

where

m_{STBC} is equal to 2 when STBC is used, and 1 otherwise.

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 26.3.10.4.2 (LDPC coding).

For an HE MU PPDU (including both MU-MIMO and OFDMA), the total number of OFDM symbols in the Data field, NSYM, is given in 26.3.10.4.4 (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 26.3.10.4.5 (Encoding process for an HE trigger-based PPDU).

T_{PE} is given by Equation 26-112.

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 26-119.

$$\text{PSDU\_LENGTH} = \begin{cases} \left\lfloor \frac{(N_{SYM.init} - m_{STBC}).N_{DBPS} + m_{STBC}.N_{DBPS.Last.init} - N_{service} - N_{tail} \cdot N_{ES}}{8} \right\rfloor & \text{for BCC encoding} \\ \left\lfloor \frac{(N_{SYM.init} - m_{STBC}).N_{DBPS} + m_{STBC}.N_{DBPS.Last.init} - N_{service}}{8} \right\rfloor & \text{for LDPC encoding} \end{cases} \quad (26\text{-}119)$$

where

$N_{SYM,init}$ is given by Equation 26-68 for BCC encoding and by Equation 26-73 for LDPC encoding;

m_{STBC} is 2 when STBC is used, and 1 otherwise;

N_{DBPS} is given in 26.5 (Parameters for HE-MCSs);

$N_{DBPS,Last,init}$ is given by Equation 26-64

The value of the PSDU_LENGTH parameter for user u returned in the PLME-TXTIME.confirm primitive and in the RXVECTOR for a HE MU PPDU is calculated using Equation 26-120.

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$$\text{PSDU\_LENGTH}_u = \begin{cases} \left\lfloor \dfrac{(N_{SYM,init} - m_{STBC}).N_{DBPS,u} + m_{STBC}.N_{DBPS,LAST,u} - N_{service} - N_{tail} \cdot N_{ES}}{8} \right\rfloor & \text{when BCC is used for user } u \\ \left\lfloor \dfrac{(N_{SYM,init} - m_{STBC}).N_{DBPS,u} + m_{STBC}.N_{DBPS,LAST,init,u} - N_{service}}{8} \right\rfloor & \text{when LDPC is used for user } u \end{cases} \quad (26\text{-}120)$$

$N_{SYM,init}$ is given by Equation 26-81

$N_{DBPS,Last,init}$ is given by Equation 26-82

The value of the PSDU_LENGTH parameter returned in the PLME-TXTIME.confirm primitive for an HE NDP PPDU is 0.

26.4.4 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 26-36 (HE PHY characteristics). The definitions for these characteristics are given in 6.5 (PLME SAP interface).

Table 26-36—HE PHY characteristics

Characteristic	Value
aTxPHYDelay	Implementation dependent
aRxPHYDelay	Implementation dependent
aCCAMidTIme	25 μs
aPPDUMaxTime	5.484 ms
aPSDUMaxLength	TBD

26.5 1 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 26-85 (HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, NSS = 1) through Table 26-92 (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 applicable to MCS 0, 1, 3 and 4 with up to TBD number of streams and for TBD RU sizes. A 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 TBD mandatory/optional. 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. N_{ES} values were chosen to yield an integer number of punctured blocks for each BCC encoder per OFDM symbol.

Table 26-37 (HE-MCSs for TBD mandatory/optional 26-tone RU, NSS = 1) to Table 26-92 (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}, N_{DBPS}, and N_{ES} are replaced with $N_{SS,r,u}$, $R_{r,u}$, $N_{BPSCS,r,u}$, $N_{CBPS,r,u}$, $N_{DBPS,r,u}$, and $N_{ES,r,u}$, respectively.

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In the tables below, the number of streams and RU sizes that DCM is applicable to are TBD.

Table 26-37—HE-MCSs for TBD mandatory/optional 26-tone RU, N_{SS} = 1

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mbps)		
										0.8 µs GI	1.6 µs GI	3.2 µs GI
0	1	BPSK	1/4	1	24	2	24	6	1	0.4	0.4	0.4
0	0		1/2	1			24	12	1	0.9	0.8	0.8
1	1	QPSK	1/4	2			48	12	1	0.9	0.8	0.8
1	0		1/2	2			48	24	1	1.8	1.7	1.5
2	N/A		3/4	2			48	36	1	2.6	2.5	2.3
3	1	16-QAM	1/4	4			96	24	1	1.8	1.7	1.5
3	0		1/2	4			96	48	1	3.5	3.3	3.0
4	1		3/8	4			96	36	1	2.6	2.5	2.3
4	0		3/4	4			96	72	1	5.3	5.0	4.5
5	N/A	64-QAM	2/3	6			144	96	1	7.1	6.7	6.0
6			3/4	6			144	108	1	7.9	7.5	6.8
7			5/6	6			144	120	1	8.8	8.3	7.5
8		256-QAM	3/4	8			192	144	1	10.6	1.0	9.0
9			5/6	8			192	160	1	11.8	11.1	10.0

Table 26-38—HE-MCSs for TBD mandatory/optional 26-tone RU, N_{SS} = 2

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mbps)		
										0.8 µs GI	1.6 µs GI	3.2 µs GI

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Table 26-38—HE-MCSs for TBD mandatory/optional 26-tone RU, N_{SS} = 2

0	1	BPSK	1/4	1	24	2	48	12	1	0.9	0.8	0.8
0	0		1/2	1			48	24	1	1.8	1.7	1.5
1	1	QPSK	1/4	2			96	24	1	1.8	1.7	1.5
1	0		1/2	2			96	48	1	3.5	3.3	3.0
2	N/A		3/4	2			96	72	1	5.3	5.0	4.5
3	1	16-QAM	1/4	4			192	48	1	3.5	3.3	3.0
3	0		1/2	4			192	96	1	7.1	6.7	6.0
4	1		3/8	4			192	72	1	5.3	5.0	4.5
4	0		3/4	4			192	144	1	10.6	10.0	9.0
5	N/A	64-QAM	2/3	6			288	192	1	14.1	13.3	12.0
6			3/4	6			288	216	1	15.9	15.0	13.5
7			5/6	6			288	240	1	17.6	16.7	15.0
8		256-QAM	3/4	8			384	288	1	21.2	20.0	18.0
9			5/6	8			384	320	1	23.5	22.2	20.0

Table 26-39—HE-MCSs for TBD mandatory/optional 26-tone RU, N_{SS} = 3

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	24	2	72	18	1	1.3	1.3	1.1
0	0		1/2	1			72	36	1	2.6	2.5	2.3
1	1	QPSK	1/4	2			144	36	1	2.6	2.5	2.3
1	0		1/2	2			144	72	1	5.3	5.0	4.5
2	N/A		3/4	2			144	108	1	7.9	7.5	6.8
3	1	16-QAM	1/4	4			288	72	1	5.3	5.0	4.5
3	0		1/2	4			288	144	1	10.6	10.0	9.0
4	1		3/8	4			288	108	1	7.9	7.5	6.8
4	0		3/4	4			288	216	1	15.9	15.0	13.5
5	N/A	64-QAM	2/3	6			432	288	1	21.2	20.0	18.0
6			3/4	6			432	324	1	23.8	22.5	20.3
7			5/6	6			432	360	1	26.5	25.0	22.5
8		256-QAM	3/4	8			576	432	1	31.8	30.0	27.0
9			5/6	8			576	480	1	35.3	33.3	30.0

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Table 26-40—HE-MCSs for TBD mandatory/optional 26-tone RU, N_{SS} = 4

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	24	2	96	24	1	1.8	1.7	1.5
0	0		1/2	1			96	48	1	3.5	3.3	3.0
1	1	QPSK	1/4	2			192	48	1	3.5	3.3	3.0
1	0		1/2	2			192	96	1	7.1	6.7	6.0
2	N/A		3/4	2			192	144	1	10.6	10.0	9.0
3	1	16-QAM	1/4	4			384	96	1	7.1	6.7	6.0
3	0		1/2	4			384	192	1	14.1	13.3	12.0
4	1		3/8	4			384	144	1	10.6	10.0	9.0
4	0		3/4	4			384	288	1	21.2	20.0	18.0
5	N/A	64-QAM	2/3	6			576	384	1	28.2	26.7	24.0
6			3/4	6			576	432	1	31.8	30.0	27.0
7			5/6	6			576	480	1	35.3	33.3	30.0
8		256-QAM	3/4	8			768	576	1	42.4	40.0	36.0
9			5/6	8			768	640	1	47.1	44.4	40.0

Table 26-41—HE-MCSs for TBD mandatory/optional 26-tone RU, N_{SS} = 5

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	24	2	120	30	1	2.2	2.1	1.9
0	0		1/2	1			120	60	1	4.4	4.2	3.8
1	1	QPSK	1/4	2			240	60	1	4.4	4.2	3.8
1	0		1/2	2			240	120	1	8.8	8.3	7.5
2	N/A		3/4	2			240	180	1	13.2	12.5	11.3
3	1	16-QAM	1/4	4			480	120	1	8.8	8.3	7.5
3	0		1/2	4			480	240	1	17.6	16.7	15.0
4	1		3/8	4			480	180	1	13.2	12.5	11.3
4	0		3/4	4			480	360	1	26.5	25.0	22.5
5	N/A	64-QAM	2/3	6			720	480	1	35.3	33.3	30.0
6			3/4	6			720	540	1	39.7	37.5	33.8
7			5/6	6			720	600	1	44.1	41.7	37.5
8		256-QAM	3/4	8			960	720	1	52.9	50.0	45.0
9			5/6	8			960	800	1	58.8	55.6	50.0

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Table 26-42—HE-MCSs for TBD mandatory/optional 26-tone RU, N_{SS} = 6

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	24	2	144	36	1	2.6	2.5	2.3
0	0		1/2	1			144	72	1	5.3	5.0	4.5
1	1	QPSK	1/4	2			288	72	1	5.3	5.0	4.5
1	0		1/2	2			288	144	1	10.6	10.0	9.0
2	N/A		3/4	2			288	216	1	15.9	15.0	13.5
3	1	16-QAM	1/4	4			576	144	1	10.6	10.0	9.0
3	0		1/2	4			576	288	1	21.2	20.0	18.0
4	1		3/8	4			576	216	1	15.9	15.0	13.5
4	0		3/4	4			576	432	1	31.8	30.0	27.0
5	N/A	64-QAM	2/3	6			864	576	1	42.4	40.0	36.0
6			3/4	6			864	648	1	47.6	45.0	40.5
7			5/6	6			864	720	1	52.9	50.0	45.0
8		256-QAM	3/4	8			1152	864	1	63.5	60.0	54.0
9			5/6	8			1152	960	1	70.6	66.7	60.0

Table 26-43—HE-MCSs for TBD mandatory/optional 26-tone RU, N_{SS} = 7

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	24	2	168	42	1	3.1	2.9	2.6
0	0		1/2	1			168	84	1	6.2	5.8	5.3
1	1	QPSK	1/4	2			336	84	1	6.2	5.8	5.3
1	0		1/2	2			336	168	1	12.4	11.7	10.5
2	N/A		3/4	2			336	252	1	18.5	17.5	15.8
3	1	16-QAM	1/4	4			672	168	1	12.4	11.7	10.5
3	0		1/2	4			672	336	1	24.7	23.3	21.0
4	1		3/8	4			672	252	1	18.5	17.5	15.8
4	0		3/4	4			672	504	1	37.1	35.0	31.5
5	N/A	64-QAM	2/3	6			1008	672	1	49.4	46.7	42.0
6			3/4	6			1008	756	1	55.6	52.5	47.3
7			5/6	6			1008	840	1	61.8	58.3	52.5
8		256-QAM	3/4	8			1344	1008	1	74.1	70.0	63.0
9			5/6	8			1344	1120	1	82.4	77.8	70.0

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Table 26-44—HE-MCSs for TBD mandatory/optional 26-tone RU, N_{SS} = 8

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	24	2	192	48	1	3.5	3.3	3.0
0	0		1/2	1			192	96	1	7.1	6.7	6.0
1	1	QPSK	1/4	2			384	96	1	7.1	6.7	6.0
1	0		1/2	2			384	192	1	14.1	13.3	12.0
2	N/A		3/4	2			384	288	1	21.2	20.0	18.0
3	1	16-QAM	1/4	4			768	192	1	14.1	13.3	12.0
3	0		1/2	4			768	384	1	28.2	26.7	24.0
4	1		3/8	4			768	288	1	21.2	20.0	18.0
4	0		3/4	4			768	576	1	42.4	40.0	36.0
5	N/A	64-QAM	2/3	6			1152	768	1	56.5	53.3	48.0
6			3/4	6			1152	864	1	63.5	60.0	54.0
7			5/6	6			1152	960	1	70.6	66.7	60.0
8		256-QAM	3/4	8			1536	1152	1	84.7	80.0	72.0
9			5/6	8			1536	1280	1	94.1	88.9	80.0

Table 26-45—HE-MCSs for TBD mandatory/optional 52-tone RU, N_{SS} = 1

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	48	4	48	12	1	0.9	0.8	0.8
0	0		1/2	1			48	24	1	1.8	1.7	1.5
1	1	QPSK	1/4	2			96	24	1	1.8	1.7	1.5
1	0		1/2	2			96	48	1	3.5	3.3	3.0
2	N/A		3/4	2			96	72	1	5.3	5.0	4.5
3	1	16-QAM	1/4	4			192	48	1	3.5	3.3	3.0
3	0		1/2	4			192	96	1	7.1	6.7	6.0
4	1		3/8	4			192	72	1	5.3	5.0	4.5
4	0		3/4	4			192	144	1	10.6	10.0	9.0
5	N/A	64-QAM	2/3	6			288	192	1	14.1	13.3	12.0
6			3/4	6			288	216	1	15.9	15.0	13.5
7			5/6	6			288	240	1	17.6	16.7	15.0
8		256-QAM	3/4	8			384	288	1	21.2	20.0	18.0
9			5/6	8			384	320	1	23.5	22.2	20.0

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Table 26-46—HE-MCSs for TBD mandatory/optional 52-tone RU, N_{SS} = 2

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	48	4	96	24	1	1.8	1.7	1.5
0	0		1/2	1			96	48	1	3.5	3.3	3.0
1	1	QPSK	1/4	2			192	48	1	3.5	3.3	3.0
1	0		1/2	2			192	96	1	7.1	6.7	6.0
2	N/A		3/4	2			192	144	1	10.6	10.0	9.0
3	1	16-QAM	1/4	4			384	96	1	7.1	6.7	6.0
3	0		1/2	4			384	192	1	14.1	13.3	12.0
4	1		3/8	4			384	144	1	10.6	10.0	9.0
4	0		3/4	4			384	288	1	21.2	20.0	18.0
5	N/A	64-QAM	2/3	6			576	384	1	28.2	26.7	24.0
6			3/4	6			576	432	1	31.8	30.0	27.0
7			5/6	6			576	480	1	35.3	33.3	30.0
8		256-QAM	3/4	8			768	576	1	42.4	40.0	36.0
9			5/6	8			768	640	1	47.1	44.4	40.0

Table 26-47—HE-MCSs for TBD mandatory/optional 52-tone RU, N_{SS} = 3

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	48	4	144	36	1	2.6	2.5	2.3
0	0		1/2	1			144	72	1	5.3	5.0	4.5
1	1	QPSK	1/4	2			288	72	1	5.3	5.0	4.5
1	0		1/2	2			288	144	1	10.6	10.0	9.0
2	N/A		3/4	2			288	216	1	15.9	15.0	13.5
3	1	16-QAM	1/4	4			576	144	1	10.6	10.0	9.0
3	0		1/2	4			576	288	1	21.2	20.0	18.0
4	1		3/8	4			576	216	1	15.9	15.0	13.5
4	0		3/4	4			576	432	1	31.8	30.0	27.0
5	N/A	64-QAM	2/3	6			864	576	1	42.4	40.0	36.0
6			3/4	6			864	648	1	47.6	45.0	40.5
7			5/6	6			864	720	1	52.9	50.0	45.0
8		256-QAM	3/4	8			1152	864	1	63.5	60.0	54.0
9			5/6	8			1152	960	1	70.6	66.7	60.0

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Table 26-48—HE-MCSs for TBD mandatory/optional 52-tone RU, N_{SS} = 4

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	48	4	192	48	1	3.5	3.3	3.0
0	0		1/2	1			192	96	1	7.1	6.7	6.0
1	1	QPSK	1/4	2			384	96	1	7.1	6.7	6.0
1	0		1/2	2			384	192	1	14.1	13.3	12.0
2	N/A		3/4	2			384	288	1	21.2	20.0	18.0
3	1	16-QAM	1/4	4			768	192	1	14.1	13.3	12.0
3	0		1/2	4			768	384	1	28.2	26.7	24.0
4	1		3/8	4			768	288	1	21.2	20.0	18.0
4	0		3/4	4			768	576	1	42.4	40.0	36.0
5	N/A	64-QAM	2/3	6			1152	768	1	56.5	53.3	48.0
6			3/4	6			1152	864	1	63.5	60.0	54.0
7			5/6	6			1152	960	1	70.6	66.7	60.0
8		256-QAM	3/4	8			1536	1152	1	84.7	80.0	72.0
9			5/6	8			1536	1280	1	94.1	88.9	80.0

Table 26-49—HE-MCSs for TBD mandatory/optional 52-tone RU, N_{SS} = 5

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	48	4	240	60	1	4.4	4.2	3.8
0	0		1/2	1			240	120	1	8.8	8.3	7.5
1	1	QPSK	1/4	2			480	120	1	8.8	8.3	7.5
1	0		1/2	2			480	240	1	17.6	16.7	15.0
2	N/A		3/4	2			480	360	1	26.5	25.0	22.5
3	1	16-QAM	1/4	4			960	240	1	17.6	16.7	15.0
3	0		1/2	4			960	480	1	35.3	33.3	30.0
4	1		3/8	4			960	360	1	26.5	25.0	22.5
4	0		3/4	4			960	720	1	52.9	50.0	45.0
5	N/A	64-QAM	2/3	6			1440	960	1	70.6	66.7	60.0
6			3/4	6			1440	1080	1	79.4	75.0	67.5
7			5/6	6			1440	1200	1	88.2	83.3	75.0
8		256-QAM	3/4	8			1920	1440	1	105.9	100.0	90.0
9			5/6	8			1920	1600	1	117.6	111.1	100.0

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Table 26-50—HE-MCSs for TBD mandatory/optional 52-tone RU, N_{SS} = 6

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	48	4	288	72	1	5.3	5.0	4.5
0	0		1/2	1			288	144	1	10.6	10.0	9.0
1	1	QPSK	1/4	2			576	144	1	10.6	10.0	9.0
1	0		1/2	2			576	288	1	21.2	20.0	18.0
2	N/A		3/4	2			576	432	1	31.8	30.0	27.0
3	1	16-QAM	1/4	4			1152	288	1	21.2	20.0	18.0
3	0		1/2	4			1152	576	1	42.4	40.0	36.0
4	1		3/8	4			1152	432	1	31.8	30.0	27.0
4	0		3/4	4			1152	864	1	63.5	60.0	54.0
5	N/A	64-QAM	2/3	6			1728	1152	1	84.7	80.0	72.0
6			3/4	6			1728	1296	1	95.3	90.0	81.0
7			5/6	6			1728	1440	1	105.9	100.0	90.0
8		256-QAM	3/4	8			2304	1728	1	127.1	120.0	108.0
9			5/6	8			2304	1920	1	141.2	133.3	120.0

Table 26-51—HE-MCSs for TBD mandatory/optional 52-tone RU, N_{SS} = 7

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	48	4	336	84	1	6.2	5.8	5.3
0	0		1/2	1			336	168	1	12.4	11.7	10.5
1	1	QPSK	1/4	2			672	168	1	12.4	11.7	10.5
1	0		1/2	2			672	336	1	24.7	23.3	21.0
2	N/A		3/4	2			672	504	1	37.1	35.0	31.5
3	1	16-QAM	1/4	4			1344	336	1	24.7	23.3	21.0
3	0		1/2	4			1344	672	1	49.4	46.7	42.0
4	1		3/8	4			1344	504	1	37.1	35.0	31.5
4	0		3/4	4			1344	1008	1	74.1	70.0	63.0
5	N/A	64-QAM	2/3	6			2016	1344	1	98.8	93.3	84.0
6			3/4	6			2016	1512	1	111.2	105.0	94.5
7			5/6	6			2016	1680	1	123.5	116.7	105.0
8		256-QAM	3/4	8			2688	2016	1	148.2	140.0	126.0
9			5/6	8			2688	2240	1	164.7	155.6	140.0

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Table 26-52—HE-MCSs for TBD mandatory/optional 52-tone RU, N_{SS} = 8

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	48	4	384	96	1	7.1	6.7	6.0
0	0		1/2	1			384	192	1	14.1	13.3	12.0
1	1	QPSK	1/4	2			768	192	1	14.1	13.3	12.0
1	0		1/2	2			768	384	1	28.2	26.7	24.0
2	N/A		3/4	2			768	576	1	42.4	40.0	36.0
3	1	16-QAM	1/4	4			1536	384	1	28.2	26.7	24.0
3	0		1/2	4			1536	768	1	56.5	53.3	48.0
4	1		3/8	4			1536	576	1	42.4	40.0	36.0
4	0		3/4	4			1536	1152	1	84.7	80.0	72.0
5	N/A	64-QAM	2/3	6			2304	1536	1	112.9	106.7	96.0
6			3/4	6			2304	1728	1	127.1	120.0	108.0
7			5/6	6			2304	1920	1	141.2	133.3	120.0
8		256-QAM	3/4	8			3072	2304	1	169.4	160.0	144.0
9			5/6	8			3072	2560	1	188.2	177.8	160.0

Table 26-53—HE-MCSs for TBD mandatory/optional 106-tone RU, N_{SS} = 1

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	102	4	102	25	1	1.8	1.7	1.6
0	0		1/2	1			102	51	1	3.8	3.5	3.2
1	1	QPSK	1/4	2			204	51	1	3.8	3.5	3.2
1	0		1/2	2			204	102	1	7.5	7.1	6.4
2	N/A		3/4	2			204	153	1	11.3	10.6	9.6
3	1	16-QAM	1/4	4			408	102	1	7.5	7.1	6.4
3	0		1/2	4			408	204	1	15.0	14.2	12.8
4	1		3/8	4			408	153	1	11.3	10.6	9.6
4	0		3/4	4			408	306	1	22.5	21.3	19.1
5	N/A	64-QAM	2/3	6			612	408	1	30.0	28.3	25.5
6			3/4	6			612	459	1	33.8	31.9	28.7
7			5/6	6			612	510	1	37.5	35.4	31.9
8		256-QAM	3/4	8			816	612	1	45.0	42.5	38.3
9			5/6	8			816	680	1	50.0	47.2	42.5

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Table 26-54—HE-MCSs for TBD mandatory/optional 106-tone RU, N_{SS} = 2

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	102	4	204	51	1	3.8	3.5	3.2
0	0		1/2	1			204	102	1	7.5	7.1	6.4
1	1	QPSK	1/4	2			408	102	1	7.5	7.1	6.4
1	0		1/2	2			408	204	1	15.0	14.2	12.8
2	N/A		3/4	2			408	306	1	22.5	21.3	19.1
3	1	16-QAM	1/4	4			816	204	1	15.0	14.2	12.8
3	0		1/2	4			816	408	1	30.0	28.3	25.5
4	1		3/8	4			816	306	1	22.5	21.3	19.1
4	0		3/4	4			816	612	1	45.0	42.5	38.3
5	N/A	64-QAM	2/3	6			1224	816	1	60.0	56.7	51.0
6			3/4	6			1224	918	1	67.5	63.8	57.4
7			5/6	6			1224	1,020	1	75.0	70.8	63.8
8		256-QAM	3/4	8			1632	1,224	1	90.0	85.0	76.5
9			5/6	8			1632	1,360	1	100.0	94.4	85.0

Table 26-55—HE-MCSs for TBD mandatory/optional 106-tone RU, N_{SS} = 3

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	102	4	306	76	1	5.6	5.3	4.8
0	0		1/2	1			306	153	1	11.3	10.6	9.6
1	1	QPSK	1/4	2			612	153	1	11.3	10.6	9.6
1	0		1/2	2			612	306	1	22.5	21.3	19.1
2	N/A		3/4	2			612	459	1	33.8	31.9	28.7
3	1	16-QAM	1/4	4			1224	306	1	22.5	21.3	19.1
3	0		1/2	4			1224	612	1	45.0	42.5	38.3
4	1		3/8	4			1224	459	1	33.8	31.9	28.7
4	0		3/4	4			1224	918	1	67.5	63.8	57.4
5	N/A	64-QAM	2/3	6			1836	1,224	1	90.0	85.0	76.5
6			3/4	6			1836	1,377	1	101.3	95.6	86.1
7			5/6	6			1836	1,530	1	112.5	106.3	95.6
8		256-QAM	3/4	8			2448	1,836	1	135.0	127.5	114.8
9			5/6	8			2448	2,040	1	150.0	141.7	127.5

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Table 26-56—HE-MCSs for TBD mandatory/optional 106-tone RU, N_{SS} = 4

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	102	4	408	102	1	7.5	7.1	6.4
0	0		1/2	1			408	204	1	15.0	14.2	12.8
1	1	QPSK	1/4	2			816	204	1	15.0	14.2	12.8
1	0		1/2	2			816	408	1	30.0	28.3	25.5
2	N/A		3/4	2			816	612	1	45.0	42.5	38.3
3	1	16-QAM	1/4	4			1632	408	1	30.0	28.3	25.5
3	0		1/2	4			1632	816	1	60.0	56.7	51.0
4	1		3/8	4			1632	612	1	45.0	42.5	38.3
4	0		3/4	4			1632	1,224	1	90.0	85.0	76.5
5	N/A	64-QAM	2/3	6			2448	1,632	1	120.0	113.3	102.0
6			3/4	6			2448	1,836	1	135.0	127.5	114.8
7			5/6	6			2448	2,040	1	150.0	141.7	127.5
8		256-QAM	3/4	8			3264	2,448	1	180.0	170.0	153.0
9			5/6	8			3264	2,720	1	200.0	188.9	170.0

Table 26-57—HE-MCSs for TBD mandatory/optional 106-tone RU, N_{SS} = 5

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	102	4	510	127	1	9.3	8.8	7.9
0	0		1/2	1			510	255	1	18.8	17.7	15.9
1	1	QPSK	1/4	2			1020	255	1	18.8	17.7	15.9
1	0		1/2	2			1020	510	1	37.5	35.4	31.9
2	N/A		3/4	2			1020	765	1	56.3	53.1	47.8
3	1	16-QAM	1/4	4			2040	510	1	37.5	35.4	31.9
3	0		1/2	4			2040	1,020	1	75.0	70.8	63.8
4	1		3/8	4			2040	765	1	56.3	53.1	47.8
4	0		3/4	4			2040	1,530	1	112.5	106.3	95.6
5	N/A	64-QAM	2/3	6			3060	2,040	1	150.0	141.7	127.5
6			3/4	6			3060	2,295	1	168.8	159.4	143.4
7			5/6	6			3060	2,550	1	187.5	177.1	159.4
8		256-QAM	3/4	8			4080	3,060	1	225.0	212.5	191.3
9			5/6	8			4080	3,400	1	250.0	236.1	212.5

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Table 26-58—HE-MCSs for TBD mandatory/optional 106-tone RU, N_{SS} = 6

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	102	4	612	153	1	11.3	10.6	9.6
0	0		1/2	1			612	306	1	22.5	21.3	19.1
1	1	QPSK	1/4	2			1224	306	1	22.5	21.3	19.1
1	0		1/2	2			1224	612	1	45.0	42.5	38.3
2	N/A		3/4	2			1224	918	1	67.5	63.8	57.4
3	1	16-QAM	1/4	4			2448	612	1	45.0	42.5	38.3
3	0		1/2	4			2448	1,224	1	90.0	85.0	76.5
4	1		3/8	4			2448	918	1	67.5	63.8	57.4
4	0		3/4	4			2448	1,836	1	135.0	127.5	114.8
5	N/A	64-QAM	2/3	6			3672	2,448	1	180.0	170.0	153.0
6			3/4	6			3672	2,754	1	202.5	191.3	172.1
7			5/6	6			3672	3,060	1	225.0	212.5	191.3
8		256-QAM	3/4	8			4896	3,672	1	270.0	255.0	229.5
9			5/6	8			4896	4,080	1	300.0	283.3	255.0

Table 26-59—HE-MCSs for TBD mandatory/optional 106-tone RU, N_{SS} = 7

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	102	4	714	178	1	13.1	12.4	11.1
0	0		1/2	1			714	357	1	26.3	24.8	22.3
1	1	QPSK	1/4	2			1428	357	1	26.3	24.8	22.3
1	0		1/2	2			1428	714	1	52.5	49.6	44.6
2	N/A		3/4	2			1428	1,071	1	78.8	74.4	66.9
3	1	16-QAM	1/4	4			2856	714	1	52.5	49.6	44.6
3	0		1/2	4			2856	1,428	1	105.0	99.2	89.3
4	1		3/8	4			2856	1,071	1	78.8	74.4	66.9
4	0		3/4	4			2856	2,142	1	157.5	148.8	133.9
5	N/A	64-QAM	2/3	6			4284	2,856	1	210.0	198.3	178.5
6			3/4	6			4284	3,213	1	236.3	223.1	200.8
7			5/6	6			4284	3,570	1	262.5	247.9	223.1
8		256-QAM	3/4	8			5712	4,284	1	315.0	297.5	267.8
9			5/6	8			5712	4,760	1	350.0	330.6	297.5

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Table 26-60—HE-MCSs for TBD mandatory/optional 106-tone RU, N_{SS} = 8

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	102	4	816	204	1	15.0	14.2	12.8
0	0		1/2	1			816	408	1	30.0	28.3	25.5
1	1	QPSK	1/4	2			1632	408	1	30.0	28.3	25.5
1	0		1/2	2			1632	816	1	60.0	56.7	51.0
2	N/A		3/4	2			1632	1,224	1	90.0	85.0	76.5
3	1	16-QAM	1/4	4			3264	816	1	60.0	56.7	51.0
3	0		1/2	4			3264	1,632	1	120.0	113.3	102.0
4	1		3/8	4			3264	1,224	1	90.0	85.0	76.5
4	0		3/4	4			3264	2,448	1	180.0	170.0	153.0
5	N/A	64-QAM	2/3	6			4896	3,264	1	240.0	226.7	204.0
6			3/4	6			4896	3,672	1	270.0	255.0	229.5
7			5/6	6			4896	4,080	1	300.0	283.3	255.0
8		256-QAM	3/4	8			6528	4,896	1	360.0	340.0	306.0
9			5/6	8			6528	5,440	1	400.0	377.8	340.0

Table 26-61—HE-MCSs for TBD mandatory/optional 242-tone RU and mandatory non-OFDMA 20 MHz, N_{SS} = 1

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	234	8	234	58	1	4.3	4.0	3.6
0	0		1/2	1			234	117	1	8.6	8.1	7.3
1	1	QPSK	1/4	2			468	117	1	8.6	8.1	7.3
1	0		1/2	2			468	234	1	17.2	16.3	14.6
2	N/A		3/4	2			468	351	1	25.8	24.4	21.9
3	1	16-QAM	1/4	4			936	234	1	17.2	16.3	14.6
3	0		1/2	4			936	468	1	34.4	32.5	29.3
4	1		3/8	4			936	351	1	25.8	24.4	21.9
4	0		3/4	4			936	702	1	51.6	48.8	43.9
5	N/A	64-QAM	2/3	6			1404	936	1	68.8	65.0	58.5
6			3/4	6			1404	1,053	1	77.4	73.1	65.8
7			5/6	6			1404	1,170	1	86.0	81.3	73.1
8		256-QAM	3/4	8			1872	1,404	1	103.2	97.5	87.8
9			5/6	8			1872	1,560	1	114.7	108.3	97.5
10		1024-QAM	3/4	10			2340	1,755	1	129.0	121.9	109.7
11			5/6	10			2340	1,950	1	143.4	135.4	121.9

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Table 26-62—HE-MCSs for TBD mandatory/optional 242-tone RU and mandatory non-OFDMA 20 MHz, N_{SS} = 2

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	234	8	468	117	1	8.6	8.1	7.3
0	0		1/2	1			468	234	1	17.2	16.3	14.6
1	1	QPSK	1/4	2			936	234	1	17.2	16.3	14.6
1	0		1/2	2			936	468	1	34.4	32.5	29.3
2	N/A		3/4	2			936	702	1	51.6	48.8	43.9
3	1	16-QAM	1/4	4			1872	468	1	34.4	32.5	29.3
3	0		1/2	4			1872	936	1	68.8	65.0	58.5
4	1		3/8	4			1872	702	1	51.6	48.8	43.9
4	0		3/4	4			1872	1,404	1	103.2	97.5	87.8
5	N/A	64-QAM	2/3	6			2808	1,872	1	137.6	130.0	117.0
6			3/4	6			2808	2,106	1	154.9	146.3	131.6
7			5/6	6			2808	2,340	1	172.1	162.5	146.3
8		256-QAM	3/4	8			3744	2,808	1	206.5	195.0	175.5
9			5/6	8			3744	3,120	1	229.4	216.7	195.0
10		1024-QAM	3/4	10			4680	3,510	1	258.1	243.8	219.4
11			5/6	10			4680	3,900	1	286.8	270.8	243.8

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Table 26-63—HE-MCSs for TBD mandatory/optional 242-tone RU and mandatory non-OFDMA 20 MHz, N_{SS} = 3

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	234	8	702	175	1	12.9	12.2	10.9
0	0		1/2	1			702	351	1	25.8	24.4	21.9
1	1	QPSK	1/4	2			1404	351	1	25.8	24.4	21.9
1	0		1/2	2			1404	702	1	51.6	48.8	43.9
2	N/A		3/4	2			1404	1,053	1	77.4	73.1	65.8
3	1	16-QAM	1/4	4			2808	702	1	51.6	48.8	43.9
3	0		1/2	4			2808	1,404	1	103.2	97.5	87.8
4	1		3/8	4			2808	1,053	1	77.4	73.1	65.8
4	0		3/4	4			2808	2,106	1	154.9	146.3	131.6
5	N/A	64-QAM	2/3	6			4212	2,808	1	206.5	195.0	175.5
6			3/4	6			4212	3,159	1	232.3	219.4	197.4
7			5/6	6			4212	3,510	1	258.1	243.8	219.4
8		256-QAM	3/4	8			5616	4,212	1	309.7	292.5	263.3
9			5/6	8			5616	4,680	1	344.1	325.0	292.5
10		1024-QAM	3/4	10			7020	5,265	1	387.1	365.6	329.1
11			5/6	10			7020	5,850	1	430.1	406.3	365.6

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Table 26-64—HE-MCSs for TBD mandatory/optional 242-tone RU and mandatory non-OFDMA 20 MHz, N_{SS} = 4

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	234	8	936	234	1	17.2	16.3	14.6
0	0		1/2	1			936	468	1	34.4	32.5	29.3
1	1	QPSK	1/4	2			1872	468	1	34.4	32.5	29.3
1	0		1/2	2			1872	936	1	68.8	65.0	58.5
2	N/A		3/4	2			1872	1,404	1	103.2	97.5	87.8
3	1	16-QAM	1/4	4			3744	936	1	68.8	65.0	58.5
3	0		1/2	4			3744	1,872	1	137.6	130.0	117.0
4	1		3/8	4			3744	1,404	1	103.2	97.5	87.8
4	0		3/4	4			3744	2,808	1	206.5	195.0	175.5
5	N/A	64-QAM	2/3	6			5616	3,744	1	275.3	260.0	234.0
6			3/4	6			5616	4,212	1	309.7	292.5	263.3
7			5/6	6			5616	4,680	1	344.1	325.0	292.5
8		256-QAM	3/4	8			7488	5,616	1	412.9	390.0	351.0
9			5/6	8			7488	6,240	1	458.8	433.3	390.0
10		1024-QAM	3/4	10			9360	7,020	1	516.2	487.5	438.8
11			5/6	10			9360	7,800	1	573.5	541.7	487.5

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Table 26-65—HE-MCSs for TBD mandatory/optional 242-tone RU and mandatory non-OFDMA 20 MHz, N_{SS} = 5

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	234	8	1170	292	1	21.5	20.3	18.3
0	0		1/2	1			1170	585	1	43.0	40.6	36.6
1	1	QPSK	1/4	2			2340	585	1	43.0	40.6	36.6
1	0		1/2	2			2340	1,170	1	86.0	81.3	73.1
2	N/A		3/4	2			2340	1,755	1	129.0	121.9	109.7
3	1	16-QAM	1/4	4			4680	1,170	1	86.0	81.3	73.1
3	0		1/2	4			4680	2,340	1	172.1	162.5	146.3
4	1		3/8	4			4680	1,755	1	129.0	121.9	109.7
4	0		3/4	4			4680	3,510	1	258.1	243.8	219.4
5	N/A	64-QAM	2/3	6			7020	4,680	1	344.1	325.0	292.5
6			3/4	6			7020	5,265	1	387.1	365.6	329.1
7			5/6	6			7020	5,850	1	430.1	406.3	365.6
8		256-QAM	3/4	8			9360	7,020	1	516.2	487.5	438.8
9			5/6	8			9360	7,800	1	573.5	541.7	487.5
10		1024-QAM	3/4	10			11700	8,775	1	645.2	609.4	548.4
11			5/6	10			11700	9,750	1	716.9	677.1	609.4

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Table 26-66—HE-MCSs for TBD mandatory/optional 242-tone RU and mandatory non-OFDMA 20 MHz, N_{SS} = 6

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	234	8	1404	351	1	25.8	24.4	21.9
0	0		1/2	1			1404	702	1	51.6	48.8	43.9
1	1	QPSK	1/4	2			2808	702	1	51.6	48.8	43.9
1	0		1/2	2			2808	1,404	1	103.2	97.5	87.8
2	N/A		3/4	2			2808	2,106	1	154.9	146.3	131.6
3	1	16-QAM	1/4	4			5616	1,404	1	103.2	97.5	87.8
3	0		1/2	4			5616	2,808	1	206.5	195.0	175.5
4	1		3/8	4			5616	2,106	1	154.9	146.3	131.6
4	0		3/4	4			5616	4,212	1	309.7	292.5	263.3
5	N/A	64-QAM	2/3	6			8424	5,616	1	412.9	390.0	351.0
6			3/4	6			8424	6,318	1	464.6	438.8	394.9
7			5/6	6			8424	7,020	1	516.2	487.5	438.8
8		256-QAM	3/4	8			11232	8,424	1	619.4	585.0	526.5
9			5/6	8			11232	9,360	1	688.2	650.0	585.0
10		1024-QAM	3/4	10			14040	10,530	1	774.3	731.3	658.1
11			5/6	10			14040	11,700	1	860.3	812.5	731.3

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Table 26-67—HE-MCSs for TBD mandatory/optional 242-tone RU and mandatory non-OFDMA 20 MHz, N_{SS} = 7

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	234	8	1638	409	1	30.1	28.4	25.6
0	0		1/2	1			1638	819	1	60.2	56.9	51.2
1	1	QPSK	1/4	2			3276	819	1	60.2	56.9	51.2
1	0		1/2	2			3276	1,638	1	120.4	113.8	102.4
2	N/A		3/4	2			3276	2,457	1	180.7	170.6	153.6
3	1	16-QAM	1/4	4			6552	1,638	1	120.4	113.8	102.4
3	0		1/2	4			6552	3,276	1	240.9	227.5	204.8
4	1		3/8	4			6552	2,457	1	180.7	170.6	153.6
4	0		3/4	4			6552	4,914	1	361.3	341.3	307.1
5	N/A	64-QAM	2/3	6			9828	6,552	1	481.8	455.0	409.5
6			3/4	6			9828	7,371	1	542.0	511.9	460.7
7			5/6	6			9828	8,190	1	602.2	568.8	511.9
8		256-QAM	3/4	8			13104	9,828	1	722.6	682.5	614.3
9			5/6	8			13104	10,920	1	802.9	758.3	682.5
10		1024-QAM	3/4	10			16380	12,285	1	903.3	853.1	767.8
11			5/6	10			16380	13,650	1	1,003.7	947.9	853.1

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Table 26-68—HE-MCSs for TBD mandatory/optional 242-tone RU and mandatory non-OFDMA 20 MHz, N_{SS} = 8

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	234	8	1872	468	1	34.4	32.5	29.3
0	0		1/2	1			1872	936	1	68.8	65.0	58.5
1	1	QPSK	1/4	2			3744	936	1	68.8	65.0	58.5
1	0		1/2	2			3744	1,872	1	137.6	130.0	117.0
2	N/A		3/4	2			3744	2,808	1	206.5	195.0	175.5
3	1	16-QAM	1/4	4			7488	1,872	1	137.6	130.0	117.0
3	0		1/2	4			7488	3,744	1	275.3	260.0	234.0
4	1		3/8	4			7488	2,808	1	206.5	195.0	175.5
4	0		3/4	4			7488	5,616	1	412.9	390.0	351.0
5	N/A	64-QAM	2/3	6			11232	7,488	1	550.6	520.0	468.0
6			3/4	6			11232	8,424	1	619.4	585.0	526.5
7			5/6	6			11232	9,360	1	688.2	650.0	585.0
8		256-QAM	3/4	8			14976	11,232	1	825.9	780.0	702.0
9			5/6	8			14976	12,480	1	917.6	866.7	780.0
10		1024-QAM	3/4	10			18720	14,040	1	1,032.4	975.0	877.5
11			5/6	10			18720	15,600	1	1,147.1	1,083.3	975.0

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Table 26-69—HE-MCSs for TBD mandatory/optional 484-tone RU and mandatory non-OFDMA 40 MHz, N_{SS} = 1

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	468	16	468	117	1	8.6	8.1	7.3
0	0		1/2	1			468	234	1	17.2	16.3	14.6
1	1	QPSK	1/4	2			936	234	1	17.2	16.3	14.6
1	0		1/2	2			936	468	1	34.4	32.5	29.3
2	N/A		3/4	2			936	702	1	51.6	48.8	43.9
3	1	16-QAM	1/4	4			1872	468	1	34.4	32.5	29.3
3	0		1/2	4			1872	936	1	68.8	65.0	58.5
4	1		3/8	4			1872	702	1	51.6	48.8	43.9
4	0		3/4	4			1872	1,404	1	103.2	97.5	87.8
5	N/A	64-QAM	2/3	6			2808	1,872	1	137.6	130.0	117.0
6			3/4	6			2808	2,106	1	154.9	146.3	131.6
7			5/6	6			2808	2,340	1	172.1	162.5	146.3
8		256-QAM	3/4	8			3744	2,808	1	206.5	195.0	175.5
9			5/6	8			3744	3,120	1	229.4	216.7	195.0
10		1024-QAM	3/4	10			4680	3,510	1	258.1	243.8	219.4
11			5/6	10			4680	3,900	1	286.8	270.8	243.8

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Table 26-70—HE-MCSs for TBD mandatory/optional 484-tone RU and mandatory non-OFDMA 40 MHz, N_{SS} = 2

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	468	16	936	234	1	17.2	16.3	14.6
0	0		1/2	1			936	468	1	34.4	32.5	29.3
1	1	QPSK	1/4	2			1872	468	1	34.4	32.5	29.3
1	0		1/2	2			1872	936	1	68.8	65.0	58.5
2	N/A		3/4	2			1872	1,404	1	103.2	97.5	87.8
3	1	16-QAM	1/4	4			3744	936	1	68.8	65.0	58.5
3	0		1/2	4			3744	1,872	1	137.6	130.0	117.0
4	1		3/8	4			3744	1,404	1	103.2	97.5	87.8
4	0		3/4	4			3744	2,808	1	206.5	195.0	175.5
5	N/A	64-QAM	2/3	6			5616	3,744	1	275.3	260.0	234.0
6			3/4	6			5616	4,212	1	309.7	292.5	263.3
7			5/6	6			5616	4,680	1	344.1	325.0	292.5
8		256-QAM	3/4	8			7488	5,616	1	412.9	390.0	351.0
9			5/6	8			7488	6,240	1	458.8	433.3	390.0
10		1024-QAM	3/4	10			9360	7,020	1	516.2	487.5	438.8
11			5/6	10			9360	7,800	1	573.5	541.7	487.5

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Table 26-71—HE-MCSs for TBD mandatory/optional 484-tone RU and mandatory non-OFDMA 40 MHz, N_{SS} = 3

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	468	16	1404	351	1	25.8	24.4	21.9
0	0		1/2	1			1404	702	1	51.6	48.8	43.9
1	1	QPSK	1/4	2			2808	702	1	51.6	48.8	43.9
1	0		1/2	2			2808	1,404	1	103.2	97.5	87.8
2	N/A		3/4	2			2808	2,106	1	154.9	146.3	131.6
3	1	16-QAM	1/4	4			5616	1,404	1	103.2	97.5	87.8
3	0		1/2	4			5616	2,808	1	206.5	195.0	175.5
4	1		3/8	4			5616	2,106	1	154.9	146.3	131.6
4	0		3/4	4			5616	4,212	1	309.7	292.5	263.3
5	N/A	64-QAM	2/3	6			8424	5,616	1	412.9	390.0	351.0
6			3/4	6			8424	6,318	1	464.6	438.8	394.9
7			5/6	6			8424	7,020	1	516.2	487.5	438.8
8		256-QAM	3/4	8			11232	8,424	1	619.4	585.0	526.5
9			5/6	8			11232	9,360	1	688.2	650.0	585.0
10		1024-QAM	3/4	10			14040	10,530	1	774.3	731.3	658.1
11			5/6	10			14040	11,700	1	860.3	812.5	731.3

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Table 26-72—HE-MCSs for TBD mandatory/optional 484-tone RU and mandatory non-OFDMA 40 MHz, N_{SS} = 4

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	468	16	1872	468	1	34.4	32.5	29.3
0	0		1/2	1			1872	936	1	68.8	65.0	58.5
1	1	QPSK	1/4	2			3744	936	1	68.8	65.0	58.5
1	0		1/2	2			3744	1,872	1	137.6	130.0	117.0
2	N/A		3/4	2			3744	2,808	1	206.5	195.0	175.5
3	1	16-QAM	1/4	4			7488	1,872	1	137.6	130.0	117.0
3	0		1/2	4			7488	3,744	1	275.3	260.0	234.0
4	1		3/8	4			7488	2,808	1	206.5	195.0	175.5
4	0		3/4	4			7488	5,616	1	412.9	390.0	351.0
5	N/A	64-QAM	2/3	6			11232	7,488	1	550.6	520.0	468.0
6			3/4	6			11232	8,424	1	619.4	585.0	526.5
7			5/6	6			11232	9,360	1	688.2	650.0	585.0
8		256-QAM	3/4	8			14976	11,232	1	825.9	780.0	702.0
9			5/6	8			14976	12,480	1	917.6	866.7	780.0
10		1024-QAM	3/4	10			18720	14,040	1	1,032.4	975.0	877.5
11			5/6	10			18720	15,600	1	1,147.1	1,083.3	975.0

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Table 26-73—HE-MCSs for TBD mandatory/optional 484-tone RU and mandatory non-OFDMA 40 MHz, N_{SS} = 5

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	468	16	2340	585	1	43.0	40.6	36.6
0	0		1/2	1			2340	1,170	1	86.0	81.3	73.1
1	1	QPSK	1/4	2			4680	1,170	1	86.0	81.3	73.1
1	0		1/2	2			4680	2,340	1	172.1	162.5	146.3
2	N/A		3/4	2			4680	3,510	1	258.1	243.8	219.4
3	1	16-QAM	1/4	4			9360	2,340	1	172.1	162.5	146.3
3	0		1/2	4			9360	4,680	1	344.1	325.0	292.5
4	1		3/8	4			9360	3,510	1	258.1	243.8	219.4
4	0		3/4	4			9360	7,020	1	516.2	487.5	438.8
5	N/A	64-QAM	2/3	6			14040	9,360	1	688.2	650.0	585.0
6			3/4	6			14040	10,530	1	774.3	731.3	658.1
7			5/6	6			14040	11,700	1	860.3	812.5	731.3
8		256-QAM	3/4	8			18720	14,040	1	1,032.4	975.0	877.5
9			5/6	8			18720	15,600	1	1,147.1	1,083.3	975.0
10		1024-QAM	3/4	10			23400	17,550	1	1,290.4	1,218.8	1,096.9
11			5/6	10			23400	19,500	1	1,433.8	1,354.2	1,218.8

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Table 26-74—HE-MCSs for TBD mandatory/optional 484-tone RU and mandatory non-OFDMA 40 MHz, N_{SS} = 6

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	468	16	2808	702	1	51.6	48.8	43.9
0	0		1/2	1			2808	1,404	1	103.2	97.5	87.8
1	1	QPSK	1/4	2			5616	1,404	1	103.2	97.5	87.8
1	0		1/2	2			5616	2,808	1	206.5	195.0	175.5
2	N/A		3/4	2			5616	4,212	1	309.7	292.5	263.3
3	1	16-QAM	1/4	4			11232	2,808	1	206.5	195.0	175.5
3	0		1/2	4			11232	5,616	1	412.9	390.0	351.0
4	1		3/8	4			11232	4,212	1	309.7	292.5	263.3
4	0		3/4	4			11232	8,424	1	619.4	585.0	526.5
5	N/A	64-QAM	2/3	6			16848	11,232	1	825.9	780.0	702.0
6			3/4	6			16848	12,636	1	929.1	877.5	789.8
7			5/6	6			16848	14,040	1	1,032.4	975.0	877.5
8		256-QAM	3/4	8			22464	16,848	1	1,238.8	1,170.0	1,053.0
9			5/6	8			22464	18,720	1	1,376.5	1,300.0	1,170.0
10		1024-QAM	3/4	10			28080	21,060	1	1,548.5	1,462.5	1,316.3
11			5/6	10			28080	23,400	1	1,720.6	1,625.0	1,462.5

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Table 26-75—HE-MCSs for TBD mandatory/optional 484-tone RU and mandatory non-OFDMA 40 MHz, N_{SS} = 7

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	468	16	3276	819	1	60.2	56.9	51.2
0	0		1/2	1			3276	1,638	1	120.4	113.8	102.4
1	1	QPSK	1/4	2			6552	1,638	1	120.4	113.8	102.4
1	0		1/2	2			6552	3,276	1	240.9	227.5	204.8
2	N/A		3/4	2			6552	4,914	1	361.3	341.3	307.1
3	1	16-QAM	1/4	4			13104	3,276	1	240.9	227.5	204.8
3	0		1/2	4			13104	6,552	1	481.8	455.0	409.5
4	1		3/8	4			13104	4,914	1	361.3	341.3	307.1
4	0		3/4	4			13104	9,828	1	722.6	682.5	614.3
5	N/A	64-QAM	2/3	6			19656	13,104	1	963.5	910.0	819.0
6			3/4	6			19656	14,742	1	1,084.0	1,023.8	921.4
7			5/6	6			19656	16,380	1	1,204.4	1,137.5	1,023.8
8		256-QAM	3/4	8			26208	19,656	1	1,445.3	1,365.0	1,228.5
9			5/6	8			26208	21,840	1	1,605.9	1,516.7	1,365.0
10		1024-QAM	3/4	10			32760	24,570	1	1,806.6	1,706.3	1,535.6
11			5/6	10			32760	27,300	1	2,007.4	1,895.8	1,706.3

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Table 26-76—HE-MCSs for TBD mandatory/optional 484-tone RU and mandatory non-OFDMA 40 MHz, N_{SS} = 8

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	468	16	3744	936	1	68.8	65.0	58.5
0	0		1/2	1			3744	1,872	1	137.6	130.0	117.0
1	1	QPSK	1/4	2			7488	1,872	1	137.6	130.0	117.0
1	0		1/2	2			7488	3,744	1	275.3	260.0	234.0
2	N/A		3/4	2			7488	5,616	1	412.9	390.0	351.0
3	1	16-QAM	1/4	4			14976	3,744	1	275.3	260.0	234.0
3	0		1/2	4			14976	7,488	1	550.6	520.0	468.0
4	1		3/8	4			14976	5,616	1	412.9	390.0	351.0
4	0		3/4	4			14976	11,232	1	825.9	780.0	702.0
5	N/A	64-QAM	2/3	6			22464	14,976	1	1,101.2	1,040.0	936.0
6			3/4	6			22464	16,848	1	1,238.8	1,170.0	1,053.0
7			5/6	6			22464	18,720	1	1,376.5	1,300.0	1,170.0
8		256-QAM	3/4	8			29952	22,464	1	1,651.8	1,560.0	1,404.0
9			5/6	8			29952	24,960	1	1,835.3	1,733.3	1,560.0
10		1024-QAM	3/4	10			37440	28,080	1	2,064.7	1,950.0	1,755.0
11			5/6	10			37440	31,200	1	2,294.1	2,166.7	1,950.0

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Table 26-77—HE-MCSs for TBD mandatory/optional 996-tone RU and mandatory non-OFDMA 80 MHz, N_{SS} = 1

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	980	16	980	245	1	18.0	17.0	15.3
0	0		1/2	1			980	490	1	36.0	34.0	30.6
1	1	QPSK	1/4	2			1960	490	1	36.0	34.0	30.6
1	0		1/2	2			1960	980	1	72.1	68.1	61.3
2	N/A		3/4	2			1960	1,470	1	108.1	102.1	91.9
3	1	16-QAM	1/4	4			3920	980	1	72.1	68.1	61.3
3	0		1/2	4			3920	1,960	1	144.1	136.1	122.5
4	1		3/8	4			3920	1,470	1	108.1	102.1	91.9
4	0		3/4	4			3920	2,940	1	216.2	204.2	183.8
5	N/A	64-QAM	2/3	6			5880	3,920	1	288.2	272.2	245.0
6			3/4	6			5880	4,410	1	324.3	306.3	275.6
7			5/6	6			5880	4,900	1	360.3	340.3	306.3
8		256-QAM	3/4	8			7840	5,880	1	432.4	408.3	367.5
9			5/6	8			7840	6,533	1	480.4	453.7	408.3
10		1024-QAM	3/4	10			9800	7,350	1	540.4	510.4	459.4
11			5/6	10			9800	8,166	1	600.4	567.1	510.4

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Table 26-78—HE-MCSs for TBD mandatory/optional 996-tone RU and mandatory non-OFDMA 80 MHz, N_{SS} = 2

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	980	16	1960	490	1	36.0	34.0	30.6
0	0		1/2	1			1960	980	1	72.1	68.1	61.3
1	1	QPSK	1/4	2			3920	980	1	72.1	68.1	61.3
1	0		1/2	2			3920	1,960	1	144.1	136.1	122.5
2	N/A		3/4	2			3920	2,940	1	216.2	204.2	183.8
3	1	16-QAM	1/4	4			7840	1,960	1	144.1	136.1	122.5
3	0		1/2	4			7840	3,920	1	288.2	272.2	245.0
4	1		3/8	4			7840	2,940	1	216.2	204.2	183.8
4	0		3/4	4			7840	5,880	1	432.4	408.3	367.5
5	N/A	64-QAM	2/3	6			11760	7,840	1	576.5	544.4	490.0
6			3/4	6			11760	8,820	1	648.5	612.5	551.3
7			5/6	6			11760	9,800	1	720.6	680.6	612.5
8		256-QAM	3/4	8			15680	11,760	1	864.7	816.7	735.0
9			5/6	8			15680	13,066	1	960.7	907.4	816.6
10		1024-QAM	3/4	10			19600	14,700	1	1,080.9	1,020.8	918.8
11			5/6	10			19600	16,333	1	1,201.0	1,134.2	1,020.8

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Table 26-79—HE-MCSs for TBD mandatory/optional 996-tone RU and mandatory non-OFDMA 80 MHz, N_{SS} = 3

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	980	16	2940	735	1	54.0	51.0	45.9
0	0		1/2	1			2940	1,470	1	108.1	102.1	91.9
1	1	QPSK	1/4	2			5880	1,470	1	108.1	102.1	91.9
1	0		1/2	2			5880	2,940	1	216.2	204.2	183.8
2	N/A		3/4	2			5880	4,410	1	324.3	306.3	275.6
3	1	16-QAM	1/4	4			11760	2,940	1	216.2	204.2	183.8
3	0		1/2	4			11760	5,880	1	432.4	408.3	367.5
4	1		3/8	4			11760	4,410	1	324.3	306.3	275.6
4	0		3/4	4			11760	8,820	1	648.5	612.5	551.3
5	N/A	64-QAM	2/3	6			17640	11,760	1	864.7	816.7	735.0
6			3/4	6			17640	13,230	1	972.8	918.8	826.9
7			5/6	6			17640	14,700	1	1,080.9	1,020.8	918.8
8		256-QAM	3/4	8			23520	17,640	1	1,297.1	1,225.0	1,102.5
9			5/6	8			23520	19,600	1	1,441.2	1,361.1	1,225.0
10		1024-QAM	3/4	10			29400	22,050	1	1,621.3	1,531.3	1,378.1
11			5/6	10			29400	24,500	1	1,801.5	1,701.4	1,531.3

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Table 26-80—HE-MCSs for TBD mandatory/optional 996-tone RU and mandatory non-OFDMA 80 MHz, N_{SS} = 4

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	980	16	3920	980	1	72.1	68.1	61.3
0	0		1/2	1			3920	1,960	1	144.1	136.1	122.5
1	1	QPSK	1/4	2			7840	1,960	1	144.1	136.1	122.5
1	0		1/2	2			7840	3,920	1	288.2	272.2	245.0
2	N/A		3/4	2			7840	5,880	1	432.4	408.3	367.5
3	1	16-QAM	1/4	4			15680	3,920	1	288.2	272.2	245.0
3	0		1/2	4			15680	7,840	1	576.5	544.4	490.0
4	1		3/8	4			15680	5,880	1	432.4	408.3	367.5
4	0		3/4	4			15680	11,760	1	864.7	816.7	735.0
5	N/A	64-QAM	2/3	6			23520	15,680	1	1,152.9	1,088.9	980.0
6			3/4	6			23520	17,640	1	1,297.1	1,225.0	1,102.5
7			5/6	6			23520	19,600	1	1,441.2	1,361.1	1,225.0
8		256-QAM	3/4	8			31360	23,520	1	1,729.4	1,633.3	1,470.0
9			5/6	8			31360	26,133	1	1,921.5	1,814.8	1,633.3
10		1024-QAM	3/4	10			39200	29,400	1	2,161.8	2,041.7	1,837.5
11			5/6	10			39200	32,666	1	2,401.9	2,268.5	2,041.6

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Table 26-81—HE-MCSs for TBD mandatory/optional 996-tone RU and mandatory non-OFDMA 80 MHz, N_{SS} = 5

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	980	16	4900	1,225	1	90.1	85.1	76.6
0	0		1/2	1			4900	2,450	1	180.1	170.1	153.1
1	1	QPSK	1/4	2			9800	2,450	1	180.1	170.1	153.1
1	0		1/2	2			9800	4,900	1	360.3	340.3	306.3
2	N/A		3/4	2			9800	7,350	1	540.4	510.4	459.4
3	1	16-QAM	1/4	4			19600	4,900	1	360.3	340.3	306.3
3	0		1/2	4			19600	9,800	1	720.6	680.6	612.5
4	1		3/8	4			19600	7,350	1	540.4	510.4	459.4
4	0		3/4	4			19600	14,700	1	1,080.9	1,020.8	918.8
5	N/A	64-QAM	2/3	6			29400	19,600	1	1,441.2	1,361.1	1,225.0
6			3/4	6			29400	22,050	1	1,621.3	1,531.3	1,378.1
7			5/6	6			29400	24,500	1	1,801.5	1,701.4	1,531.3
8		256-QAM	3/4	8			39200	29,400	1	2,161.8	2,041.7	1,837.5
9			5/6	8			39200	32,666	1	2,401.9	2,268.5	2,041.6
10		1024-QAM	3/4	10			49000	36,750	1	2,702.2	2,552.1	2,296.9
11			5/6	10			49000	40,833	1	3,002.4	2,835.6	2,552.1

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Table 26-82—HE-MCSs for TBD mandatory/optional 996-tone RU and mandatory non-OFDMA 80 MHz, N_{SS} = 6

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	980	16	5880	1,470	1	108.1	102.1	91.9
0	0		1/2	1			5880	2,940	1	216.2	204.2	183.8
1	1	QPSK	1/4	2			11760	2,940	1	216.2	204.2	183.8
1	0		1/2	2			11760	5,880	1	432.4	408.3	367.5
2	N/A		3/4	2			11760	8,820	1	648.5	612.5	551.3
3	1	16-QAM	1/4	4			23520	5,880	1	432.4	408.3	367.5
3	0		1/2	4			23520	11,760	1	864.7	816.7	735.0
4	1		3/8	4			23520	8,820	1	648.5	612.5	551.3
4	0		3/4	4			23520	17,640	1	1,297.1	1,225.0	1,102.5
5	N/A	64-QAM	2/3	6			35280	23,520	1	1,729.4	1,633.3	1,470.0
6			3/4	6			35280	26,460	1	1,945.6	1,837.5	1,653.8
7			5/6	6			35280	29,400	1	2,161.8	2,041.7	1,837.5
8		256-QAM	3/4	8			47040	35,280	1	2,594.1	2,450.0	2,205.0
9			5/6	8			47040	39,200	1	2,882.4	2,722.2	2,450.0
10		1024-QAM	3/4	10			58800	44,100	1	3,242.6	3,062.5	2,756.3
11			5/6	10			58800	49,000	1	3,602.9	3,402.8	3,062.5

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Table 26-83—HE-MCSs for TBD mandatory/optional 996-tone RU and mandatory non-OFDMA 80 MHz, N_{SS} = 7

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	980	16	6860	1,715	1	126.1	119.1	107.2
0	0		1/2	1			6860	3,430	1	252.2	238.2	214.4
1	1	QPSK	1/4	2			13720	3,430	1	252.2	238.2	214.4
1	0		1/2	2			13720	6,860	1	504.4	476.4	428.8
2	N/A		3/4	2			13720	10,290	1	756.6	714.6	643.1
3	1	16-QAM	1/4	4			27440	6,860	1	504.4	476.4	428.8
3	0		1/2	4			27440	13,720	1	1,008.8	952.8	857.5
4	1		3/8	4			27440	10,290	1	756.6	714.6	643.1
4	0		3/4	4			27440	20,580	1	1,513.2	1,429.2	1,286.3
5	N/A	64-QAM	2/3	6			41160	27,440	1	2,017.6	1,905.6	1,715.0
6			3/4	6			41160	30,870	1	2,269.9	2,143.8	1,929.4
7			5/6	6			41160	34,300	1	2,522.1	2,381.9	2,143.8
8		256-QAM	3/4	8			54880	41,160	1	3,026.5	2,858.3	2,572.5
9			5/6	8			54880	45,733	1	3,362.7	3,175.9	2,858.3
10		1024-QAM	3/4	10			68600	51,450	1	3,783.1	3,572.9	3,215.6
11			5/6	10			68600	57,166	1	4,203.4	3,969.9	3,572.9

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Table 26-84—HE-MCSs for TBD mandatory/optional 996-tone RU and mandatory non-OFDMA 80 MHz, N_{SS} = 8

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	980	16	7840	1,960	1	144.1	136.1	122.5
0	0		1/2	1			7840	3,920	1	288.2	272.2	245.0
1	1	QPSK	1/4	2			15680	3,920	1	288.2	272.2	245.0
1	0		1/2	2			15680	7,840	1	576.5	544.4	490.0
2	N/A		3/4	2			15680	11,760	1	864.7	816.7	735.0
3	1	16-QAM	1/4	4			31360	7,840	1	576.5	544.4	490.0
3	0		1/2	4			31360	15,680	1	1,152.9	1,088.9	980.0
4	1		3/8	4			31360	11,760	1	864.7	816.7	735.0
4	0		3/4	4			31360	23,520	1	1,729.4	1,633.3	1,470.0
5	N/A	64-QAM	2/3	6			47040	31,360	1	2,305.9	2,177.8	1,960.0
6			3/4	6			47040	35,280	1	2,594.1	2,450.0	2,205.0
7			5/6	6			47040	39,200	1	2,882.4	2,722.2	2,450.0
8		256-QAM	3/4	8			62720	47,040	1	3,458.8	3,266.7	2,940.0
9			5/6	8			62720	52,266	1	3,843.1	3,629.6	3,266.6
10		1024-QAM	3/4	10			78400	58,800	1	4,323.5	4,083.3	3,675.0
11			5/6	10			78400	65,333	1	4,803.9	4,537.0	4,083.3

Table 26-85—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, N_{SS} = 1

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	1960	32	1960	490	1	36.0	34.0	30.6
0	0		1/2	1			1960	980	1	72.1	68.1	61.3
1	1	QPSK	1/4	2			3920	980	1	72.1	68.1	61.3
1	0		1/2	2			3920	1,960	1	144.1	136.1	122.5
2	N/A		3/4	2			3920	2,940	1	216.2	204.2	183.8
3	1	16-QAM	1/4	4			7840	1,960	1	144.1	136.1	122.5
3	0		1/2	4			7840	3,920	1	288.2	272.2	245.0
4	1		3/8	4			7840	2,940	1	216.2	204.2	183.8
4	0		3/4	4			7840	5,880	1	432.4	408.3	367.5
5	N/A	64-QAM	2/3	6			11760	7,840	1	576.5	544.4	490.0
6			3/4	6			11760	8,820	1	648.5	612.5	551.3
7			5/6	6			11760	9,800	1	720.6	680.6	612.5
8		256-QAM	3/4	8			15680	11,760	1	864.7	816.7	735.0
9			5/6	8			15680	13,066	1	960.7	907.4	816.6
10		1024-QAM	3/4	10			19600	14,700	1	1,080.9	1,020.8	918.8
11			5/6	10			19600	16,333	1	1,201.0	1,134.2	1,020.8

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Table 26-86—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, N_{SS} = 2

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	1960	32	3920	980	1	72.1	68.1	61.3
0	0		1/2	1			3920	1,960	1	144.1	136.1	122.5
1	1	QPSK	1/4	2			7840	1,960	1	144.1	136.1	122.5
1	0		1/2	2			7840	3,920	1	288.2	272.2	245.0
2	N/A		3/4	2			7840	5,880	1	432.4	408.3	367.5
3	1	16-QAM	1/4	4			15680	3,920	1	288.2	272.2	245.0
3	0		1/2	4			15680	7,840	1	576.5	544.4	490.0
4	1		3/8	4			15680	5,880	1	432.4	408.3	367.5
4	0		3/4	4			15680	11,760	1	864.7	816.7	735.0
5	N/A	64-QAM	2/3	6			23520	15,680	1	1,152.9	1,088.9	980.0
6			3/4	6			23520	17,640	1	1,297.1	1,225.0	1,102.5
7			5/6	6			23520	19,600	1	1,441.2	1,361.1	1,225.0
8		256-QAM	3/4	8			31360	23,520	1	1,729.4	1,633.3	1,470.0
9			5/6	8			31360	26,133	1	1,921.5	1,814.8	1,633.3
10		1024-QAM	3/4	10			39200	29,400	1	2,161.8	2,041.7	1,837.5
11			5/6	10			39200	32,666	1	2,401.9	2,268.5	2,041.6

Table 26-87—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, N_{SS} = 3

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	1960	32	5880	1,470	1	108.1	102.1	91.9
0	0		1/2	1			5880	2,940	1	216.2	204.2	183.8
1	1	QPSK	1/4	2			11760	2,940	1	216.2	204.2	183.8
1	0		1/2	2			11760	5,880	1	432.4	408.3	367.5
2	N/A		3/4	2			11760	8,820	1	648.5	612.5	551.3
3	1	16-QAM	1/4	4			23520	5,880	1	432.4	408.3	367.5
3	0		1/2	4			23520	11,760	1	864.7	816.7	735.0
4	1		3/8	4			23520	8,820	1	648.5	612.5	551.3
4	0		3/4	4			23520	17,640	1	1,297.1	1,225.0	1,102.5
5	N/A	64-QAM	2/3	6			35280	23,520	1	1,729.4	1,633.3	1,470.0
6			3/4	6			35280	26,460	1	1,945.6	1,837.5	1,653.8
7			5/6	6			35280	29,400	1	2,161.8	2,041.7	1,837.5
8		256-QAM	3/4	8			47040	35,280	1	2,594.1	2,450.0	2,205.0
9			5/6	8			47040	39,200	1	2,882.4	2,722.2	2,450.0
10		1024-QAM	3/4	10			58800	44,100	1	3,242.6	3,062.5	2,756.3
11			5/6	10			58800	49,000	1	3,602.9	3,402.8	3,062.5

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Table 26-88—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, N_{SS} = 4

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	1960	32	7840	1,960	1	144.1	136.1	122.5
0	0		1/2	1			7840	3,920	1	288.2	272.2	245.0
1	1	QPSK	1/4	2			15680	3,920	1	288.2	272.2	245.0
1	0		1/2	2			15680	7,840	1	576.5	544.4	490.0
2	N/A		3/4	2			15680	11,760	1	864.7	816.7	735.0
3	1	16-QAM	1/4	4			31360	7,840	1	576.5	544.4	490.0
3	0		1/2	4			31360	15,680	1	1,152.9	1,088.9	980.0
4	1		3/8	4			31360	11,760	1	864.7	816.7	735.0
4	0		3/4	4			31360	23,520	1	1,729.4	1,633.3	1,470.0
5	N/A	64-QAM	2/3	6			47040	31,360	1	2,305.9	2,177.8	1,960.0
6			3/4	6			47040	35,280	1	2,594.1	2,450.0	2,205.0
7			5/6	6			47040	39,200	1	2,882.4	2,722.2	2,450.0
8		256-QAM	3/4	8			62720	47,040	1	3,458.8	3,266.7	2,940.0
9			5/6	8			62720	52,266	1	3,843.1	3,629.6	3,266.6
10		1024-QAM	3/4	10			78400	58,800	1	4,323.5	4,083.3	3,675.0
11			5/6	10			78400	65,333	1	4,803.9	4,537.0	4,083.3

Table 26-89—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, N_{SS} = 5

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	1960	32	9800	2,450	1	180.1	170.1	153.1
0	0		1/2	1			9800	4,900	1	360.3	340.3	306.3
1	1	QPSK	1/4	2			19600	4,900	1	360.3	340.3	306.3
1	0		1/2	2			19600	9,800	1	720.6	680.6	612.5
2	N/A		3/4	2			19600	14,700	1	1,080.9	1,020.8	918.8
3	1	16-QAM	1/4	4			39200	9,800	1	720.6	680.6	612.5
3	0		1/2	4			39200	19,600	1	1,441.2	1,361.1	1,225.0
4	1		3/8	4			39200	14,700	1	1,080.9	1,020.8	918.8
4	0		3/4	4			39200	29,400	1	2,161.8	2,041.7	1,837.5
5	N/A	64-QAM	2/3	6			58800	39,200	1	2,882.4	2,722.2	2,450.0
6			3/4	6			58800	44,100	1	3,242.6	3,062.5	2,756.3
7			5/6	6			58800	49,000	1	3,602.9	3,402.8	3,062.5
8		256-QAM	3/4	8			78400	58,800	1	4,323.5	4,083.3	3,675.0
9			5/6	8			78400	65,333	1	4,803.9	4,537.0	4,083.3
10		1024-QAM	3/4	10			98000	73,500	1	5,404.4	5,104.2	4,593.8
11			5/6	10			98000	81,666	1	6,004.9	5,671.3	5,104.1

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Table 26-90—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, N_{SS} = 6

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	1960	32	11760	2,940	1	216.2	204.2	183.8
0	0		1/2	1			11760	5,880	1	432.4	408.3	367.5
1	1	QPSK	1/4	2			23520	5,880	1	432.4	408.3	367.5
1	0		1/2	2			23520	11,760	1	864.7	816.7	735.0
2	N/A		3/4	2			23520	17,640	1	1,297.1	1,225.0	1,102.5
3	1	16-QAM	1/4	4			47040	11,760	1	864.7	816.7	735.0
3	0		1/2	4			47040	23,520	1	1,729.4	1,633.3	1,470.0
4	1		3/8	4			47040	17,640	1	1,297.1	1,225.0	1,102.5
4	0		3/4	4			47040	35,280	1	2,594.1	2,450.0	2,205.0
5	N/A	64-QAM	2/3	6			70560	47,040	1	3,458.8	3,266.7	2,940.0
6			3/4	6			70560	52,920	1	3,891.2	3,675.0	3,307.5
7			5/6	6			70560	58,800	1	4,323.5	4,083.3	3,675.0
8		256-QAM	3/4	8			94080	70,560	1	5,188.2	4,900.0	4,410.0
9			5/6	8			94080	78,400	1	5,764.7	5,444.4	4,900.0
10		1024-QAM	3/4	10			117600	88,200	1	6,485.3	6,125.0	5,512.5
11			5/6	10			117600	98,000	1	7,205.9	6,805.6	6,125.0

Table 26-91—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, N_{SS} = 7

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	1960	32	13720	3,430	1	252.2	238.2	214.4
0	0		1/2	1			13720	6,860	1	504.4	476.4	428.8
1	1	QPSK	1/4	2			27440	6,860	1	504.4	476.4	428.8
1	0		1/2	2			27440	13,720	1	1,008.8	952.8	857.5
2	N/A		3/4	2			27440	20,580	1	1,513.2	1,429.2	1,286.3
3	1	16-QAM	1/4	4			54880	13,720	1	1,008.8	952.8	857.5
3	0		1/2	4			54880	27,440	1	2,017.6	1,905.6	1,715.0
4	1		3/8	4			54880	20,580	1	1,513.2	1,429.2	1,286.3
4	0		3/4	4			54880	41,160	1	3,026.5	2,858.3	2,572.5
5	N/A	64-QAM	2/3	6			82320	54,880	1	4,035.3	3,811.1	3,430.0
6			3/4	6			82320	61,740	1	4,539.7	4,287.5	3,858.8
7			5/6	6			82320	68,600	1	5,044.1	4,763.9	4,287.5
8		256-QAM	3/4	8			109760	82,320	1	6,052.9	5,716.7	5,145.0
9			5/6	8			109760	91,466	1	6,725.4	6,351.8	5,716.6
10		1024-QAM	3/4	10			137200	102,900	1	7,566.2	7,145.8	6,431.3
11			5/6	10			137200	114,333	1	8,406.8	7,939.8	7,145.8

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Table 26-92—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, N_{SS} = 8

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	1960	32	15680	3,920	1	288.2	272.2	245.0
0	0		1/2	1			15680	7,840	1	576.5	544.4	490.0
1	1	QPSK	1/4	2			31360	7,840	1	576.5	544.4	490.0
1	0		1/2	2			31360	15,680	1	1,152.9	1,088.9	980.0
2	N/A		3/4	2			31360	23,520	1	1,729.4	1,633.3	1,470.0
3	1	16-QAM	1/4	4			62720	15,680	1	1,152.9	1,088.9	980.0
3	0		1/2	4			62720	31,360	1	2,305.9	2,177.8	1,960.0
4	1		3/8	4			62720	23,520	1	1,729.4	1,633.3	1,470.0
4	0		3/4	4			62720	47,040	1	3,458.8	3,266.7	2,940.0
5	N/A	64-QAM	2/3	6			94080	62,720	1	4,611.8	4,355.6	3,920.0
6			3/4	6			94080	70,560	1	5,188.2	4,900.0	4,410.0
7			5/6	6			94080	78,400	1	5,764.7	5,444.4	4,900.0
8		256-QAM	3/4	8			125440	94,080	1	6,917.6	6,533.3	5,880.0
9			5/6	8			125440	104,533	1	7,686.3	7,259.2	6,533.3
10		1024-QAM	3/4	10			156800	117,600	1	8,647.1	8,166.7	7,350.0
11			5/6	10			156800	130,666	1	9,607.8	9,074.0	8,166.6

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Annex C

(normative)

ASN.1 encoding of the MAC and PHY MIB

C.3 MIB Detail

Insert the following (after getting some sucker to validate MIB compilation, etc.):

```
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 the dot11PPEThresholdsTable MIB."
DEFVAL { false }
::= { dot11StationConfigEntry <ANA> }

--------------------------------------------------------------------
-- ********************************************************************
-- * 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 Map-
       pings 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>, 9.47 (HE Post-FEC Padding and Packet Exten-
       sion)"
::= { dot11smt 4 }

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 {
dot11PPEThresholdsMappingIndexUnsigned32,
dot11PPEThresholdsMappingNSSInteger,
dot11PPEThresholdsMappingRUIndexInteger,
dot11PPEThresholdsMappingPPET8Integer,
dot11PPEThresholdsMappingPPET16Integer,
```

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```
dot11PPEThresholdsMappingStatusRowStatus }

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 Thresh-
      olds 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 TBD tones,
      3 is reserved."
::= { 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 Pad-
      ding 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 16QAM, 3 is 64QAM, 4 is
      256QAM, 5 is 1024QAM, 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 Pad-
      ding 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 16QAM, 3 is 64QAM, 4 is 256QAM, 5 is
      1024QAM, 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 }
```


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```
::= { dot11PPEThresholdsMappingsEntry 6 }

--------------------------------------------------------------------------
-- * End of dot11PPEThresholdsMappings TABLE
-- --------------------------------------------------------------------------
```

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APPENDIX I

IEEE P802.11ax™/D0.5, September 2016
(amendment to IEEE P802.11REVmc™/D8.0
as 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™/D1.0)

IEEE P802.11ax™/D0.5

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(#1121)

Prepared by the 802.11 Working Group of the

LAN/MAN Standards Committee
of the
IEEE Computer Society

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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

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This introduction is not part of IEEE P802.11ax /D0.5, September 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(#1121).

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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Table 26-95—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, NSS = 4 345
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Table 26-99—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, NSS = 8 347

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IEEE P802.11ax™/D0.5

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(#1121)

[This amendment is based on IEEE P802.11REVmc/D6.0(#2111) amended by IEEE P802.11ai/D4.0, IEEE P802.11ah/D5.0, IEEE P802.11aq/D3.0, IEEE P802.11ak/D1.0 and IEEE P802.11aj/D1.0]

NOTE—The editing instructions contained in this amendment define how to merge the material contained therein into the existing base standard and its amendments to form the comprehensive standard.

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

Editorial Notes

Editor's Note: Editorial Notes in the body of the standard appear like this. They will be removed before publication. They may highlight some issue that the editor has had to address during the implementation of a change. Where there may be any technical impact from an editing issue, the editor will raise a technical letter ballot comment. There is no need for voters to comment on such issues unless they have a specific resolution they wish to present.

Editor's Note: Headings with empty content or Headings preceding editing instructions that modify the contents of the referenced subclause are there to provide context to the reader of this document, they have no other significance.

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Editor's Note: The default IEEE-SA style for tables is to "float". This means that they be repositioned later, usually at the head of the next page, to avoid splitting the table and reduce the amount of blank space. The table can appear to move out of the subclause it is referenced first from, and can even split a paragraph. This is the intended IEEE-SA behavior, please do not report it as a defect in the draft. In many cases, additional line feeds have been inserted to force tables to follow text, rather than float beyond sequential text. The additional line feeds will be removed before publication, please do not report them as a defect in the text.

Editor's Note: Line numbering is only approximate. This is a limitation of the FrameMaker tool. Whitespace between paragraphs is part of the IEEE-SA style, as defined in their templates. The combination of these two facts leads to the appearance of blank lines in the draft between every paragraph. Please do not report this as an editorial defect as it is the unavoidable behavior.

Tags:

Tags are placed in this draft near changes to identify the source of the change. Changes resulting from incorporation of an approved proposal are shown like this: (#<number>), where <number> identifies the submission/revision that introduced that change.

These tags will be hidden in versions of the draft sent out to letter ballot - i.e., they are present only to assist the editorial review panel in checking that changes have been properly applied.

Tags are shown close to the point of change. When a whole subclause is new, the heading is tagged.

Otherwise, when a whole paragraph is new, the paragraph is tagged. Otherwise tags are placed after a section of changes within a paragraph or at the end of the paragraph if the changes are substantial.

New tables are tagged in the table caption (if there is one), or in the introductory paragraph. Otherwise, new rows in existing tables are tagged only in the first column, to avoid distraction. Otherwise, a modified cell is tagged.

Finally, any other changes made by the editor (e.g., for grammar, language, style & consistency with other comment resolutions, baseline, etc.) are tagged (#Ed).

Editor's Note: A cumulative status of the versions of this draft is shown below.

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

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3. Definitions, acronyms, and abbreviations

3.2 Definitions specific to IEEE 802.11

Insert the following definitions maintaining alphabetical order:

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.(#355)

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.(#544)

3.4 Abbreviations and acronyms

Insert the following acronym definitions (maintaining alphabetical order):

DCM	Dual carrier modulation(#2567)
DL	Downlink(#2401)
DL MU	Downlink multi-user
HE	High efficiency
OBO	Orthogonal frequency division multiple access (OFDMA) backoff(#1747)
OCW	Orthogonal frequency division multiple access (OFDMA) contention window(#1747)
OFDMA	Orthogonal frequency-division multiple access
OMI	Operation mode indication(#2200)(#2328)
PPE	PHY padding extension(#1723)
MU-RTS	Multi-user request to send
UL	Uplink
UL MU	Uplink multi-user(#545)

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4. General description

4.3 Components of the IEEE Std 802.11 architecture

Insert a new subclause after subclause 4.3.12 as follows:

4.3.12a High efficiency (HE) STA

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

An HE STA is VHT STA or HT non-AP STA that, in addition to the features supported as a VHT STA or HT non-AP STA respectively, supports the MAC features defined in Clause 25 and the PHY features defined in Clause 26.(PHY Motion #163)

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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

(#2306)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,

HE Capabilities,(#1227)(#1238)

VendorSpecificInfo

)

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

Name	Type	Valid range	Description
HE Capabilities	As defined in HE Capabilities element.(#1122)	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(

...,

HE Capabilities,(#1227)(#1239)(#1240)(#2294)

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.(#1122)	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(

...

HE Capabilities,(#1227)(#1239)(#1240)

VendorSpecificInfo

)

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

Name	Type	Valid range	Description
HE Capabilities	As defined in HE Capabilities element.(#1122)	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.(#1122)	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 (#1230)present if dot11HEOptionImplemented is true; otherwise, this parameter is not present.
HE Operation	As defined in HE Operation element.(#1122)	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 (#1152)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):

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MLME-DLS.indication(

...,

HE Capabilities,

VendorSpecificInfo

)(#1352)

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.

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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(#2420)
)

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 26-1 (TXVECTOR and RXVECTOR parameters(#1780)) is present for a 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(#2420)
)

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.

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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 fields

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

9.2.4.1.10 Order field

Change this subclause as follows:

The Order field is 1 bit in length. The setting of the Order field is as follows:

- 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 Order field is set to 0.

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

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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. 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 a 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 25.5.2 (UL MU operation).(#2445) 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.(MAC Motion #85) 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 25.5.2 (UL MU operation)).(#172)

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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).(#172)

9.2.4.6 HT Control field

9.2.4.6.1 General

Remove Figure 9-8 (HT Control field).

Insert Table 9-9a(#2373) 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(#548)	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~~,~~:(#359)(#1878) the HT variant, ~~and~~ (#1879)the VHT variant, and the HE variant. These forms differ in the values of the VHT and(#711) 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.(#1750)(#1244) The VHT subfield is set to 0 to indicate an(#2829) 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(#2829) HE variant HT Control field(#960)(#1127).

The HT Control Middle subfield is defined in 9.2.4.6.2 (HT variant)(#2203) 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)(#2203)(#58).

~~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.~~

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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).(#550)

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(#1132) is shown in Figure 9-15a (Aggregated Control subfield of the HE variant HT Control field(#360)(#792)(#1711)(#2204)).

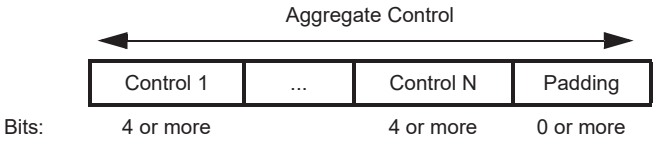


Figure 9-15a—Aggregated Control subfield of the HE variant HT Control field(#360)(#792)(#1711)(#2204)

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.

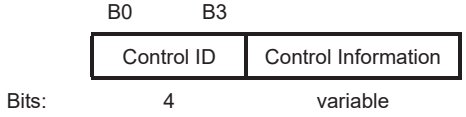


Figure 9-15b—Control subfield format

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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 reserved.(#1251)(#1133) 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(#2209)	16	See 9.2.4.6.4.3 (Operating Mode(#2209))
2	HE link adaptation	TBD	See 9.2.4.6.4.4 (HE link adaptation)
3	Buffer Status Report (BSR)(#824)	26	See 9.2.4.6.5 (Buffer Status Report (BSR)(#824))
4	UL Power Headroom(#340)	8	See 9.2.4.6.5.1 (UL power headroom)
5-15	Reserved		

(#1252)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.(#792)(#793)(#363)

9.2.4.6.4.2 UL MU response scheduling

If the Control ID subfield is 0, the Control Information subfield contains(#1257) 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 25.5.2.2 (Rules for soliciting UL MU frames)).(#2208)

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

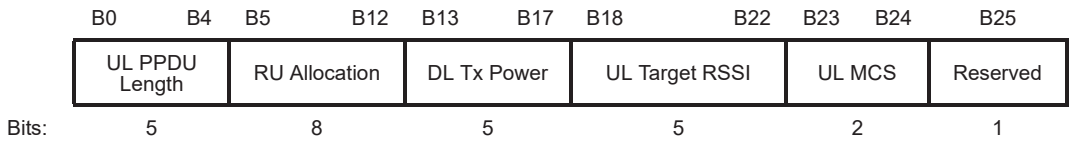


Figure 9-15c—Control Information subfield format when Control ID subfield is 0

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(#Ed). The duration of the HE trigger-based PPDU is calculated as defined in 26.4.2 (TXTIME and PSDU_LENGTH calculation).(#94)

(#1)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).

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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 26.5 (Parameters for HE-MCSs(#552))).

9.2.4.6.4.3 Operating Mode(#2209)

If the Control ID subfield is 1, the Control Information subfield contains(#1257) information related to the operating mode change(#2209)(#95) of the STA transmitting the frame containing this information (see 25.8 (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(#95)	3(#95)	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(#1258) 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. (#365)(#656)(#794)(#1135)(1260)(#2407)

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 $N_{SS} - 1$.(#2463)

9.2.4.6.4.4 HE link adaptation

If the Control ID subfield is 2, the Control Information subfield contains(#1257) information related to the HE link adaptation procedure (see 9.31.4 (Link adaptation using the HE variant HT Control field)).

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

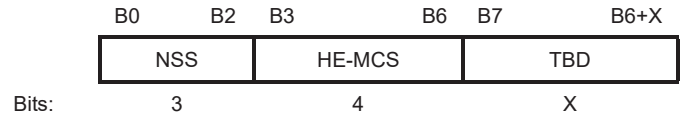


Figure 9-15e—Control Information subfield format when Control ID subfield is 2

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 26.5 (Parameters for HE-MCSs(#552))).

9.2.4.6.5 Buffer Status Report (BSR)(#824)

The Control Information subfield, when the Control ID subfield is 3, contains buffer status information used for UL MU operation (see 25.5.2.5 (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).

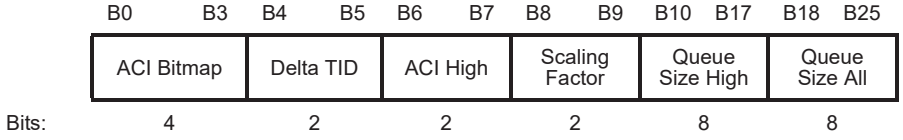


Figure 9-15f—Control Information subfield format when Control ID subfield is 3

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

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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).(#824)(#93)(#1067)(#2388)

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9.2.4.6.5.1 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).

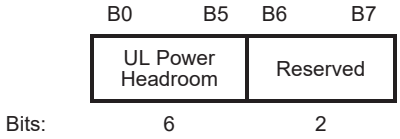


Figure 9-15g—Control Information subfield format when the Control ID subfield is 4

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.(#340)

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(11ah), 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.(#2579)

...

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.(#2410)

...

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)

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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.(#2579)

Change item b) of the 2nd paragraph as follows:(#366)

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(11ah)

—Any pending PS-Poll or NDP PS-Poll frame exchanges by paged STAs(11ah)

—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.

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.

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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 or MU-BAR 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.

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)).(#2411)

9.3 Format of individual frame types

9.3.1 Control frames

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.(#2603)

9.3.1.8 BlockAckReq frame format

9.3.1.8.2 Basic BlockAckReq variant

Change Figure 9-28 as follows:

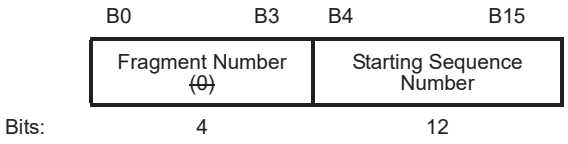


Figure 9-28—Block Ack Starting Sequence Control subfield(#515)

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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(#804)(2412)	Reserved	TID_INFO
Bits:	1	~~1~~	~~1~~	~~2(11ak)~~	4	~~8~~7	4

Figure 9-33—BA Control field

Change the 3rd paragraph of this subclause as follows:

The RA field of the BlockAck frame that is not a Multi-STA BlockAck variant(#Ed) is the address of the recipient STA that requested the Block Ack. 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 address of the recipient STA that requested the Block Ack frame.(#2212)

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. A Multi-STA BlockAck frame is not sent under Delayed and HT-delayed agreements.

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Change Table 9-24 as follows:

Table 9-24—BlockAck frame variant encoding(11ak)

~~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(#961)(#1137)(#212)
		~~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(#2413)
		~~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(11ak)).

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

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frames by an HT STA or DMG STA). ~~The Fragment Number subfield of the Block Ack Starting Sequence Control subfield is set to 0.~~

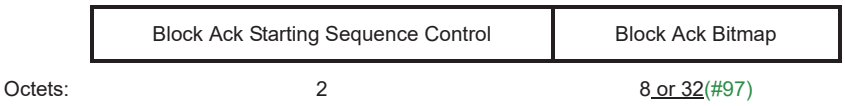


Figure 9-34—BA Information field (Compressed BlockAck)

(#97)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 25.3 (Fragmentation)).					

Change the remainder of 9.3.1.9.3 as follows:

(#97)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(#1279) 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(#1280) 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.

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When (#1806)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(#1281) 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(#1282) is 0, it indicates that the MPDU has not been received.(#1138)

NOTE—When (#1808)the B0 of the Fragment Number subfield is equal to 1 then the (#1139)Block Ack Bitmap subfield(#1278) is split into (#1809)(Block Ack Bitmap subfield length)/4 subbitmaps, each of which indicates receive status for (#1270)up to 4 fragments of each of the MSDUs(#2300) as indicated in Table 9-24a (Fragment Number subfield encoding for the Compressed BlockAck variant). (#1275)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(#Ed) frames shall be supported if either UL MU or multi-TID A-MPDU operation is supported.(#80)

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 (#1271)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: (#555)	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(#1408)	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(#2581) carries the AID of the non-AP STA for which the Per STA Info subfield(#1272) is intended. When the Multi-STA BlockAck variant is intended for an AP, the AID subfield is set to 0.(#99)

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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.(#80)

The TID subfield(#2581) 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.(#100)

If the Ack Type(#1408) subfield is (#2185)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(#1274) are not present and the Per STA Info subfield(#1141) acknowledges(#Ed) successful reception of a single MPDU indicated by the TID of the Per AID TID Info subfield. (#2414)(#2582)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(#Ed) successful reception of all the MPDUs carried in the eliciting A-MPDU. (#2232)(#2458)The Ack Type field is not set to 1 when responding to a BlockAckReq frame or an MU-BAR frame. If the Ack Type(#1408) subfield is 0, then the Block Ack Starting Sequence Control and Block Ack Bitmap subfields(#1141) are present.

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

Table 9-24b—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 25.3 (Fragmentation)).					

When B0 of the Fragment Number subfield of the Block Ack Starting Sequence Control subfield(#1289) is 0(#515)(#1182), 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(#Ed) the Fragment Number subfield as defined in the Table 9-24b (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

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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(#1290) 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(#Ed) the Fragment Number subfield as shown in the Table 9-24b (Fragment Number subfield encoding for the Multi-STA BlockAck variant). If bit position *n* of the Block Ack Bitmap subfield(#1281) 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(#1282) is 0, it indicates that the MPDU has not been received.(#1138)

NOTE—When B0 of the Fragment Number subfield is 1(#1142) then the Block Ack Bitmap(#1143) 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(#2300) as indicated in Table 9-24b (Fragment Number subfield encoding for the Multi-STA BlockAck variant). (#1287)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:

(#1222)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).(#Ed)

	B0 B10	B11 B24	B25 B26	B27	B28	B29 B31
	AID11	Partial BW Info	Feedback Type And Ng	Disambiguation (#Ed)	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).

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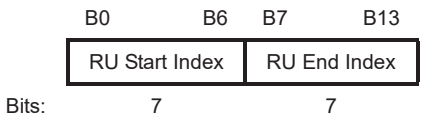


Figure 9-51c—Partial BW Info subfield

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 = {2, 4}
001	SU, Ng4, quantization resolution = {4, 6}
010	SU, Ng16, quantization resolution = {2, 4}
011	SU, Ng16, quantization resolution = {4, 6}
100	MU+Ng4, quantization resolution = {5, 7}
101	MU+Ng4, quantization resolution = {7, 9}
110	CQI only feedback
111	MU+Ng16, quantization resolution = {7, 9}

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(#2195) after the PPDU that carries the Trigger frame(#368). The Trigger frame also carries other information required by the responding STA to send an HE trigger-based PPDU(#718).

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

The Duration(#1297) 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.(#262) 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.(#102)

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	Frame Control	Duration	(RA)	TA	Common Info	User Info(#1520)	...	User Info(#1520)	Padding	FCS
Octets:	2	2	6	6	TBD	TBD		TBD	variable(#2890)	4

Figure 9-52c—Trigger frame

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(#2134)(#101)).

	B0 B3	B4 B15	B16	B17	B18 B19	B20 B21	B22	B23 B25	B26
	Trigger Type	Length	Cascade Indication	CS Required	BW	GI And LTF Type(#1420)(#1300)	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	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(#2134)(#101)

The Trigger Type subfield indicates the type of the Trigger frame. The Trigger frame can include an optional Trigger Dependent Common Info field(#613) and optional Trigger Dependent User Info field(#1520)(#613). The Trigger Type subfield encoding is defined in Table 9-25a (Trigger Type subfield encoding)(#376).

Table 9-25a—Trigger Type subfield encoding

Trigger Type field value	Description
0	Basic Trigger
1	Beamforming Report Poll(#Ed)
2	MU-BAR
3	MU-RTS
4	Buffer Status Report Poll (BSRP)(#824)
5-15(#262)	Reserved

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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 25.7 (TWT operation) and in 25.15.2 (Power save with UL OFDMA-based random access) follows the current Trigger frame. Otherwise the Cascade Indication subfield is 0.(#372)

The CS Required subfield is set to 1 to indicate that the STAs identified in the User Info(#1520) 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(#557). The CS Required(#2689) subfield is set to 0 to indicate that the STAs identified in the User Info(#1520) fields are not required to(#234) 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).(#101)

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(#1420)(#1300) of the Common Info field indicates the GI(#1420) and HE-LTF type of the HE trigger-based PPDU response. The GI And LTF Type subfield(#1420)(#1300) encoding is defined in Table 9-25c (GI And LTF Type subfield(#1420)(#1300) encoding).

Table 9-25c—GI And LTF Type subfield(#1420)(#1300) encoding

GI(#1420) And LTF field value	Description
0	1x LTF + 1.6 μs GI(#101)
1	2x LTF + 0.8 μs GI(#1420)
2	2x LTF + 1.6 μs GI(#1420)
3	4x LTF + 3.2 μs GI(#1420,#1146)

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.(#227) The MU-

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MIMO LTF Mode subfield encoding is defined in Table 9-25d (MU-MIMO LTF Mode subfield encoding).(#101)

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-LTFs 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. The number of HE-LTF subfield encoding is defined in Table 22-13.

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 subfield of the Common Info field indicates the status of LDPC Extra Symbol. It is set to 1 when LDPC extra symbol 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).(#101)

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

(#101)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(#2564) and the third bit indicates the PE-Disambiguity.

The Spatial Reuse subfield(#Ed) 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

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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.(SR Motion #11)

The exact location of each 20 MHz for 80 MHz BW is TBD.

The Doppler subfield indicates(#Ed) a high doppler mode of transmission.

Editor's Note: The edits in 16/780r1 change Figure 9-51c without change tracking. Presumably HE-SIG-A Info subfield is changed to HE-SIG-A Reserved subfield. However, no edits delete the next paragraph, and, in fact, a comment (#1299) modifying this paragraph is accepted in the same document.

The HE-SIG-A Info subfield of the Common Info field indicates the content of the HE-SIG-A field of the HE trigger-based PPDU response. The TBD bits in HE-SIG-A of the HE trigger-based PPDU that are(#1299) implicitly known by all responding STAs can be excluded.

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.(#101)(PHY Motion #169)

The User Info(#1520) field is defined in Figure 9-52e (User Info(#1520) field(#262)(#663)).(#101)

	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(#1520)
Bits:	12	8	1	4	1	6	7	1	variable

Figure 9-52e—User Info(#1520) field(#262)(#663)

The AID12 subfield of the User Info(#1520) field carries the least significant(#Ed) 12 bits of the AID of the STA for which the User Info field is intended(#511). An AID12 subfield that is 0 indicates that the User Info field identifies an RU for random access.(#558) 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.(MAC Motion #86)

The RU Allocation subfield of the User Info(#1520) field indicates the RU used by the HE trigger-based PPDU of the STA identified by the AID12(#Ed) subfield(#1302). 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

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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(#Ed)).

Table 9-25f—The encoding of B19-B13 of the RU Allocation subfield(#Ed)

B19-B13	Description(#Ed)	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

(#864)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 26-3 (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 26-4 (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 26-5 (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(#1520) field indicates the code type of the HE trigger-based PPDU response of the STA identified by the AID12(#Ed) subfield(#1302). Set to 0 for BCC and set to 1 for LDPC.

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The MCS subfield of the User Info(#1520) field indicates the MCS of the HE trigger-based PPDU response of the STA identified by the AID12(#Ed) subfield(#1302). The encoding of the MCS field is as defined in Section XXX.

The DCM subfield of the User Info(#1520) field indicates dual carrier modulation of the HE trigger-based PPDU response of the STA identified by the AID12(#Ed) subfield(#1302). A value of 1 indicates that the HE trigger-based PPDU response shall use DCM as defined in section XXX. A value 0 indicates that DCM is not be used(#237).

The SS Allocation subfield of the User Info(#1520) field indicates the spatial streams of the HE trigger-based PPDU response of the STA identified by the AID12(#Ed) subfield(#1302). The format of the SS Allocation subfield is defined in Figure 9-52f (SS Allocation subfield format).(#663)

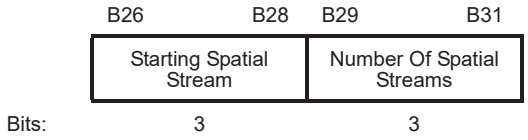


Figure 9-52f—SS Allocation subfield format

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).(#663)

Table 9-25g—Target RSSI subfield encoding

Target RSSI subfield	Description
0-90	Values 0 to 90 map to –100 dBm to –20 dBm
91-127	Reserved

The Padding field extends the frame length to give the recipient STAs more time to prepare a response. (#2890)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).

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

where

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

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

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

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.(#2890)

9.3.1.23.1 Basic Trigger variant(#2219)

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).(#Ed)

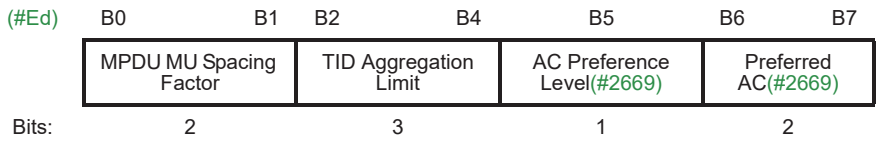


Figure 9-52g—Trigger Dependent User Info field for the Basic Trigger variant

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(MAC Motion #92) that can be aggregated by a STA in a multi-TID A-MPDU carried in the responding HE trigger-based PPDU.

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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.(MAC Motion #92)

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)).(#2669)

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.(#Ed)(#2669)

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).(#2669)

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(#9)

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).

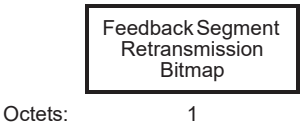


Figure 9-52h—Trigger Dependent User Info field for the Beamforming Report Poll variant

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.

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9.3.1.23.3 MU-BAR variant

(#5)The Trigger Dependent Common Info field is not present in the MU-BAR variant Trigger frame. The Trigger Dependent User Info(#1520) field of the MU-BAR variant Trigger frame is defined(#1307) in Figure 9-52i (Trigger Dependent User Info field for the MU-BAR variant(#2700))(#2698).

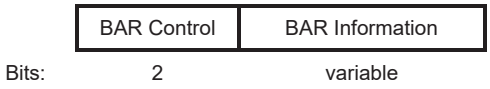


Figure 9-52i—Trigger Dependent User Info field for the MU-BAR variant(#2700)

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 9-24b (Fragment Number subfield encoding for the Multi-STA BlockAck variant) for a Multi-TID BAR variant.(#5)

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.(#2894)

NOTE—The TA field value is the address of the STA transmitting the MU-RTS frame.(#2603)

(#2222)The Common Info field is defined in Figure 9-52d (Common Info field(#2134)(#101)).

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, 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(#1520) field(#262)(#663)).

The MCS,(#863) Coding Type, DCM, SS Allocation and Target RSSI fields are reserved.

(#110)The RU Allocation subfield in the User Info(#1520) field addressed to the STA follows the same definition as described in 9.3.1.23 (Trigger frame format) and(#2222) 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.(#1763)

(#1311)(#2222)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

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B19-B13 to RU Allocation subfield follows the RU index in Table 26-3 (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.(#2222)

9.3.1.23.5 BSRP variant(#824)

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(#2134)(#101)) 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(#1520) field(#262)(#663)) and the Trigger Dependent User Info field is not present.

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.

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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(#Ed)	HE Capabilities	The HE Capabilities element is present when dot11HEOptionImplemented(#1313) is true; otherwise it is not present.
74	HE Operation	The HE Operation element is present when dot11HEOptionImplemented(#1313) is true; otherwise it is not present.
75	TWT	The TWT element is optionally present when dot11TWTOptionActivated(#1313) is true; otherwise it is not present.
76	RAPS	The RAPS element is optionally present when dot11OFDMARandomAccessOptionImlemented is true; otherwise it is not present.(#600)

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(#198)):

Table 9-29—Association Request frame body(#198)

Order	Information	Notes
43(#2304)(#Ed)	HE Capabilities	The HE Capabilities element is present when dot11HEOptionImplemented(#1313) 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)

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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.(#1315)
54(#2304)(#Ed)	HE Capabilities	The HE Capabilities element is present when dot11HEOptionImplemented(#1313) is true; otherwise it is not present.
55	HE Operation	The HE Operation element is present when dot11HEOptionImplemented(#1313) is true; otherwise it is not present.

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(#198)) (header shown for convenience):

Table 9-31—Reassociation Request frame body(#198)

Order	Information	Notes
47(#2305)(#Ed)	HE Capabilities	The HE Capabilities element is present when dot11HEOptionImplemented(#1313) 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)

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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.(#1315)
55(#2305)(#Ed)	HE Capabilities	The HE Capabilities element is present when dot11HEOptionImplemented(#1313) is true; otherwise it is not present.
56	HE Operation	The HE Operation element is present when dot11HEOptionImplemented(#1313) is true; otherwise it is not present.

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(#198)):

Table 9-33—Probe Request frame body(#198)

Order	Information	Notes
32(#2306)(#Ed)	HE Capabilities	The HE Capabilities element is present when dot11HEOptionImplemented(#1313) 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)

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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(#2306)(#Ed)	HE Capabilities	The HE Capabilities element is present when dot11HEOptionImplemented(#1313) is true; otherwise it is not present.
93	HE Operation	The HE Operation element is present when dot11HEOptionImplemented(#1313) 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.(#1315)
95	RAPS	The RAPS element is optionally present when dot11OFDMARandomAccessOptionImlemented is true; otherwise it is not present.(#600)

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
~~21~~<ANA+1>–125	Reserved	—	—	—
	...			

Insert the following subclauses after 9.4.1.61:

9.4.1.62 HE MIMO Control field(#223)

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).

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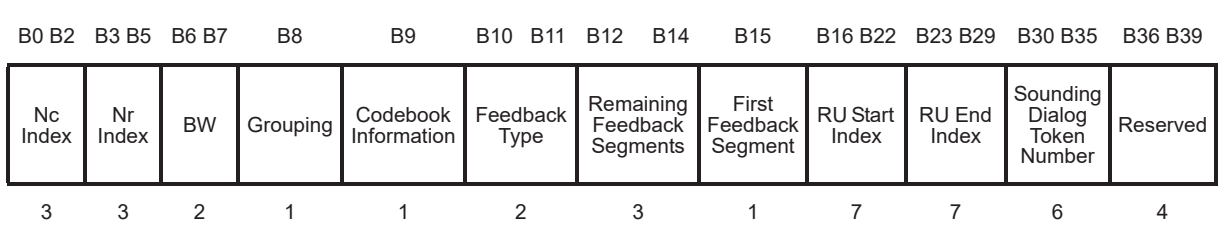


Figure 9-121a—HE MIMO Control field

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 (#Ed)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
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 {9, 7}

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

Feedback Type	Indicates the feedback type: Set to 0 for SU Set to 1 for MU Set to 2 for CQI feedback(#971)(#2713) 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.[sic]

In an HE Compressed Beamforming frame not carrying all or part of a 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

(#112)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 25.6 (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.

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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 26.2 (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 as the VHT Compressed Beamforming Report information as defined in Table 9-69 (VHT Compressed Beamforming Report Information).

In Table 9-69 (VHT 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(#223))). 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, subcarrier $scidx(i) = scidx(i - 1) + Ng$, where $1 \le i \le Ns - 2$. The S-tone and E-tone corresponding to the possible RU indices are listed in Table 9-76b (Feedback subcarrier indices indicating start 26-tone RU index and end 26-tone RU index for Ng = 4) for *Ng* = 4 and Table 9-76c (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 9-76b (Feedback subcarrier indices indicating start 26-tone RU index and end 26-tone RU index for Ng = 4) and Table 9-76c (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 $1 \le i \le Ns - 2$, includes all subcarrier indices between the S-tone and the E-tone subcarrier indices described in Table 9-76d (Feedback subcarrier indices for 20 MHz bandwidth for Ng = 4 and Ng = 16) for *Ng* = 4 and *Ng* = 16.

Table 9-76b—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

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Table 9-76b—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				

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Table 9-76b—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 9-76c—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				

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

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

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Table 9-76d—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 the Table 8-53f is an 8-bit twos complement integer whose definition is shown in Table 8-53h (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 9-76b (Feedback subcarrier indices indicating start 26-tone RU index and end 26-tone RU index for Ng = 4) for *Ng* = 4 and Table 9-76c (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*.

(PHY Motion 160)For HE beamformee, supporting *Ng* = 16 in the HE Compressed Beamforming Report field is optional for both SU and MU feedback types(#Ed). A beamformer shall not request *Ng* = 16 in an HE NDP Announcement frame(#Ed) 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 {4, 2} in the HE Compressed Beamforming Report field is optional for SU feedback type(#Ed). A beamformer shall not request codebook size {4, 2} in an HE NDP Announcement frame(#Ed) if the beamformee does not indicate support for the codebook size {4, 2} in the HE Capabilities element it transmits (see 9.4.2.218 (HE Capabilities element)).

For an HE beamformee, supporting codebook size {7, 5} in the HE Compressed Beamforming Report field is optional for MU feedback type(#Ed). A beamformer shall not request the codebook size {7, 5} in an HE NDP Announcement frame if the beamformee does not indicate support for the codebook size {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

(#112)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 26.3.3.7 (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 25.6 (HE sounding protocol)). HE Compressed Beamforming Report information and HE MU Exclusive Beamforming Report information are included in

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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 as the VHT MU Exclusive Beamforming Report information defined in Table 9-72 (MU Exclusive Beamforming Report information).

In Table 9-72 (MU Exclusive Beamforming Report information), Ns' is the number of subcarriers for which the Delta SNR subfield is sent back to the beamformer. Subcarriers *sscidx*(0) and *sscidx*($Ns' - 1$) represent the S-tone corresponding to the RU Start Index and E-tone corresponding to the RU End Index, respectively. For 40 MHz and 80 MHz, subcarrier *sscidx*(i) = *sscidx*($i - 1$) + *Ng*, where $1 \le i \le Ns' - 2$. The S-tone and E-tone corresponding to the possible RU indices are listed in Table 9-76b (Feedback subcarrier indices indicating start 26-tone RU index and end 26-tone RU index for Ng = 4) for *Ng* = 4 and Table 9-76c (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 9-76b (Feedback subcarrier indices indicating start 26-tone RU index and end 26-tone RU index for Ng = 4) and Table 9-76c (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, *sscidx*(*i*), where $1 \le i \le Ns' - 2$, includes all subcarrier indices between the S-tone and the E-tone subcarrier indices described in Table 9-76d (Feedback subcarrier indices for 20 MHz bandwidth for Ng = 4 and Ng = 16) for *Ng* = 4 and *Ng* = 16.

9.4.1.65 HE CQI-only Report field

(#112)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 25.6 (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

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Type field of the HE MIMO Control field. The structure of the HE CQI-only Report field is shown in Table 9-76e (HE CQI-only Report information).

Table 9-76e—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 9-76f (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 9-76f (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 9-76f (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 9-76f (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 9-76f (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 9-76f (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 $1 \leq i \leq Ncqi - 2$.

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

Table 9-76f—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 9-76f (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(#450)))	255	<ANA>	Yes

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9.4.2.27 Extended Capabilities element

(#1803)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).

9.4.2.196 TWT element

Change as Figure 9-586ax (Control field format) follows.

	B1	B2	B3	~~B3~~B4 B8
	NDP Paging Indicator	Responder PM Mode	Broadcast	Reserved
Bits:	1	1	1	~~6~~5

Figure 9-586ax—Control field format

Insert the following paragraph after Table 9-257l (TWT Setup Command field values):

The Broadcast field indicates if the TWT SP indicated by the TWT element is a broadcast TWT as defined in 10.44.3 (Broadcast TWT Operation)(#954). The Broadcast field is 1 to indicate that the TWT(s) defined by the TWT element are broadcast TWT(s). The Broadcast field is 0, otherwise.(#382)

Change Figure 9-586ay (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 9-586ay—Request Type field format

Insert the following paragraph after Table 9-257l (TWT Setup Command field values):

The Trigger field indicates if the TWT SP indicated by the TWT element includes Trigger frames as defined in 10.44 (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.

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Change the text as shown in subclause 9.4.2.196 TWT element:

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(#1320) 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(#1320) during the broadcast TWT SP, encoded according to Table 9-257l1 (TWT Flow Identifier field for a broadcast TWT element).

Insert a new table as follows:

Table 9-257l1—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.
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 25.5.1 (HE DL MU operation), 25.5.2 (UL MU operation), 25.8 (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 25.6 (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 25.7.3.2 (Rules for TWT scheduling STA)).(#114)

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Table 9-257l1—TWT Flow Identifier field for a broadcast TWT element

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 25.5.1 (HE DL MU operation), 25.5.2 (UL MU operation), 25.8 (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 25.6 (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 25.7.3.2 (Rules for TWT scheduling STA)).(#114)
3-7	Reserved

Change the paragraph below as follows:

In a TWT element transmitted by a TWT requesting or scheduled STA(#1324), 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(#1324), 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(#1324) that is sent by the scheduled STA(#1324) to negotiate the wake intervals for Beacon frames that contain a TWT(#384) element that indicates a broadcast TWT(#1324), the TWT wake interval indicates the value of the listen interval (see 10.44.3.4 (Negotiation of TBTT and listen interval))(#616).

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) × $2^{(\text{TWT Wake Interval Exponent})}$(#1326).

Change the paragraph below 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.(#1324) 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 (#1324)and it does not contain the TWT Group Assignment field.

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Change Table 9-257l (TWT Setup Command field values) by adding two new columns as shown:

Table 9-257l—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(#682)	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.(#682)	N/A
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.(#682)	N/A

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Table 9-257l—TWT Setup Command field values *(continued)*

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)(#1328) 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
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.(#682)

(#2391)Change the two paragraph in the middle of the subclause (in strikethrough below) as follows:

~~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).~~

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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(#200))..

	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(#200)

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

(#200)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

(#200)The format of the HE MAC Capabilities Information field is defined in Figure 9-589ck (HE MAC Capabilities Information field format)(#617).

	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(#1589)

	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(#824)	1	1	1	1	4

	B25	B26	B27 B28	B29	B30 B31	B32 B39
	OMI A-Control Support	OFDMA RA Support	Maximum A-MPDU Length Exponent	Downlink MU-MIMO on Partial Bandwidth Rx	UL MU-MIMO	Reserved
Bits:	1	1(#Ed)	2(#2258)	1	2	8(#Ed)

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.

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

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 VHT single MPDU, no support for dynamic fragments within an A-MPDU that is not a VHT Single MPDU. Set to 2 for support for dynamic fragments that are contained within a Single MPDU(#11ah) 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(#11ah). Set to 3 for support for dynamic fragments that are contained within a Single MPDU(#11ah) and support for multiple dynamic fragments for each MSDU within an (#1160)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(#11ah).
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.
Minimum Fragment Size	Indicates the minimum payload size in octets of the first fragment of an MSDU that is supported by the STA.(#Ed)	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.(#Ed)
Trigger Frame MAC Padding Duration	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 25.10.4 (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.

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

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 25.7.3 (Broadcast TWT operation(#1779)(#1874)(#1214)).	Set to 1 when the STA supports broadcast TWT functionality. Set to 0 otherwise.
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 25.5.3 (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 25.10.4 (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.

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

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 25.5.2.6 (UL OFDMA-based random access)).	Set to 1 if supported.(#Ed) Set to 0 otherwise.
Maximum A-MPDU Length Exponent		
Downlink MU-MIMO On Partial Bandwidth Rx	Indicates support by a non-AP STA to receive an MU-MIMO transmission on an MU in an HE MU PPDU where the RU does not span the entire PPDU bandwidth.(#1801)	Set to 1 if supported. Set to 0 otherwise.(#Ed)
UL MU-MIMO	B1 of the UL MU MIMO subfield indicates the STA supports transmission of full bandwidth UL MU-MIMO transmission. B2 of the UL MU MIMO subfield indicates the STA supports transmission of UL MU-MIMO transmission on an RU in an HE MU PPDU where the RU does not span the entire PPDU bandwidth.(#1801)	

(#2258)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 $2^{(16+\text{ Maximum A-MPDU Length Exponent subfield in}}$

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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

(#2064)(PHY Motion #168)The format of the HE PHY Capabilities Information field is defined in Figure 9-589cl (HE PHY Capabilities Information field format)(#617).

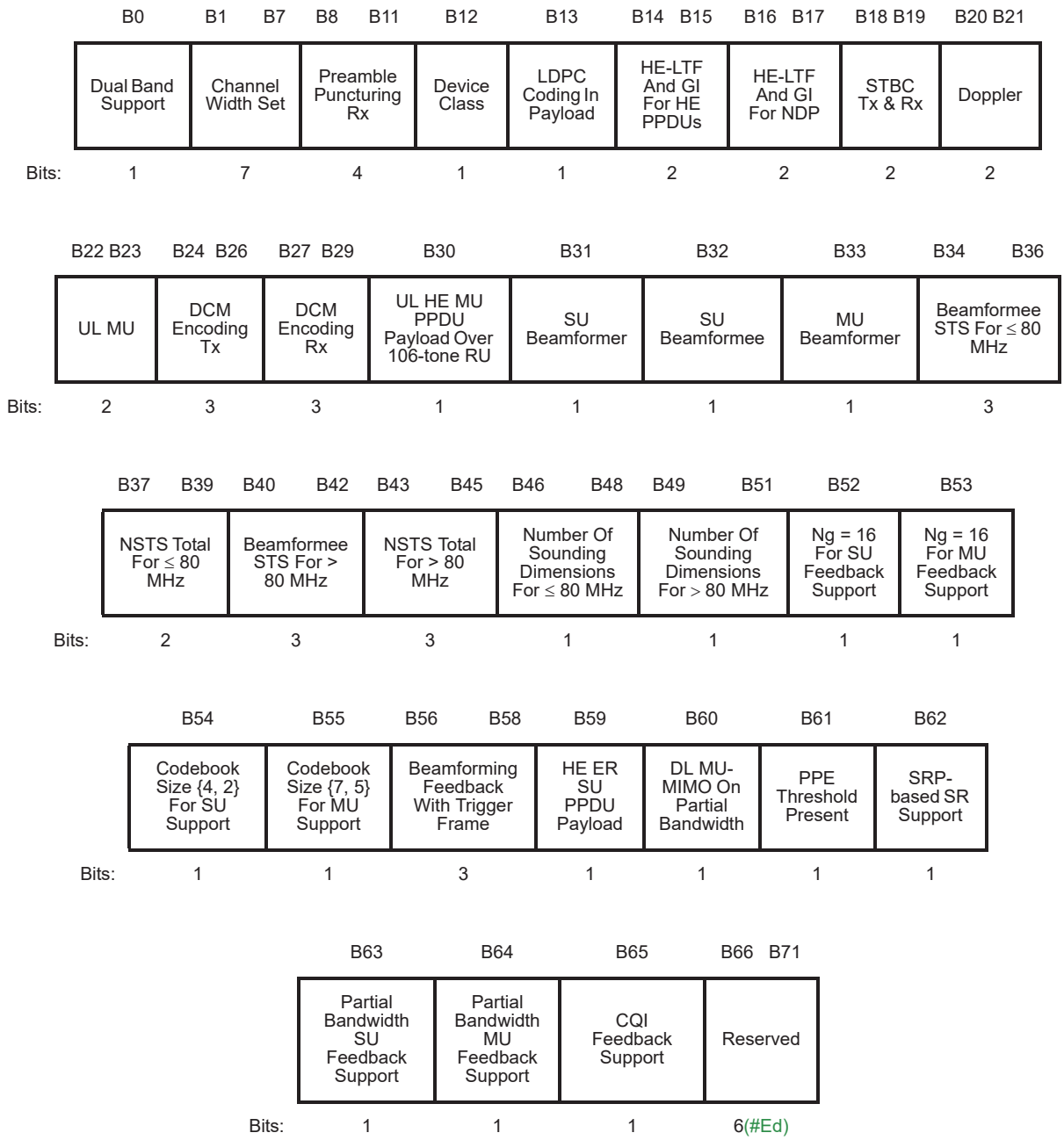


Figure 9-589cl—HE PHY Capabilities Information field format

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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.

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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 DL MU-MIMO

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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 over 106-tone RU	It indicates STA supports of reception of HE MU PPDU payload over a 106-tone RU within 20 MHz	Set to 1 if supported by the STA. Set to 0 otherwise
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.

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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 {4, 2} For SU Support	Indicates if the HE beamformee is capable of feedback with codebook size {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 {7, 5} For MU Support	Indicates if HE beamformee is capable of feedback with codebook size {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.
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 by the STA. Otherwise, set to 0.

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

Subfield	Definition	Encoding
DL MU-MIMO on Partial BW	It indicates non-AP STA supports reception of 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 non-AP STA. This field is reserved for an AP.
PPE Threshold Present	It indicates if the PPE Threshold field is present or not.	Set to 1 if PPE Threshold field is present. Set to 0, otherwise
SRP-based SR Support	It indicates if the STA supports SRP-based SR operation	Set to 1 if supported. Set to 0 otherwise.
Partial Bandwidth SU Feedback Support	Indicates whether the beamformee is capable of SU-Type feedback over partial BW in the HE Compressed Beamforming Report field(PHY Motion #167)	Set to 1 if supported. Set to 0 otherwise.
Partial Bandwidth MU Feedback Support	Indicates whether the beamformee is capable of MU-Type feedback over partial BW in the HE Compressed Beamforming Report field and HE MU exclusive beamforming Report field(PHY Motion #167)	Set to 1 if supported. Set to 0 otherwise.
CQI Feedback Support	Indicates whether the beamformee is capable of CQI-only feedback with RU start index and RU end index in the HE CQI-only Report field(PHY Motion #167)	Set to 1 if supported. Set to 0 otherwise.

A STA that declares(#1165) support for HE trigger-based PPDUs(#1342) shall also declare whether they belong to class A or class B. Class A STAs (#575)are high capability devices and class(#1345) B STAs are low capability devices.

9.4.2.218.4 Tx Rx HE MCS Support field

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

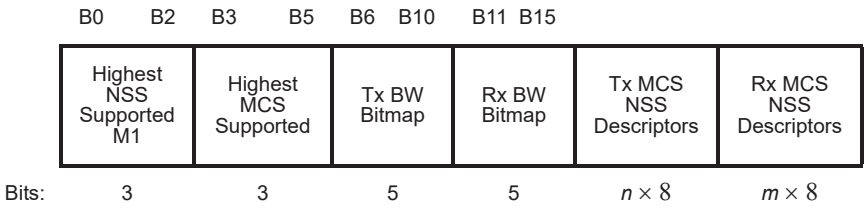


Figure 9-589cm—Tx Rx HE MCS Support field format

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

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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.

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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).

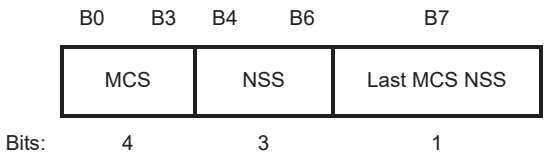


Figure 9-589cn—Tx MCS NSS Descriptor and Rx MCS NSS Descriptor subfield format

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

(#200)The format of the PPE Thresholds field is defined in Figure 9-589co (PPE Thresholds field format)(#2834).

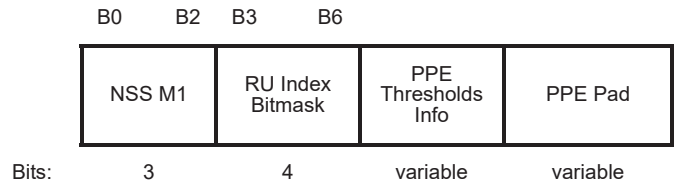


Figure 9-589co—PPE Thresholds field format

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.(#1334)

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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(#1337) in length. The format of the PPE Thresholds Info field is defined in Figure 9-589cp (PPE Thresholds Info field format)(#2835).

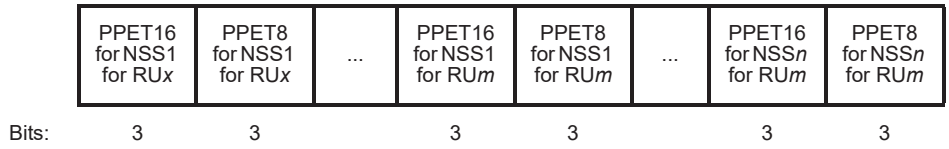


Figure 9-589cp—PPE Thresholds Info field format

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*, …, *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.

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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).(#1349)(#619).

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

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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 > PPET8 or PPET8 = None	*x* > 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(#1337)

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(#1895) of octets.

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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
Octets:	1	1	4(#Ed)	2(#667)

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(#1350) field format).

	B0 B5	B6 B8	B9	B10 B19	B20	B21 B31
	BSS Color	Default PE Duration	TWT Required	HE Duration Based RTS Threshold	Partial BSS Color	Reserved
Bits:	6(#244)	3(#1)	1(#667)	10(#576)	1	11(#Ed)

Figure 9-589cr—HE Operation Parameters(#1350) field format

The BSS Color field is an unsigned integer whose value is the BSS color(#1165) 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(#1165) 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.(#73)

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.(#1)

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 25.7.2 (Individual TWT agreements(#1214)), or TWT scheduled STA, as described in 25.7.3 (Broadcast TWT operation(#1779)(#1874)(#1214)) and set to 0 otherwise.(#1640)

(#576)The HE Duration Based RTS Threshold field allows an HE AP to manage RTS/CTS usage by the associated HE STAs. The value is specified as an unsigned integer, in units of 32 μs. The value 0 indicates that RTS/CTS must be used for all the data transmit sequences. The value 1023 indicates that this feature is disabled.

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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.(MAC Motion #88)

(#667)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 16 bits. Each 2 bit pair in the bitmap(#Ed) 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).

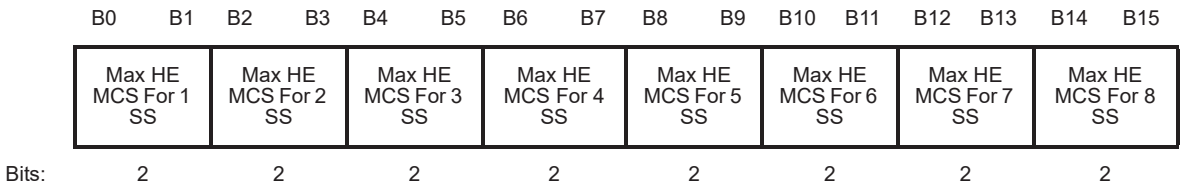


Figure 9-589cs—Basic HE-MCS And NSS Set field format

9.4.2.220 OFDMA-based Random Access Parameter Set (RAPS) element(#450)

The metrics of the OFDMA-based random access mechanism (see 25.5.2.6 (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).

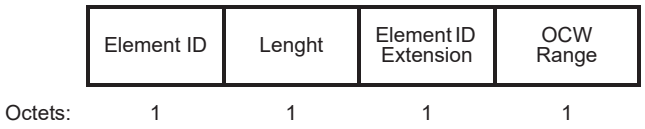


Figure 9-589ct—RAPS element format

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).

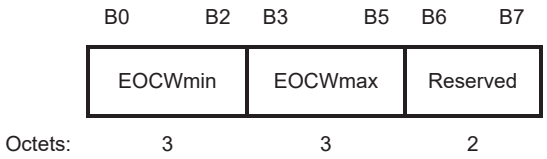


Figure 9-589cu—OCW Range field format

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

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

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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

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

9.4.2.221 MU EDCA Parameter Set element

(MAC Motion #91)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 EDCA Timer	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	1	2	2	2	2

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 MU EDCA Timer 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.

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
Octets:	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.

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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).

9.6 Action frame format details

9.6.4 DLS Action frame details

9.6.4.2 DLS Request frame format

(#1352)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 dot11HEOption-Implemented 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

(#1352)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 dot11HEOption-Implemented is true; otherwise it is not present.

9.6.5 Block Ack Action frame details

9.6.5.1 General

(#2268)Change Table 9-302 (Block Ack Action field values) as follows:

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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

(#1352)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 dot11HEOption-Implemented is true; otherwise it is not present, The HE Capabilities element is defined in 9.4.2.218 (HE Capabilities element)

9.6.13 TDLS Action field formats

9.6.13.2 TDLS Setup Request Action field format

(#1352)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 dot11HEOption-Implemented is true; otherwise it is not present. The HE Capabilities element is defined in 9.4.2.218 (HE Capabilities element)

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9.6.13.3 TDLS Setup Request Action field format

(#1352)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

(#1352)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

(#1352)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.
13	HE Operation	The HE Operation element is present when dot11HEOptionImplemented is true; otherwise it is not present.

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9.6.16.3 Mesh Peering Confirm frame format

9.6.16.3.2 Mesh Peering Confirm frame details

(#1352)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 dot11HEOptionImplemented is true; otherwise it is not present.

9.6.28 HE Action frame details

9.6.28.1 HE Action field

A 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
1-255	Reserved

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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 a 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.

9.7 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 or HE PPDU.(#2481)

Change the 6th and subsequent paragraphs as follows:

In a VHT or HE PPDU(#2482), 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.

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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. (#2258)The maximum length of an A-MPDU pre-EOF padding in a 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(#2483) as described in 10.13.6 (A-MPDU padding for VHT PPDU). Set to 1 in the MPDU delimiter of a VHT single 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(#2484) 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:

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

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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(11ah)

— The FORMAT parameter set to HE_SU, HE_MU, HE_TRIG or HE_EXT

Insert the following paragraph:

An A-MPDU carried in an(#2829) HE MU PPDU may include MPDUs with different values of the TID field. Additional rules are TBD.

(#2429)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:

(#805)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).

(#2430)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

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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.

(#805)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(11ah) context	The A-MPDU is transmitted within a VHT PPDU or a HE PPDU and contains an S-MPDU(11ah).	Table 9-429 (A-MPDU contents in the VHT single 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.		

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(#805)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

MPDU Description	Conditions	
Ack	If the preceding PPDU contains an MPDU that requires an Ack frame response, a single Ack frame at the start of the A-MPDU.	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.
HT-immediate BlockAck	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.	
Multi-STA BlockAck(#Ed)	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.	
Delayed BlockAcks	BlockAck frames with the BA Ack Policy subfield equal to No Acknowledgment with a TID for which an HT-delayed block ack agreement exists.	
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.	
Action No Ack	Action No Ack frames.	
Delayed BlockAckReqs	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.	

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

MPDU Description	Conditions	
Data frames without HT-immediate block ack agreement	QoS Data frames with multiple TIDs which have no HT-immediate block ack agreement See NOTE 1.	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, 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 — Trigger frame only when AP transmits the A-MPDU
Data frames sent under an HT-immediate block ack agreement	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.	
QoS Null MPDUs with Ack Policy set to No Ack	In a DMG BSS, QoS Null MPDUs with Ack Policy set to No Ack. In a HE BSS, QoS Null MPDUs with Ack Policy set to No Ack.	
Immediate BlockAckReq	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	
Action	At most one Action frame	
Trigger	One or more Trigger Type is Basic Trigger, MU-BAR, BSRP. See NOTE 2	

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

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(#805)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	One or more Trigger frames where the Trigger Type field is Basic Trigger, MU-BAR, BSRP when AP transmits the A-MPDU. See NOTE 1.
NOTE 1—An AP including Trigger frame and BlockAck is not required to include QoS Data in that A-MPDU.	

(#805)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

MPDU	Conditions	
Ack	Ack frame transmitted in response to an MPDU that requires an Ack frame.	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.
BlockAck	BlockAck frame with a TID that corresponds to an HT-immediate block ack agreement.	
Multi-STA BlockAck	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.	
Action No Ack	+HTC Action No Ack frames carrying a Management Action Body containing an explicit feedback response or BRP frame.	

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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..."):

(MAC Motion #91)In addition, an HE AP may temporarily 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 25.2.3 (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 (#1389)is another(#396) means of distribution of this medium reservation information.

(#576)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 initiate RTS/CTS when TXOP is longer than 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:

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A first(11ah) 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(11ah). 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(#Ed).(#2596)

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 25.2.2 (Updating two NAVs).(#1775) 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.(#162)

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 25.2.2 (Updating two NAVs).(#1775)

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. ~~When the received frame's RA is equal to the STA's own MAC address, the STA shall not update its NAV.~~ When the STA is solicited for an immediate response by the PPDU carrying the received frame, the STA shall not update its NAV.(#2905) 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:

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- 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(#2316)

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.(#966)

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(#2316) 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(#2316) 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 non-AP HE STA.(#576)

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.(#576)

Insert a new subclause following 10.3.2.8:

10.3.2.8a MU-RTS/CTS procedure(#1432)

10.3.2.8a.1 General

The MU-RTS/CTS procedure allows an AP to protect an MU transmission(#397). An HE AP may transmit an MU-RTS frame to solicit simultaneous CTS responses from one or more HE STAs.

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Figure 10-9a (Example of MU-RTS/CTS/DL MU PPDU/Acknowledgement Response and NAV setting(#2224)) shows an example of the exchange of MU-RTS and simultaneous CTS responses to protect DL MU PPDU and acknowledgement responses..

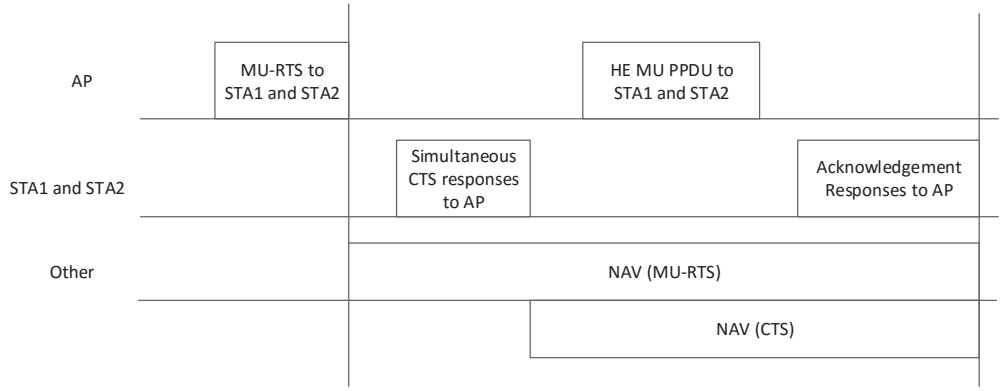


Figure 10-9a—Example of MU-RTS/CTS/DL MU PPDU/Acknowledgement Response and NAV setting(#2224)

Figure 10-9b (Example of MU-RTS/CTS/Trigger/HE trigger-based PPDU/Multi-STA BlockAck and NAV setting(#2224)) 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.

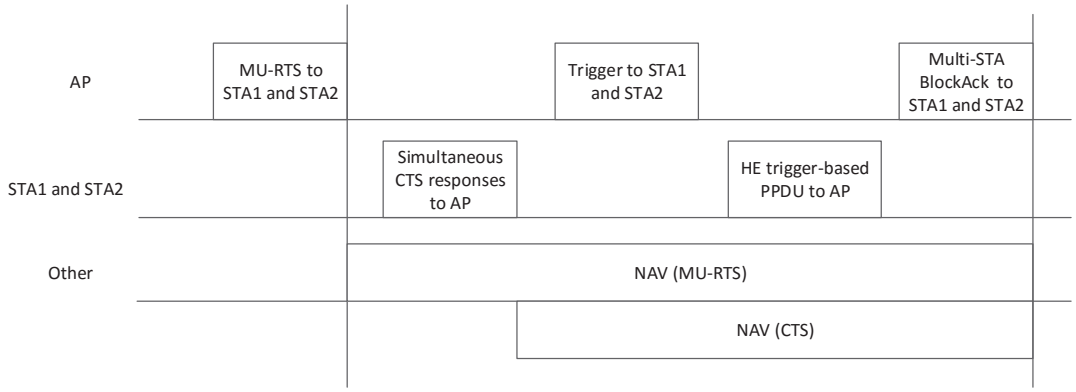


Figure 10-9b—Example of MU-RTS/CTS/Trigger/HE trigger-based PPDU/Multi-STA BlockAck and NAV setting(#2224)

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.(#1644)(#Ed)

(#2428)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

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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.(#160)

An MU-RTS frame shall not be carried in an HE MU PPDU.(MU Motion #60)

10.3.2.8a.3 CTS response(#996) to MU-RTS

If an(#2829) HE STA receives an MU-RTS frame, the HE STA shall commence the transmission of a CTS frame(#1396) 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(#1520) fields addressed to the STA.

— The UL MU CS condition described in 25.5.2.4 (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.(#2650)

— 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.(#2428)

— The MU-RTS frame is sent by the AP with which the STA is associated and the value of the regular NAV is 0.(#125)

The CTS frame sent in response to an MU-RTS frame shall be carried in a non-HT or non-HT duplicate PPDU.(#13)

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.(#127) The rate selection rule for the CTS frame(#1396) is defined in 10.7.6 (Rate selection for Control frames). The data rate to be used for the non-HT PPDU response shall be 6 Mb/s (see 17.1.1 General).(#863)

(#963)A CTS frame sent in response to an MU-RTS frame(#1396) shall be transmitted on the 20 MHz channels indicated(#Ed) in the RU Allocation subfield of the User Info field of the MU-RTS frame(#1520)(#1727) 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.(#1070)(#2651)

Figure 10-9c (An example of an MU-RTS frame soliciting CTS frame(#Ed)(#1396) responses on the primary 40 MHz channel(#2224)) shows an example of the exchange of MU-RTS and simultaneous CTS frame(#1396) responses on the(#1397) primary 40 MHz channel. In this example, MU-RTS is transmitted in a 40 MHz non-HT duplicate PPDU on the(#1397) primary 40 MHz channel. Further, the MU-RTS frame(Ed) requests STA1 to transmit a CTS frame(#1396) response in a non-HT PPDU on the(#1397) pri-

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mary 20 MHz channel and STA2 to transmit a CTS frame(#1396) response in a 40 MHz non-HT duplicate PPDU on the(#1397) primary 40 MHz channel.

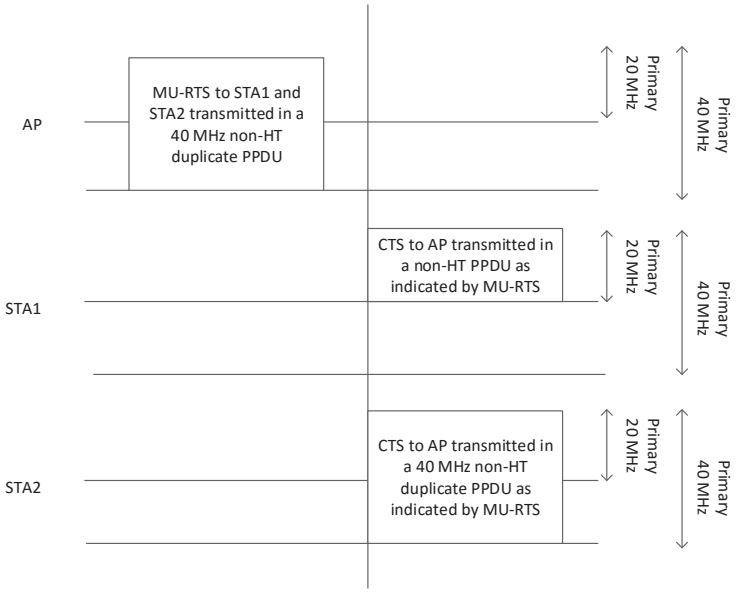


Figure 10-9c—An example of an MU-RTS frame soliciting CTS frame(#Ed)(#1396) responses on the primary 40 MHz channel(#2224)

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).(#2115)

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(#129)(#406) 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(#129)(#406).

NOTE—All MPDUs transmitted within a VHT MU PPDU or an HE MU PPDU for DL transmission(#129)(#406) 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 transmission(#129)(#406) that are not immediate responses to the VHT MU PPDU or the HE MU PPDU for DL transmission(#129)(#406) 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).

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Recovery within the TXOP that contains a VHT MU PPDU or an HE MU PPDUfor DL transmission(#129)(#406) can be performed according to the rules of 10.22.2.7 (Multiple frame transmission in an EDCA TXOP). BlockAckRequest frames related to A-MPDUs within a VHT MU PPDU or an HE MU PPDU for DL transmission(#129)(#406) can be transmitted in a TXOP separate from the one that contained the VHT MU PPDU or the HE MU PPDU for DL transmission(#129)(#406).

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(#405) to a Single MPDU(11ah) in the VHT MU PPDU or the HE MU PPDU for DL transmission(#129)(#406). 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(#131).

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 10.3.2.11.2 and 10.3.2.11.3 as follows:

10.3.2.10.2 Acknowledgement procedure for DL(#1410) MU PPDU in MU format

A non-AP STA that is the recipient, within an(#2829) HE MU PPDU, of a QoS Data frame or QoS Null frame(#2606) that solicits an immediate response with Ack Policy equal to MU Ack in QoS Control field, or of an MMPDU that solicits an immediate response(#130), 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 in the(#1402) MAC header. If no valid Trigger frame(s) (see 9.3.1.23 (Trigger frame format))(#130)(#407) or MAC header header (see 9.2.4.6.4.2 (UL MU response scheduling))(#130)(#407) containing UL trigger information 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(#1730)).

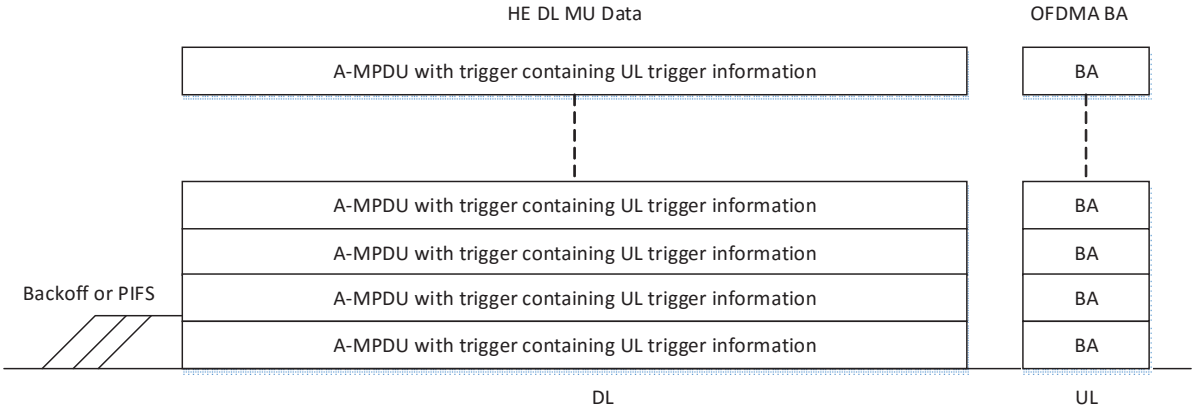


Figure 10-12a—An example of an HE MU PPDU transmission with an immediate UL OFDMA acknowledgement(#1730)

(#2607)

10.3.2.10.3 Acknowledgement(#1410) procedure for an UL MU transmission

When receiving frames(#409) from more than one STA that are part of an UL MU transmission (see(#1406) 9.42.2) and that require an immediate acknowledgement, an AP may send either multiple BlockAck frames (or Ack(#1408) frames) in an HE MU PPDU, or a Multi-STA BlockAck frame(#1407)(#1424) (see 25.4

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(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.(#1427) 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.(#2608) 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.(MU Motion #58)

An example of a DL OFDMA BA is(#410) shown in Figure 10-12b (An example of an UL MU transmission with an immediate DL MU transmission containing individually addressed(#1512) BlockAck frames acknowledging the frames received from the respective STAs(#1732)).(#1427)

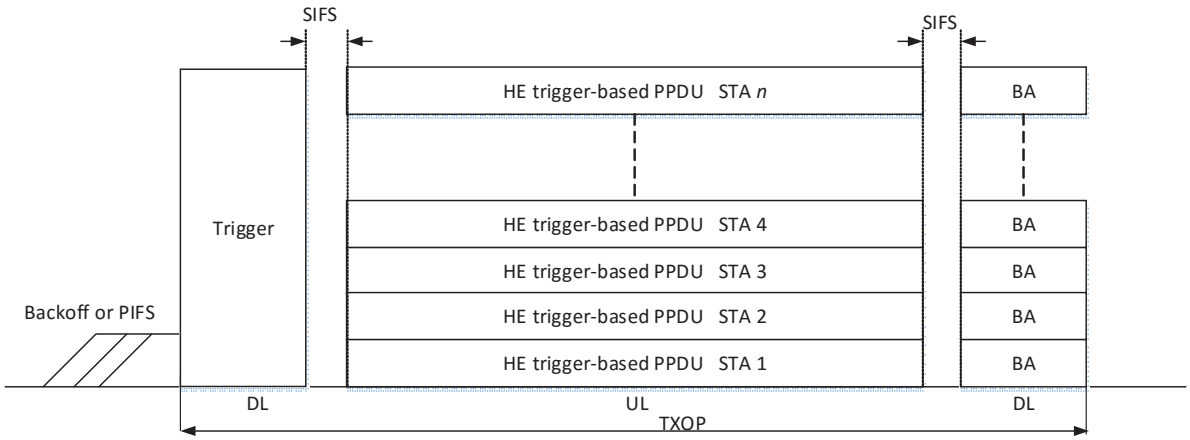


Figure 10-12b—An example of an UL MU transmission with an immediate DL MU transmission containing individually addressed(#1512) BlockAck frames acknowledging the frames received from the respective STAs(#1732)

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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(#1407) acknowledging the MPDUs(#1732)).(#1427)

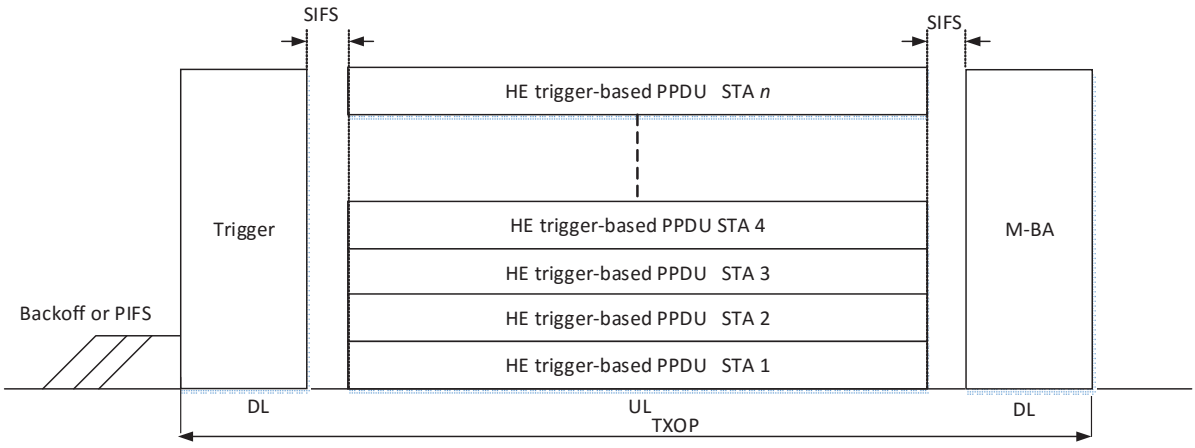


Figure 10-12c—An example of UL MU transmissions with an immediate Multi-STA BlockAck frame(#1407) acknowledging the MPDUs(#1732)

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(#1732)).(#1427)

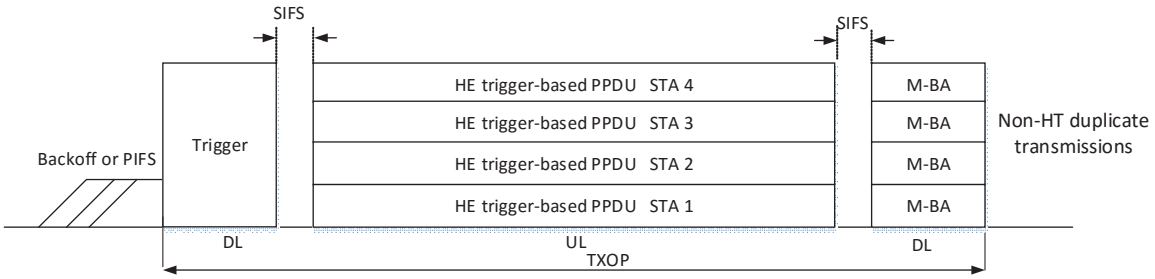


Figure 10-12d—An example of UL MU transmissions with an immediate DL non-HT duplicate PPDU containing the Multi-STA BlockAck frame(#1732)

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An example of a Multi-STA BlockAck frame acknowledgement in an OFDMA HE MU PPDU is given in Figure 10-12e (An example of UL MU transmissions with an immediate OFDMA HE MU PPDU containing Multi-STA BlockAck frames(#1732)).(#1427)

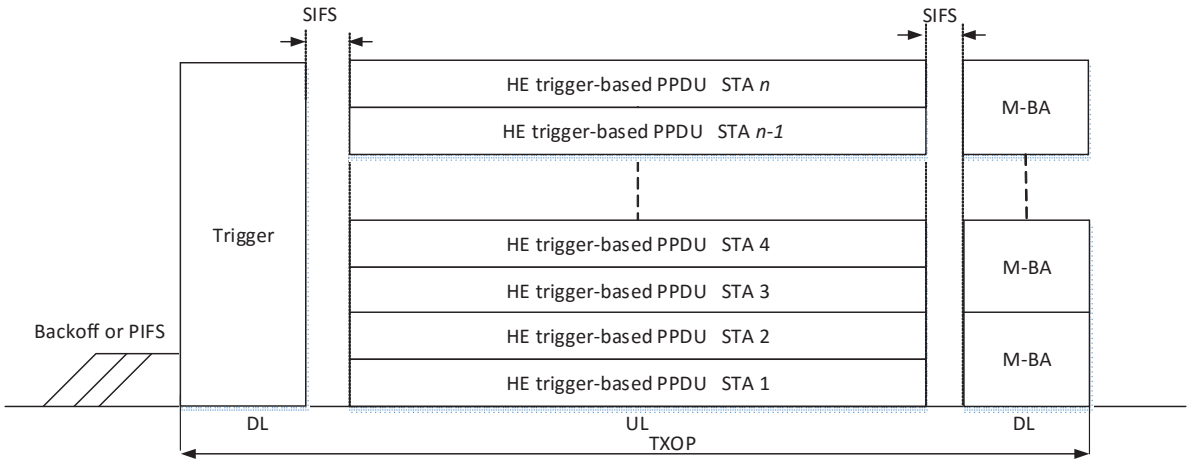


Figure 10-12e—An example of UL MU transmissions with an immediate OFDMA HE MU PPDU containing Multi-STA BlockAck frames(#1732)

10.5 Fragmentation

Change the 2nd paragraph as follows:

With static fragmentation, tThe 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 25.3.2 (Support and requirements for dynamic fragmentation) are met, static fragmentation is used.(#1484)

10.7 Multirate support

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:

(#863)If a Multi-STA BlockAck frame or DL OFDMA acknowledgement frame is sent as an immediate response to an HE trigger-based PPDU(#1767), the AP may ignore the <HE-MCS, NSS> tuples that are used for MPDUs in HE trigger-based PPDU(#1767) from non-AP STAs that elicits the DL acknowledgement.

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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(#623).

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 (#1433)dot11HEControlFieldOptionImplemented(#1313) is true, a STA shall set the +HTC-HE Support subfield of the HE Capabilities(#2397) 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(#1515)(#1), dot11HEMCSFeedbackOptionImplemented or dot11HEROMIOptionImplemented is true shall set dot11HEControlFieldOptionImplemented(#1313) to true.(#1434)(#1435)

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(#2495) 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(#Ed) that carries an immediate acknowledgement, as described in 25.5.2 (UL MU operation)(#2315).
- A value of 1 in the Control ID subfield when the transmitting STA changes the receive operating mode(#2209), as described in 25.8 (Operating mode indication)(#2228).
- 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 25.5.2.5 (HE buffer status feedback operation for UL MU)(#824)
- A value of 4 in the Control ID subfield when the transmitting STA follows the UL MU operation procedure, as described in 26.3.13.2 (Power pre-correction).

If the HT Control field is present in an MPDU aggregated in an A-MPDU(#1436), 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

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the same A-MPDU(#1436) shall contain an HT Control field. The HT Control field of all MPDUs containing the HT Control field aggregated in the same A-MPDU(#1436) 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.(#1253)(#134)

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.(#362)(#2206)

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, bits~~-~~ 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.(#147)

10.13.2 A-MPDU length limit rules

(#2258)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 a 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

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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 a 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.

Editor's Note: Edits to 4th paragraph from 16/929r3 not applied since quoted baseline is out of date and changes appear to be unnecessary

Insert the following at the end of subclause 10.22.2.2:

(MU Motion #57)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.

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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 25.5.2.4 (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.(#2448)

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 25.10.4 (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.(#809)

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.(#809)

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:

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- 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.(#593)(#1530)(#2631)(#39)(#1531)

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(#2450) 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(#2450) 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(#2450)

b) Any required acknowledgments

c) Any frames required for protection, including one of the following:
   1) An RTS/CTS or MU-RTS/CTS(#2450) 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(#2450) 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:

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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.(#2451)

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(#204)(#2193)(#2613):

— The received CF-End frame is an inter-BSS frame and the most recent NAV update was due to an intra-BSS frame (see 25.2.1 (Intra-BSS and inter-BSS frame detection))(#18)(#673)(#1440)(#1660).

— The received CF-End frame is an intra-BSS frame and the most recent NAV update was due to an inter-BSS frame (see 25.2.1 (Intra-BSS and inter-BSS frame detection)).

NOTE 1—For HE STAs with two NAVs, the TXOP truncation rule applies to each NAV separately.(#737)(#2283)(#2447)(#2614)(#992)

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(#2470) 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(#2817) MU-BAR frame (MU-BAR variant Trigger frame(#1532)) to one or more of the HE STAs(#1213). Upon reception of the BlockAck frame from one or more HE STAs, the(#2818) originator may send an(#2817) MU-BAR frame to

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one or more other(#413) HE STAs that have a GCR block ack agreement(#21), and this process may be repeated multiple times.(#136)

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(#2819) HE STA receives an(#2817) MU-BAR frame with User Identifier subfield(#1444)(#2843) 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(#414) 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 ack retransmission 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(#22)(#415)(#1442)) 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(#2817) MU-BAR to group members 1 and 2 of the GCR group, waits for the BlockAck frames, and then sends an(#2817) 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(#22)(#1442). After receiving the BlockAck frames(#22)(#1442), the HE AP

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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.

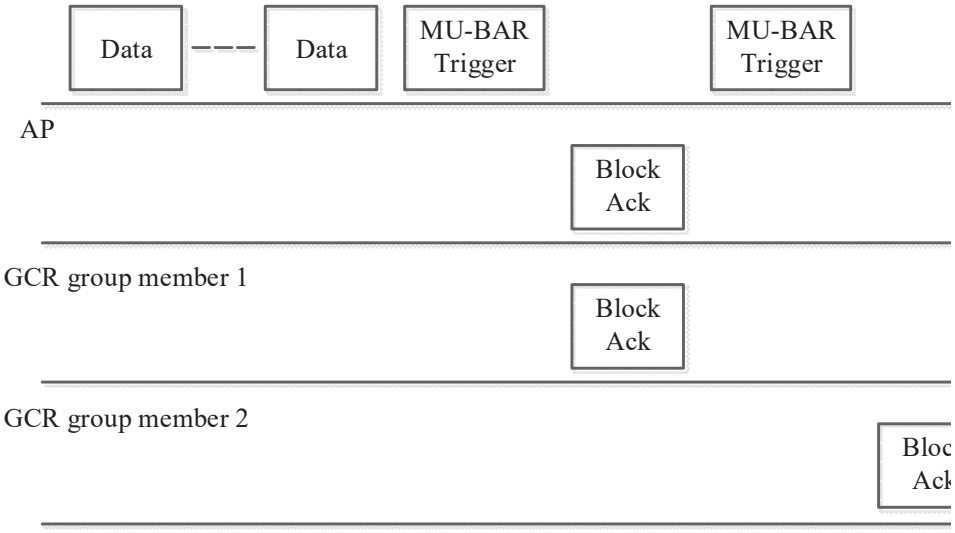


Figure 10-36a—Example of a frame exchange with GCR block ack retransmission policy(#22)(#415)(#1442)

Change the 6th,7th and 8th paragraph as follows:

After completing the BlockAckReq or MU-BAR and BlockAck frame exchanges(#23), 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 (#1443)send an MU-BAR frame with AID12 fields(#1444) 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.

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Change the last paragraph as follows:

If the beginning of such reception does not occur during the first slot time following a SIFS(#24)(#587)(#694)(#1756)(#1769)(#2615)(#2231), then the originator may perform error recovery by retransmitting a BlockAckReq frame or an MU-BAR frame(Ed) 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 Block-Ack 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.

10.45 Target wake time (TWT)

10.45.1 TWT overview

Change the 2nd paragraph of 9.44.1 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(#1381). 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 10.45.2.2 (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 10.45.3 (Implicit TWT operation).

(#1655)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

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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 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. The broadcast TWT agreement is not necessarily a newly created TWT agreement. The responding STA will not create any new individual TWT agreement with the requester at this time.
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.
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.

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Table 10-19a—TWT Setup exchange Command interpretation

Demand TWT with Wake TBTT Negotiation subfield = 1	Accept TWT with Broadcast subfield = 1	An active broadcast TWT agreement exists or has been created with the TWT parameters indicated in the initiating frame.
Suggest TWT with Wake TBTT Negotiation subfield = 1	Accept TWT with Broadcast subfield = 1	An active broadcast TWT agreement exists or has been created with the TWT parameters indicated in the responding frame.
Request TWT with Wake TBTT Negotiation subfield = 1	Alternate TWT with 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. 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.
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	No frame transmitted	A broadcast TWT agreement exists and is using the TWT parameters identified in the initiating frame.
Alternate TWT or Dictate TWT with Wake TBTT Negotiation subfield = 1	No frame transmitted	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.
Reject TWT with Wake TBTT Negotiation subfield = 1	No frame transmitted	The broadcast TWT agreement identified by the TWT Flow ID and the TA of the initiating frame frame is terminated.
Reject TWT with Wake TBTT Negotiation 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 have Broadcast subfield value of 0.

NOTE 2—Request frame settings not listed in the table are not allowed.

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11. MLME

11.2 Power management

11.2.2 Power management in a non-DMG infrastructure network

11.2.2.17 TIM Broadcast

(#152)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.(#1352)

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:

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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.(#1352)
- 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)

$$AID(5:8) = bin[(BCB(0:3) - (BSSID(44:47) \oplus BSSID(40:43))) \bmod 2^4, 4]$$

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.(MAC Motion #88)

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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

(#2115)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).

(#2115)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

(#2115)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 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.

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Insert new Clauses 25 and 26 following Clause 24 as follows:

25. High Efficiency (HE) MAC specification

25.1 Introduction

The use of HCCA and TSPEC are banned at HE STAs.(#2414)

25.2 Channel Access

25.2.1 Intra-BSS and inter-BSS frame detection

An HE STA(#2331) determines whether a received(#1577) 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)(#186)(#2434) or MAC address(#1575).

A frame received(#1577) by the STA is an intra-BSS frame if one of the following conditions is true:

— The RXVECTOR parameter BSS_COLOR(#2435) in the received PPDU carrying the frame(#1577) 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(#2438)(#2662) of the received(#1577) frame with the Individual/Group bit forced to the value 0(#447) is the same as the BSSID of AP to which the STA is associated(#608)

— The AP to which the STA is associated is a member of a Multiple BSSID Set with two or more members(#703)(#257)(#2332) and the RA field, TA field or BSSID field(#2438, #2662) of the received(#1577) frame with the Individual/Group bit forced to the value 0(#447) 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(#2437)

— 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.(#705)(#2436)(MAC Motion #88)

A frame received by the STA is an inter-BSS frame if one of the following conditions is true(#62)(#2718):

— 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(#Ed)

— 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

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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(#Ed)

— 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(#2439)

— 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.(#705)(#2439)(MAC Motion #88)

— An HE AP receives either a VHT MU PPDU or an HE MU PPDU.(#2440)

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 (#640)(#2661)(#776).

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(#62).

25.2.2 Updating two NAVs

An HE non-AP STA shall maintain two NAV timers. An HE AP STA may maintain two NAV timers.(#2316)

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.(#1775)

For the two NAVs maintained by an(#2829) HE STA, one is identified as intra-BSS(#1465) NAV, and the second one is identified as regular NAV. Intra-BSS NAV is used to store NAV value, if needed, from a PPDU identified as intra-BSS. Regular 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.(#1742) Note that the method of identifying a PPDU as intra-BSS or inter-BSS is described in 25.2.1 (Intra-BSS and inter-BSS frame detection).(#1466)

(#164)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(#164)

— 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.(#1759)

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:(#164)

— The frame is identified as intra-BSS according to the rule described in 25.2.1 (Intra-BSS and inter-BSS frame detection)(#164)(#1466)

— The indicated duration information is greater than the STA's current intra-BSS NAV value(#164)

— The STA is not solicited an immediate response by the PPDU carrying the frame.(#2905)

A STA shall update the regular NAV with the duration information indicated by the received frame in a PSDU if and only if all the following conditions are met:(#164)

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- The frame is identified as inter-BSS or cannot be identified as intra-BSS or inter-BSS according to the rule described in 25.2.1 (Intra-BSS and inter-BSS frame detection)(#164)(#1466)
- The indicated duration information is greater than the STA's current regular NAV value(#164)
- The STA is not solicited an immediate response by the PPDU carrying the frame.(#2905)

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:(#164)

- The RXVECTOR parameter TXOP_DURATION is not set to all 1s(#164)
- The PPDU that carried information of the RXVECTOR parameter is identified as intra-BSS or cannot be identified as intra-BSS or inter-BSS(#632) according to the rule described in 25.2.1 (Intra-BSS and inter-BSS frame detection)(#164)(#1466)
- 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(#164)
- The duration information indicated by the RXVECTOR parameter TXOP_DURATION is greater than the STA's current intra-BSS NAV(#164)
- The PPDU that carried information of the RXVECTOR parameter is not an HE trigger-based PPDU triggered by the STA(#2473)

A STA shall update the regular NAV with the duration information indicated by the RXVECTOR parameter TXOP_DURATION if and only if all the following conditions are met:(#164)

- The RXVECTOR parameter TXOP_DURATION is not set to all 1s(#164)
- The PPDU that carried information for the RXVECTOR parameter is identified as inter-BSS according to the rule described in 25.2.1 (Intra-BSS and inter-BSS frame detection)(#164)(#1466)
- 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(#164)
- The duration information indicated by the RXVECTOR parameter TXOP_DURATION is greater than the STA's current regular NAV(#164)

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 25.12 (TXVECTOR parameter TXOP_DURATION for an HE PPDU(#2596)).(#1759)

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.(#164)(#1744)

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 25.5.2.4 (UL MU CS mechanism).(#2905)

Various additional conditions may set or reset the intra-BSS NAV or regular 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).(#1775)(#966)

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 regular 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 25.5.2.4 (UL MU CS mechanism).(#1743)

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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 × aSIFSTime + CTS_Time + aRxPHYStartDelay + 2 × aSlotTime starting when the MAC receives a PHY-RXEND.indication primitive corresponding to the detection of the RTS or MU-RTS frame.(MAC Motion #89)

25.2.3 Obtaining an EDCA TxOP for UL MU capable STAs

(MAC Motion #91)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] and AIFSN[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.

— Update its HEMUEDCATimer state variable to the values contained in the most recently received MU EDCA Parameter Set element sent by the AP to which the STA is associated.

The HEMUEDCATimer shall uniformly count down to 0 when its value is nonzero.

NOTE—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.

An UL MU capable non-AP HE STA may update its CWmin[AC], CWmax[AC] and AIFSN[AC] state variables for all ACs to the values contained in the most recently received EDCA Parameter Set element sent by the AP to which the STA is associated or to the default dot11EDCATable when an EDCA Parameter Set element has not been received when the HEMUEDCATimer reaches 0.

25.3 Fragmentation

25.3.1 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.(#1484)

An HE STA can dynamically fragment individually addressed 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 25.5 (MU operation))(#30).

25.3.2 Support and requirements for dynamic fragmentation

A dynamic fragment is an MPDU, the payload of which carries a portion of an 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 25.3.4 (Procedure at the recipient).(#2627)(#2626)

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— 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(#1471).

— The length of each fragment is not required to be equal for all fragments of the 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 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 with a size that is less than the minimum fragment size shall not be fragmented.(#30)(#697)(#696)(#1470)(#165)

25.3.3 Procedure at the originator(#1484)

25.3.3.1 General(#Ed)

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 25.3.3.4 (Level 3 dynamic fragmentation(#1484))).(#2629)(#1794).

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 or MMPDU have been successfully received then the STA may retransmit the full 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 or MMPDU at that STA.(#1225)

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).(#1225)

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.(#1480)(#1479)(#1478)(#750)

25.3.3.2 Level 1 dynamic fragmentation(#1484)

An originator STA may transmit to a recipient STA an MPDU(#1472) or VHT single MPDU(#1473) that contains one dynamic fragment of an MSDU or MMPDU if the recipient STA has indicated a value 1 in the HE Fragmentation Support field of its HE Capabilities element. The originator STA shall follow the rules defined in 10.13.8 (Transport of VHT single MPDUs) for generating the VHT single MPDU.(#Ed)

25.3.3.3 Level 2 dynamic fragmentation(#1484)

An originator STA may transmit to a recipient STA, which has indicated a value 2 in the HE Fragmentation Support field of its HE Capabilities element, an MPDU, VHT single MPDU, or A-MPDU(#1473) that contains:

— One dynamic fragment of an MSDU or MMPDU in an MPDU or VHT single MPDU(#1474)
  • The originator STA shall follow the rules defined in 10.13.8 (Transport of VHT single MPDUs) for generating the VHT single MPDU

— Up to one dynamic fragment of an MSDU or MMPDU for each MSDU and for the MMPDU in an A-MPDU format(#1474)(#2464)

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- 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 25.10.4 (A-MPDU with multiple TIDs) for generating the multi-TID A-MPDU (that can contain the fragment of the MMPDU)(#1476)

25.3.3.4 Level 3 dynamic fragmentation(#1484)

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.(#2268)(#2198)(#1800)(#1796)(#1663)

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).(#2268)(#2198)(#1800)(#1796)(#1663)

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, VHT single MPDU, or A-MPDU(#1473) that contains:

— One dynamic fragment of an MSDU or MMPDU in an MPDU or VHT single MPDU(#1474)
  - The originator STA shall follow the rules defined in 10.13.8 (Transport of VHT single MPDUs) for generating the VHT single MPDU

— Up to four dynamic fragments of an MSDU(#1475) for each MSDU and up to one dynamic fragment of an MMPDU(#1476)(#1475)(#2465) in an A-MPDU
  - 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(#Ed) frame that corresponds to a TID of a transmitted fragment (see 10.24.7 (HT-immediate block ack extensions) and 25.4 (Block acknowledgement).(#697)(#Ed)(#166)(#1818)

25.3.4 Procedure at the recipient

25.3.4.1 General(#Ed)

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 25.3.3.2 (Level 1 dynamic fragmentation(#1484))

— Set to 2 if the STA supports reception of dynamic fragments following the procedure defined in 25.3.3.3 (Level 2 dynamic fragmentation(#1484))

— Set to 3 if the STA supports reception of dynamic fragments following the procedure defined in 225.3.3.4 (Level 3 dynamic fragmentation(#1484))

(#1481)(#424)Defragmentation of dynamic fragments shall follow the rules defined in 10.6 (Defragmentation) with the following exceptions:(#Ed)

— The recipient STA shall support the concurrent reception of dynamic fragments of a number of *outstanding* MSDUs or 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

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outstanding refers to an MPDU containing all or part of an MSDU or MMPDU for which transmission has been started, and for which delivery of the MSDU or MMPDU has not yet been completed (i.e., an acknowledgment of the final fragment has not been received and the MSDU or MMPDU has not been discarded due to retries, lifetime, or for some other reason). (#1482)(#697)(#167)(#1484)

— The recipient STA is not subject to the receive timer rules(#1483) for each of the MSDUs/MMPDUs defined in 10.6 (Defragmentation)(#2318).

25.3.4.2 Level 1 dynamic defragmentation

Upon reception of an MPDU or VHT single 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 VHT single 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 25.4 (Block acknowledgement) for generating the Multi-STA BlockAck frame that contains the acknowledgement for the soliciting VHT single MPDU carried in a Trigger-based PPDU(#1793)(#2628).

25.3.4.3 Level 2 dynamic fragmentation(#1484)

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 VHT single 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 25.4 (Block acknowledgement) for generating the Multi-STA BlockAck frame that contains the acknowledgement for the soliciting VHT single MPDU carried in a HE trigger-based PPDU(#1793)(#2628).

— A BlockAck frame when the received fragments, up to one fragment for each MSDU, are contained in an A-MPDU that solicits an immediate response(#1820)(#1485). 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 25.4 (Block acknowledgement) for generating the Multi-STA BlockAck frame(#1793), 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(#Ed) frame that corresponds to a TID of a received fragment(#967)
- 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(#1486)(#Ed) only when an MSDU that is received in fragments is successfully reconstructed (see 10.6 (Defragmentation)) otherwise it shall not update the block ack record(#Ed) for that MSDU.(#1793)(#1217)

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(#Ed) 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(#Ed) frame (where the comparison of the two values is performed modulo 4096)(#1662)(#2197)(#1217).

25.3.4.4 Level 3 dynamic fragmentation(#1484)

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:

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— An Ack frame when the received fragment is contained in an MPDU or VHT single 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 25.4 (Block acknowledgement) for generating the Multi-STA BlockAck frame that contains the acknowledgement for the soliciting VHT single MPDU carried in a Trigger-based PPDU(#1793)(#2628).

— A BlockAck frame when the received fragments, one or more fragments for each MSDU, are contained in an A-MPDU where at least one MPDU's Fragment Number field is of non-zero value(#2268) that solicits the immediate response and is sent during a BA session that was setup with an L3 FRAG ADDBA Response frame(#2268). 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(#1488) *B*(#633) of the Block Ack Bitmap field that corresponds to a successfully received fragment and shall set it to 0 otherwise, with *B*(#633) calculated as:
  $B = 4 \times (SN - SSN) + FN$, where the operations on the sequence numbers are performed module 4096(#675)(#2270)(#2254)(#1624)(#1491)(#1489)
  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(#1486) only when an 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.(#1793)(#1217)

The(#Ed) recipient STA shall discard any fragments that have been received during an HT-immediate BA session for a TID if it receives a BlockAckReq(#Ed) 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(#Ed) frame (where the comparison of the two values is performed modulo 4096)(#1662)(#2197)(#1217).

25.4 Block acknowledgement

25.4.1 Overview

(#168)An HE STA can use Compressed BlockAck frame or Multi-STA BlockAck frame after setting up a block ack agreement(#Ed). 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 25.5.2 (UL MU operation)) or multi-TID A-MPDU operation (25.10.4 (A-MPDU with multiple TIDs)) is supported in the role of recipient(#1495).

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.(MU Motion #59)

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.(#1664)

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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.(#1493)(#2212)

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(#1408) field is 0 then the Block Ack Starting Sequence Control(#1490), TID and Block Ack Bitmap fields(#Ed) of the STA Info field are processed according to 10.24.7 (HT-immediate block ack extensions) and 25.3 (Fragmentation).(MAC Motion #87)

— If the Ack Type(#1408) 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.(MAC Motion #87)

Editor's Note: Instruction in 16/1241r2 is "Insert the following at the end of subclause 25.4.5". No such subclause.

(#567)An HE STA that receives a BlockAckReq(#Ed) frame or a MU-BAR(#Ed) 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 25.4 (Block acknowledgement).

An HE STA that receives a Multi-TID BlockAckReq(#Ed) frame or a MU-BAR(#Ed) 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).

25.4.2 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.

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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(#Ed) 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 25.3 (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 25.4.3 (Negotiation of block ack bitmap lengths).

An originator(#168) shall examine each received Multi-STA BlockAck frame(#Ed)(#1900)(#2319) 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(#31) Per STA Info field that has an AID field addressed(#Ed) 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(#2185) 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), (#1498)25.3 (Fragmentation), and as defined below.

— If the ACK Type field is 1(#2185) then the Per STA Info field indicates either the acknowledgement of a single MPDU identified by the value of the TID or of all MPDUs(#1500) carried in the eliciting PPDU as defined by the acknowledgement context.

25.4.3 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

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- 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.(#Ed)

(#1498)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 25.3 (Fragmentation).

25.4.4 Per-PPDU acknowledgment selection rules

25.4.4.1 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(#Ed) 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(#Ed) variant or Multi-TID BlockAckReq(#Ed) variant in each of

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the Per User Info fields. An HE AP shall not send a Multi-TID BlockAckReq(#Ed) (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).

25.4.4.2 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 VHT Single 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).

25.4.4.3 DL MU PPDU soliciting an HE trigger-based PPDU response(#Ed)

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 VHT Single 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(#Ed) 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.

25.4.4.4 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:

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1) If the HE trigger-based PPDU carries a Single MPDU(11ah) from a single STA that solicits an immediate response, then the HE AP shall respond with an Ack frame or a Multi-STA BlockAck frame with ACK Type 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 Compressed BlockAck frame or a Multi-STA Block Ack frame with Ack Type 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(11ah), A-MPDUs, or multi-TID A-MPDUs from more than one STA, or a combination of Single MPDUs(11ah) 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.

25.4.4.5 HE trigger-based PPDU soliciting a DL MU PPDU response

A non-AP STA that sends a 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 HE MU PPDU format, then the HE AP shall follow the following acknowledgment procedure:

a) If the HE trigger-based PPDU carries Single MPDU(11ah) from more than one STAs, or (multi-TID) A-MPDU from more than one STAs, or a combination of Single MPDU(11ah) 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(11ah) 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) using TBD mechanism 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.(#1218).

25.5 MU operation

25.5.1 HE DL MU operation

25.5.1.1 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.

(#221)(#250)(#1502)(#1505)(#1901)An AP shall not transmit to a STA an(#2829) 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(#1507) subfield of the HE Capabilities element to 1.

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The transmission of each RU in an HE MU PPDU(#1507)(#1508) shall be padded to end at the same time, indicated by the L-SIG field as described in 26.3.10.5 (L-SIG).(#1903)

The padding procedure for each A-MPDU in an HE MU PPDU is defined in 25.10.3 (A-MPDU padding for an HE trigger-based PPDU(#1585)).

(#667)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.

25.5.1.2 HE MU PPDU payload

(#427)The Type and Subtype subfields in the Frame Control field(#753)(#Ed) and address type (individually addressed or group addressed(#1509)) of MPDUs may be different across A-MPDUs in different RUs within a same HE MU PPDU(#598).

An AP shall not set more than one STA-ID field in the HE-SIG-B field to indicate the same value. 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(#Ed) the same HE MU PPDU.(#2633)

An MPDU sent in a broadcast RU of an HE MU PPDU(#33)(#754)(#755)(#756) shall not include information intended for a STA that is identified as the recipient of another RU in the same HE MU PPDU.

25.5.2 UL MU operation

25.5.2.1 General

The UL MU operation allows an AP to solicit simultaneous immediate response frames(#1513) from one or more non-AP STAs. Non-AP STAs transmit their response frames using(#1514) HE trigger-based PPDU format, in either UL OFDMA(#1515),(#431) 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(#1432))).(#1184)

(#34)An HE STA with dot11ULMUMIMOOptionImplemented set to true shall set the UL MU-MIMO(#1507) subfield of the HE Capabilities element it transmits to 1. Otherwise, the HE STA shall set the UL MU-MIMO subfield of the HE Capabilities element it transmits to 0(#417).

A non-AP STA with (#34)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.(#1)

(#1343)A STA shall not transmit a Trigger frame soliciting a UL OFDMA With MIMO PPDU from a STA from which it has not received an HE Capabilities element with the UL OFDMA With MIMO Support bit set to 1.

A STA shall not transmit a Trigger frame soliciting a Full BW UL MU MIMO PPDU from a STA from which it has not received from which it has not received an HE Capabilities element with the Full BW UL MU MIMO Support bit set to 1.

A STA transmitting an UL OFDMA PPDU shall operate as either a class A or class B device as defined in 26.3.14 (Transmit requirements for an HE trigger-based PPDU(#340)). A STA that is a class A device shall

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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.

25.5.2.2 Rules for soliciting UL MU frames

25.5.2.2.1 General

(#34)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.(#1)

An AP may transmit a PPDU that elicits an HE trigger-based PPDU from one or more STAs by including in the PPDU:(#34)

— One or more Trigger frames that includes one or more User Info fields(#1520) addressed to one or more of the recipient STAs. For recipient STAs that are associated with the AP, the User Info field(#1520) is addressed to a recipient STA if the value of the AID12(#Ed) subfield(#2683) of the User Info(#1520) field is equal to the AID of the STA or to 0 (indicating a random access allocation).(#34)(#170)(#1078). A value of 0 also indicates that non-associated STAs can transmit on the allocated resource using the random access procedure as described in 25.5.2.6 (UL OFDMA-based random access).

— An UL MU Response Scheduling A-Control subfield of individually addressed MPDUs contained in the HE MU PPDU that:(#1)

  • Are carried in a VHT single MPDU format that solicits an immediate Ack frame (see 10.13.8 (Transport of VHT single 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 25.10.4 (A-MPDU with multiple TIDs))

NOTE—The AP additionally follows the rules defined in 25.3.3 (Procedure at the originator(#1484)) when fragments are present in the generated MPDU(s).

The following two frames shall not be present in the same A-MPDU:(#595)

— A Trigger frame with a User Info field(#1520) addressed to a STA

— An(#1525) MPDU that contains an UL MU Response Scheduling A-Control subfield and that is addressed to a STA(#1)

(#2640)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.(#1906)(#Ed)

(#1634)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. AP shall apply the Trigger Frame MAC

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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).

25.5.2.2.2 Allowed settings of the Trigger frame fields

If dot11MultiBSSIDActivated is false, then the TA field of a Trigger frame shall be set to TBD. If dot11MultiBSSIDActivated is true and at least two of the Trigger frame recipient STAs are associated with two different BSSIDs, then the TA field shall be set to TBD.(#2176)

The RA field of the MPDUs sent in response to a Trigger frame shall be set to TBD.(#171)

An AP shall not set any subfields of the Common Info field(#1529) of a Trigger frame(#36) to a value that is not supported by all the recipient STAs of the Trigger frame.

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.(#36)

If a Trigger frame is transmitted in an RU of an(#2829) HE MU PPDU and the RU is addressed to multiple STAs(#252), 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(#Ed).(#38)(#677)

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.(#2642)

Editor's Note: Incomplete sentence from 16/929r3 not included here

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 variant Trigger frame (see 9.3.1.23.1 (Basic Trigger variant(#2219))) intended to it.(#2219)

The AP shall set the value in the TID Aggregation Limit subfield in the Type dependent Per User Information field to 0 or 1 for an HE STA with STA that has indicated a zero value in the Multi-TID Support field of the HE Capabilities element it transmits and is identified by the AID12 subfield of the User Info field of a Basic Trigger variant Trigger frame (see 9.3.1.23 (Trigger frame format)).(#2669) 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.(MAC Motion #92)

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The AP may assign any value between 0 and 7 in the TID Aggregation Limit subfield in the Trigger Dependent User Info field to 1 for an HE STA with STA that has indicated a nonzero value in the Multi-TID Support field of the HE Capabilities element it transmits and is identified by the AID12 subfield of the User Info field of a Basic Trigger variant Trigger frame.(#Ed)(#2669)

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 variant Trigger frame.(#2669)

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 variant Trigger frame.(#2669)

NOTE—A STA follows the rules in 25.10.4 (A-MPDU with multiple TIDs) for aggregating the QoS Data frames with multiple TIDs in HE trigger-based PPDUs.(#2669)

25.5.2.2.3 AP access procedures for UL MU operation

(#172)(#173)When an AP receives an immediate response with at least one MPDU from at least one STA solicited by a Trigger frame(#1535), the procedures described in 9.22.2.7 (Multiple frame transmission in an EDCA TXOP) apply.(#39)(#1531)

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.(#593)

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).(#593)

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.(MAC Motion #90)

25.5.2.3 STA behavior

A STA shall not send an HE trigger-based PPDU unless it is(#2824) explicitly triggered by an AP in one of the operation modes described in this subclause(#1304).

The inter-frame space between a PPDU that contains a Trigger frame or contains an HE variant HT Control field that solicits an immediate response and the triggered HE trigger-based PPDU is SIFS.(#40)

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(#1532) (that is not an MU-RTS variant(#Ed)) with a User Info(#1520) field addressed to the STA, or an MPDU addressed to the STA that contains an UL MU Response Scheduling A-Control subfield(#1). The User Info(#1520) field is addressed to a STA if the AID12(#Ed) subfield(#2685) is equal to the AID of the STA and(#766) 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(#977) UL MU CS condition described in 25.5.2.4 (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

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A STA transmitting an HE trigger-based PPDU in response to a Trigger frame sets the TXVECTOR parameter as follows:(#175)

— 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 25.2.2 (Updating two NAVs)

— The BSS_COLOR parameter shall be set as follows:

  • If the preceding Trigger frame was received in a 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(#253) of the eliciting Trigger frame(#1)

— The HE_LTF_TYPE(#Ed) parameter 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 [??] parameter shall be set to the value indicated by the Number Of HE-LTF Symbols(#Ed) subfield of the Common Info field of the eliciting Trigger frame

— The STBC(#Ed) parameter shall be set to the value indicated by the STBC subfield of the Common Info field of the eliciting Trigger frame

— The [??] parameter shall be set to the value indicated by the LDPC Extra Symbol 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 [??] 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(#1520) 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(#1520) 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(#1535)

— 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 (26.3.14.2 (Power pre-correction)).

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(#1)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(#2564) shall be set to 4 (see 26.3.12 (Packet extension(#1781)))

— TXOP_DURATION parameter shall be set according the rules defined in 25.2.1 (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 25.5.2.4 (UL MU CS mechanism)).

NOTE 2—The use of BCC limits the available RU sizes as defined in 26.3.11.8 (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 25.4 (Block acknowledgement) for generating the Multi-STA BlockAck frame.

NOTE—The STA additionally follows the rules defined in 25.3.3 (Procedure at the originator(#1484)) when fragments are present in the soliciting (A-)MPDU(s).

The MAC padding procedure is described in 10.42.2.1.2.(#1536)

The content of each A-MPDU(#1537) in an HE MU PPDU is based on the rules specified in 9.7.3 (A-MPDU contents)(#2172) with the following additional rules.

If the Trigger Type field(#1539) 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. The MPDUs included in the response shall not solicit a response.(#176)

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.(#1541)(#42)

A STA may include MPDUs with any TID in an HE trigger-based PPDU sent in response to a Trigger frame subject the rules of 25.10.4 (A-MPDU with multiple TIDs).(#2644)

NOTE—The frame type of MPDUs may be different across A-MPDUs within a same HE trigger-based PPDU.(#598).

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25.5.2.4 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(#978)(#2647). ED-based CCA is described in 21.3.18.5.2 (CCA sensitivity for operating classes requiring CCA-ED)(#978)(#2647) 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(#1544) unless one of the following conditions is met:(#1220)(#2648)(#437)

— 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(#700)

— The NAV was set by an intra-BSS frame(#1467)

NOTE 1—The details of how a STA is solicited by the Trigger frame for transmission are described in 25.5.2.2.2 (Allowed settings of the Trigger frame fields).(#1544)

(#2316)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(#768)) and the virtual carrier sense (NAV) before UL MU transmission in response to the Trigger frame(#1532). 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(#1295) in the Trigger frame are considered idle; if the STA detects that the 20 MHz channels containing the allocated RUs(#1295) are not all idle, then the STA shall not transmit anything in the allocated RUs(#1295).

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.(#979)

The CS Required subfield in the MU-RTS variant of the Trigger frame shall be set to 1.(#2226)

The AP shall set the CS Required subfield to 1 except when all solicited HE trigger-based PPDUs contain(#Ed) an Ack or BlockAck frame(#1547)(#1546) and the Length subfield in the Common Info field of the Trigger frame is less than or equal to 418(#206).

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 (26-17). 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), 25.5.2.3 (STA behavior), and 26.3.4 (HE PPDU formats)).(#206)

25.5.2.5 HE buffer status feedback operation for UL MU

(#1550)(#254)(#769)(#2711)(#1062)(#45)(#770)(#438)(#1065)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).(#178)(#2189)

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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 25.10.4 (A-MPDU with multiple TIDs) for aggregating QoS Data frames with multiple TIDs. The HE STA does not follow the rules defined in 25.10.3 (A-MPDU with multiple TIDs) for QoS Null frames whose Ack Policy subfield is No Ack.(#771)(#1066)(#2190)(#2191)

— 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)).(#45)(#178)(#770)(#817)(#1066)

NOTE 1—The STA can send an unsolicited BSR in response to Basic variant Trigger frames (with or without random RUs, as defined in 25.5.2.3 (STA behavior) and in 25.5.2.6 (UL OFDMA-based random access)) or it can send the unsolicited BSR after accessing the WM using EDCA.(#254)(#769)(#2189)

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)).(#1062) 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 25.5.2.3 (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 25.5.2.6 (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).(#254)(#769)(#1065)

— The STA shall include in the HE trigger-based PPDU one or more QoS Null or QoS Data frames containing one 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.(#771)(#1066)(#2190)(#2191)
  • 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 9.2.4.6.5 (Buffer Status Report (BSR)(#824))).(#45)(#770)(#817)(#1066)(#2190)(#2191)

— 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).(#438)

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.

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25.5.2.6 UL OFDMA-based random access

25.5.2.6.1 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.(#2383) 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(#450)) in Beacon and Probe Response frames it transmits. The AP shall indicate the range of OFDMA contention window (OCW)(#179) 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.

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 dot11ULOFDMARandomAccessOptionImlemented set to true shall maintain an internal OFDMA backoff (OBO) counter(#2712). The HE STA shall follow the random access procedure defined in 25.5.2.6.2 (Random access procedure) to contend for an RU assigned for random access.(#450)

25.5.2.6.2 Random access procedure

In this subclause(#1304), the random access procedure is described with respect to UL OFDMA contention parameters. The procedure is also illustrated in Figure 25-1 (Illustration of the UL OFDMA-based random access procedure). The OFDMA contention window (OCW) is an integer with an initial value of OCWmin.

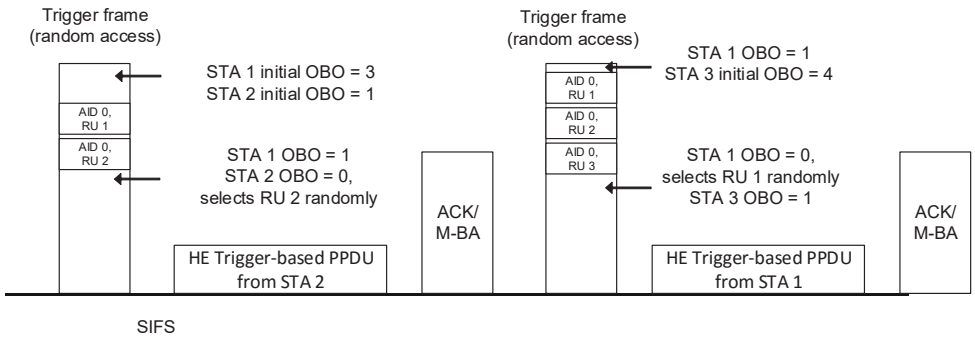


Figure 25-1—Illustration of the UL OFDMA-based random access procedure

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(#48), when an HE STA obtains the value of OCWmin from the HE AP indicated in the RAPS

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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 25-1 (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(#1551) randomly selects one of the RUs assigned to AID value 0. If the selected RU is idle as a result of both physical and virtual carrier sensing as defined in subclause 25.5.2.4 (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.(#787)

If the HE trigger-based PPDU is successfully transmitted in the randomly selected RU, then the STA shall set its OCW to OCWmin(#Ed).(#51)

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.(#51)

The MU acknowledgment procedure for random access follows the procedure as defined in 10.3.2.10.3 (Acknowledgement(#1410) 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 25.5.2.6.3 (Retransmission procedure for random access).(#450)

25.5.2.6.3 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 25.5.2.6.2 (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 $2 \times \mathrm{OCW} + 1$ for every retransmission, until the OCW reaches the value of OCWmax(#Ed). Once the OCW reaches OCWmax for successive retransmission attempts, the OCW shall remain at the value of OCWmax until the OCW is reset.(#51)

25.5.3 HE MU cascading operation

A TXOP can include both DL MU and UL MU transmissions.

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An(#603) 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 a DL MU PPDU in the same TXOP, as illustrated in Figure 25-2 (An example of cascading sequence of MU PPDUs).

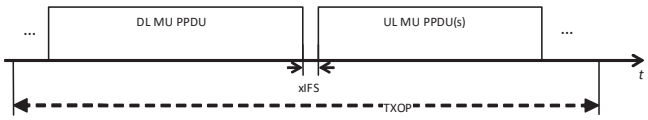


Figure 25-2—An example of cascading sequence of MU PPDUs

The cascading sequence has only one DL transmitter. The cascading sequence may have different UL transmitters within each HE trigger-based PPDU(#1556). The cascading sequence may have a different set of transmitters in HE trigger-based PPDUs as compared to the DL HE MU PPDU that follows the HE trigger-based PPDUs within the same TXOP.

25.6 HE sounding protocol

Editor's Note: Editing instructions in 16/773r2 do not mention the existing text in this subclause. I'll leave it here until the group decides what they want to do with it (delete, modify, move).

The HE sounding protocol is initiated by an AP sending an NDP Announcement frame (TBD) followed by an HE NDP transmitted a SIFS after the end of the PPDU carrying the NDP Announcement (TBD).

An HE AP may use the Trigger frame to solicit HE beamforming feedback from a STA provided that the UL MU Capable field of the most recently received HE Capabilities element from that STA is 1 (see 25.5.2 (UL MU operation)).

An HE AP may solicit beamforming feedback from multiple STAs sequentially through SU transmission.

An example of the HE sounding protocol using MU operation to solicit feedback is shown in Figure 25-3 (An example of the HE sounding protocol using MU operation).

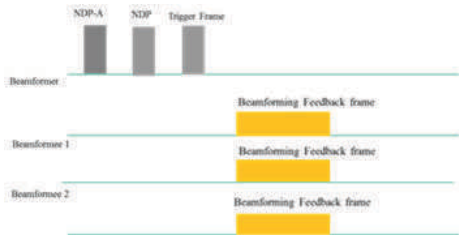


Figure 25-3—An example of the HE sounding protocol using MU operation

(#802)(#2234)(#55)(#1221)(#1915)(#1695)(#1000)

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25.6.1 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 HE sounding protocol to determine the channel state information. Similar to VHT, HE uses explicit feedback mechanism where the HE beamformee measures the channel from the 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.

25.6.2 Rules for HE sounding protocol sequences

The HE beamformer shall initiate a sounding sequence by transmitting a HE NDP Announcement frame followed by a HE NDP after SIFS.

If the HE NDP Announcement frame includes more than one STA Info field, the RA of the HE NDP Announcement frame shall be set to a broadcast address, else 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 CBF except when the HE NDP Announcement frame contains only one STA Info element with the Feedback Type subfield in the STA Info field is equal to SU. When the HE NDP Announcement frame contains only one STA Info element with the Feedback Type subfield in the STA Info field set to SU, then the *Ng*, codebook and *Nc* to be used for the generation of the Compressed Beamforming Report(#Ed) shall be determined by the recipient of the NDP Announcement frame.

A HE beamformer that transmits a HE NDP Announcement frame with more than one STA info field should transmit a Beamforming Report Poll Trigger frame 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 SIFS after receiving the HE Compressed Beamforming feedback to retrieve subsequent feedbacks in the same TXOP.

A HE beamformer that sets the Feedback Type subfield of a STA Info field to MU shall set the Nc Index field(#Ed) 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 25.8 (Operating mode indication)).

The HE beamformee shall indicate the maximum number of space-time streams it can receive in a 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.

A HE beamformer that sets the Feedback Type subfield of the STA Info field to MU shall set the Ng field(#Ed) value in the STA Info field of the HE NDP Announcement frame to either 0 (for $Ng = 4$) or 1 (for $Ng = 16$).

A HE beamformer shall set the RU Start Index and RU End Index in the STA Info field to indicate the starting 26-tone RU(#Ed) and the ending 26-tone RU(#Ed) of the requested HE compressed beamforming

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report. The RU Start Index is 7 bits and indicates the lowest 26-tone RU(#Ed) for which the HE beamformer is requesting feedback. The RU End Index is 7 bits and indicates the highest 26-tone RU(#Ed) for which the HE beamformer is requesting feedback. The 26-tone RU(#Ed) location is based on the RXVECTOR parameter(#Ed) CH_BANDWIDTH of the HE NDP Announcement when received in a HE PPDU or the RXVECTOR parameter(#Ed) CH_BANDWIDTH_IN_NON_HT when the HE NDP Announcement is received in a non-HT PPDU.

The HE beamformer shall set the starting RU index to a value equal to the maximum of:

— The minimum 26-tone RU(#Ed) located within the channel width in the VHT Operation Information field

— The minimum 26-tone RU(#Ed) located within the channel width in the Receive Operating Mode Notification Indication (see 25.8 (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(#Ed) located within the channel width in the VHT Operation Information field

— The maximum 26-tone RU(#Ed) located within the channel width in the Receive Operating Mode Notification Indication

A HE beamformer that transmits a HE NDP Announcement frame that has only one STA Info field with the Feedback Type subfield equal to SU 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 25-4 (An example of the sounding protocol with a single HE beamformee).

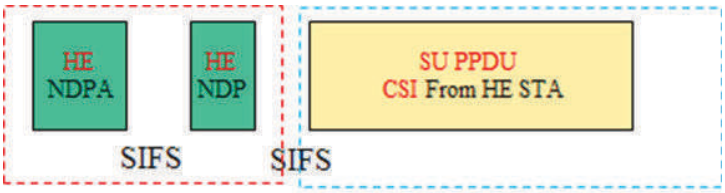


Figure 25-4—An example of the sounding protocol with a single HE beamformee

A non-AP HE beamformee that receives a HE NDP Announcement frame for a 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 SIFS after receiving the HE NDP. The TXVECTOR parameter CH_BANDWIDTH for(#Ed) the PPDU containing the HE compressed beamforming feedback shall be set to indicate a bandwidth not wider than that indicated by the RXVECTOR parameter(#Ed) CH_BANDWIDTH of the HE NDP Frame.

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An example of HE sounding protocol with more than one HE beamformee is shown in Figure 25-5 (An example of the sounding protocol with a single HE beamformee).

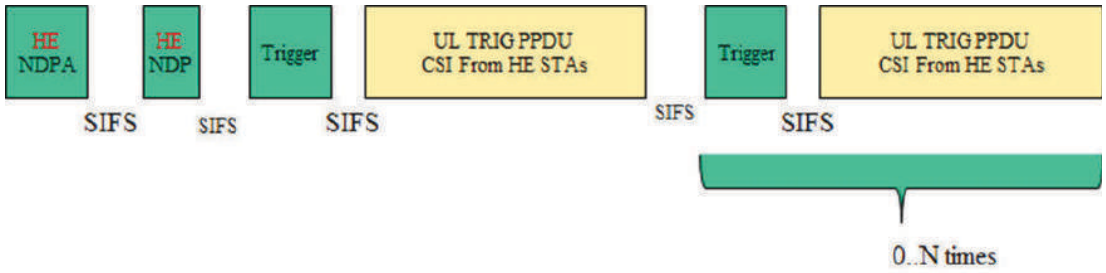


Figure 25-5—An example of the sounding protocol with a single HE beamformee

A non-AP HE beamformee that receives a HE NDP Announcement frame from a 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(#Ed) variant Trigger frame that contains the AID of the STA in any of the User Info(#Ed) fields following the rules defined in 25.5.2.3 (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.

(PHY Motion #167)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).

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25.6.3 Rules for segmented feedback in HE sounding protocol sequences(#1222)

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

25.7 TWT operation

25.7.1 General(#1779)

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 10.45 (Target wake time (TWT)), subject to the additional rules and restrictions that are defined in 25.7.2 (Individual TWT agreements(#1214)). 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 25.7.3 (Broadcast TWT operation(#1779)(#1874)(#1214)).(#1779)

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.(#1737)

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.(#1651)(#1649)(#141)(#26)

An HE AP shall set the TWT Responder Support subfields of the Extended Capabilities element and HE Capabilities element to 1.(#1803)

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 25.7.2 (Individual TWT agreements(#1214)), or participate in broadcast TWT operation, as defined in 25.7.3 (Broadcast TWT operation(#1779)(#1874)(#1214)).(#1640)

25.7.2 Individual TWT agreements(#1214)

An HE STA may negotiate individual TWT agreements with another HE STA as defined in 10.45.1 (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.

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- 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 10.45.7 (TWT Sleep Setup).(#156)

— 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(#1214)
- A successful TWT agreement whose Flow Type subfield is 1 is an unannounced TWT; otherwise it is an announced TWT(#2616)(#1214)

— 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.(#139)(#2399)(#1652)

— 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.(#2391)

An HE STA that successfully sets up a TWT agreement with another HE STA shall follow the rules defined in 10.45.1 (TWT overview) and 10.45.4 (Implicit TWT operation), except that the additional rules defined in this subclause supercede the respective rules defined in 10.45.1 (TWT overview) and 10.45.4 (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 10.45.1 (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.(#1736)(#1214)(#1318)

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).(#1650)

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.(#1639)(#155)

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.(#1658)(#1646)(#959)(#138)

NOTE—The STA decides what frames to transmit within or outside TWT SPs.

(#1651)(#1651)(#1736)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 25.5.2 (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.(#137)(#452)

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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 25.8 (Receive operating mode).

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.

(#1779)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 25.5.2 (UL MU operation))(#1738). 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.(#2398)

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 25.5.2 (UL MU operation)).(#1738)

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.(#2845)(#153)

— 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.(#2845)(#153)

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.

(#2616)(#139)(#2399)(#1652)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(#2617)(#137)(#742)(#744)
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(#2617)(#137)(#742)(#744)

(#2617)(#137)(#25)(#1653)

25.7.3 Broadcast TWT operation(#1779)(#1874)(#1214)

25.7.3.1 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 25.7.3.2 (Rules for TWT

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scheduling STA). The TWT scheduling STA may also include the broadcast TWT element in broadcast Probe Response frames.(#2618)(#2619)

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(#1649)(#141)(#26)

— 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 25.7.2 (Individual TWT agreements(#1214)).

A TWT scheduled STA follows the schedule provided by the TWT scheduling STA as described in 25.7.3.3 (Rules for TWT scheduled STA(#1657)(#958)(#2400)(#142)(#957))(#1657)(#958)(#2400)(#142)(#957). A TWT scheduled STA can negotiate the wake(#1654)(#420) TBTT and listen interval for Beacon frames it intends to receive as described in 25.7.3.3 (Rules for TWT scheduled STA(#1657)(#958)(#2400)(#142)(#957)).

An example of broadcast TWT operation is shown in Figure 25-6 (Example of broadcast TWT operation), where the AP is the TWT scheduling STA and STA 1 and STA 2 are the TWT scheduled STAs.

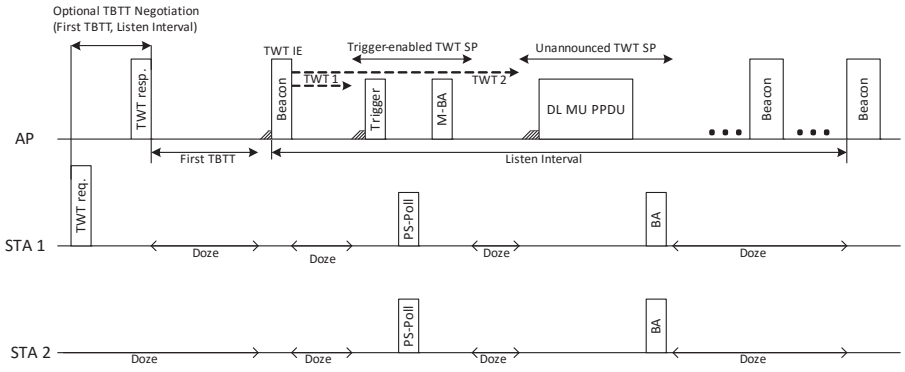


Figure 25-6—Example of broadcast TWT operation

25.7.3.2 Rules for TWT scheduling STA

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 10.45.7 (TWT Sleep Setup)). Each TWT parameter set specifies the TWT parameters of a broadcast TWT that are valid within a broadcast TWT SP.

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(#1642)(#2621)(#1643)(#143)(#2899)

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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(#1214).

The TWT scheduling STA shall schedule for transmission a Trigger frame addressed to(#2620) 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.(#137)(#452)

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 25.8 (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(#1214)(#2616).

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)(#1641).

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)(#1641) 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 25.5.2.6 (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 25.5.2.6 (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 25.5.2.6 (UL OFDMA-based random access)).(#1322)

The TWT scheduling STA shall set the TWT field to the TSF timer [4: 19](#144) at which the first TWT is scheduled for this TWT parameter set(#1741).

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(#145).

The TWT parameters are valid for each successive TWT of the periodic TWT or for the only TWT of the aperiodic TWT(#145).

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(#1432)), or CTS-to-self as described in 10.3.2.13 (NAV distribution); otherwise it shall set it to 0.(#2391)

(#1077)(#695)(#139)(#2399)(#1652)(#146)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:

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— 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.(#2845)(#153)

— 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.(#2845)

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.(#1642)(#2621)(#1643)(#143)(#2899)

25.7.3.3 Rules for TWT scheduled STA(#1657)(#958)(#2400)(#142)(#957)

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.(#1658)(#1646)(#959)(#138)

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.(#151) 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.(#25)

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.(#2617)(#137)(#742)(#744)

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.(#2617)(#137)(#742)(#744)

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 25.5.2 (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 25.5.2.6 (UL OFDMA-based random access) then the STA can follow the rules defined in 25.15.2 (Power save with UL OFDMA-based random access) to determine an early TWT SP termination event.(#1653)

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 25.5.2 (UL MU operation)). The TWT scheduled STA

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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.(#2845)(#745)(#2398)

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 25.5.2 (UL MU operation).

25.7.3.4 Negotiation of wake(#1654)(#420) 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(#420) TBTT of the first Beacon frame and the wake(#420) 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 (#1656)(#2622)(#682)

— 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(#1656)(#2820) 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(#1656)(#2622)(#682)

— The value of the allocated first wake TBTT(#1654)(#420) 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(#1654)(#420) 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 in 25.7.3.3 (Rules for TWT scheduled STA(#1657)(#958)(#2400)(#142)(#957))(#1657).

Either STA can tear down an established negotiation following the tear down procedure described in 10.44.8 (TWT Teardown).

25.8 Operating mode indication

25.8.1 General

An HE STA can change its operating mode setting either using the procedure described in 11.42 (Notification of operating mode changes)(#2327), or the procedure described(#1561) in this subclause.

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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.(#445)(#1565)(#1569)(#1573)(#2238)(#856)

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.(#1565)(#2238)

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(#1563) that solicits an immediate acknowledgement and is addressed(#Ed) to the OMI responder.(#207)(#1562)(#2236) The OMI A-Control field indicates that the OMI initiator supports(#444) 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 25.8.2 (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(#1563) that solicits an acknowledgement frame immediate response immediate acknowledgement and is addressed to the OMI responder as defined in 25.8.3.(#2236)

(#2657)

25.8.2 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.

(#685)(#1223)(#2330)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:(#685)(#446)(#2239)(#1223)(#1224)(#1572)

— 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(#1570), the OMI initiator attempts the recovery procedure defined in 10.22.2.7 (Multiple frame transmission in an EDCA TXOP)(#1571).(#1572)

If an OMI mode change is reported during a TXOP then the change should occur at least after that TXOP.(#2)(#61)(#185)

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.(#2)(#61)(#185)

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.(#1574)(#184)

NOTE—A subsequent PPDU is a PPDU that is intended for the ROM Initiator and needs not be the immediately following PPDU.(#2463)(#2469)

(#1574)

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25.8.3 Rules for transmit operation mode (TOM) indication(#95)

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 25.5.2 (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.(#2463)(#2659)

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 25.5.2 (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(#2463)
  • 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(#2469)(#2658)
— 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(#2463)(#2659)
— 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(#2469)(#2658)

25.9 Spatial reuse operation

25.9.1 General

The objective of the HE spatial reuse operation is to improve the system level performance, the utilization of medium resources and power saving(#2714) in dense deployment scenarios by early identification of signals from overlapping basic service sets (OBSSs) and interference management.

25.9.2 OBSS_PD-based spatial reuse operation

25.9.2.1 General

(#2386)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:

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— The received PPDU is an Inter-BSS PPDU (see 25.2.1 (Intra-BSS and inter-BSS frame detection))

— The received power level measured from the legacy portion of the PPDU is below the OBSS_PD level (defined in 25.9.2.2 (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(#Ed)
  • A non-HT PPDU that carries a group addressed Public Action frame(#Ed)

(#2664)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 shall be decreased by 3 dB to compensate for the power boost factor when compared to the OBSS PD level.

25.9.2.2 Adjustment of OBSS_PD and transmit power

(#2386)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:

Allowable $OBSS\_PD_{level} \leq max(OBSSPD_{min}, min(OBSSPD_{max}, OBSSPD_{min} + (TXPWR_{ref} - TXPWR)))$

The adjustment rule is illustrated in Figure 25-7 (Illustration of the adjustment rules for OBSS_PD and TX_PWR).

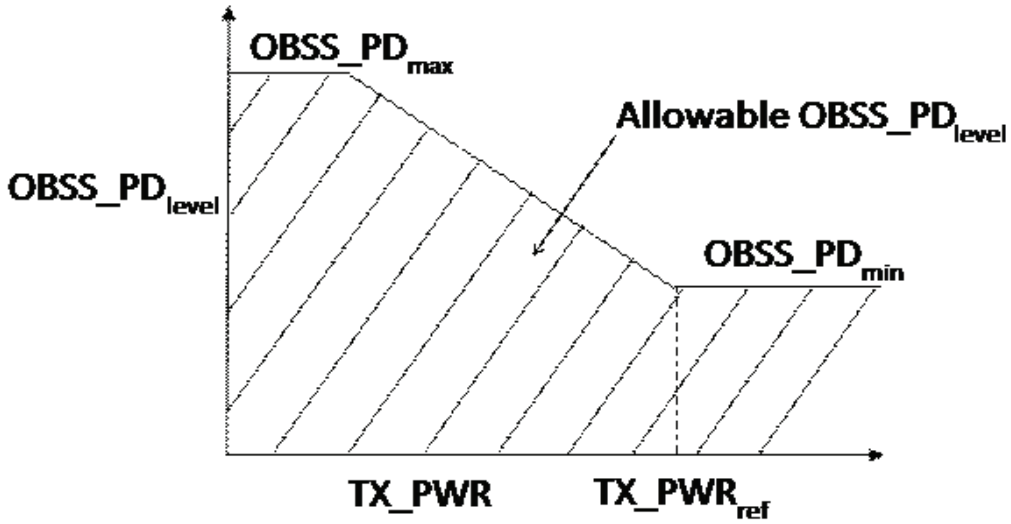


Figure 25-7—Illustration of the adjustment rules for OBSS_PD and TX_PWR

The $OBSS\_PD_{level}$ is applicable to the start of a 20 MHz PPDU received on the primary 20 MHz channel(#Ed). The $OBSS\_PD_{level}$(40 MHz) which is applicable to the start of a 40 MHz PPDU received on the primary 40 MHz channel(#Ed), the $OBSS\_PD_{level}$(80 MHz) which is applicable to the start of a 80 MHz PPDU received on the primary 80 MHz channel(#Ed) 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(#Ed), 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

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— $OBSS\_PD_{level}$(160 MHz or 80+80 MHz) = $OBSS\_PD_{level}$ + 9 dB

$TXPWR_{ref}$ = 21 dBm for non-AP STAs or for AP STAs with 1 and 2 spatial streams and $TXPWR_{ref}$ = 25 dBm for AP STAs of 3 spatial streams or more.

$OBSS\_PD_{min\_default}$ = –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 (25-1).

$$TXPWR_{max} = \begin{cases} \text{unconstrained, if } OBSS\_PD_{level} = OBSS\_PD_{min} \\ TXPWR_{ref} - (OBSS\_PD_{level} - OBSS\_PD_{min}), \text{ if } OBSS\_PD_{max} \geq OBSS\_PD_{level} > OBSS\_PD_{min} \end{cases} \quad (25\text{-}1)$$

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 (25-1), 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 (25-1).

25.10 A-MPDU operation

25.10.1 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.(#681)

25.10.2 A-MPDU padding for an HE SU PPDU, HE extended range SU PPDU and HE MU PPDU

An HE STA that transmits an DL(#2258) 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).(#1585) 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).(#2258)

25.10.3 A-MPDU padding for an HE trigger-based PPDU(#1585)

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(#1585).

The STA computes the PSDU_LENGTH based on the TXVECTOR parameters.

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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 25.10.4 (A-MPDU with multiple TIDs)(#2446)) 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:(#1586)

— 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(#1586) 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(#1587), 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(#1774) 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(11ah) (see 10.13.7 (Setting the EOF field of the MPDU delimiter)).

(#2446)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

25.10.4 A-MPDU with multiple TIDs

(#71)(#190)A multi-TID A-MPDU is an A-MPDU that contains QoS Data frames with two or more different TID values.

(#70)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. A 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.

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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 25.4 (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 dot11MultiTIDAMPDUImplemented 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 25.4 (Block acknowledgement)(#70).(#1292)

(#2669)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

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indicated in the TID Aggregation Limit subfield in the Trigger Dependent User Info field(#Ed) 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(#Ed) 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(#Ed) 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(#Ed) 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(#Ed) 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(#Ed) field of a Basic Trigger(#Ed) 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(#Ed) 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(#Ed) 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(#Ed) field of a Basic Trigger variant Trigger frame.

NOTE—A multi-TID A-MPDU allows the aggregation of an Action Ack frame as well.

(#2670)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.

25.11 TXVECTOR parameters STA_ID_LIST, UPLINK_FLAG, BEAM_CHANGE and BSS_COLOR for an HE PPDU(#2517)

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:

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- For an AP with dot11MultiBSSIDActivated equal to false, if the RU is intended for all STAs in the BSS, the STA_ID_LIST element is set to 0
- For an AP with dot11MultiBSSIDActivated equal to true, if the RU is intended for all STAs 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))
- For an AP with dot11MultiBSSIDActivated equal to true, if the RU is intended for all STAs on all its BSSs, the STA_ID_LIST element is set to 2047

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
- 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(#1592) 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.

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(#Ed) than 2 or the PPDU is the first PPDU in a TXOP.(#2517)

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 25.9 (Spatial reuse operation)(#2338) or reduce power consumption as described in 25.15.1 (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(#1594) 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.(#643)(#2259)(#2260)

An HE STA that received an HE PPDU with RXVECTOR parameter BSS_COLOR with(#Ed) a value between 1 and 63 may ignore the HE PPDU subject to the rules as described in 25.9 (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.

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A 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.(#73)(#210)

25.12 TXVECTOR parameter TXOP_DURATION for an HE PPDU(#2596)

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 26-1 (TXVECTOR and RXVECTOR parameters(#1780)).

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25.13 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(#1597) by the post-FEC padding pre-FEC padding factor(#2564) (see 26.3.11 (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.

25.14 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.(#4)(#2740)

25.15 Power management

25.15.1 Intra-PPDU power save for HE non-AP STAs

An HE non-AP STA (#1598)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(#2848) 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.(#Ed)

— The PPDU is an HE MU PPDU, HE SU PPDU or HE extended range SU PPDU and one of the following conditions are true:(#Ed)

- 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(#194)

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— 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(#1599)

— The PPDU is a VHT PPDU where(#782) 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.(#Ed)

— The PPDU is a PPDU with(#782):

- 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,(MAC Motion #93)
- The RA is not the(#Ed) 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(#2850) 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(#2851).(#1600)

25.15.2 Power save with UL OFDMA-based random access

This subclause(#1304) illustrates the power save mechanisms for HE STAs using the(#1601) random access procedure (see 25.5.2.6.2 (Random access procedure)).

An HE AP may indicate values of one or multiple Trigger frame start time(s) for random access in the broadcast TWT element that is included in the Beacon frame as described in 25.7.3.2 (Rules for TWT scheduling STA)(#723). The power save operation with the indication of one value of Trigger frame start time in a Beacon for random access is shown in Figure 25-8 (Trigger frame (TF) start time in the Beacon frame for power save operation with random access operation(#2852)).

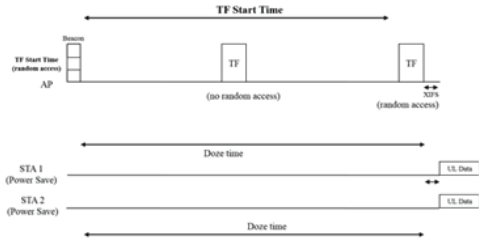


Figure 25-8—Trigger frame (TF) start time in the Beacon frame for power save operation with random access operation(#2852)

An HE STA that receives a Beacon 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(#1602) the start of that TWT SP as described in 25.7.3.3 (Rules for TWT scheduled STA(#1657)(#958)(#2400)(#142)(#957)).(#723)

If random access(#646) is enabled by a sequence of Trigger frames, 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(#1603) 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

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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.

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26. High Efficiency (HE) PHY specification

26.1 Introduction

26.1.1 Introduction to the HE PHY

Clause 26 specifies the PHY entity for a high efficiency (HE) orthogonal frequency division multiplexing (OFDM) system. In addition to the requirements in Clause 26, an HE STA shall be capable of transmitting and receiving PPDUs that are compliant with the mandatory requirements of the following PHY specifications:(#348)

— Clause 19 (High Throughput (HT) PHY specification) and Clause 21 (Very High Throughput (VHT) PHY specification)(#1021) when the HE STA with greater than or equal to 80 MHz capability is operating in the 5 GHz band(PHY Motion #163)

— Clause 19 (High Throughput (HT) PHY specification) when the 20 MHz only non-AP HE STA is operating in the 5 GHz band(PHY Motion #163)

— 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)(#1021), which in turn is based on the HT PHY defined in Clause 19 (High Throughput (HT) PHY specification)(#1021), which in turn is further based on the OFDM PHY defined in Clause 17 (Orthogonal frequency division multiplexing (OFDM) PHY specification)(#1021). The HE PHY with 20 MHz only capability (see 26.3.9 (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.(PHY Motion #163) 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(#1185) 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(PHY Motion #163). For channel widths greater than or equal to 80 MHz, the HE PHY supports channel puncturing(PHY Motion #161) 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.(#879)

The HE PHY provides support for 0.8 µs, 1.6 µs and 3.2 µs(#1922) 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).(#269)

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.(#1605) The HE PHY data subcarriers are modulated using binary phase shift keying (BPSK), quadrature phase shift keying (QPSK), 16-quadrature amplitude modulation (16-QAM), 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 shall support the following Clause 26 features:(#351)

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- Binary convolutional coding for 26-, 52-, 106- and 242-tone RUs (transmit and receive) when the number of spatial streams is less than or equal to 4
- Binary convolution coding for a 20 MHz HE SU PPDU (transmit and receive) when the number of spatial streams is less than or equal to 4
- LDPC as the only coding scheme for 484-, 996- and 2×996-tone RUs (transmit and receive)
- LDPC coding for 40 MHz, 80 MHz, 160 MHz and 80+80 MHz HE SU PPDUs
- LDPC when declaring support for more than 4 spatial streams
- LDPC when declaring support for MCS10 and MCS11(PHY Motion #158)
- A combination of 2x LTF with 0.8 μs GI duration on both LTF and data
- A combination of 2x LTF with 1.6 μs GI duration on both LTF and data
- A combination of 4x LTF with 3.2 μs GI duration on both LTF and data

An HE STA may support the following Clause 26 features:(#351)

- Other combinations of LTF durations and GI durations
- LDPC coding for 26-, 52-, 106- and 242-tone RUs (transmit and receive) when the number of spatial streams is less than or equal to 4
- LDPC coding for a 20 MHz HE SU PPDU (transmit and receive) when the number of spatial streams is less than or equal to 4
- LDPC (transmit and receive) when declaring support for less than or equal to 4 spatial streams and when declaring not supporting MCS10 and MCS11(PHY Motion #158)
- Dual carrier modulation (transmit and receive)

Editor's Note: Once mandatory and optional TBDs are decided, the above text will be revised.(#1461)(#2352)

26.1.2 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.(#2354)

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.(#1021) A non-AP STA with 20 MHz only capability supports a mixture of HE, Clause 19 and Clause 17 PHYs.(PHY Motion #163)

26.1.3 HE PHY functions

26.1.3.1 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 26.3 (HE PHY) and 26.4 (HE PLME). The HE PHY service is provided to the MAC through the PHY service primitives defined in Clause 7 (PHY service specification). The HE PHY service interface is described in 26.2 (HE PHY service interface).

26.1.3.2 PHY management entity (PLME)

The PLME performs management of the local PHY functions in conjunction with the MLME.

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26.1.3.3 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.

26.1.4 PPDU formats

The structure of the PPDU transmitted by an HE STA is determined by the TXVECTOR parameters as defined in Table 26-1 (TXVECTOR and RXVECTOR parameters(#1780)).

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).(#468)
- 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 SU format, except that the HE-SIG-A field is repeated. Support for the HE extended range SU PPDU format is mandatory(#834).
- 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(#834).

26.2 HE PHY service interface

26.2.1 Introduction

(#Ed)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.

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26.2.2 TXVECTOR and RXVECTOR parameters

The parameters in Table 26-1 (TXVECTOR and RXVECTOR parameters(#1780)) 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 26-1—TXVECTOR and RXVECTOR parameters(#1780)

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(#1029).	Y	Y
NON_HT_MODULATION	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).			
L_LENGTH	FORMAT is HE_SU or HE_MU or HE_EXT_SU	Not present. NOTE—The Length field of the L-SIG for HE PPDU is defined in Equation (26-12) using the TXTIME value defined in 26.4.2 (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).		

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Table 26-1—TXVECTOR and RXVECTOR parameters(#1780) *(continued)*

L_DATARATE	FORMAT is HE_SU or HE_MU or 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 or HE_MU or 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 or HE_MU or 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 or HE_MU or 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 or HE_MU or 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 or HE_MU or HE_EXT_SU or HE_TRIG	Not present	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
ANTENNA_SET	FORMAT is HE_SU or HE_MU or 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 or HE_MU or HE_EXT_SU or HE_TRIG	Not present	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		

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Table 26-1—TXVECTOR and RXVECTOR parameters(#1780) *(continued)*

EXPANSION_MAT_TYPE	FORMAT is HE_SU or HE_MU or 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 or HE_EXT_SU or HE_TRIG	Contains a vector in the number of selected subcarriers containing feedback matrices as defined in 26.3.15.2 (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 26.3.15.2 (Beamforming feedback matrix V) based on the channel measured during the training symbols of previous HE NDP PPDUs or VHT NDP PPDUs.	M U	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
CHAN_MAT_TYPE	FORMAT is HE_SU or HE_MU or 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).		
CHAN_MAT	FORMAT is HE_SU and PSDU_LENGTH equals 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).		

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Table 26-1—TXVECTOR and RXVECTOR parameters(#1780) *(continued)*

DELTA_SNR	FORMAT is HE_SU or HE_MU or 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.	M U	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 or or HE_EXT_SU	Contains an array of received SNR measurements for each spatial stream. SNR indications of 8 bits are supported. 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
	FORMAT is HE_MU	Contains an array of received SNR measurements for each spatial stream of the receiver. SNR indications of 8 bits are supported. SNR shall be the sum of the decibel values of SNR per tone divided by the number of tones which are assigned to the receiver in each stream as described in 9.4.1.63 (HE Compressed Beamforming Report field)	N	Y
	FORMAT is HE_TRIG	Contains an array of received SNR measurements for each spatial stream per user. SNR indications of 8 bits are supported. SNR shall be the sum of the decibel values of SNR per tone divided by the number of tones which are assigned to the user 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 equals 0	Contains an array of received SNR measurements for each spatial stream per 26-tone RU. Each SNR is an absolute number represented by 6 bits, with 1 dB granularity and a range of -10 dB to 53 dB	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).		
NO_SIG_EXTN	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Not present.	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		

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Table 26-1—TXVECTOR and RXVECTOR parameters(#1780) *(continued)*

FEC_CODING	FORMAT is HE_SU or HE_MU or 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.	M U	M U
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
STBC	FORMAT is HE_SU or HE_MU or 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 that indicate 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.	Y	Y
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
GI_TYPE	FORMAT is HE_SU or HE_MU or 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).		
TXPWR_LEVEL_INDEX	FORMAT is HE_SU or HE_MU or 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).		

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Table 26-1—TXVECTOR and RXVECTOR parameters(#1780) *(continued)*

RSSI	FORMAT is HE_SU or or HE_EXT_SU	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
	FORMAT is HE_MU	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 PHY legacy preamble. RSSI is intended to be used in a relative manner, and it is a monotonically increasing function of the received power.	N	Y
	FORMAT is HE_TRIG	Not present	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
MCS	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Indicates the modulation and coding scheme used in the transmission of the PPDU. Integer: range 0 to 11	M U	M U
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
DCM	FORMAT is HE_SU or HE_MU or or 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.	M U	M U
	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
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

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Table 26-1—TXVECTOR and RXVECTOR parameters(#1780) *(continued)*

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 or 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).		
CH_BANDWIDTH	FORMAT is HE_SU or HE_EXT_SU or HE_TRIG	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_MU	Indicates the channel occupied by the transmitted PPDU, supporting channel bonding. See the field of Bandwidth in Table 26-16 (Fields in the HE-SIG-A for an HE MU PPDU)	Y	Y
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
DYN_BANDWIDTH_IN_NON_HT	FORMAT is HE_SU or HE_MU or 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 or HE_MU or HE_EXT_SU or HE_TRIG	Not present.	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		

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Table 26-1—TXVECTOR and RXVECTOR parameters(#1780) *(continued)*

LENGTH	FORMAT is HE_SU or HE_MU or 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 or HE_MU or 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.	M U	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
PSDU_LENGTH	FORMAT is HE_SU or HE_MU or 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 26-43 (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 or HE_MU or HE_EXT_SU or HE_TRIG	Not present.	N	N
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).(#1780)		
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 in the TXVECTOR per user 0-4 in the RXVECTOR per MU-MIMO RU 1-8 per non MU-MIMO RU in the TXVECTOR 0-8 per non MU-MIMO RU in the RXVECTOR NUM_STS summed over all users per RU is not greater than 8.	M U	M U
	FORMAT is HE_TRIG	Indicates the number of space-time streams. Integer in the range: 1-4 in the TXVECTOR for MU-MIMO RU 0-4 per user in the RXVECTOR per MU-MIMO RU 1-8 in the TXVECTOR for non MU-MIMO RU 0-8 per non MU-MIMO RU in the RXVECTOR NUM_STS summed over all users per RU is not greater than 8.	M U	M U
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		

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Table 26-1—TXVECTOR and RXVECTOR parameters(#1780) *(continued)*

GROUP_ID	FORMAT is HE_SU or HE_MU or 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 or HE_MU or 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 or HE_MU or HE_EXT_SU or HE_TRIG	Indicates a duration of time that is used to update the NAV for this TXOP (see 25.2.2 (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 25.12 (TXVECTOR parameter TXOP_DURATION for an HE PPDU(#2596))). 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 25.12 (TXVECTOR parameter TXOP_DURATION for an HE PPDU(#2596)) for more details.(#783)	Y	Y
	Otherwise	Not present.	N	N
SPATIAL_REUSE	FORMAT is HE_SU or HE_MU or 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 26.3.10.7.2 (Content)	Y	Y
	Otherwise	Not present	N	N
DOPPLER	FORMAT is HE_SU or HE_MU or 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
NUM_USERS	FORMAT is HE_SU or HE_MU or 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).		

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Table 26-1—TXVECTOR and RXVECTOR parameters(#1780) *(continued)*

RU_ALLOCATION	FORMAT is HE_MU	Each 8 bit per 20 MHz PPDU BW for signaling: The RU arrangement in frequency domain Number of MU-MIMO allocations See 26.3.10.8.4 (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.	M U	O
	Otherwise	See corresponding entry in Table 21-1 (TXVECTOR and RXVECTOR parameters).		
HE_LTF_TYPE	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Indicates the type of HE-LTF. Enumerated type: 1x HE-LTF 2x HE-LTF 4x HE-LTF See 26.3.10.10 (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
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

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Table 26-1—TXVECTOR and RXVECTOR parameters(#1780) *(continued)*

TXOP_PS_NOT_ALLOWED	FORMAT is HE_SU or HE_MU or 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
PE_DURATION	FORMAT is HE_SU or HE_MU or 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.	Y	Y
BEAM_CHANGE	FORMAT is HE_SU or HE_EXT_SU(#2675)	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.(#481)	Y (#2153)	Y (#2153)
	Otherwise	Not present(#2675)		
BSS_COLOR	FORMAT is HE_SU or HE_MU or HE_EXT_SU or HE_TRIG	Set to a value of the AP's choosing within the range 0 to 63(#835) (see 25.11 (TXVECTOR parameters STA_ID_LIST, UPLINK_FLAG, BEAM_CHANGE and BSS_COLOR for an HE PPDU(#2517))).	Y	Y
	Otherwise	Not present	N	N

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Table 26-1—TXVECTOR and RXVECTOR parameters(#1780) *(continued)*

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.(#1611) Set to 0 otherwise (see 25.11 (STA ID, Uplink Flag and BSS Color in HE PPDUs)).	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 25.11 (TXVECTOR parameters STA_ID_LIST, UPLINK_FLAG, BEAM_CHANGE and BSS_COLOR for an HE PPDU(#2517))).	M U	Y
	Otherwise	Not present	N	N
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.(#127)	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.(#2676) Parameters specified to be present per user are conceptually supplied as an array of values indexed by *u*, where *u*(#2356) takes values 0 to NUM_USERS–1.

26.3 HE PHY

26.3.1 Introduction

26.3.2 MU transmission(#507)

26.3.2.1 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.

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The HE PHY supports OFDMA transmissions, both in the DL and the UL where different users can occupy different RUs in a PPDU (see 26.3.9 (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.

26.3.3 OFDMA and SU tone allocation

Orthogonal Frequency Division Multiple Access (OFDMA) is an OFDM-based multiple access scheme where different subsets of subcarriers are allocated to different users(#1946), allowing simultaneous data transmission to or from(#2524) several users. In OFDMA, in general, users are allocated different subsets of subcarriers which can change from one PPDU(#Ed) to the next(#2525). 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 26-15 (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. In HE, the subcarriers that form an RU(#1948) are physically adjacent (contiguous except at the middle of the band where nulls are placed at DC).

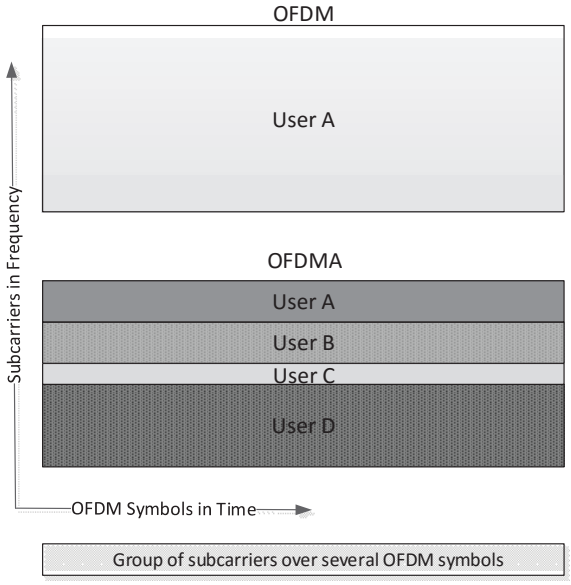


Figure 26-1—Illustration of OFDM and OFDMA concepts

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.(#1949)

(#2365)(#2526)In OFDMA, an OFDM symbol is constructed of subcarriers, the number of which is a function of the DFT(#2366) size. There are several subcarrier types: 1) Data subcarriers which are used for

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data transmission; defined in 26.3.3.1 (Resource unit, guard and DC subcarriers(#1951)), 2) Pilot subcarriers which are utilized for phase information and parameter tracking; defined in 26.3.3.3 (Pilot tones), and 3) unused subcarriers which are not used for data/pilot transmission. The unused subcarriers are the DC subcarrier (defined in 26.3.3.1 (Resource unit, guard and DC subcarriers(#1951))), the Guard band subcarriers at the band edges (defined in 26.3.3.1 (Resource unit, guard and DC subcarriers(#1951))), and the Null subcarriers (defined in 26.3.3.2 (Null subcarriers)).

26.3.3.1 Resource unit, guard and DC subcarriers(#1951)

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(#838)(#1337)(#353).

The 26-tone RU, 52-tone RU, 106-tone RU and 242-tone RU(PHY Motion #172) 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. The 484-tone RU(#838) 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(#838) 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.(#888)

The 242-tone and larger RUs are used in the HE SU PPDU formats. The 242-tone RU(#838) is used in the 20 MHz HE SU PPDU format. The 484-tone RU(#838) is used in the 40 MHz HE SU PPDU format. The 996-tone RU(#838) is used in the 80 MHz HE SU PPDU format. The 2×996-tone RU(#838)(#1337) is used in the 160 MHz and 80+80 MHz HE SU PPDU formats.(#888)

The maximum number(#Ed) of RUs in the 20 MHz, 40 MHz, 80 MHz, 160 MHZ and 80+80 MHz HE PPDU formats are defined in Table 26-2 (Maximum number of RUs for each channel width(#1850)).(#285).

Table 26-2—Maximum number of RUs for each channel width(#1850)

RU type	CBW20	CBW40	CBW80	CBW80+80 and CBW160
26-tone RU(#838)	9	18	37	74
52-tone RU	4	8	16	32
106-tone RU	2	4	8	16
242-tone RU	1-SU/MU-MIMO	2	4	8
484-tone RU	N/A	1-SU/MU-MIMO	2	4
996-tone RU	N/A	N/A	1-SU/MU-MIMO	2
2×996 tone RU(#1337)	N/A	N/A	N/A	1-SU/MU-MIMO

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An HE MU PPDU using OFDMA transmission can carry a mixture of 26-, 52- and 106-tone RUs within any of the 242-tone RU(#838) boundaries(#888).

Table 26-3—Subcarrier indices for RUs in a 20 MHz HE PPDU

RU type					
26-tone RU(#838)	RU 1 [−121: −96](#1111)	RU 2 [−95: −70]	RU 3 [−68: −43]	RU 4 [−42: −17]	RU 5 [−16: −4, 4: 16](#1111)
	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 26-4—Subcarrier indices for RUs in a 40 MHz HE PPDU

RU type					
26-tone RU(#838)	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]				

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Table 26-5—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](#2758)		
996-tone RU	RU 1 [−500: −3, 3: 500]				

A 26-tone RU(#838) consists of 24 data subcarriers and 2 pilot subcarriers. The positions of the pilots for the 26-tone RU(#838) are(#1957) defined in 26.3.3.3 (Pilot tones). The location of the 26-tone RUs(#838) are fixed as defined in Table 26-3 (Subcarrier indices for RUs in a 20 MHz HE PPDU), Table 26-4 (Subcarrier indices for RUs in a 40 MHz HE PPDU) and Table 26-5 (Subcarrier indices for RUs in an 80 MHz HE PPDU)(#1958) and shown in Figure 26-2 (RU locations in a 20 MHz HE PPDU), Figure 26-3 (RU locations in a 40 MHz HE PPDU) and Figure 26-4 (RU locations in an 80 MHz HE PPDU)(#2759) 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

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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(#838) in the 20 MHz and 80 MHz HE MU PPDU or HE trigger-based PPDU formats using OFDMA transmission (Figure 26-2 (RU locations in a 20 MHz HE PPDU) and Figure 26-4 (RU locations in an 80 MHz HE PPDU)) is located on subcarriers [−16: −4, 4: 16].(#888)

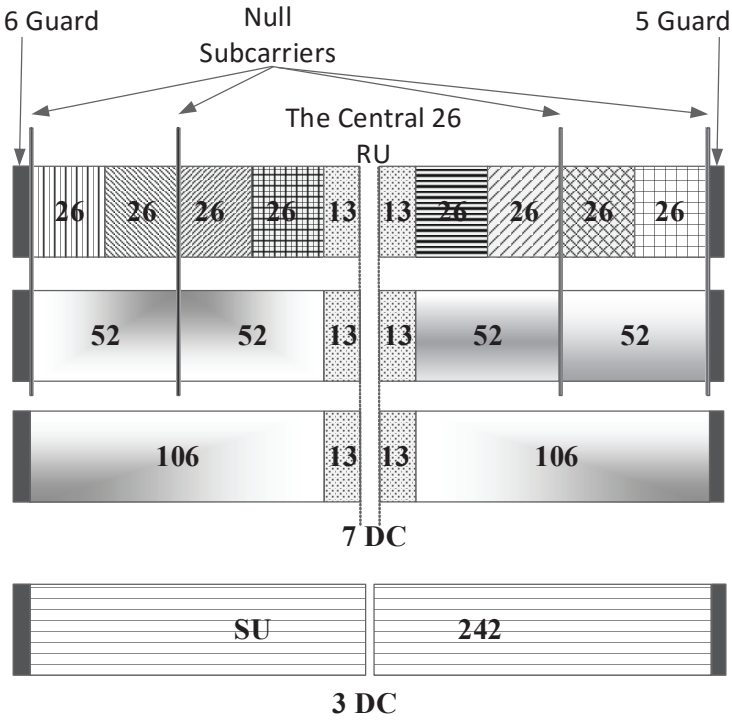


Figure 26-2—RU locations in a 20 MHz HE PPDU

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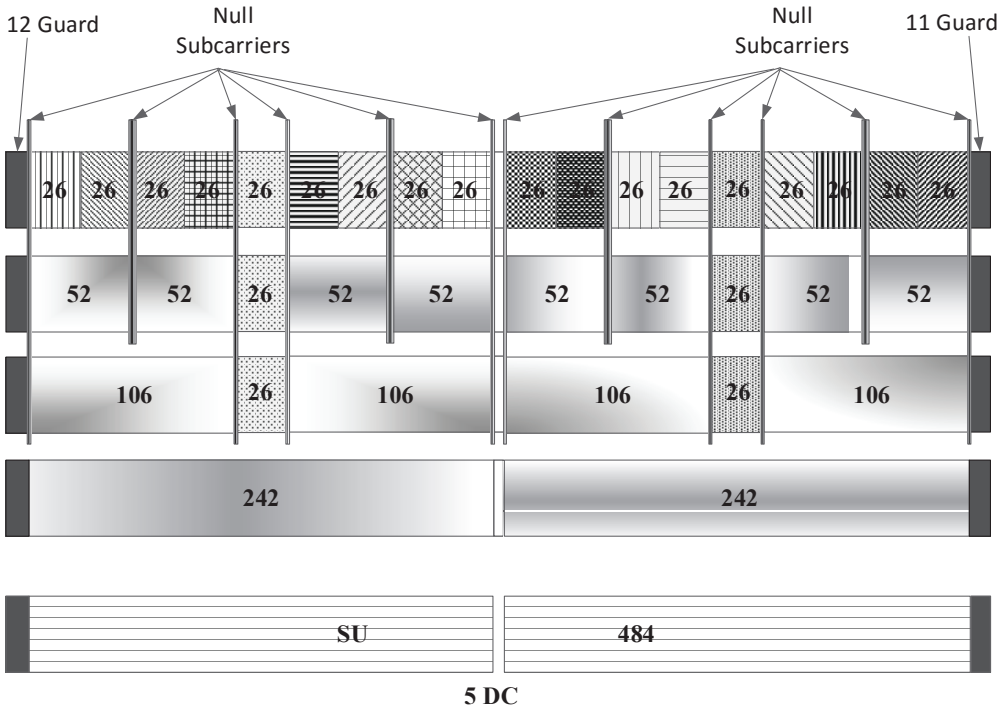


Figure 26-3—RU locations in a 40 MHz HE PPDU

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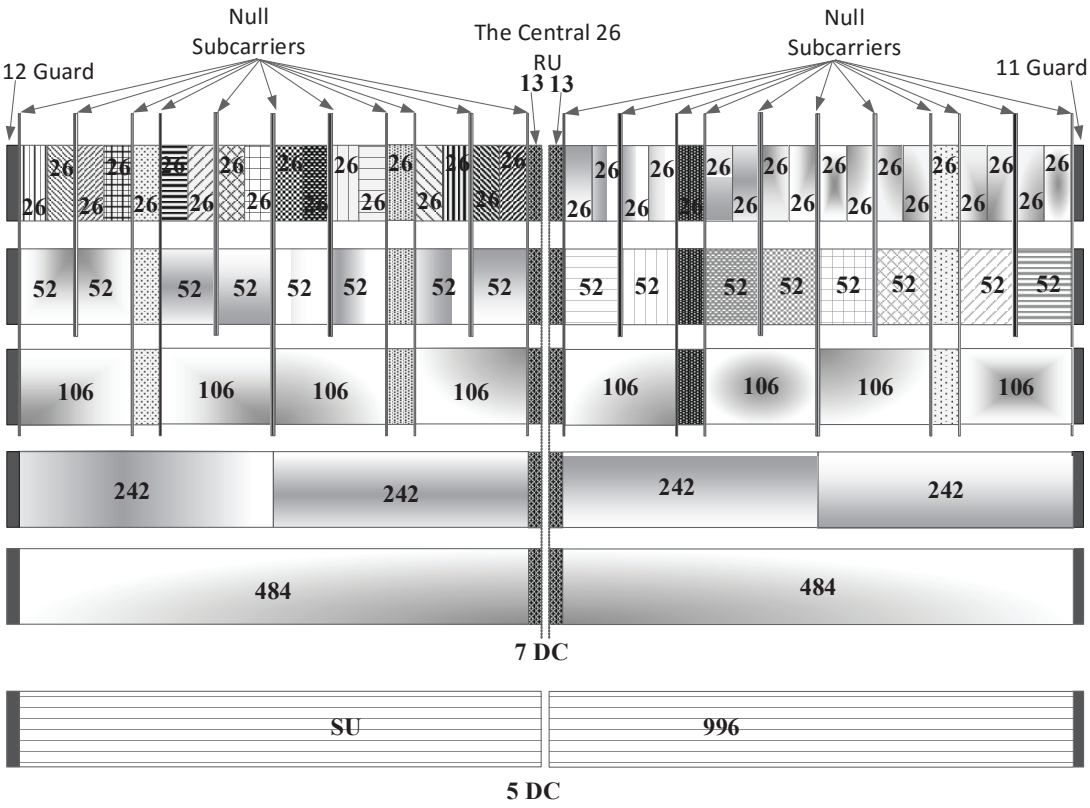


Figure 26-4—RU locations in an 80 MHz HE PPDU

A 52-tone RU(#838) consists of 48 data subcarriers and 4 pilot subcarriers. The positions of the pilots for the 52-tone RU(#838) are(#1960) defined in 26.3.3.3 (Pilot tones). The locations of the 52-tone RUs(#838) are fixed as defined in Table 26-3 (Subcarrier indices for RUs in a 20 MHz HE PPDU), Table 26-4 (Subcarrier indices for RUs in a 40 MHz HE PPDU) and Table 26-5 (Subcarrier indices for RUs in an 80 MHz HE PPDU) and illustrated in Figure 26-2 (RU locations in a 20 MHz HE PPDU), Figure 26-3 (RU locations in a 40 MHz HE PPDU) and Figure 26-4 (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.(#888)

A 106-tone RU(#838) consists of 102 data subcarriers and 4 pilot subcarriers. The positions of the pilots for the 106-tone RU(#838) are(#1961) defined in 26.3.3.3 (Pilot tones). The locations of the 106-tone RUs(#838) are fixed as defined in Table 26-3 (Subcarrier indices for RUs in a 20 MHz HE PPDU), Table 26-4 (Subcarrier indices for RUs in a 40 MHz HE PPDU) and Table 26-5 (Subcarrier indices for RUs in an 80 MHz HE PPDU) and illustrated in Figure 26-2 (RU locations in a 20 MHz HE PPDU), Figure 26-3 (RU locations in a 40 MHz HE PPDU) and Figure 26-4 (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.

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A 242-tone RU(#838) consists of 234 data subcarriers and 8 pilot subcarriers. The positions of pilots for the 242-tone RU(#838) are(#1962) defined in 26.3.3.3 (Pilot tones). The locations of the 242-tone RUs(#838) are fixed as defined in Table 26-3 (Subcarrier indices for RUs in a 20 MHz HE PPDU),(#1669) Table 26-4 (Subcarrier indices for RUs in a 40 MHz HE PPDU) and Table 26-5 (Subcarrier indices for RUs in an 80 MHz HE PPDU) and illustrated in Figure 26-2 (RU locations in a 20 MHz HE PPDU), Figure 26-3 (RU locations in a 40 MHz HE PPDU) and Figure 26-4 (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.(#888)

A 484-tone RU(#838) consists of 468 data subcarriers and 16 pilot subcarriers. The position of the pilots for the 484-tone RU(#838) is defined in 26.3.3.3 (Pilot tones). The locations of the 484-tone RUs(#838) are fixed as defined in Table 26-4 (Subcarrier indices for RUs in a 40 MHz HE PPDU) and Table 26-5 (Subcarrier indices for RUs in an 80 MHz HE PPDU) and illustrated in Figure 26-3 (RU locations in a 40 MHz HE PPDU) and Figure 26-4 (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.(#888)

A 996-tone RU(#838) consists of 980 data subcarriers and 16 pilot subcarriers. The position of the pilots for the 996-tone RU(#838) is defined in 26.3.3.3 (Pilot tones). The locations of the 996-tone RUs(#838) 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(#Ed) HE PPDU formats.(#888)

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(#838) 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].(#1963)(#888)

The 20 MHz HE PPDU format has 11 guard subcarriers (6, 5) located at [−128: −123] and [123: 127] as shown in Figure 26-2 (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 26-3 (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 26-4 (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.

(PHY Motion #165)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.

26.3.3.2 Null subcarriers

There are null subcarriers between the 26-, 52- and 106-tone RU(#838) locations as illustrated in Figure 26-2 (RU locations in a 20 MHz HE PPDU), Figure 26-3 (RU locations in a 40 MHz HE PPDU) and

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Figure 26-4 (RU locations in an 80 MHz HE PPDU). The null subcarriers have zero energy. The indices of the null subcarrier are enumerated in Table 26-6 (Null subcarrier indices).

Table 26-6— 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

26.3.3.3 Pilot tones

If pilot tones are present in the HE-LTF field, the pilot tone locations in the HE-LTF field and Data field shall be the same. All pilot tones are at the even indices enumerated in Table 26-7 (Pilot tone indices).(#1789)

Table 26-7— Pilot tone indices

Channel Width	RU Size	Pilot Tone 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

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Table 26-7— Pilot tone indices *(continued)*

160 MHz	26, 52, 106, 242, 484	{pilot tone indices in 80 MHz –512, pilot tone indices in 80 MHz +512}
	996	{for the first 80 MHz, pilot tone indices in 80 MHz –512, for the second 80 MHz, pilot tone indices in 80 MHz +512}(#841)

The pilot tones locations for 160 MHz or 80+80 MHz shall use the same 80 MHz locations for both 80 MHz.

26.3.3.4 RU restriction rules when operating 20 MHz(#854)

A non-AP STA can operate with 20 MHz, because either it is a 20 MHz-only HE device (see 26.3.9 (Mathematical description of signals)), or it reduces operating channel width to 20 MHz by ROM (see 25.8 (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 26.3.3.1 (Resource unit, guard and DC subcarriers(#1951))). 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 26-4 (Subcarrier indices for RUs in a 40 MHz HE PPDU) and Table 26-5 (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 26-4 (Subcarrier indices for RUs in a 40 MHz HE PPDU) and Table 26-5 (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 26-4 (Subcarrier indices for RUs in a 40 MHz HE PPDU) and Table 26-5 (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.

26.3.3.5 20 MHz only HE STAs

(PHY Motion #163)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

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mandatory mode. It is indicated in the capability field, whether an HE STA is 20 MHz only, 80 MHz, 160 MHz or 80+80MHz capable. 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 26.3.3.4 (RU restriction rules when operating 20 MHz(#854))).

26.3.3.6 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.

26.3.3.7 DL MU-MIMO

26.3.3.7.1 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.

26.3.3.7.2 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 'HE-MCS and Nss Map' 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 Beamformee STS Capability in the HE Capabilities element(#1785).

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.

26.3.3.7.3 Maximum number of total spatial streams in an HE MU PPDU(#1863)

A DL MU-MIMO capable STA shall support reception of DL MU PPDUs with the total number of space-time streams across the N_{user} users being less than or equal to its DL MU-MIMO STS Capability in the HE Capabilities.

26.3.3.7.4 Resource indication in an HE MU PPDU(#Ed)

An AP that transmits an HE MU PPDU shall set the UL/DL field in the HE-SIG-A field to 0.(#1862) 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.(#2126) 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/

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MU-MIMO(#1507) 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 26-21 (RU allocation signaling: arrangement and number of MU-MIMO allocations(#2032)). 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(#1507) group is indicated in the Number Of HE-SIG-B Symbols Or MU-MIMO Users field(#853) 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 fblock 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.(#1005) The number of spatial streams, $N_{SS,r,u}$, is indicated by the NSTS field in user specific block as defined in Table 26-22 (Fields of the HE-SIG-B user field for an(#916) non-MU-MIMO(#1101) allocation(#2037)) and Table 26-23 (Fields of the HE-SIG-B user field for an(#2817) MU-MIMO allocation(#2037)).(#946) The allocated spatial streams for a designated MU-MIMO(#1507) 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(#1507) STA as defined in Table 26-24 (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.

26.3.3.8 UL MU transmission

26.3.3.8.1 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.

26.3.3.9 UL MU-MIMO

26.3.3.9.1 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

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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.

26.3.3.9.2 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.(#1862)

26.3.3.9.3 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.

26.3.3.9.4 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 'HE-MCS and Nss Map' field in the HE Capabilities element(#1785).

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.

26.3.3.9.5 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(#948) about when to transmit the UL MU-MIMO PPDUs, the duration of the payload, and packet-extension. The GI duration(#1420) for UL OFDMA/MU-MIMO transmissions shall also be explicitly indicated by AP in the Trigger frame. The value of GI duration(#1420) 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.(#1862) The allocated RU and spatial streams are carried in the fields of RU allocation info and SS allocation of User Info(#1520) field, where Address field is set as the AID of designated MU-MIMO(#1507) STA.(PHY Motion #169)

If a STA finds that there is no User Info(#1520) 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.

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26.3.4 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 26-5 (HE SU PPDU format). This PPDU format is used for SU transmission and, in this format, the HE-SIG-A field is not repeated(#1838).

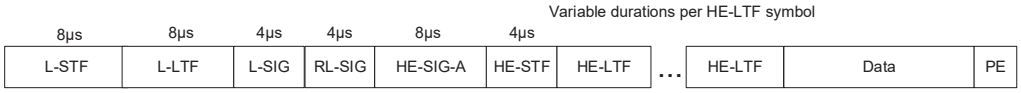


Figure 26-5—HE SU PPDU format

The format of the HE MU PPDU is defined as in Figure 26-6 (HE MU PPDU format). This format is used for transmission to one or more users that is not a response of a Trigger frame.(#271) The HE-SIG-B field is present in this format.(#1839)

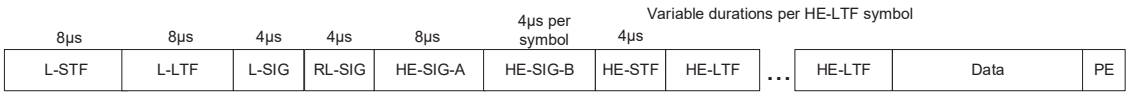


Figure 26-6—HE MU PPDU format

The format of the HE extended range SU PPDU is defined as in Figure 26-7 (HE extended range SU PPDU format). This format is used for SU transmission and, in this format,(#1840) the HE-SIG-A field is repeated.

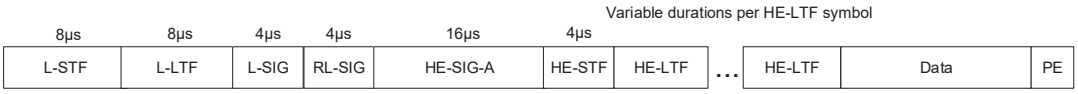


Figure 26-7—HE extended range SU PPDU format

The format of the HE trigger-based PPDU is defined as in Figure 26-8 (HE trigger-based PPDU format). This format is used for a transmission that is a response to a Trigger frame.(#1032) 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.(#881)

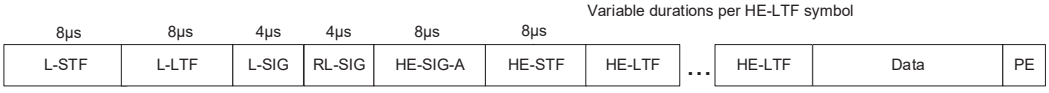


Figure 26-8—HE trigger-based PPDU format

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The fields of the HE PPDU formats are summarized in Figure 26-8 (HE PPDU fields(#2343)).

Table 26-8—HE PPDU fields(#2343)

Field	Description
L-STF	Non-HT Short Training field
L-LTF	Non-HT Long Training field
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. (#1612)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.

(#2061)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 μs in duration

NOTE—The number of HE-LTF OFDM symbols, $N_{HE\text{-}LTF}$, (#1612)is a function of the total number of space-time streams N_{STS} as shown in Table 26-12 (Frequently used parameters(#282)).

(#883)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.(#472)

26.3.5 Transmitter block diagram

The generation of each field in an(#2829) 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

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i) DCM tone mapper
j) Pilot insertion
k) Replicate over multiple 20 MHz (if BW > 20 MHz)
l) Multiply by 1st column of $P_{HE\text{-}LTF}$(#1090)
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(PHY Motion #172)
s) Inverse discrete Fourier transform (IDFT)
t) Cyclic shift diversity (CSD) per chain insertion
u) Guard interval (GI) insertion
v) Windowing

Figure 26-9 (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(#1659)) to Figure 26-17 (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 26-9 (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(#1659)) shows the transmit process for the L-SIG, RL-SIG, and HE-SIG-A fields of an(#2829) 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(#470) of the HE PPDU when the Beam Change subfield in HE-SIG-A field is set to 1, with the following exceptions(#Ed):

— The BCC encoder and interleaver 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.

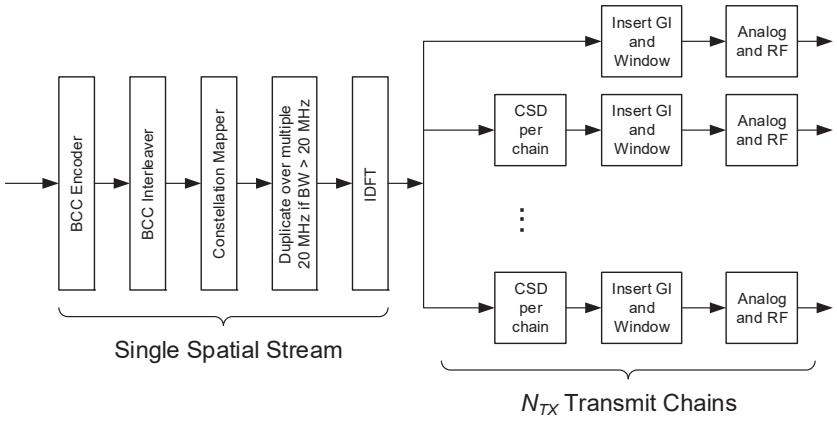


Figure 26-9—Transmitter block diagram for the L-SIG, RL-SIG and HE-SIG-A fields for an HE SU PPDU and HE extended range SU PPDU when the Beam Change field is 1 and the HE MU PPDU(#1659)

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Figure 26-10 (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(#2360)(#1659)) shows the transmit process for the L-SIG, RL-SIG, and HE-SIG-A fields of an(#2829) 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(#471) 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 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.

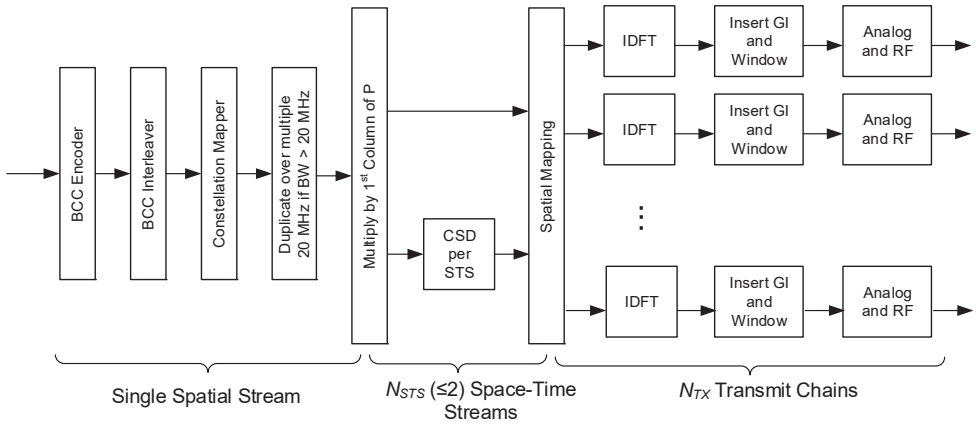


Figure 26-10—Transmitter block diagram for the L-SIG, RL-SIG and HE-SIG-A fields for an HE SU PPDU and HE extended range SU PPDU when the Beam Change field is 0(#2360)(#1659)

Figure 26-11 (Transmitter block diagram for the L-SIG, RL-SIG and HE-SIG-A fields of an HE trigger-based PPDU(#1659)) 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 HE modulated fields are located. When the HE modulated fields are located in more than

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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.(#1659)

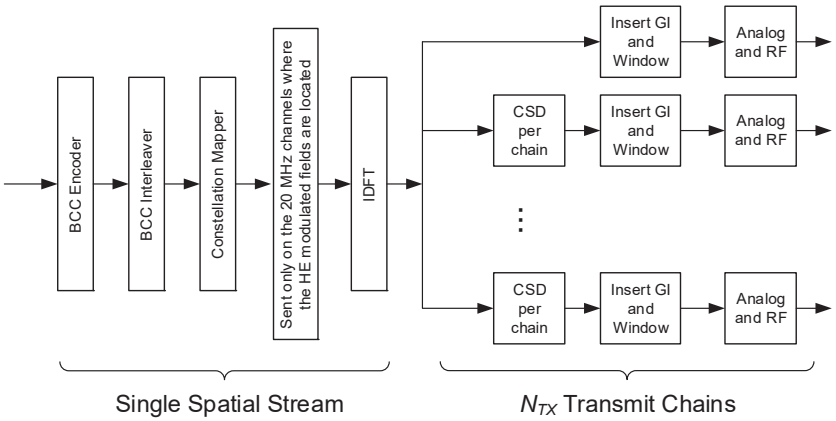


Figure 26-11—Transmitter block diagram for the L-SIG, RL-SIG and HE-SIG-A fields of an HE trigger-based PPDU(#1659)

Figure 26-12 (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 26.3.10.8.1 (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.(#519)

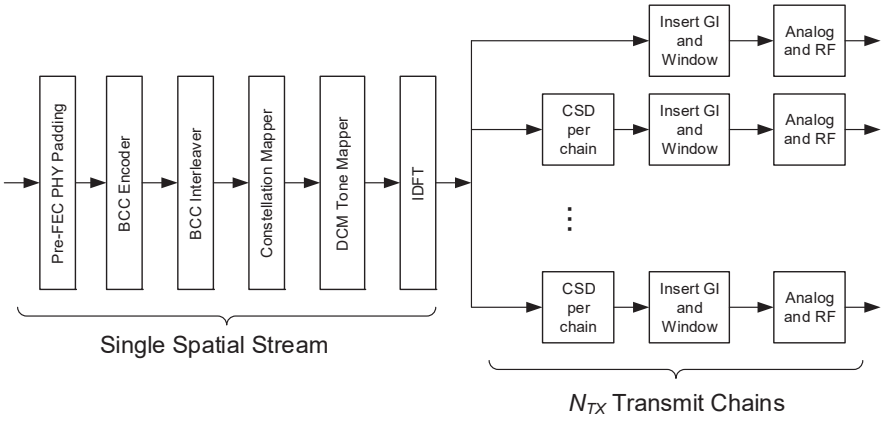


Figure 26-12—Transmitter block diagram for the HE-SIG-B field

Figure 26-13 (Transmitter block diagram for the Data field of an HE SU transmission in a 26-, 52-, 106- or 242-tone RU(#838) 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(#838) 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

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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 26-26 (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(#1059)). 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 26-13 (Transmitter block diagram for the Data field of an HE SU transmission in a 26-, 52-, 106- or 242-tone RU(#838) with BCC encoding)(#1117), are also used to generate the HE-STF field. (#520)This figure also applies to the data field with BCC encoding in an(#2829) HE trigger-based PPDU.

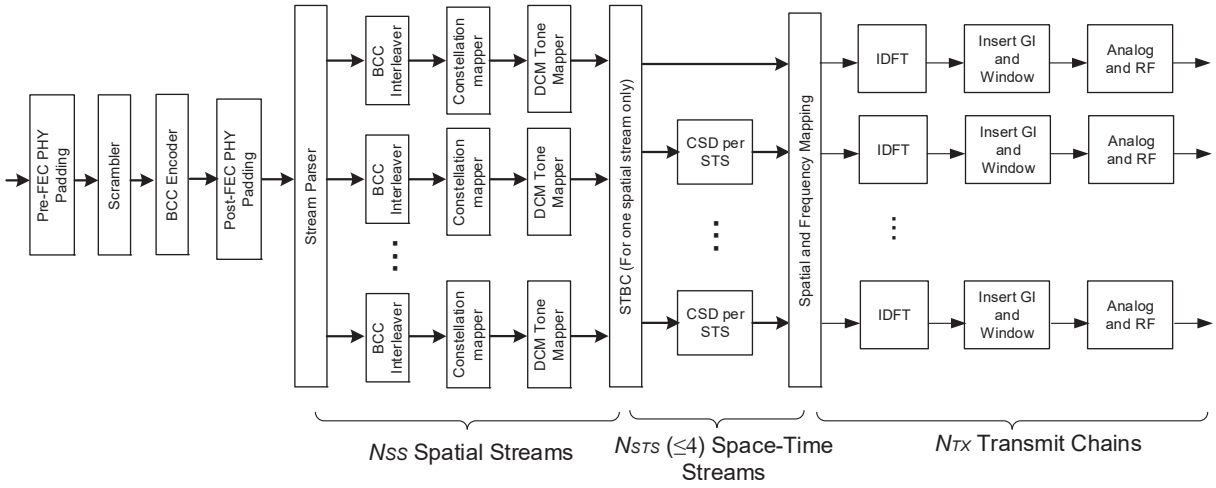


Figure 26-13—Transmitter block diagram for the Data field of an HE SU transmission in a 26-, 52-, 106- or 242-tone RU(#838) with BCC encoding

Figure 26-14 (Transmitter block diagram for the Data field of an HE SU transmission in 26-, 52-, 106-, 242-, 484- or 996-tone(#838) 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(#838) 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

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DCM is not applied. The DCM tone Mapper is applied only when the DCM indication for the RU is set to 1. (#519)This figure also applies to the data field with LDPC encoding in an(#2829) HE trigger-based PPDU.

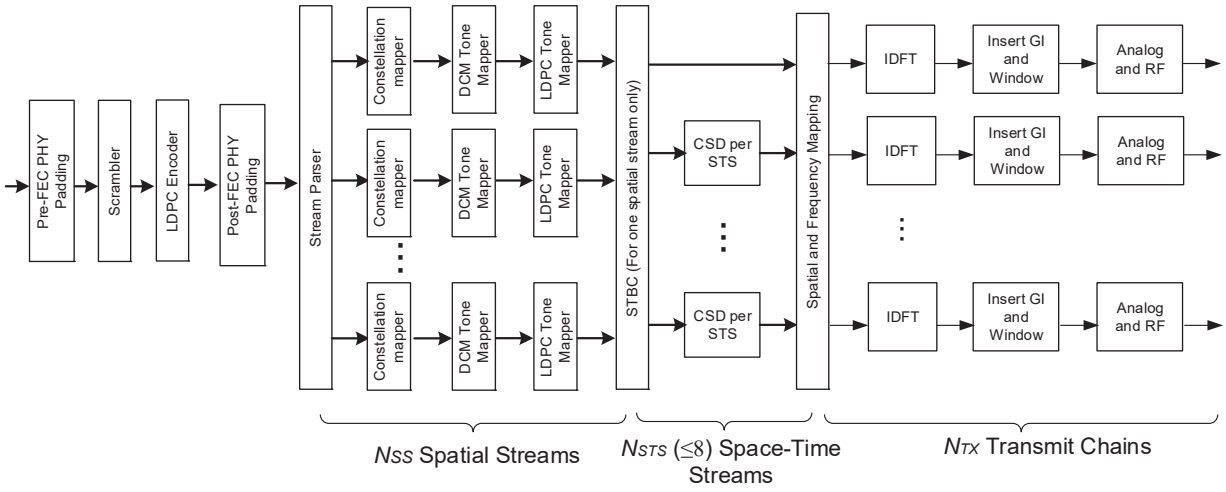


Figure 26-14—Transmitter block diagram for the Data field of an HE SU transmission in 26-, 52-, 106-, 242-, 484- or 996-tone(#838) RU with LDPC encoding

Figure 26-15 (Transmitter block diagram for the Data field of an HE downlink MU-MIMO transmission in 106-, 242-, 484- or 996-tone(#838) RU with LDPC encoding(#277)) shows the transmitter blocks used to generate the Data field of an(#2829) HE downlink MU-MIMO transmission within a 106-, 242-, 484-, or

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996-tone(#838) RU with LDPC encoding. This also includes the downlink MU-MIMO transmission in an RU that is part of a downlink (#276)OFDMA PPDU.

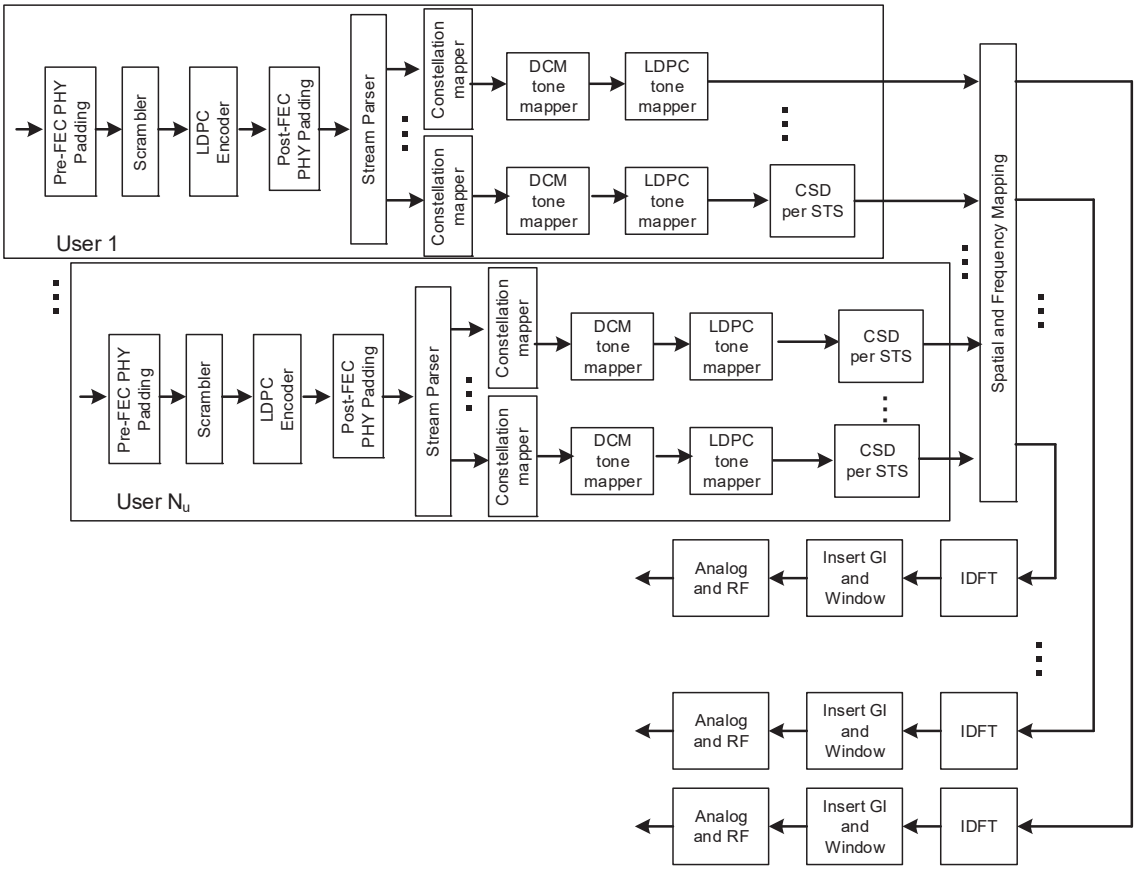


Figure 26-15—Transmitter block diagram for the Data field of an HE downlink MU-MIMO transmission in 106-, 242-, 484- or 996-tone(#838) RU with LDPC encoding(#277)

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Figure 26-16 (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.

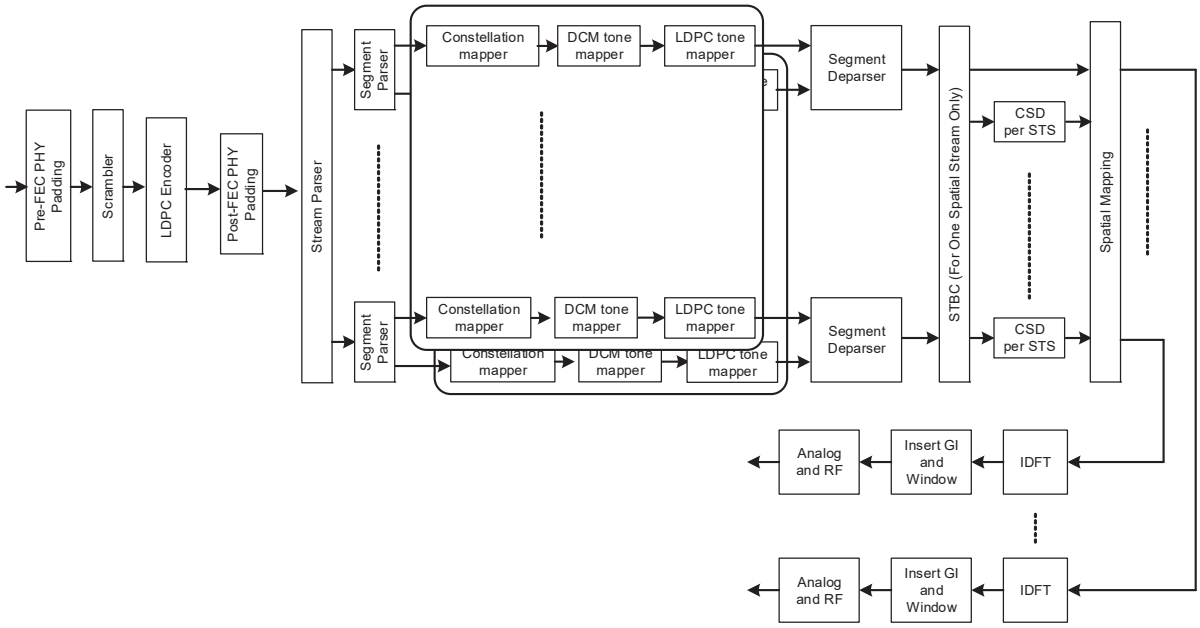


Figure 26-16—Transmitter block diagram for the Data field of an HE SU PPDU in 160 MHz with LDPC encoding

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Figure 26-17 (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.

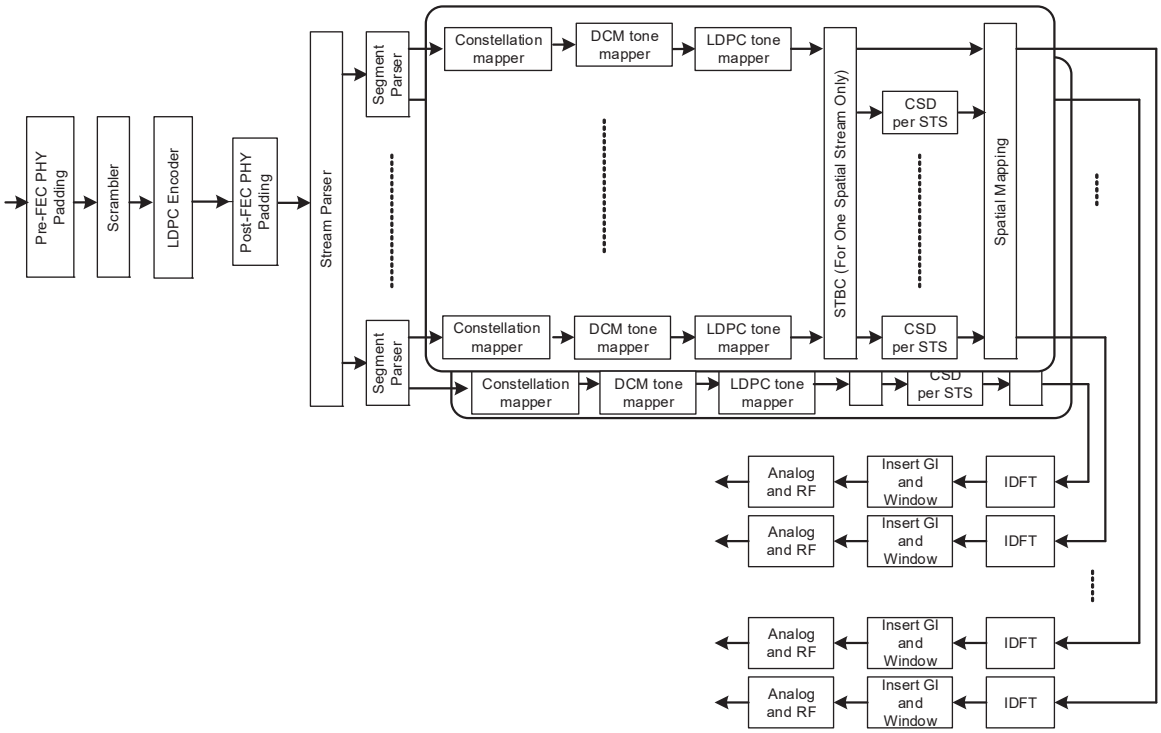


Figure 26-17—Transmitter block diagram for the Data field of an HE SU PPDU in 80+80 MHz with LDPC encoding

26.3.6 Overview of the PPDU encoding process

26.3.7 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(#Ed) 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.(#2518)

Rate-dependent parameters for the full set of HE-MCSs are shown in Table 26-44 (HE-MCSs for mandatory 26-tone RU, NSS = 1) to Table 26-99 (HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, NSS = 8) (in 26.5 (Parameters for HE-MCSs(#552))). 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 is 20

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MHz and can only be transmitted with the <HE-MCS, NSS> tuples <MCS 0, 1>, <MCS 1, 1> and <MCS 2, 1>(#1616)(#278). The 106-tone RU can only be transmitted with the <HE-MCS, NSS> tuples <MCS 0, 1>. The 106-tone RU location within the 20MHz tone plan is fixed as the right one.(PHY Motion #166)

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.

26.3.8 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 26-9 (Timing-related constants) defines the timing-related parameters for HE PPDU formats..

Table 26-9— Timing-related constants

Parameter	Values	Description
$\Delta_{F,\text{Pre-HE}}$	312.5 kHz	Subcarrier frequency spacing for the pre-HE modulated fields(#279).
$\Delta_{F,\text{HE}}$	78.125 kHz	Subcarrier frequency spacing for the HE modulated fields(#279).
$T_{DFT,\text{Pre-HE}}$	3.2 µs	IDFT/DFT period for the pre-HE modulated fields(#279).
$T_{DFT,\text{HE}}$	12.8 µs	IDFT/DFT period for the HE Data field(#279)(#Ed).
$T_{GI,\text{LegacyPreamble}}$	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.
$T_{GI,\text{HE-LTF}}$	$T_{GI1,Data}$, $T_{GI2,Data}$ 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(#1108)(#279)
T_{SYM2}	14.4 µs = $T_{DFT,\text{HE}} + T_{GI2,Data} = 1.125 \times T_{DFT,HE}$	OFDM symbol duration with double GI(#1109)
T_{SYM4}	16 µs = $T_{DFT,\text{HE}} + T_{GI4,Data} = 1.25 \times T_{DFT,\text{HE}}$	OFDM symbol duration with quadruple GI(#1110)

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Table 26-9— Timing-related constants *(continued)*

T_{SYM}	T_{SYM1}, T_{SYM2}, or T_{SYM4} depending on the GI used (see Table 26-14 (Tone scaling factor and guard interval duration values for HE PPDU fields)(#2757))	Symbol interval
$T_{\text{L-STF}}$	8 μs = 10 × $T_{DFT,\text{Pre-HE}}$ /4	Non-HT Short Training field duration
$T_{\text{L-LTF}}$(#1040)	8 μs = 2 × $T_{DFT,\text{Pre-HE}}$ + $T_{GI2,Data}$	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(#279)	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 (#279)
$T_{\text{HE-LTF-SYM}}$	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(#Ed)
$N_{service}$	16	Number of bits in the SERVICE field
N_{tail}	6 for BCC encoder, 0 for LDPC encoder	Number of tail bits per encoder(#2521)
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(#279)

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Table 26-10 (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 26-10—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 26-11 (Tone allocation related constants for RUs in an OFDMA HE PPDU(#2522))(#281) defines tone allocation related parameters for a OFDMA HE PPDU.

Table 26-11—Tone allocation related constants for RUs in an OFDMA HE PPDU(#2522)

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: $N_{ST} = N_{SD} + N_{SP}$								

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Table 26-12 (Frequently used parameters(#282)) defines parameters used frequently in Clause 26.

Table 26-12—Frequently used parameters(#282)

Symbol	Explanation
N_{CBPS}, $N_{CBPS,u}$	Number of coded bits per symbol at r-th RU for user u, u = 0, ..., $N_{user,total}$ – 1.(#2522) For an HE SU PPDU, $N_{CBPS} = N_{CBPS,0,0}$(#1042) 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 at r-th RU for user u, u = 0, ..., $N_{user,total}$ – 1.(#2522) For the Data field of an HE SU PPDU, $N_{CBPSS} = N_{CBPSS,0,0}$ 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.(#2522) 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 at r-th RU for user u, u = 0, ..., $N_{user,total}$ – 1.(#2522) For an HE SU PPDU, $N_{BPSCS} = N_{BPSCS,0,0}$ 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).
$N_{user,r}$(#1043)	For pre-HE modulated fields, $N_{uset,r}$ = 1. For HE modulated fields, $N_{uset,r}$ represents the number of users at r-th RU in 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(#1044) 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, $N_{STS,r,total}$(#522) 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(#2531). Note that $N_{STS,r,total} = N_{STS}$ for an HE SU PPDU.

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Table 26-12—Frequently used parameters(#282) *(continued)*

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, $u = 0, ..., N_{user,total} - 1$.(#2522) 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 26.3.9.10 (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
R, R_u	R_u is the coding rate for user u, $u = 0, ..., N_{user,total} - 1$.(#2522) 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, $u = 1, ..., N_{user,r} - 1$.
(#472)NOTE—For pre-HE modulated fields, u and r are zeros only since $N_{user,r} = 1$ and $N_{RU} = 1$.	

26.3.9 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 26:

$[Q]_{m,n}$ indicates the element in row m and column n of matrix, where $1 \le m \le N_{row}$ and $1 \le n \le N_{col}$(#2369)

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(#1966) 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(#Ed) 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.

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For a 20 MHz OFDMA HE PPDU(#Ed) 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(#Ed) 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(#Ed) 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(#Ed) 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(#898) 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}(#1967) is related to the complex baseband signal by the relation shown in Equation (26-1).

$$r_{RF}^{(i_{Seg}, i_{TX})}(t) = \mathrm{Re}\left\{ \frac{1}{\sqrt{N_{Seg}}} r_{PPDU}^{(i_{Seg}, i_{TX})}(t) \exp\left(j2\pi f_c^{(i_{Seg})} t\right) \right\}, \quad i_{Seg} = 0, \ldots, N_{Seg} - 1; \; i_{TX} = 1, \ldots, N_{TX} \quad (26\text{-}1)$$

where

N_{Seg} represents the number of frequency segments in the transmit signal as defined in Table 26-10 (Tone allocation related constants for Data field in a non-OFDMA HE PPDU)(#1671)

$r_{PPDU}^{(i_{Seg}, i_{TX})}$ 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}(#1968)

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 26-18 (Timing boundaries for HE PPDU fields(#899)), where $N_{\text{HE-LTF}}$ is the number of HE-LTF symbols and is defined in Table 26-12 (Frequently used parameters(#282)), $N_{\text{HE-SIG-B}}$ is the number of symbols in the HE-SIG-B field, and N_{SYM} is the number of symbols in the Data field.

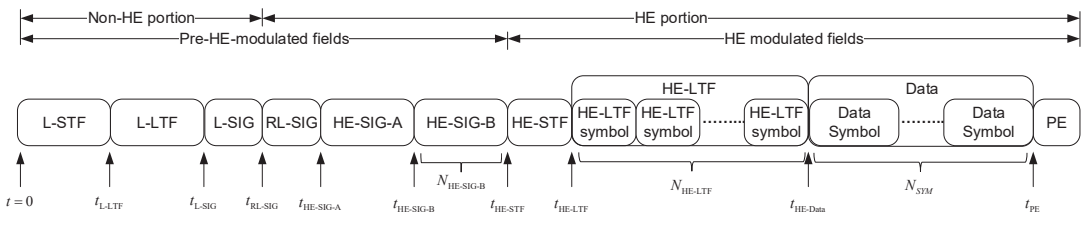


Figure 26-18—Timing boundaries for HE PPDU fields(#899)

The time offset, t_{Field}, determines the starting time of the corresponding field relative to the start of L-STF ($t = 0$).

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The signal transmitted on frequency segment i_{Seg} of transmit chain i_{TX} shall be as shown in Equation (26-2).

$$\begin{aligned} r_{PPDU}^{(i_{Seg}, i_{TX})}(t) = {} & r_{\text{L-STF}}^{(i_{Seg}, i_{TX})}(t) + r_{\text{L-LTF}}^{(i_{Seg}, i_{TX})}(t - t_{\text{L-LTF}}) \\ & + r_{\text{L-SIG}}^{(i_{Seg}, i_{TX})}(t - t_{\text{L-SIG}}) + r_{\text{RL-SIG}}^{(i_{Seg}, i_{TX})}(t - t_{\text{RL-SIG}}) + r_{\text{HE-SIG-A}}^{(i_{Seg}, i_{TX})}(t - t_{\text{HE-SIG-A}}) + r_{\text{HE-SIG-B}}^{(i_{Seg}, i_{TX})}(t - t_{\text{HE-SIG-B}}) \\ & + r_{\text{HE-STF}}^{(i_{Seg}, i_{TX})}(t - t_{\text{HE-STF}}) + r_{\text{HE-LTF}}^{(i_{Seg}, i_{TX})}(t - t_{\text{HE-LTF}}) + r_{\text{HE-Data}}^{(i_{Seg}, i_{TX})}(t - t_{\text{HE-Data}}) + r_{\text{HE-PE}}^{(i_{Seg}, i_{TX})}(t - t_{\text{HE-PE}}) \end{aligned} \quad (26\text{-}2)$$

where

$r_{\text{HE-SIG-B}}^{(i_{Seg}, i_{TX})}(t - t_{\text{HE-SIG-B}})$ is only applicable to an HE MU PPDU(#1970)

$0 \le i_{Seg} \le N_{Seg} - 1$

$1 \le i_{TX} \le N_{TX}$

$t_{\text{L-LTF}} = T_{\text{L-STF}}$

$t_{\text{L-SIG}} = t_{\text{L-LTF}} + T_{\text{L-LTF}}$

$t_{\text{RL-SIG}} = t_{\text{L-SIG}} + T_{\text{L-SIG}}$

$t_{\text{HE-SIG-A}} = t_{\text{RL-SIG}} + T_{\text{RL-SIG}}$

$$t_{\text{HE-SIG-B}} = \begin{cases} t_{\text{HE-SIG-A}} + T_{\text{HE-SIG-A}}, & \text{for an HE MU PPDU} \\ undefined, & \text{otherwise} \end{cases}$$

$$t_{\text{HE-STF}} = \begin{cases} t_{\text{HE-SIG-A}} + T_{\text{HE-SIG-A}}, & \text{for an HE SU PPDU and HE trigger-based PPDU} \\ t_{\text{HE-SIG-A}} + T_{\text{HE-SIG-A-R}}, & \text{for an HE extended range SU PPDU} \\ t_{\text{HE-SIG-B}} + N_{\text{HE-SIG-B}} T_{\text{HE-SIG-B}}, & \text{for an HE MU PPDU} \end{cases}$$

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 (26-3) and Equation (26-4) as the summation of one or more subfields. Each subfield is defined to be an inverse discrete Fourier transform(#2158).(#526)(#286)(#1976)(#1971)(PHY Motion #172)

$$\begin{aligned} r_{Field}^{(i_{Seg}, i_{TX})}(t) = w_{T_{Field}}(t) \sum_{r=0}^{N_{RU}-1} \frac{\alpha_r \beta_r^{Field}}{\sqrt{N_{Norm,r}}} \sum_{k \in K_r} \eta_{Field,k} \sum_{u=0}^{N_{user,r}-1} \sum_{m=1}^{N_{STS,r,u}} \left[Q_k^{(i_{Seg})} \right]_{i_{TX}, (M_{r,u}+m)} \Upsilon_{k,BW} \\ X_{k,r,u}^{i_{Seg}, m} \exp(j 2\pi k \Delta_{F,Field} (t - T_{GI,Field} - T_{CS,\text{HE}}(M_{r,u} + m))) \end{aligned} \quad (26\text{-}3)$$

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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 (26-4).(#526)(#286)

$$r_{Field}^{(i_{Seg}, i_{TX})}(t) = \frac{\alpha_r \beta_r^{Field}}{\sqrt{N_{Norm,r}}} w_{T_{Field}}(t) \sum_{k \in K_r} \eta_{Field,k} \sum_{m=1}^{N_{STS,r,u}-1} \left[Q_k^{(i_{Seg})} \right]_{i_{TX}, (M_{r,u}+m)} \Upsilon_{k,BW} \quad (26\text{-}4)$$
$$X_{k,r,u}^{(i_{Seg}, m)} \exp(j2\pi k \Delta_{F,Field}(t - T_{GI,Field} - T_{CS,\mathrm{HE}}(M_{r,u}+m)))$$

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 26-18 (Timing boundaries for HE PPDU fields(#899)). 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 (26-3) the following notations(#1975) 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 26-12 (Frequently used parameters(#282)). 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(#2760) is the set of subcarriers indices from $-N_{SR}$ to N_{SR} as defined in Table 26-13 (Highest data subcarrier index NSR for pre-HE modulated fields).(#289) 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 26-10 (Tone allocation related constants for Data field in a non-OFDMA HE PPDU)(#289). 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.

Table 26-13—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	52	104	208
L-LTF	26	52	104	208
L-SIG	28	56	112	224
RL-SIG	28	56	112	224
HE-SIG-A	28	56	112	224
HE-SIG-B	28	56	112	224

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$\eta_{Field,k}$ is the power boost factor per OFDM symbol, which is $\sqrt{2}$ for the L-STF, L-LTF, HE-STF and HE-LTF fields in the HE extended range SU PPDU, and 1 otherwise.(#526)

$$\eta_{\text{L-SIG},k} = \begin{cases} \sqrt{2}, k = -28, -27, 27, 28 \text{ for an HE extended range SU PPDU} \\ 1, \text{ otherwise} \end{cases} \quad \text{(\#526)} \qquad \text{(26-5)}$$

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].(#1689)

β_r^{Field} is the power normalization factor and is defined in Equation (26-6)(#286)

$$\beta_r^{Field} = \begin{cases} \dfrac{\varepsilon_{Field}}{\sqrt{N_{Field}^{\text{Tone}}}}, & \text{Pre-HE modulated fields when BEAM\_CHANGE = 1} \\ \varepsilon_{Field} \sqrt{\dfrac{|K_r|}{|K_r^{Field}|}} \Big/ \sqrt{\sum_{r=1}^{N_{RU}} \alpha_r^2 |K_r|}, & \text{otherwise} \end{cases} \quad \text{(\#526)} \qquad \text{(26-6)}$$

$|K_r|$ is the cardinality of the set of subcarriers K_r

$|K_r^{Field}|$ is the cardinality of the set of modulated subcarriers within K_r for each field.(#298)(#1978)

N_{Field}^{Tone} Table 26-14 (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.(#1977)

Table 26-14—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(#1988)	-	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	$T_{GI,\text{LegacyPreamble}}$

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Table 26-14—Tone scaling factor and guard interval duration values for HE PPDU fields

HE-STF not in an HE trigger-based PPDU	14	30	62	124(#287)	-
HE-STF in an HE trigger-based PPDU	30	60	124	248	-
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(#1988)	-	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.					

$$\varepsilon_{Field} = \begin{cases} \sqrt{\dfrac{N_{\text{L-LTF}}^{\text{Tone}}}{N_{\text{L-SIG}}^{\text{Tone}}}}, \text{ For the L-STF and L-LTF fields} \\ 1, \text{ otherwise} \end{cases} \quad (\#526)$$

$Q_k^{(i_{Seg})}$ 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 $N_{STS,total}$ 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 TBD; otherwise it is identical to the spatial mapping $Q_k^{(i_{Seg})}$ for HE modulated fields(#1848).

$\Delta_{F,Field}$ is the subcarrier frequency spacing. For pre-HE modulated fields, $\Delta_{F,Field} = \Delta_{F,\text{Pre-HE}}$ given in Table 26 3. For HE modulated fields, $\Delta_{F,Field} = \Delta_{F,\text{HE}}$ given in Table 26-9 (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(#902) 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.

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$T_{GI, Field}$ is the guard interval duration used for each OFDM symbol in the field. The value for each field is as defined in Table 26-9 (Timing-related constants)(#1674).

$T_{CS, \mathrm{HE}}(l)$ For pre-HE modulated fields, $T_{CS, \mathrm{HE}}(l) = 0$. For HE modulated fields, $T_{CS, \mathrm{HE}}(l)$ represents the cyclic shift per space-time stream, whose value is defined in Table 25-xx (Cyclic shift values for the HE modulated fields of a PPDU).

$\Upsilon_{k, BW}$ is used to represent tone rotation. BW in $\Upsilon_{k, BW}$ is determined by the TXVECTOR parameter CH_BANDWIDTH as defined in Table 26-15 (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.(#2761)(#293)

Table 26-15—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

26.3.10 HE preamble

26.3.10.1 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(#2762). The pre-HE modulated fields for the various HE PPDU formats are the following(#291):

— 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

26.3.10.2 Cyclic shift(#1052)

26.3.10.2.1 Cyclic shift for pre-HE modulated fields

When the TXVECTOR parameter BEAM_CHANGE is 1(#Ed), the cyclic shift value $T_{CS}^{i_{TX}}$ for the L-STF, L-LTF, L-SIG, RL-SIG, HE-SIG-A and HE-SIG-B fields of the PPDU for transmit chain i_{TX} out of a total of

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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)(PHY Motion #172). 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(#Ed), 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.

26.3.10.2.2 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(#Ed), and apply to the entire PPDU when the TXVECTOR parameter BEAM_CHANGE is 0(#Ed).

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. The cyclic shift value $T_{CS,\,\mathrm{HE}}(n)$ for the HE modulated fields for space-time stream n out of $N_{STS,total}$ total space-time streams is shown in Table 21-11 (Cyclic shift values for the VHT modulated fields of a PPDU)(PHY Motion #172).

26.3.10.3 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 (26-7). The equation applies to all contiguous signals up to 160 MHz and non contiguous 80+80 MHz.

$$r_{\text{L-STF}}^{(i_{Seg}i_{TX})}(t) = \frac{\varepsilon}{\sqrt{N_{TX}\cdot N_{\text{L-STF}}^{\text{Tone}}}} w_{T_{\text{L-STF}}}(t) \sum_{i_{BW}\in\Omega_{20\text{MHz}}} \sum_{k=-26}^{26} \eta_{\text{L-STF},k} \left(\Upsilon_{(k-K_{\text{Shift}}(i_{BW})),\,\text{BW}} S_{k,20} \cdot \exp(j2\pi(k-K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F,\,\text{Pre-HE}}(t-T_{CS}^{i_{TX}})) \right) \quad (26\text{-}7)$$

(#525)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

$$\eta_{\text{L-STF},k} = \begin{cases} \sqrt{2}, & \text{for an HE extended range SU PPDU} \\ 1, & \text{otherwise} \end{cases} \text{ (\#1986)} \quad (26\text{-}8)$$

$N_{20\text{MHz}}$ 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 26.3.10.2.1 (Cyclic shift for pre-HE modulated fields).

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$N_{\text{L-STF}}^{\text{Tone}}$ has the value given in Table 26-14 (Tone scaling factor and guard interval duration values for HE PPDU fields)(#1988).

$\Omega_{20\text{MHz}}$ 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 (18-6).(#1985)(#1989)

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 (26-9). The equation applies to all contiguous signals up to 160 MHz and non contiguous 80+80 MHz.

$$r_{\text{L-STF}}^{(i_{Seg} i_{TX})}(t) = \frac{\varepsilon}{\sqrt{N_{STS,\,total} \cdot N_{\text{L-STF}}^{\text{Tone}}}} w_{T_{\text{L-STF}}}(t) \quad \text{(\#2531)(26-9)}$$

$$\sum_{i_{BW}=0}^{N_{20\text{MHz}}-1} \sum_{k=-26}^{26} \sum_{m=1}^{N_{STS}} \eta_{\text{L-STF},k} \left(\left[Q_{4(k-K_{\text{Shift}}(i_{BW}))}^{(i_{Seg})} \right]_{i_{TX},m} \left[A_{\text{HE-LTF}}^{4(k-K_{\text{Shift}}(i_{BW}))} \right]_{m,1} S_{k,20} \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F,\,\text{Pre-HE}}(t - T_{CS,\,\text{HE}}(m))) \right)$$

(#1050)(#525)where

$T_{CS,\,\text{HE}}(m)$ represents the cyclic shift for space time stream m as defined in 26.3.10.2.2 (Cyclic shift for HE modulated fields)(#1052)

$Q_k^{(i_{Seg})}$ 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 26-9 (Timing-related constants). Refer to the descriptions in 22.3.10.11.1 (Transmission in VHT format) for examples of $Q_k^{(i_{Seg})}$.(#1991)

$A_{\text{HE-LTF}}^{k}$ is defined in Equation (26-56)

26.3.10.4 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 (26-10). The equation applies to all contiguous signals up to 160 MHz and non contiguous 80+80 MHz.(PHY Motion #172)

$$r_{\text{L-LTF}}^{(i_{Seg} i_{TX})}(t) = \frac{\varepsilon}{\sqrt{N_{TX} \cdot N_{\text{L-LTF}}^{\text{Tone}}}} w_{T_{\text{L-LTF}}}(t) \quad \text{(26-10)}$$

$$\sum_{i_{BW} \in \Omega_{20\text{MHz}}} \sum_{k=-26}^{26} \eta_{\text{L-LTF},k} \left(\Upsilon_{(k-K_{\text{Shift}}(i_{BW})),\,\text{BW}} L_{k,20} \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F,\,\text{Pre-HE}}(t - T_{GI,\,\text{L-LTF}} - T_{CS}^{i_{TX}})) \right)$$

$\eta_{\text{L-LTF},k}$ is a PPDU format dependent scaling factor for the L-LTF field on tone index k with the same value as $\eta_{\text{L-STF},k}$.(#525)

$N_{20\text{MHz}}$ is defined in 21.3.7.3 (Channel frequencies)

$K_{Shift}(i) = (N_{20\text{MHz}} - 1 - 2i) \cdot 32$

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$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain i_{TX} with a value given in 26.3.10.2.1 (Cyclic shift for pre-HE modulated fields).

$N_{\text{L-LTF}}^{\text{Tone}}$ has the value given in Table 26-14 (Tone scaling factor and guard interval duration values for HE PPDU fields)(#1988).

$L_{k,20}$ is defined as $L_{-26,26}$ in Equation (18-8).(#1992)

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 (26-11). The equation applies to all contiguous signals up to 160 MHz and non contiguous 80+80 MHz.

$$r_{\text{L-LTF}}^{(i_{Seg} i_{TX})}(t) = \frac{\varepsilon}{\sqrt{N_{STS,\,total} \cdot N_{\text{L-LTF}}^{\text{Tone}}}} w_{T_{\text{L-LTF}}}(t) \sum_{i_{BW}=0}^{N_{20\text{MHz}}} \sum_{k=-26}^{26} \sum_{m=1}^{N_{STS}} \eta_{\text{L-LTF},k} \left(\left[Q_{4(k-K_{\text{Shift}}(i_{BW}))}^{(i_{Seg})} \right]_{i_{TX},\,m} \left[A_{\text{HE-LTF}}^{4(k-K_{\text{Shift}}(i_{BW}))} \right]_{m,\,1} L_{k,\,20} \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F,\,\text{Pre-HE}}(t - T_{GI,\,\text{LegacyPreamble}} - T_{CS,\,\text{HE}}(m))) \right) \quad (26\text{-}11)$$

(#2531)(#1050)where

$T_{CS,\,\text{HE}}(m)$ represents the cyclic shift for space time stream m as defined in 26.3.10.2.2 (Cyclic shift for HE modulated fields)(#1052)

$Q_k^{(i_{Seg})}$ is defined in 26.3.9 (Mathematical description of signals)(#1094)

$A_{\text{HE-LTF}}^{k}$ is defined in Equation (26-56)

26.3.10.5 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)(#1835).

In an(#2829) 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)(#1835). In a non-HT duplicate PPDU, the RATE field is defined in 17.3.4.2 (RATE field)(#1835) using the L_DATARATE parameter in the TXVECTOR.

The LENGTH field shall be set to the value given by Equation (26-12).

$$\text{Length} = \left\lceil \frac{\text{TXTIME} - 20}{4} \right\rceil \times 3 - 3 - m \text{ (\#1683)} \quad (26\text{-}12)$$

where

TXTIME (in μs) is defined in 26.4.3 (TXTIME and PSDU_LENGTH calculation).

m is 1 for an HE MU PPDU and HE extended range SU PPDU, and 2 otherwise.

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)(#2859) 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.

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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(#1997). The 4 extra tones [–28, –27, 27, 28] of L-SIG in 20 MHz HE PPDU is [–1, –1, –1, 1].(#1835)

If the TXVECTOR parameter BEAM_CHANGE is 1, the time domain waveform of the L-SIG field shall be as given by Equation (26-13).

$$r_{\text{L-SIG}}^{(i_{Seg} i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{\text{L-SIG}}^{\text{Tone}}}} w_{T_{\text{L-SIG}}}(t) \sum_{i_{BW} \in \Omega_{20\text{MHz}}} \sum_{k=-28}^{28} \left(\begin{array}{l} \Upsilon_{(k - K_{\text{Shift}}(i_{BW})), \text{BW}} \eta_{\text{L-SIG}, k} (D_{k,20} + p_0 P_k) \\ \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}})) \Delta_{F, \text{Pre-HE}} (t - T_{GI, \text{LegacyPreamble}} - T_{CS}^{i_{TX}})) \end{array} \right) \quad (26\text{-}13)$$

where

$N_{20\text{MHz}}$ is defined in 21.3.7.3 (Channel frequencies)

$K_{Shift}(i) = (N_{20\text{MHz}} - 1 - 2i) \cdot 32$

$$D_{k,20} = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ -1, k = -28, -27, 27 \\ 1, k = 28 \\ d_{M_{20}^r(k)}, \text{otherwise} \end{cases} \quad (\#1684)$$

$$M_{20}^r(k) = \begin{cases} k + 26, -26 \le k \le -22 \\ k + 25, -20 \le k \le -8 \\ k + 24, -6 \le k \le -1 \\ k + 23, 1 \le k \le 6 \\ k + 22, 8 \le k \le 20 \\ k + 21, 22 \le k \le 26 \end{cases}$$

P_k is defined in 17.3.5.10 (OFDM modulation)(#1835)

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 26-14 (Tone scaling factor and guard interval duration values for HE PPDU fields)(#476)

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain i_{TX} with a value given in 26.3.10.2.1 (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)(#1835).

If the TXVECTOR parameter BEAM_CHANGE is 0, the time domain waveform of the L-SIG field shall be as given by Equation (26-14).

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$$r_{\text{L-SIG}}^{(i_{Seg} i_{TX})}(t) = \frac{1}{\sqrt{N_{STS,\,total} \cdot N_{\text{L-SIG}}^{\text{Tone}}}} w_{T_{\text{L-SIG}}}(t) \quad (26\text{-}14)$$

$$\sum_{i_{BW}=0}^{N_{20\text{MHz}}} \sum_{k=-28}^{28} \sum_{m=1}^{N_{STS}} \left(\left[Q_{4(k-K_{\text{Shift}}(i_{BW}))}^{(i_{Seg})} \right]_{i_{TX},\,m} \left[A_{\text{HE-LTF}}^{4(k-K_{\text{Shift}}(i_{BW}))} \right]_{m,\,1} \eta_{\text{L-SIG},\,k} (D_{k,\,20} + p_0 P_k) \right.$$
$$\left. \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F,\,\text{Pre-HE}}(t - T_{GI,\,\text{LegacyPreamble}} - T_{CS,\,\text{HE}}(m))) \right)$$

(#2531)(#1050)(#525)where

$\eta_{\text{L-SIG},\,k}$ is a PPDU dependent scaling factor for the L-SIG field on the tone index k with the following value:

$$\eta_{\text{L-SIG},\,k} = \begin{cases} \sqrt{2}, & k = \pm 28, \pm 27 \text{ for an HE extended range SUPPDU} \\ 1, & \text{otherwise} \end{cases} \quad (\#525)$$

$T_{CS,\,\text{HE}}(m)$ represents the cyclic shift for space time stream m as defined in 26.3.10.2.2 (Cyclic shift for HE modulated fields)(#1052)

$Q_k^{(i_{Seg})}$ is defined in 26.3.9 (Mathematical description of signals)(#1094)

$A_{\text{HE-LTF}}^{k}$ is defined in Equation (26-56)

26.3.10.6 RL-SIG

The RL-SIG field is used to identify an(#2829) 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 (26-15).(#294)

$$_{g}^{i_{TX})}_{\text{SIG}}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{\text{RL-SIG}}^{\text{Tone}}}} w_{T_{\text{RL-SIG}}}(t) \quad (26\text{-}15)$$

$$\sum_{i_{BW} \in \Omega_{20\text{MHz}}} \sum_{k=-28}^{28} \eta_{\text{L-SIG},\,k} \left(\Upsilon_{(k-K_{\text{Shift}}(i_{BW})),\,\text{BW}} \eta_{\text{L-SIG},\,k} (D_{k,\,20} + p_1 P_k) \right.$$
$$\left. \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F,\,\text{Pre-HE}}(t - T_{GI,\,\text{LegacyPreamble}} - T_{CS}^{i_{TX}})) \right)$$

If the TXVECTOR parameter BEAM_CHANGE is 1, the time domain waveform of the RL-SIG field shall be as given by Equation (26-16).(#294)

$$_{Seg}^{i_{TX})}_{\text{-SIG}}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{\text{RL-SIG}}^{\text{Tone}}}} w_{T_{\text{RL-SIG}}}(t) \quad (26\text{-}16)$$

$$\sum_{i_{BW}=0}^{N_{20\text{MHz}}-1} \sum_{k=-28}^{28} \eta_{\text{L-SIG},\,k} \sum_{m=1}^{N_{STS}} \left(\left[Q_{4(k-K_{\text{Shift}}(i_{BW}))}^{(i_{Seg})} \right]_{i_{TX},\,m} \left[A_{\text{HE-LTF}}^{4(k-K_{\text{Shift}}(i_{BW}))} \right]_{m,\,1} (D_{k,\,20} + p_0 P_k) \right.$$
$$\left. \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F,\,\text{Pre-HE}}(t - T_{GI,\,\text{LegacyPreamble}} - T_{CS,\,\text{HE}}(m))) \right)$$

26.3.10.7 HE-SIG-A

26.3.10.7.1 General

The HE-SIG-A field carries information required to interpret HE PPDUs.(#1846)

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26.3.10.7.2 Content

The HE-SIG-A field for an HE SU PPDU or an HE extended range SU PPDU contains the fields listed in Table 26-16 (HE-SIG-A field of an HE SU PPDU and HE extended range SU PPDU(#Ed)).

Table 26-16—HE-SIG-A field of an HE SU PPDU and HE extended range SU PPDU(#Ed)

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:(#1685) 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.(#1196)
	B1	Beam Change	1	Set to 1 indicates that the pre-HE-STF portion of the PPDU(#481) is spatially mapped differently from HE-LTF1. Set to 0 indicates that the pre-HE-STF portion of the PPDU(#481) 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(#2002) This field indicates DL for TDLS, mesh and IBSS(#2864). 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 MCS*n*, 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 MCS*n*, 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.(#2007)

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Table 26-16—HE-SIG-A field of an HE SU PPDU and HE extended range SU PPDU(#Ed)

	B8-B13	BSS Color	6	The BSS Color field is an identifier of the BSS
	B14	Reserved	1	Reserved and set to 1(PHY Motion #162)
	B15-B18	Spatial Reuse	4	Set to SR Disallowed to disallow SRP-based spatial reuse (see 25.9 (Spatial reuse operation) and 25.11a (TXVECTOR parameters SPATIAL_REUSE for an HE PPDU)).(#226) NOTE—This part needs further development.(#2169)
	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(#Ed) 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(#1420)	3	Indicates the GI duration(#1420) 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 3.2 μs GI(#2005)
	B23-B25	Nsts	3	Indicates the number of space time streams.(#1457) 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(#2001) Values 2-7 are reserved
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(#Ed) in Table 26-1 (TXVECTOR and RXVECTOR parameters(#1780)).(#783)
	B7	Coding	1	Indicates whether BCC or LDPC is used: Set to 0 to indicate BCC Set to 1 to indicate LDPC(#1197)
	B8	LDPC Extra Symbol	1	Indicates the presence of the extra OFDM symbol for LDPC.(#1197) 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.

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Table 26-16—HE-SIG-A field of an HE SU PPDU and HE extended range SU PPDU(#Ed)

	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(#2564)	2	Indicates the pre-FEC padding factor(#1626)(#2564) value as defined in Table 26-39 (Pre-FEC Padding Factor(#2564) subfield encoding).(#2534)
	B13	PE Disambiguity	1	Indicate PE Disambiguity as defined in 26.3.12 (Packet extension(#1781)).(#2534)
	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(#2167)
	B16-B19	CRC	4	CRC for bits 0-41 of the HE-SIG-A field (see 26.3.10.7.3 (CRC computation)). The first bit to be transmitted is bit *c7* as explained in 26.3.10.7.3 (CRC computation)).(#2535)
	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.

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(#475)The HE-SIG-A field of an HE MU PPDU contains the fields listed in Table 26-17 (HE-SIG-A field of an HE MU PPDU(#Ed)).

Table 26-17—HE-SIG-A field of an HE MU PPDU(#Ed)

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(#2002) This field indicates DL for TDLS, mesh and IBSS(#2864). 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(#1616) The values 6 and 7 are reserved(#847)
	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 25.9 (Spatial reuse operation) and 25.11a (TXVECTOR parameters SPATIAL_REUSE for an HE PPDU)).(#226) NOTE—This part needs further development.(#2169)
	B15-B17	Bandwidth	3(#846)	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(#Ed) 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 pre-amble 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 pre-amble the primary 40 MHz is present.(PHY Motion #161)

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Table 26-17—HE-SIG-A field of an HE MU PPDU(#Ed) *(continued)*

	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.(#821) If the SIGB Compression field is 1, indicates the number of MU-MIMO users minus 1.(#296)
	B22	SIGB Compression	1	Set to 1 for full BW MU-MIMO. Set to 0 otherwise.
	B23-B24	GI+LTF Size(#1420)	3	Indicates the GI duration(#1420) and HE-LTF size. 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(#2005) The value 0 is reserved(#Ed)
	B25	Doppler	1	Set to 0 if Doppler mode is not used Set to 1 if Doppler mode is used(#2167)
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(#Ed) in Table 26-1 (TXVECTOR and RXVECTOR parameters(#1780)).(#783)
	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.(#2127)
	B11	LPDC Extra Symbol	1	Indication of the presence of the extra OFDM symbol for LDPC.
	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.(#540)
	B13-B14	Pre-FEC Padding Factor(#2564)	2	Indicates the pre-FEC padding factor(#1626)(#2564) value as defined in Table 26-39 (Pre-FEC Padding Factor(#2564) subfield encoding).(#2534)
	B15	PE Disambiguity	1	Indicate PE Disambiguity as defined in 26.3.12 (Packet extension(#1781)).(#2534)

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Table 26-17—HE-SIG-A field of an HE MU PPDU(#Ed) *(continued)*

	B16-B19	CRC	4	CRC for bits 0-41 of the HE-SIG-A field (see 26.3.10.7.3 (CRC computation)). The first bit to be transmitted is bit *c7* as explained in 26.3.10.7.3 (CRC computation)).(#2535)
	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 26.3.10.8 (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 26-18 (HE-SIG-A field of an HE trigger-based PPDU(#Ed)).

Table 26-18—HE-SIG-A field of an HE trigger-based PPDU(#Ed)

Two Parts of HE-SIG-A	Bit	Field	Number of bits	Description
HE-SIG-A1	B0	Format	1	Set to 0 for an HE SU PPDU Set to 1 for an HE trigger-based PPDU
	B1-B6	BSS Color	6	The BSS Color field is an identifier of the BSS

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Table 26-18—HE-SIG-A field of an HE trigger-based PPDU(#Ed) *(continued)*

B7-B10	Spatial Reuse 1(SR Motion #11)	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 25.9 (Spatial reuse operation) and 25.11a (TXVECTOR parameters SPATIAL_REUSE for an HE PPDU)). Set to value 1 to 14 corresponding to SRP value (see Table 26-19 (Spatial Reuse subfield encoding)) for SRP-based SR operation. The value 15 is reserved.(#226)
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 25.9 (Spatial reuse operation) and 25.11a (TXVECTOR parameters SPATIAL_REUSE for an HE PPDU)). Set to value 1 to 14 corresponding to SRP value (see Table 26-19 (Spatial Reuse subfield encoding)) for SRP-based SR operation. The value 15 is reserved.(#226)

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Table 26-18—HE-SIG-A field of an HE trigger-based PPDU(#Ed) *(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 25.9 (Spatial reuse operation) and 25.11a (TXVECTOR parameters SPATIAL_REUSE for an HE PPDU)). Set to value 1 to 14 corresponding to SRP value (see Table 26-19 (Spatial Reuse subfield encoding)) for SRP-based SR operation. The value 15 is reserved.(#226)
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 25.9 (Spatial reuse operation) and 25.11a (TXVECTOR parameters SPATIAL_REUSE for an HE PPDU)). Set to value 1 to 14 corresponding to SRP value (see Table 26-19 (Spatial Reuse subfield encoding)) for SRP-based SR operation. The value 15 is reserved.(#226)
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.(PHY Motion #169)
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(#2001)

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Table 26-18—HE-SIG-A field of an HE trigger-based PPDU(#Ed) *(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(#Ed) in Table 26-1 (TXVECTOR and RXVECTOR parameters(#1780)).(#783)
	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 26.3.10.7.3 (CRC computation). The first bit to be transmitted is bit C3 as explained in 26.3.10.7.3 (CRC computation)).(#2535)
	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.

(#226)Table 26-19 (Spatial Reuse subfield encoding) defines the encoding for the Spatial Reuse 1, Spatial Reuse 2, Spatial Reuse 3 and Spatial Reuse 4 subfields.

Table 26-19—Spatial Reuse subfield encoding

Value	Meaning
0	SR disallow
1	SRP = –80 dBm
2	SRP = –74 dBm

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Table 26-19—Spatial Reuse subfield encoding *(continued)*

Value	Meaning
3	SRP = –68 dBm
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}: –10 dBm to 26 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.

26.3.10.7.3 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(#2015) 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 26-20 (Common Block field(#2024)) for N and the conditions under which the Center 26-tone RU subfield is present.(#2016)(#Ed)

The value of the CRC field shall be the 1s complement of

$$crc(D) = (M(D) + I(D))D^{8} mod\ G(D)$$

where

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$$M(D) = \sum_{i=0}^{L} m_{L-i} D^i$$

where

$$I(D) = \sum_{i=L-7}^{L} D^i$$

$G(D)$ is defined in Equation (19-18)(#2018)

The CRC field is transmitted from *c4* to *c7* with *c7* first.(#2286)

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*.

26.3.10.7.4 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), 26.3.11.8 (BCC interleavers)(#2183), 17.3.5.8 (Subcarrier modulation mapping), and 17.3.5.9 (Pilot subcarriers)(#2771), respectively. The constellation mappings of HE-SIG-A in HE SU PPDU, HE MU PPDU and HE trigger-based PPDU are shown in Figure 26-19 (Data tone constellation of HE-SIG-A symbols)(#2772). 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 (26-17).(#2287)(#525)

$$r_{\text{HE-SIG-A}}^{(i_{Seg} i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{\text{HE-SIG-A}}^{\text{Tone}}}} \sum_{n=0}^{1} w_{T_{SYML}}(t - nT_{SYML}) \sum_{i_{BW} \in \Omega_{20\text{MHz}}} \sum_{k=-28}^{28} \left(\begin{array}{l} \Upsilon_{(k - K_{\text{Shift}}(i_{BW})), \text{BW}}(D_{k,n,20} + p_{n+2} P_k) \\ \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F,\text{Pre-HE}}(t - nT_{SYML} - T_{GI,\text{LegacyPreamble}} - T_{CS}^{i_{TX}})) \end{array} \right) \quad (26\text{-}17)$$

$N_{20\text{MHz}}$ is defined in 21.3.7.3 (Channel frequencies)

$$K_{\text{Shift}}(i) = (N_{20\text{MHz}} - 1 - 2i) \cdot 32$$

$$D_{k,n,20} = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ d_{M_{20}^r(k), n}, \text{otherwise} \end{cases}$$

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$$M_{20}^{r}(k) = \begin{cases} k+28, -28 \le k \le -22 \\ k+27, -20 \le k \le -8 \\ k+26, -6 \le k \le -1 \\ k+25, 1 \le k \le 6 \\ k+24, 8 \le k \le 20 \\ k+23, 22 \le k \le 28 \end{cases} \quad \text{(\#525)}$$

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 26-14 (Tone scaling factor and guard interval duration values for HE PPDU fields)(#476)

$T_{CS}^{i_{TX}}$ represents the cyclic shift for transmit chain i_{TX} with a value given in 26.3.10.2.1 (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 (26-18).

$$\dot{}_{\text{HE-SIG-A}}^{(i_{Seg} i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{\text{HE-SIG-A}}^{\text{Tone}}}} \sum_{n=0}^{1} w_{T_{SYML}}(t - nT_{SYML}) \sum_{i_{BW}=0}^{N_{20\text{MHz}}-1} \sum_{k=-N_{SR}}^{N_{SR}} \left(\begin{array}{l} (D_{k,n,i_{BW}}^{i_{Seg}} + p_{n+4} P_k) \\ \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F,\text{ Pre-HE}}(t - nT_{SYML} - T_{GI,\text{ LegacyPreamble}} - T_{CS}^{i_{TX}})) \end{array} \right) \quad (26\text{-}18)$$

(#2288)(#1050)(#525)where

$T_{CS,\text{ HE}}(m)$ represents the cyclic shift for space time stream m as defined in 26.3.10.2.2 (Cyclic shift for HE modulated fields)(#1052)

$Q_k^{(i_{Seg})}$ is defined in 26.3.9 (Mathematical description of signals)(#1094)

$A_{\text{HE-LTF}}^{k}$ is defined in Equation (26-56)

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(#912) and have pilots inserted. The constellation mappings of the HE-SIG-A field in an HE extended range SU PPDU is shown in Figure 26-19 (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 (26-12), which indicates HE MU PPDU or HE extended range SU PPDU(#1687). HE-SIG-A4 shall be BCC encoded at rate, $R = 1/2$, mapped to a BPSK constellation without interleaving(#913) and have pilots inserted. BCC encoding, Data interleaving, constellation mapping and pilot insertion follow the steps described in 17.3.5.6 (Convolutional encoder), 26.3.11.8 (BCC

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interleavers)(#2183), 17.3.5.8 (Subcarrier modulation mapping), and 17.3.5.9 (Pilot subcarriers)(#2774), respectively.

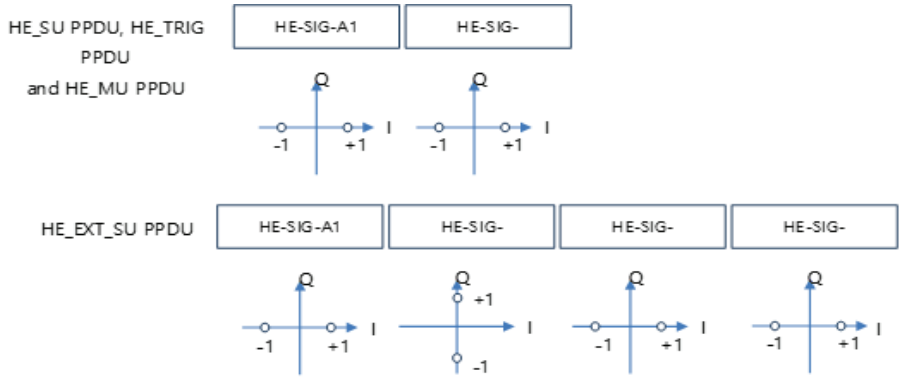


Figure 26-19—Data tone constellation of HE-SIG-A symbols

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 (26-19).

$$r_{\text{HE-SIG-A}}^{(i_{Seg} i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{\text{HE-SIG-A}}^{\text{Tone}}}} \sum_{n=0}^{3} w_{T_{\text{SYML}}}(t - nT_{SYML}) \sum_{i_{BW}=0}^{N_{20\text{MHz}}-1} \sum_{k=-28}^{28} \left(\begin{array}{l} \Upsilon_{(k-K_{\text{Shift}}(i_{BW})),\,\text{BW}}(R_n D_{k,n,20} + p_{n+2} P_k) \\ \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F,\,\text{Pre-HE}}(t - nT_{SYML} - T_{GI,\,\text{LegacyPreamble}} - T_{CS}^{i_{TX}})) \end{array} \right) \quad (26\text{-}19)$$

(#2289)where

R_n is a phase rotation vector defined as $[1, j, 1, 1]$(#2372)

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 (26-20).(#2290)(#2531)

$$r_{\text{HE-SIG-A}}^{(i_{Seg} i_{TX})}(t) = \frac{1}{\sqrt{N_{STS} \cdot N_{\text{HE-SIG-A}}^{\text{Tone}}}} \sum_{n=0}^{3} w_{T_{SYML}}(t - nT_{SYML}) \sum_{i_{BW}=0}^{N_{20\text{MHz}}-1} \sum_{k=-28}^{28} \sum_{m=1}^{N_{STS}} \left(\begin{array}{l} \left[Q_{4(k-K_{\text{Shift}}(i_{BW}))}^{(i_{Seg})} \right]_{i_{TX},\,m} \left[A_{\text{HE-LTF}}^{4(k-K_{\text{Shift}}(i_{BW}))} \right]_{m,\,1} (R_n D_{k,n,20} + p_{n+2} P_k) \\ \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F,\,\text{Pre-HE}}(t - nT_{SYML} - T_{\text{GI,\,LegacyPreamble}} - T_{CS,\,HE}(m))) \end{array} \right) \quad (26\text{-}20)$$

26.3.10.8 HE-SIG-B

26.3.10.8.1 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 26-20 (HE-SIG-B field encoding structure in each 20 MHz). It consists of a

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Common Block field followed by a User Specific field which together are referred to as the HE-SIG-B content channel(#2020).

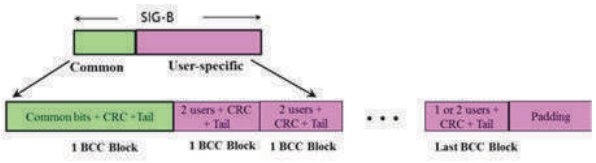


Figure 26-20—HE-SIG-B field encoding structure in each 20 MHz

The Common Block field of a HE-SIG-B content channel(#2020) contains information regarding the resource unit allocation such as the RU arrangement 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 26.3.10.8.4 (HE-SIG-B common content).

The User Specific field of a HE-SIG-B content channel(#2020) consists of one or more(#2022) User Block fields. Each User Block field is made up of two user fields that contain(#2020) information for two STAs to decode their payloads. The last User Block field may contain information for one or two STAs depending on whether the number of users indicated by the RU allocation signaling is odd and depending on the signaling of the center 26-tone RU(#302). See 26.3.10.8.5 (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.(#2543)

26.3.10.8.2 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 26-21 (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 26-21—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 26-22 (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

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between [3:244].(#2544) 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 26-22—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 26-23 (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.(#2544) 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].(#1692) 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.(#1692) 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.(#1692)(#2023) 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.

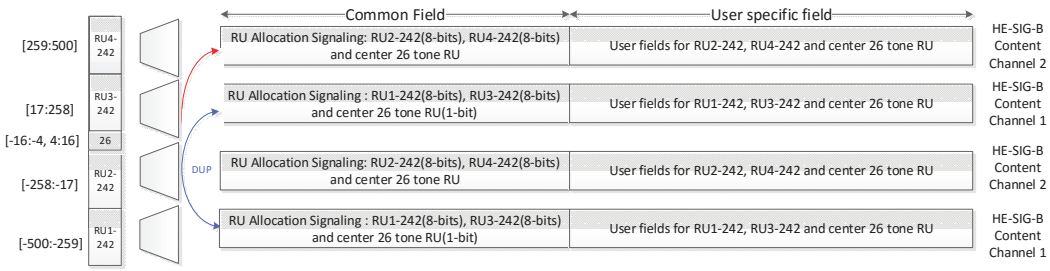


Figure 26-23—Default mapping of the two HE-SIG-B channels and their duplication in an 80 MHz PPDU

The 160 MHz PPDU contains two content channels each of which are duplicated four times as shown in Figure 26-24 (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.(#2023) The first content channel occupies the tones in the 20 MHz segment with the lowest subcarrier indices and the second

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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 sub-carrier index is carried in HE-SIG-B content channel 1 as a 1-bit sub-field placed at the end of 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 sub-field placed at the end of 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.(#1692) 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 sub-carrier index.

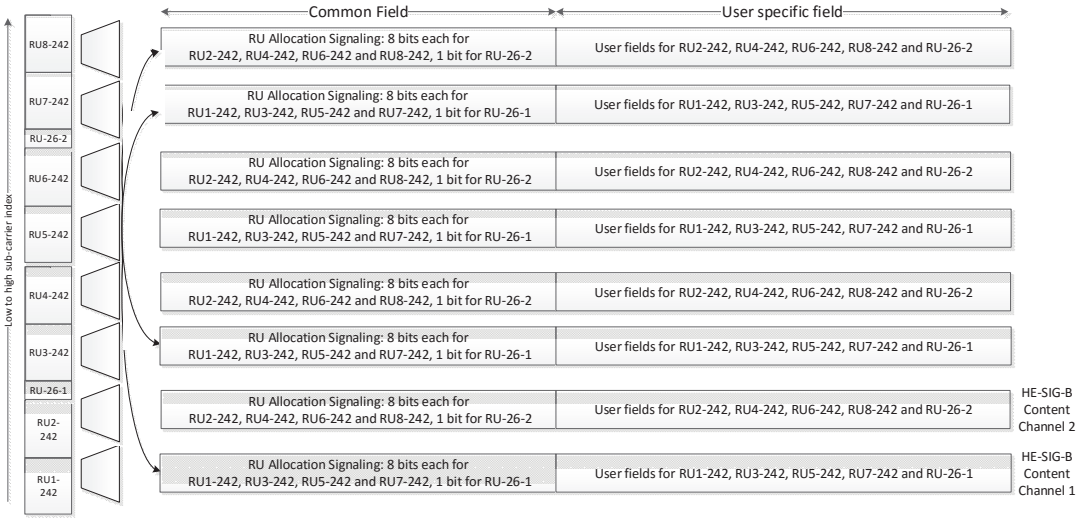


Figure 26-24—Default mapping of the two HE-SIG-B channels and their duplication in a 160 MHz PPDU

For an MU-MIMO allocation of RU size greater than 242 subcarriers(#2546), the User Block subfields are dynamically split between the two HE-SIG-B content channels (1/2) and the split is decided by the AP (on a per case basis). See 26.3.10.8.4 (HE-SIG-B common content) and 26.3.10.8.5 (HE-SIG-B per-user content)(#1006) for more details.

(PHY Motion #161)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 26-17 (HE-SIG-A field of an HE MU PPDU(#Ed))), 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.

26.3.10.8.3 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 26.3.10.7.3 (CRC computation).(#2025) 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(#Ed) are split into groups of two. Each group of two User fields shall have CRC and tail bits added and then BCC encoded at rate R = ½ using

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the encoder described in 17.3.5.6 (Convolutional encoder)(#307). If the number of users in the content channel is odd, the User Block field corresponding to the last user, who is not grouped, is encoded after adding tail and CRC bits. After encoding, padding bits are added to each content channel to round up the number of symbols the content channel occupies to the nearest integer value. Further padding is added to each content channel until the number of OFDM symbols in the content channel equals the Number of HE-SIG-B symbols signaled by a 4-bit 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.(#306)(#2027)For both the Common Block and User Specific fields, when the code rate is not equal to ½, the convolutional encoder output bits for each field (including padding bits) are concatenated, then the concatenated bit streams are punctured as described in 17.3.5.6 (Convolutional encoder)(#307)(#2028).

The coded bits are interleaved as in 26.3.11.8 (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)(#307), respectively.(#2183)

The guard interval(#915) used for HE-SIG-B shall be 0.8 μs.(#2030)

The number of OFDM symbols in the HE-SIG-B field, denoted by $N_{SYM,\text{HE-SIG-B}}$, shall be signaled by a 4-bit field in the HE-SIG-A field of a HE MU PPDU(#477) (see (#1304)26.3.10.7.2 (Content)(#2781)).

(#2031)For the c-th content channel (c = 1 or 2), denote the sample on the k-th data(#525) subcarrier of the n-th symbol by $d_{k,n,c}$. The time domain waveform for the HE-SIG-B follows Equation (26-21).

$$r_{\text{HE-SIG-B}}^{(i_{Seg} i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{\text{HE-SIG-B}}^{\text{Tone}}}} \sum_{n=0}^{N_{SYM,\text{HE-SIG\_B}}} w_{T_{\text{HE-SIG-B}}}(t - nT_{SYML}) \quad (26\text{-}21)$$

$$\sum_{i_{BW} \in \Omega_{20\text{MHz}}} \sum_{k=-N_{SR}}^{N_{SR}} \left(\begin{array}{l} \Upsilon_{(k - K_{\text{Shift}}(i_{BW})),\,\text{BW}} \Gamma_{M_{20}^{r}(k)} (D_{k,n,i_{BW}}^{i_{Seg}} + p_{n+4} P_k) \\ \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}})) \Delta_{F,\,\text{Pre-HE}} (t - nT_{SYML} - T_{GI,\,\text{LegacyPreamble}} - T_{CS}^{i_{TX}})) \end{array} \right)$$

(#525)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,

$$\Gamma_{M_{20}^{r}(k)} = \begin{cases} 1 & 0 \le M_{20}^{r}(k) < 26 \\ (-1)^{M_{20}^{r}(k)} & 26 \le M_{20}^{r}(k) < 52 \end{cases} \quad (\#525)$$

$N_{20\text{MHz}}$ and $K_{\text{Shift}}(i)$ are defined in 21.3.8.2.4 (L-SIG definition)(#2782)

$$D_{k,n,i_{BW}}^{i_{Seg}} = \begin{cases} 0, k = 0, \pm 7, \pm 21 \\ d_{M_{20}^{r}(k),\,n,\,(i_{BW} mod\ 2)+1}, \text{otherwise} \end{cases}$$

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$$M^{r}_{20}(k) = \begin{cases} k+28, -28 \le k \le -22 \\ k+27, -20 \le k \le -8 \\ k+26, -6 \le k \le -1 \\ k+25, 1 \le k \le 6 \\ k+24, 8 \le k \le 20 \\ k+23, 22 \le k \le 28 \end{cases}$$

P_k and p_n are defined in 17.3.5.10 (OFDM modulation)(#307)

$N_{SYM,\text{HE-SIG-B}}$ his the number of OFDM symbols in the HE-SIG-B field

26.3.10.8.4 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 26-20 (Common Block field(#2024)).

Table 26-20—Common Block field(#2024)

Subfield	Number of bits	Description
RU Allocation	*N* x 8	Indicates the RU arrangement 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 26.3.10.7.3 (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.(#1010)		

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:

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— The RU arrangement in the frequency domain: indexes the size of the RUs and their placement in the frequency domain.

— Number of user fields in each RU in 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 arrangement and the number of user fields per RU is defined in the Table 26-21 (RU allocation signaling: arrangement and number of MU-MIMO allocations(#2032)). In the table, the number of entries column refers to the number of 8-bit indices that refer to the same RU arrangement in the frequency domain but differ in the number of users fields per RU. The RU arrangement 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(#1001).

Table 26-21—RU allocation signaling: arrangement and number of MU-MIMO allocations(#2032)

8 bits indices (B7 B6 B5 B4 B3 B2 B1 B0)	#1	#2	#3	#4	#5	#6	#7	#8	#9	Number of entries
00000000	26	26	26	26	26	26	26	26	26	1
00000001	26	26	26	26	26	26	26	52		1
00000010	26	26	26	26	26	52		26	26	1
00000011	26	26	26	26	26	52		52		1
00000100	26	26	52		26	26	26	26	26	1
00000101	26	26	52		26	26	26	52		1
00000110	26	26	52		26	52		26	26	1
00000111	26	26	52		26(#1060)	52		52		1
00001000	52		26	26	26	26	26	26	26	1
00001001	52		26	26	26	26	26	52		1
00001010	52		26	26	26	52		26	26	1
00001011	52		26	26	26	52		52		1
00001100	52		52		26	26	26	26	26	1
00001101	52		52		26	26	26	52		1
00001110	52		52		26	52		26	26	1

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Table 26-21—RU allocation signaling: arrangement and number of MU-MIMO allocations(#2032) *(continued)*

00001111	52		52		26(#1060)	52		52				1
00010$y_2y_1y_0$	52		52		-	106						8
00011$y_2y_1y_0$	106				-	52		52				8
00100$y_2y_1y_0$	26	26	26	26	26	106						8
00101$y_2y_1y_0$	26	26	52		26(#1060)	106						8
00110$y_2y_1y_0$	52		26	26	26	106						8
00111$y_2y_1y_0$	52		52		26	106						8
01000$y_2y_1y_0$	106				26	26	26	26	26			8
01001$y_2y_1y_0$	106				26	26	26	52				8
01010$y_2y_1y_0$	106				26	52		26	26			8
01011$y_2y_1y_0$	106				26	52		52				8
0110$y_1y_0z_1z_0$	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(#2035)											4
011111x_1x_0	Reserved(#2035)											8
10$y_2y_1y_0z_2z_1z_0$	106				26	106						64
11000$y_2y_1y_0$	242											8
11001$y_2y_1y_0$	484											8
11010$y_2y_1y_0$	996											8

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Table 26-21—RU allocation signaling: arrangement and number of MU-MIMO allocations(#2032) *(continued)*

$11011y_2y_1y_0$	2×996	8
$111x_4x_3x_2x_1x_0$	Reserved(#2035)	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(#2035). 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(#2035). 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#2035). 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(#2035). 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.(#2035)

x_1x_0 = 00-11, $x_4x_3x_2x_1x_0$ = 00000-11111.(#2035)

'-' 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, for a 20 MHz and a 40 MHz PPDU, each HE-SIG-B content channel contains one RU Allocation subfield followed by multiple user fields. The position of the user-field in the user-specific field together with the 8-bit RU Allocation subfield 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 user fields corresponding to the first RU allocation signaling field are followed by the user fields indicated by the second RU allocation signaling 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 user fields for each of the 20 MHz segments in the content channel are arranged by the order in which their RU allocation signaling fields appear in the common field.(#2784)

26.3.10.8.5 HE-SIG-B per-user content

The user-specific field consists of multiple user fields. The user fields follow the common block field of HE-SIG-B. The RU allocation subfield in the Common block 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.(#1010) 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 26-25 (Illustration for the mapping of the 8-bit RU allocation subfield and the position of the user-field to the STA's assignment(PHY Motion #172)). The RU arrangement 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

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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.

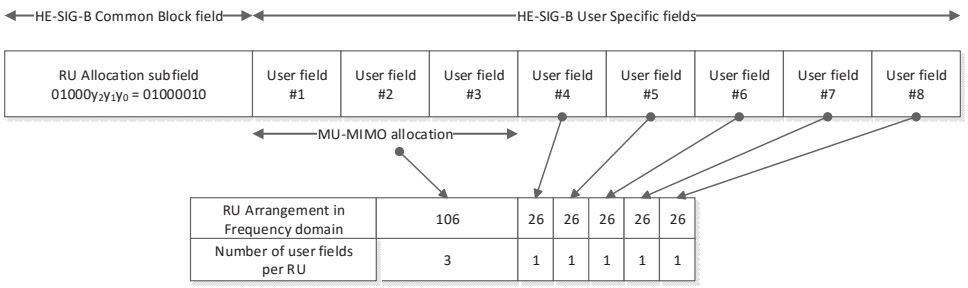


Figure 26-25—Illustration for the mapping of the 8-bit RU allocation subfield and the position of the user-field to the STA's assignment(PHY Motion #172)

The contents of the user field differ based on whether the field addresses a single-STA in an RU or a STA in an(#2817) MU-MIMO allocation in an RU. Irrespective of whether the allocation is for a STA in an(#196) SU or an MU-MIMO allocation, the size of the user field is the same.

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The HE-SIG-B user field for an(#916) SU allocation contain the subfields shown in Table 26-22 (Fields of the HE-SIG-B user field for an(#916) non-MU-MIMO(#1101) allocation(#2037)).

Table 26-22—Fields of the HE-SIG-B user field for an(#916) non-MU-MIMO(#1101) allocation(#2037)

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.(#1002) 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(#2681) — 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.(#Ed)
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

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Table 26-22—Fields of the HE-SIG-B user field for an(#916) non-MU-MIMO(#1101) allocation(#2037) *(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.(#1010)			

The HE-SIG-B user field for an STA in MU-MIMO allocation contain the subfields shown in Table 26-23 (Fields of the HE-SIG-B user field for an(#2817) MU-MIMO allocation(#2037)).

Table 26-23—Fields of the HE-SIG-B user field for an(#2817) MU-MIMO allocation(#2037)

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.(#1003)
B11-B14	Spatial Configuration	4	Indication for the number of spatial streams for a STA in an(#2817) MU-MIMO allocation. See Table 26-24 (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.(#1010)			

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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 26-24 (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(#310), 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(#310), 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}(#2786), 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(#310) 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(#310) 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 26-24—Spatial Configuration subfield encoding

N_{user}	B3...B0(#2035)	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	

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Table 26-24—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. For bandwidths larger than 20 MHz, the User block 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 block fields are carried in HE-SIG-B content channel 1 and $\lceil k/2 \rceil + 1, \ldots, k$ User block fields in HE-SIG-B content channel 2.(#2543)

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 26-24 (Spatial Configuration subfield encoding) under the column Total Nsts(#311).

26.3.10.9 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 $T_{\text{HE-STF-NT}}$(#312) (periodicity of 0.8 μs with 5 periods) and the duration of the HE-STF field for an HE trigger-based PPDU is $T_{\text{HE-STF-T}}$(#312) (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 (26-22).

$$i_{STF} \bmod 16 = 0, \lfloor N_{DC}/2 \rfloor < |i_{STF}| \le N_{SR}$$
$$i_{STF} : \text{HE-STF tone index} \qquad (26\text{-}22)$$

The tone indices for HE-STF fields for an HE trigger-based PPDU are defined in Equation (26-23).

$$i_{STF} \bmod 8 = 0, \lfloor N_{DC}/2 \rfloor < |i_{STF}| \le N_{SR}$$
$$i_{STF} : \text{HE-STF tone index} \qquad (26\text{-}23)$$

For the HE-STF field, the M sequence is defined by Equation (26-24).

$$M = \{-1, -1, -1, 1, 1, 1, -1, 1, 1, 1, -1, 1, 1, -1, 1\} \qquad (26\text{-}24)$$

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.(#313)

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For a 20 MHz transmission, the frequency domain sequence for HE PPDUs except HE trigger-based PPDUs is given by Equation (26-25).

$$HES_{-112:16:112} = \{M\} \cdot (1+j)/\sqrt{2}$$
$$HES_{0} = 0 \quad (26\text{-}25)$$

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 (26-26).

$$HES_{-240:16:240} = \{M, 0, -M\} \cdot (1+j)/\sqrt{2} \quad (26\text{-}26)$$

For an 80 MHz transmission, the frequency domain sequence for HE PPDUs except HE trigger-based PPDUs is given by Equation (26-27).

$$HES_{-496:16:496} = \{M, 1, -M, 0, -M, 1, -M\} \cdot (1+j)/\sqrt{2} \quad (26\text{-}27)$$

For a 160 MHz transmission, the frequency domain sequence for HE PPDUs except HE trigger-based PPDUs is given by Equation (26-28).(#529)

$$HES_{-1008:16:1008} = \{M, 1, -M, 0, -M, 1, -M, 0, -M, -1, M, 0, -M, 1, -M\} \cdot (1+j)/\sqrt{2} \quad (26\text{-}28)$$

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 (26-27).

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 (26-29).(#529)

$$HES_{-496:16:496} = \{-M, -1, M, 0, -M, 1, -M\} \cdot (1+j)/\sqrt{2} \quad (26\text{-}29)$$

For a 20 MHz transmission, the frequency domain sequence for HE trigger-based PPDUs is given by Equation (26-30).

$$HES_{-120:8:120} = \{M, 0, -M\} \cdot (1+j)/\sqrt{2} \quad (26\text{-}30)$$

For a 40 MHz transmission, the frequency domain sequence for HE trigger-based PPDUs is given by Equation (26-31).

$$HES_{-248:8:248} = \{M, -1, -M, 0, M, -1, M\} \cdot (1+j)/\sqrt{2}$$
$$HES_{\pm 248} = 0 \quad (26\text{-}31)$$

For an 80 MHz transmission, the frequency domain sequence for HE trigger-based PPDUs is given by Equation (26-32).

$$HES_{-504:8:504} = \{M, -1, M, -1, -M, -1, M, 0, -M, 1, M, 1, -M, 1, -M\} \cdot (1+j)/\sqrt{2}$$
$$HES_{\pm 504} = 0 \quad (26\text{-}32)$$

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For a 160 MHz transmission, the frequency domain sequence for HE trigger-based PPDUs is given by Equation (26-33).(#530)

$$HES_{-1016:8:1016} = \{M, -1, M, -1, -M, -1, M, 0, -M, 1, M, 1, -M, 1, -M, 0$$
$$-M, 1, -M, 1, M, 1, -M, 0, -M, 1, M, 1, -M, 1, -M\} \cdot (1+j)/\sqrt{2} \quad (26\text{-}33)$$
$$HES_{\pm 8} = 0, HES_{\pm 1016} = 0$$

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 (26-32).(#530)

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 (26-34).(#530)

$$HES_{-504:8:504} = \{-M, 1, -M, 1, M, 1, -M, 0, -M, 1, M, 1, -M, 1, -M\} \cdot (1+j)/\sqrt{2}$$
$$HES_{\pm 504} = 0 \quad (26\text{-}34)$$

For an OFDMA transmission, the coefficients in Equation (26-25) to Equation (26-32) are set to zero if those values are corresponding to tone indices for which no RUs are defined (see 26.3.9 (Mathematical description of signals))(#917).

The time domain representation of the signal for HE PPDUs except HE trigger-based PPDUs on frequency segment i_{Seg} of transmit chain i_{TX} shall be as specified in Equation (26-35).

$$r_{\text{HE-STF}}^{(i_{Seg} i_{TX})}(t) = w_{T_{\text{HE-STF-NT}}}(t) \cdot \sum_{r=0}^{N_{RU}-1} \frac{\alpha_r \beta_r}{\sqrt{N_{STS,r,total}}} \quad (26\text{-}35)$$
$$\sum_{k \in K} \sum_{u=0}^{N_{user,r}-1} \sum_{m=1}^{N_{STS,r,u}} \left(\eta_{\text{HE-STF},k} \left[Q_k^{(i_{Seg})} \right]_{i_{TX}, M_{r,u}+m} HES_k \cdot \exp(j2\pi k \Delta_{F,\text{HE}} (t - T_{CS,HE}(M_{r,u}+m))) \right)$$

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].(#1689)

$\eta_{\text{HE-STF},k}$ is an HE PPDU format dependent scaling factor, defined by

$$\eta_{\text{HE-STF},k} = \begin{cases} \sqrt{2}, & \text{for an HE extended range SU PPDU} \\ 1, & \text{otherwise} \end{cases} \text{(\#2045)(\#526)}$$

β_r is the per-RU power normalization factor and defined by

$$\beta_r = \left(\sqrt{\frac{|K_r|}{|K_r^{\text{HE-STF}}|}} \right) / \left(\sqrt{\sum_{r=1}^{N_{RU}} \alpha_r^2 |K_r|} \right) \text{(\#315)}$$

$|K_r|$ 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(#2046)

$T_{CS,\text{HE}}(M_{r,u}+m)$ represents the cyclic shift for space time stream $M_{r,u}+m$ as defined in 26.3.10.2.2 (Cyclic shift for HE modulated fields)(#1052)

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$Q_k^{(i_{Seg})}$ is defined in 26.3.9 (Mathematical description of signals)(#1094)

$w_{T_{\text{HE-STF-NT}}}$ is the windowing function for HE-STF field in the non-HE trigger-based PPDU

The time domain representation of the signal for HE trigger-based PPDUs on frequency segment i_{Seg} of transmit chain i_{TX} shall be as specified in Equation (26-36).

$$r_{\text{HE-STF}}^{(i_{Seg}i_{TX})}(t) = \frac{1}{\sqrt{\left|K_r^{\text{HE-STF}}\right| N_{STS,\,r,\,total}}} w_{T_{\text{HE-STF-T}}}(t) \sum_{k \in K} \sum_{m=1}^{N_{STS,\,r,\,u}} \left(\left[Q_k^{(i_{Seg})} \right]_{i_{TX},\,(M_{r,\,u}+m)} HES_k \cdot \exp(j2\pi k \Delta_{F,\,\text{HE}}(t - T_{CS,\,HE}(M_{r,\,u}+m))) \right) \quad \text{(\#316)} \quad \text{(26-36)}$$

where

$w_{T_{\text{HE-STF-T}}}$ is the windowing function for HE-STF field in the HE trigger-based PPDU

26.3.10.10 HE-LTF

The HE-LTF field(#918) 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. A 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 tones 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 tones 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)(PHY Motion #159), 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 26-12 (Frequently used parameters(#282))(#2792). In an HE trigger-based PPDU, $N_{\text{HE-LTF}}$(#922) is indicated in the Trigger frame that triggers the transmission of the PPDU. In an HE MU PPDU, $N_{\text{HE-LTF}}$(#922) is indicated in the HE-SIG-A field. In an HE MU PPDU with more than one RU and an HE trigger-based PPDU, $N_{\text{HE-LTF}}$(#922) may take any value among one, two, four, six or eight, which is greater than or equal to the maximum value of the function in Table 26-12 (Frequently used parameters(#282)) when it is calculated for each $N_{STS,r,total}$ separately.(PHY Motion #159)

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.(PHY Motion #159) 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:

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— 2x HE-LTF, $T_{GI1,Data}$(#2498)

— 2x HE-LTF, $T_{GI2,Data}$(#2496)

— 4x HE-LTF, $T_{GI4,Data}$(#2497)

The optional combinations of HE-LTF mode and GI duration are:

— 1x HE-LTF, $T_{GI1,Data}$(#2499) in an(#2829) HE SU PPDU or HE extended SU PPDU

— 1x HE-LTF, $T_{GI1,Data}$(#2500) in a non-OFDMA, MU-MIMO HE MU PPDU

— 1x HE-LTF, $T_{GI2,Data}$(#2501) in a non-OFDMA, MU-MIMO HE trigger-based PPDU

The duration of each HE-LTF symbol is $T_{\text{HE-LTF}}$(#2875) is defined in Equation (26-37). 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.

$$T_{\text{HE-LTF}} = \begin{cases} T_{\text{HE-LTF-1X}}, \text{ if 1x HE-LTF} \\ T_{\text{HE-LTF-2X}}, \text{ if 2x HE-LTF} \\ T_{\text{HE-LTF-4X}}, \text{ if 4x HE-LTF} \end{cases} \quad (26\text{-}37)$$

where $T_{\text{HE-LTF-1X}}$, $T_{\text{HE-LTF-2X}}$, $T_{\text{HE-LTF-4X}}$ are defined in Table 26-9 (Timing-related constants).

In a 20 MHz transmission, the 1x HE-LTF sequence transmitted and located on subcarriers [−122:122](#2553) is given by Equation (26-38).

$$\begin{aligned} &HELTF_{-122,122} = \\ &\{0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, \\ &0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, \\ &-1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, \\ &0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, 0, 0, 0, \\ &0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, \\ &0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, \\ &0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, \\ &−1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0\} \end{aligned} \quad (26\text{-}38)$$

In a 20 MHz transmission, the 2x HE-LTF sequence transmitted and located on subcarriers [−122:122](#2553) is given by Equation (26-39).

$$\begin{aligned} &HELTF_{-122,122} = \\ &\{−1, 0, −1, 0, −1, 0, +1, 0, +1, 0, −1, 0, +1, 0, −1, 0, −1, 0, −1, 0, −1, 0, +1, 0, −1, 0, +1, \\ &0, −1, 0, −1, 0, +1, 0, +1, 0, −1, 0, +1, 0, +1, 0, +1, 0, +1, 0, +1, 0, −1, 0, +1, 0, −1, 0, +1, \\ &0, −1, 0, −1, 0, +1, 0, +1, 0, −1, 0, +1, 0, −1, 0, −1, 0, −1, 0, −1, 0, +1, 0, −1, 0, +1, 0, +1, \\ &0, +1, 0, −1, 0, −1, 0, +1, 0, −1, 0, −1, 0, −1, 0, −1, 0, −1, 0, +1, 0, −1, 0, −1, 0, −1, 0, +1, \\ &0, +1, 0, +1, 0, −1, 0, −1, 0, +1, 0, 0, 0, +1, 0, −1, 0, +1, 0, +1, 0, −1, 0, +1, 0, +1, 0, −1, \\ &0, +1, 0, +1, 0, −1, 0, −1, 0, +1, 0, −1, 0, +1, 0, +1, 0, +1, 0, +1, 0, −1, 0, +1, 0, −1, 0, +1, \\ &0, +1, 0, −1, 0, −1, 0, +1, 0, −1, 0, −1, 0, −1, 0, −1, 0, −1, 0, +1, 0, −1, 0, +1, 0, +1, 0, −1, \\ &0, −1, 0, +1, 0, +1, 0, −1, 0, +1, 0, −1, 0, −1, 0, −1, 0, −1, 0, +1, 0, −1, 0, +1, 0, +1, 0, +1, \\ &0, −1, 0, −1, 0, +1, 0, −1, 0, −1, 0, −1, 0, −1, 0, −1, 0, +1, 0, −1, 0, +1\} \end{aligned} \quad (26\text{-}39)$$

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In a 20 MHz transmission, the 4x HE-LTF sequence transmitted and located on subcarriers [−122:122](#2553) is given by Equation (26-40).

$$
\begin{aligned}
&HELTF_{-122,122} = \\
&\{-1, -1, +1, -1, +1, -1, +1, +1, +1, -1, +1, +1, +1, -1, -1, +1, -1, -1, -1, -1, -1, +1, \\
&+1, -1, -1, -1, -1, +1, +1, -1, +1, -1, +1, +1, +1, +1, -1, +1, -1, -1, +1, +1, -1, +1, +1, \\
&+1, +1, -1, -1, +1, -1, -1, -1, +1, +1, +1, +1, -1, +1, +1, -1, -1, -1, -1, +1, -1, -1, +1, \\
&+1, -1, +1, -1, -1, -1, -1, +1, -1, +1, -1, -1, -1, -1, -1, -1, +1, +1, -1, -1, -1, -1, -1, \\
&+1, -1, -1, +1, +1, +1, -1, +1, +1, +1, -1, +1, -1, +1, -1, -1, -1, -1, -1, +1, +1, +1, -1, \\
&-1, -1, +1, -1, +1, +1, +1, 0, 0, 0, -1, +1, -1, +1, -1, +1, +1, -1, +1, +1, +1, -1, -1, +1, \\
&-1, -1, +1, -1, +1, -1, +1, +1, +1, -1, +1, +1, +1, -1, -1, -1, -1, -1, -1, +1, +1, \\
&-1, -1, -1, -1, -1, -1, +1, -1, +1, -1, -1, -1, -1, +1, -1, +1, +1, -1, -1, +1, -1, -1, -1, \\
&-1, +1, +1, -1, +1, +1, +1, +1, +1, +1, +1, -1, +1, +1, -1, -1, -1, -1, +1, -1, -1, +1, +1, \\
&-1, +1, -1, -1, -1, -1, +1, -1, +1, -1, -1, +1, +1, +1, +1, -1, -1, +1, +1, +1, +1, +1, -1, \\
&+1, +1, -1, -1, -1, +1, -1, -1, -1, +1, -1, +1, -1, +1, +1\}
\end{aligned}
\tag{26-40}
$$

In a 40 MHz transmission, the 1x HE-LTF sequence transmitted and located on subcarriers [−244:244](#2553) is given by Equation (26-41).

$$
\begin{aligned}
&HELTF_{-244,244} = \\
&\{+1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, \\
&0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, \\
&0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, \\
&0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, \\
&-1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, \\
&0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, \\
&0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, \\
&0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, 0, 0, 0, 0, +1, \\
&0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, \\
&+1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, \\
&0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, \\
&0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, \\
&0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, \\
&+1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, \\
&0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, \\
&0, 0, +1, 0, 0, 0, -1, 0, 0, 0, -1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1\}
\end{aligned}
\tag{26-41}
$$

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In a 40 MHz transmission, the 2x HE-LTF sequence transmitted and located on subcarriers [–244:244](#2553) is given by Equation (26-42).

$$
\begin{aligned}
&HELTF_{-244,244} = \\
&\{+1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, \\
&0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, \\
&0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, \\
&0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, \\
&0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, \\
&0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, \\
&0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, \\
&0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, \\
&0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, -1, 0, \\
&-1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, \\
&-1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, +1, 0, \\
&+1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, \\
&-1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, +1, 0, +1, 0, \\
&+1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, \\
&-1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, \\
&+1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, \\
&-1, 0, -1, 0, +1, 0, -1, 0, +1, 0, -1, 0, +1\}
\end{aligned}
\tag{26-42}
$$

In a 40 MHz transmission, the 4x HE-LTF sequence transmitted and located on subcarriers [–244:244](#2553) is given by Equation (26-43).

$$
\begin{aligned}
&HELTF_{-244,244} = \\
&\{+1, -1, -1, -1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, -1, +1, +1, -1, +1, -1, -1, -1, \\
&+1, +1, -1, -1, -1, -1, -1, -1, -1, +1, -1, -1, +1, +1, -1, +1, -1, -1, -1, -1, -1, +1, -1, \\
&+1, +1, +1, -1, -1, +1, +1, +1, -1, -1, +1, +1, +1, +1, -1, +1, +1, -1, -1, +1, -1, +1, -1, \\
&+1, -1, -1, +1, -1, +1, +1, +1, -1, -1, +1, +1, +1, -1, -1, -1, -1, +1, -1, -1, +1, +1, -1, \\
&+1, -1, -1, -1, -1, -1, +1, -1, +1, +1, +1, -1, -1, +1, +1, +1, +1, +1, +1, +1, +1, -1, +1, \\
&+1, -1, -1, +1, -1, +1, +1, +1, +1, +1, -1, +1, -1, -1, -1, +1, +1, -1, -1, -1, -1, -1, -1, \\
&-1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, -1, +1, +1, -1, +1, -1, -1, -1, +1, +1, -1, -1, \\
&-1, -1, -1, -1, -1, +1, -1, -1, +1, +1, -1, +1, -1, -1, -1, -1, -1, +1, -1, +1, +1, +1, -1, \\
&-1, +1, +1, +1, -1, -1, -1, -1, -1, -1, +1, -1, -1, +1, +1, -1, +1, -1, +1, -1, +1, +1, -1, \\
&+1, -1, -1, -1, +1, +1, -1, -1, -1, +1, +1, +1, +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\}
\end{aligned}
\tag{26-43}
$$

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In an 80 MHz transmission, the 1x HE-LTF sequence transmitted and located on subcarriers [−500:500](#2553) is given by Equation (26-44).

$$
\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, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, \\
&−1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, \\
&0, +1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, +1, 0, 0, 0, −1, 0, \\
&0, 0, −1, 0, 0, 0, −1, 0, 0, 0, +1, 0, 0, 0, −1, 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{26-44}
$$

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In an 80 MHz transmission, the 2x HE-LTF sequence transmitted and located on subcarriers [−500:500](#2553) is given by Equation (26-45).

$$
\begin{aligned}
&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, +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\}
\end{aligned}
\tag{26-45}
$$

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In an 80 MHz transmission, the 4x HE-LTF sequence transmitted and located on subcarriers [−500:500](#2553) is given by Equation (26-46).

$$
\begin{aligned}
&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,+1,0,0,0,0,0,+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,+1\}
\end{aligned}
\tag{26-46}
$$

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In a 160 MHz transmission, the 1x HE-LTF sequence is given by Equation (26-47).

$$HELTF_{-1012,1012} = \{LTF_{80\text{MHz_primary_1x}}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, LTF_{80\text{MHz_secondary_1x}}\} \quad (26\text{-}47)$$

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

$LTF_{80\text{MHz_secondary_1x}} = \{LTF_{80\text{MHz_left_1x}}, 0, (-1)*LTF_{80\text{MHz_right_1x}}\}$ 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}(#2558)(#2554)(#1865)

In a 160 MHz transmission, the 2x HE-LTF sequence is given by Equation (26-48).

$$HELTF_{-1012,1012} = \{LTF_{80\text{MHz_primary_2x}}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, LTF_{80\text{MHz_secondary_2x}}\} \quad (26\text{-}48)$$

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where

$$LTF_{80\text{MHz_primary_2x}} = \{LTF_{80\text{MHz_part1_2x}}, LTF_{80\text{MHz_part2_2x}}, LTF_{80\text{MHz_part3_2x}}, LTF_{80\text{MHz_part4_2x}}, LTF_{80\text{MHz_part5_2x}}\} \quad (26\text{-}49)$$

$$LTF_{80\text{MHz_secondary_2x}} = \{LTF_{80\text{MHz_part1_2x}}, LTF_{80\text{MHz_part2_2x}}, LTF_{80\text{MHz_part3_2x}}, LTF_{80\text{MHz_part4_2x}}, LTF_{80\text{MHz_part5_2x}}\} \quad (26\text{-}50)$$

$$\begin{aligned}LTF_{80\text{MHz_part1_2x}} = \{&+1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0,\\ &-1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0,\\ &+1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0,\\ &+1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0,\\ &-1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0,\\ &-1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0,\\ &+1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0,\\ &+1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0,\\ &+1, 0, -1, 0, +1, 0\}\end{aligned}$$

$$\begin{aligned}LTF_{80\text{MHz_part2_2x}} = \{&+1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0,\\ &+1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0,\\ &+1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0,\\ &-1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0,\\ &-1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0,\\ &+1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0,\\ &+1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0,\\ &-1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0,\\ &+1, 0, +1, 0, +1, 0\}\end{aligned}$$

$$\begin{aligned}LTF_{80\text{MHz_part3_2x}} = \{&+1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, 0, 0, 0, 0, 0, 0, +1, 0, -1, 0, -1, 0, +1,\\ &0, +1, 0, -1, 0, +1\}\end{aligned}$$

$$\begin{aligned}LTF_{80\text{MHz_part4_2x}} = \{&0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1,\\ &0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1,\\ &0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1,\\ &0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1,\\ &0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1,\\ &0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1,\\ &0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1,\\ &0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1,\\ &0, +1, 0, +1, 0, -1\}\end{aligned}$$

$$\begin{aligned}LTF_{80\text{MHz_part5_2x}} = \{&0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1,\\ &0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1,\\ &0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1,\\ &0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1,\\ &0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1,\\ &0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1,\\ &0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1,\\ &0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1,\\ &0, -1, 0, +1, 0, +1\}\end{aligned}$$ (#2556)

In a 160 MHz transmission, the 4x HE-LTF sequence is given by Equation (26-51).

$$HELTF_{-1012,1012} = \{LTF_{80\text{MHz_primary_4x}}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, LTF_{80\text{MHz_secondary_4x}}\} \quad (26\text{-}51)$$

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where

$$LTF_{80MHz\_primary\_4x} = \{LTF_{80MHz\_left\_4x}, 0, LTF_{80MHz\_right\_4x}\} \quad (26\text{-}52)$$

$$LTF_{80MHz\_secondary\_4x} = \{LTF_{80MHz\_left\_4x}, 0, (-1)^{*}LTF_{80MHz\_right\_4x}\} \quad (26\text{-}53)$$

$LTF_{80MHz\_left\_4x}$ = {+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}

$LTF_{80MHz\_right\_4x}$ = {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,
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−1, −1, −1, −1, +1, −1, −1, +1, +1, +1, −1, +1, +1, −1, −1, +1, −1, +1, −1, +1, +1, +1, −1, +1,
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+1, −1, +1, +1, −1, +1, +1, −1, +1, −1, −1, −1, +1, +1, −1, +1, +1, +1, −1, −1, +1, +1, +1, +1,
+1, −1, +1, +1, +1, +1, +1, −1, −1, +1, +1, +1, +1, +1, −1, +1, +1, −1, −1, −1, +1, −1, −1, −1,
+1, −1, +1, −1, +1, +1, +1, +1, +1, −1, −1, −1, +1, +1, +1, +1, −1, +1, +1, −1, −1, −1, +1, −1,
−1, +1, +1, −1, +1, −1, +1, −1, −1, −1, −1, −1, −1, −1, +1, +1, −1, −1, −1, +1, −1, −1, +1, +1, +1,
−1, +1, −1, −1, +1, −1, −1, +1, −1, +1, −1, +1, −1, +1, −1, −1, +1, +1, −1, +1, −1, +1, +1, +1,
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−1, −1, +1, +1, −1, +1, +1, +1, −1, −1, +1, +1, +1, +1, +1, −1, +1, −1, −1, −1, −1, +1, +1, −1,
−1, −1, −1, −1, +1, −1, −1, +1, +1, +1, −1, +1, +1, +1, −1, +1, −1, +1, −1, −1, −1, −1, −1, +1,
+1, +1, −1, −1, −1, −1, +1, −1, −1, +1, +1, +1, −1, +1, +1, −1, −1, +1, −1, +1, −1, +1}

For an 80+80 MHz transmission, the primary 80 MHz frequency segment shall use the 80 MHz 1x HE-LTF sequence, $HELTF_{-500,500} = LTF_{80MHz\_primary\_1x}$, and the secondary 80 MHz frequency segment shall use the 80 MHz 1x HE-LTF sequence, $HELTF_{-500,500} = LTF_{80MHz\_secondary\_1x}$.

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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, $HELTF_{-500,500} = LTF_{80\text{MHz\_secondary\_4x}}$.(#323)(#2557)

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 (26-54).

$$HELTF_k' = \begin{cases} HELTF_k \cdot Porth_k^{\,u}, & \text{if } HELTF_k \neq 0 \\ HELTF_k, & \text{if } HELTF_k = 0 \end{cases} \tag{26-54}$$

Where $HELTF_k$ is the k-th element of the common HE-LTF sequence generated by the one of the bandwidth specific $HELTF$ equations above(#Ed). For user u of any UL MU-MIMO frequency allocation, the orthogonal code $Porth_k^{\,u}$ is defined by Equation (26-55).

$$Porth_k^{\,u} = \left\{ \left[P_{8\times 8}\right]_u^1, \left[P_{8\times 8}\right]_u^2, \ldots, \left[P_{8\times 8}\right]_u^{\frac{N_{\text{nz-HE-LTF}}}{8}}, \left[P_{8\times 8}\right]_{u,\,1:M} \right\} \tag{26-55}$$

Where $\left[P_{8\times 8}\right]_u^i$, $i = 1, 2, \ldots, \left\lfloor \frac{N_{\text{nz-HE-LTF}}}{8} \right\rfloor$ is the i-th repetition of the u-th row of the $P_{8\times 8}$ matrix defined in Equation (22-46). $N_{\text{nz-HE-LTF}}$ is the number of nonzero elements in the common HE-LTF. $\left[P_{8\times 8}\right]_{u,\,1:M}$ is the first M elements of the u-th row of the $P_{8\times 8}$. If $N_{\text{nz-HE-LTF}}$ is not a multiple of 8, the remaining M nonzero elements of the common HE-LTF sequence are masked by the first M elements of the orthogonal code.(#1059)

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 (#1059)is shown in Figure 26-26

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(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(#1059)) where $A^{k}_{\text{HE-LTF}}$ is given by Equation (26-56).

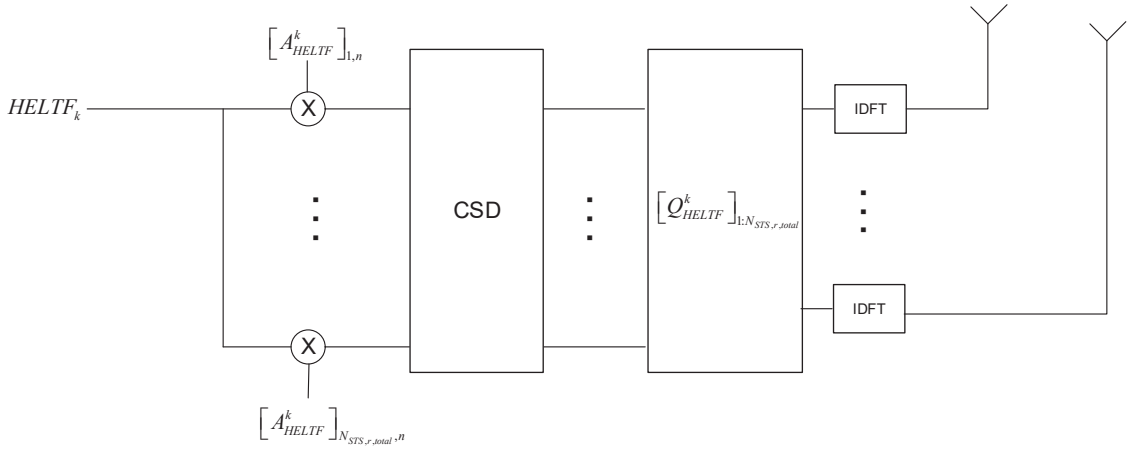


Figure 26-26—Generation of HE-LTF symbols per frequency segment in an HE SU PPDU, HE MU PPDU, HE extended range SU PPDU and HE trigger-based PPDU(#1059)

$A^{k}_{\text{HE-LTF}}$ is given by Equation (26-56).

$$A^{k}_{\text{HE-LTF}} = \begin{cases} R_{\text{HE-LTF}}, \text{ if } k \in K_{\text{Pilot}} \text{ and single stream pilots are used} \\ P_{\text{HE-LTF}}, \text{ otherwise} \end{cases} \quad (26\text{-}56)$$

where

K_{Pilot} is the set of subcarrier indices for the pilot tones as defined in 26.3.3.3 (Pilot tones)(#2794).

$R_{\text{HE-LTF}}$ is a $N_{\text{HE-LTF}} \times N_{\text{HE-LTF}}$ matrix whose elements are defined in Equation (26-57)(#2877).

$$\left[R_{\text{HE-LTF}}\right]_{m,n} = \left[P_{\text{HE-LTF}}\right]_{1,n}, 1 \le m, n \le N_{\text{HE-LTF}} \quad (26\text{-}57)$$

$P_{\text{HE-LTF}}$ is defined in Equation (26-58).

$$P_{\text{HE-LTF}} = \begin{cases} P_{4\times 4}, N_{\text{HE-LTF}} \le 4 \\ P_{6\times 6}, N_{\text{HE-LTF}} = 6 \\ P_{8\times 8}, N_{\text{HE-LTF}} = 8 \end{cases} \quad (26\text{-}58)$$

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)(#2878).

When the 1x HE-LTF is used for non-OFDMA UL MU-MIMO, single stream pilot are not used.(#1059)

In an HE SU PPDU, HE MU PPDU, HE extended range SU PPDU and HE trigger-based PPDU(#1059), the time domain representation of the waveform transmitted on frequency segment i_{Seg} of transmit chain i_{TX} shall be as described by Equation (26-59)(#2798).

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$$s_{\text{HE-LTF}}^{(i_{Seg} i_{TX})}(t) = \frac{\eta_{\text{HE-LTF-Mode}}}{\sqrt{\sum_{r=0}^{N_{RU}-1} \alpha_r^2 |K_r|}} \sum_{n=0}^{N_{\text{HE-LTF}}-1} w_{T_{\text{HE-LTF}}}(t - nT_{\text{HE-LTF}}) \sum_{r=0}^{N_{RU}-1} \frac{\alpha_r}{\sqrt{N_{STS,r,total}}} \eta_{\text{HE-LTF},k} \quad (26\text{-}59)$$

$$\sum_{k \in K_r} \sum_{u=0}^{N_{user,r}-1} \sum_{m=1}^{N_{STS,r,u}} \left(\left[Q_k^{(i_{Seg})} \right]_{i_{TX},(M_{r,u}+m)} \left[A_{\text{HE-LTF}}^{k} \right]_{(M_{r,u}+m),(n+1)} HELTF_k'' \cdot \exp(j2\pi k \Delta_{F,\text{HE}}(t - nT_{\text{HE-LTF}} - T_{GI} - T_{CS,\text{HE}}(M_{r,u}+m))) \right)$$

(#1050)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.(#1059)

26.3.11 Data field

26.3.11.1 General

The number of OFDM symbols in the Data field is determined by the Length field in L-SIG (see Equation (26-12)(#1625)), the preamble duration and the settings of the GI+LTF Size(#1420), Pre-FEC Padding Factor(#2564) and PE Disambiguity fields(#2560) in the HE-SIG-A field (see 26.3.10.7 (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.(#2561)

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 (bits for SU and bits for each user u in MU). 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.

26.3.11.2 Pre-FEC encoding 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(#2829) HE PPDU, the 4 possible boundaries partition(#1837) 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(#326)(#2564).

Figure 26-27 (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 as shown in Figure 26-28 (HE PPDU padding process in the last OFDM symbol (STBC) when a = 1), are modulated into the last two OFDM symbols by STBC

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encoding, each with the same number of effective symbol segments, the pre-FEC padding factor(#2564) being 1.

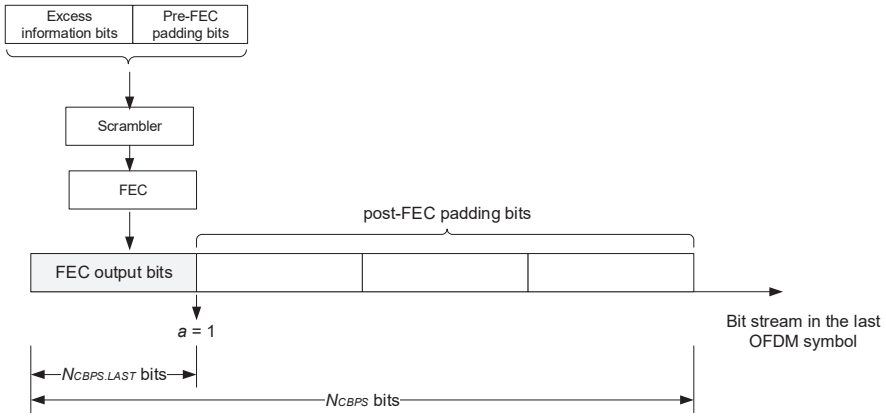


Figure 26-27—HE PPDU padding process in the last OFDM symbol (non STBC) when *a* = 1

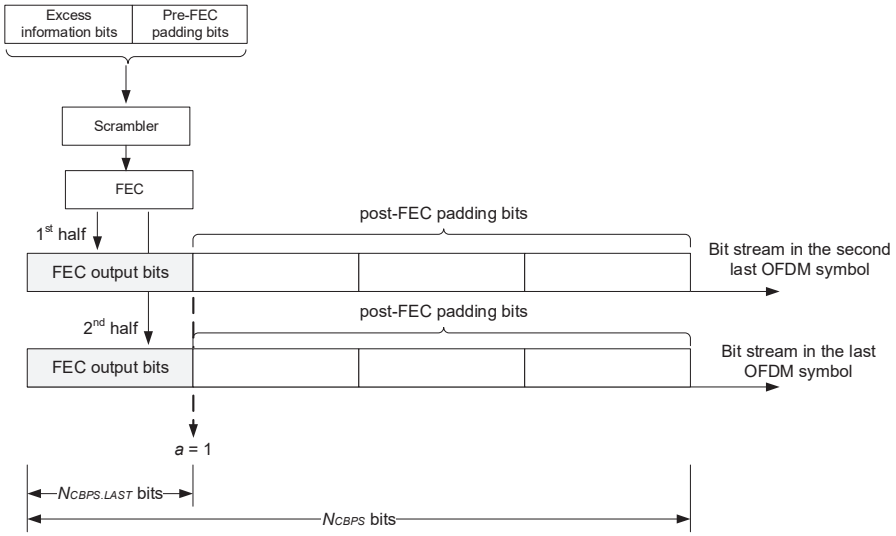


Figure 26-28—HE PPDU padding process in the last OFDM symbol (STBC) when *a* = 1

The pre-FEC padding process is described in this subclause, and the encoding and post-FEC padding process are described in 26.3.11.5 (Coding)(#1113). While this subclause describes the pre-FEC padding processing of an SU transmission, its extension to MU transmission is described in 25.3.10.3.4 (Encoding Process for HE MU PPDUs).

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 (26-60).

$$N_{Excess} = mod(8 \cdot \text{APEP\_LENGTH} + N_{Tail} + N_{service}, m_{STBC} \cdot N_{DBPS}) \quad (26\text{-}60)$$

where

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m_{STBC} is 2 when STBC is used, and 1 otherwise
APEP_LENGTH is the TXVECTOR parameter APEP_LENGTH

(#2521)Based(#2060) on N_{Excess}, compute the initial number of symbol segments in the last OFDM symbol(s), pre-FEC padding factor(#1626)(#2564) value or a_{init}, as shown in Equation (26-61).

$$a_{init} = \begin{cases} 4, & \text{if } N_{Excess} = 0 \\ \min\left(\left\lceil \frac{N_{Excess}}{m_{STBC} \cdot N_{DBPS,SHORT}} \right\rceil, 4\right), & \text{otherwise} \end{cases} \quad \text{(PHY Motion \#174)} \qquad (26\text{-}61)$$

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 26-25 (NSD,SHORT values(#1857)).

Table 26-25—$N_{SD,SHORT}$ values(#1857)

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 (26-62).

$$N_{DBPS.LAST.init} = \begin{cases} a_{init} N_{DBPS.SHORT}, & \text{if } a_{init} < 4 \\ N_{DBPS}, & \text{if } a_{init} = 4 \end{cases}$$

$$N_{CBPS.LAST.init} = \begin{cases} a_{init} N_{CBPS.SHORT}, & \text{if } a_{init} < 4 \\ N_{CBPS}, & \text{if } a_{init} = 4 \end{cases} \qquad (26\text{-}62)$$

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For an(#2829) HE SU PPDU with BCC encoding, the number of pre-FEC pad bits is calculated using Equation (26-63).

$$N_{PAD,\text{ Pre-FEC}} = (N_{SYM.init} - m_{STBC})N_{DBPS} + m_{STBC}N_{DBPS.LAST.init} - 8 \cdot \text{APEP\_LENGTH} - N_{Tail} - N_{service} \quad (26\text{-}63)$$

where $N_{SYM.init}$ is defined as in Equation (26-66) for BCC encoding, and Equation (26-71)(#2802) for LDPC encoding.

For an(#2829) HE SU PPDU with LDPC encoding, the number of pre-FEC pad bits is calculated using Equation (26-64).

$$N_{PAD,\text{ Pre-FEC}} = (N_{SYM.init} - m_{STBC})N_{DBPS} + m_{STBC}N_{DBPS.LAST.init} - 8 \cdot \text{APEP\_LENGTH} - N_{service} \quad (26\text{-}64)$$

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 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 (26-65).

$$N_{PAD,\text{ Pre-FEC,MAC}} = \left\lfloor \frac{N_{PAD,\text{ Pre-FEC}}}{8} \right\rfloor \cdot 8$$
$$N_{PAD,\text{ Pre-FEC,PHY}} = N_{PAD,\text{ Pre-FEC}} \bmod 8 \quad (26\text{-}65)$$

26.3.11.3 SERVICE field

The SERVICE field of HE PPDU is as shown in Table 26-26 (SERVICE field).

Table 26-26—SERVICE field

Bits	Field	Description
B0-B6	Scrambler Initialization	Set to 0
B7-B15	Reserved	Set to 0

26.3.11.4 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 a HE MU PPDU.(#2442)

26.3.11.5 Coding

The Data field shall be encoded using either the binary convolutional code (BCC) defined in 26.3.11.5.1 (Binary convolutional coding and puncturing) or the low density parity check (LDPC) code defined in

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26.3.11.5.2 (LDPC coding)(#2803). 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(#2829) HE MU PPDU, as defined in 26.3.10.7 (HE-SIG-A) and 26.3.10.8 (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(#838). 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.(PHY Motion #158) 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(PHY Motion #158), 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.

26.3.11.5.1 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)(#2804) (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)(#2805).

The initial number of OFDM symbols in the Data field with BCC encoding in an(#2829) HE SU PPDU is calculated using Equation (26-66).

$$N_{SYM,\,init} = m_{STBC} \cdot \left\lceil \frac{8 \cdot \text{APEP\_LENGTH} + N_{Tail} + N_{service}}{m_{STBC} N_{DBPS}} \right\rceil \text{(\#282)} \qquad \text{(26-66)}$$

For an(#2829) HE SU PPDU with BCC encoding,

$$N_{SYM} = N_{SYM.init} \qquad \text{(26-67)}$$

and

$$a = a_{init} \qquad \text{(26-68)}$$

The number of data bits per symbol in the last OFDM symbol(s) of an HE SU PPDU is $N_{DBPS.LAST} = N_{DBPS.LAST.init}$.(#328)

The number of coded bits per symbol in the last OFDM symbol(s) of an(#2829) HE SU PPDU is given by Equation (26-69).

$$N_{CBPS,\,LAST} = \begin{cases} a \cdot N_{CBPS,\,SHORT}, & \text{if } a < 4 \\ N_{CBPS}, & \text{if } a = 4 \end{cases} \qquad \text{(26-69)}$$

26.3.11.5.2 LDPC coding

For an(#2829) 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)(#2806) shall be used with the following modifications. First,

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all bits in the Data field including the scrambled SERVICE, PSDU, and pre-FEC pad bits are encoded, i.e., $N_{pld} = N_{service} + 8 \times \text{APEP\_LENGTH} + N_{PAD,Pre\text{-}FEC}$(#2067). Thus, N_{pld} for HE PPDUs shall be computed using Equation (26-70) instead of Equation (20-35).

$$N_{pld} = (N_{SYM.init} - m_{STBC})N_{DBPS} + m_{STBC}N_{DBPS.LAST.init} \tag{26-70}$$

where

$$N_{SYM.init} = m_{STBC} \cdot \left\lceil \frac{8 \cdot \text{APEP\_LENGTH} + N_{service}}{m_{STBC} \cdot N_{DBPS}} \right\rceil \tag{26-71}$$

Following the calculation of N_{pld}, N_{avbits} shall be computed using Equation (26-72) instead of Equation (20-36).

$$N_{avbits} = (N_{SYM,\,init} - m_{STBC}) \cdot N_{CBPS} + m_{STBC} \cdot N_{CBPS,\,LAST,\,init} \tag{26-72}$$

In addition, in step d) of LDPC encoding process as described in 19.3.11.7.5 (LDPC PPDU encoding process)(#1405)(#2807), 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 OFDM Symbol field of HE-SIG-A shall be set to 1, and increment N_{avbits} by the following Equation (26-73) instead of Equations (19-39), followed by recomputing N_{punc} as in Equation (19-40)(#2808):

$$N_{avbits} = \begin{cases} N_{avbits} + m_{STBC} \cdot (N_{CBPS} - 3N_{CBPS.SHORT}), & \text{if } a_{init} = 3 \\ N_{avbits} + m_{STBC} \cdot N_{CBPS.SHORT}, & \text{otherwise} \end{cases} \tag{26-73}$$

and then update a and N_{SYM} values by the following Equation (26-74):

$$\begin{cases} N_{SYM} = N_{SYM.init} + m_{STBC} \text{ and } a = 1, & \text{if } a_{init} = 4 \\ N_{SYM} = N_{SYM.init} \text{ and } a = a_{init} + 1, & \text{otherwise} \end{cases} \tag{26-74}$$

If in step d) of LDPC encoding process as described in 19.3.11.7.5 (LDPC PPDU encoding process)(#1405)(#2809), the above mentioned condition is not met, then the LDPC Extra OFDM Symbol field of HE-SIG-A shall be set to 0, and

$$N_{SYM} = N_{SYM,\,init} \text{ (\#2068)} \qquad a = a_{init} \tag{26-75}$$

With the final pre-FEC padding factor(#2564) value a, update the N_{CBPS} of the last symbol as:

$$N_{CBPS.LAST} = \begin{cases} a \cdot N_{CBPS.SHORT}, & \text{if } a < 4 \\ N_{CBPS}, & \text{if } a = 4 \end{cases} \tag{26-76}$$

For completeness, the number of data bits of the last symbol $N_{DBPS.LAST} = N_{DBPS.LAST.init}$.(#329)

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LDPC codes used in HE MU PPDUs shall also follow the definitions in 19.3.11.7 (LDPC codes)(#2810). Refer to 26.3.11.5.4 (Encoding process for an HE MU PPDU)(#2069) for a description of the LDPC encoding process for HE MU PPDUs.

26.3.11.5.3 Post-FEC padding

The number of post-FEC padding bits in each of the last m_{STBC} symbol(s) is computed by:

$$N_{PAD.POST\text{-}FEC} = N_{CBPS} - N_{CBPS.LAST} \tag{26-77}$$

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.(#2070)

26.3.11.5.4 Encoding process for an HE MU PPDU

For an HE MU PPDU, all the users shall use a common pre-FEC padding factor(#2564) value and a common N_{SYM} value. The padding process is described as follows.

First compute initial pre-FEC padding factor(#2564) value ($a_{init,u}$) for each user u using Equation (26-61), and the initial number of OFDM symbols ($N_{init,init}$)(#2071) for each user u using Equation (26-66) if user u is BCC encoded, or Equation (26-71) if user u is LDPC encoded. Among all the users, derive the user index with the longest encoded packet duration, as in Equation (26-78).

$$u_{\max} = \arg\max_{u=0}^{N_u - 1} (N_{SYM.init.u} - m_{STBC} + 0.25 m_{STBC} a_{init.u}) \tag{26-78}$$

where m_{STBC} is the common STBC setting among all the users, as described in 26.3.10.8.

Then the common a_{init} and N_{init} values among all the users are derived by Equation (26-79):

$$\begin{aligned} N_{SYM.init} &= N_{SYM.init.u_{\max}} \\ a_{init} &= a_{init.u_{\max}} \end{aligned} \tag{26-79}$$

Update each user's initial number of coded bits in its last symbol as below:

$$\begin{aligned} N_{DBPS.LAST.init.u} &= \begin{cases} a_{init} N_{DBPS.SHORT.u}, \text{ if } a_{init} < 4 \\ N_{DBPS.u}, \text{ if } a_{init} = 4 \end{cases} \\ N_{CBPS.LAST.init.u} &= \begin{cases} a_{init} N_{CBPS.SHORT.u}, \text{ if } a_{init} < 4 \\ N_{CBPS.u}, \text{ if } a_{init} = 4 \end{cases} \end{aligned} \tag{26-80}$$

For each user with LDPC encoding, the number of pre-FEC padding bits is computed as in Equation (26-81):

$$\begin{aligned} N_{PAD,\,\text{Pre-FEC},\,u} = {} & (N_{SYM.init} - m_{STBC}) N_{DBPS,\,u} + m_{STBC} N_{DBPS.LAST.init.u} \\ & - 8 \cdot \text{APEP\_LENGTH}_u - N_{service} \end{aligned} \tag{26-81}$$

For each user with LDPC encoding, the parameters $N_{pld,u}$ and $N_{avbits,u}$ are computed using Equation (26-82) and Equation (26-83) respectively:

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$$N_{pld,u} = (N_{SYM.init} - m_{STBC})N_{DBPS,u} + m_{STBC}N_{DBPS.LAST.init.u} \quad (26\text{-}82)$$

$$N_{avbits,u} = (N_{SYM.init} - m_{STBC})N_{CBPS,u} + m_{STBC}N_{CBPS.LAST.init.u} \quad (26\text{-}83)$$

For each user(#2072) with LDPC encoding continue LDPC encoding process as in 19.3.11.7.5 (LDPC PPDU encoding process)(#1405)(#2811) 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)(#1405)(#2812), meets the following condition:

$(N_{punc,u} > 0.1 \times N_{CW,u} \times L_{LDPC,u} \times (1 - R_u))$ AND $\left(N_{shrt,u} < 1.2 \times N_{punc,u} \times \frac{R_u}{1 - R_u}\right)$ is true OR if

$N_{punc,u} > 0.3 \times N_{CW,u} \times L_{LDPC,u} \times (1 - R_u)$ 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)(#2813), and R_u is the coding rate of user u, then the LDPC Extra symbol bit 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:

$$N_{avbits,u} = \begin{cases} N_{avbits,u} + m_{STBC} \cdot (N_{CBPS} - 3N_{CBPS.SHORT.u}), & \text{if } a_{init} = 3 \\ N_{avbits,u} + m_{STBC} \cdot N_{CBPS.SHORT.u}, & \text{otherwise} \end{cases} \quad (26\text{-}84)$$

$$N_{punc,u} = \max(0, (N_{CW,u} \times L_{LDPC,u}) - N_{avbits,u} - N_{shrt,u}) \quad (26\text{-}85)$$

Update the common pre-FEC padding factor(#2564) and N_{SYM} values for all users by the following equation:

$$\begin{cases} N_{SYM} = N_{SYM.init} + m_{STBC} \text{ and } a = 1, & \text{if } a_{init} = 4 \\ N_{SYM} = N_{SYM.init} \text{ and } a = a_{init} + 1, & \text{otherwise} \end{cases} \quad (26\text{-}86)$$

If among all the users with LDPC encoding, in step d) of 19.3.11.7.5 (LDPC PPDU encoding process)(#1405)(#2814), 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 bit in HE-SIG-A shall be set to 0, and:

$$a = a_{init}, N_{SYM} = N_{SYM,init} \quad (26\text{-}87)$$

Note that users with BCC encoding shall also use the common N_{SYM} and a parameters as in Equation (26-86)(#2073).

(#331)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

$$N_{CBPS.LAST.u} = \begin{cases} a \cdot N_{CBPS.SHORT.u}, \text{ if } a < 4 \\ N_{CBPS.u}, \text{ if } a_{init} = 4 \end{cases}$$

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For the users with BCC encoding, the number of pre-FEC padding bits is shown in Equation (26-88).

$$N_{PAD,\,\text{Pre-FEC},\,u} = (N_{SYM} - m_{STBC})N_{DBPS,\,u} + m_{STBC}N_{DBPS.LAST.u} - 8 \cdot \text{APEP\_LENGTH}_u - N_{Tail} - N_{service} \quad (26\text{-}88)$$

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 (26-89):

$$N_{PAD,\,\text{Post-FEC},\,u} = N_{CBPS,\,u} - N_{CBPS.LAST.u} \quad (26\text{-}89)$$

(#2070)

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 (26-90) and Equation (26-91).(#2076)

$$N_{PAD,\,\text{Pre-FEC},\,MAC} = 8 \cdot \left\lfloor \frac{N_{PAD,\,\text{Pre-FEC}}}{8} \right\rfloor \quad (26\text{-}90)$$

$$N_{PAD,\,\text{Pre-FEC},\,PHY} = N_{PAD,\,\text{Pre-FEC}} \bmod 8 \quad (26\text{-}91)$$

26.3.11.5.5 Encoding process for an HE trigger-based PPDU

The AP indicates the common N_{SYM}, pre-FEC padding factor(#2564), STBC indication and LDPC Extra Symbol 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 25.3.10.1.1 (pre-FEC padding process), 26.3.11.5.1 (Binary convolutional coding and puncturing), and 26.3.11.5.3 (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(#2564) 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 26.3.11.2 (Pre-FEC encoding process), 26.3.11.5.2 (LDPC coding), and 26.3.11.5.3 (Post-FEC padding), with the following exceptions:

When the Trigger frame indicates LDPC Extra Symbol = 1, set the initial parameters following Equation (26-92):

$$\begin{cases} a_{init} = 4 \text{ and } N_{SYM.init} = N_{SYM} - m_{STBC}, & \text{if } a = 1 \\ a_{init} = a - 1 \text{ and } N_{SYM.init} = N_{SYM}, & \text{otherwise} \end{cases} \quad (26\text{-}92)$$

where N_{SYM} and a are the common number of symbols and pre-FEC padding factor(#2564) 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)(#1405), during which in step d) of 20.3.11.7.5 (LDPC PPDU encoding process)(#1405), always increment N_{avbits} as in Equation (26-73), and always recompute N_{punc} as in Equation (20-40), followed by updating $a = a_{init} + 1$ if $a_{init} < 4$, or $a = 1$ if $a_{init} = 4$.

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When the Trigger frame indicates LDPC Extra Symbol = 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(#1626)(#2564) indicated in the Trigger frame respectively. Then continue with the LDPC encoding process as in 20.3.11.7.5 (LDPC PPDU encoding process)(#1405), during which in step d) of 20.3.11.7.5 (LDPC PPDU encoding process)(#1405), N_{avbits} and N_{punc} are not changed, and $a = a_{init}$.

26.3.11.6 Stream parser

After coding, scrambling,(#2078) 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(#2829) HE MU transmission). This operation is referred to as "stream parsing" and is described in this subclause(#1304).

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 (26-93).

$$s = max(1, \frac{N_{BPSCS}}{2}) \quad (26\text{-}93)$$

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.(#2079)(#Ed)

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

$$i = (i_{SS} - 1)s + S \cdot \left\lfloor \frac{k}{s} \right\rfloor + (k \bmod s) \text{ (\#2080)}$$

$$i_{SS} = 1, 2, \ldots, N_{SS}$$

$$i = 0, 1, \ldots, N_{CBPS} - 1$$

$$k = 0, 1, \ldots, N_{CBPSS} - 1 \text{ (\#2081)}$$

26.3.11.7 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.(#Ed)

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 (26-94).

$$y_{k,l} = x_k \quad (26\text{-}94)$$

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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 (26-95).

$$y_{k,l} = x_m \tag{26-95}$$

$$m = 2s \cdot \left\lfloor \frac{k}{s} \right\rfloor + l \cdot s + (k \bmod s), \quad k = 0, 1, \ldots, \frac{N_{CBPSS}}{2} - 1 \tag{26-96}$$

and

x_m is bit m of a block of N_{CBPSS} bits and $m = 0, \ldots, N_{CBPSS} - 1$

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 (26-93)(#2566)

26.3.11.8 BCC interleavers

(#1866)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(#2522). 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.(#482) (#2183)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 26-27 (BCC interleaver parameters).

Table 26-27—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}	48	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	-

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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 26-27 (BCC interleaver parameters).

NOTE—DCM is not used on the HE-SIG-A field.

26.3.11.9 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(#1782)(#Ed). For 1024-QAM, the mapping of the bits at the output of the interleaver to the complex constellation points is defined in Figure 26-29 (Constellation bit encoding for 1024-QAM (1st quadrant)), Figure 26-30 (Constellation bit encoding for 1024-QAM (2nd quadrant)), Figure 26-31 (Constellation bit encoding for 1024-QAM (3rd quadrant)) and Figure 26-32 (Constellation bit encoding for 1024-QAM (4th quadrant)).

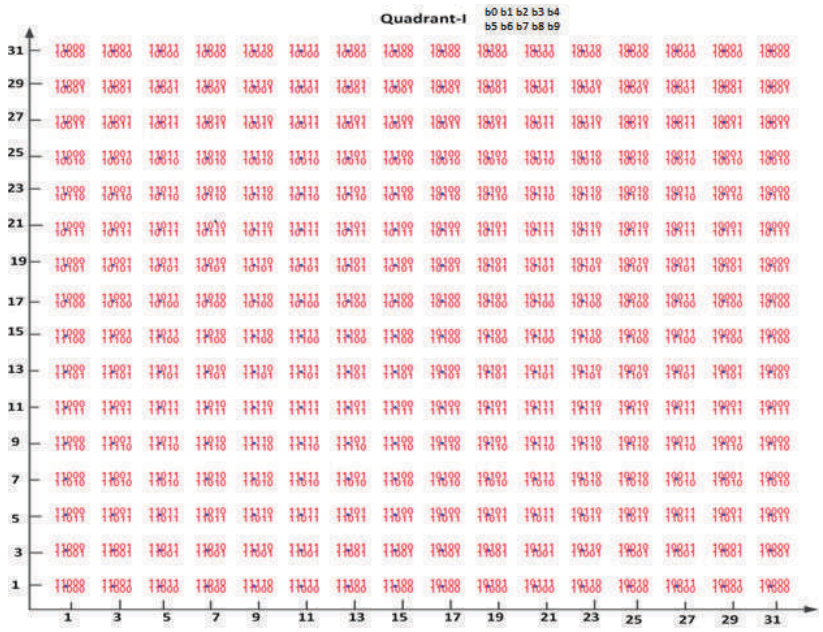


Figure 26-29—Constellation bit encoding for 1024-QAM (1st quadrant)

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Figure 26-30—Constellation bit encoding for 1024-QAM (2nd quadrant)

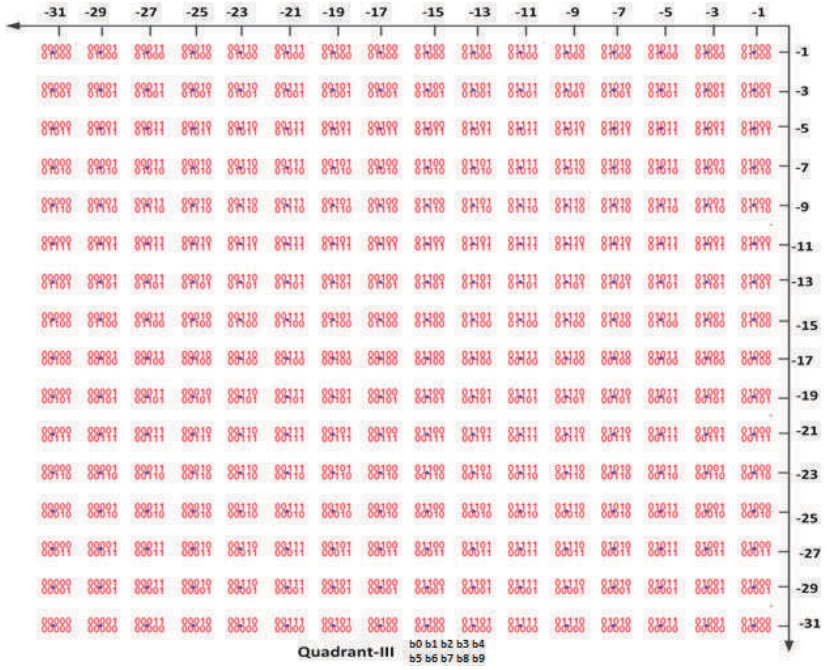


Figure 26-31—Constellation bit encoding for 1024-QAM (3rd quadrant)

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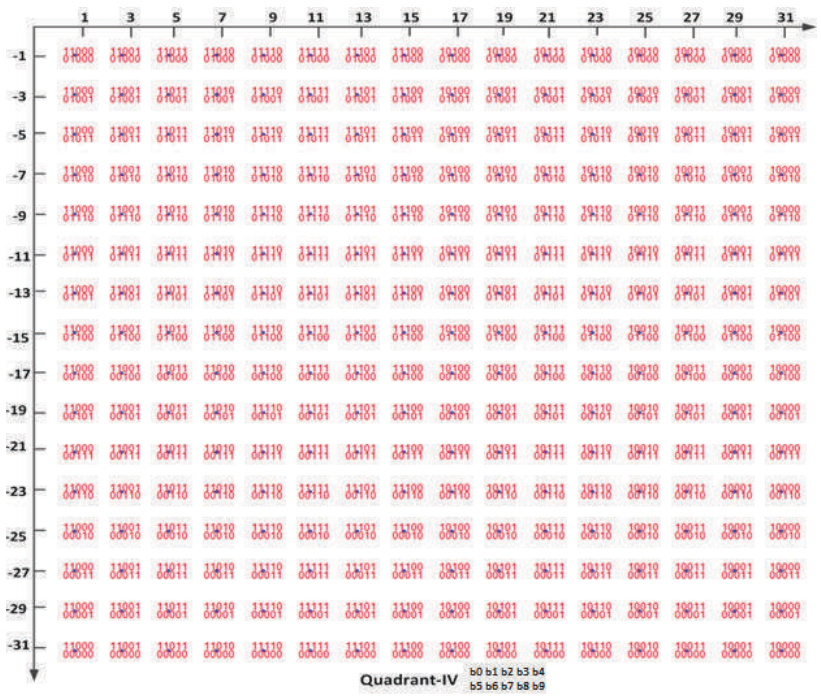


Figure 26-32—Constellation bit encoding for 1024-QAM (4th quadrant)

The normalization factor K_{mod} for 1024 QAM is $1/\sqrt{682}$.(#1782)

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.(#482)

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 $N_{SD} \le k \le N_{SD} - 1$ in order to exploit frequency diversity. 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.(#482)

For BPSK modulation with DCM, the input stream is broken into groups of N_{CBPS} or $N_{CBPS,u}$ bits $(B_0, B_1, \ldots, B_{N_{CBPS,u}-1})$(#2522). 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.(#482)

For QPSK modulation with DCM, the input stream is broken into groups of N_{CBPS} or $N_{CBPS,u}$(#333) bits $(B_0, B_1, \ldots, B_{N_{CBPS,u}-1})$ (#2522). Each pair of bits (B_{2k}, B_{2k+1}) is QPSK modulated to a symbol d_k. This

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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, $d_{k+N_{SD}} = conj(d_k)$ (#482).

For 16-QAM modulation with DCM, the input stream is broken into groups of N_{CBPS} or $N_{CBPS,u}$ bits ($B_0, B_1, \ldots, B_{N_{CBPS,u}-1}$)(#2522). 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.(#482)

26.3.11.10 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 (TBD: undecided whether in HE-SIG-A for HE_MU). 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)(#1405), with $N_{SS,0} = 1$ and $N_{STS,0} = 2$.

26.3.11.11 LDPC tone mapper

(#1859)The LDPC tone mapping shall be performed on all LDPC encoded streams mapped in an(#Ed) 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, $D_{\text{TM\_DCM}}$(#1860) shall be applied on both the lower half data subcarriers in an(#Ed) 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 26-28 (LDPC tone mapping distance for each RU size).

Table 26-28—LDPC tone mapping distance for each RU size

Parameter	RU Size (tones)						
	26	52	106	242	484	996	2×996(#1337)
D_{TM}	1	3	6	9	12	20	20
D_{TM_DCM}	1	1	3	9	9	14	14(#1861)

NOTE—The LDPC tone mapping parameters D_{TM} and D_{TM_DCM} are applied for each frequency subblock, $l = 0$ and $l = 1$.(#1866)

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 26.3.11.9 (Constellation mapping)) to

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$$d''_{t(k),\,i,\,n,\,l,\,r,\,u} = d'_{k,\,i,\,n,\,l,\,r,\,u};$$

$k = 0, 1, \ldots, N_{SD} - 1$ for a 26-, 52-, 106-, 242-, 484- and 996-tone RU

$k = 0, 1, \ldots, \frac{N_{SD}}{2} - 1$ for a 2x996-tone RU

$i = 1, \ldots, N_{SS,\,r,\,u}$

$n = 0, 1, \ldots, N_{SYM} - 1$

$l = 0$ for a 26-, 52-, 106-, 242-, 484- and 996-tone RU

$l = 0, 1$ for a 2x996-tone RU

$u = 0, \ldots, N_{user,\,r} - 1$

$r = 0, \ldots, N_{RU} - 1$

(26-97)

where N_{SD} is the number of data tones in the r-th RU.

$$t(k) = \begin{cases} D_{TM}\left(k \bmod \frac{N_{SD}}{D_{TM}}\right) + \left\lfloor \frac{k \cdot D_{TM}}{N_{SD}} \right\rfloor, & \text{for a 26-, 52-, 106-, 242-, 484- and 996-tone RU} \\ D_{TM}\left(k \bmod \frac{N_{SD}/2}{D_{TM}}\right) + \left\lfloor \frac{k \cdot D_{TM}}{N_{SD}/2} \right\rfloor, & \text{for a 2x996-tone RU} \end{cases} \quad (26\text{-}98)$$

For an(#2829) 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) to

$$d''_{t(k),i,n,l,r,u} = \begin{cases} d'_{k,i,n,l,r,u}; \\ d'_{k',i,n,l,r,u}; \end{cases} \quad (26\text{-}99)$$

where

$k = 0, 1, \ldots, \frac{N_{SD}}{2} - 1$

$k' = k - \frac{N_{SD}}{2}$, for $k = \frac{N_{SD}}{2}, \frac{N_{SD}}{2} + 1, \ldots, N_{SD} - 1$

$i = 1, \ldots, N_{SS,\,r,\,u}$

$n = 0, 1, \ldots, N_{SYM} - 1$

$l = \begin{cases} 0 \text{ for a 26-, 52-, 106-, 242-, 494- and 996-tone RU} \\ 0, 1 \text{ for a 2x996-tone RU} \end{cases}$

$u = 0, \ldots, N_{user,\,r} - 1$

$r = 0, \ldots, N_{RU} - 1$

N_{SD} is the number of data tones in the r-th RU and

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$$t(k) = \begin{cases} D_{\text{TM\_DCM}}\left(k \bmod \frac{N_{SD}/2}{D_{\text{TM\_DCM}}}\right) + \left\lfloor \frac{k \cdot D_{\text{TM\_DCM}}}{N_{SD}/2} \right\rfloor, & \text{for a 26-, 52-, 106-, 242-, 484- and 996-tone RU} \\ D_{\text{TM\_DCM}}\left(k' \bmod \frac{N_{SD}/2}{D_{\text{TM\_DCM}}}\right) + \left\lfloor \frac{k' \cdot D_{\text{TM\_DCM}}}{N_{SD}/2} \right\rfloor + \frac{N_{SD}}{2}, & \text{for a 26-, 52-, 106-, 242-, 484- and 996-tone RU} \\ D_{\text{TM\_DCM}}\left(k \bmod \frac{N_{SD}/2}{D_{\text{TM\_DCM}}}\right) + \left\lfloor \frac{k \cdot D_{\text{TM\_DCM}}}{N_{SD}/2} \right\rfloor, & \text{for a 2x996-tone RU} \end{cases} \quad (26\text{-}100)$$

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(#2088). LDPC tone mapping is performed separately for the upper and lower 80 MHz frequency segments of a 2×996-tone RU(#1337) 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, the following applies:

$$d''_{k,i,n,l,r,u} = d'_{k,i,n,l,r,u};$$

$k = 0, 1, \ldots, N_{SD} - 1$ for a 26-, 52-, 106-, 242-, 484- and 996-tone RU

$k = 0, 1, \ldots, \frac{N_{SD}}{2} - 1$ for a 2x996-tone RU

$i = 1, \ldots, N_{SS,r,u}$

$n = 0, 1, \ldots, N_{SYM} - 1$ (26-101)

$l = 0$ for a 26-, 52-, 106-, 242-, 484- and 996-tone RU

$l = 0, 1$ for a 2x996-tone RU

$u = 0, \ldots, N_{user,r} - 1$

$r = 0, \ldots, N_{RU} - 1$

26.3.11.12 Segment deparser

For a 26-, 52-, 106-, 242-, 484- and 996-tone RU(#Ed), the segment deparsing is not performed and $d^{(i_{Seg})}_{k,i,n,l,r,u}$ is specified in Equation (26-102).

$$d^{(i_{Seg})}_{k,i,n,l,r,u} = d''_{k,i,n,0,r,u}, \quad \text{if } 0 \le k \le N_{SD} - 1, i_{Seg} = 0 \quad (26\text{-}102)$$

For a 2×996-tone RU in a 160 MHz HE PPDU(#Ed), the two frequency subblocks at the output of the LDPC tone mapper are combined into one frequency segment as specified in Equation (26-103).

$$d^{(i_{Seg})}_{k,i,n,l,r,u} = \begin{cases} d''_{k,i,n,0,r,u}, & \text{if } 0 \le k \le \frac{N_{SD}}{2} - 1 \\ d''_{k-\frac{N_{SD}}{2},i,n,l,r,u}, & \text{if } \frac{N_{SD}}{2} \le k \le N_{SD} - 1 \end{cases}, i_{Seg} = 0 \quad (26\text{-}103)$$

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 (26-104).

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$$d^{(i_{Seg})}_{k,i,n,r,u} = d''_{k,i,n,i_{Seg},r,u}, \quad \text{if } 0 \le k \le N_{SD}-1, i_{Seg} = 0, 1 \tag{26-104}$$

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.(#2092)

26.3.11.13 Pilot subcarriers

For a user transmitting on the i-th 26-tone RU in a given PPDU BW, two pilot tones shall be inserted in subcarriers $k \in K_{R26_i}$, where K_{R26_i} is given by the(#926) i-th pilot index set in the row of given PPDU BW of Table 26-29 (Pilot indices for a 26-tone RU).

Table 26-29—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
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 tone indices in 80 MHz −512, pilot tone indices in 80 MHz +512}

The pilot mapping P_n^k(#346) for the(#927) subcarrier k for symbol n shall be as specified in Equation (26-105).

$$P_n^{K_{R26_i}} = \{\Psi_{n \bmod 2}, \Psi_{(n+1) \bmod 2}\} \text{ (#347)}$$
$$P_n^{k \notin K_{R26_i}} = 0 \tag{26-105}$$

where

Ψ_m is defined in Table 26-30 (The 2 pilot values for a 26-tone RU(#347))

Table 26-30—The 2 pilot values for a 26-tone RU(#347)

Ψ_0	Ψ_1
1	−1

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For a user transmitting on the *i*-th 52-tone RU in a given PPDU BW, four pilot tones shall be inserted in subcarriers $k \in K_{R52_i}$, where K_{R52_i} is given by the(#Ed) *i*-th pilot index set in the row of given PPDU BW of Table 26-31 (Pilot indices for 52-tone RU transmission).

Table 26-31—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 tone indices in 80 MHz −512, pilot tone indices in 80 MHz +512}

The pilot mapping P_n^k (#346) for the(#933) subcarrier k for symbol n shall be as specified in Equation (26-106).

$$P_n^{K_{R52_i}} = \{\Psi_{n \bmod 4}, \Psi_{(n+1) \bmod 4}, \Psi_{(n+2) \bmod 4}, \Psi_{(n+3) \bmod 4}\} \text{ (#347)}$$
$$P_n^{k \notin K_{R52_i}} = 0 \qquad (26\text{-}106)$$

where

Ψ_m is defined in Table 26-32 (The 4 pilot values in a 52- and 106-tone RU(#347))

Table 26-32—The 4 pilot values in a 52- and 106-tone RU(#347)

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 tones shall be inserted in subcarriers $k \in K_{R106_i}$, where K_{R106_i} is given by the(#932) *i*-th pilot index set in the row of given PPDU BW of Table 26-33 (Pilot indices for 106-tone RU transmission).

Table 26-33—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

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Table 26-33—Pilot indices for 106-tone RU transmission *(continued)*

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 tone indices in 80 MHz −512, pilot tone indices in 80 MHz +512}

The pilot mapping P_n^k (#346) for the(#930) subcarrier k for symbol n shall be as specified in Equation (26-107).

$$P_n^{K_{R106_i}} = \{\Psi_{n \bmod 4}, \Psi_{(n+1) \bmod 4}, \Psi_{(n+2) \bmod 4}, \Psi_{(n+3) \bmod 4}\}$$
$$P_n^{k \notin K_{R106_i}} = 0 \quad (26\text{-}107)$$

where

Ψ_m is defined in Table 26-32 (The 4 pilot values in a 52- and 106-tone RU(#347))

For a user transmitting on the i-th 242-tone RU in a given PPDU BW, eight pilot tones shall be inserted in subcarriers $k \in K_{R242_i}$, where K_{R242_i} is given by the(#929) i-th pilot index set in the row of given PPDU BW of Table 26-34 (Pilot indices for 242-tone RU transmission).

Table 26-34—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 tone indices in 80 MHz −512, pilot tone indices in 80 MHz +512}

The pilot mapping P_n^k (#346) for the(#936) subcarrier k for symbol n shall be as specified in Equation (26-108).

$$P_n^{K_{R242_i}} = \{\Psi_{n \bmod 8}, \Psi_{n+1 \bmod 8}, \Psi_{n+2 \bmod 8}, \Psi_{n+3 \bmod 8}, \Psi_{(n+4) \bmod 8}, \Psi_{(n+5) \bmod 8}, \Psi_{(n+6) \bmod 8}, \Psi_{(n+7) \bmod 8}\}$$
$$P_n^{k \notin K_{R242_i}} = 0 \quad (26\text{-}108)$$

where

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Ψ_m is defined in Table 26-35 (The 8 pilot values in a 242-tone RU(#347))

Table 26-35—The 8 pilot values in a 242-tone RU(#347)

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(#347) a user transmitting on the *i*-th 484-tone RU in a given PPDU BW, sixteen pilot tones shall be inserted in subcarriers $k \in K_{R484_i}$, where K_{R484_i} is given by the(#938) *i*-th pilot index set in the row of given PPDU BW of Table 26-36 (Pilot indices for 484-tone RU transmission).

Table 26-36—Pilot indices for 484-tone RU transmission

PPD BW	K_{R484_i}
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 tone indices in 80 MHz −512, pilot tone indices in 80 MHz +512}

The pilot mapping P_n^k(#346) for the(#942) subcarrier k for symbol n shall be as specified in Equation (26-109).

$$
\begin{aligned}
P_n^{K_{R484_i}} = \{ & \Psi_{n \bmod 8}, \Psi_{n+1 \bmod 8}, \Psi_{n+2 \bmod 8}, \Psi_{n+3 \bmod 8}, \\
& \Psi_{(n+4) \bmod 8}, \Psi_{(n+5) \bmod 8}, \Psi_{(n+6) \bmod 8}, \Psi_{(n+7) \bmod 8}, \\
& \Psi_{(n+8) \bmod 8}, \Psi_{(n+9) \bmod 8}, \Psi_{(n+10) \bmod 8}, \Psi_{(n+11) \bmod 8}, \quad \text{(\#347)} \\
& \Psi_{(n+12) \bmod 8}, \Psi_{(n+13) \bmod 8}, \Psi_{(n+14) \bmod 8}, \Psi_{(n+15) \bmod 8} \} \\
P_n^{k \notin K_{R484_i}} = 0 &
\end{aligned}
\qquad \text{(26-109)}
$$

where

Ψ_m is defined in Table 26-35 (The 8 pilot values in a 242-tone RU(#347))

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(#347) a user transmitting on the *i*-th 996-tone RU in a given PPDU BW,

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sixteen pilot tones shall be inserted in subcarriers $k \in K_{R996_i}$, where K_{R996_i} is given by the(#941) i-th pilot index set in the row of given PPDU BW of Table 26-37 (Pilot indices for 996-tone RU transmission).

Table 26-37—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 tone indices in 80 MHz −512, for i = 2 pilot tone indices in 80 MHz +512}(#2095)

The pilot mapping P_n^k(#346) for the(#939) subcarrier k for symbol n shall be as specified in Equation (26-110).

$$
\begin{aligned}
P_n^{K_{R996_i}} = \{ & \Psi_{n \bmod 8}, \Psi_{(n+1) \bmod 8}, \Psi_{(n+2) \bmod 8}, \Psi_{(n+3) \bmod 8}, \\
& \Psi_{(n+4) \bmod 8}, \Psi_{(n+5) \bmod 8}, \Psi_{(n+6) \bmod 8}, \Psi_{(n+7) \bmod 8}, \\
& \Psi_{(n+8) \bmod 8}, \Psi_{(n+9) \bmod 8}, \Psi_{(n+10) \bmod 8}, \Psi_{(n+11) \bmod 8}, \quad \text{(\#347)} \\
& \Psi_{(n+12) \bmod 8}, \Psi_{(n+13) \bmod 8}, \Psi_{(n+14) \bmod 8}, \Psi_{(n+15) \bmod 8} \} \\
P_n^{k \notin K_{R996_i}} = 0 &
\end{aligned}
\qquad \text{(26-110)}
$$

where

Ψ_m is defined in Table 26-35 (The 8 pilot values in a 242-tone RU(#347))

For a 160 MHz transmission (equivalently two 996-tone RU transmissions), the 80 MHz (equivalently 996-tone RU)(#347) pilot mapping is replicated in the two 80 MHz subchannels of the 160 MHz transmission. Specifically, thirty-two pilot tones shall be inserted in subcarriers $k \in K_{\text{R2x996}_i}$, 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(#346) for the(#944) subcarrier k for symbol n shall be as specified in Equation (26-111).

$$
\begin{aligned}
P_n^{K_{R2x996_i}} = \{ & \Psi_{n \bmod 8}, \Psi_{(n+1) \bmod 8}, \Psi_{(n+2) \bmod 8}, \Psi_{(n+3) \bmod 8}, \\
& \Psi_{(n+4) \bmod 8}, \Psi_{(n+5) \bmod 8}, \Psi_{(n+6) \bmod 8}, \Psi_{(n+7) \bmod 8}, \\
& \Psi_{(n+8) \bmod 8}, \Psi_{(n+9) \bmod 8}, \Psi_{(n+10) \bmod 8}, \Psi_{(n+11) \bmod 8}, \\
& \Psi_{(n+12) \bmod 8}, \Psi_{(n+13) \bmod 8}, \Psi_{(n+14) \bmod 8}, \Psi_{(n+15) \bmod 8}, \\
& \Psi_{n \bmod 8}, \Psi_{(n+1) \bmod 8}, \Psi_{(n+2) \bmod 8}, \Psi_{(n+3) \bmod 8}, \quad \text{(\#347)} \\
& \Psi_{(n+4) \bmod 8}, \Psi_{(n+5) \bmod 8}, \Psi_{(n+6) \bmod 8}, \Psi_{(n+7) \bmod 8}, \\
& \Psi_{(n+8) \bmod 8}, \Psi_{(n+9) \bmod 8}, \Psi_{(n+10) \bmod 8}, \Psi_{(n+11) \bmod 8}, \\
& \Psi_{(n+12) \bmod 8}, \Psi_{(n+13) \bmod 8}, \Psi_{(n+14) \bmod 8}, \Psi_{(n+15) \bmod 8} \} \\
P_n^{k \notin K_{R2x996_i}} = 0 &
\end{aligned}
\qquad \text{(26-111)}
$$

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where

Ψ_m is defined in Table 26-35 (The 8 pilot values in a 242-tone RU(#347))

For a noncontiguous 80+80 MHz transmission, each frequency segment shall follow the 80 MHz pilot tone allocation and values defined for 996-tone RU in 80 MHz transmission as specified in Equation (26-110) and TBD pilot values for 996-tone RU in 80 MHz PPDU BW.

The above pilot mapping shall be copied to all space-time streams before the space-time stream cyclic shifts are applied.

26.3.11.14 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}(#2097), shall be as defined in Equation (26-112).

$$r_{\text{HE-Data}}^{(i_{Seg} i_{TX})}(t) = \frac{1}{\sqrt{\sum_{r=1}^{N_{RU}} \alpha_r^2 |K_r|}} \sum_{n=0}^{N_{SYM}-1} w_{T_{\text{HE-Data}}}(t - nT_{SYM}) \sum_{r=0}^{N_{RU}-1} \frac{\alpha_r}{\sqrt{N_{STS,r,total}}} \sum_{k \in K_r} \sum_{u=0}^{N_{user,r}-1} \sum_{m=1}^{N_{STS,r,u}} \left(\left[Q_k^{(i_{Seg})} \right]_{i_{TX}, (M_{r,u}+m)} (\tilde{D}_{k,m,n,r}^{(i_{Seg},u)} + p_{n+2+N_{\text{HE-SIG-A}}+N_{\text{HE-SIG-B}}} P_n^k) \cdot \exp(j2\pi k \Delta_{F,\text{HE}} (t - nT_{SYM} - T_{GI,Data} - T_{CS,\text{HE}}(M_{r,u}+m))) \right) \quad (26\text{-}112)$$

where

p_n is defined in 18.3.5.10 (OFDM modulation)

P_n^k is defined in 26.3.11.13 (Pilot subcarriers)(#1056)(#334)

$N_{\text{HE-Data}}^{\text{Tone}}$ is defined in Table 26-14 (Tone scaling factor and guard interval duration values for HE PPDU fields)(#476)

$T_{CS,\text{HE}}(M_{r,u}+m)$ represents the cyclic shift for space time stream $M_{r,u}+m$ as defined in 26.3.10.2.2 (Cyclic shift for HE modulated fields)(#1052)

$T_{GI,Data}$ is the guard interval duration as defined in Table 26-9 (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 (26-113).

$$\tilde{D}_{k,m,n,r}^{(i_{Seg},u)} = \begin{cases} 0, & k \in K_{\text{Pilot}} \\ \tilde{d}_{M_r(k),m,n,r,u}^{(i_{Seg})}, & \text{otherwise} \end{cases} \quad (26\text{-}113)$$

where

K_{Pilot} is the set of subcarrier indices of pilot tones, as defined in 26.3.3.3 (Pilot tones)

$M_r(k)$ is defined in Equation (26-114)

$$M_r(k) = k - K_{r,\min} - \left| \{ k' : K_{r,\min} \le k' < k \} \cap K_{\text{Pilot}} \right| \quad (26\text{-}114)$$

where

$K_{r,min}$ is the minimum value of the set K_r

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$|\Phi|$ 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(#1948) ($0 \le M_r(k) \le N_{SD,r}$). 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 tones 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 26.3.9 (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 (26-115).

$$r_{\text{HE-Data}}^{(i_{Seg} i_{TX})}(t) = \frac{\alpha_r}{\sqrt{|K_r|}} \sum_{n=0}^{N_{SYM}-1} w_{T_{\text{HE-Data}}}(t - nT_{SYM}) \frac{1}{\sqrt{N_{STS,\,r,\,total}}} \sum_{k \in K_r} \sum_{m=1}^{N_{STS,\,r,\,u}} \left(\left[Q_k^{(i_{Seg})} \right]_{i_{TX},\,(M_{r,\,u}+m)} (\tilde{D}_{k,\,m,\,n,\,r}^{(i_{Seg},\,u)} + p_{n+4} P_n^k) \cdot \exp(j2\pi k \Delta_{F,\,\text{HE}}(t - nT_{SYM} - T_{GI,\,Data} - T_{CS,\,HE}(M_{r,\,u}+m))) \right) \quad \text{(\#2099)} \quad (26\text{-}115)$$

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 $Q_k^{(i_{Seg})}$.

26.3.11.15 Dual carrier modulation

Dual carrier modulation (DCM)(#2567) 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 26.3.11.9 (Constellation mapping). The LDPC tone mapper for DCM is defined in 26.3.11.11 (LDPC tone mapper). The BCC interleaver for DCM is defined in 26.3.11.8 (BCC interleavers)(#2183).(#335)

26.3.12 Packet extension(#1781)

A 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(#2100).

The PE field is applied for the recipient of the PPDU to obtain longer processing time at the end of an(#2829) HE PPDU, and its duration is determined by both the pre-FEC padding factor(#2564) 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(#1459) field in HE Capabilities element (see 9.4.2.218 (HE Capabilities element))(#1460)(#Ed).

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For an(#2829) 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))(#1459)(#Ed) 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(#2564) 1, 2, 3 and 4, respectively, as shown in Figure 26-33 (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(#2564) 1, 2, 3 and 4, respectively, as shown in Figure 26-34 (PE field when maximum PE duration is 16 µs (non STBC)).

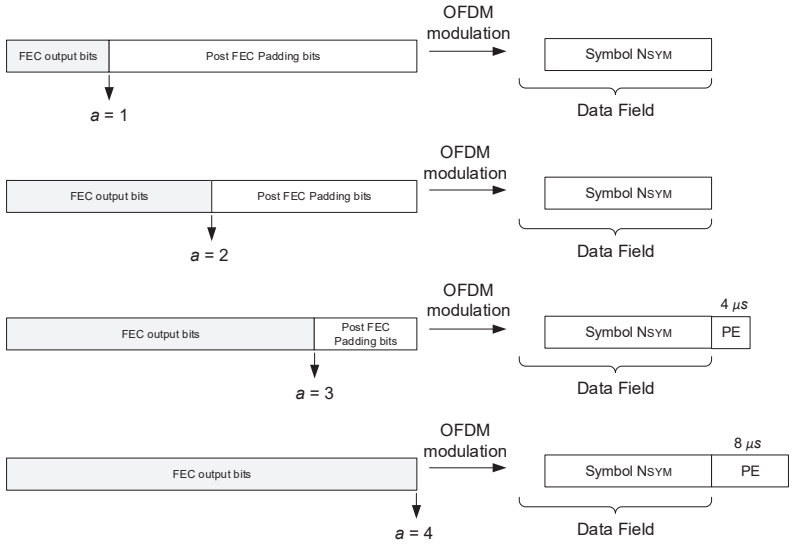


Figure 26-33—PE field when maximum PE duration is 8 µs (non STBC)

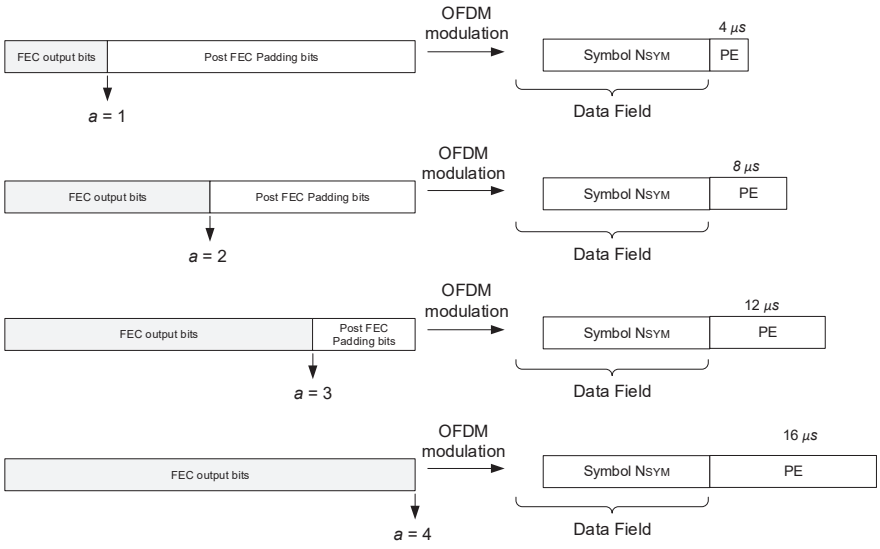


Figure 26-34—PE field when maximum PE duration is 16 µs (non STBC)

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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(#1626)(#2564) value among all users as described in 26.3.11.5.4 (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:

$$T_{PE} = \max_u(T_{PE,u}) \tag{26-116}$$

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(#Ed). The first two bits in the Packet Extension subfield indicate the pre-FEC padding factor(#2564) and the third bit indicates the PE-Disambiguity. Each user, when responding to(#2103) 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 (26-117).(#2135)

$$T_{PE} = \left\lfloor \frac{\left(\frac{\text{LENGTH} + m + 3}{3} \times 4 - T_{\text{RL-SIG}} - T_{\text{HE-SIG-A}} - T_{\text{HE-PREAMBLE}}\right) - N_{SYM} T_{SYM}}{4} \right\rfloor \times 4 \tag{26-117}$$

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 26-9 (Timing-related constants)

Editor's Note: The HE-SIG-A bits definition below should be moved into 26.3.10.7 (HE-SIG-A)

The 3-bit Packet Extension field in HE-SIG-A are defined as in Table 26-38 (Packet Extension field in HE-SIG-A).

Table 26-38—Packet Extension field in HE-SIG-A

Name	bits	Definition
Pre-FEC Padding Factor(#2564)	B0-B1	Indicates the pre-FEC padding factor(#1626)(#2564) value of the current PPDU
PE Disambiguity	B2	Indicates PE disambiguity

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The Pre-FEC Padding Factor(#2564) subfield of the Packet Extension field is encoded as shown in Table 26-39 (Pre-FEC Padding Factor(#2564) subfield encoding).

Table 26-39—Pre-FEC Padding Factor(#2564) subfield encoding

Pre-FEC padding factor value	Pre-FEC Padding Factor subfield encoding
1	b01
2	b10
3	b11
4	b00

The PE Disambiguity(#1049) subfield of the Packet Extension field shall be set to 1 if the condition in Equation (26-118) is met, otherwise it shall be set to 0.

$$T_{PE} + 4 \times \left(\left\lceil \frac{\text{TXTIME} - 20}{4} \right\rceil - \left(\frac{\text{TXTIME} - 20}{4} \right) \right) \geq T_{SYM} \quad (26\text{-}118)$$

where

T_{PE} is the PE field duration

T_{SYM} is the symbol duration of the Data field as defined in 26.3.8 (Timing-related parameters)

TXTIME (in µs) is defined in 26.4.2 (TXTIME and PSDU_LENGTH calculation).

(#2105)The receiver computes N_{SYM} and T_{PE} using Equation (26-119) and Equation (26-120), respectively.

$$N_{SYM} = \left\lfloor \left(\frac{\text{L\_LENGTH} + m + 3}{3} \times 4 - T_{\text{HE-PREAMBLE}} \right) / T_{SYM} \right\rfloor - b_{\text{PE-Disambiguity}} \quad (26\text{-}119)$$

$$T_{PE} = \left\lfloor \frac{\left(\frac{\text{L\_LENGTH} + m + 3}{3} \times 4 - T_{\text{HE-PREAMBLE}} \right) - N_{SYM} T_{SYM}}{4} \right\rfloor \times 4 \quad (26\text{-}120)$$

where

$$T_{\text{HE-PREAMBLE}} = \begin{cases} T_{\text{RL-SIG}} + T_{\text{HE-SIG-A}} + T_{\text{HE-STF-T}} + N_{\text{HE-LTF}} T_{\text{HE-STF, }SYM}, \text{ for an HE trigger-based PPDU} \\ T_{\text{RL-SIG}} + T_{\text{HE-SIG-A}} + T_{\text{HE-STF-NT}} + N_{\text{HE-LTF}} T_{\text{HE-STF, }SYM}, \text{ for an HE SU PPDU} \\ T_{\text{RL-SIG}} + T_{\text{HE-SIG-A}} + N_{\text{HE-SIG-B}} T_{\text{HE-SIG-B}} + T_{\text{HE-STF-NT}} + N_{\text{HE-LTF}} T_{\text{HE-STF, }SYM}, \text{ for an HE MU PPDU} \\ T_{\text{RL-SIG}} + T_{\text{HE-SIG-A}} + T_{\text{HE-SIG-A-R}} + T_{\text{HE-STF-NT}} + N_{\text{HE-LTF}} T_{\text{HE-STF, }SYM}, \text{ for an HE extended range SU PPDU} \end{cases}$$

$T_{\text{RL-SIG}}$, $T_{\text{HE-STF-T}}$, $T_{\text{HE-STF-NT}}$, $T_{\text{HE-LTF,SYM}}$, $T_{\text{HE-SIG-A}}$, $T_{\text{HE-SIG-A-R}}$, $T_{\text{HE-SIG-B}}$ are defined in Table 26-9 (Timing-related constants)

$N_{\text{HE-SIG-B}}$, $N_{\text{HE-LTF}}$ are defined in Table 26-12 (Frequently used parameters(#282))

$b_{\text{PE-Disambiguity}}$ is PE Disambiguity subfield in the Packet Extension subfield of the HE-SIG-A field

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26.3.13 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, HE STAs that may be present in a part of a 40 MHz, 80 MHz, or 160 MHz channel (see Error! Reference source not found.). 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 (26-60).

For 80 MHz and 160 MHz non-HT duplicate transmissions, the Data field shall be as defined by Error! Reference source not found..

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 Error! Reference source not found..

26.3.14 Transmit requirements for an HE trigger-based PPDU(#340)

26.3.14.1 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 26.3.14.2 (Power pre-correction) and shall meet pre-correction accuracy requirements described in 26.3.14.3 (Pre-correction accuracy requirements).

26.3.14.2 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 (26-121).

$$Tx_{pwr}^{STA} = PL_{DL} + Target_{RSSI} \quad (26\text{-}121)$$

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.

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Each STA computes PL_{DL} using Equation (26-122).

$$PL_{DL} = Tx_{pwr}^{AP} - DL_{RSSI} \quad (26\text{-}122)$$

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.(PHY Motion #170)

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 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 (26-123).

$$HR_{STA} = Tx_{pwr}^{Max} - Tx_{pwr}^{STA} \quad (26\text{-}123)$$

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 9.2.4.6.5.1 (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.

26.3.14.3 Pre-correction accuracy requirements

A STA that transmits an HE trigger-based PPDU shall support per chain max(P–32, –10 dBm)(#1422) as the minimum transmit power, with P the maximum power the STA can transmit at the antenna connector of that chain using MCS 0(#1616) 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(#1616)(PHY Motion #173).

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 26-40 (Transmit power and RSSI

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measurement accuracy). The absolute transmit power accuracy is applicable for the entire range of transmit

Table 26-40—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(#340)	±5 dB	The difference between the RSSI and the received power(#1786) 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.(#340)

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.(#340)

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.(#340)

A STA that transmits an HE trigger-based PPDU shall have timing accuracy of ±0.4 μs relative to the PPDU carrying the Trigger frame. This requirement does not include round trip delay.

26.3.15 SU-MIMO and DL MU-MIMO beamforming

26.3.15.1 General

(#507)For SU-MIMO 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 (26-124), 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.

$$\boldsymbol{y}_{k,u} = \boldsymbol{H}_{k,u} \times [Q_{k,0}, Q_{k,1}, \ldots, Q_{k,N_{user}-1}] \times \boldsymbol{x}_k + \boldsymbol{n} \quad (26\text{-}124)$$

where

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$\boldsymbol{H}_{k,u}$ 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 26-12 (Frequently used parameters(#282))) 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).

26.3.15.2 Beamforming feedback matrix *V*

Upon receipt of a 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 20.3.12.3.6. The angles, $\phi(k,v)$ and $\psi(k,u)$, are quantized according to Table 8-53e. 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 is addressed to a single non-AP STA and SU type feedback is solicited. The compressed beamforming feedback matrix as defined in(#Ed) 19.3.12.3.6 (Compressed beamforming feedback matrix) is the only Clause 26 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 (20-79). 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.

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26.3.15.3 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 9.4.1.64. The CQI values to be fed back are derived from quantized SNRs according to Table XX-4. The beamformee shall transmit the HE CQI-only feedback for space-time stream 1, …, 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.

26.3.16 Transmit specification

26.3.16.1 Transmit spectral mask

(#2351)The bandwidth of the spectral mask applied to an HE PPDU(#Ed) 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 26.3.16.4.2 (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 26-35 (Example transmit spectral

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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.

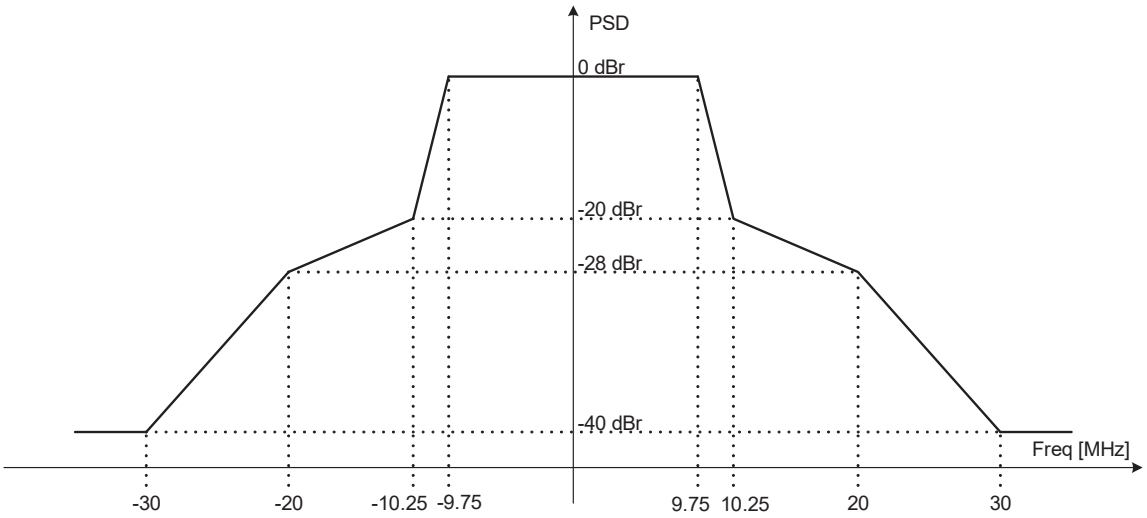


Figure 26-35—Example transmit spectral mask for a 20 MHz mask PPDU

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 26-36 (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.

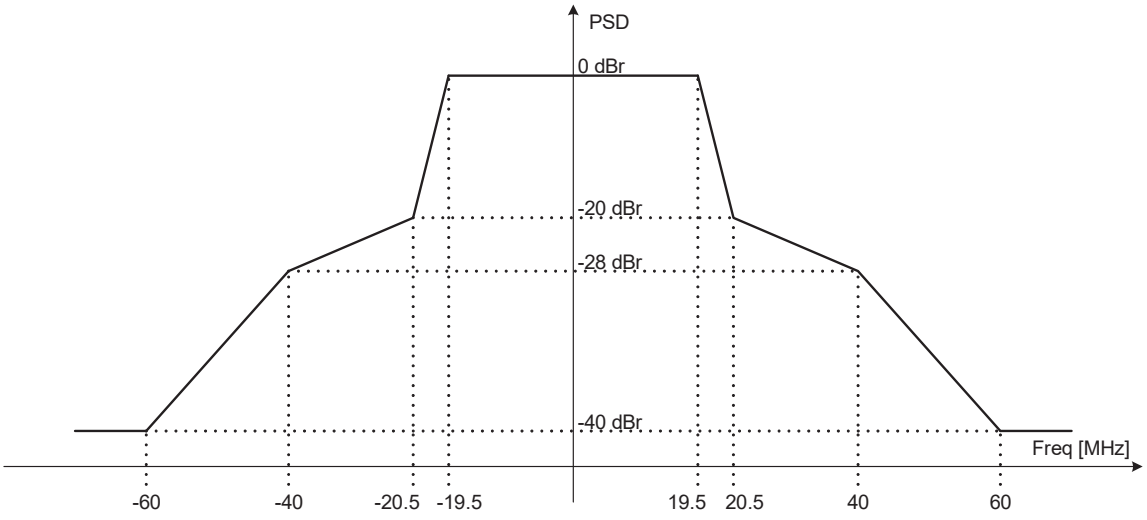


Figure 26-36—Example transmit spectral mask for a 40 MHz mask PPDU

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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 26-37 (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.

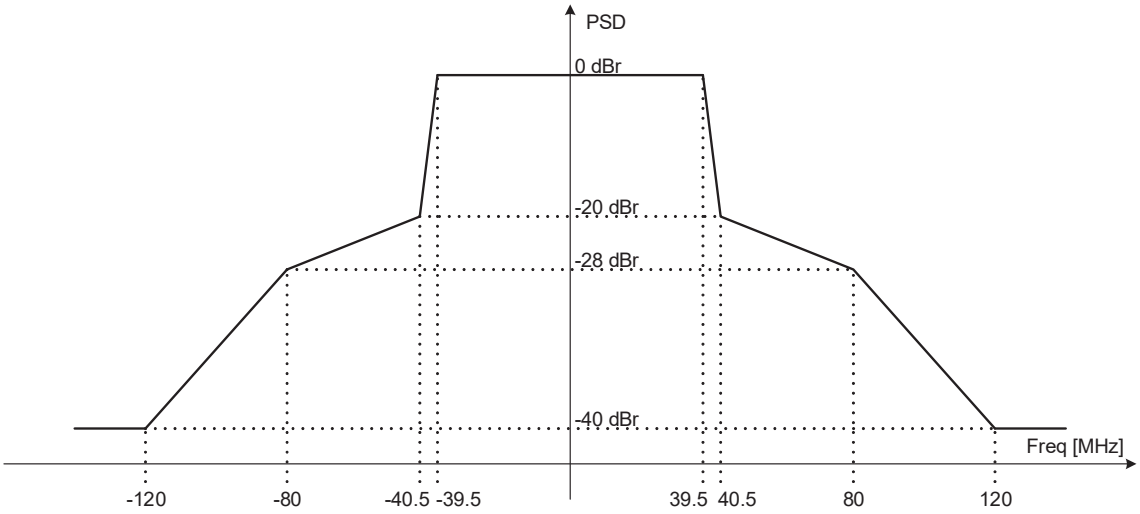


Figure 26-37—Example transmit spectral mask for a 80 MHz mask PPDU

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 26-38 (Example

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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.

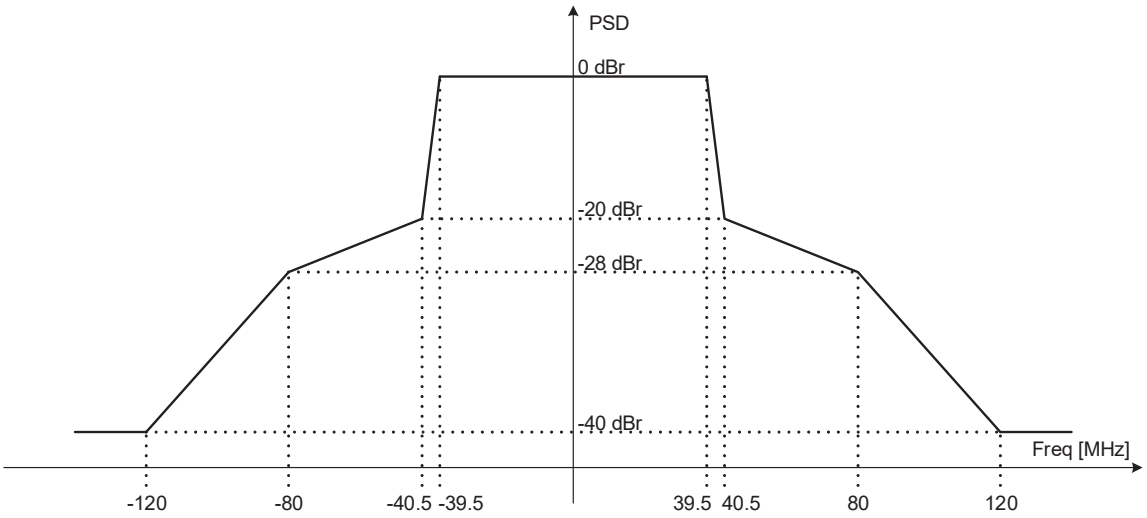


Figure 26-38—Example transmit spectral mask for a 160 MHz mask PPDU

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 26-39 (Example transmit spectral mask for a 80+80 MHz mask PPDU) shows an example of a transmit spectral mask for a noncontiguous transmission using

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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.

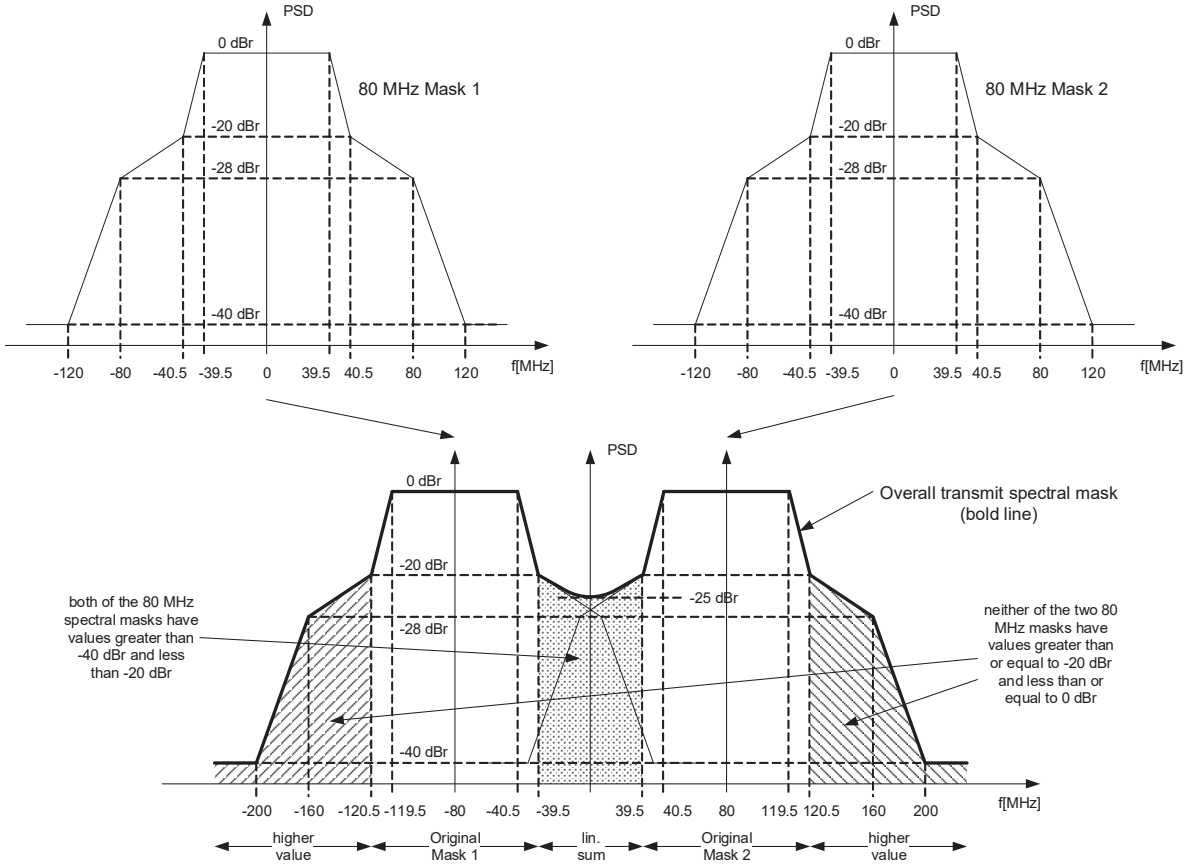


Figure 26-39—Example transmit spectral mask for a 80+80 MHz mask PPDU

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 26-39 (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.

(PHY Motion #161)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.

26.3.16.2 Spectral flatness

(#2351)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.

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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 timing drift error.

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 a HE data symbol. In a contiguous HE transmission having a bandwidth listed in Table 26-41 (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 26-41 (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 26-41—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 26.3.11.14 (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.

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26.3.16.3 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 26.3.14 (Transmit requirements for an HE trigger-based PPDU(#340)).(#2351)

26.3.16.4 Modulation accuracy

26.3.16.4.1 Introduction to modulation accuracy tests

Transmit modulation accuracy specifications are described in 26.3.16.4.2 (Transmit center frequency leakage) and 26.3.16.4.3 (Transmitter constellation error). The test method is described in 26.3.16.4.4 (Transmitter modulation accuracy (EVM) test).(#2351)

26.3.16.4.2 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 26.3.16.1 (Transmit spectral mask).(#2351)

26.3.16.4.3 Transmitter constellation error

(#2351)The relative constellation RMS error, calculated by first averaging over subcarriers, frequency segments, HE PPDUs, and spatial streams (see Equation (26-125)) shall not exceed a data-rate dependent value according to Table 26-42 (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.

Table 26-42—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 without preamble puncturing (dB)	Relative constellation error in HE MU PPDU with preambling puncturing and HE trigger-based PPDU (dB)
Without DCM	With DCM			
N/A	BPSK	1/2	–5	TBD
BPSK	QPSK	1/2	–5	TBD
QPSK	16-QAM	1/2	–10	TBD
QPSK	16-QAM	3/4	–13	TBD
16-QAM	N/A	1/2	–16	TBD
16-QAM	N/A	3/4	–19	TBD

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Table 26-42—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 without preamble puncturing (dB)	Relative constellation error in HE MU PPDU with preambling puncturing and HE trigger-based PPDU (dB)
Without DCM	With DCM			
64-QAM	N/A	2/3	–22	TBD
64-QAM	N/A	3/4	–25	TBD
64-QAM	N/A	5/6	–27	TBD
256-QAM	N/A	3/4	–30	TBD
256-QAM	N/A	5/6	–32	TBD
1024-QAM	N/A	3/4	–35	TBD
1024-QAM	N/A	5/6	–35	TBD

26.3.16.4.4 Transmitter modulation accuracy (EVM) test

(#2351)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 26-42 (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 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.

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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 (26-125).

$$Error_{RMS} = \frac{1}{N_f}\sum_{i_f=1}^{N_f}\sqrt{\frac{\sum_{i_s=1}^{N_{SYM}}\sum_{i_{ss}=1}^{N_{SS}}\sum_{i_{sc}=1}^{N_{ST}}(I_e(i_f, i_s, i_{ss}, i_{sc}) - I_0(i_f, i_s, i_{ss}, i_{sc}))^2 + (Q_e(i_f, i_s, i_{ss}, i_{sc}) - Q_0(i_f, i_s, i_{ss}, i_{sc}))^2}{N_{SYM}N_{SS}N_{ST}P_0}} \quad (26\text{-}125)$$

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 (26-125)). 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 and a preamble-punctured HE MU 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 maximum average unoccupied subcarriers error of the PPDU shall meet relative constellation error minus TBD margin in dB scale for each modulation and code rates 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

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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, estimate the power of each subcarriers.

f) Compute the average un-occupied subcarrier error vetor magnitude for each PPDU over 26 subcarriers and average across PPDUs of the RMS of all errors per PPDU as given by Equation (26-126).

$$UnusedToneError_{RMS}(k) = TBD \quad (26\text{-}126)$$

g) Compute the maximum average unoccupied subcarrier error vector magnitude as given by Equation (26-127).

$$UnusedToneError_{\text{MAX-RMS}} = \max_{\forall k}(UnusedToneError_{RMS}(k)) \quad (26\text{-}127)$$

The test shall be performed over at least 20 PPDUs (N_f as defined in Equation (26-125)). 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 un-occupied subcarriers transmit modulation accuracy test. Random data shall be used for the symbols.

26.3.16.5 Time of Departure accuracy

(#2351)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.

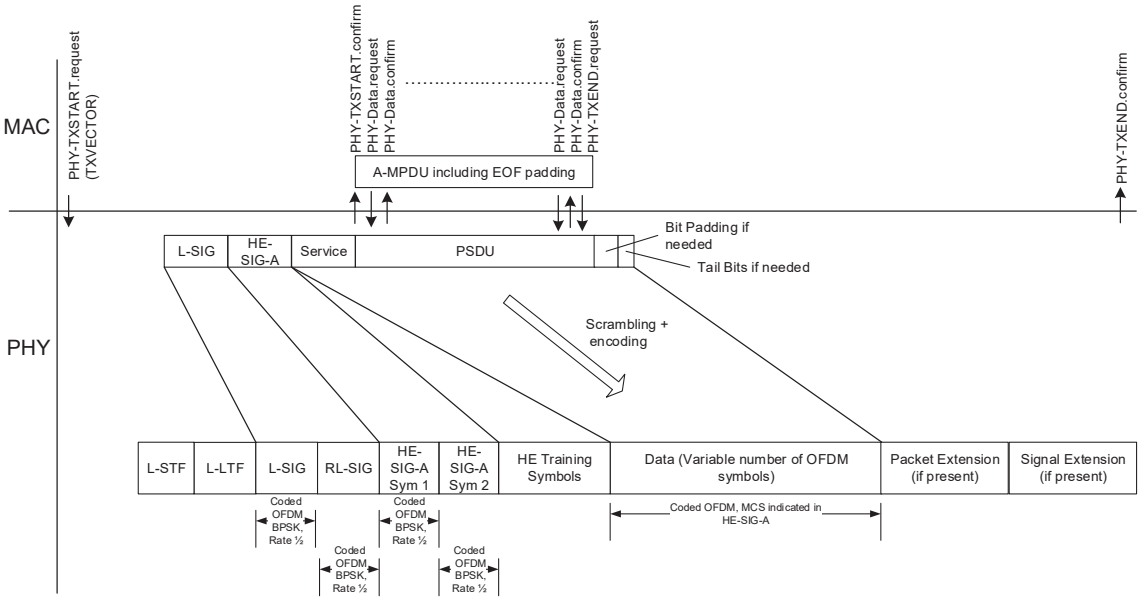
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— FIRST_TRANSITION_FIELD is L-STF.
— SECOND_TRANSITION_FIELD is L-LTF.
— TRAINING_FIELD is L-LTF windowed in a manner which should approximate the windowing described in 17.3.2.5 (Mathematical conventions in the signal descriptions) with TTR = 100 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.

26.3.17 HE transmit procedure

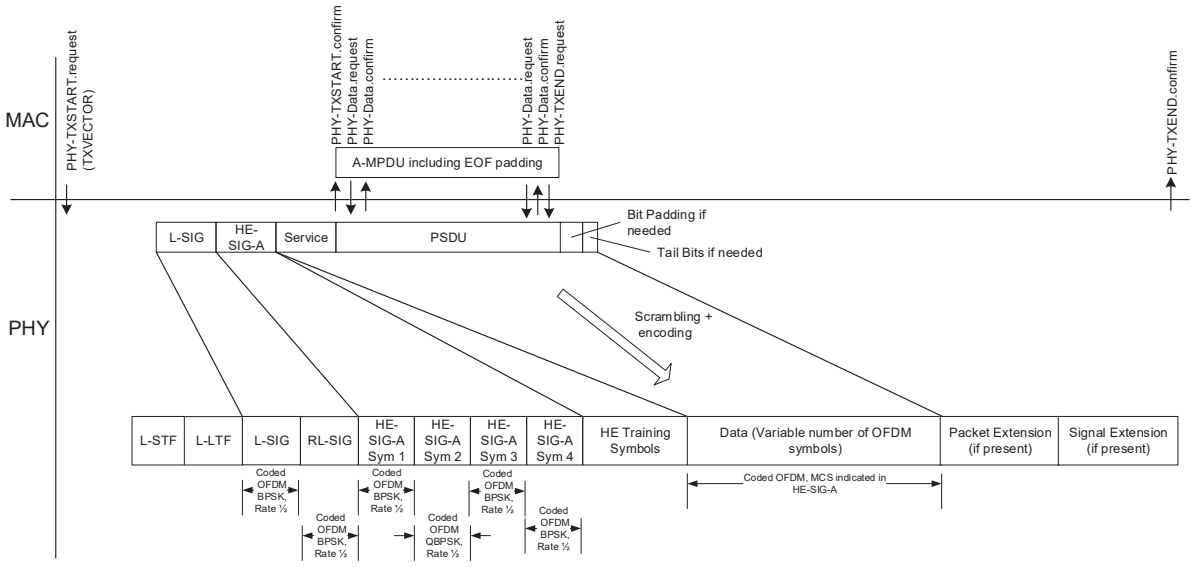
(#493)There are five options for the transmit PHY procedure. The first four options, for which typical transmit procedures are shown in Figure 26-40 (PHY transmit procedure for an HE SU PPDU), Figure 26-42 (PHY transmit procedure for an HE MU PPDU), Figure 26-41 (PHY transmit procedure for an HE extended range SU PPDU) and Figure 26-43 (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(PHY Motion #173).



NOTE—This procedure does not describe the operation of optional features, such as xxx.

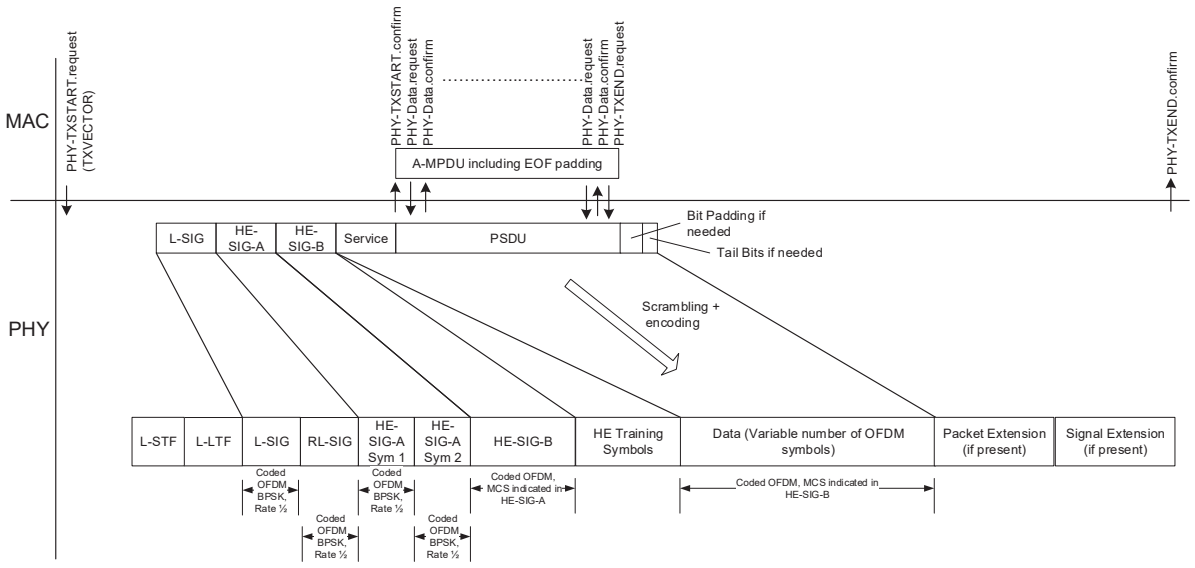
Figure 26-40—PHY transmit procedure for an HE SU PPDU

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NOTE—This procedure does not describe the operation of optional features, such as xxx.

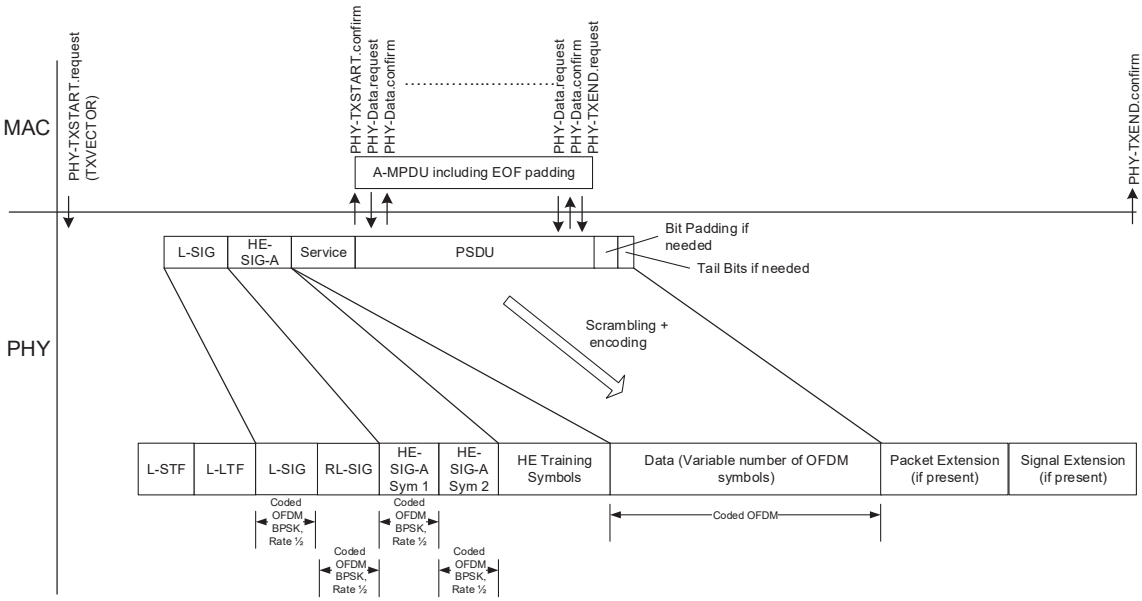
Figure 26-41—PHY transmit procedure for an HE extended range SU PPDU



NOTE—This procedure does not describe the operation of optional features, such as xxx.

Figure 26-42—PHY transmit procedure for an HE MU PPDU

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NOTE—This procedure does not describe the operation of optional features, such as xxx.

Figure 26-43—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 26.3.10 (HE preamble) and 26.3.13 (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 26-42 (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 26.4 (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 26.2.2 (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 26-1 (TXVECTOR and RXVECTOR parameters(#1780)).

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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 26.3.4 (HE PPDU formats).

The SERVICE field and PSDU are encoded as described in 26.3.5 (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 26-44 (PHY transmit state machine for an HE PPDU). Request (.request) and confirmation(.confirm)

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primitives are issued once per state as shown. This state machine does not describe the operation of optional features, such as DCM.

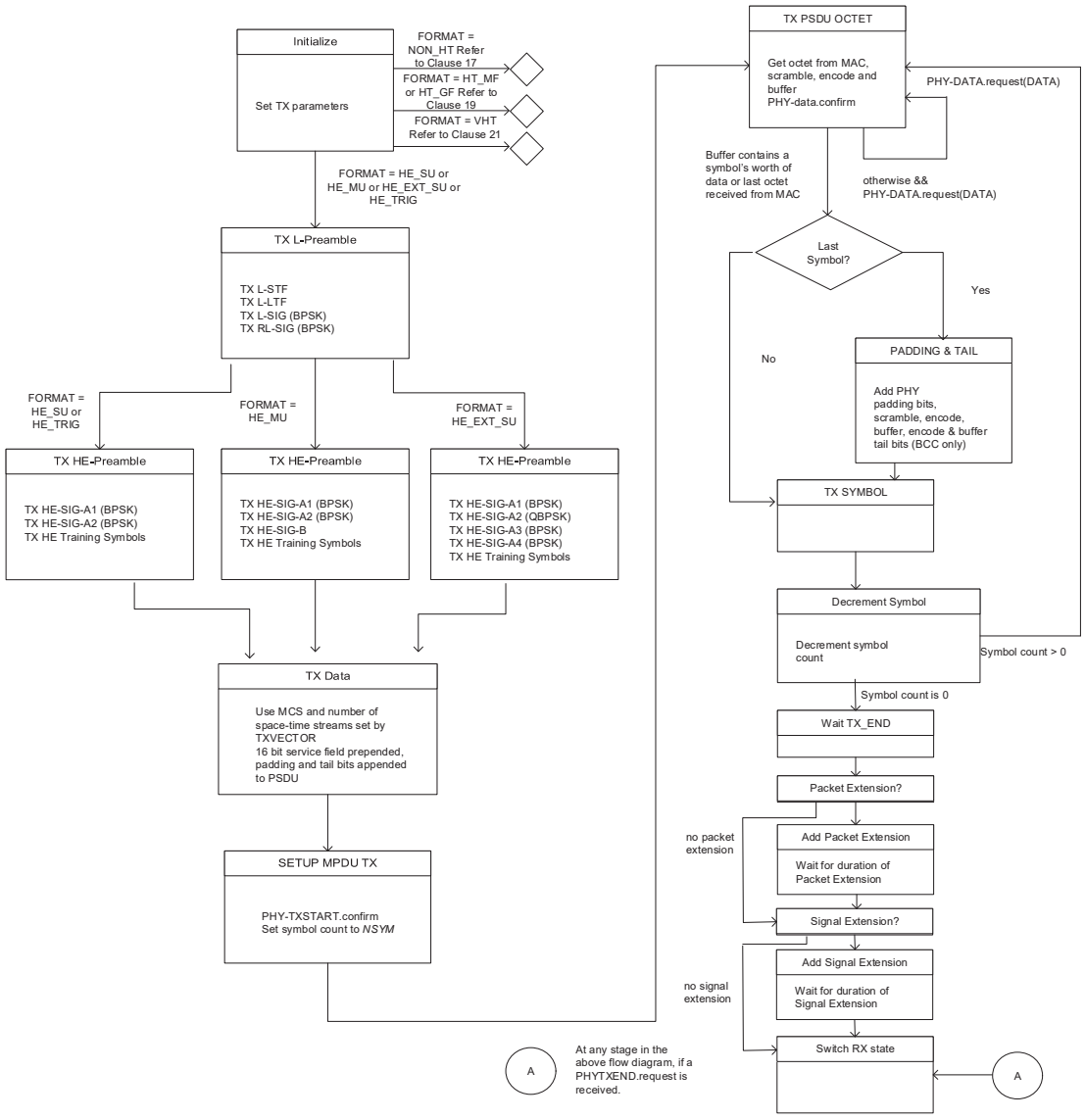


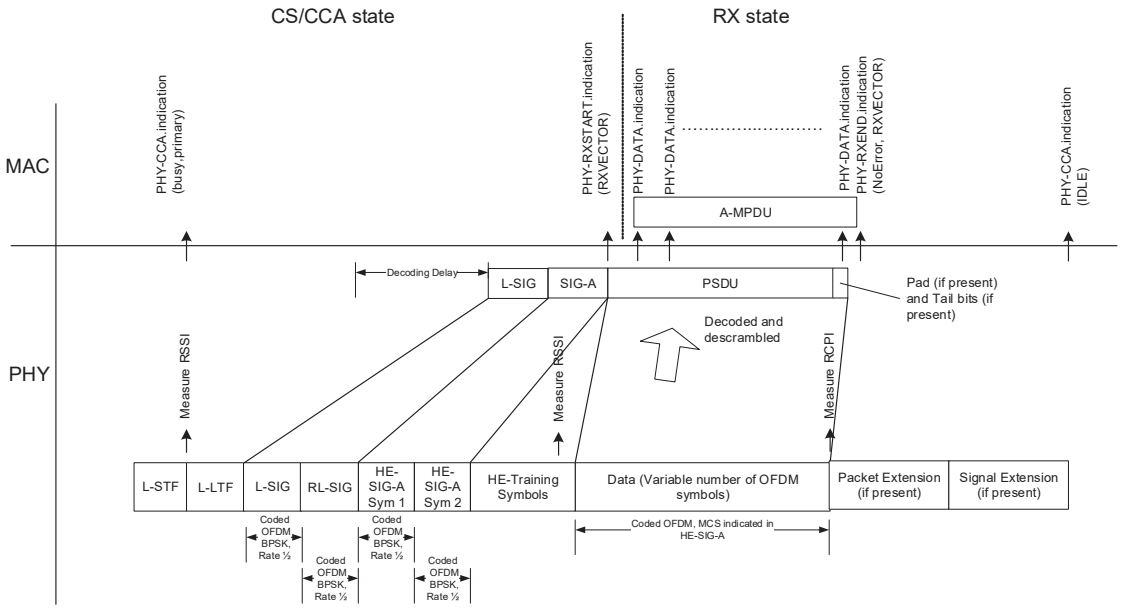
Figure 26-44—PHY transmit state machine for an HE PPDU

26.3.18 HE receive procedure

(#494)Typical PHY receive procedures are shown in Figure 26-45 (PHY receive procedure for an HE SU PPDU), Figure 26-46 (PHY receive procedure for an HE extended range SU PPDU), Figure 26-47 (PHY receive procedure for an HE MU PPDU), and Figure 26-48 (PHY receive procedure for an HE trigger-based PPDU) respectively. A typical state machine implementation of the receive PHY is given in Figure 26-49 (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

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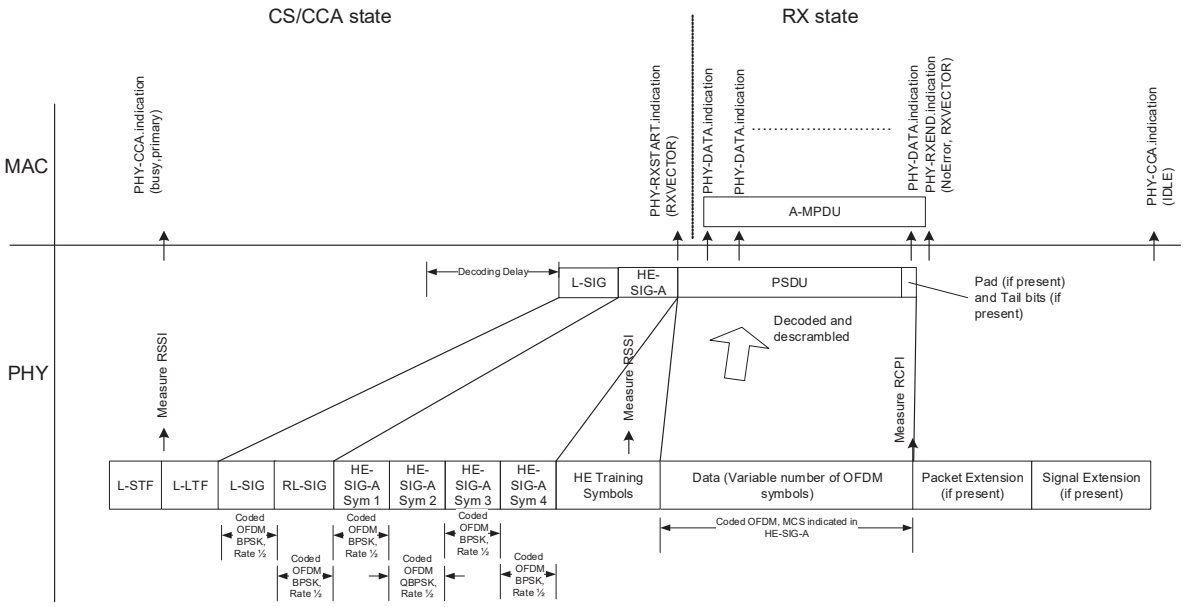
machine in Clause 19 (High Throughput (HT) PHY specification). If the detected format indicates a VHT PPDU format, refer to the receive procedure and state machine in Clause 21 (Very High Throughput (VHT) PHY specification).Through station management (via the PLME) the PHY is set to the appropriate frequency, as specified in 26.4 (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 xxx.

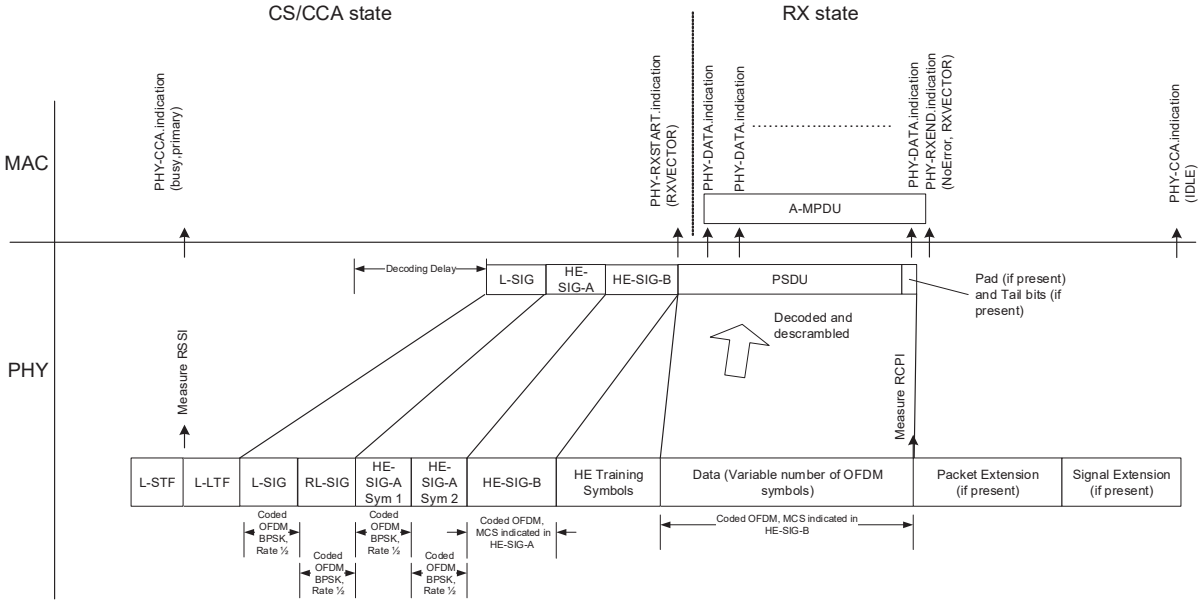
Figure 26-45—PHY receive procedure for an HE SU PPDU

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NOTE—This procedure does not describe the operation of optional features, such as xxx.

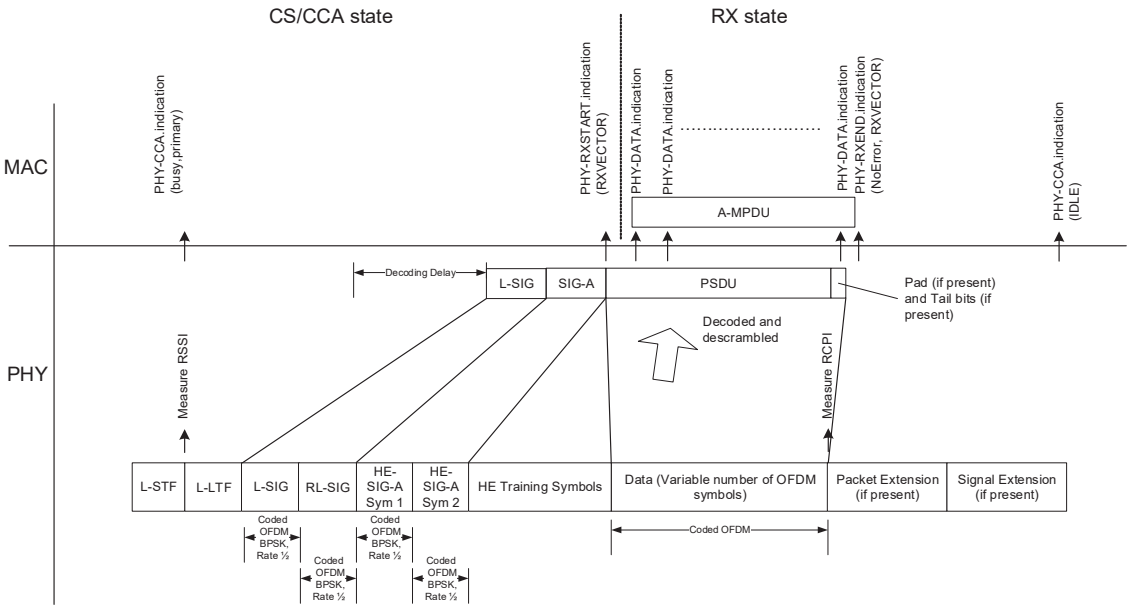
Figure 26-46—PHY receive procedure for an HE extended range SU PPDU



NOTE—This procedure does not describe the operation of optional features, such as xxx.

Figure 26-47—PHY receive procedure for an HE MU PPDU

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NOTE—This procedure does not describe the operation of optional features, such as xxx.

Figure 26-48—PHY receive procedure for an HE trigger-based PPDU

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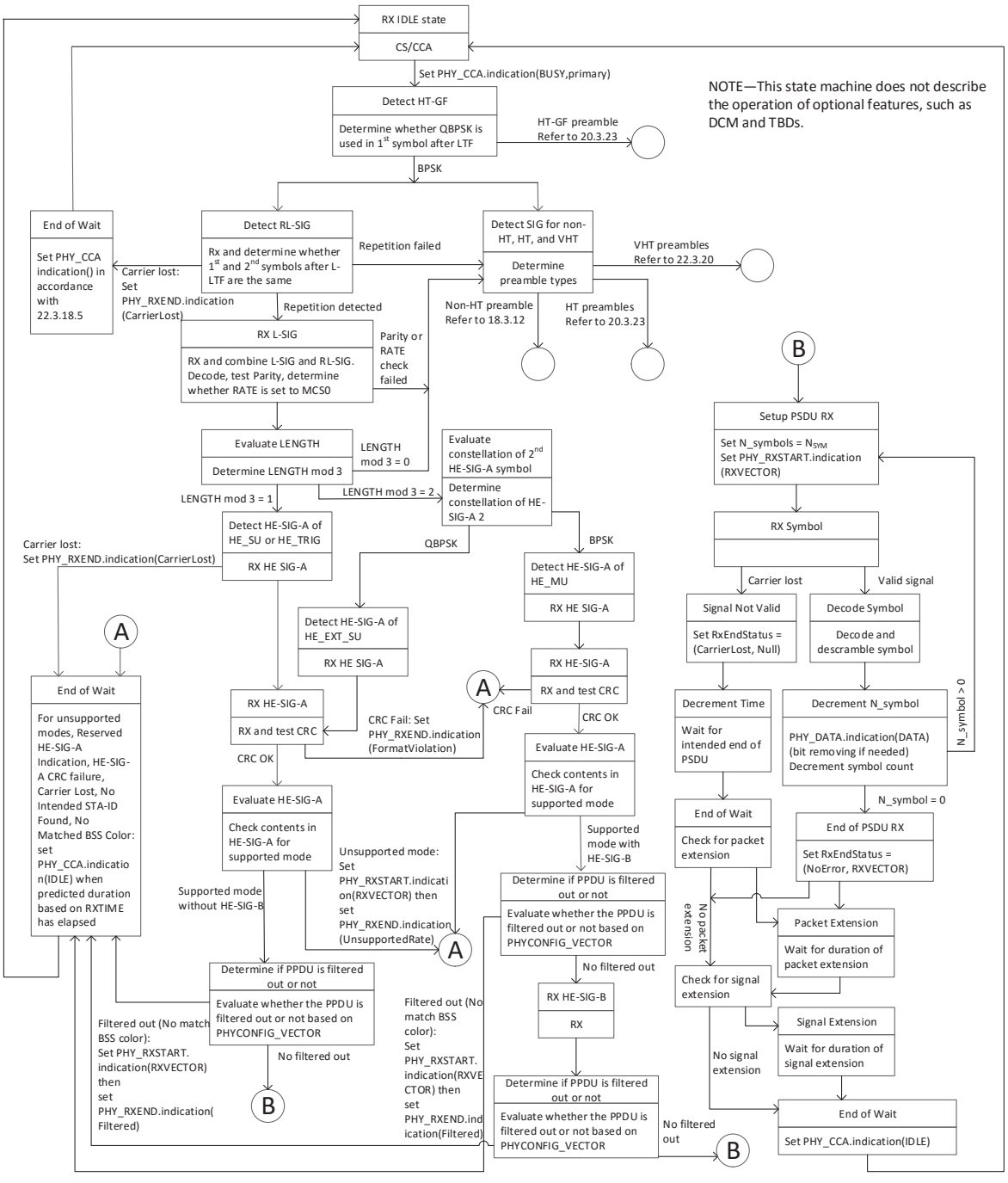


Figure 26-49—PHY receive state machine

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

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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.(PHY Motion #173)

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 traing 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 26-45 (PHY receive procedure for an HE SU PPDU) and Figure 26-48 (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 (21-106), 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(PHY Motion #169). 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 HE_EXT_SU PPDU shown in Figure 26-42. 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

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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 (21-106), 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(PHY Motion #169). 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 HE_MU PPDU shown in Figure 26-43. 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 (26-128), 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(PHY Motion #169). 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 (26-128) the PHY shall set the PHY-CCA.indication (IDLE) primitive and return to the RX IDLE state.

$$\text{RXTIME}(\mu s) = \left\lceil \frac{\text{L\_LENGTH} + 3}{3} \right\rceil 4 + 20 + \text{Signal Extension} \qquad (26\text{-}128)$$

Signal Extension is 0 μs when TXVECTOR parameter NO_SIG_EXTN is true and is aSignalExtension as defined in Table xxx of 26.3 (HE PHY) 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 (26-119) and Equation (26-120), respectively.(#2105)

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

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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 26-49 (PHY receive state machine).

The receiving procedures are subject to further changes depending on the decisions of spatial reuse and 20 MHz only devices.

26.4 HE PLME

26.4.1 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).(PHY Motion #173)

26.4.2 TXTIME and PSDU_LENGTH calculation

The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated for an(#2829) HE PPDU using Equation (26-129) for an HE SU PPDU and HE trigger-based PPDU, Equation (26-130) for an HE MU PPDU and Equation (26-131) for an HE extended range SU PPDU.

$$\text{TXTIME} = T_{\text{LEG\_PREAMBLE}} + T_{\text{L-SIG}} + T_{\text{RL-SIG}} + T_{\text{HE-SIG-A}} + T_{\text{HE\_PREAMBLE}} + N_{SYM}T_{SYM} + T_{PE} \quad (26\text{-}129)$$

$$\text{TXTIME} = T_{\text{LEG\_PREAMBLE}} + T_{\text{L-SIG}} + T_{\text{RL-SIG}} + T_{\text{HE-SIG-A}} + N_{\text{HE-SIG-B}}T_{\text{HE-SIG-B}} + T_{\text{HE\_PREAMBLE}} + N_{SYM}T_{SYM} + T_{PE} \quad (26\text{-}130)$$

$$\text{TXTIME} = T_{LEG\_PREAMBLE} + T_{L-SIG} + T_{RL-SIG} + T_{HE-SIG-A} + T_{HE-SIG-A-R} + T_{HE\_PREAMBLE} + N_{SYM}T_{SYM} + T_{PE} \quad (26\text{-}131)$$

where

$T_{\text{LEG\_PREAMBLE}} = T_{L-STF} + T_{L-LTF}$

$$T_{\text{HE\_PREAMBLE}} = \begin{cases} T_{\text{HE-STF-T}} + N_{HELTF}T_{\text{HE-LTF,SYM}}, & \text{for an HE trigger-based PPDU} \\ T_{\text{HE-STF-NT}} + N_{HELTF}T_{\text{HE-LTF,SYM}}, & \text{otherwise} \end{cases}$$

$T_{\text{L-STF}}$, $T_{\text{L-LTF}}$, $T_{\text{HE-STF-T}}$, $T_{\text{HE-STF-NT}}$, $T_{\text{HE-LTF,SYM}}$, $T_{\text{L-SIG}}$, $T_{\text{RL-SIG}}$, $T_{\text{HE-SIG-A}}$, $T_{\text{HE-SIG-A-R}}$, $T_{\text{HE-SIG-B}}$, and T_{SYM} are defined in Table 26-9 (Timing-related constants)

$N_{\text{HE-SIG-B}}$ and $N_{\text{HE-LTF}}$ are defined in Table 26-12 (Frequently used parameters(#282))

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 (26-67)(#2108).

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 26.3.11.5.2 (LDPC coding).

For an HE MU PPDU (including both MU-MIMO and OFDMA), the total number of OFDM symbols in the Data field, NSYM, is given in 26.3.11.5.4 (Encoding process for an HE MU PPDU).

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For an HE trigger-based PPDU, the total number of OFDM symbols in the Data field, N_{SYM}, is given in 26.3.11.5.5 (Encoding process for an HE trigger-based PPDU).

T_{PE} is given by Equation (26-116).

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 (26-132).(#2521)

$$\text{PSDU\_LENGTH} = \left\lfloor \frac{(N_{SYM,init} - m_{STBC})N_{DBPS} + m_{STBC}N_{DBPS,Last,init} - N_{service} - N_{tail}}{8} \right\rfloor \quad (26\text{-}132)$$

where

$N_{SYM,init}$ is given by Equation (26-66) for BCC encoding and by Equation (26-71) for LDPC encoding;
m_{STBC} is 2 when STBC is used, and 1 otherwise;
N_{DBPS} is given in 26.5 (Parameters for HE-MCSs);
$N_{DBPS,Last,init}$ is given by Equation (26-62)

The value of the PSDU_LENGTH parameter for user u returned in the PLME-TXTIME.confirm primitive and in the RXVECTOR for an(#2829) HE MU PPDU is calculated using Equation (26-133).(#2521)

$$\text{PSDU\_LENGTH}_u = \left\lfloor \frac{(N_{SYM,init} - m_{STBC})N_{DBPS} + m_{STBC}N_{DBPS,Last,init} - N_{service} - N_{tail}}{8} \right\rfloor \quad (26\text{-}133)$$

$N_{SYM,init}$ is given by Equation (26-79)
$N_{DBPS,Last,init}$is given by Equation (26-80)

The value of the PSDU_LENGTH parameter returned in the PLME-TXTIME.confirm primitive for an HE NDP PPDU is 0.

26.4.3 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 26-43 (HE PHY characteristics). The definitions for these characteristics are given in 6.5 (PLME SAP interface).

Table 26-43—HE PHY characteristics

Characteristic	Value
aTxPHYDelay	Implementation dependent
aRxPHYDelay	Implementation dependent
aCCAMidTIme	25 µs
aPPDUMaxTime	5.484 ms
aPSDUMaxLength	TBD

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26.5 Parameters for HE-MCSs(#552)

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 $N_{SS} = 1, \ldots, 8$ are given in Table 26-92 (HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, NSS = 1) through Table 26-99 (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 $N_{SS,r,u} = 2$).(PHY Motion #171) A 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 $N_{SS} = 2, \ldots, 8$. 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(PHY Motion #173). 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 $N_{SS} = 1, \ldots, 8$ is optional.(#282)

Table 26-44 (HE-MCSs for mandatory 26-tone RU, NSS = 1) to Table 26-99 (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(#2522).

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In the tables below, the number of streams and RU sizes that DCM is applicable to are TBD.

Table 26-44—HE-MCSs for mandatory 26-tone RU, N_{SS} = 1

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 µs GI	1.6 µs GI	3.2 µs GI
0	1	BPSK	1/4	1	24	2	24	6	0.4	0.4	0.4
0	0		1/2	1			24	12	0.9	0.8	0.8
1	1	QPSK	1/4	2			48	12	0.9	0.8	0.8
1	0		1/2	2			48	24	1.8	1.7	1.5
2	N/A		3/4	2			48	36	2.6	2.5	2.3
3	1	16-QAM	1/4	4			96	24	1.8	1.7	1.5
3	0		1/2	4			96	48	3.5	3.3	3.0
4	1		3/8	4			96	36	2.6	2.5	2.3
4	0		3/4	4			96	72	5.3	5.0	4.5
5	N/A	64-QAM	2/3	6			144	96	7.1	6.7	6.0
6			3/4	6			144	108	7.9	7.5	6.8
7			5/6	6			144	120	8.8	8.3	7.5
8		256-QAM	3/4	8			192	144	10.6	1.0	9.0
9			5/6	8			192	160	11.8	11.1	10.0

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Table 26-45—HE-MCSs for mandatory 26-tone RU, N_{SS} = 2

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 μs GI	1.6 μs GI	3.2 μs GI
0	1	BPSK	1/4	1	24	2	48	12	0.9	0.8	0.8
0	0		1/2	1			48	24	1.8	1.7	1.5
1	1	QPSK	1/4	2			96	24	1.8	1.7	1.5
1	0		1/2	2			96	48	3.5	3.3	3.0
2	N/A		3/4	2			96	72	5.3	5.0	4.5
3	1	16-QAM	1/4	4			192	48	3.5	3.3	3.0
3	0		1/2	4			192	96	7.1	6.7	6.0
4	1		3/8	4			192	72	5.3	5.0	4.5
4	0		3/4	4			192	144	10.6	10.0	9.0
5	N/A	64-QAM	2/3	6			288	192	14.1	13.3	12.0
6			3/4	6			288	216	15.9	15.0	13.5
7			5/6	6			288	240	17.6	16.7	15.0
8		256-QAM	3/4	8			384	288	21.2	20.0	18.0
9			5/6	8			384	320	23.5	22.2	20.0

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Table 26-46—HE-MCSs for mandatory 26-tone RU, N_{SS} = 3

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 μs GI	1.6 μs GI	3.2 μs GI
0	1	BPSK	1/4	1	24	2	72	18	1.3	1.3	1.1
0	0		1/2	1			72	36	2.6	2.5	2.3
1	1	QPSK	1/4	2			144	36	2.6	2.5	2.3
1	0		1/2	2			144	72	5.3	5.0	4.5
2	N/A		3/4	2			144	108	7.9	7.5	6.8
3	1	16-QAM	1/4	4			288	72	5.3	5.0	4.5
3	0		1/2	4			288	144	10.6	10.0	9.0
4	1		3/8	4			288	108	7.9	7.5	6.8
4	0		3/4	4			288	216	15.9	15.0	13.5
5	N/A	64-QAM	2/3	6			432	288	21.2	20.0	20.3
6			3/4	6			432	324	23.8	22.5	20.3
7			5/6	6			432	360	26.5	25.0	22.5
8		256-QAM	3/4	8			576	432	31.8	30.0	27.0
9			5/6	8			576	480	35.3	33.3	30.0

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Table 26-47—HE-MCSs for mandatory 26-tone RU, N_{SS} = 4

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 μs GI	1.6 μs GI	3.2 μs GI
0	1	BPSK	1/4	1	24	2	96	24	1.8	1.7	1.5
0	0		1/2	1			96	48	3.5	3.3	3.0
1	1	QPSK	1/4	2			192	48	3.5	3.3	3.0
1	0		1/2	2			192	96	7.1	6.7	6.0
2	N/A		3/4	2			192	144	10.6	10.0	9.0
3	1	16-QAM	1/4	4			384	96	7.1	6.7	6.0
3	0		1/2	4			384	192	14.1	13.3	12.0
4	1		3/8	4			384	144	10.6	10.0	9.0
4	0		3/4	4			384	288	21.2	20.0	18.0
5	N/A	64-QAM	2/3	6			576	384	28.2	26.7	24.0
6			3/4	6			576	432	31.8	30.0	27.0
7			5/6	6			576	480	35.3	33.3	30.0
8		256-QAM	3/4	8			768	576	42.4	40.0	36.0
9			5/6	8			768	640	47.1	44.4	40.0

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Table 26-48—HE-MCSs for mandatory 26-tone RU, N_{SS} = 5

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 µs GI	1.6 µs GI	3.2 µs GI
0	1	BPSK	1/4	1	24	2	120	30	2.2	2.1	1.9
0	0		1/2	1			120	60	4.4	4.2	3.8
1	1	QPSK	1/4	2			240	60	4.4	4.2	3.8
1	0		1/2	2			240	120	8.8	8.3	7.5
2	N/A		3/4	2			240	180	13.2	12.5	11.3
3	1	16-QAM	1/4	4			480	120	8.8	8.3	7.5
3	0		1/2	4			480	240	17.6	16.7	15.0
4	1		3/8	4			480	180	13.2	12.5	11.3
4	0		3/4	4			480	360	26.5	25.0	22.5
5	N/A	64-QAM	2/3	6			720	480	35.3	33.3	30.0
6			3/4	6			720	540	39.7	37.5	33.8
7			5/6	6			720	600	44.1	41.7	37.5
8		256-QAM	3/4	8			960	720	52.9	50.0	45.0
9			5/6	8			960	800	58.8	55.6	50.0

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Table 26-49—HE-MCSs for mandatory 26-tone RU, N_{SS} = 6

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 μs GI	1.6 μs GI	3.2 μs GI
0	1	BPSK	1/4	1	24	2	144	36	2.6	2.5	2.3
0	0		1/2	1			144	72	5.3	5.0	4.5
1	1	QPSK	1/4	2			288	72	5.3	5.0	4.5
1	0		1/2	2			288	144	10.6	10.0	9.0
2	N/A		3/4	2			288	216	15.9	15.0	13.5
3	1	16-QAM	1/4	4			576	144	10.6	10.0	9.0
3	0		1/2	4			576	288	21.2	20.0	18.0
4	1		3/8	4			576	216	15.9	15.0	13.5
4	0		3/4	4			576	432	31.8	30.0	27.0
5	N/A	64-QAM	2/3	6			864	576	42.4	40.0	36.0
6			3/4	6			864	648	47.6	45.0	40.5
7			5/6	6			864	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	8			1 152	960	70.6	66.7	60.0

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Table 26-50—HE-MCSs for mandatory 26-tone RU, N_{SS} = 7

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 μs GI	1.6 μs GI	3.2 μs GI
0	1	BPSK	1/4	1	24	2	168	42	3.1	2.9	2.6
0	0		1/2	1			168	84	6.2	5.8	5.3
1	1	QPSK	1/4	2			336	84	6.2	5.8	5.3
1	0		1/2	2			336	168	12.4	11.7	10.5
2	N/A		3/4	2			336	252	18.5	17.5	15.8
3	1	16-QAM	1/4	4			672	168	12.4	11.7	10.5
3	0		1/2	4			672	336	24.7	23.3	21.0
4	1		3/8	4			672	252	18.5	17.5	15.8
4	0		3/4	4			672	504	37.1	35.0	31.5
5	N/A	64-QAM	2/3	6			1 008	672	49.4	46.7	42.0
6			3/4	6			1 008	756	55.6	52.5	47.3
7			5/6	6			1 008	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	8			1 344	1 120	82.4	77.8	70.0

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Table 26-51—HE-MCSs for mandatory 26-tone RU, N_{SS} = 8

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 μs GI	1.6 μs GI	3.2 μs GI
0	1	BPSK	1/4	1	24	2	192	48	3.5	3.3	3.0
0	0		1/2	1			192	96	7.1	6.7	6.0
1	1	QPSK	1/4	2			384	96	7.1	6.7	6.0
1	0		1/2	2			384	192	14.1	13.3	12.0
2	N/A		3/4	2			384	288	21.2	20.0	18.0
3	1	16-QAM	1/4	4			768	192	14.1	13.3	12.0
3	0		1/2	4			768	384	28.2	26.7	24.0
4	1		3/8	4			768	288	21.2	20.0	18.0
4	0		3/4	4			768	576	42.4	40.0	36.0
5	N/A	64-QAM	2/3	6			1 152	768	56.5	53.3	48.0
6			3/4	6			1 152	864	63.5	60.0	54.0
7			5/6	6			1 152	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	8			1 536	1 280	94.1	88.9	80.0

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Table 26-52—HE-MCSs for mandatory 52-tone RU, N_{SS} = 1

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 µs GI	1.6 µs GI	3.2 µs GI
0	1	BPSK	1/4	1	48	4	48	12	0.9	0.8	0.8
0	0		1/2	1			48	24	1.8	1.7	1.5
1	1	QPSK	1/4	2			96	24	1.8	1.7	1.5
1	0		1/2	2			96	48	3.5	3.3	3.0
2	N/A		3/4	2			96	72	5.3	5.0	4.5
3	1	16-QAM	1/4	4			192	48	3.5	3.3	3.0
3	0		1/2	4			192	96	7.1	6.7	6.0
4	1		3/8	4			192	72	5.3	5.0	4.5
4	0		3/4	4			192	144	10.6	10.0	9.0
5	N/A	64-QAM	2/3	6			288	192	14.1	13.3	12.0
6			3/4	6			288	216	15.9	15.0	13.5
7			5/6	6			288	240	17.6	16.7	15.0
8		256-QAM	3/4	8			384	288	21.2	20.0	18.0
9			5/6	8			384	320	23.5	22.2	20.0

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Table 26-53—HE-MCSs for mandatory 52-tone RU, N_{SS} = 2

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 μs GI	1.6 μs GI	3.2 μs GI
0	1	BPSK	1/4	1	48	4	96	24	1.8	1.7	1.5
0	0		1/2	1			96	48	3.5	3.3	3.0
1	1	QPSK	1/4	2			192	48	3.5	3.3	3.0
1	0		1/2	2			192	96	7.1	6.7	6.0
2	N/A		3/4	2			192	144	10.6	10.0	9.0
3	1	16-QAM	1/4	4			384	96	7.1	6.7	6.0
3	0		1/2	4			384	192	14.1	13.3	12.0
4	1		3/8	4			384	144	10.6	10.0	9.0
4	0		3/4	4			384	288	21.2	20.0	18.0
5	N/A	64-QAM	2/3	6			576	384	28.2	26.7	24.0
6			3/4	6			576	432	31.8	30.0	27.0
7			5/6	6			576	480	35.3	33.3	30.0
8		256-QAM	3/4	8			768	576	42.4	40.0	36.0
9			5/6	8			768	640	47.1	44.4	40.0

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Table 26-54—HE-MCSs for mandatory 52-tone RU, N_{SS} = 3

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 µs GI	1.6 µs GI	3.2 µs GI
0	1	BPSK	1/4	1	48	4	144	36	2.6	2.5	2.3
0	0		1/2	1			144	72	5.3	5.0	4.5
1	1	QPSK	1/4	2			288	72	5.3	5.0	4.5
1	0		1/2	2			288	144	10.6	10.0	9.0
2	N/A		3/4	2			288	216	15.9	15.0	13.5
3	1	16-QAM	1/4	4			576	144	10.6	10.0	9.0
3	0		1/2	4			576	288	21.2	20.0	18.0
4	1		3/8	4			576	216	15.9	15.0	13.5
4	0		3/4	4			576	432	31.8	30.0	27.0
5	N/A	64-QAM	2/3	6			864	576	42.4	40.0	36.0
6			3/4	6			864	648	47.6	45.0	40.5
7			5/6	6			864	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	8			1 152	960	70.6	66.7	60.0

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Table 26-55—HE-MCSs for mandatory 52-tone RU, N_{SS} = 4

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 μs GI	1.6 μs GI	3.2 μs GI
0	1	BPSK	1/4	1	48	4	192	48	3.5	3.3	3.0
0	0		1/2	1			192	96	7.1	6.7	6.0
1	1	QPSK	1/4	2			384	96	7.1	6.7	6.0
1	0		1/2	2			384	192	14.1	13.3	12.0
2	N/A		3/4	2			384	288	21.2	20.0	18.0
3	1	16-QAM	1/4	4			768	192	14.1	13.3	12.0
3	0		1/2	4			768	384	28.2	26.7	24.0
4	1		3/8	4			768	288	21.2	20.0	18.0
4	0		3/4	4			768	576	42.4	40.0	36.0
5	N/A	64-QAM	2/3	6			1 152	768	56.5	53.3	48.0
6			3/4	6			1 152	864	63.5	60.0	54.0
7			5/6	6			1 152	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	8			1 536	1 280	94.1	88.9	80.0

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Table 26-56—HE-MCSs for mandatory 52-tone RU, N_{SS} = 5

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 µs GI	1.6 µs GI	3.2 µs GI
0	1	BPSK	1/4	1	48	4	240	60	4.4	4.2	3.8
0	0		1/2	1			240	120	8.8	8.3	7.5
1	1	QPSK	1/4	2			480	120	8.8	8.3	7.5
1	0		1/2	2			480	240	17.6	16.7	15.0
2	N/A		3/4	2			480	360	26.5	25.0	22.5
3	1	16-QAM	1/4	4			960	240	17.6	16.7	15.0
3	0		1/2	4			960	480	35.3	33.3	30.0
4	1		3/8	4			960	360	26.5	25.0	45.0
4	0		3/4	4			960	720	52.9	50.0	45.0
5	N/A	64-QAM	2/3	6			1 440	960	70.6	66.7	60.0
6			3/4	6			1 440	1080	79.4	75.0	67.5
7			5/6	6			1 440	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	8			1 920	1 600	117.6	111.1	100.0

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Table 26-57—HE-MCSs for mandatory 52-tone RU, N_{SS} = 6

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 μs GI	1.6 μs GI	3.2 μs GI
0	1	BPSK	1/4	1	48	4	288	72	5.3	5.0	4.5
0	0		1/2	1			288	144	10.6	10.0	9.0
1	1	QPSK	1/4	2			576	144	10.6	10.0	9.0
1	0		1/2	2			576	288	21.2	20.0	18.0
2	N/A		3/4	2			576	432	31.8	30.0	27.0
3	1	16-QAM	1/4	4			1 152	288	21.2	20.0	18.0
3	0		1/2	4			1 152	576	42.4	40.0	36.0
4	1		3/8	4			1 152	432	31.8	30.0	27.0
4	0		3/4	4			1 152	864	63.5	60.0	54.0
5	N/A	64-QAM	2/3	6			1 728	1 152	84.7	80.0	72.0
6			3/4	6			1 728	1 296	95.3	90.0	81.0
7			5/6	6			1 728	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	8			2 304	1 920	141.2	133.3	120.0

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Table 26-58—HE-MCSs for mandatory 52-tone RU, N_{SS} = 7

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 µs GI	1.6 µs GI	3.2 µs GI
0	1	BPSK	1/4	1	48	4	336	84	6.2	5.8	5.3
0	0		1/2	1			336	168	12.4	11.7	10.5
1	1	QPSK	1/4	2			672	168	12.4	11.7	10.5
1	0		1/2	2			672	336	24.7	23.3	21.0
2	N/A		3/4	2			672	504	37.1	35.0	31.5
3	1	16-QAM	1/4	4			1 344	336	24.7	23.3	21.0
3	0		1/2	4			1 344	672	49.4	46.7	42.0
4	1		3/8	4			1 344	504	37.1	35.0	31.5
4	0		3/4	4			1 344	1 008	74.1	70.0	63.0
5	N/A	64-QAM	2/3	6			2 016	1 344	98.8	93.3	84.0
6			3/4	6			2 016	1 512	111.2	105.0	94.5
7			5/6	6			2 016	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	8			2 688	2 240	164.7	155.6	140.0

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Table 26-59—HE-MCSs for mandatory 52-tone RU, N_{SS} = 8

HE-MCS Index	DCM	Modulation	R	N_{BPCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	Data rate (Mbps)		
									0.8 μs GI	1.6 μs GI	3.2 μs GI
0	1	BPSK	1/4	1	48	4	384	96	7.1	6.7	6.0
0	0		1/2	1			384	192	14.1	13.3	12.0
1	1	QPSK	1/4	2			768	192	14.1	13.3	12.0
1	0		1/2	2			768	384	28.2	26.7	24.0
2	N/A		3/4	2			768	576	42.4	40.0	36.0
3	1	16-QAM	1/4	4			1 536	384	28.2	26.7	24.0
3	0		1/2	4			1 536	768	56.5	53.3	48.0
4	1		3/8	4			1 536	576	42.4	40.0	36.0
4	0		3/4	4			1 536	1 152	84.7	80.0	72.0
5	N/A	64-QAM	2/3	6			2 304	1 536	112.9	106.7	96.0
6			3/4	6			2 304	1 728	127.1	120.0	108.0
7			5/6	6			2 304	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	8			3 072	2 560	188.2	177.8	160.0

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Table 26-60—HE-MCSs for mandatory 106-tone RU, N_{SS} = 1

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	102	4	102	25	1	1.8	1.7	1.6
0	0		1/2	1			102	51	1	3.8	3.5	3.2
1	1	QPSK	1/4	2			204	51	1	3.8	3.5	3.2
1	0		1/2	2			204	102	1	7.5	7.1	6.4
2	N/A		3/4	2			204	153	1	11.3	10.6	9.6
3	1	16-QAM	1/4	4			408	102	1	7.5	7.1	6.4
3	0		1/2	4			408	204	1	15.0	14.2	12.8
4	1		3/8	4			408	153	1	11.3	10.6	9.6
4	0		3/4	4			408	306	1	22.5	21.3	19.1
5	N/A	64-QAM	2/3	6			612	408	1	30.0	28.3	25.5
6			3/4	6			612	459	1	33.8	31.9	28.7
7			5/6	6			612	510	1	37.5	35.4	31.9
8		256-QAM	3/4	8			816	612	1	45.0	42.5	38.3
9			5/6	8			816	680	1	50.0	47.2	42.5

Table 26-61—HE-MCSs for mandatory 106-tone RU, N_{SS} = 2

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	102	4	204	51	1	3.8	3.5	3.2
0	0		1/2	1			204	102	1	7.5	7.1	6.4
1	1	QPSK	1/4	2			408	102	1	7.5	7.1	6.4
1	0		1/2	2			408	204	1	15.0	14.2	12.8
2	N/A		3/4	2			408	306	1	22.5	21.3	19.1
3	1	16-QAM	1/4	4			816	204	1	15.0	14.2	12.8
3	0		1/2	4			816	408	1	30.0	28.3	25.5
4	1		3/8	4			816	306	1	22.5	21.3	19.1
4	0		3/4	4			816	612	1	45.0	42.5	38.3
5	N/A	64-QAM	2/3	6			1224	816	1	60.0	56.7	51.0
6			3/4	6			1224	918	1	67.5	63.8	57.4
7			5/6	6			1224	1,020	1	75.0	70.8	63.8
8		256-QAM	3/4	8			1632	1,224	1	90.0	85.0	76.5
9			5/6	8			1632	1,360	1	100.0	94.4	85.0

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Table 26-62—HE-MCSs for mandatory 106-tone RU, N_{SS} = 3

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	102	4	306	76	1	5.6	5.3	4.8
0	0		1/2	1			306	153	1	11.3	10.6	9.6
1	1	QPSK	1/4	2			612	153	1	11.3	10.6	9.6
1	0		1/2	2			612	306	1	22.5	21.3	19.1
2	N/A		3/4	2			612	459	1	33.8	31.9	28.7
3	1	16-QAM	1/4	4			1224	306	1	22.5	21.3	19.1
3	0		1/2	4			1224	612	1	45.0	42.5	38.3
4	1		3/8	4			1224	459	1	33.8	31.9	28.7
4	0		3/4	4			1224	918	1	67.5	63.8	57.4
5	N/A	64-QAM	2/3	6			1836	1,224	1	90.0	85.0	76.5
6			3/4	6			1836	1,377	1	101.3	95.6	86.1
7			5/6	6			1836	1,530	1	112.5	106.3	95.6
8		256-QAM	3/4	8			2448	1,836	1	135.0	127.5	114.8
9			5/6	8			2448	2,040	1	150.0	141.7	127.5

Table 26-63—HE-MCSs for mandatory 106-tone RU, N_{SS} = 4

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	102	4	408	102	1	7.5	7.1	6.4
0	0		1/2	1			408	204	1	15.0	14.2	12.8
1	1	QPSK	1/4	2			816	204	1	15.0	14.2	12.8
1	0		1/2	2			816	408	1	30.0	28.3	25.5
2	N/A		3/4	2			816	612	1	45.0	42.5	38.3
3	1	16-QAM	1/4	4			1632	408	1	30.0	28.3	25.5
3	0		1/2	4			1632	816	1	60.0	56.7	51.0
4	1		3/8	4			1632	612	1	45.0	42.5	38.3
4	0		3/4	4			1632	1,224	1	90.0	85.0	76.5
5	N/A	64-QAM	2/3	6			2448	1,632	1	120.0	113.3	102.0
6			3/4	6			2448	1,836	1	135.0	127.5	114.8
7			5/6	6			2448	2,040	1	150.0	141.7	127.5
8		256-QAM	3/4	8			3264	2,448	1	180.0	170.0	153.0
9			5/6	8			3264	2,720	1	200.0	188.9	170.0

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Table 26-64—HE-MCSs for mandatory 106-tone RU, N_{SS} = 5

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	102	4	510	127	1	9.3	8.8	7.9
0	0		1/2	1			510	255	1	18.8	17.7	15.9
1	1	QPSK	1/4	2			1020	255	1	18.8	17.7	15.9
1	0		1/2	2			1020	510	1	37.5	35.4	31.9
2	N/A		3/4	2			1020	765	1	56.3	53.1	47.8
3	1	16-QAM	1/4	4			2040	510	1	37.5	35.4	31.9
3	0		1/2	4			2040	1,020	1	75.0	70.8	63.8
4	1		3/8	4			2040	765	1	56.3	53.1	47.8
4	0		3/4	4			2040	1,530	1	112.5	106.3	95.6
5	N/A	64-QAM	2/3	6			3060	2,040	1	150.0	141.7	127.5
6			3/4	6			3060	2,295	1	168.8	159.4	143.4
7			5/6	6			3060	2,550	1	187.5	177.1	159.4
8		256-QAM	3/4	8			4080	3,060	1	225.0	212.5	191.3
9			5/6	8			4080	3,400	1	250.0	236.1	212.5

Table 26-65—HE-MCSs for mandatory 106-tone RU, N_{SS} = 6

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	102	4	612	153	1	11.3	10.6	9.6
0	0		1/2	1			612	306	1	22.5	21.3	19.1
1	1	QPSK	1/4	2			1224	306	1	22.5	21.3	19.1
1	0		1/2	2			1224	612	1	45.0	42.5	38.3
2	N/A		3/4	2			1224	918	1	67.5	63.8	57.4
3	1	16-QAM	1/4	4			2448	612	1	45.0	42.5	38.3
3	0		1/2	4			2448	1,224	1	90.0	85.0	76.5
4	1		3/8	4			2448	918	1	67.5	63.8	57.4
4	0		3/4	4			2448	1,836	1	135.0	127.5	114.8
5	N/A	64-QAM	2/3	6			3672	2,448	1	180.0	170.0	153.0
6			3/4	6			3672	2,754	1	202.5	191.3	172.1
7			5/6	6			3672	3,060	1	225.0	212.5	191.3
8		256-QAM	3/4	8			4896	3,672	1	270.0	255.0	229.5
9			5/6	8			4896	4,080	1	300.0	283.3	255.0

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Table 26-66—HE-MCSs for mandatory 106-tone RU, N_{SS} = 7

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	102	4	714	178	1	13.1	12.4	11.1
0	0		1/2	1			714	357	1	26.3	24.8	22.3
1	1	QPSK	1/4	2			1428	357	1	26.3	24.8	22.3
1	0		1/2	2			1428	714	1	52.5	49.6	44.6
2	N/A		3/4	2			1428	1,071	1	78.8	74.4	66.9
3	1	16-QAM	1/4	4			2856	714	1	52.5	49.6	44.6
3	0		1/2	4			2856	1,428	1	105.0	99.2	89.3
4	1		3/8	4			2856	1,071	1	78.8	74.4	66.9
4	0		3/4	4			2856	2,142	1	157.5	148.8	133.9
5	N/A	64-QAM	2/3	6			4284	2,856	1	210.0	198.3	178.5
6			3/4	6			4284	3,213	1	236.3	223.1	200.8
7			5/6	6			4284	3,570	1	262.5	247.9	223.1
8		256-QAM	3/4	8			5712	4,284	1	315.0	297.5	267.8
9			5/6	8			5712	4,760	1	350.0	330.6	297.5

Table 26-67—HE-MCSs for mandatory 106-tone RU, N_{SS} = 8

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	102	4	816	204	1	15.0	14.2	12.8
0	0		1/2	1			816	408	1	30.0	28.3	25.5
1	1	QPSK	1/4	2			1632	408	1	30.0	28.3	25.5
1	0		1/2	2			1632	816	1	60.0	56.7	51.0
2	N/A		3/4	2			1632	1,224	1	90.0	85.0	76.5
3	1	16-QAM	1/4	4			3264	816	1	60.0	56.7	51.0
3	0		1/2	4			3264	1,632	1	120.0	113.3	102.0
4	1		3/8	4			3264	1,224	1	90.0	85.0	76.5
4	0		3/4	4			3264	2,448	1	180.0	170.0	153.0
5	N/A	64-QAM	2/3	6			4896	3,264	1	240.0	226.7	204.0
6			3/4	6			4896	3,672	1	270.0	255.0	229.5
7			5/6	6			4896	4,080	1	300.0	283.3	255.0
8		256-QAM	3/4	8			6528	4,896	1	360.0	340.0	306.0
9			5/6	8			6528	5,440	1	400.0	377.8	340.0

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Table 26-68—HE-MCSs for mandatory 242-tone RU and mandatory non-OFDMA 20 MHz, N_{SS} = 1

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	234	8	234	58	1	4.3	4.0	3.6
0	0		1/2	1			234	117	1	8.6	8.1	7.3
1	1	QPSK	1/4	2			468	117	1	8.6	8.1	7.3
1	0		1/2	2			468	234	1	17.2	16.3	14.6
2	N/A		3/4	2			468	351	1	25.8	24.4	21.9
3	1	16-QAM	1/4	4			936	234	1	17.2	16.3	14.6
3	0		1/2	4			936	468	1	34.4	32.5	29.3
4	1		3/8	4			936	351	1	25.8	24.4	21.9
4	0		3/4	4			936	702	1	51.6	48.8	43.9
5	N/A	64-QAM	2/3	6			1404	936	1	68.8	65.0	58.5
6			3/4	6			1404	1,053	1	77.4	73.1	65.8
7			5/6	6			1404	1,170	1	86.0	81.3	73.1
8		256-QAM	3/4	8			1872	1,404	1	103.2	97.5	87.8
9			5/6	8			1872	1,560	1	114.7	108.3	97.5
10		1024-QAM	3/4	10			2340	1,755	1	129.0	121.9	109.7
11			5/6	10			2340	1,950	1	143.4	135.4	121.9

Table 26-69—HE-MCSs for mandatory 242-tone RU and mandatory non-OFDMA 20 MHz, N_{SS} = 2

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	234	8	468	117	1	8.6	8.1	7.3
0	0		1/2	1			468	234	1	17.2	16.3	14.6
1	1	QPSK	1/4	2			936	234	1	17.2	16.3	14.6
1	0		1/2	2			936	468	1	34.4	32.5	29.3
2	N/A		3/4	2			936	702	1	51.6	48.8	43.9
3	1	16-QAM	1/4	4			1872	468	1	34.4	32.5	29.3
3	0		1/2	4			1872	936	1	68.8	65.0	58.5
4	1		3/8	4			1872	702	1	51.6	48.8	43.9
4	0		3/4	4			1872	1,404	1	103.2	97.5	87.8
5	N/A	64-QAM	2/3	6			2808	1,872	1	137.6	130.0	117.0
6			3/4	6			2808	2,106	1	154.9	146.3	131.6
7			5/6	6			2808	2,340	1	172.1	162.5	146.3
8		256-QAM	3/4	8			3744	2,808	1	206.5	195.0	175.5
9			5/6	8			3744	3,120	1	229.4	216.7	195.0
10		1024-QAM	3/4	10			4680	3,510	1	258.1	243.8	219.4
11			5/6	10			4680	3,900	1	286.8	270.8	243.8

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Table 26-70—HE-MCSs for mandatory 242-tone RU and mandatory non-OFDMA 20 MHz, N_{SS} = 3

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	234	8	702	175	1	12.9	12.2	10.9
0	0		1/2	1			702	351	1	25.8	24.4	21.9
1	1	QPSK	1/4	2			1404	351	1	25.8	24.4	21.9
1	0		1/2	2			1404	702	1	51.6	48.8	43.9
2	N/A		3/4	2			1404	1,053	1	77.4	73.1	65.8
3	1	16-QAM	1/4	4			2808	702	1	51.6	48.8	43.9
3	0		1/2	4			2808	1,404	1	103.2	97.5	87.8
4	1		3/8	4			2808	1,053	1	77.4	73.1	65.8
4	0		3/4	4			2808	2,106	1	154.9	146.3	131.6
5	N/A	64-QAM	2/3	6			4212	2,808	1	206.5	195.0	175.5
6			3/4	6			4212	3,159	1	232.3	219.4	197.4
7			5/6	6			4212	3,510	1	258.1	243.8	219.4
8		256-QAM	3/4	8			5616	4,212	1	309.7	292.5	263.3
9			5/6	8			5616	4,680	1	344.1	325.0	292.5
10		1024-QAM	3/4	10			7020	5,265	1	387.1	365.6	329.1
11			5/6	10			7020	5,850	1	430.1	406.3	365.6

Table 26-71—HE-MCSs for mandatory 242-tone RU and mandatory non-OFDMA 20 MHz, N_{SS} = 4

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	234	8	936	234	1	17.2	16.3	14.6
0	0		1/2	1			936	468	1	34.4	32.5	29.3
1	1	QPSK	1/4	2			1872	468	1	34.4	32.5	29.3
1	0		1/2	2			1872	936	1	68.8	65.0	58.5
2	N/A		3/4	2			1872	1,404	1	103.2	97.5	87.8
3	1	16-QAM	1/4	4			3744	936	1	68.8	65.0	58.5
3	0		1/2	4			3744	1,872	1	137.6	130.0	117.0
4	1		3/8	4			3744	1,404	1	103.2	97.5	87.8
4	0		3/4	4			3744	2,808	1	206.5	195.0	175.5
5	N/A	64-QAM	2/3	6			5616	3,744	1	275.3	260.0	234.0
6			3/4	6			5616	4,212	1	309.7	292.5	263.3
7			5/6	6			5616	4,680	1	344.1	325.0	292.5
8		256-QAM	3/4	8			7488	5,616	1	412.9	390.0	351.0
9			5/6	8			7488	6,240	1	458.8	433.3	390.0
10		1024-QAM	3/4	10			9360	7,020	1	516.2	487.5	438.8
11			5/6	10			9360	7,800	1	573.5	541.7	487.5

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Table 26-72—HE-MCSs for mandatory 242-tone RU and mandatory non-OFDMA 20 MHz, N_{SS} = 5

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	234	8	1170	292	1	21.5	20.3	18.3
0	0		1/2	1			1170	585	1	43.0	40.6	36.6
1	1	QPSK	1/4	2			2340	585	1	43.0	40.6	36.6
1	0		1/2	2			2340	1,170	1	86.0	81.3	73.1
2	N/A		3/4	2			2340	1,755	1	129.0	121.9	109.7
3	1	16-QAM	1/4	4			4680	1,170	1	86.0	81.3	73.1
3	0		1/2	4			4680	2,340	1	172.1	162.5	146.3
4	1		3/8	4			4680	1,755	1	129.0	121.9	109.7
4	0		3/4	4			4680	3,510	1	258.1	243.8	219.4
5	N/A	64-QAM	2/3	6			7020	4,680	1	344.1	325.0	292.5
6			3/4	6			7020	5,265	1	387.1	365.6	329.1
7			5/6	6			7020	5,850	1	430.1	406.3	365.6
8		256-QAM	3/4	8			9360	7,020	1	516.2	487.5	438.8
9			5/6	8			9360	7,800	1	573.5	541.7	487.5
10		1024-QAM	3/4	10			11700	8,775	1	645.2	609.4	548.4
11			5/6	10			11700	9,750	1	716.9	677.1	609.4

Table 26-73—HE-MCSs for mandatory 242-tone RU and mandatory non-OFDMA 20 MHz, N_{SS} = 6

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	234	8	1404	351	1	25.8	24.4	21.9
0	0		1/2	1			1404	702	1	51.6	48.8	43.9
1	1	QPSK	1/4	2			2808	702	1	51.6	48.8	43.9
1	0		1/2	2			2808	1,404	1	103.2	97.5	87.8
2	N/A		3/4	2			2808	2,106	1	154.9	146.3	131.6
3	1	16-QAM	1/4	4			5616	1,404	1	103.2	97.5	87.8
3	0		1/2	4			5616	2,808	1	206.5	195.0	175.5
4	1		3/8	4			5616	2,106	1	154.9	146.3	131.6
4	0		3/4	4			5616	4,212	1	309.7	292.5	263.3
5	N/A	64-QAM	2/3	6			8424	5,616	1	412.9	390.0	351.0
6			3/4	6			8424	6,318	1	464.6	438.8	394.9
7			5/6	6			8424	7,020	1	516.2	487.5	438.8
8		256-QAM	3/4	8			11232	8,424	1	619.4	585.0	526.5
9			5/6	8			11232	9,360	1	688.2	650.0	585.0
10		1024-QAM	3/4	10			14040	10,530	1	774.3	731.3	658.1
11			5/6	10			14040	11,700	1	860.3	812.5	731.3

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Table 26-74—HE-MCSs for mandatory 242-tone RU and mandatory non-OFDMA 20 MHz, N_{SS} = 7

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	234	8	1638	409	1	30.1	28.4	25.6
0	0		1/2	1			1638	819	1	60.2	56.9	51.2
1	1	QPSK	1/4	2			3276	819	1	60.2	56.9	51.2
1	0		1/2	2			3276	1,638	1	120.4	113.8	102.4
2	N/A		3/4	2			3276	2,457	1	180.7	170.6	153.6
3	1	16-QAM	1/4	4			6552	1,638	1	120.4	113.8	102.4
3	0		1/2	4			6552	3,276	1	240.9	227.5	204.8
4	1		3/8	4			6552	2,457	1	180.7	170.6	153.6
4	0		3/4	4			6552	4,914	1	361.3	341.3	307.1
5	N/A	64-QAM	2/3	6			9828	6,552	1	481.8	455.0	409.5
6			3/4	6			9828	7,371	1	542.0	511.9	460.7
7			5/6	6			9828	8,190	1	602.2	568.8	511.9
8		256-QAM	3/4	8			13104	9,828	1	722.6	682.5	614.3
9			5/6	8			13104	10,920	1	802.9	758.3	682.5
10		1024-QAM	3/4	10			16380	12,285	1	903.3	853.1	767.8
11			5/6	10			16380	13,650	1	1,003.7	947.9	853.1

Table 26-75—HE-MCSs for mandatory 242-tone RU and mandatory non-OFDMA 20 MHz, N_{SS} = 8

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	234	8	1872	468	1	34.4	32.5	29.3
0	0		1/2	1			1872	936	1	68.8	65.0	58.5
1	1	QPSK	1/4	2			3744	936	1	68.8	65.0	58.5
1	0		1/2	2			3744	1,872	1	137.6	130.0	117.0
2	N/A		3/4	2			3744	2,808	1	206.5	195.0	175.5
3	1	16-QAM	1/4	4			7488	1,872	1	137.6	130.0	117.0
3	0		1/2	4			7488	3,744	1	275.3	260.0	234.0
4	1		3/8	4			7488	2,808	1	206.5	195.0	175.5
4	0		3/4	4			7488	5,616	1	412.9	390.0	351.0
5	N/A	64-QAM	2/3	6			11232	7,488	1	550.6	520.0	468.0
6			3/4	6			11232	8,424	1	619.4	585.0	526.5
7			5/6	6			11232	9,360	1	688.2	650.0	585.0
8		256-QAM	3/4	8			14976	11,232	1	825.9	780.0	702.0
9			5/6	8			14976	12,480	1	917.6	866.7	780.0
10		1024-QAM	3/4	10			18720	14,040	1	1,032.4	975.0	877.5
11			5/6	10			18720	15,600	1	1,147.1	1,083.3	975.0

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Table 26-76—HE-MCSs for mandatory 484-tone RU and mandatory non-OFDMA 40 MHz, N_{SS} = 1

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	468	16	468	117	1	8.6	8.1	7.3
0	0		1/2	1			468	234	1	17.2	16.3	14.6
1	1	QPSK	1/4	2			936	234	1	17.2	16.3	14.6
1	0		1/2	2			936	468	1	34.4	32.5	29.3
2	N/A		3/4	2			936	702	1	51.6	48.8	43.9
3	1	16-QAM	1/4	4			1872	468	1	34.4	32.5	29.3
3	0		1/2	4			1872	936	1	68.8	65.0	58.5
4	1		3/8	4			1872	702	1	51.6	48.8	43.9
4	0		3/4	4			1872	1,404	1	103.2	97.5	87.8
5	N/A	64-QAM	2/3	6			2808	1,872	1	137.6	130.0	117.0
6			3/4	6			2808	2,106	1	154.9	146.3	131.6
7			5/6	6			2808	2,340	1	172.1	162.5	146.3
8		256-QAM	3/4	8			3744	2,808	1	206.5	195.0	175.5
9			5/6	8			3744	3,120	1	229.4	216.7	195.0
10		1024-QAM	3/4	10			4680	3,510	1	258.1	243.8	219.4
11			5/6	10			4680	3,900	1	286.8	270.8	243.8

Table 26-77—HE-MCSs for mandatory 484-tone RU and mandatory non-OFDMA 40 MHz, N_{SS} = 2

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	468	16	936	234	1	17.2	16.3	14.6
0	0		1/2	1			936	468	1	34.4	32.5	29.3
1	1	QPSK	1/4	2			1872	468	1	34.4	32.5	29.3
1	0		1/2	2			1872	936	1	68.8	65.0	58.5
2	N/A		3/4	2			1872	1,404	1	103.2	97.5	87.8
3	1	16-QAM	1/4	4			3744	936	1	68.8	65.0	58.5
3	0		1/2	4			3744	1,872	1	137.6	130.0	117.0
4	1		3/8	4			3744	1,404	1	103.2	97.5	87.8
4	0		3/4	4			3744	2,808	1	206.5	195.0	175.5
5	N/A	64-QAM	2/3	6			5616	3,744	1	275.3	260.0	234.0
6			3/4	6			5616	4,212	1	309.7	292.5	263.3
7			5/6	6			5616	4,680	1	344.1	325.0	292.5
8		256-QAM	3/4	8			7488	5,616	1	412.9	390.0	351.0
9			5/6	8			7488	6,240	1	458.8	433.3	390.0
10		1024-QAM	3/4	10			9360	7,020	1	516.2	487.5	438.8
11			5/6	10			9360	7,800	1	573.5	541.7	487.5

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Table 26-78—HE-MCSs for mandatory 484-tone RU and mandatory non-OFDMA 40 MHz, N_{SS} = 3

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	468	16	1404	351	1	25.8	24.4	21.9
0	0		1/2	1			1404	702	1	51.6	48.8	43.9
1	1	QPSK	1/4	2			2808	702	1	51.6	48.8	43.9
1	0		1/2	2			2808	1,404	1	103.2	97.5	87.8
2	N/A		3/4	2			2808	2,106	1	154.9	146.3	131.6
3	1	16-QAM	1/4	4			5616	1,404	1	103.2	97.5	87.8
3	0		1/2	4			5616	2,808	1	206.5	195.0	175.5
4	1		3/8	4			5616	2,106	1	154.9	146.3	131.6
4	0		3/4	4			5616	4,212	1	309.7	292.5	263.3
5	N/A	64-QAM	2/3	6			8424	5,616	1	412.9	390.0	351.0
6			3/4	6			8424	6,318	1	464.6	438.8	394.9
7			5/6	6			8424	7,020	1	516.2	487.5	438.8
8		256-QAM	3/4	8			11232	8,424	1	619.4	585.0	526.5
9			5/6	8			11232	9,360	1	688.2	650.0	585.0
10		1024-QAM	3/4	10			14040	10,530	1	774.3	731.3	658.1
11			5/6	10			14040	11,700	1	860.3	812.5	731.3

Table 26-79—HE-MCSs for mandatory 484-tone RU and mandatory non-OFDMA 40 MHz, N_{SS} = 4

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	468	16	1872	468	1	34.4	32.5	29.3
0	0		1/2	1			1872	936	1	68.8	65.0	58.5
1	1	QPSK	1/4	2			3744	936	1	68.8	65.0	58.5
1	0		1/2	2			3744	1,872	1	137.6	130.0	117.0
2	N/A		3/4	2			3744	2,808	1	206.5	195.0	175.5
3	1	16-QAM	1/4	4			7488	1,872	1	137.6	130.0	117.0
3	0		1/2	4			7488	3,744	1	275.3	260.0	234.0
4	1		3/8	4			7488	2,808	1	206.5	195.0	175.5
4	0		3/4	4			7488	5,616	1	412.9	390.0	351.0
5	N/A	64-QAM	2/3	6			11232	7,488	1	550.6	520.0	468.0
6			3/4	6			11232	8,424	1	619.4	585.0	526.5
7			5/6	6			11232	9,360	1	688.2	650.0	585.0
8		256-QAM	3/4	8			14976	11,232	1	825.9	780.0	702.0
9			5/6	8			14976	12,480	1	917.6	866.7	780.0
10		1024-QAM	3/4	10			18720	14,040	1	1,032.4	975.0	877.5
11			5/6	10			18720	15,600	1	1,147.1	1,083.3	975.0

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Table 26-80—HE-MCSs for mandatory 484-tone RU and mandatory non-OFDMA 40 MHz, N_{SS} = 5

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	468	16	2340	585	1	43.0	40.6	36.6
0	0		1/2	1			2340	1,170	1	86.0	81.3	73.1
1	1	QPSK	1/4	2			4680	1,170	1	86.0	81.3	73.1
1	0		1/2	2			4680	2,340	1	172.1	162.5	146.3
2	N/A		3/4	2			4680	3,510	1	258.1	243.8	219.4
3	1	16-QAM	1/4	4			9360	2,340	1	172.1	162.5	146.3
3	0		1/2	4			9360	4,680	1	344.1	325.0	292.5
4	1		3/8	4			9360	3,510	1	258.1	243.8	219.4
4	0		3/4	4			9360	7,020	1	516.2	487.5	438.8
5	N/A	64-QAM	2/3	6			14040	9,360	1	688.2	650.0	585.0
6			3/4	6			14040	10,530	1	774.3	731.3	658.1
7			5/6	6			14040	11,700	1	860.3	812.5	731.3
8		256-QAM	3/4	8			18720	14,040	1	1,032.4	975.0	877.5
9			5/6	8			18720	15,600	1	1,147.1	1,083.3	975.0
10		1024-QAM	3/4	10			23400	17,550	1	1,290.4	1,218.8	1,096.9
11			5/6	10			23400	19,500	1	1,433.8	1,354.2	1,218.8

Table 26-81—HE-MCSs for mandatory 484-tone RU and mandatory non-OFDMA 40 MHz, N_{SS} = 6

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	468	16	2808	702	1	51.6	48.8	43.9
0	0		1/2	1			2808	1,404	1	103.2	97.5	87.8
1	1	QPSK	1/4	2			5616	1,404	1	103.2	97.5	87.8
1	0		1/2	2			5616	2,808	1	206.5	195.0	175.5
2	N/A		3/4	2			5616	4,212	1	309.7	292.5	263.3
3	1	16-QAM	1/4	4			11232	2,808	1	206.5	195.0	175.5
3	0		1/2	4			11232	5,616	1	412.9	390.0	351.0
4	1		3/8	4			11232	4,212	1	309.7	292.5	263.3
4	0		3/4	4			11232	8,424	1	619.4	585.0	526.5
5	N/A	64-QAM	2/3	6			16848	11,232	1	825.9	780.0	702.0
6			3/4	6			16848	12,636	1	929.1	877.5	789.8
7			5/6	6			16848	14,040	1	1,032.4	975.0	877.5
8		256-QAM	3/4	8			22464	16,848	1	1,238.8	1,170.0	1,053.0
9			5/6	8			22464	18,720	1	1,376.5	1,300.0	1,170.0
10		1024-QAM	3/4	10			28080	21,060	1	1,548.5	1,462.5	1,316.3
11			5/6	10			28080	23,400	1	1,720.6	1,625.0	1,462.5

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Table 26-82—HE-MCSs for mandatory 484-tone RU and mandatory non-OFDMA 40 MHz, N_{SS} = 7

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	468	16	3276	819	1	60.2	56.9	51.2
0	0		1/2	1			3276	1,638	1	120.4	113.8	102.4
1	1	QPSK	1/4	2			6552	1,638	1	120.4	113.8	102.4
1	0		1/2	2			6552	3,276	1	240.9	227.5	204.8
2	N/A		3/4	2			6552	4,914	1	361.3	341.3	307.1
3	1	16-QAM	1/4	4			13104	3,276	1	240.9	227.5	204.8
3	0		1/2	4			13104	6,552	1	481.8	455.0	409.5
4	1		3/8	4			13104	4,914	1	361.3	341.3	307.1
4	0		3/4	4			13104	9,828	1	722.6	682.5	614.3
5	N/A	64-QAM	2/3	6			19656	13,104	1	963.5	910.0	819.0
6			3/4	6			19656	14,742	1	1,084.0	1,023.8	921.4
7			5/6	6			19656	16,380	1	1,204.4	1,137.5	1,023.8
8		256-QAM	3/4	8			26208	19,656	1	1,445.3	1,365.0	1,228.5
9			5/6	8			26208	21,840	1	1,605.9	1,516.7	1,365.0
10		1024-QAM	3/4	10			32760	24,570	1	1,806.6	1,706.3	1,535.6
11			5/6	10			32760	27,300	1	2,007.4	1,895.8	1,706.3

Table 26-83—HE-MCSs for mandatory 484-tone RU and mandatory non-OFDMA 40 MHz, N_{SS} = 8

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	468	16	3744	936	1	68.8	65.0	58.5
0	0		1/2	1			3744	1,872	1	137.6	130.0	117.0
1	1	QPSK	1/4	2			7488	1,872	1	137.6	130.0	117.0
1	0		1/2	2			7488	3,744	1	275.3	260.0	234.0
2	N/A		3/4	2			7488	5,616	1	412.9	390.0	351.0
3	1	16-QAM	1/4	4			14976	3,744	1	275.3	260.0	234.0
3	0		1/2	4			14976	7,488	1	550.6	520.0	468.0
4	1		3/8	4			14976	5,616	1	412.9	390.0	351.0
4	0		3/4	4			14976	11,232	1	825.9	780.0	702.0
5	N/A	64-QAM	2/3	6			22464	14,976	1	1,101.2	1,040.0	936.0
6			3/4	6			22464	16,848	1	1,238.8	1,170.0	1,053.0
7			5/6	6			22464	18,720	1	1,376.5	1,300.0	1,170.0
8		256-QAM	3/4	8			29952	22,464	1	1,651.8	1,560.0	1,404.0
9			5/6	8			29952	24,960	1	1,835.3	1,733.3	1,560.0
10		1024-QAM	3/4	10			37440	28,080	1	2,064.7	1,950.0	1,755.0
11			5/6	10			37440	31,200	1	2,294.1	2,166.7	1,950.0

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Table 26-84—HE-MCSs for mandatory 996-tone RU and mandatory non-OFDMA 80 MHz, N_{SS} = 1

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	980	16	980	245	1	18.0	17.0	15.3
0	0		1/2	1			980	490	1	36.0	34.0	30.6
1	1	QPSK	1/4	2			1960	490	1	36.0	34.0	30.6
1	0		1/2	2			1960	980	1	72.1	68.1	61.3
2	N/A		3/4	2			1960	1,470	1	108.1	102.1	91.9
3	1	16-QAM	1/4	4			3920	980	1	72.1	68.1	61.3
3	0		1/2	4			3920	1,960	1	144.1	136.1	122.5
4	1		3/8	4			3920	1,470	1	108.1	102.1	91.9
4	0		3/4	4			3920	2,940	1	216.2	204.2	183.8
5	N/A	64-QAM	2/3	6			5880	3,920	1	288.2	272.2	245.0
6			3/4	6			5880	4,410	1	324.3	306.3	275.6
7			5/6	6			5880	4,900	1	360.3	340.3	306.3
8		256-QAM	3/4	8			7840	5,880	1	432.4	408.3	367.5
9			5/6	8			7840	6,533	1	480.4	453.7	408.3
10		1024-QAM	3/4	10			9800	7,350	1	540.4	510.4	459.4
11			5/6	10			9800	8,166	1	600.4	567.1	510.4

Table 26-85—HE-MCSs for mandatory 996-tone RU and mandatory non-OFDMA 80 MHz, N_{SS} = 2

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	980	16	1960	490	1	36.0	34.0	30.6
0	0		1/2	1			1960	980	1	72.1	68.1	61.3
1	1	QPSK	1/4	2			3920	980	1	72.1	68.1	61.3
1	0		1/2	2			3920	1,960	1	144.1	136.1	122.5
2	N/A		3/4	2			3920	2,940	1	216.2	204.2	183.8
3	1	16-QAM	1/4	4			7840	1,960	1	144.1	136.1	122.5
3	0		1/2	4			7840	3,920	1	288.2	272.2	245.0
4	1		3/8	4			7840	2,940	1	216.2	204.2	183.8
4	0		3/4	4			7840	5,880	1	432.4	408.3	367.5
5	N/A	64-QAM	2/3	6			11760	7,840	1	576.5	544.4	490.0
6			3/4	6			11760	8,820	1	648.5	612.5	551.3
7			5/6	6			11760	9,800	1	720.6	680.6	612.5
8		256-QAM	3/4	8			15680	11,760	1	864.7	816.7	735.0
9			5/6	8			15680	13,066	1	960.7	907.4	816.6
10		1024-QAM	3/4	10			19600	14,700	1	1,080.9	1,020.8	918.8
11			5/6	10			19600	16,333	1	1,201.0	1,134.2	1,020.8

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Table 26-86—HE-MCSs for mandatory 996-tone RU and mandatory non-OFDMA 80 MHz, N_{SS} = 3

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	980	16	2940	735	1	54.0	51.0	45.9
0	0		1/2	1			2940	1,470	1	108.1	102.1	91.9
1	1	QPSK	1/4	2			5880	1,470	1	108.1	102.1	91.9
1	0		1/2	2			5880	2,940	1	216.2	204.2	183.8
2	N/A		3/4	2			5880	4,410	1	324.3	306.3	275.6
3	1	16-QAM	1/4	4			11760	2,940	1	216.2	204.2	183.8
3	0		1/2	4			11760	5,880	1	432.4	408.3	367.5
4	1		3/8	4			11760	4,410	1	324.3	306.3	275.6
4	0		3/4	4			11760	8,820	1	648.5	612.5	551.3
5	N/A	64-QAM	2/3	6			17640	11,760	1	864.7	816.7	735.0
6			3/4	6			17640	13,230	1	972.8	918.8	826.9
7			5/6	6			17640	14,700	1	1,080.9	1,020.8	918.8
8		256-QAM	3/4	8			23520	17,640	1	1,297.1	1,225.0	1,102.5
9			5/6	8			23520	19,600	1	1,441.2	1,361.1	1,225.0
10		1024-QAM	3/4	10			29400	22,050	1	1,621.3	1,531.3	1,378.1
11			5/6	10			29400	24,500	1	1,801.5	1,701.4	1,531.3

Table 26-87—HE-MCSs for mandatory 996-tone RU and mandatory non-OFDMA 80 MHz, N_{SS} = 4

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	980	16	3920	980	1	72.1	68.1	61.3
0	0		1/2	1			3920	1,960	1	144.1	136.1	122.5
1	1	QPSK	1/4	2			7840	1,960	1	144.1	136.1	122.5
1	0		1/2	2			7840	3,920	1	288.2	272.2	245.0
2	N/A		3/4	2			7840	5,880	1	432.4	408.3	367.5
3	1	16-QAM	1/4	4			15680	3,920	1	288.2	272.2	245.0
3	0		1/2	4			15680	7,840	1	576.5	544.4	490.0
4	1		3/8	4			15680	5,880	1	432.4	408.3	367.5
4	0		3/4	4			15680	11,760	1	864.7	816.7	735.0
5	N/A	64-QAM	2/3	6			23520	15,680	1	1,152.9	1,088.9	980.0
6			3/4	6			23520	17,640	1	1,297.1	1,225.0	1,102.5
7			5/6	6			23520	19,600	1	1,441.2	1,361.1	1,225.0
8		256-QAM	3/4	8			31360	23,520	1	1,729.4	1,633.3	1,470.0
9			5/6	8			31360	26,133	1	1,921.5	1,814.8	1,633.3
10		1024-QAM	3/4	10			39200	29,400	1	2,161.8	2,041.7	1,837.5
11			5/6	10			39200	32,666	1	2,401.9	2,268.5	2,041.6

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Table 26-88—HE-MCSs for mandatory 996-tone RU and mandatory non-OFDMA 80 MHz, N_{SS} = 5

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	980	16	4900	1,225	1	90.1	85.1	76.6
0	0		1/2	1			4900	2,450	1	180.1	170.1	153.1
1	1	QPSK	1/4	2			9800	2,450	1	180.1	170.1	153.1
1	0		1/2	2			9800	4,900	1	360.3	340.3	306.3
2	N/A		3/4	2			9800	7,350	1	540.4	510.4	459.4
3	1	16-QAM	1/4	4			19600	4,900	1	360.3	340.3	306.3
3	0		1/2	4			19600	9,800	1	720.6	680.6	612.5
4	1		3/8	4			19600	7,350	1	540.4	510.4	459.4
4	0		3/4	4			19600	14,700	1	1,080.9	1,020.8	918.8
5	N/A	64-QAM	2/3	6			29400	19,600	1	1,441.2	1,361.1	1,225.0
6			3/4	6			29400	22,050	1	1,621.3	1,531.3	1,378.1
7			5/6	6			29400	24,500	1	1,801.5	1,701.4	1,531.3
8		256-QAM	3/4	8			39200	29,400	1	2,161.8	2,041.7	1,837.5
9			5/6	8			39200	32,666	1	2,401.9	2,268.5	2,041.6
10		1024-QAM	3/4	10			49000	36,750	1	2,702.2	2,552.1	2,296.9
11			5/6	10			49000	40,833	1	3,002.4	2,835.6	2,552.1

Table 26-89—HE-MCSs for mandatory 996-tone RU and mandatory non-OFDMA 80 MHz, N_{SS} = 6

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	980	16	5880	1,470	1	108.1	102.1	91.9
0	0		1/2	1			5880	2,940	1	216.2	204.2	183.8
1	1	QPSK	1/4	2			11760	2,940	1	216.2	204.2	183.8
1	0		1/2	2			11760	5,880	1	432.4	408.3	367.5
2	N/A		3/4	2			11760	8,820	1	648.5	612.5	551.3
3	1	16-QAM	1/4	4			23520	5,880	1	432.4	408.3	367.5
3	0		1/2	4			23520	11,760	1	864.7	816.7	735.0
4	1		3/8	4			23520	8,820	1	648.5	612.5	551.3
4	0		3/4	4			23520	17,640	1	1,297.1	1,225.0	1,102.5
5	N/A	64-QAM	2/3	6			35280	23,520	1	1,729.4	1,633.3	1,470.0
6			3/4	6			35280	26,460	1	1,945.6	1,837.5	1,653.8
7			5/6	6			35280	29,400	1	2,161.8	2,041.7	1,837.5
8		256-QAM	3/4	8			47040	35,280	1	2,594.1	2,450.0	2,205.0
9			5/6	8			47040	39,200	1	2,882.4	2,722.2	2,450.0
10		1024-QAM	3/4	10			58800	44,100	1	3,242.6	3,062.5	2,756.3
11			5/6	10			58800	49,000	1	3,602.9	3,402.8	3,062.5

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Table 26-90—HE-MCSs for mandatory 996-tone RU and mandatory non-OFDMA 80 MHz, N_{SS} = 7

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	980	16	6860	1,715	1	126.1	119.1	107.2
0	0		1/2	1			6860	3,430	1	252.2	238.2	214.4
1	1	QPSK	1/4	2			13720	3,430	1	252.2	238.2	214.4
1	0		1/2	2			13720	6,860	1	504.4	476.4	428.8
2	N/A		3/4	2			13720	10,290	1	756.6	714.6	643.1
3	1	16-QAM	1/4	4			27440	6,860	1	504.4	476.4	428.8
3	0		1/2	4			27440	13,720	1	1,008.8	952.8	857.5
4	1		3/8	4			27440	10,290	1	756.6	714.6	643.1
4	0		3/4	4			27440	20,580	1	1,513.2	1,429.2	1,286.3
5	N/A	64-QAM	2/3	6			41160	27,440	1	2,017.6	1,905.6	1,715.0
6			3/4	6			41160	30,870	1	2,269.9	2,143.8	1,929.4
7			5/6	6			41160	34,300	1	2,522.1	2,381.9	2,143.8
8		256-QAM	3/4	8			54880	41,160	1	3,026.5	2,858.3	2,572.5
9			5/6	8			54880	45,733	1	3,362.7	3,175.9	2,858.3
10		1024-QAM	3/4	10			68600	51,450	1	3,783.1	3,572.9	3,215.6
11			5/6	10			68600	57,166	1	4,203.4	3,969.9	3,572.9

Table 26-91—HE-MCSs for mandatory 996-tone RU and mandatory non-OFDMA 80 MHz, N_{SS} = 8

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	980	16	7840	1,960	1	144.1	136.1	122.5
0	0		1/2	1			7840	3,920	1	288.2	272.2	245.0
1	1	QPSK	1/4	2			15680	3,920	1	288.2	272.2	245.0
1	0		1/2	2			15680	7,840	1	576.5	544.4	490.0
2	N/A		3/4	2			15680	11,760	1	864.7	816.7	735.0
3	1	16-QAM	1/4	4			31360	7,840	1	576.5	544.4	490.0
3	0		1/2	4			31360	15,680	1	1,152.9	1,088.9	980.0
4	1		3/8	4			31360	11,760	1	864.7	816.7	735.0
4	0		3/4	4			31360	23,520	1	1,729.4	1,633.3	1,470.0
5	N/A	64-QAM	2/3	6			47040	31,360	1	2,305.9	2,177.8	1,960.0
6			3/4	6			47040	35,280	1	2,594.1	2,450.0	2,205.0
7			5/6	6			47040	39,200	1	2,882.4	2,722.2	2,450.0
8		256-QAM	3/4	8			62720	47,040	1	3,458.8	3,266.7	2,940.0
9			5/6	8			62720	52,266	1	3,843.1	3,629.6	3,266.6
10		1024-QAM	3/4	10			78400	58,800	1	4,323.5	4,083.3	3,675.0
11			5/6	10			78400	65,333	1	4,803.9	4,537.0	4,083.3

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Table 26-92—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, N_{SS} = 1

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	1960	32	1960	490	1	36.0	34.0	30.6
0	0		1/2	1			1960	980	1	72.1	68.1	61.3
1	1	QPSK	1/4	2			3920	980	1	72.1	68.1	61.3
1	0		1/2	2			3920	1,960	1	144.1	136.1	122.5
2	N/A		3/4	2			3920	2,940	1	216.2	204.2	183.8
3	1	16-QAM	1/4	4			7840	1,960	1	144.1	136.1	122.5
3	0		1/2	4			7840	3,920	1	288.2	272.2	245.0
4	1		3/8	4			7840	2,940	1	216.2	204.2	183.8
4	0		3/4	4			7840	5,880	1	432.4	408.3	367.5
5	N/A	64-QAM	2/3	6			11760	7,840	1	576.5	544.4	490.0
6			3/4	6			11760	8,820	1	648.5	612.5	551.3
7			5/6	6			11760	9,800	1	720.6	680.6	612.5
8		256-QAM	3/4	8			15680	11,760	1	864.7	816.7	735.0
9			5/6	8			15680	13,066	1	960.7	907.4	816.6
10		1024-QAM	3/4	10			19600	14,700	1	1,080.9	1,020.8	918.8
11			5/6	10			19600	16,333	1	1,201.0	1,134.2	1,020.8

Table 26-93—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, N_{SS} = 2

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	1960	32	3920	980	1	72.1	68.1	61.3
0	0		1/2	1			3920	1,960	1	144.1	136.1	122.5
1	1	QPSK	1/4	2			7840	1,960	1	144.1	136.1	122.5
1	0		1/2	2			7840	3,920	1	288.2	272.2	245.0
2	N/A		3/4	2			7840	5,880	1	432.4	408.3	367.5
3	1	16-QAM	1/4	4			15680	3,920	1	288.2	272.2	245.0
3	0		1/2	4			15680	7,840	1	576.5	544.4	490.0
4	1		3/8	4			15680	5,880	1	432.4	408.3	367.5
4	0		3/4	4			15680	11,760	1	864.7	816.7	735.0
5	N/A	64-QAM	2/3	6			23520	15,680	1	1,152.9	1,088.9	980.0
6			3/4	6			23520	17,640	1	1,297.1	1,225.0	1,102.5
7			5/6	6			23520	19,600	1	1,441.2	1,361.1	1,225.0
8		256-QAM	3/4	8			31360	23,520	1	1,729.4	1,633.3	1,470.0
9			5/6	8			31360	26,133	1	1,921.5	1,814.8	1,633.3
10		1024-QAM	3/4	10			39200	29,400	1	2,161.8	2,041.7	1,837.5
11			5/6	10			39200	32,666	1	2,401.9	2,268.5	2,041.6

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Table 26-94—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, N_{SS} = 3

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	1960	32	5880	1,470	1	108.1	102.1	91.9
0	0		1/2	1			5880	2,940	1	216.2	204.2	183.8
1	1	QPSK	1/4	2			11760	2,940	1	216.2	204.2	183.8
1	0		1/2	2			11760	5,880	1	432.4	408.3	367.5
2	N/A		3/4	2			11760	8,820	1	648.5	612.5	551.3
3	1	16-QAM	1/4	4			23520	5,880	1	432.4	408.3	367.5
3	0		1/2	4			23520	11,760	1	864.7	816.7	735.0
4	1		3/8	4			23520	8,820	1	648.5	612.5	551.3
4	0		3/4	4			23520	17,640	1	1,297.1	1,225.0	1,102.5
5	N/A	64-QAM	2/3	6			35280	23,520	1	1,729.4	1,633.3	1,470.0
6			3/4	6			35280	26,460	1	1,945.6	1,837.5	1,653.8
7			5/6	6			35280	29,400	1	2,161.8	2,041.7	1,837.5
8		256-QAM	3/4	8			47040	35,280	1	2,594.1	2,450.0	2,205.0
9			5/6	8			47040	39,200	1	2,882.4	2,722.2	2,450.0
10		1024-QAM	3/4	10			58800	44,100	1	3,242.6	3,062.5	2,756.3
11			5/6	10			58800	49,000	1	3,602.9	3,402.8	3,062.5

Table 26-95—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, N_{SS} = 4

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	1960	32	7840	1,960	1	144.1	136.1	122.5
0	0		1/2	1			7840	3,920	1	288.2	272.2	245.0
1	1	QPSK	1/4	2			15680	3,920	1	288.2	272.2	245.0
1	0		1/2	2			15680	7,840	1	576.5	544.4	490.0
2	N/A		3/4	2			15680	11,760	1	864.7	816.7	735.0
3	1	16-QAM	1/4	4			31360	7,840	1	576.5	544.4	490.0
3	0		1/2	4			31360	15,680	1	1,152.9	1,088.9	980.0
4	1		3/8	4			31360	11,760	1	864.7	816.7	735.0
4	0		3/4	4			31360	23,520	1	1,729.4	1,633.3	1,470.0
5	N/A	64-QAM	2/3	6			47040	31,360	1	2,305.9	2,177.8	1,960.0
6			3/4	6			47040	35,280	1	2,594.1	2,450.0	2,205.0
7			5/6	6			47040	39,200	1	2,882.4	2,722.2	2,450.0
8		256-QAM	3/4	8			62720	47,040	1	3,458.8	3,266.7	2,940.0
9			5/6	8			62720	52,266	1	3,843.1	3,629.6	3,266.6
10		1024-QAM	3/4	10			78400	58,800	1	4,323.5	4,083.3	3,675.0
11			5/6	10			78400	65,333	1	4,803.9	4,537.0	4,083.3

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Table 26-96—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, N_{SS} = 5

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	1960	32	9800	2,450	1	180.1	170.1	153.1
0	0		1/2	1			9800	4,900	1	360.3	340.3	306.3
1	1	QPSK	1/4	2			19600	4,900	1	360.3	340.3	306.3
1	0		1/2	2			19600	9,800	1	720.6	680.6	612.5
2	N/A		3/4	2			19600	14,700	1	1,080.9	1,020.8	918.8
3	1	16-QAM	1/4	4			39200	9,800	1	720.6	680.6	612.5
3	0		1/2	4			39200	19,600	1	1,441.2	1,361.1	1,225.0
4	1		3/8	4			39200	14,700	1	1,080.9	1,020.8	918.8
4	0		3/4	4			39200	29,400	1	2,161.8	2,041.7	1,837.5
5	N/A	64-QAM	2/3	6			58800	39,200	1	2,882.4	2,722.2	2,450.0
6			3/4	6			58800	44,100	1	3,242.6	3,062.5	2,756.3
7			5/6	6			58800	49,000	1	3,602.9	3,402.8	3,062.5
8		256-QAM	3/4	8			78400	58,800	1	4,323.5	4,083.3	3,675.0
9			5/6	8			78400	65,333	1	4,803.9	4,537.0	4,083.3
10		1024-QAM	3/4	10			98000	73,500	1	5,404.4	5,104.2	4,593.8
11			5/6	10			98000	81,666	1	6,004.9	5,671.3	5,104.1

Table 26-97—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, N_{SS} = 6

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	1960	32	11760	2,940	1	216.2	204.2	183.8
0	0		1/2	1			11760	5,880	1	432.4	408.3	367.5
1	1	QPSK	1/4	2			23520	5,880	1	432.4	408.3	367.5
1	0		1/2	2			23520	11,760	1	864.7	816.7	735.0
2	N/A		3/4	2			23520	17,640	1	1,297.1	1,225.0	1,102.5
3	1	16-QAM	1/4	4			47040	11,760	1	864.7	816.7	735.0
3	0		1/2	4			47040	23,520	1	1,729.4	1,633.3	1,470.0
4	1		3/8	4			47040	17,640	1	1,297.1	1,225.0	1,102.5
4	0		3/4	4			47040	35,280	1	2,594.1	2,450.0	2,205.0
5	N/A	64-QAM	2/3	6			70560	47,040	1	3,458.8	3,266.7	2,940.0
6			3/4	6			70560	52,920	1	3,891.2	3,675.0	3,307.5
7			5/6	6			70560	58,800	1	4,323.5	4,083.3	3,675.0
8		256-QAM	3/4	8			94080	70,560	1	5,188.2	4,900.0	4,410.0
9			5/6	8			94080	78,400	1	5,764.7	5,444.4	4,900.0
10		1024-QAM	3/4	10			117600	88,200	1	6,485.3	6,125.0	5,512.5
11			5/6	10			117600	98,000	1	7,205.9	6,805.6	6,125.0

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Table 26-98—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, N_{SS} = 7

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	1960	32	13720	3,430	1	252.2	238.2	214.4
0	0		1/2	1			13720	6,860	1	504.4	476.4	428.8
1	1	QPSK	1/4	2			27440	6,860	1	504.4	476.4	428.8
1	0		1/2	2			27440	13,720	1	1,008.8	952.8	857.5
2	N/A		3/4	2			27440	20,580	1	1,513.2	1,429.2	1,286.3
3	1	16-QAM	1/4	4			54880	13,720	1	1,008.8	952.8	857.5
3	0		1/2	4			54880	27,440	1	2,017.6	1,905.6	1,715.0
4	1		3/8	4			54880	20,580	1	1,513.2	1,429.2	1,286.3
4	0		3/4	4			54880	41,160	1	3,026.5	2,858.3	2,572.5
5	N/A	64-QAM	2/3	6			82320	54,880	1	4,035.3	3,811.1	3,430.0
6			3/4	6			82320	61,740	1	4,539.7	4,287.5	3,858.8
7			5/6	6			82320	68,600	1	5,044.1	4,763.9	4,287.5
8		256-QAM	3/4	8			109760	82,320	1	6,052.9	5,716.7	5,145.0
9			5/6	8			109760	91,466	1	6,725.4	6,351.8	5,716.6
10		1024-QAM	3/4	10			137200	102,900	1	7,566.2	7,145.8	6,431.3
11			5/6	10			137200	114,333	1	8,406.8	7,939.8	7,145.8

Table 26-99—HE-MCSs for optional non-OFDMA 160 MHz and 80+80 MHz, N_{SS} = 8

HE-MCS Index	DCM	Modulation	R	N_{BPSCS}	N_{SD}	N_{SP}	N_{CBPS}	N_{DBPS}	N_{ES}	Data rate (Mb/s)		
										0.8 usec GI	1.6 usec GI	3.2 usec GI
0	1	BPSK	1/4	1	1960	32	15680	3,920	1	288.2	272.2	245.0
0	0		1/2	1			15680	7,840	1	576.5	544.4	490.0
1	1	QPSK	1/4	2			31360	7,840	1	576.5	544.4	490.0
1	0		1/2	2			31360	15,680	1	1,152.9	1,088.9	980.0
2	N/A		3/4	2			31360	23,520	1	1,729.4	1,633.3	1,470.0
3	1	16-QAM	1/4	4			62720	15,680	1	1,152.9	1,088.9	980.0
3	0		1/2	4			62720	31,360	1	2,305.9	2,177.8	1,960.0
4	1		3/8	4			62720	23,520	1	1,729.4	1,633.3	1,470.0
4	0		3/4	4			62720	47,040	1	3,458.8	3,266.7	2,940.0
5	N/A	64-QAM	2/3	6			94080	62,720	1	4,611.8	4,355.6	3,920.0
6			3/4	6			94080	70,560	1	5,188.2	4,900.0	4,410.0
7			5/6	6			94080	78,400	1	5,764.7	5,444.4	4,900.0
8		256-QAM	3/4	8			125440	94,080	1	6,917.6	6,533.3	5,880.0
9			5/6	8			125440	104,533	1	7,686.3	7,259.2	6,533.3
10		1024-QAM	3/4	10			156800	117,600	1	8,647.1	8,166.7	7,350.0
11			5/6	10			156800	130,666	1	9,607.8	9,074.0	8,166.6

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Annex C

(normative)

ASN.1 encoding of the MAC and PHY MIB

C.3 MIB Detail

Change the dot11smt object as follows:

```
(#1123)dot11smt OBJECT IDENTIFIER ::= { ieee802dot11 1 }
…
-- dot11STACivicLocationConfigTable::= { dot11smt 37 }
-- dot11HEStationConfigTable::= { dot11smt <ANA> }
…
```

Change Dot11StationConfigEntry as follows:

```
Dot11StationConfigEntry ::= SEQUENCE
    {
        …,
        dot11FutureChannelGuidanceActivated                    TruthValue,
        dot11HEOptionImplemented                               TruthValule
    }
…

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 getting some sucker to validate MIB compilation, etc.):

```
Dot11HEStationConfigEntry ::= SEQUENCE
    {
        dot11HEDynamicFragmentationImplemented,                TruthValue
    }

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 <XX>}
```

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```
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 Exten-
      sion Thresholds exist and are provided in dot11PPEThresholdsTable(#1313)."
   DEFVAL { false }
   ::= { dot11StationConfigEntry <ANA>}(#1481)

-- ************************************************************************
-- * 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>, 25.13 (HE PPDU post FEC padding and packet
      extension)(#1632)"
::= { dot11smt 4 }

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
```


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```
    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 TBD tones, 3 is reserved."
::= { 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(#1633),
         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#1633), 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
-- ************************************************************************

dot11HEComplianceGroup OBJECT-GROUP
    OBJECTS {
        dot11HEDynamicFragmentationImplemented}
    STATUS current
    DESCRIPTION
        "Attributes that configure the HE Group for IEEE 802.11."
::= { dot11Groups <XX> }(#1481)
```

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(#576)Insert the following:

```
dot11DurationRTSThreshold OBJECT-TYPE
    SYNTAX Unsigned16 (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 }
::= { Dot11OperationEntry <ANA> }
```


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APPENDIX J

The Wayback Machine - https://web.archive.org/web/20161121130718/http://www.ieee802.org/11/abt80211.h…

ABOUT IEEE P802.11 AND HOW TO PARTICIPATE

The following are general statements of how to participate in the IEEE802.11 Working Group. For the official rules, please see the Policies and Procedures of the IEEE Project 802, LAN MAN Standards Committee (LMSC) and the IEEE 802.11 Working Group Operations Manual.

Introduction

IEEE P802.11 is a standards working group on wireless local area networks. The working group is a part of IEEE LMSC (LAN MAN Standards Committee) formerly called IEEE Project 802. IEEE LMSC reports to the Standards Activity Board (SAB) of the IEEE Computer Society.

Open Forum

All meetings of the standards activities of IEEE are open meetings. Everybody is allowed to attend as long as he/she pays their dues to the organization to offset the costs of the meeting. It is not required to be a member of IEEE to participate in, or to become a voting member of the working group. We recommend, however, that you become a member of either the IEEE or of the Computer Society.

Voting

At all meetings of the working group and its sub and ad-hoc groups, participation in the discussions and voting is limited to the voting members (see section Membership for the rules to become a member), although the chair has the discretion to allow non-members to participate in the discussions. At study-group meetings, however, all attendees can participate in discussions and in voting. The voting rules are defined in LMSC WG P&P, and described in the 802.11 Operations Manual.

Organizational matters

A handy guide for how to develop standards is provided in the IEEE Standards Association Develop Standards site. More formal rules regarding the organization of our work are provided in the IEEE Standards Board Bylaws and the IEEE Standards Operations Manual. A short summary made specifically for 802.11 follows below.

Before a standard can be developed, a Project Authorization Request (PAR) has to be approved by the IEEE Standards Board. The PARs approved for the work of 802.11 are available here.

Once the working group has agreed on a draft standard (i.e., the draft was approved by a working group letter ballot), the draft is balloted in a sponsor balloting group. Membership of sponsor balloting groups is limited to members of the IEEE or the Computer Society. After approval by the balloting group, the result is reviewed by the Standards Board before publication. The IEEE Standards Board Review Committee (RevCom) are responsible for deciding whether the procedure for the development of the standard was followed correctly.

Meeting schedule

Currently the 802.11 standards working group meets 3 times a year during the plenary sessions of IEEE LMSC. LMSC meets in plenary sessions in March, July and November. And 802.11 holds interim meetings an additional 3 times a year in January, May and September. Refer to the meeting plan.

Additional 802.11 interim meetings are held to host TGaj (China Milli-Metre Wave) meetings in China.

Membership of standards development working group

The membership rules are defined in LMSC WG P&P, and described in the 802.11 Operations Manual.

In summary, membership belongs to an individual, not to an organization, and may not be transferred. You have to gain voting membership rights by participating in at least 2 plenary meetings out of 4 consecutive plenary meetings and then recording attendance at a subsequent plenary (at which you may vote). Participation means that you attend at least 75% of the time of the whole session of meetings. You may substitute one interim meeting for a plenary meeting.

Member categories and gaining voting rights

IEEE 802.11 recognises the following categories of membership:

1. Aspirant members. Those members have participated in one plenary or interim session of meetings within the last 4 plenary sessions.
2. Potential voter members. Those have participated in two sessions of meetings, at least one of which being a plenary session within the last 4 plenary sessions.
3. Voter members. Those members qualify for voting membership status.

Potential voter members become voter members in the beginning of the first session they attend and and at which they record attendance.

"Participation" means recording electronic attendance for 75% of the "in hours" 802.11 meeting slots during a meeting and paying the meeting fee.

Note that recording attendance in some other (i.e., non-802.11) working-group's meeting during an 802.11 session does not count towards this 75% target.

Sponsor Ballot Group

Before LMSC sends a proposed standard to the IEEE Standards Board for approval, they must have a positive response from a letter ballot among the members of the related sponsor ballot group (the "pool") within its organization. The sponsor ballot pool for an 802.11 standard is established by invitation to interested members of IEEE-SA before the first sponsor ballot of that standard. The pool is not changed once it has been established - i.e., the voters on the first sponsor ballot are also the voters for all subsequent recirculation ballots of the same standard.

The rules and procedures for sponsor ballot groups are provided in section 5.4 of the IEEE Standards Operations Manual. In summary they are as follows. For each main PAR, LMSC establishes a ballot pool. If you want to be invited to participate in sponsor ballots of IEEE P802.11 and you are a member of the IEEE Standards

Association (IEEE-SA), you can register interest in a standards project. A short time before a sponsor ballot for the project is issued, the IEEE sends the people in the pool an invitation to ballot. If you agree to commit to review and vote on the acceptability, you can apply for membership of that ballot pool. LMSC is responsible for balancing the membership of the ballot pool among various classifications, typically: producer, user and general-interest.

Document distribution

All documents submitted to and produced by the P802.11 working Group (excluding draft standards), such as liaison statements, minutes of meetings, meeting announcements, etc., are provided to the members of the working group by way of the IEEE802.11 document server (see https://mentor.ieee.org/802.11/documents).

Draft standards are available to active participants of 802.11 in its members area. (Access is available by username/password supplied to active participants by 802.11 officers).

During 802.11 plenary and interim sessions, documents and drafts are available to all attendees using a local fileserver.

Procedures

The Policies and Procedures of IEEE Project 802, LAN MAN Standards Committee require that Robert's Rules of Order are used in combination with the LMSC Policies and Procedures and the Working Group Policies and Procedures with the LMSC Policies and Procedure taking precedence.

Submissions to the working group

The 802.11 Working Group Policies and Procedures requires that every document must be formatted to a common standard before being submitted to the document server. Special tools and instructions are available to make the task for submitters easy.

All submissions made to 802.11 WG and its sub-groups must be submitted to the document server before any presentation is made. The ensures that all members have equal access to the material at the time is is being presented.

This page is maintained by Adrian Stephens. Comments are welcome.

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APPENDIX K

The Wayback Machine - https://web.archive.org/web/20160205145836/http://www.ieee802.org/11/

IEEE 802.11™ WIRELESS LOCAL AREA NETWORKS

The Working Group for WLAN Standards

Agenda for WG11 meetings in the January 2016 session

Please refer to the latest revision of 11-15/1485

IEEE 802.11 Presentation

The publicity standing committee (PUB SC) have produced a presentation called "What 802.11 is doing" intended to be used to explain 802.11's current activities to those outside 802.11. This is now available on this website.

IEEE 802 STANDARDS AVAILABLE FOR FREE DOWNLOAD !

The IEEE has made available IEEE 802 standards for free download. Under this program, a standard may be downloaded for free six months after the initial publication of the standard.

All relevant IEEE 802.11 Standard, Amendments, and Recommended Practices are listed here.

ACCESS TO 802 DRAFT STANDARDS

Draft standards are available from a number of sources:

- If you are a voting 802.11 member, go to the members' area and log in using the 802.11 members ID and password supplied to you by the 802.11 officers. Contact Adrian Stephens if you have lost this. During an 802.11 session, attendees may access 802.11 draft standards from a local fileserver, regardless of their membership status.
- If you are an active member of one of the other 802 groups, you may be able to access the 802.11 members' area using the same credentials used to access your own group. If this doesn't work, ask your group's Chair to request access from the 802.11 Chair (Adrian Stephens).
- Draft IEEE standards are, from time to time, made available for purchase using the IEEE store or Techstreet.

IEEE STANDARDS DEVELOPMENT GUIDE

The IEEE-SA has created an easy to use Online Standards Development web site that has a wealth of information that details the whole standards process flow, from creation of the initial PAR, to balloting to final draft, and beyond. It even includes, tutorials, and online forms of the various processes evolved. This site is recommended for all Members and Chairs involved.

Many of the IEEE 802.11 teleconferences use "Join Me". We share a single IEEE-SA supplied account amongst these meetings. The meeting credentials and local dial-in numbers are shown here.

802 11
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Thursday, January 21
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APPENDIX L

IEEE P802.11 Wireless LANs

Submission

Designator: **doc.: IEEE 802.11-15/1485r5**

Venue Date: **January 2016**

First Author: Adrian Stephens, Chair, IEEE 802.11 WLANs Working Group

Subject: **WG Agenda January 2016**

Full Date: 2016-01-22

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Abstract:

This document is the combined session agenda for the stated IEEE 802.11 Working Group session, including (dire
by reference) agendas for all sub-groups (Standing Committees, Task Groups and Study Groups).

155th IEEE 802.11 WIRELESS LOCAL AREA NETWORKS SESSION

Hyatt Regency, Atlanta, GA, USA

January 17-22, 2016



IEEE 802.11™

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Links

Task Group (TG), Standing Committee (SC) and Study Group (SG) Agenda Links				
Group **	**Description**	**Chair**	**Agenda Document**	
ARC SC	Architecture Standing Committee	Mark Hamilton	https://mentor.ieee.org/802.11/dcn/11-15-1519	
PAR SC	Project Authorization Review (PAR) Review Standing Committee	Jon Rosdahl		Not meeting
REG SC	Regulatory Standing Committee	Rich Kennedy	https://mentor.ieee.org/802.11/dcn/11-15-1523	
WNG SC	Wireless Next Generation Standing Committee	Jim Lansford	https://mentor.ieee.org/802.11/dcn/11-15-1518	
TGah	< 1 GHz	Yongho Seok	https://mentor.ieee.org/802.11/dcn/11-15-1511	
TGai	Fast Initial Link Setup	Hiroshi Mano	https://mentor.ieee.org/802.11/dcn/11-15-1536	
TGaj	China Millimeter Wave (CMMW)	Xiaoming Peng	https://mentor.ieee.org/802.11/dcn/11-15-1521	
TGak	General Link	Donald Eastlake 3rd	https://mentor.ieee.org/802.11/dcn/11-15-1473	
TGaq	Pre-association Discovery	Stephen McCann	https://mentor.ieee.org/802.11/dcn/11-15-1515	
MC	Revision MC	Dorothy Stanley	https://mentor.ieee.org/802.11/dcn/11-15-1522	
TGax	High efficiency wireless LAN (HEW)	Osama Aboul-Magd	https://mentor.ieee.org/802.11/dcn/11-15-1516	
TGay	Next Generation 60 GHz	Edward Au	https://mentor.ieee.org/802.11/dcn/11-15-1472	
TGaz	Next Generation Positioning	Jonathan Segev	https://mentor.ieee.org/802.11/dcn/11-15-1466	
LRLP TIG	Long range low power Topic Interest Group	Tim Godfrey	https://mentor.ieee.org/802.11/dcn/11-15-1520	

Note the TGaj meeting takes place the week following the Atlanta interim in Harbin, CN.

Policy Links	
Refer to the 802.11 WG Agenda for links to policy documents under which the session operates.	

WG Information	
802.11 Website	http://www.ieee802.org/11/
802.11 Document Server	https://mentor.ieee.org/802.11/documents
802.11 Reflector Request	http://grouper.ieee.org/groups/802/11/Reflector.html
802.11 Meeting Plan	http://www.ieee802.org/11/Meetings/Meeting_Plan.htm
802.11 Members' Area	http://www.ieee802.org/11/private/index.shtml
802.11 Operations Manaul	TBD
802.11 Officers	http://www.ieee802.org/11/Photographs/officers.htm

WG Session Reports	
WG Agenda	https://mentor.ieee.org/802.11/dcn/11-15-1485
Opening report	https://mentor.ieee.org/802.11/dcn/11-15-1486
Snapshots	https://mentor.ieee.org/802.11/dcn/11-15-1526
1st vice chair	https://mentor.ieee.org/802.11/dcn/11-15-1524
2nd vice chair	https://mentor.ieee.org/802.11/dcn/11-15-1527
Treasurer	https://mentor.ieee.org/802.11/dcn/11-15-1525
Supplementary Material	https://mentor.ieee.org/802.11/dcn/11-15-1487
Motions	https://mentor.ieee.org/802.11/dcn/11-15-1528
Closing report	https://mentor.ieee.org/802.11/dcn/11-15-1529

Session Information	http://802world.org/attendee

*Embedded Agendas ***	
WG11	IEEE 802.11 Working Group
CAC	IEEE 802.11 Chair's Advisory Committee
JTC1	JTC1 EC SC

Other Meetings	
NM	New Members Orientation

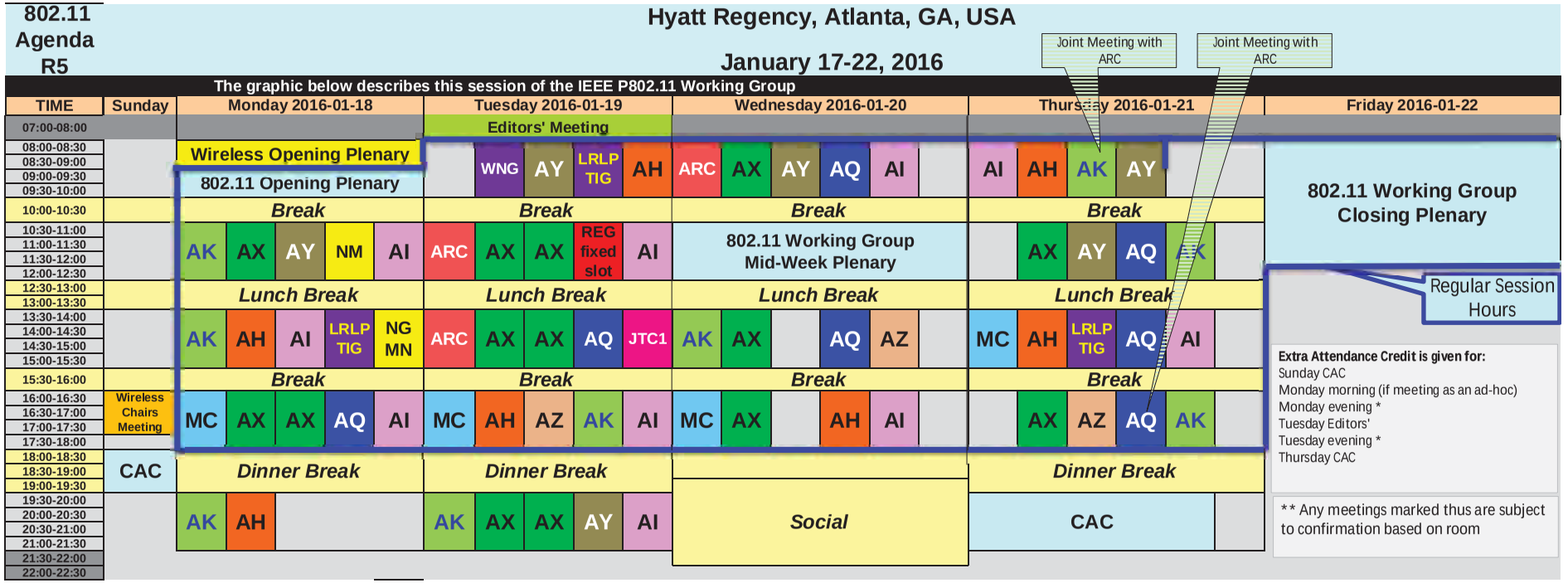
*** The colours used for these entries matches the colour used in the Agenda Graphic*

802.11 Agenda R5

Hyatt Regency, Atlanta, GA, USA

January 17-22, 2016

The graphic below describes this session of the IEEE P802.11 Working Group



155th IEEE 802.11 WIRELESS LOCAL AREA NETWORKS SESSION
Hyatt Regency, Atlanta, GA, USA
January 17-22, 2016

WG Chair - Adrian Stephens (Intel Corporation)
WG Vice Chair - Jon Rosdahl (CSR - Qualcomm)
WG Vice Chair - Dorothy Stanley (HPE - Aruba)
WG Secretary - Stephen McCann (Blackberry)

Agenda R5

WG11 Agenda - Mon 2016-01-18 - 09:00 to 10:00

Item	Type	Description	Document	Presenter	Start Time	Duration	End Time	Changes
1		**Opening formalities**						
1.1	II	Meeting called to order & assertion of quorum		Stephens	9:00	1	9:01	
1.2	II	Front table introductions. Introduce IEEE-SA staff representative, if present.		All	9:01	1	9:02	
1.3	II	Meeting Decorum (i.e., how to behave in meetings)	Opening Report	Stephens	9:02	1	9:03	
1.4	MI	Review and approve 802.11 session agenda	WG Agenda	Stephens	9:03	2	9:05	
1.5	MI	Review and approve WG minutes	WG minutes	McCann	9:05	1	9:06	
1.6	II	Straw poll of new attendees		Stephens	9:06	0	9:06	
2		**Announcements**						
2.1	**II**	**Policies and procedures (P&Ps)**						
2.1.1	II	Review Patent Policy slides (including call for essential patents)	PatCom materials	Stanley	9:06	6	9:12	
2.1.2	**II**	**Inform participants of the following P&Ps**						
2.1.2.1	II	IEEE Code of Ethics	Code of ethics	Stanley	9:12	1	9:13	
2.1.2.2	II	IEEE Standards Association (IEEE-SA) Affiliation FAQ	Affiliation FAQ	Stanley	9:13	0	9:13	
2.1.2.3	II	IEEE-SA Antitrust and Competition Policy		Stanley	9:13	0	9:13	
2.1.2.4	II	IEEE-SA Letter of Assurance (LoA) form	LoA form	Stanley	9:13	0	9:13	
2.1.2.5	II	IEEE-SA Patent Committee (PatCom) information	PatCom website	Stanley	9:13	0	9:13	
2.1.2.6	II	IEEE 802 LAN/MAN Standards Committee (LMSC) P&Ps, Chairs Guidelines, Operations Manual	LMSC P&P	Stanley	9:13	0	9:13	
2.1.2.7	II	IEEE 802 LMSC WG P&P	LMSC WG P&P	Stanley	9:13	0	9:13	
2.1.2.8	II	IEEE 802 LMSC rules changes		Stanley	9:13	1	9:14	
2.1.2.9	II	IEEE 802.11 Operations Manual changes		Stanley	9:14	1	9:15	
2.2	II	Reflectors		Stanley	9:15	1	9:16	
2.3	II	Attendance action from November 2015		Stanley	9:16	1	9:17	
2.4		**Incoming Liaisons**						
2.4.1	II	Summary of new and pending liaisons and processing this week	Opening Report	Stephens	9:17	2	9:19	
2.5	II	Other Anouncements		All	9:19	0	9:19	
2.6					9:19	0	9:19	
3		**Logistics and Key events/activities**						
3.1	II	Working group session documents	Opening Report	Stephens	9:19	1	9:20	
3.2	II	Joint meetings & Reciprocal Credit	Opening Report	Stephens	9:20	1	9:21	
3.3	II	Other WG meeting plans	1st VC Report	Rosdahl	9:21	1	9:22	
3.4	II	Meeting room locations	1st VC Report	Rosdahl	9:22	1	9:23	
3.5	II	Next meeting reminder	1st VC Report	Rosdahl	9:23	1	9:24	
3.6	II	Meeting registration	1st VC Report	Rosdahl	9:24	1	9:25	
3.7	II	Recording attendance	1st VC Report	Rosdahl	9:25	1	9:26	
3.8	II	File server	1st VC Report	Rosdahl	9:26	1	9:27	
3.9	II	Breakfast, breaks, Social logistics	1st VC Report	Rosdahl	9:27	1	9:28	
3.10	II	Wednesday Topics	Opening Report	Stephens	9:28	1	9:29	
3.11	II	Report on 802 EC or IEEE-SA Standards Board decisions	Opening Report	Stephens	9:29	3	9:32	
3.12					9:32	0	9:32	
4		**Opening reports, objectives & plans**						
4.1		**WG reports**						
4.1.1	II	802.11 groups	Opening Report	Stephens	9:32	1	9:33	
4.1.2	II	802.11 PARS	Opening Report	Stephens	9:33	1	9:34	
4.1.3	II	Officers	Opening Report	Stephens	9:34	1	9:35	
4.1.4	II	Standards pipeline and 802.11 revisions	Opening Report	Stephens	9:35	1	9:36	
4.1.5	II	Summary of Ballots / Comment collections	Opening Report	Stephens	9:36	2	9:38	
4.1.6	II	WG membership summary	Opening Report	Stephens	9:38	1	9:39	
4.1.7	II	WG ANA report	Opening Report	Stephens	9:39	1	9:40	
4.1.8	II	WG timeline report / planning		McCann	9:40	1	9:41	
4.1.9	II	WG technical editor	Snapshots Report	Ecclesine	9:41	1	9:42	
4.1.10					9:42	0	9:42	
4.2		**Standing committee reports**						

4.2.1	II	Architecture (ARC) (including 802 Architecture status)	Snapshots Report	Levy	9:42	2	9:44
4.2.2	II	PAR Review (PAR)	Snapshots Report	Rosdahl	9:44	1	9:45
4.2.3	II	Regulatory (REG)	Snapshots Report	Kennedy	9:45	1	9:46
4.2.4	II	Wireless Next Generation (WNG)	Snapshots Report	Lansford	9:46	1	9:47
4.2.5	II	JTC1 802 SC	Snapshots Report	Myles	9:47	1	9:48
4.3		**Task Group reports**					
4.3.1	II	TGmc - Revision mc (REVmc)	Snapshots Report	Stanley	9:48	1	9:49
4.3.2	II	TGah - Sub 1 GHz (S1G)	Snapshots Report	Seok	9:49	1	9:50
4.3.3	II	TGai - Fast Initial Link Setup (FILS)	Snapshots Report	Mano	9:50	1	9:51
4.3.4	II	TGaj - China Millimeter-Wave (CMMW)	Snapshots Report	Stanley	9:51	1	9:52
4.3.5	II	TGak - General Link (GLK)	Snapshots Report	Eastlake	9:52	1	9:53
4.3.6	II	TGaq - Pre-Association Discovery (PAD)	Snapshots Report	McCann	9:53	1	9:54
4.3.7	II	TGax - High Efficiency Wireless LAN (HEW)	Snapshots Report	Aboul-Magd	9:54	1	9:55
4.3.8	II	TGay - Next generation 60 GHz	Snapshots Report	Au	9:55	1	9:56
4.3.9	II	TGaz - Next generation positioning (NGP)	Snapshots Report	Segev	9:56	1	9:57
4.4		**Study Group / TIG reports**					
4.4.1	II	LRLP - Long Range Low Power TIG	Snapshots Report	Godfrey	9:57	1	9:58

5		**New Business**					
5.1					9:58	0	9:58
5.2					9:58	0	9:58

6		**Recess**		**Stephens**	**9:58**	**0**	**9:58**
		Slack Time				**2**	**10:00**

WG11 Agenda - Wed 2016-01-20 - 10:30 to 12:30

Item	Type	Description	Document	Presenter	Start Time	Duration	End Time	Changes
1		**Opening formalities**						
1.1	II	Meeting called to order		Stephens	10:30	1	10:31	
1.2	II	Front Table introductions		All	10:31	1	10:32	
1.3	MI	Modify and approve modifications to agenda	WG Agenda	Stephens	10:32	1	10:33	
2		**Announcements**						
2.1	II	Policies and Procedures (P&P) reminder	Supplementary	Stephens	10:33	1	10:34	
2.2	II	Call for essential patents	Supplementary	Stephens	10:34	1	10:35	
2.3	II	Reminder of Thursday night CAC meeting	Supplementary	Stephens	10:35	1	10:36	
2.4	II	Any other announcements		All	10:36	0	10:36	
2.5					10:36	0	10:36	
3		**Old business**						
3.1	II	Treasurer's Report	11-15/1525	Rosdahl	10:36	0	10:36	
3.2	II	Any WG reports carried forward			10:36	5	10:41	
3.3					10:41	0	10:41	
4		**Liaisons**						
4.1		**External (non-802) liaisons**						
4.1.1	II	Wi Fi Alliance		Sherlock	10:41	5	10:46	
4.1.2	II	Internet Engineering Task Force (IETF)		Stanley	10:46	10	10:56	
4.2		**Internal (802) liaisons**						
4.2.1					10:56	0	10:56	
4.2.2					10:56	0	10:56	
5		**New business**						
5.1	MI	Room change requests & Graphic update	WG Agenda	Stephens	10:56	6	11:02	
5.2	II	Status & Future of Regulatory		Stephens	11:02	2	11:04	
5.3	DT	State of Regulatory in 802 / 802.11	11-15/1537	Kennedy	11:04	15	11:19	
5.4	II	Reminder about process		Stephens	11:19	5	11:24	
5.5	II	EC workshop description		Stephens	11:24	5	11:29	
5.6	II	Report on leadership summit with WFA		Stephens	11:29	10	11:39	
5.7	II	Report on Attendance Rules	11-16/0025	Stanley	11:39	15	11:54	
5.8	DT	Making progress on IMT-2020		Levy	11:54	30	12:24	
5.9	II	Macau Logistics		Slykhouse	12:24	10	12:34	
6		**Recess**		**Stephens**	**12:34**	**0**	**12:34**	
		Slack Time				**-4**	**12:30**	

WG11 Agenda - Fri 2016-01-22 - 08:00 to 12:00

Item	Type	Description	Document	Presenter	Start Time	Duration	End Time	Changes
1		**Opening formalities**						
1.1	II	Meeting called to order		Stephens	8:00	1	8:01	
1.2	II	Front Table introductions		All	8:01	1	8:02	
1.3	MI	Modify and approve modifications to agenda	WG Agenda	Stephens	8:02	1	8:03	
2		**Announcements**						
2.1	II	Policies and Procedures (P&P) reminder	Supplementary	Stephens	8:03	1	8:04	
2.2	II	Call for essential patents	Supplementary	Stephens	8:04	1	8:05	

2.3	II	Reminder to get minutes to WG secretary		McCann	8:05	1	8:06
2.4	II	Reminder to get objectives & agendas for next session to WG Chair by 1st CAC telecon	Supplementary	Stephens	8:06	1	8:07
2.5	II	Letters of Assurance (LoAs) received	Supplementary	Stephens	8:07	1	8:08
2.6	II	Drafts for Sale in IEEE Shop	Supplementary	Stephens	8:08	1	8:09
2.7	II	Drafts to liaise with ISO/JTC1/SC6	Supplementary	Stephens	8:09	1	8:10
2.8	II	Status of ballots	Supplementary	Stephens	8:10	1	8:11
2.9	II	3GPP presentation on LWA (LTE WiFi Access)		Stephens	8:11	1	8:12
3		**Closing reports**					
3.1		**Working Group**					
3.1.1	II	Straw Poll of membership regarding this meeting location		Rosdahl	8:12	2	8:14
3.1.2	DT	Future venues insight	1st VC Report	Rosdahl	8:14	10	8:24
3.1.3	II	Treasurer's report		Rosdahl	8:24	10	8:34
3.1.4	II	Timeline		McCann	8:34	5	8:39
3.1.5	II	Attendance report	Closing Report	Stephens	8:39	2	8:41
3.1.6	II	WG Editor	Closing Report	Ecclesine	8:41	3	8:44
3.1.7					8:44	0	8:44
3.2		**Standing committee reports**					
3.2.1	II	Architecture (ARC)	Closing Report	Levy	8:44	3	8:47
3.2.2	II	PAR Review (PAR)	Closing Report	Rosdahl	8:47	0	8:47
3.2.3	II	Regulatory (REG)	Closing Report	Kennedy	8:47	3	8:50
3.2.4	II	Wireless Next Generation (WNG)	Closing Report	Lansford	8:50	3	8:53
3.2.5	II	JTC1 802 SC	Closing Report	Myles	8:53	3	8:56
3.3		**Task Group reports**					
3.3.1	II	TGmc - Revision mc (REVmc)	Closing Report	Stanley	8:56	3	8:59
3.3.2	II	TGah - Sub 1 GHz (S1G)	Closing Report	Seok	8:59	3	9:02
3.3.3	II	TGai - Fast Initial Link Setup (FILS)	Closing Report	Mano	9:02	3	9:05
3.3.4	II	TGaj - China Millimeter-Wave (CMMW)	Closing Report	Peng	9:05	0	9:05
3.3.5	II	TGak - General Link (GLK)	Closing Report	Eastlake	9:05	3	9:08
3.3.6	II	TGaq - Pre-Association Discovery (PAD)	Closing Report	McCann	9:08	3	9:11
3.3.7	II	TGax - High Efficiency Wireless LAN (HEW)	Closing Report	Aboul-Magd	9:11	3	9:14
3.3.8	II	TGay - Next Generation 60 GHz	Closing Report	Au	9:14	3	9:17
3.3.9	II	TGaz - Next Generation Positioning (NGP)	Closing Report	Segev	9:17	3	9:20
3.4		**Study Group / Topic Interest Group**					
3.4.1	II	LRLP - Long Range Low Power TIG	Closing Report	Godfrey	9:20	3	9:23
3.5		**Ad-hoc reports**					
3.5.1		NGMN ad-hoc	Closing Report	Stanley	9:23	3	9:26
3.6		**Liaison**					
3.6.1	II	802.15 liaison report	Closing Report	Chaplin	9:26	5	9:31
3.6.2	II	802.18 RR TAG liaison report	Closing Report	Kennedy	9:31	3	9:34
3.6.3	II	802.24 liaison report	Closing Report	Godfrey	9:34	5	9:39
3.6.4	II	802.1CF (OmniRAN) Status Update	Closing Report	Riegel	9:39	5	9:44
4		**Discussion topics**					
4.1					9:44	0	9:44
5		**Motions (old business)**					
5.1		**Working Group motions**					
5.1.1	MI	Telecon schedule	Motions	Stanley	9:44	3	9:47
5.1.2	MI	OM Updates		Stanley	9:47	0	9:47
5.1.3					9:47	0	9:47
5.2		**Standing committee motions**					
5.2.1	ME	Architecture (ARC)		Hamilton	9:47	0	9:47
5.2.2	ME	PAR Review (PAR)		Rosdahl	9:47	0	9:47
5.2.3	ME	Publicity (PUB)		McCann	9:47	0	9:47
5.2.4	ME	Regulatory (REG)		Kennedy	9:47	0	9:47
5.2.5	MI	Wireless Next Generation (WNG)		Lansford	9:47	0	9:47
5.2.6	ME	JTC1 802 SC		Myles	9:47	0	9:47
5.3		**Task Group motions**					
5.3.1	ME	TGmc - Revision mc (REVmc)		Stanley	9:47	0	9:47
5.3.2	MI	TGah - Sub 1 GHz (S1G		Seok	9:47	0	9:47
5.3.4	MI	TGai - Fast Initial Link Setup (FILS)		Mano	9:47	0	9:47
5.3.5	MI	TGaj - China Millimeter-Wave (CMMW)		Peng	9:47	0	9:47
5.3.6	MI	TGak - General Link (GLK)	Motions	Eastlake	9:47	5	9:52
5.3.7	MI	TGaq - Pre-Association Discovery (PAD)		McCann	9:52	0	9:52
5.3.8	MI	TGax - High Efficiency Wireless LAN (HEW)		Aboul-Magd	9:52	0	9:52
5.3.9	MI	TGay - Next Generation 60 GHz (NG60)		Au	9:52	0	9:52
5.3.10	MI	TGaz - Next Generation Positioning (NGP)		Segev	9:52	0	9:52
5.4		**Study Group / Topic Interest Group motions**					
5.4.1	ME	LRLP - Long Range Low Power TIG		Godfrey	9:52	0	9:52
6		**New Business**					
6.1	ME	802 liaison to ITU-R WP5D	Motions	Myles	9:52	10	10:02
6.2	DT	Making progress with IMT-2020 - Straw polls	Motions	Levy	10:02	30	10:32
6.3	DT	Leadership summit - does the WG need to approve?		Stephens	10:32	15	10:47
6.4	DT	Future of 802.18	11-16/196r0	Kennedy	10:47	15	11:02
6.5					11:02	0	11:02

7		**Closing formalities**					
7.1	II	Reminder about wireless chairs meeting	Supplementary	Stephens	11:02	1	11:03
7.2	II	Next meeting reminder	Supplementary	Stephens	11:03	1	11:04
7.3	MI	Adjourn		Stephens	11:04	0	11:04
		Slack Time				**56**	**12:00**

JTC1 SC AGENDA & OBJECTIVES FOR THIS SESSION

CHAIR - ANDREW MYLES (Cisco)

- **Forum to discuss any IEEE 802 issues related to ISO/IEC JTC1/SC6**

IEEE 802 JTC1 Standing Committee Ad Hoc AGENDA - 18 Jan 2016 - AM1

1	*	IEEE 802 JTC1 SC Meeting Call To Order	-	Chair	1
2	*	Select secretary for session	-	Chair	1
3	II	Review IEEE 802 Policies and Rules	-	Chair	2
4	MI	Approve Agenda	-	All	5
5	DT	Review meeting dates and agenda for SC6 meeting in February 2016	-	All	?
6	DT	Consider any submissions made for SC6 meeting in February 2016		All	?
7	DT	Recess			

IEEE 802 JTC1 Standing Committee AGENDA - 18 Jan 2016 - PM1

1	*	IEEE 802 JTC1 SC Meeting Call To Order	-	Chair	1
2	*	Select secretary for session	-	Chair	1
3	II	Review IEEE 802 Policies and Rules	-	Chair	2
4	II	Chair's Update	-	Chair	2
5	MI	Approve Agenda	-	All	5
6	MI	Approve previous minutes	-	All	2
7	DT	Review goals of IEEE 802 JTC1 SC	-	All	2
8	DT	Review status of IEEE 802 liaisons previously sent to SC6	-	All	5
9	DT	Review status of FDIS ballots in SC6	-	All	5
10	DT	Review agenda of next SC6 meeting	-	All	?
11	DT	Consider other matters	-	All	?
12	DT	Consider any motions	-	All	?
13	DT	Adjourn	-	All	?

ME - Motion, External MI - Motion, Internal

DT- Discussion Topic II - Information Item

^ - All time durations are estimates.

Recess and adjournment times are fixed.

155th IEEE 802.11 WIRELESS LOCAL AREA NETWORKS SESSION
Hyatt Regency, Atlanta, GA, USA
January 17-22, 2016

WG Chair - Adrian Stephens (Intel Corporation)
WG Vice Chair - Jon Rosdahl (CSR - Qualcomm)
WG Vice Chair - Dorothy Stanley (HPE - Aruba)
WG Secretary - Stephen McCann (Blackberry)

Agenda R5

CAC Agenda - Thu 2016-01-21 - 19:30 to 21:30

Item	Type	Description	Document	Presenter	Start Time	Duration	End Time	Changes
1		Meeting called to order		Stephens	19:00	0	19:00	
2		Review closing reports for closing plenary		Stanley	19:00	15	19:15	
3		Review closing motions for closing plenary		Stanley	19:15	15	19:30	
4		Review room requests and prepare room request schedule		Rosdahl	19:30	30	20:00	
5		Review agenda for closing plenary		Stephens	20:00	15	20:15	
6		Review material for closing 802 EC (Plenary sessions only)			20:15	15	20:30	
7		Adjourn			20:30	0	20:30	
		Slack Time				60	21:30	

Session Description:	155th IEEE 802.11 WIRELESS LOCAL AREA NETWORKS SESSION
Session Location:	Hyatt Regency, Atlanta, GA, USA
Readable Session Date Range:	January 17-22, 2016
Start Date:	Sunday 2016-01-17
General Session Start Date	Monday 2016-01-18
Duration (days):	6
End Date:	Friday 2016-01-22
Revision:	5

APPENDIX M

Wi-Fi 6

Protocol and Network

For a complete listing of titles in the
Artech House Mobile Communications Library,
turn to the back of this book.

Wi-Fi 6

Protocol and Network

Susinder R. Gulasekaran

Sundar G. Sankaran



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Dedicated to all those who have contributed to Wi-Fi and love Wi-Fi

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Chapter 1

Introduction

Wi-Fi has become a necessity in today's world. It has evolved into a fundamental utility, like electricity and water, that everyone—without any thought—expects to be available everywhere irrespective of whether it is a school, a hotel, a restaurant, a stadium, an office building, or even public transportation.

Wi-Fi is a wireless local area network (WLAN) technology, essentially an Ethernet replacement that allows devices to connect to the internet without being tethered by any wires or cables. It is based on Institute of Electrical and Electronic Engineers (IEEE) 802.11 standards. The absence of wires and cables extends access to places where the wires and cables cannot reach. This also brings down the network deployment cost since it avoids any trenching and drilling needed to create physical connections.

Wi-Fi is one of the greatest success stories of the modern technology era. Wi-Fi enabled devices can connect to the internet via a wireless access point (AP). APs have a range between 10 and 30 meters indoors, and the range can be much longer outdoors. Hundreds of millions of Wi-Fi access points connect billions of computers, smartphones, smart TVs, game consoles, cameras, printers, Internet of Things (IoT) devices, and other consumer devices to the internet to enable millions of applications to reach everyone, everywhere. According to a study commissioned by Wi-Fi Alliance (WFA), this generates a global economic value estimated at $3.3 trillion USD. This is expected to grow to $4.9 trillion by 2025.

The total global mobile traffic is estimated to increase from around 51 exabytes (51 billion gigabytes) per month by the end of 2020 to 226 exabytes per month in 2026. Operators have long been leveraging Wi-Fi networks to scale capacity to meet these ever-increasing bandwidth needs of their subscribers.

One of the main catalysts for the widespread adoption of Wi-Fi is the decision by regulatory bodies around the world to make significant blocks of spectrum available on a license-exempt basis. Unlike licensed bands, where the wireless communication protocol to be used is mandated as part of the licensing process, no protocols were specified for these unlicensed bands. This unregulated environment created opportunities for the industry to develop novel wireless communication protocols for various applications, including computer-to-computer communication. However, this resulted in several companies developing WLAN products that were incompatible with each other. The IEEE 802.11 standard was later developed in order to guarantee compatibility and interoperability.

1.1 IEEE STANDARDIZATION PROCESS

IEEE standardization starts with an idea for a standard. A group of individuals or companies form a study group under the IEEE Standards Association's umbrella for up to six months before their work gets approved as an IEEE standards project. The most famous among IEEE standards projects is the IEEE 802 project that focuses on local area network (LAN) standards. Working groups are formed within a project to develop standards to address a particular aspect of the problem. The working groups are assigned a number, which is written after the decimal point for the corresponding projects. WLAN happens to be the eleventh working group formed under IEEE 802, and hence got the number 802.11. The working group opens a PAR – a Project Authorization Request – that includes items such as the purpose and scope of the standard, who will chair the working group, and the expected duration of the project. After the PAR is approved by the IEEE SA's standards board, the working group begins the work to develop the standard. The standard that the working group develops is called a draft standard. At least 75 percent of the sponsor ballot group comprising interested entities or individuals needs to approve the draft standard by a letter ballot before it gets sent to the IEEE-SA Standards Board for approval. Once approved, it becomes an officially ratified standard. Then the publishing process begins, and the standard is made available to everyone.

As the standard gets used and as technology advances, an inevitable need to update the standard arises. This restarts the standardization process all over again. Task groups are formed within working groups to amend or add to the standard and are assigned alphabet(s) beneath the working group. The task group then submits a PAR. Once the PAR is approved, the draft to revise the standard is developed; the draft is then balloted and sent to the IEEE-SA Standards Board for approval.

The document produced by the task group is identified by the project number and working group number, followed by the alphabet(s) assigned to the task group. Task Group a (TGa) is the first WLAN task group formed and the standard developed by this task group is called IEEE 802.11a specification. Table 1.1 lists all the specifications, also known as amendments, developed by the IEEE 802.11 task groups.

Periodically, once every four years or so in the case of IEEE 802.11, a task group is formed to roll up the amendments into the parent specification. The first such task group TGma was formed in 2003 to create a single document that merged 8 amendments (802.11a, b, d, e, g, h, i, j) with the original IEEE 802.11 standard. The resultant document, approved in 2007, became the new base standard named IEEE 802.11-2007. The most recent rolled out standard is IEEE 802.11-2020, which was produced by the fourth maintenance task group referred to as TGmd. Maintenance/revision for IEEE 802.11-2020 is being handled by TGme.

1.2 WI-FI ALLIANCE

IEEE 802.11 is a long and complex standard. Despite the best efforts, some sections of the standard are bound to be ambiguous or not fully defined. Furthermore, the standard includes several optional features and different manufacturers might make different choices in their designs. To avoid interoperability problems, a non profit organization called Wireless Ethernet Compatibility Alliance (WECA) was formed by a group of major manufacturers two years after the original standard was ratified. The main objectives of WECA were to promote the use and implementation of the new standard and to certify products that conform to subsets of the 802.11 standard for interoperability. In 2000, WECA changed the name of its technology from Wireless Ethernet to Wi-Fi, a name coined by the brand consulting firm Interbrand as a pun on hi-fi and the organization was renamed WFA.

Since its founding in 1999, WFA has developed several interoperability certification programs to ensure that the Wi-Fi devices from different vendors interoperate seamlessly. These certification programs test various aspects of the 802.11 specifications on devices under test primarily for interoperability. The devices that pass these tests are certified to be "Wi-Fi Certified TM" for the specific 802.11 technology. Wi-Fi Certified TM is an internationally recognized certificate of approval for products indicating that these products have met industry standards of interoperability and security. Currently, WFA has more than 750 companies from around the

Table 1.1
IEEE 802.11 Amendments

Amendment	*Year Ratified*	*Description*
802.11b	1999	OFDM PHY in 5 GHz (Wi-Fi 2)
802.11a	1999	2.4 GHz CCK 5.5 and 11 Mbps (Wi-Fi 1)
802.11d	2001	Tx power and frequency compliance for regulatory domains
802.11g	2003	OFDM PHY in 2.4 GHz (Wi-Fi 3)
802.11h	2003	DFS and TPC to protect radar
802.11i	2004	Wi-Fi security enhancements (AES CCMP)
802.11j	2004	Japan regulatory domain rules in 4.9-5 GHz band
802.11e	2005	QoS enhancements EDCA, UAPSD, blockacks, direct link setup
802.11k	2008	Radio resource management
802.11r	2008	Fast roaming for WPA2
802.11y	2008	High power operation in 3650 to 3700 MHz
802.11n	2009	Wi-Fi 4
802.11w	2009	Protected management frames
802.11p	2010	Wireless access for vehicular applications using OFDM in upper 5-GHz band
802.11z	2010	Tunneled Direct link setup
802.11v	2011	Wireless network management and BSS transition management
802.11u	2011	Seamless roaming between participating Wi-Fi networks (Hotspot 2.0)
802.11s	2011	Wireless mesh networking
802.11ae	2012	Medium access prioritization of management frames
802.11ad	2012	60 GHz Wi-Fi
802.11ac	2013	Wi-Fi 5
802.11af	2014	Wi-Fi operation in TV White spaces frequency band (59-790 MHz)
802.11mc	2015	Maintenance standard which also added Wi-Fi positioning
802.11ah	2016	Standard for Wi-Fi operation below 1 GHz (755-928 MHz) intended for long range and IoT applications
802.11ai	2016	Fast Initial Link Setup
802.11aj	2018	Amendments to 802.11ad for operation in China
802.11ak	2018	Defines how clients with both 802.11 Wi-Fi and 802.3 wired capability can bridge the two mediums and also provides services like VLAN, audio-visual stream, and time synchronization for audio-visual streams
802.11aq	2018	Defines how APs can advertise network service information to clients prior to connecting to a network
802.11ax	2021	Wi-Fi 6
TGay	To be ratified	Next generation standard upgrade to 802.11ad for 60 GHz
TGaz	To be ratified	Next generation Wi-Fi positioning
TGbe	To be ratified	Wi-Fi 7

world as members and has certified more than 50,000 products for various Wi-Fi technologies.

The Wi-Fi standards, as described earlier, are identified as IEEE 802.11n, IEEE 802.11ac, IEEE 802.11ax, and so on. These are not very user-friendly, so, the WFA introduced a new naming convention in 2018 to easily recognize the Wi-Fi capability of devices. The new Wi-Fi naming scheme easily identifies the different generations by using a numerical sequence, each one of which corresponds to a major advancement in Wi-Fi technology. This numbering scheme makes it easier to see the progression of different generations of Wi-Fi. It is not obvious to most people that IEEE 802.11ac was the next generation from IEEE 802.11n, but it is much easier to see that Wi-Fi 6 is the next development on from Wi-Fi 5. This approach is very similar to the concept of technology generations, like 2G, 3G, 4G, and 5G, used in the cellular industry.

1.3 SPECTRUM

Since Wi-Fi operates in unlicensed spectrum, Wi-Fi networks can be deployed by anyone without any license or permission from the government. In the early days, Wi-Fi used the unlicensed 2.4 GHz ISM band. However, the 2.4-GHz band is crowded as it is used by more than just Wi-Fi. Old cordless phones, baby monitors, microwave ovens, and Bluetooth devices tend to use the 2.4-GHz band. To overcome the connectivity issues such as slow and dropped connections, Wi-Fi devices started using the 5-GHz unlicensed band also known as Unlicensed National Information Infrastructure (U-NII) band. Initially, Wi-Fi was allowed to operate only in a small fraction of the U-NII band. But as the demand for Wi-Fi increased, to mitigate congestion, regulatory bodies opened up more parts of the U-NII band. Table 1.2 lists various sub bands of the U-NII band. The availability as well as the regulations for using the allowed sub bands varies depending on the country.

1.4 OUTLINE OF CHAPTERS

Wi-Fi has gone through six generations over the last 25 years. Each new generation is built on the previous one to achieve improvements in speed and spectral efficiency. Over these six generations, Wi-Fi speed and efficiency have improved by three orders of magnitude.

This book is about the latest sixth-generation Wi-Fi, based on 802.11ax standard. Wi-Fi 6 supports a maximum data rate of nearly 10 Gbps with spectral

APPENDIX N

The Beacon

Wi-Fi® 2015: The top-10 list

by Craig Mathias

With 2015 now here (what, already?), it's time for the annual Top-10 lists to hit the airwaves. And what could be more interesting or important than a look at what's really going to matter in Wi-Fi® over the next year? Sure, many already take Wi-Fi for granted as a mature fixture in networking, and that's actually a good thing. Wi-Fi has indeed become ubiquitous to the point that it's achieved the networking nirvana of (however inelegant this may sound) *plumbing*. That's right, Wi-Fi *just works*. It's right up there with Ethernet and LTE as an *essential* networking and communications technology that few – *very, very few*, and, regardless, no one I know – could live without.

But that doesn't mean that the folks at the Patent Office can relax – the rate of innovation in Wi-Fi remains at a significant pace, and new developments continue to enable advanced applications that will yield far-reaching benefits. So what follows is a look at what I think will be the most important advances in Wi-Fi technologies, and more, for 2015 – and, as we'll allude below, about which there will be plenty of talk about in the outyears. I've listed my Top-10 in no particular order, with no prioritization or relative importance implied. With Wi-Fi, again, now so important across so many applications, it would be tough to say which of the following is truly Number One.

802.11ac takes off

But let's start with what's usually top-of-mind today, *802.11ac*. As we forecast about two years ago, 2015 will be *the* year in which sales of 802.11ac-based products exceed those of 802.11n. This is not to say that 802.11n is obsolete; indeed, sales of .11n-based products will continue and we still don't see any large-scale de-commissioning of 802.11n installations occurring before 2018 (and even then, 802.11ac will still provide backwards compatibility for the many still-in-service 802.11n clients). But the rate-vs.-range performance of .11ac, thanks primarily to beamforming and clever vendor implementations, and the improvement in overall capacity inherent in 802.11ac, thanks to increased channel bandwidths, will bring even the most skeptical IT managers and residential buyers into the 802.11ac fold in 2015. Sure, vendors are leading with the amazing throughput numbers enabled by 802.11ac, with four-stream products offering in excess of 3 Gbps aggregate throughput now available, but most deployments will really be all about improved *range, reliability, management*, and the *capacity* to support multiple, simultaneous, and demanding users, devices, and applications ranging from streaming video to the Internet of Things.

WiGig® on the move

802.11ad, or WiGig, will also gain a good deal of steam in 2015. Many have not yet even heard of 802.11ad, perhaps because it's getting lost in the alphabet soup (see the final item, below) of WLAN standards, and the fact is that few products are available today. But 802.11ad is no afterthought, and it won't be to .11ac like 802.11a was to 802.11g, a powerful but underutilized also-ran. 802.11ad is best thought of as a *complement* to 802.11ac, designed for *very* (very!) high throughput over more limited range. 802.11ad operates in the 60 GHz bands, where's there's a *vast* amount of available spectrum, and can reach close to 7 Gbps. OK, you say; so can 802.11ac - but that's possible only in an 8x8 MIMO configuration, and such won't be common in 2015, if ever. But, again you say, the 5 GHz. of 802.11ac propagates more efficiently, and 60 GHz really doesn't go through walls. True – but in open offices, for in-room full-speed HD video links, high-performance virtual reality and medical applications, and many more, however – let's just say that *a lot* more people will appreciate what 802.11ad can really do by the end of 2015. And with Wi-Fi Alliance® hard at work on a certification program here, many of these folks will soon have direct experience with just how amazing 802.11ad really is. Stay tuned – *this is going to be big*.

Passpoint™: Cellular-like connectivity comes to Wi-Fi

Passpoint is one of the most important innovations ever to come out of Wi-Fi Alliance, ranking right up with WPA™, the brilliant solution that addressed the fundamental flaws in WEP that at the time threatened to derail the momentum that was just beginning to build behind wireless LANs. Just like WPA, Passpoint is simple and elegant, and designed to make authenticating with Wi-Fi hotspots as easy and as transparent as handsets connecting to a cellular network. In other words, the same seamless authentication experience that is essential to cellular will become *common* in Wi-Fi based hotspots and beyond in 2015 – momentum is building, and the flexibility inherent in Passpoint leaves few opportunities for either objections or alternatives – a done deal, in other words.

Wi-Fi and the cloud – In more ways than one

Which leads us to the future of information systems and IT overall as the continuous connectivity enabled by Wi-Fi becomes commonplace. I'm of the opinion that the Cloud, not apps, wins in the long run. Why? Because modern organizational computing centers on large (make that *vast*) amounts of data, sufficient server processing power to deal with all that data, and real-time, anytime/anywhere communication and collaboration. The argument about needing to be productive when offline is now moot: *no one can really be productive without access to the network*. Wi-Fi – *real mobile broadband networking* – is going to be available almost everywhere (it'll be rare to be on a flight that doesn't offer Wi-Fi, for example), and often the *first* choice for this essential connectivity (see the next item). Look for HTML5-based applications, desktop virtualization, all manner of network and other operational management services, and, really, all cloud services available at the end of a Wi-Fi connection to *define* IT from 2015 onwards. And remember - *only* Wi-Fi offers the combination of throughput, capacity, and cost-effectiveness that truly makes the cloud mobile.

Wi-Fi is critical to the success of - *Cellular*

Going hand-in-hand with (and also augmented by) Passpoint is the emerging momentum towards *cellular offload*. I've argued for some time that Wi-Fi is *fundamental – essential,* really – to the future of wide-area wireless communications because cellular networks are so limited in terms of available spectrum. Sure, the trend towards small cells and LTE-Advanced will help here, but more spectrum is always king in wireless. With vast amounts of spectrum available on an unlicensed basis, and rapid reuse of this spectrum due to both efficient sharing mechanisms and limited transmit power, Wi-Fi is an *ideal* complement to cellular, especially indoors and in high-population-density, high-demand areas. In fact, all that abundant spectrum and 802.11ac-equipped clients will likely drive the nascent *"Wi-Fi First"* movement that's just coming onto radar screens. And such exciting developments as the increasing availability of Wi-Fi in cars as both mobile hotspots and as a core element in intelligent vehicles and highways, the increasing application of voice over Wi-Fi, and even mobile unified communications (landlines? remember those?), and more – exciting just doesn't begin to describe it!

Wi-Fi and the enterprise: Two key developments

Just as is the case in the residence, enterprises are now provisioning Wi-Fi as not just their primary or preferred networks, but rather as their *only* access for essentially *everyone*, from staff to contractors to guests. As a consequence, wired networks in organizations are now taking on a supporting role, providing connectivity, power (over Ethernet), and backhaul for the ever-increasingly dense population of APs. This means that *unified wired/wireless management* is gaining steam, as IT staffs always pressed to improve productivity seek to optimize Wi-Fi performance end-to-end and minimize operational expense, and the rise of big-data *analytics* to help spot performance and potential security and integrity issues before these can have an impact.

Wi-Fi maintains its leading role in location-based services

One of the most interesting applications (again, almost everywhere) going forward will be *location-based services* and, at least in some cases, Wi-Fi-based *tracking* in the interests of enhancing these services and a number of dimensions of security. Many in the press are ga-ga about beacons based on Bluetooth Low Energy (BLE), but let's face it: these have limited range and are broadcast-only – meaning another wireless technology is required to close the loop. And that technology is – well, I think you know… And Wi-Fi can also be used for the location and tracking of unmodified clients, with excellent range, accuracy, and convenience. We'll see the launch of new location-based services and applications across a broad range of market opportunities. Even the obvious privacy concerns can be addressed – such represent, after all, a *political*, and not technical, challenge.

Wi-Fi dominates in IoT applications

2015, as I **recently wrote**, will see the dramatically increased application of Wi-Fi in M2M/IoT/IoE. The real beauty of Wi-Fi in the Internet of Things world is that Wi-Fi already speaks IP natively, and new applications can in many cases leverage a robust, broadband infrastructure that's already in place. Everything required is in fact here today – security, authentication, and even low-cost, low-power (I recently reviewed, for example, a Wi-Fi *camera* that can run for up to 90 days on a single USB charge!) implementations suitable for anything that needs to be done in the residence, or the enterprise. Wi-Fi is a very serious alternative to other M2M/IoT/IoE radio technologies, and I expect Wi-Fi will even *dominate* many IoT applications going forward. And let's not forget the many potential beneifts of Wi-Fi Direct® here as well.

Service discovery: Convenience and value

Just announced by Wi-Fi Alliance, Wi-Fi Aware™ is an exciting advance in the vital service-discovery space. The idea here is for devices and users to learn about potential services, applications, information, and beyond *before* connecting to a given Wi-Fi network. The implications here are huge: looking for a printer? How about being notified about an item on your shopping list being not just available nearby, but also on sale? Think of service discovery as social networking that runs in the background on mobile devices. The real power of service discovery will be unlocked when application developers discover all that's here – but it's going to be exciting (there's that word again!) nonetheless, and, yes, in 2015.

And the innovation continues: We're not done yet

OK, most of these extend well beyond 2015, but you'll see many new products based on the continuing innovation coming out of IEEE 802.11 Working Groups in 2015 and beyond. A few notable examples here include work on 802.11ax, which could reach (around 2018, I think) the magical 10 Gbps level of throughput; 802.11ah, for additional M2M/IoT opportunities in the sub-1 GHz. bands; 802.11ai, for improved connect times (this is a/k/a Fast Link Setup); and 802.11aq, or Pre-Association Discovery – which should fit nicely with the Wi-Fi Aware effort noted above (and, once again, Wi-Fi Alliance is well ahead of the formal standards process). While Wi-Fi Alliance has yet to announce

plans in many of these areas, the ongoing high levels of activity and innovation in wireless LANs point to a future that will yield numerous additional benefits for us all.

So you see what I mean: Wi-Fi is indeed *everywhere* and has achieved the status of an *essential* technology - it's right up there with electricity, the Internet, and, yes, indoor plumbing as a universal requisite for effective business, education, government, health and healthcare, entertainment - and much, much more.

Happy New Year – *and an innovative 2015* – to all!

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Submitted by Anonymous on Fri, 03/13/2015 - 14:46

Permalink

this is one of the world best

this is one of the world best application

Reply

Submitted by Vinod Vyas on Sun, 10/25/2015 - 06:55

Permalink

Whats the latest update, we are in Q4 2015

Good article Craig. Whats the update. We are in Q4 2015. How do you see WiFi now after lots of changes in technology and recent acquisition of Aruba by HP and Meru by Fortinet.

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APPENDIX O

IEEE Spectrum

NEWS TELECOMMUNICATIONS

What's Next After 25 Years of Wi-Fi? › The 25th anniversary of the IEEE 802.11 wireless standard provides a chance to glimpse next-gen Wi-Fi

BY JEREMY HSU

10 SEP 2015



PHOTO: ISTOCKPHOTO

IN 1997, THE FIRST VERSION OF WI-FI APPEARED. (The same year saw a bout half of U.S. homes using AOL as their Internet Service Provider, Netscape with the most web browser users, and Microsoft rescuing Apple from the verge of bankruptcy.) Today, the the Wi-Fi standard known as IEEE 802.11 celebrates its 25th anniversary in a world where many people take Wi-Fi access for granted while streaming high-definition video and checking in on social media through their smartphones and laptops.

The IEEE 802.11 wireless technology standard has come a long way since it first originated from a working group meeting in September 1990. Early Wi-Fi supported data rates of just 2 megabits per second. By comparison, the latest Wi-Fi standard supports 3,500 times faster data rates, ranging up to 7 gigabits per second. *IEEE Spectrum* spoke with Dorothy Stanley, a vice chair of the IEEE 802.11 Working Group and senior standards architect at Aruba Networks, about what to expect from the next generation of Wi-Fi.

This interview has been edited and condensed for clarity.

IEEE Spectrum: How have the goals of the 802.11 Working Group evolved since it first met 25 years ago?

Dorothy Stanley: At a high level, the goal of the group that first met is very similar to the goal of the group we have today, which is to incorporate technology into the 802.11 standard that improves throughput and capacity and capability. And the technology we have to work with today is obviously much more advanced. Standards have gone from rates of 1 to 2 megabits per second—which at the time was very respectable—to 11 Mb/s, then 54 Mb/s, then hundreds of Mb/s and now into the gigabit range. The impact of the technology has exceeded anyone's crystal ball predictions.

IEEE Spectrum: What do you see as the biggest impacts of Wi-Fi on society?

Dorothy Stanley: Today, 802.11 technology is global and it's almost an expected infrastructure utility in many places. I think the generation growing up now and anyone who is 30 years or younger expects Wi-Fi to be there. Since their cell phone data plans are limited, they look for Wi-Fi and they value Wi-Fi.

I think the 802.11 standard is a prime example of how

technology has made it possible for people to access data and information in a very cost-effective way. 802.11 was the first case of making wireless technology effectively available to the masses. Any person could set up a wireless network. They didn't have to get a license, go through an operator, or get someone else to get it done. You empower individuals and corporations to use the technology and experiment with it and improve productivity in a very cost-effective way.

IEEE Spectrum: What can we expect next-generation Wi-Fi standards to deliver?

Dorothy Stanley: The 802.11ad amendment deals with 60 gigahertz wireless operations. The technical challenges of building radios in 60 GHz are much more difficult than in the 2-4 GHz or 5 GHz ranges. Those products are going to be later to market; I expect they'll be more prevalent in 2016, 2017 and beyond. 60 GHz will be another spectrum band that will be available for very low range applications such as those within a room; primarily docking applications and video applications. The current 60 GHz standard provides data rates of up to 7 Gb/s. The next-gen 60 GHz standard, 802.11ay, will go up to 20 Gb/s. You'll get very high throughput.

Another amendment is the 802.11ax amendment for high-

efficiency wireless local area networks. That looks for efficiency in dense deployments such as stadiums, shopping malls, and subways where you have a lot of people accessing the Wi-Fi system.

There is also work going on with the next-generation 802.11az amendment, which is designed for new positioning applications designed to run on wireless networks. It's about more efficient positioning and location finding that can augment GPS for indoor locations.

IEEE Spectrum: Have there been big challenges in the next-generation 802.11ah standard being developed for the Internet of Things (IoT)?

Dorothy Stanley: The Internet of Things is a little different from Internet access applications, because you're not interested so much in high Internet throughput, but you're interested in longer range and higher power efficiency. 802.11ah provides protocols and definitions for operating in the sub-one-gigahertz band (900 megahertz). In the sub-one-gigahertz spectrum, there is much less spectrum available. The spectrum that is available is different in different countries; it's not like the 2.4 gigahertz band where you had virtually all channels available globally. Work is underway with regulators,

particularly in Europe, to get additional spectrum allocated.

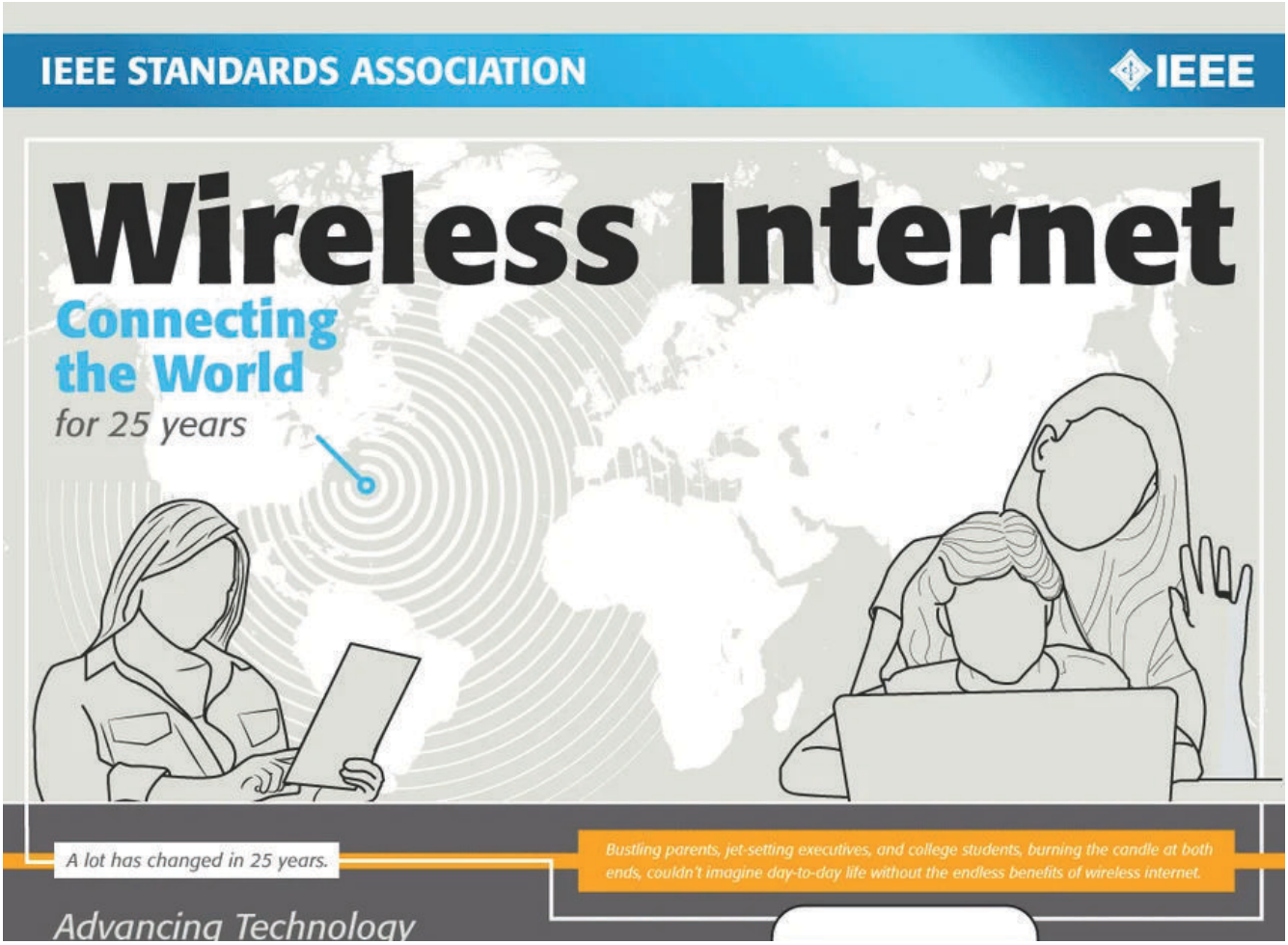
Here, the data rates are in the hundreds of kilobits range rather than in the hundreds of megabits range. But because you're operating at sub-one-gigahertz, the range is longer. The transmission range is up to a kilometer. For most smart grid or Internet of Things applications, a kilometer is more than adequate. A lot of the consumer applications that have been identified as use cases would be 802.11ah-enabled appliances, such as water softeners down in the basement, the furnace, or the lighting around the house.

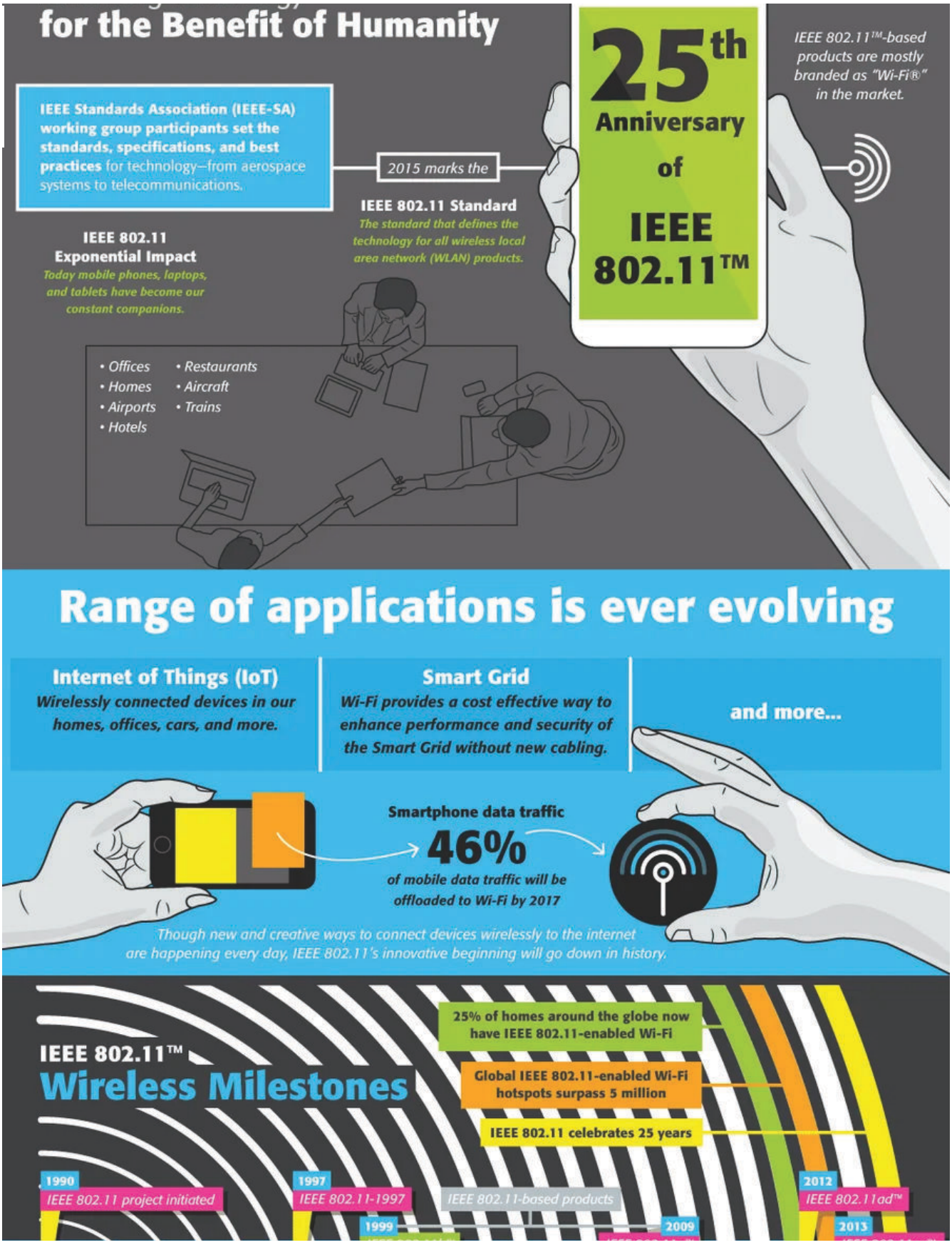
IEEE Spectrum: Why do you think the IEEE 802.11 Working Group process has been successful over the past 25 years? And do you expect the process to continue working well in the future?

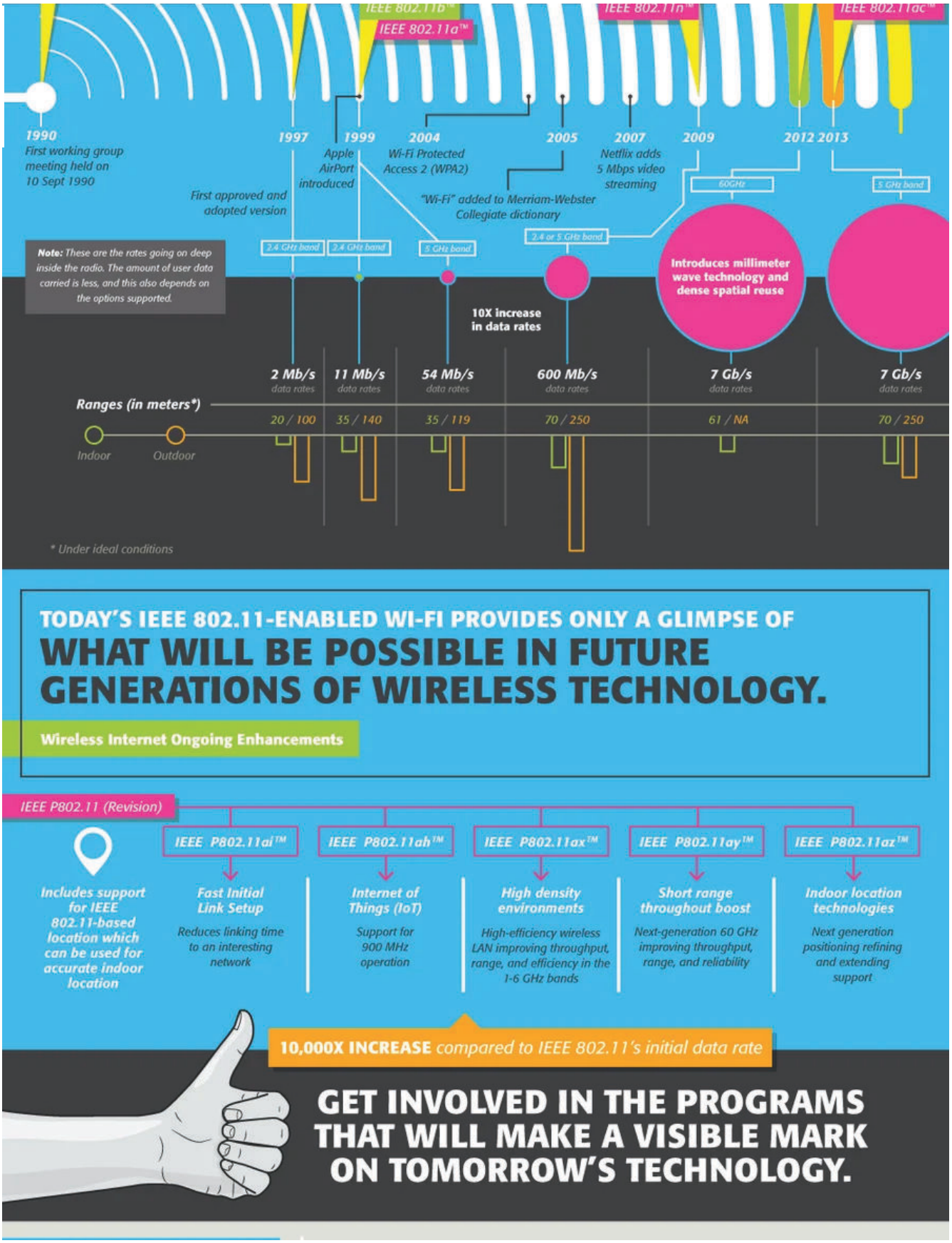
Dorothy Stanley: There is a very open, global and collaborative consensus process in place. The benefit is that you can have any people come who have technology or information to contribute. You don't have to be associated with a government; people come from new companies, established companies and academia to provide contributions. The success of the 802.11 standard is really due to not just the folks who developed the standard, but also due to the engineers in all the companies who built products based on the standard, and to

companies who built products based on the standard, and to the customers who bought those products.

It's not just companies supporting us in going to the Wi-Fi standard, but also end consumers and the world in general accessing the Internet. My kids and the college generation expect Wi-Fi to be there. Our goal is to make sure the 802.11 standards are there in the future to provide an efficient technology that people can use and improve their lives with.




for the Benefit of Humanity
IEEE Standards Association (IEEE-SA) working group participants set the standards, specifications, and best practices for technology—from aerospace systems to telecommunications.
2015 marks the
IEEE 802.11 Standard
The standard that defines the technology for all wireless local area network (WLAN) products.
25th Anniversary of IEEE 802.11™
IEEE 802.11™-based products are mostly branded as "Wi-Fi®" in the market.
IEEE 802.11 Exponential Impact
Today mobile phones, laptops, and tablets have become our constant companions.
• Offices
• Homes
• Airports
• Hotels
• Restaurants
• Aircraft
• Trains
Range of applications is ever evolving
Internet of Things (IoT)
Wirelessly connected devices in our homes, offices, cars, and more.
Smart Grid
Wi-Fi provides a cost effective way to enhance performance and security of the Smart Grid without new cabling.
and more...
Smartphone data traffic
46%
of mobile data traffic will be offloaded to Wi-Fi by 2017
Though new and creative ways to connect devices wirelessly to the internet are happening every day, IEEE 802.11's innovative beginning will go down in history.
IEEE 802.11™
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25% of homes around the globe now have IEEE 802.11-enabled Wi-Fi
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1990
IEEE 802.11 project initiated
1997
IEEE 802.11-1997
1999
IEEE 802.11-based products
2009
2012
IEEE 802.11ad™
2013


IEEE 802.11a™
1990
First working group meeting held on 10 Sept 1990
1997
First approved and adopted version
1999
Apple AirPort introduced
2004
Wi-Fi Protected Access 2 (WPA2)
2005
"Wi-Fi" added to Merriam-Webster Collegiate dictionary
2007
Netflix adds 5 Mbps video streaming
2009
2012 2013
60GHz
5 GHz band
2.4 GHz band
2.4 GHz band
5 GHz band
2.4 or 5 GHz band
Note: These are the rates going on deep inside the radio. The amount of user data carried is less, and this also depends on the options supported.
10X increase in data rates
Introduces millimeter wave technology and dense spatial reuse
2 Mb/s data rates
11 Mb/s data rates
54 Mb/s data rates
600 Mb/s data rates
7 Gb/s data rates
7 Gb/s data rates
Ranges (in meters*)
20 / 100
35 / 140
35 / 119
70 / 250
61 / NA
70 / 250
Indoor
Outdoor
* Under ideal conditions
TODAY'S IEEE 802.11-ENABLED WI-FI PROVIDES ONLY A GLIMPSE OF
WHAT WILL BE POSSIBLE IN FUTURE GENERATIONS OF WIRELESS TECHNOLOGY.
Wireless Internet Ongoing Enhancements
IEEE P802.11 (Revision)
IEEE P802.11ai™
Includes support for IEEE 802.11-based location which can be used for accurate indoor location
Fast Initial Link Setup
Reduces linking time to an interesting network
IEEE P802.11ah™
Internet of Things (IoT)
Support for 900 MHz operation
IEEE P802.11ax™
High density environments
High-efficiency wireless LAN improving throughput, range, and efficiency in the 1-6 GHz bands
IEEE P802.11ay™
Short range throughout boost
Next-generation 60 GHz improving throughput, range, and reliability
IEEE P802.11az™
Indoor location technologies
Next generation positioning refining and extending support
10,000X INCREASE compared to IEEE 802.11's initial data rate
GET INVOLVED IN THE PROGRAMS THAT WILL MAKE A VISIBLE MARK ON TOMORROW'S TECHNOLOGY.



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APPENDIX P

ACCEPTED FROM OPEN CALL

IEEE 802.11AX: HIGH-EFFICIENCY WLANS

BORIS BELLALTA

ABSTRACT

IEEE 802.11ax-2019 will replace both IEEE 802.11n-2009 and IEEE 802.11ac-2013 as the next high-throughput WLAN amendment. In this article, we review the expected future WLAN scenarios and use cases that justify the push for a new PHY/MAC IEEE 802.11 amendment. After that, we overview a set of new technical features that may be included in the IEEE 802.11ax-2019 amendment, and describe both their advantages and drawbacks. Finally, we discuss some of the network-level functionalities that are required to fully improve the user experience in next-generation WLANs and note their relation with other ongoing IEEE 802.11 amendments.

INTRODUCTION

IEEE 802.11 wireless local area networks (WLANs) [1] are a cost-efficient solution for wireless Internet access that can satisfy most current communication requirements in domestic, public, and business scenarios.

Similar to other wireless technologies, WLANs have evolved by integrating the latest technological advances in the field as soon as they have become sufficiently mature, aiming to continuously improve spectrum utilization and raw WLAN performance. IEEE 802.11n-2009 adopted single-user multiple-input multiple-output (SU-MIMO), channel bonding, and packet aggregation. Those mechanisms were further extended in IEEE 802.11ac-2013, which also introduced downlink multi-user (MU) MIMO transmissions. In addition, new amendments such as IEEE 802.11af-2013 and IEEE 802.11ah-2016 are further expanding the application scenarios of WLANs, which include cognitive radio, long-range communication, advanced power saving mechanisms, and support for machine-to-machine (M2M) devices.

Partly because of their own success, next-generation WLANs face two main challenges. First, they must address dense scenarios, which is motivated by the continuous deployment of new access points (APs) to cover new areas and provide higher transmission rates. Second, the current evolution of Internet usage toward real-time high-definition audio and video content will also significantly increase users' throughput needs in the coming years.

To address those challenges, the High-Efficiency WLAN (HEW) Task Group [2] is currently working on a new high-throughput amendment named IEEE 802.11ax-2019. This new amendment will develop new physical (PHY) and medium access control (MAC) layer enhancements to further improve the WLAN performance, with a focus on the throughput and battery duration. This article overviews some of those new enhancements, and describes the potential benefits and drawbacks of each one. We have grouped these enhancements into four main categories: spatial reuse, temporal efficiency, spectrum sharing, and multiple-antenna technologies. Moreover, we also discuss several key system-level improvements for next-generation WLANs, as in addition to the IEEE 802.11ax-2019 amendment, they will likely implement other in-progress amendments such as IEEE 802.11aq-2016 (pre-association discovery of services), IEEE 802.11ak-2017 (bridged networks), and IEEE 802.11ai-2016 (fast initial link setup time) to satisfy the created expectations.

SCENARIOS, USE CASES, AND REQUIREMENTS

The forecast number of devices and networks, and traffic characteristics and user demands for the 2020–2030 decade motivate the development of a new PHY/MAC IEEE 802.11 amendment to cope with the new challenges and usages WLANs will face [2].

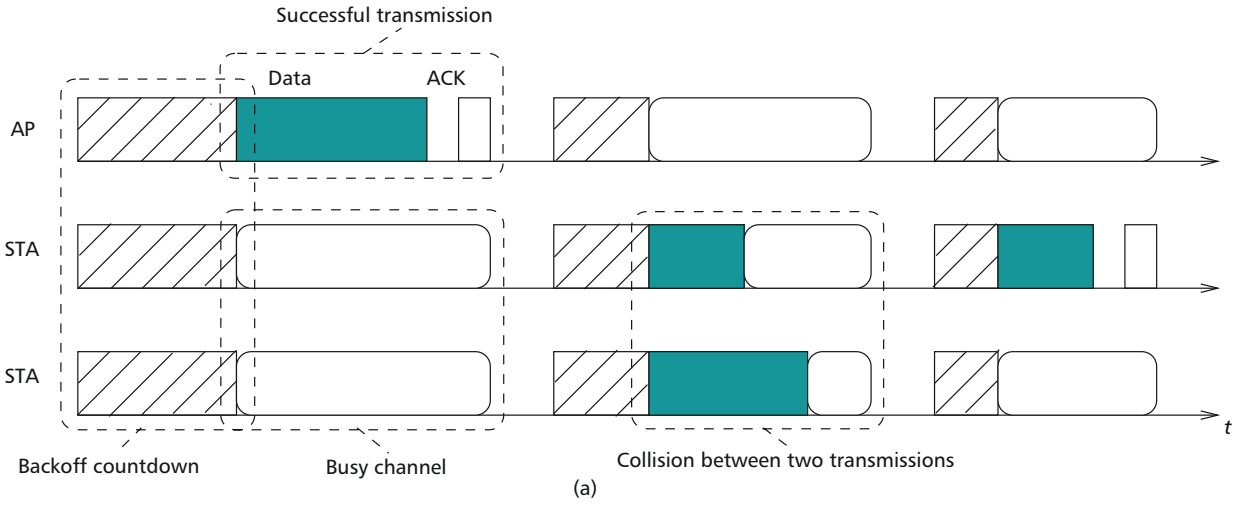
One of the most representative characteristics of WLANs is the use of carrier sense multiple access with collision avoidance (CSMA/CA) as the MAC protocol. It offers a reasonable trade-off between performance, robustness, and implementation costs. Using CSMA/CA, when a node has a packet ready for transmission, it listens to the channel. Once the channel has been detected as free (i.e., the energy level on the channel is lower than the clear channel assessment, CCA, threshold), the node starts the backoff procedure by selecting a random initial value for the backoff counter. The node then starts decreasing the backoff counter while sensing the channel. Whenever a transmission, either from other nodes within the same WLAN or belonging to other WLANs, is detected on the channel, the backoff counter is paused until the channel is detected to be free again, at which point the countdown is resumed. When the backoff counter reaches zero, the node starts transmitting. Figure 1a shows an example of CSMA/CA operation.

DENSE WLAN SCENARIOS

Providing high data rates in scenarios where the density of WLAN users is very high (e.g., 1 user/m^2) requires the deployment of many APs

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Scenario (area, m²)	APs	STAs	Description
Stadium (~12,500 m²)	> 1000	> 50,000	Large events that require many APs to provide a satisfactory connectivity service able to support video uploading/downloading.
Train (~600 m²)	< 10	> 1000	Full coverage inside a train to provide both work and entertainment services.
Apartment building — 4 floors, 6 apartments/floor (~2400 m²)	> 120	< 480	Several short-range APs deployed in each apartment, offering full coverage and high data rates for bandwidth hungry entertainment applications, as well as connectivity for house appliances. Community APs may also be deployed in the corridors and shared spaces.

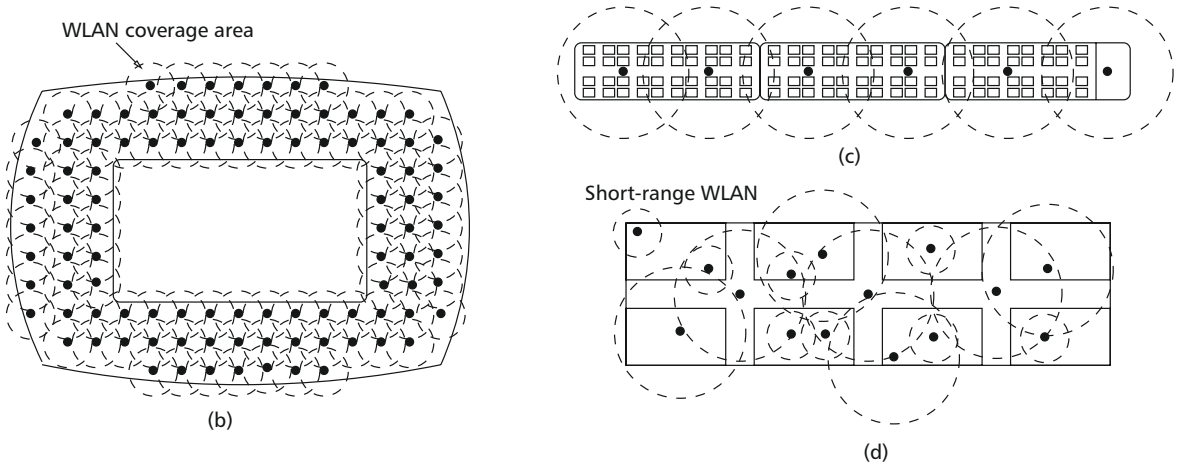


Figure 1. Key scenarios in next-generation WLANs: a) example of CSMA/CA temporal evolution with one AP and two STAs; b) stadium; c) train; d) floor of a building with several apartments.

placed close to each other (e.g., within 5–10 m of one another). Figure 1 depicts and describes three of those scenarios: a stadium, a train, and an apartment building. In these dense scenarios, most relevant challenges are related to interference issues, which increase the packet error rate and reduce the number of concurrent transmissions in a given area by preventing neighboring WLANs from accessing the channel. Additionally, the presence of many stations (STAs) in the same area increases the chances that the backoff counters of two or more STAs reach zero simultaneously, which results in a collision.

In the stadium scenario, many people are concentrated in small areas because of a fair, a conference, or a sporting event. The presence of many people results in a high density of STAs and the necessity of deploying many APs to offer satisfactory service. A fundamental challenge in these scenarios is to deploy, optimize, and coordinate such a large number of APs and STAs.

Public transport is also a key scenario for next-generation WLANs because trains, buses, and planes will offer broadband Internet access. In these scenarios, the user density may be notably high, with several people per square meter. Then smart AP coordination can help improve spatial reuse, and the use of an efficient medium

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Interactive and high-definition video applications are predicted to dominate future Internet usage. Two examples of applications that require throughputs of several gigabits per second are high-definition multi-party video conferences in business environments, and virtual reality entertainment applications at home, which include culture, films, and games.

access protocol may help support many simultaneous contenders.

Finally, in an apartment building, we can find multiple autonomous and heterogeneous WLANs overlapping, including short-range WLANs that offer high transmission rates in small spaces [3]. In this scenario, each WLAN is primarily configured independent of the others, where the channel selection, channel width, and transmission power are randomly set or are simply the preset values. Therefore, autonomous WLANs must be able to implement smart decentralized self-configuration and self-adaptation mechanisms to minimize the interference among them.

WLANs must also coexist with other wireless networks that operate in the industrial, scientific, and medical (ISM) band, such as wireless sensor networks and personal area networks. In addition, Long Term Evolution (LTE) operators are currently considering deploying LTE networks in the ISM band [4], which is known as LTE-Unlicensed, thus opening further coexistence challenges for WLANs.

Future WLAN Usages

Interactive and high-definition video applications are predicted to dominate future Internet usage. Two examples of applications that require throughputs of several gigabits per second are high-definition multi-party video conferences in business environments, which can help avoid unnecessary travel and meetings, and virtual reality entertainment applications at home, which include culture, films, and games. Additionally, web surfing is moving further toward a multimedia experience, where rich text, images, audio, and video content interact. Furthermore, file storage, management, and synchronization in the cloud are becoming the standard in terms of content management and generation. Those applications are bandwidth-demanding, and require both reliability and limited delay.

Requirements

Based on the aforementioned scenarios and expected use cases, there are four key requirements for the IEEE 802.11ax-2019 amendment.

Coexistence: WLANs operate as unlicensed devices in the ISM bands. Therefore, the IEEE 802.11ax-2019 amendment has to include the required mechanisms to coexist with both the other wireless networks that operate there and the licensed devices.

Higher Throughput: Improving both the system and user throughput requires the improved use of channel resources. IEEE 802.11ax-2019 aims for a four-fold throughput increase compared to IEEE 802.11ac-2013. To achieve this goal, some new wireless technologies such as dynamic CCA, OFDMA (orthogonal frequency-division multiple access), and advanced multiple-antenna techniques may be used.

Energy Efficiency: The target in IEEE 802.11ax-2019 is, at least, to not consume more energy than the previous amendments, considering the aforementioned four-fold throughput increase, which requires both new low-power hardware architectures [5] and new low-power PHY/MAC functionalities.

Backward Compatibility: Because WLANs implementing IEEE 802.11ax-2019 must also support devices using any previous IEEE 802.11 PHY/MAC amendments, mechanisms must also be implemented to make it backward compatible (i.e., common frame headers and transmission rates), although it is a clear source of inefficiency.

New Features and Concepts

The IEEE 802.11ax-2019 amendment may include some new technical features compared to the IEEE 802.11ac-2013 amendment. We introduce them in this section, providing insight into their potential performance gains and limitations. All numerical results presented in this section are obtained using the analytical model and parameters from [6], unless otherwise stated.

Spatial Reuse

In dense scenarios, the combined use of CSMA/CA, a conservative CCA, and a high transmit power level may result in scenarios with limited spatial reuse. A conservative configuration of both the CCA and transmit power levels minimizes the interference among the WLANs, which supports higher transmission rates. However, the number of concurrent transmissions is reduced, which may decrease the achievable area throughput. The alternatives that can be used to reach an optimal trade-off between individual transmission rates and the number of concurrent transmissions that maximize the area throughput include dynamically adapting the transmit power level, the CCA level, and the use of directional transmissions based on the observed network performance.

Figure 2a shows three neighboring WLANs. The channels that each WLAN uses are shown in Fig. 2b. Because WLANs A and C, and B and C partially share their channels, they overlap. The three APs are inside the carrier sense range of the others, as shown in Fig. 2a, which pauses their backoff if either of the other two transmits. Although WLAN C uses the widest channel, it achieves the lowest throughput because it overlaps with WLANs A and B, which are independent of each other (Fig. 2c).

Dynamic Adaptation of the Transmit Power and CCA Levels: Reducing the used transmission power in a WLAN reduces its influence area, which benefits the spatial reuse. However, it may result in a larger number of packet errors and lower transmission rates, as well as an increased number of hidden nodes.

Alternatively, to reduce the area of influence of neighboring WLANs and increase each WLAN's chances to transmit, the nodes in a WLAN may increase their CCA level, hence requiring a higher energy level in the channel to consider it as occupied and pause the backoff countdown. In [7], significant throughput gains are achieved by tuning the CCA level in a multicell WLAN scenario. The downside of increasing the CCA level is again the higher interference that a node may suffer, which could be detrimental in some cases.

Beamforming: Omnidirectional transmissions homogeneously spread the transmitted energy in all directions, which fills the channel with energy

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in areas where it is not required. Concentrating the energy toward the desired destination improves the spatial reuse because the devices that are placed in other directions will observe the channel as being empty and, therefore start their own transmissions concurrently. However, similar to the previous case, those nodes outside the energy beam may also become hidden nodes.

Temporal Efficiency

The backoff countdown, packet headers, interframe spaces, collisions, and retransmissions are an intrinsic part of the CSMA/CA channel access scheme, but they significantly decrease the effective time that a node spends transmitting data every time it accesses the channel. IEEE 802.11ax-2019 may include several solutions to mitigate such overheads.

Control Packets: The time consumed by the exchange of control packets may result in large overheads, particularly because they are usually transmitted at a low rate. Common control packet exchanges between the AP and STAs include the request to send/clear to send (RTS/CTS) exchange to avoid hidden nodes and ACKs to acknowledge the reception of data packets.

Additionally, some of the new technical features described in the next sections that enable multi-user transmissions may require frequent exchange of control packets to synchronize all involved STAs, hence also increasing the control packets' overheads.

Packet Headers, Aggregation, and Piggy-Backing: Packet aggregation was introduced in IEEE 802.11n-2009 to reduce temporal overheads by combining short packets into a longer one. Using packet aggregation, multiple packets can be transmitted with a single backoff, distributed inter-frame space (DIFS), short inter-frame space (SIFS), PHY header, and ACK.

The packet header overheads can be reduced by supporting variable size headers and using only the minimum required fields for every packet. Additionally, the use of shorter identifiers instead of the full MAC address is considered.

Moreover, the piggybacking of ACKs with DATA will improve the efficiency, although some changes in the current setting of the network allocation vector (NAV) are required because the full transmission duration is unknown to the transmission initiator.

Efficient Retransmissions: Packet errors are also a source of overhead because they currently require full retransmission of the data packet. Further work about the use of incremental redundancy-based automatic repeat requests (ARQs) can reduce the time spent in retransmissions, although it implies some extra complexity in both transmitter and receiver firmware.

Simultaneous Transmit and Receive: By allowing the AP and a STA to simultaneously transmit and receive (STR), which is commonly known as full-duplex communication, the channel capacity can be theoretically doubled [8]. Using CSMA/CA, the only way they can have full-duplex communication is if they finish their backoff countdown simultaneously. Otherwise, one will start transmitting before the other, causing the latter to pause its backoff until the former finishes its transmission. Only when the number of active STAs is low do they have bidirectional and saturated traffic flows, and use a small backoff contention window; here, the use of STR can result in significant gains. Therefore, specific channel access mechanisms should be considered in the IEEE 802.11ax-2019 amendment in case the STR capability is finally considered. Alternatively, the STR capability can allow WLANs to replace the CA feature of CSMA/CA with collision detection (CD), because collisions can be promptly detected and resolved.

Collision-Free MAC Protocols: Collisions represent an important waste of channel resources

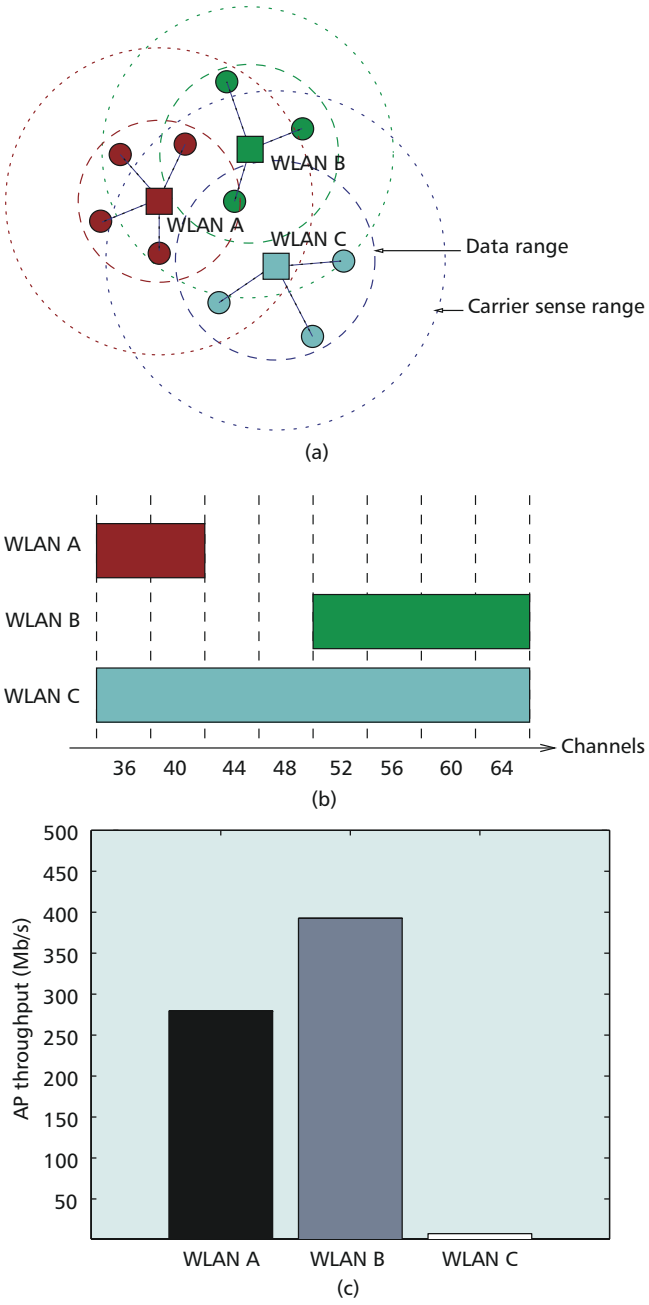


Figure 2. Throughput unfairness between overlapping WLANs: a) three overlapping WLANs; b) channel used by each WLAN; c) throughput achieved by each WLAN.

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An unplanned deployment of WLANs results in chaotic and fragmented spectrum occupancy, which causes many inefficiencies and undesirable interactions among neighboring WLANs. To improve the spectrum usage efficiency, two main approaches can be considered in IEEE 802.11ax-2019: dynamic channel bonding and OFDMA.

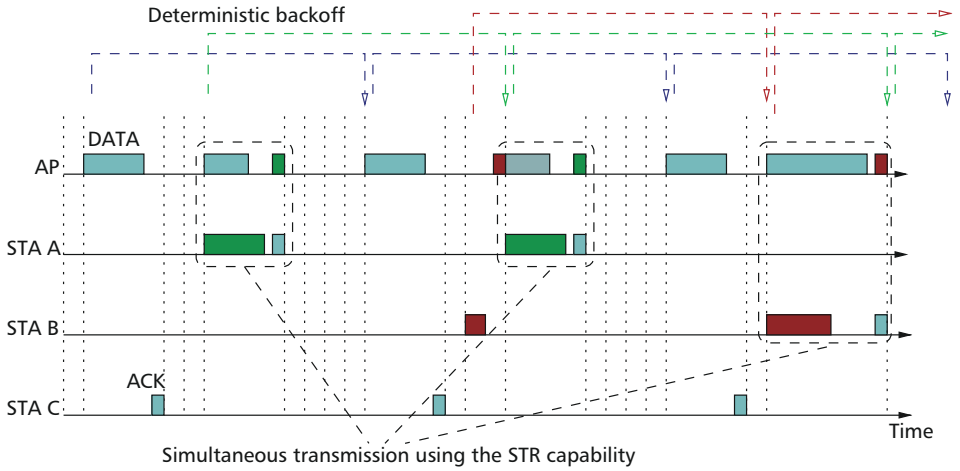


Figure 3. CSMA/ECA operation. It can be observed how the use of a deterministic backoff allows prediction of when a node will transmit again after successful transmission.

in WLANs. IEEE 802.11ax-2019 may consider enhancing or changing the underlying CSMA/CA protocol to minimize collisions. There are two possibilities: moving to a centralized solution or enhancing the current CSMA/CA protocol. Because centralized options such as hybrid coordination function controlled channel access (HCCA) were never adopted in WLANs, a focus on enhancing CSMA/CA appears more plausible. CSMA with enhanced CA (CSMA/ECA) is a particularly good candidate to replace CSMA/CA because it is backward compatible, is easily implemented, and outperforms CSMA/CA in all cases [9].

Figure 3 shows the basic operation of CSMA/ECA with STR. Compared to CSMA/CA, the main difference observed for CSMA/ECA is its use of a deterministic backoff after successful transmissions. This deterministic backoff guarantees that after some time, a collision-free schedule can be achieved. In addition, because the AP can learn when the STAs will transmit, the use of STR can provide huge performance gains.

Spectrum Sharing

An unplanned deployment of WLANs results in a chaotic and fragmented spectrum occupancy, which causes many inefficiencies and undesirable interactions among neighboring WLANs [6]. To improve the spectrum usage efficiency, two main approaches can be considered in IEEE 802.11ax-2019: dynamic channel bonding and OFDMA.

Dynamic Channel Bonding: To adapt to the instantaneous channel occupancy, IEEE 802.11ax-2019 may consider extending the dynamic bandwidth channel access (DBCA) scheme introduced in the IEEE 802.11ac-2013 amendment [10]. Using DBCA, only the available channel width is used at each transmission, which allows WLANs to adapt to the instantaneous spectrum occupancy. This mechanism helps fill most spectrum gaps and share them fairly among neighboring WLANs.

OFDMA: The use of orthogonal frequency-division multiple access (OFDMA) adds a new degree of flexibility to the use of spectrum resources by dividing the channel width into multiple narrow channels. Then these narrow channels can be used to transmit to multiple users in parallel [11]. A basic implementation of OFDMA in WLANs may simply consider the use of multiple independent 20 MHz channels. This approach is shown in Fig. 4: when channel bonding is used, each 20 MHz subchannel can be independently allocated to a different user. The RTS packet has been extended to announce the subchannels allocation to the STAs. Additionally, OFDMA may enable the use of non-contiguous channel bonding and remove the requirement to use only 20 MHz consecutive channels.

Figure 4a shows an example where dynamic channel bonding and OFDMA operate together. The upper part of Fig. 4a shows a snapshot of the spectrum occupancy for a group of neighboring WLANs. The lower part of Fig. 4a shows two transmissions: a node in the target WLAN transmits to a single user via a bonded channel of 40 MHz (left), and a node uses a bonded channel of 80 MHz and OFDMA to transmit to three different users (right). Figure 4b shows the AP throughput when OFDMA is used to split a 160 MHz channel into multiple subchannels. The parallelization of temporal overheads clearly improves the throughput.

Multiple Antennas

Spatial multiplexing using multiple antennas at both APs and STAs remains one of the key technologies to achieve high throughput in WLANs. IEEE 802.11ax-2019 will continue implementing both SU-MIMO and downlink MU-MIMO, as in IEEE 802.11ac-2013. However, it may also include or provide support for uplink MU-MIMO, massive MIMO, and network MIMO, as well as distributed antenna solutions.

Multi-User MIMO: Multi-user MIMO enables multiple simultaneous transmissions to different STAs from the AP in the downlink, and from multiple STAs to the AP in the uplink. A survey of MU-MIMO MAC protocols for WLANs is presented in [12], where the challenges and requirements to design an MU-MIMO MAC

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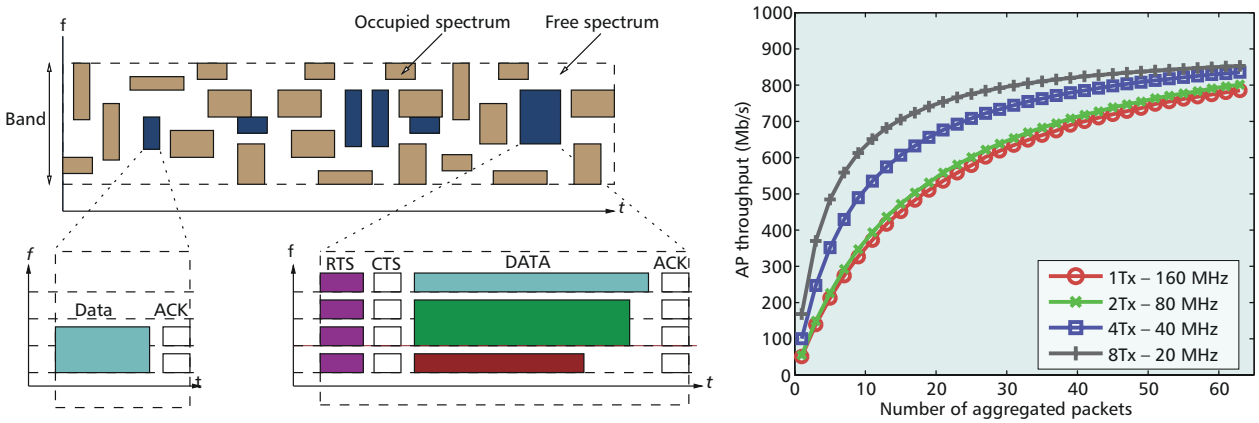


Figure 4. Dynamic spectrum access with and without OFDMA: a) dynamic channel bonding and OFDMA; b) achievable downlink throughput using a channel width of 160 MHz and OFDMA. The RTS size is $120 + 56 \cdot N_{tx}$ bits, with N_{tx} the number of OFDMA subchannels.

protocol are introduced, and several uplink and downlink MAC proposals are reviewed.

In the downlink, a challenge for IEEE 802.11ax-2019 is to reduce the channel sounding overheads given the same explicit approach as in IEEE 802.11ac-2013 is considered. The overhead caused by the explicit channel sounding protocol implemented depends on the channel sounding rate and number of sounded STAs, which can result in an unacceptable overhead in scenarios with many STAs. Solutions to reduce such a large overhead, apart from replacing the current channel sounding protocol with a more efficient solution, will require the use of smart schedulers that consider the current traffic patterns and the quality of service (QoS) demands of users to decide when the channel state information (CSI) has to be requested, and from which STAs.

To support MU-MIMO transmissions in the uplink, IEEE 802.11ax-2019 must also detail how the uplink CSI from each STA is obtained by the AP, introduce a mechanism to signal a group of STAs to simultaneously start a transmission, and include techniques to overcome channel calibration and timing issues in order to efficiently decode all the simultaneously received packets at the AP.

In both cases, using the collected CSI, the AP has to select the specific STAs that will take part in the next MU-MIMO transmission. Therefore, the design of an efficient mechanism to create groups of STAs with low spatial channel correlation and similar channel quality is still an open challenge. Failing to properly create those groups may prevent next-generation WLANs from fully benefiting from MU-MIMO technology.

Figure 5a shows an AP with three STAs. On the left, we have three downlink MU-MIMO transmissions. The ones directed to STAs A, B, and C contain four, two, and one SU-MIMO spatial streams, respectively. To start a downlink transmission, the AP omnidirectionally sends the PHY header with information about the group of selected STAs and the number of spatial streams that are transmitted to each STA in SU-MIMO mode. On the right, we show an uplink MU-MIMO transmission. In IEEE 802.11ax-2019, because several STAs are unlikely to finish their backoff countdowns at the same time, uplink MU-MIMO transmissions may be started by the AP using a special RTS″ packet containing information about the STAs that can transmit in parallel. Then the selected STAs will simply start transmitting at the same time and wait to receive the corresponding ACKs. This approach allows all selected STAs to be synchronized, but requires knowledge of the STAs's buffer occupancy by the AP, which can be provided by the same STAs as in previous transmissions. Figure 5b shows the throughput achieved by the AP in two downlink MU-MIMO configurations (cases 16:4:4 and 16:16:1). The obtained throughput values are compared with the case where a single spatial stream is transmitted to only one destination (case 1:1:1).

Massive MIMO: Massive MIMO refers to the case where the AP has many more antennas than STAs and uses them to create a nearly identical number of point-to-point links as the number of active STAs [13]. In addition to the cost of APs, the extra processing complexity, and higher energy consumption, other open challenges for massive MIMO include obtaining the CSI information; WLANs may require switching to an implicit channel feedback approach.

Network MIMO: In coordinated WLAN deployments, network MIMO can be used to minimize the interference among simultaneous transmissions from different APs. The idea behind network MIMO is that different APs can coordinate the transmissions as if they were a large array of antennas, which reduces the inter-transmission interference and increases the spatial reuse [14]. However, effectively solving the tight synchronization requirements among the APs remains an open challenge.

WLAN-Level Improvements

The user experience in next-generation WLANs will not be simply enhanced by increasing the achievable network and user throughput as previous technical features do. To achieve that goal, apart from the IEEE 802.11ax-2019 amendment, there are other IEEE 802.11 amendments in progress. Figure 6 shows the most significant ones, including the new features they are targeting.

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To achieve that goal, apart from the IEEE 802.11ax-2019 amendment, there are other IEEE 802.11 amendments in progress.

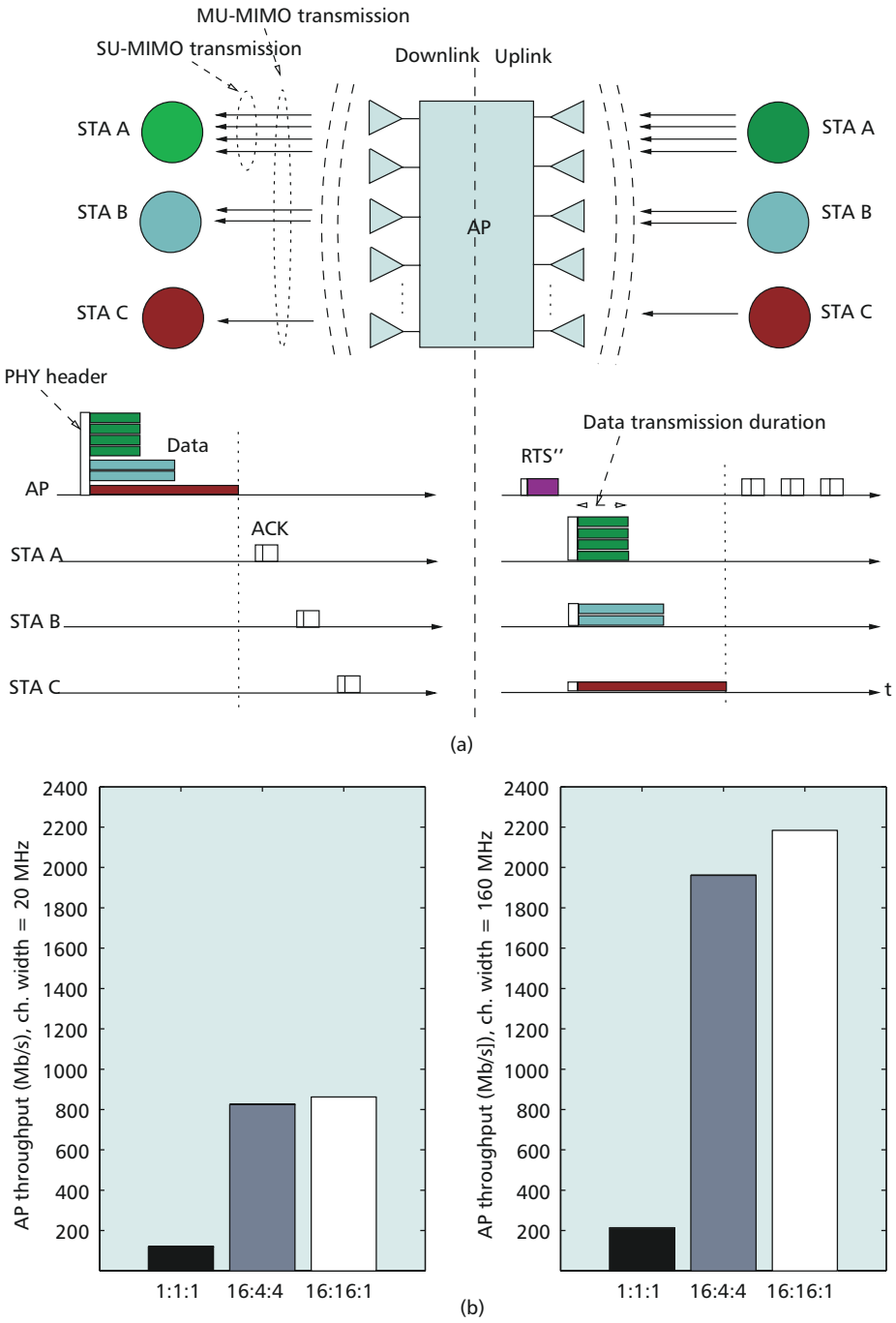
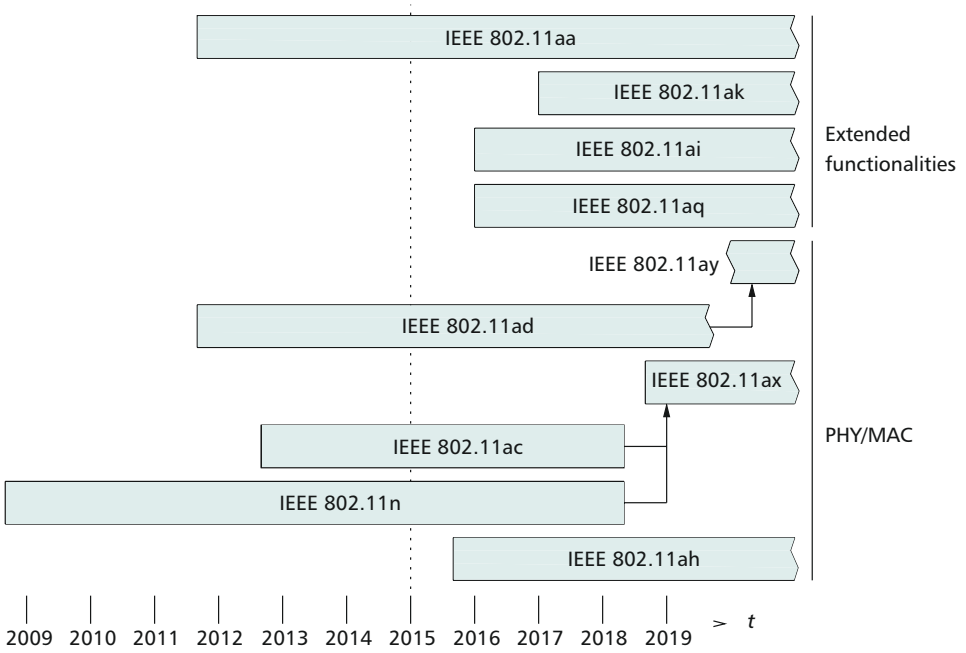


Figure 5. Multi-user spatial multiplexing: a) downlink and uplink MU-MIMO transmissions in WLANs; b) downlink throughput. The AP is equipped with 16 antennas. Each configuration is identified by the code x:y:z, where x refers to the total number of transmitted spatial streams, y the number of destinations, and z the number of streams transmitted to each destination.

In scenarios where multiple APs are used to offer a large coverage area and higher data rates by deploying multiple WLANs nearby, a mechanism that enables fast handoff among the APs is required because the current large delays when a STA switches to a new AP are unacceptable. The IEEE 802.11ai-2016 amendment targets this challenge. It aims to provide a handoff duration below 100 ms by implementing preemptive channel sensing and user authentication. Alternatives based on network virtualization and software defined networks are also an interesting option as they are able to centralize all decisions, including the handoff between overlapping APs. Future IEEE amendments will probably consider such an approach.

Device-to-device (D2D) communications, which are also known as WiFi Direct in the IEEE WLAN context, will also be a key element in next-generation WLANs [15]. Examples of D2D communications are file synchronization

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Feature	Amendment	Objective
Fast handoff between APs	IEEE 802.11ai-2016	Handoff duration below 100 ms by implementing preemptive channel sensing and user authentication.
D2D/WiFi Direct	WiFi Alliance feature	STAs with D2D capability can decide to create their own WLAN to communicate directly.
Multi-technology APs and bridging capabilities	IEEE 802.11ak-2017	Interconnection of multiple WLANs.
Video traffic differentiation	IEEE 8v02.11aa-2012	Stream prioritization and groupcast mechanisms.
AP/service selection	IEEE 802.11aq-2018	APs provide pre-association information about the services offered to help STAs to choose between multiple APs

Figure 6. Upcoming IEEE 802.11 amendments.

with an external hard disk and instantaneous file exchange between a mobile phone and a projector/smart television. The use of D2D communications will reduce the amount of airtime required for each transmission by allowing higher data rates and avoiding the use of the AP as a relay. Beamforming is an interesting feature for D2D communication because it may allow concurrent transmissions inside the same WLAN by different groups of nodes.

IEEE 802.11ax-2019 aims to operate in the 2.4 and 5 GHz bands by superseding and integrating the IEEE 802.11n-2009 and IEEE 802.11ac-2013 amendments. In a few years, every single AP will most likely implement two IEEE 802.11ax-2019 instances that independently operate at 2.4 and 5 GHz, with a IEEE 802.11ah-2016 instance at 1 GHz for M2M and long-range communications, and one IEEE 802.11ad-2012 (or the future IEEE 802.11ay-202x) at 60 GHz for very fast millimeter-wave communications. In this situation, the STAs of any of those networks should be able to communicate with the STAs in any of the other WLANs. This is the aim of the IEEE 802.11ak-2017 amendment, which focuses on adding bridging capabilities to WLANs.

Finally, next-generation WLANs will use traffic differentiation, flow admission control, and groupcast mechanisms from the IEEE 802.11e-2007, IEEE 802.11ae-2012 and IEEE 802.11aa-2012 amendments to support multimedia traffic with the required QoS. Also, further advances in power saving mechanisms are expected to keep WLAN energy consumption as low as possible.

Conclusion

We have reviewed some technological options that could be included in the IEEE 802.11ax-2019 amendment for next-generation WLANs. Individually, all those solutions offer some per-

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In addition to the higher achievable throughput provided by IEEE 802.11ax-2019 PHY/MAC features, we believe that the most disruptive performance and user experience improvements in next-generation WLANs will also be related to the development and implementation of the other recently approved or ongoing amendments.

formance gains by improving the spatial reuse and spectrum utilization. However, the analysis of the actual performance gains when several of those solutions are combined and used simultaneously is still an open challenge requiring significant research efforts in the next years. For instance, for a given transmission power, multiplexing different users in a single transmission using channel bonding and spatial multiplexing reduces the received power per Hertz and user, which may require the selection of lower-order modulation schemes and coding rates, and the theoretical gain in throughput obtained by the combined use of spatial multiplexing and channel bonding may be lost by the larger transmission delay.

Finally, in addition to the higher achievable throughput provided by IEEE 802.11ax-2019 PHY/MAC features, we believe that the most disruptive performance and user experience improvements in next-generation WLANs will also be related to the development and implementation of the other recently approved or ongoing amendments, and by developing efficient and smart mechanisms to improve the coexistence and cooperation among WLANs.

Acknowledgments

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Biography

Boris Bellalta is an associate professor in the Deparment of Information and Communication Technologies at University Pompeu Fabra (UPF), where he leads the Wireless Networking research group. He obtained his degree in telecommunications engineering from Universitat Politecnica de Catalunya in 2002 and his Ph.D. in information and communication technologies from UPF in 2007. His research interests are in the area of wireless networks, with emphasis on the design and performance evaluation of PHY/MAC protocols and network architectures.

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APPENDIX Q



Edward Au

Exciting Projects for PHY and MAC Layers of IEEE 802.11

The first few widely accepted amendments to IEEE 802.11 [1] wireless networking specifications, namely IEEE 802.11a, IEEE 802.11b, and IEEE 802.11g, featured relatively low spectral efficiencies and data rates. Driven by technological advances in signal processing and communications theory, sustained improvement in spectral efficiency, coverage, and quality of service has been achieved in IEEE 802.11n and IEEE 802.11ac [2]. Particularly, progressive system improvement is achieved by the successive introduction of novel techniques, including orthogonal frequency division multiplexing (OFDM) and multiple-input, multiple-output (MIMO) antenna techniques. Some advanced transmission techniques, especially multiuser (MU)-MIMO and transmit beamforming, have also helped to boost the performance of Wi-Fi to gigabit-per-second speed, and they have led to the current state of the art, namely IEEE 802.11ac in 2.4- and 5-GHz bands, and IEEE 802.11ad in the 60-GHz frequency band [3].

In this column, I would like to share with you a few interesting and exciting projects related to both the physical (PHY) layer and the media access (MAC) layer of wireless local area networks (WLANs), which are developed in IEEE 802.11 Working Group under the management of the IEEE 802 LAN/MAN Standards Committee.

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IEEE 802.11ah

Existing IEEE 802.11 technologies are now being used by Internet of Things (IoT) applications that may require lower power consumption and/or extended transmission range with limited throughput, such as backhaul sensor and meter data, home automation, and wearable devices. IEEE 802.11ah is a new amendment in IEEE 802.11 [4] that has dedicated MAC and PHY features for these kinds of IoT applications. Specifically, IEEE 802.11ah targets a sub-1-GHz frequency band that enables extended transmission range with respect to the existing IEEE 802.11 technologies operating in 2.4- and 5-GHz frequency bands. As per the task group's project authorization request [5], it aims to define a standardized modification to OFDM MAC and PHY operating in the license-exempt bands below 1 GHz with a transmission range of up to 1 km and data rates of 100 kb/s and beyond.

With respect to the existing IEEE 802.11 amendments, IEEE 802.11ah can be considered as an evolution of IEEE 802.11 MAC and PHY but with dedicated enhancement for a sub-1-GHz frequency band, which includes optimization for highly robust links and low-power consumption required for battery-operated devices and the support of a larger number of devices per access point. In particular, IEEE 802.11ah OFDM PHY features not only the fast Fourier transform size of 64, but also a smaller one of 32. To accommodate outdoor operation and to work with a larger delay spread, a new reliable modulation and coding scheme (MCS), namely MSC10, is also proposed. As for the channel bandwidth, there are a few options other than the minimum channel bandwidth of 20 MHz used in IEEE 802.11n and IEEE 802.11ac. Specifically, 1- and 2-MHz channel bandwidths are mandatory and globally interoperable modes optimized for sensor networking, while 4-, 8-, and 16-MHz channel bandwidths are optional higher data-rate modes for extended range. For IEEE 802.11ah MAC, it would support up to 8,191 devices per access point by introducing a restricted access window operation and hierarchical traffic indication map structure. Furthermore, it considers efficient frame transmission

DRIVEN BY TECHNOLOGICAL ADVANCES IN SIGNAL PROCESSING AND COMMUNICATIONS THEORY, SUSTAINED IMPROVEMENT IN SPECTRAL EFFICIENCY, COVERAGE, AND QUALITY OF SERVICE HAS BEEN ACHIEVED IN IEEE 802.11N AND IEEE 802.11AC.

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In particular, both single user MIMO and downlink MU-MIMO are proposed for maximizing throughput and allowing the distribution of capacity to multiple nonaccess point/nonpriority code point stations, respectively.

by incorporating short control and management frames together with asymmetric and bidirectional transmission. A target wake-time mechanism and an extended sleeping and listen internal are also introduced for the purpose of reducing power consumption. To further extend the transmission range, relay operation is also introduced.

As for the progress of amendment development, IEEE 802.11ah is currently working toward a completion of resolution of comments received from the initial sponsor ballot on version 7.0 of the draft amendment. The target completion date is August 2016.

IEEE 802.11ax

IEEE 802.11ax represents the next major generation of Wi-Fi technology evolution after IEEE 802.11a, IEEE 802.11g, IEEE 802.11n, and IEEE 802.11ac. While the former amendments focus mainly on improvement in maximum throughput of a station measured at an MAC data service access point, IEEE 802.11ax started its activity [6] to consider improving the spectrum efficiency and system throughput per area in high-density scenarios of access points and stations in both indoor and outdoor deployments, such as crowded public spaces, public transportation, and dense apartment buildings. As per the task group's project authorization request [7], it aims to achieve improvement at least four times the average throughput per station measured at the MAC data service access point in a dense deployment scenario, while maintaining or improving power efficiency per station between 1- and 6-GHz frequency bands that will improve performance in dense deployment scenarios. Furthermore, backward compatibility and coexistence with legacy IEEE 802.11 devices operating in the same frequency band are also required.

With respect to the current state-of-the-art IEEE 802.11ac, the task group is currently discussing a large variety of technical proposals on different features with the aim to fulfill the aforementioned requirements. For example, while downlink MU-MIMO and 256 quadrature amplitude modulation (QAM) are adopted in IEEE 802.11ac, uplink MU-MIMO and 1024 QAM are now considered in IEEE 802.11ax for the purpose of improving throughput upstream and boosting the maximum throughput further, respectively. Furthermore, OFDM access is proposed for both the uplink and the downlink for extending transmission range and reducing system overhead, respectively. In a realistic deployment of a Wi-Fi network, there are always a lot of interfering sources, and the access points are always heavily loaded. To tackle these problems, MCS0 with twice repetition is introduced to increase robustness to interference, and spatial reuse is proposed to increase multiple basic service set support system capacity so as to enhance medium reuse. Lastly, there are also a number of proposals for the improvement of MAC control signaling with the aim to improve the efficiency of operation while reducing power consumption.

As for the progress of amendment development, IEEE 802.11ax is now working on version 1.0 of the draft amendment, which is expected to be ready for letter ballot in July 2016. The target completion date of this program is March 2019.

IEEE 802.11ay

IEEE 802.11ay [8] is considered an extension of IEEE 802.11ad with the aim to further improve the maximum throughput per station measured at the MAC data service access point. While the maximum throughput achieved by IEEE 802.11ad is about 4.7 and 6.9 Gb/s when single-carrier and OFDM modes are respectively implemented, IEEE 802.11ay aims to define modifications for both the IEEE 802.11 PHY and MAC layers that enable at least one mode of operation that is capable of supporting a maximum throughput of at least 20 Gb/s measured at the MAC data service access point while maintaining or improving the power efficiency per station. One of the main reasons this new project is needed is the increasing demand for capacity for not only existing applications of IEEE 802.11ad (e.g., docking) but also new usage scenarios and applications, including crowded public spaces, data centers, and fronthaul and backhaul communication. As per the task group's project authorization request [9], this amendment also defines operations for license-exempt bands above 45 GHz while ensuring backward compatibility and coexistence with legacy directional multigigabit stations (defined by the IEEE 802.11ad 2012 amendment) operating in the same band.

With respect to IEEE 802.11ad, IEEE 802.11ay just starts to discuss many technical proposals on different features with the aim to fulfill all the aforementioned requirements. In particular, both single user MIMO and downlink MU-MIMO are proposed for maximizing throughput and allowing the distribution of capacity to multiple nonaccess point/nonpersonal basic service set control point stations, respectively. Channel bonding of at least two 2.16-GHz channels as well as contiguous and noncontiguous channel aggregation of at least two 2.16-GHz channels are also proposed as two key technologies to meet the throughput requirement for a majority of the usage scenarios considered by the task

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MCS0 WITH TWICE REPETITION IS INTRODUCED TO INCREASE ROBUSTNESS TO INTERFERENCE, AND SPATIAL REUSE IS PROPOSED TO INCREASE MULTIPLE BASIC SERVICE SET SUPPORT SYSTEM CAPACITY SO AS TO ENHANCE MEDIUM REUSE.

group. Furthermore, IEEE 802.11ay is also discussing a few proposals on MIMO channel access and beamforming protocols that would potentially utilize antenna pattern reciprocity to allow for multiple devices to perform beamforming training simultaneously. As for the time line of amendment development, IEEE 802.11ay is currently working on a few task group documents, including functional requirements, channel model, and evaluation methodology. Furthermore, the task group is now working on an initial version of the draft amendment, which is expected to go for a letter ballot in May 2017. The target completion date is December 2019.

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PRESIDENT'S MESSAGE

(continued from page 4)

need more volunteers to maintain and expand our level of activities. Volunteers can participate in our technical committees, publications, conferences, etc. VTS has a dedicated section on our web portal to disseminate volunteer positions. Please have a look and get in touch with us if you would like to participate in VTS whether your interests are reflected or not in the current list of open volunteer positions. We need volunteers from all our fields of interest: automotive electronics and motor vehicles, land transportation and railways, and mobile radio.

Chapters provide a good opportunity to volunteer and engage with the Society at the local level. You can find the list of VTS Chapters on our web portal together with the contact details of our Chapters' chair, Pawel Dmochowski. If you do not have a Chapter in your country or region but would like to form one, get in touch with Pawel. One of the many advantages of belonging to a VTS Chapter is that it gives you access to our Distinguished Lecturers program, one of the largest within the IEEE.

Our Distinguished Lecturers are internationally recognized technical experts and leaders. It is important that we all recognize the efforts, impact, and leadership of our members and volunteers, and VTS has several awards to do so. The information on the VTS awards can, again, be found in our portal. Please, do not hesitate to contact our awards chair, David Haccoun, if you would like to nominate a colleague. You might also want to recognize a colleague by nominating him or her for the possibility to be elevated to IEEE Fellow. If this is the case, please contact Gordon Stüber, the chair of the Fellows committee, to get more information on the timing and process to submit your nomination through VTS.

2016 is certainly going to be an exciting year for VTS and for me, and I hope we will provide the level and quality of service that you expect from your Society. It is important that you let us know, electronically or personally at one of our VTS meetings, how we are doing and how we can improve further our value and level of service. I would like to finish this message thanking all our members and the VTS board of governors for giving me the honor to serve the VTS members as 2016 president.

VT

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APPENDIX R

OFFICIAL IEEE 802.11 WORKING GROUP PROJECT TIMELINES - 2025-04-23

IN PROCESS - Standards, Amendments, and Recommended Practices

IEEE Project and Final Document	Final Doc Type	Project Authorization Request (PAR)	Task Group and Activity	Documentation: Session End Snapshot Format & Version	Documentation: Session End Snapshot Incorporated Baselines	Current Status	PAR Approved, Modified, or Extended [Expires]	WG Letter Ballots: Draft Predicted Initial	WG Letter Ballots: Date Predicted Recirc	WG Letter Ballots: Result	Form Standards Association (SA) Ballot Pool / Reform	MEC / MDR Done	IEEE SA Ballots: Draft Predicted Initial	IEEE SA Ballots: Date Predicted Recirc	IEEE SA Ballots: Result	Final 802.11 WG Approval	Final or Conditional 802 LMSC Approval	RevCom & Standards Board Final or Continuous Process Approval	ANSI Approved	Sup Wit Sta E
IEEE Std P802.11bq	A	Integrated Millimeter Wave	TGbq		802.11-2020 802.11ax-2021 802.11ay-2021 802.11ba-2021 802.11-2020/Cor1-2022 802.11az-2022 802.11bd-2022 802.11bb-2023 802.11bc-2023 802.11-2020/Cor2-2024 802.11me 802.11bh 802.11be 802.11bk 802.11bf 802.11bi 802.11mf 802.11bn 802.11bp	Actual	2024-12-11													
						Predicted	C												N/A	
IEEE Std P802.11mf	A	802.11 Accumulated Maintenance Changes	TGmf		802.11-2020 802.11ax-2021 802.11ay-2021 802.11ba-2021 802.11-2020/Cor1-2022 802.11az-2022 802.11bd-2022 802.11bb-2023 802.11bc-2023 802.11-2020/Cor2-2024 802.11me 802.11bh 802.11be 802.11bk 802.11bf 802.11bi	Actual	2024-11-12													
						Predicted	C	May 2025	Jan 2026		Oct 2026	Oct 2026	Jan 2027	Jul 2027		Nov 2027	Nov 2027	Feb 2028	N/A	
IEEE Std P802.11bp	A	Ambient Power Communication	TGbp		802.11-2020 802.11ax-2021 802.11ay-2021 802.11ba-2021 802.11-2020/Cor1-2022 802.11az-2022 802.11bd-2022 802.11bb-2023 802.11bc-2023 802.11-2020/Cor2-2024 802.11me 802.11bh 802.11be 802.11bk 802.11bf 802.11bi 802.11mf 802.11bn	Actual	2024-03-19 [2028-12-31]													
						Predicted	C	Feb 2026	Nov 2026		Mar 2027	Oct 2027	Aug 2027	Oct 2027		Jan 2028	Mar 2028	May 2028	N/A	
IEEE Std P802.11bn	A	Ultra High Reliability	TGbn	D0.20	802.11-2020 802.11ax-2021 802.11ay-2021 802.11ba-2021 802.11-2020/Cor1-2022 802.11az-2022 802.11bd-2022 802.11bb-2023 802.11bc-2023 802.11-2020/Cor2-2024 802.11me 802.11bh 802.11be 802.11bk 802.11bf 802.11bi 802.11mf	Actual	2023-09-21 [2027-12-31]													
						Predicted	C	May 2025	May 2026		Mar 2027	May 2027	May 2027	Jul 2027		Mar 2028	Mar 2028	May 2028	N/A	
IEEE Std P802.11bk	A	320 MHz Positioning	TGbk	PDF D5.00	802.11-2020 802.11ax-2021 802.11ay-2021 802.11ba-2021 802.11-2020/Cor1-2022 802.11az-2022 802.11bd-	Actual	2022-12-03	D1.0 D2.0 D3.0	2023-12-28 2024-04-26 2024-08-15	95% 97% 98%	2024-05-01	2024-06-01	D3.0 D4.0 D5.0	2024-11-10 2025-02-07 2025-03-30	94% 97% 98%	2025-03-12	2025-03-14			