- 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).

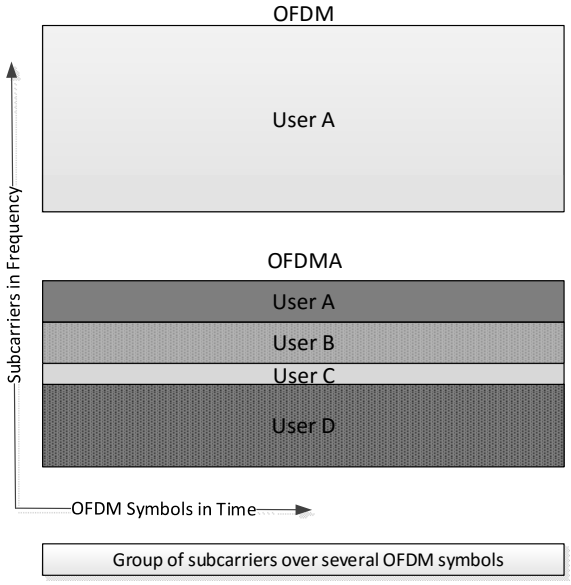


Figure 26-1—Illustration of OFDM and OFDMA concepts

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)

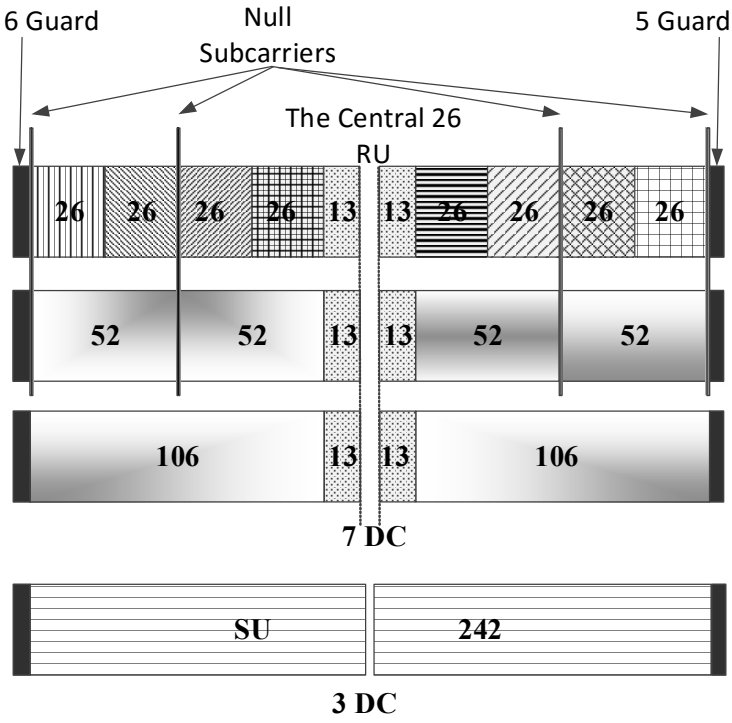


Figure 26-2—RU locations in a 20 MHz HE PPDU

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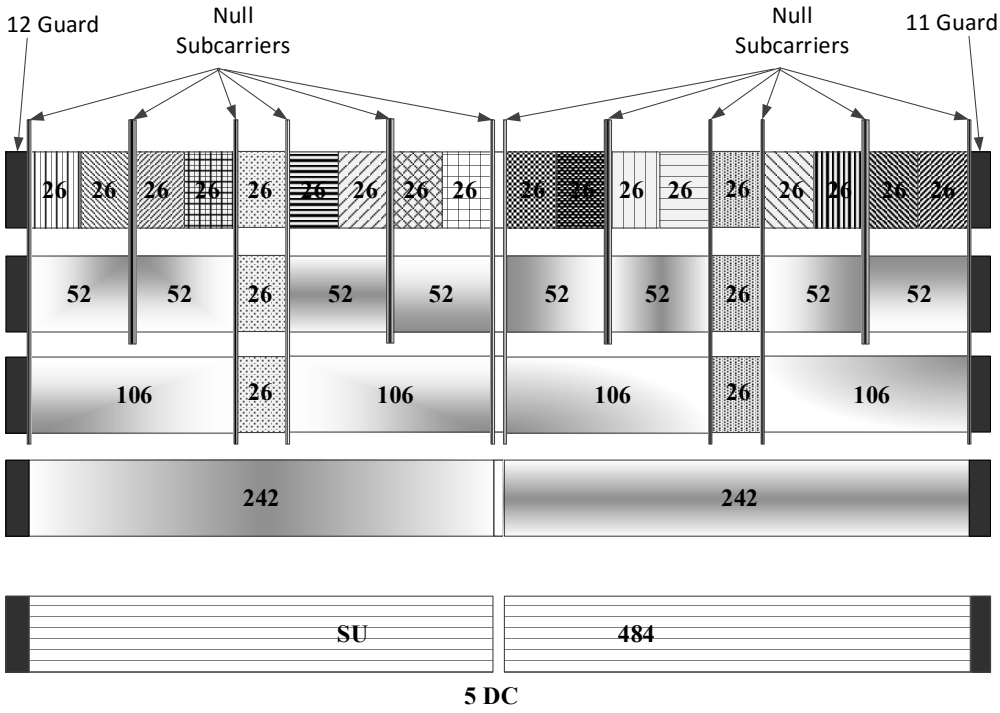


Figure 26-3—RU locations in a 40 MHz HE PPDU

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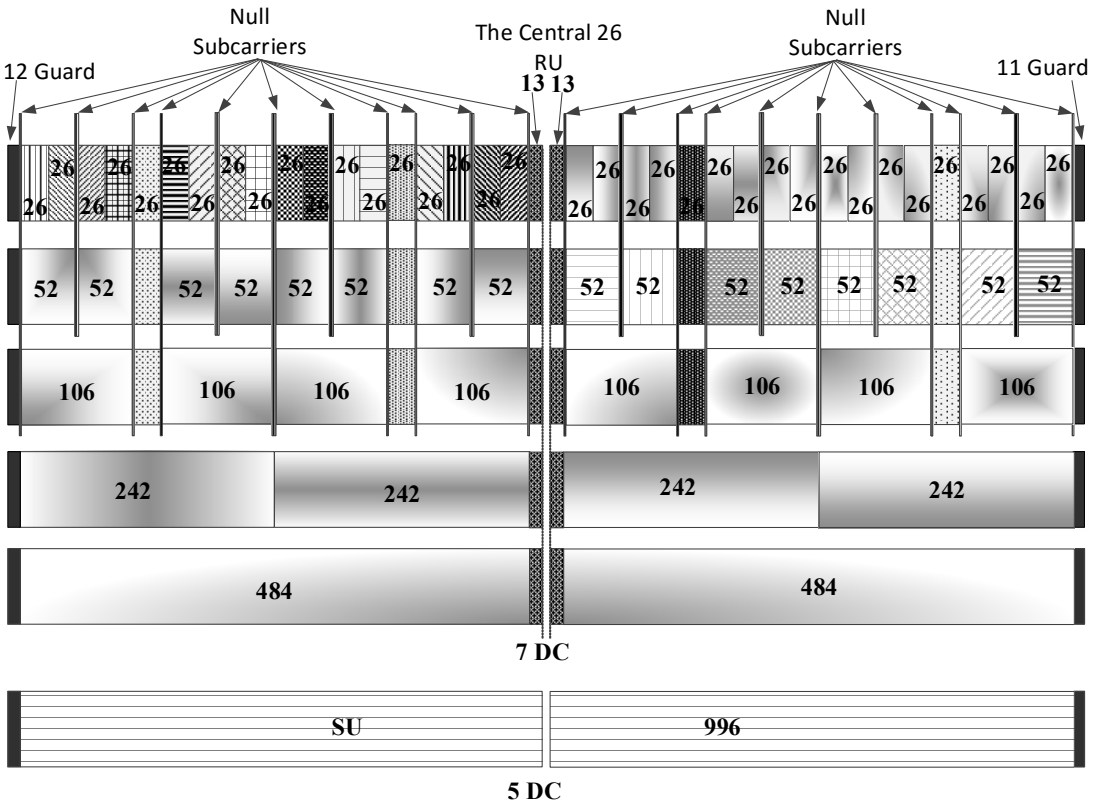


Figure 26-4—RU locations in an 80 MHz HE PPDU

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).

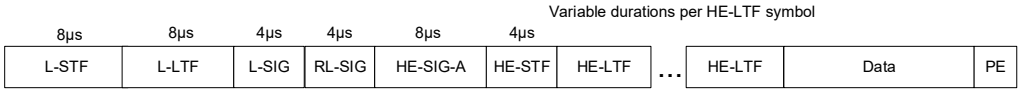


Figure 26-5—HE SU PPDU format

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)

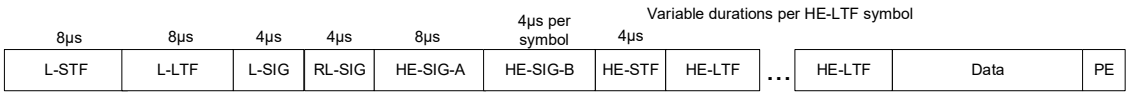


Figure 26-6—HE MU PPDU format

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.

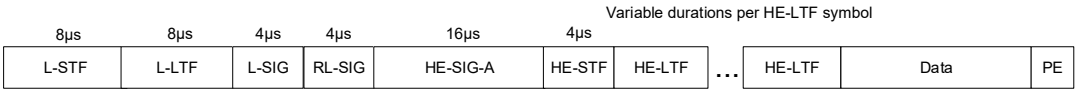


Figure 26-7—HE extended range SU PPDU format

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)

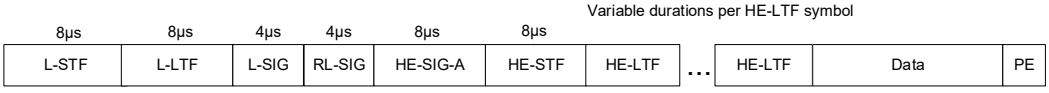


Figure 26-8—HE trigger-based PPDU format

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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.

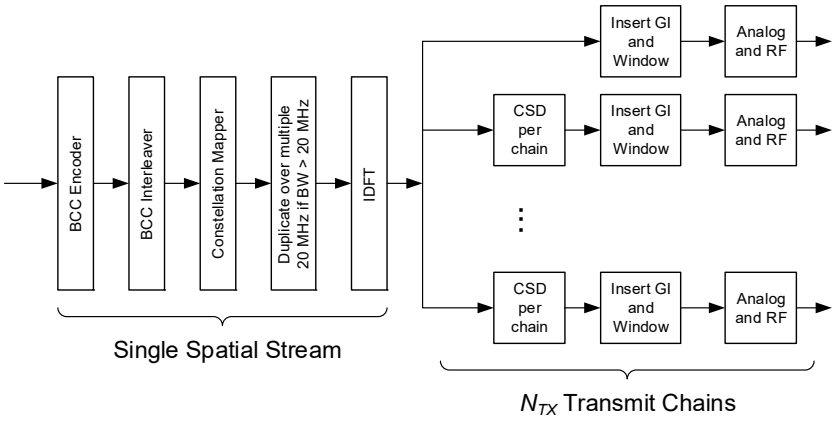


Figure 26-9—Transmitter block diagram for the L-SIG, RL-SIG and HE-SIG-A fields for an HE SU PPDU and HE extended range SU PPDU when the Beam Change field is 1 and the HE MU PPDU(#1659)

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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.

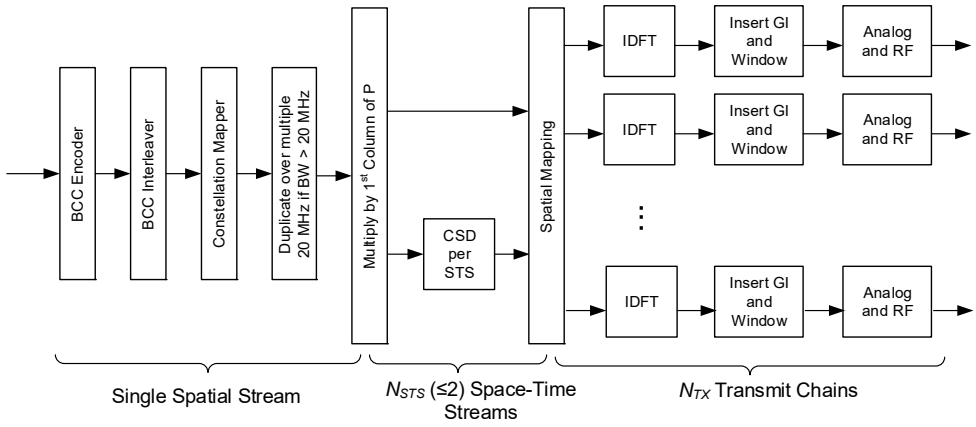


Figure 26-10—Transmitter block diagram for the L-SIG, RL-SIG and HE-SIG-A fields for an HE SU PPDU and HE extended range SU PPDU when the Beam Change field is 0(#2360)(#1659)

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)

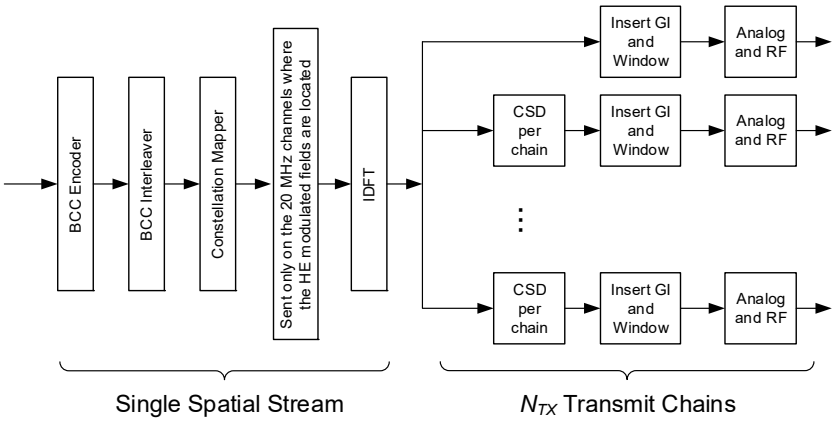


Figure 26-11—Transmitter block diagram for the L-SIG, RL-SIG and HE-SIG-A fields of an HE trigger-based PPDU(#1659)

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)

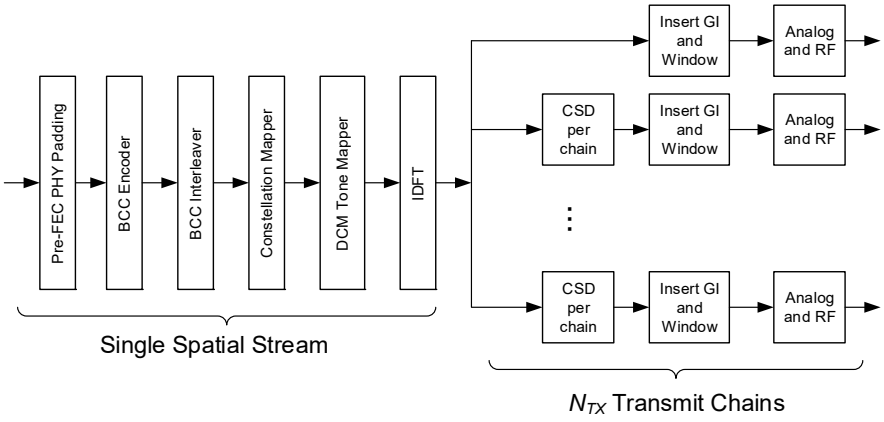


Figure 26-12—Transmitter block diagram for the HE-SIG-B field

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.

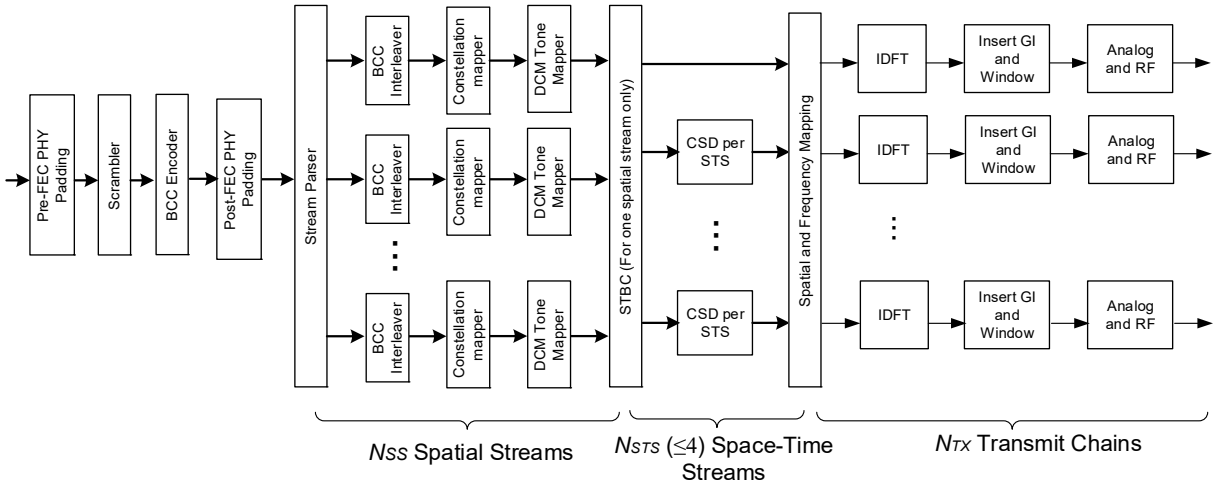


Figure 26-13—Transmitter block diagram for the Data field of an HE SU transmission in a 26-, 52-, 106- or 242-tone RU(#838) with BCC encoding

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.

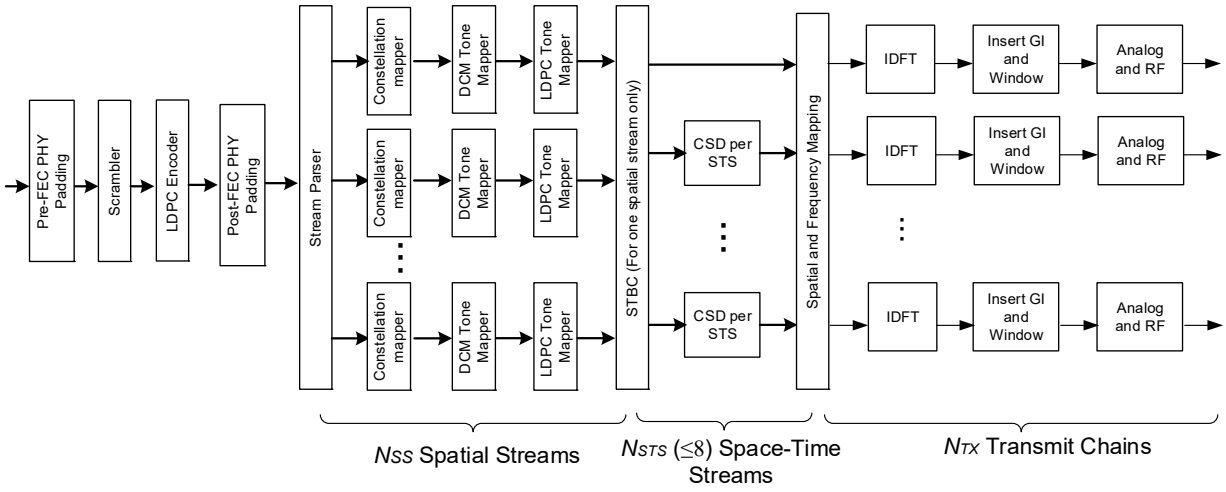


Figure 26-14—Transmitter block diagram for the Data field of an HE SU transmission in 26-, 52-, 106-, 242-, 484- or 996-tone(#838) RU with LDPC encoding

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.

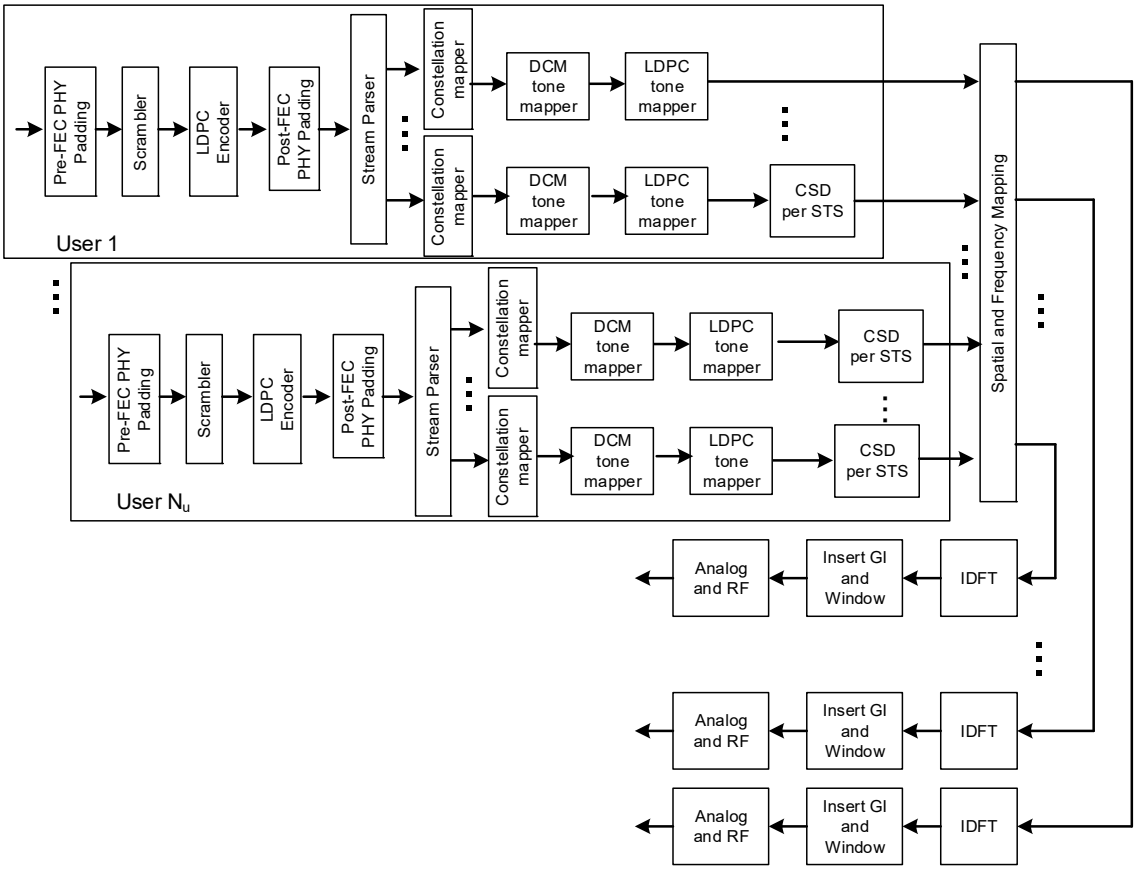


Figure 26-15—Transmitter block diagram for the Data field of an HE downlink MU-MIMO transmission in 106-, 242-, 484- or 996-tone(#838) RU with LDPC encoding(#277)

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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.

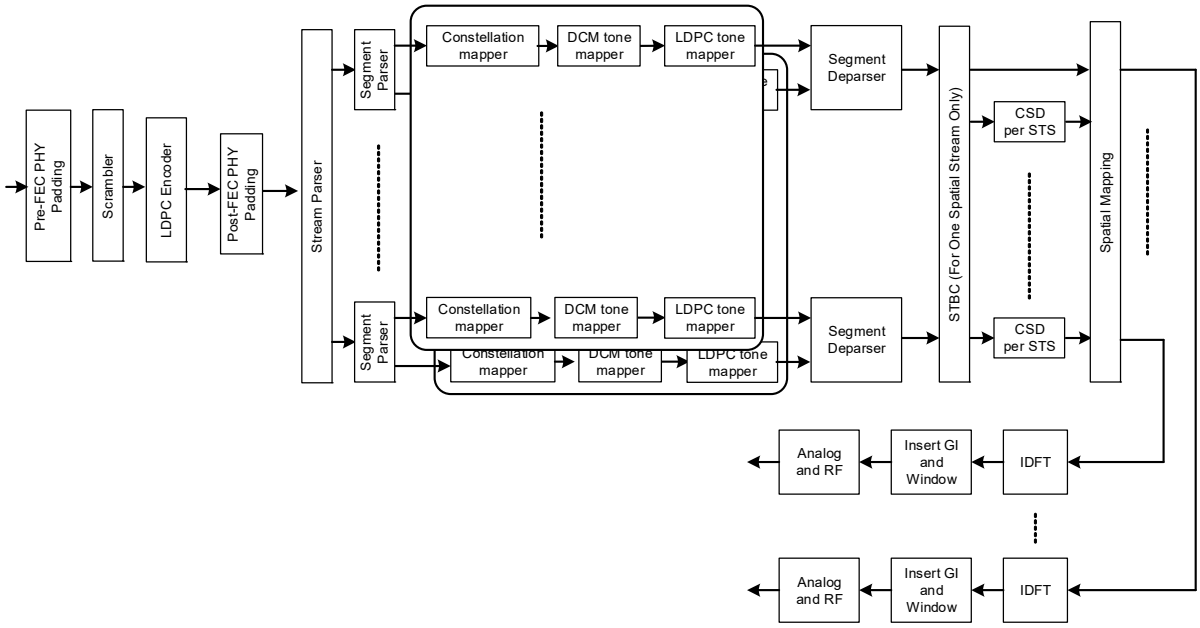


Figure 26-16—Transmitter block diagram for the Data field of an HE SU PPDU in 160 MHz with LDPC encoding

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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.

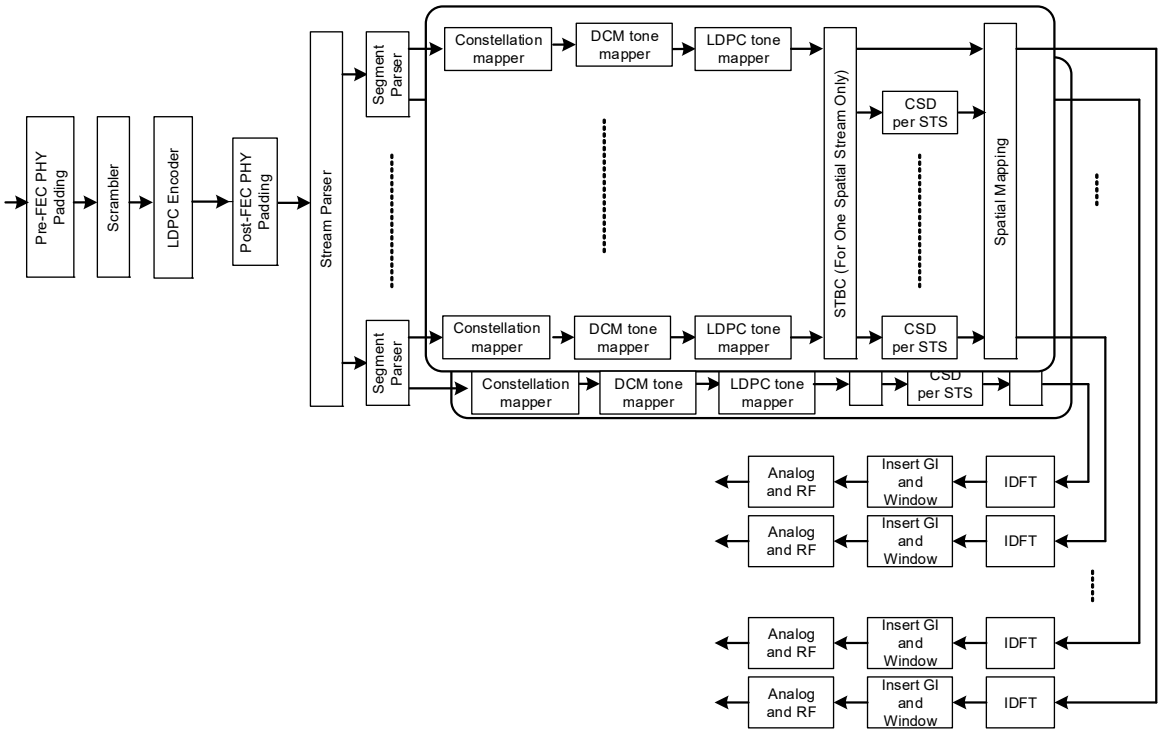


Figure 26-17—Transmitter block diagram for the Data field of an HE SU PPDU in 80+80 MHz with LDPC encoding

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.

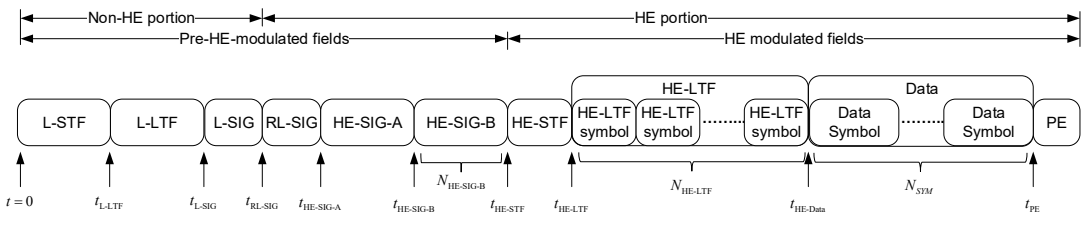


Figure 26-18—Timing boundaries for HE PPDU fields(#899)

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)

$$\eta_{\text{L-SIG},k} = \begin{cases} \sqrt{2}, & k = -28, -27, 27, 28 \text{ for an HE extended range SU PPDU} \\ 1, & \text{otherwise} \end{cases} \quad \text{(\#526)} \qquad (26\text{-}5)$$

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)

$$\beta_r^{Field} = \begin{cases} \dfrac{\varepsilon_{Field}}{\sqrt{N_{Field}^{\text{Tone}}}}, & \text{Pre-HE modulated fields when BEAM\_CHANGE = 1} \\ \varepsilon_{Field} \sqrt{\dfrac{|K_r|}{|K_r^{Field}|}} \Big/ \sqrt{\sum_{r=1}^{N_{RU}} \alpha_r^2 |K_r|}, & \text{otherwise} \end{cases} \quad \text{(\#526)} \qquad (26\text{-}6)$$

$|K_r|$ 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

$$\eta_{\text{L-STF},\,k} = \begin{cases} \sqrt{2}, & \text{for an HE extended range SU PPDU (\#1986)} \\ 1, & \text{otherwise} \end{cases} \quad (26\text{-}8)$$

$N_{20\text{MHz}}$ 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)

$$r_{\text{HE-SIG-A}}^{(i_{Seg} i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{\text{HE-SIG-A}}^{\text{Tone}}}} \sum_{n=0}^{1} w_{T_{SYML}}(t - n T_{SYML}) \sum_{i_{BW} \in \Omega_{20\text{MHz}}} \sum_{k=-28}^{28} \left(\begin{array}{l} \Upsilon_{(k - K_{\text{Shift}}(i_{BW})), \text{BW}}(D_{k,n,20} + p_{n+2} P_k) \\ \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}})) \Delta_{F,\text{Pre-HE}}(t - n T_{SYML} - T_{GI,\text{LegacyPreamble}} - T_{CS}^{i_{TX}})) \end{array} \right) \quad (26\text{-}17)$$

$N_{20\text{MHz}}$ 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).

$$\dot{}_{\text{HE-SIG-A}}^{(i_{Seg} i_{TX})}(t) = \frac{1}{\sqrt{N_{TX} \cdot N_{\text{HE-SIG-A}}^{\text{Tone}}}} \sum_{n=0}^{1} w_{T_{SYML}}(t - nT_{SYML}) \qquad \text{(26-18)}$$

$$\sum_{i_{BW}=0}^{N_{20\text{MHz}}-1} \sum_{k=-N_{SR}}^{N_{SR}} \left(\begin{array}{l} (D_{k,n,i_{BW}}^{i_{Seg}} + p_{n+4} P_k) \\ \cdot \exp(j2\pi(k - K_{\text{Shift}}(i_{\text{BW}}))\Delta_{F,\text{ Pre-HE}}(t - nT_{SYML} - T_{GI,\text{ LegacyPreamble}} - T_{CS}^{i_{TX}})) \end{array} \right)$$

(#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.

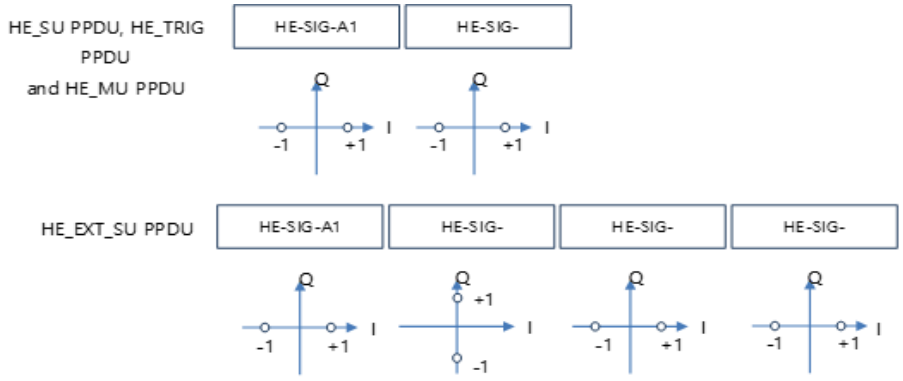


Figure 26-19—Data tone constellation of HE-SIG-A symbols

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).

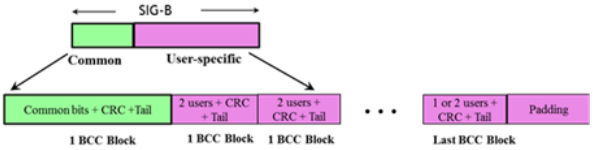


Figure 26-20—HE-SIG-B field encoding structure in each 20 MHz

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.

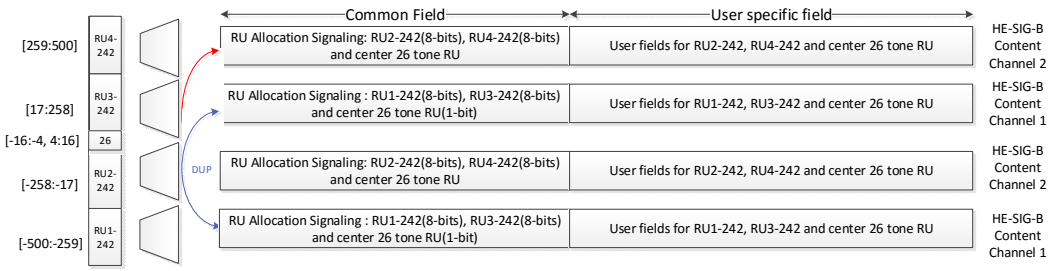


Figure 26-23—Default mapping of the two HE-SIG-B channels and their duplication in an 80 MHz PPDU

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.

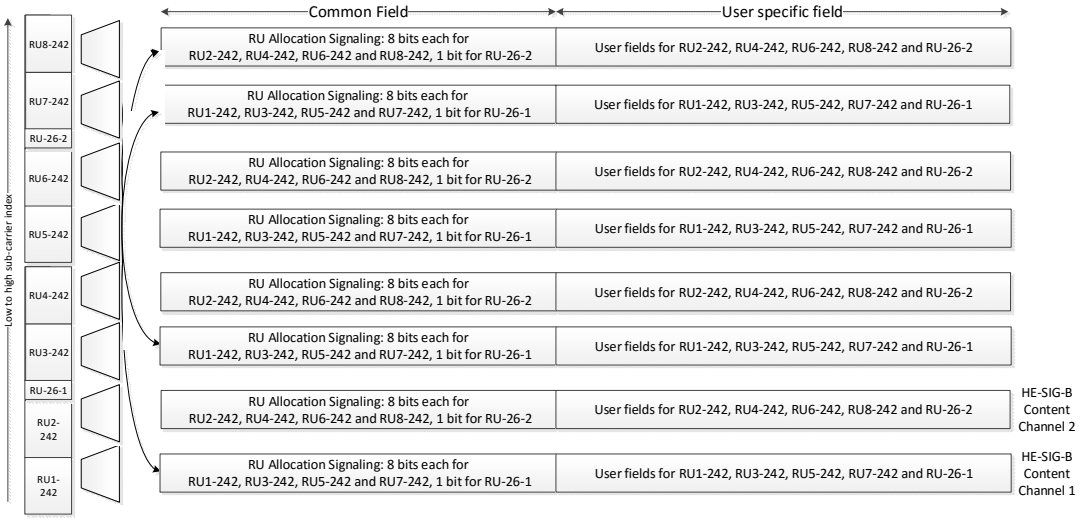


Figure 26-24—Default mapping of the two HE-SIG-B channels and their duplication in a 160 MHz PPDU

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.

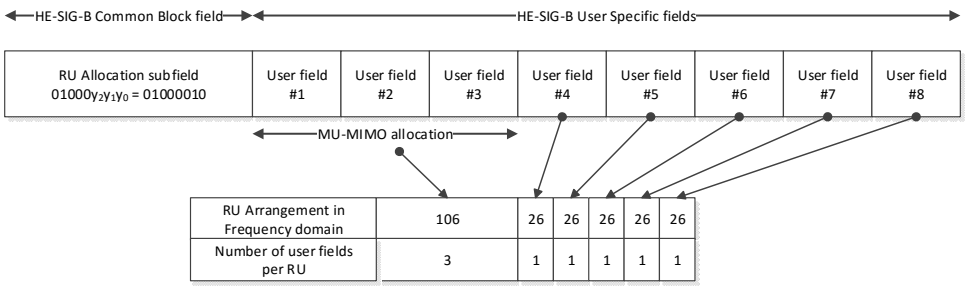


Figure 26-25—Illustration for the mapping of the 8-bit RU allocation subfield and the position of the user-field to the STA's assignment(PHY Motion #172)

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)

$$\begin{aligned} HES_{-1016:8:1016} = \{&M, -1, M, -1, -M, -1, M, 0, -M, 1, M, 1, -M, 1, -M, 0 \\ &-M, 1, -M, 1, M, 1, -M, 0, -M, 1, M, 1, -M, 1, -M\} \cdot (1+j)/\sqrt{2} \\ HES_{\pm 8} = 0,\ HES_{\pm 1016} = 0 \end{aligned} \tag{26-33}$$

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)

$$\begin{aligned} HES_{-504:8:504} &= \{-M, 1, -M, 1, M, 1, -M, 0, -M, 1, M, 1, -M, 1, -M\} \cdot (1+j)/\sqrt{2} \\ HES_{\pm 504} &= 0 \end{aligned} \tag{26-34}$$

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).

$$\begin{aligned} r_{\text{HE-STF}}^{(i_{Seg} i_{TX})}(t) = w_{T_{\text{HE-STF-NT}}}(t) \cdot \sum_{r=0}^{N_{RU}-1} \frac{\alpha_r \beta_r}{\sqrt{N_{STS,r,total}}} \\ \sum_{k \in K} \sum_{u=0}^{N_{user,r}-1} \sum_{m=1}^{N_{STS,r,u}} \left(\eta_{\text{HE-STF},k} \left[Q_k^{(i_{Seg})} \right]_{i_{TX}, M_{r,u}+m} HES_k \cdot \exp(j 2\pi k \Delta_{F,\text{HE}} (t - T_{CS,HE}(M_{r,u}+m))) \right) \end{aligned} \tag{26-35}$$

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

$$\eta_{\text{HE-STF},k} = \begin{cases} \sqrt{2}, & \text{for an HE extended range SU PPDU} \\ 1, & \text{otherwise} \end{cases}$$ (#2045)(#526)

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

$$\beta_r = \left(\sqrt{\frac{|K_r|}{|K_r^{\text{HE-STF}}|}} \right) \Big/ \left(\sqrt{\sum_{r=1}^{N_{RU}} \alpha_r^2 |K_r|} \right)$$ (#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).

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

In a 20 MHz transmission, the 2x HE-LTF sequence transmitted and located on subcarriers [−122:122](#2553) is given by Equation (26-39).

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

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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).

$HELTF_{-244,244}$ =

{+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, −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}

In a 40 MHz transmission, the 4x HE-LTF sequence transmitted and located on subcarriers [−244:244](#2553) 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, −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 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\}
\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, 0, -1, 0, -1, 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,+1,+1,-1,+1,+1,-1,+1,\\
&-1,-1,-1,+1,-1,+1,-1,-1,-1,-1,+1,+1,+1,-1,-1,+1,0,0,0,0,0,+1,-1,-1,-1,\\
&-1,-1,-1,+1,-1,+1,+1,-1,-1,+1,+1,-1,+1,-1,+1,+1,-1,-1,+1,-1,+1,-1,-1,\\
&-1,+1,+1,-1,+1,+1,+1,-1,+1,+1,+1,+1,+1,+1,+1,-1,+1,-1,-1,+1,-1,-1,+1,\\
&-1,+1,+1,+1,-1,-1,+1,-1,-1,-1,+1,+1,-1,-1,-1,-1,-1,+1,-1,-1,-1,-1,-1,\\
&+1,+1,-1,-1,-1,-1,-1,+1,-1,-1,+1,+1,+1,-1,+1,+1,+1,-1,+1,-1,+1,-1,-1,\\
&-1,-1,-1,+1,+1,+1,-1,-1,-1,-1,+1,-1,-1,+1,+1,+1,-1,+1,+1,-1,-1,+1,-1,\\
&+1,-1,-1,-1,-1,-1,-1,-1,+1,+1,-1,-1,-1,+1,-1,-1,+1,+1,+1,-1,+1,-1,-1,\\
&+1,-1,-1,+1,-1,+1,+1,+1,-1,+1,-1,-1,+1,+1,-1,+1,-1,+1,+1,+1,-1,-1,+1,\\
&-1,-1,-1,+1,-1,-1,-1,-1,-1,-1,-1,+1,-1,+1,+1,-1,+1,+1,-1,+1,-1,-1,-1,\\
&+1,+1,-1,+1,+1,+1,-1,-1,+1,+1,+1,+1,+1,-1,+1,-1,-1,-1,-1,+1,+1,-1,-1,\\
&-1,-1,-1,+1,-1,-1,+1,+1,+1,-1,+1,+1,+1,-1,+1,-1,+1,-1,-1,-1,-1,-1,+1,\\
&+1,+1,-1,-1,-1,-1,+1,-1,-1,+1,+1,+1,-1,+1,+1,-1,-1,+1,-1,+1,-1,+1,+1,\\
&+1,-1,+1,-1,-1,+1,+1,-1,+1,-1,+1,+1,+1,-1,-1,+1,-1,-1,-1,+1,-1,-1,-1,\\
&-1,-1,-1,-1,+1,-1,+1,+1,-1,+1,+1,-1,+1,-1,-1,-1,+1,+1,-1,+1,+1,+1,-1,\\
&-1,+1,+1,+1,+1,+1,-1,+1,+1,+1,+1,+1,-1,-1,+1,+1,+1,+1,+1,-1,+1,+1,-1,\\
&-1,-1,+1,-1,-1,-1,+1,-1,+1,-1,+1,+1,+1,+1,+1,-1,-1,-1,+1,+1,+1,+1,-1,\\
&+1,+1,-1,-1,-1,+1,-1,-1,+1,+1,-1,+1,-1,+1,-1,-1,-1,-1,-1,-1,+1,+1,-1,\\
&-1,-1,+1,-1,-1,+1,+1,+1,-1,+1,-1,-1,+1,-1,-1,+1,-1,+1,-1,+1,-1,+1,-1,\\
&-1,+1,+1,-1,+1,-1,+1,+1,+1,-1,-1,+1,-1,-1,-1,+1,-1,-1,-1,-1,-1,-1,-1,\\
&+1,-1,+1,+1,-1,+1,+1,-1,+1,-1,-1,-1,+1,+1,-1,+1,+1,+1,-1,-1,+1,+1,+1,\\
&+1,+1,-1,+1,-1,-1,-1,-1,+1,+1,-1,-1,-1,-1,-1,+1,-1,-1,-1,+1,-1,-1,+1,\\
&+1,+1,-1,+1,-1,+1,-1,-1,-1,-1,-1,+1,+1,+1,-1,-1,-1,-1,+1,-1,-1,+1,+1,\\
&+1,-1,+1,+1,-1,-1,+1,-1,+1,-1,+1\}
\end{aligned}
\tag{26-46}
$$

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

$$HELTF_{-1012,1012} = \{LTF_{80MHz_primary_1x}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, LTF_{80MHz_secondary_1x}\} \quad (26\text{-}47)$$

where

$LTF_{80MHz_primary_1x} = \{LTF_{80MHz_left_1x}, 0, LTF_{80MHz_right_1x}\}$ and shall be used in the primary 80 MHz frequency segment

$LTF_{80MHz_secondary_1x} = \{LTF_{80MHz_left_1x}, 0, (-1)*LTF_{80MHz_right_1x}\}$ and shall be used in the secondary 80 MHz frequency segment

$LTF_{80MHz_left_1x}$ = {−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, −1, 0, 0, 0}

$LTF_{80MHz_right_1x}$ = {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).

$$HELTF_{-1012,1012} = \{LTF_{80MHz_primary_2x}, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, LTF_{80MHz_secondary_2x}\} \quad (26\text{-}48)$$

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where

$$LTF_{80\text{MHz_primary_2x}} = \{LTF_{80\text{MHz_part1_2x}}, LTF_{80\text{MHz_part2_2x}}, LTF_{80\text{MHz_part3_2x}}, LTF_{80\text{MHz_part4_2x}}, LTF_{80\text{MHz_part5_2x}}\} \quad (26\text{-}49)$$

$$LTF_{80\text{MHz_secondary_2x}} = \{LTF_{80\text{MHz_part1_2x}}, LTF_{80\text{MHz_part2_2x}}, LTF_{80\text{MHz_part3_2x}}, LTF_{80\text{MHz_part4_2x}}, LTF_{80\text{MHz_part5_2x}}\} \quad (26\text{-}50)$$

$$LTF_{80\text{MHz_part1_2x}} = \{+1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0\}$$

$$LTF_{80\text{MHz_part2_2x}} = \{+1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0\}$$

$$LTF_{80\text{MHz_part3_2x}} = \{+1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, 0, 0, 0, 0, 0, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1\}$$

$$LTF_{80\text{MHz_part4_2x}} = \{0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1\}$$

$$LTF_{80\text{MHz_part5_2x}} = \{0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, -1, 0, -1, 0, +1, 0, -1, 0, -1, 0, -1, 0, +1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1, 0, +1, 0, -1, 0, +1, 0, +1\}$$ (#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,
−1, −1, +1, −1, −1, +1, +1, +1, −1, +1, +1, +1, −1, +1, −1, +1, −1, −1, −1, −1, −1, +1, +1, +1,
−1, −1, −1, −1, +1, −1, −1, +1, +1, +1, −1, +1, +1, −1, −1, +1, −1, +1, −1, +1, +1, +1, −1, +1,
−1, −1, +1, +1, −1, +1, −1, +1, +1, +1, −1, −1, +1, −1, −1, −1, +1, −1, −1, −1, −1, −1, −1, −1,
+1, −1, +1, +1, −1, +1, +1, −1, +1, −1, −1, −1, +1, +1, −1, +1, +1, +1, −1, −1, +1, +1, +1, +1,
+1, −1, +1, +1, +1, +1, +1, −1, −1, +1, +1, +1, +1, +1, −1, +1, +1, −1, −1, −1, +1, −1, −1, −1,
+1, −1, +1, −1, +1, +1, +1, +1, +1, −1, −1, −1, +1, +1, +1, +1, −1, +1, +1, −1, −1, −1, +1, −1,
−1, +1, +1, −1, +1, −1, +1, −1, −1, −1, −1, −1, −1, +1, +1, −1, −1, −1, +1, −1, −1, +1, +1, +1,
−1, +1, −1, −1, +1, −1, −1, +1, −1, +1, −1, +1, −1, +1, −1, −1, +1, +1, −1, +1, −1, +1, +1, +1,
−1, −1, +1, −1, −1, −1, +1, −1, −1, −1, −1, −1, −1, −1, +1, −1, +1, +1, −1, +1, +1, −1, +1, −1,
−1, −1, +1, +1, −1, +1, +1, +1, −1, −1, +1, +1, +1, +1, +1, −1, +1, −1, −1, −1, −1, +1, +1, −1,
−1, −1, −1, −1, +1, −1, −1, +1, +1, +1, −1, +1, +1, +1, −1, +1, −1, +1, −1, −1, −1, −1, −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).

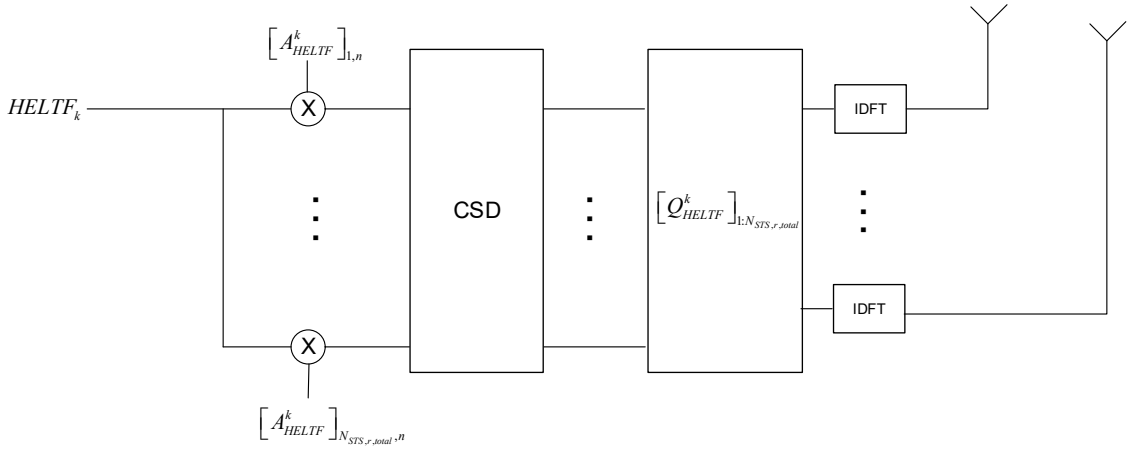


Figure 26-26—Generation of HE-LTF symbols per frequency segment in an HE SU PPDU, HE MU PPDU, HE extended range SU PPDU and HE trigger-based PPDU(#1059)

$A^k_{\text{HE-LTF}}$ 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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$$r^{(i_{Seg} i_{TX})}_{\text{HE-LTF}}(t) = \frac{\eta_{\text{HE-LTF-Mode}}}{\sqrt{\sum_{r=0}^{N_{RU}-1} \alpha_r^2 |K_r|}} \sum_{n=0}^{N_{\text{HE-LTF}}-1} w_{T_{\text{HE-LTF}}}(t - nT_{\text{HE-LTF}}) \sum_{r=0}^{N_{RU}-1} \frac{\alpha_r}{\sqrt{N_{STS,r,total}}} \eta_{\text{HE-LTF},k} \quad (26\text{-}59)$$

$$\sum_{k \in K_r} \sum_{u=0}^{N_{user,r}-1} \sum_{m=1}^{N_{STS,r,u}} \left(\left[Q_k^{(i_{Seg})} \right]_{i_{TX},(M_{r,u}+m)} \left[A^k_{\text{HE-LTF}} \right]_{(M_{r,u}+m),(n+1)} HELTF_k'' \cdot \exp(j2\pi k \Delta_{F,\text{HE}}(t - nT_{\text{HE-LTF}} - T_{GI} - T_{CS,\text{HE}}(M_{r,u}+m))) \right)$$

(#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.

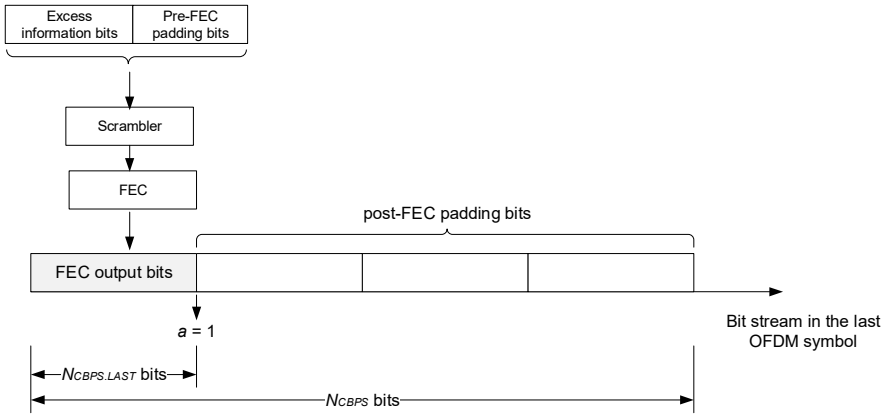


Figure 26-27—HE PPDU padding process in the last OFDM symbol (non STBC) when *a* = 1

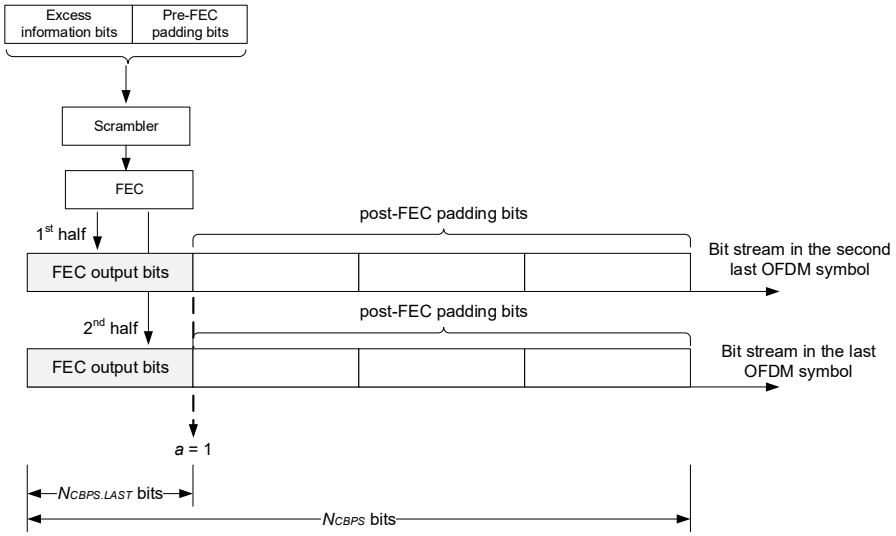


Figure 26-28—HE PPDU padding process in the last OFDM symbol (STBC) when *a* = 1

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).

$$a_{init} = \begin{cases} 4, & \text{if } N_{Excess} = 0 \\ \min\left(\left\lceil \frac{N_{Excess}}{m_{STBC} \cdot N_{DBPS,SHORT}} \right\rceil, 4\right), & \text{otherwise} \end{cases} \text{ (PHY Motion \#174)} \quad (26\text{-}61)$$

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).

$$N_{DBPS.LAST.init} = \begin{cases} a_{init} N_{DBPS.SHORT}, & \text{if } a_{init} < 4 \\ N_{DBPS}, & \text{if } a_{init} = 4 \end{cases}$$

$$N_{CBPS.LAST.init} = \begin{cases} a_{init} N_{CBPS.SHORT}, & \text{if } a_{init} < 4 \\ N_{CBPS}, & \text{if } a_{init} = 4 \end{cases} \quad (26\text{-}62)$$

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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)

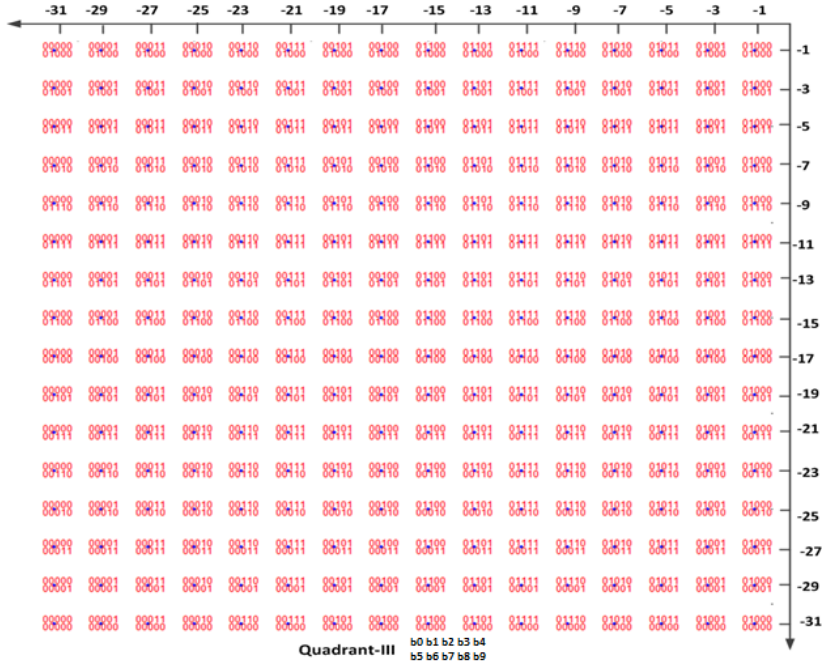


Figure 26-31—Constellation bit encoding for 1024-QAM (3rd quadrant)

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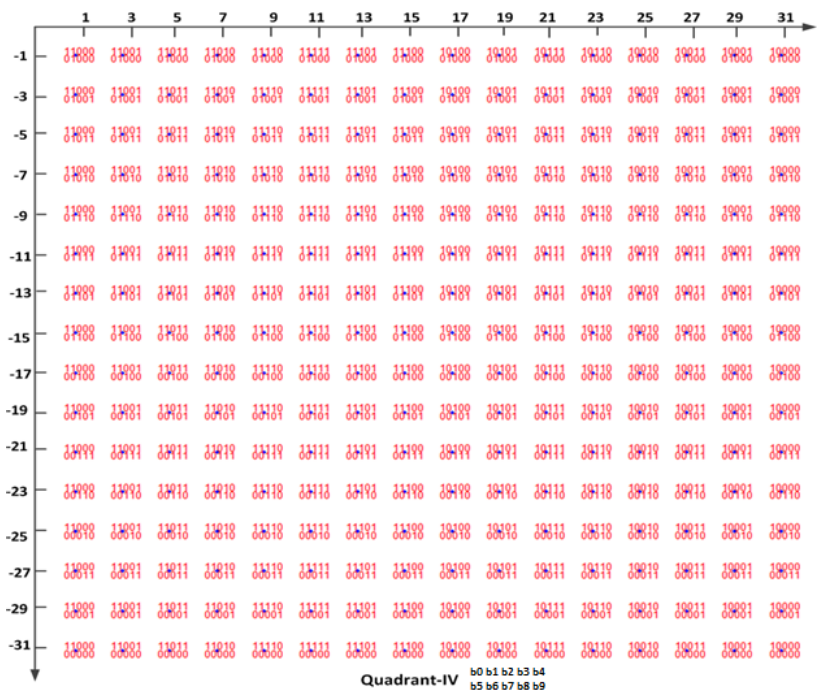


Figure 26-32—Constellation bit encoding for 1024-QAM (4th quadrant)

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).

$$\begin{aligned} P_n^{K_{R26_i}} &= \{\Psi_{n \bmod 2}, \Psi_{(n+1) \bmod 2}\} \text{ (#347)} \\ P_n^{k \notin K_{R26_i}} &= 0 \end{aligned} \tag{26-105}$$

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).

$$r_{\text{HE-Data}}^{(i_{Seg} i_{TX})}(t) = \frac{1}{\sqrt{\sum_{r=1}^{N_{RU}} \alpha_r^2 |K_r|}} \sum_{n=0}^{N_{SYM}-1} w_{T_{\text{HE-Data}}}(t - nT_{SYM}) \sum_{r=0}^{N_{RU}-1} \frac{\alpha_r}{\sqrt{N_{STS,r,total}}} \sum_{k \in K_r} \sum_{u=0}^{N_{user,r}-1} \sum_{m=1}^{N_{STS,r,u}} \left(\begin{array}{l} \left[Q_k^{(i_{Seg})} \right]_{i_{TX}, (M_{r,u}+m)} (\tilde{D}_{k,m,n,r}^{(i_{Seg},u)} + p_{n+2+N_{\text{HE-SIG-A}}+N_{\text{HE-SIG-B}}} P_n^k) \\ \cdot \exp(j2\pi k \Delta_{F,\text{HE}} (t - nT_{SYM} - T_{GI,Data} - T_{CS,\text{HE}}(M_{r,u}+m))) \end{array} \right) \quad (26\text{-}112)$$

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).

$$r_{\text{HE-Data}}^{(i_{Seg} i_{TX})}(t) = \frac{\alpha_r}{\sqrt{|K_r|}} \sum_{n=0}^{N_{SYM}-1} w_{T_{\text{HE-Data}}}(t - nT_{SYM}) \frac{1}{\sqrt{N_{STS,\,r,\,total}}} \sum_{k \in K_r} \sum_{m=1}^{N_{STS,\,r,\,u}} \left(\left[Q_k^{(i_{Seg})} \right]_{i_{TX},\,(M_{r,\,u}+m)} (\tilde{D}_{k,\,m,\,n,\,r}^{(i_{Seg},\,u)} + p_{n+4} P_n^k) \cdot \exp(j2\pi k \Delta_{F,\,\text{HE}}(t - nT_{SYM} - T_{GI,\,Data} - T_{CS,\,HE}(M_{r,\,u}+m))) \right) \quad \text{(26-115)}$$

(#2099)

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)).

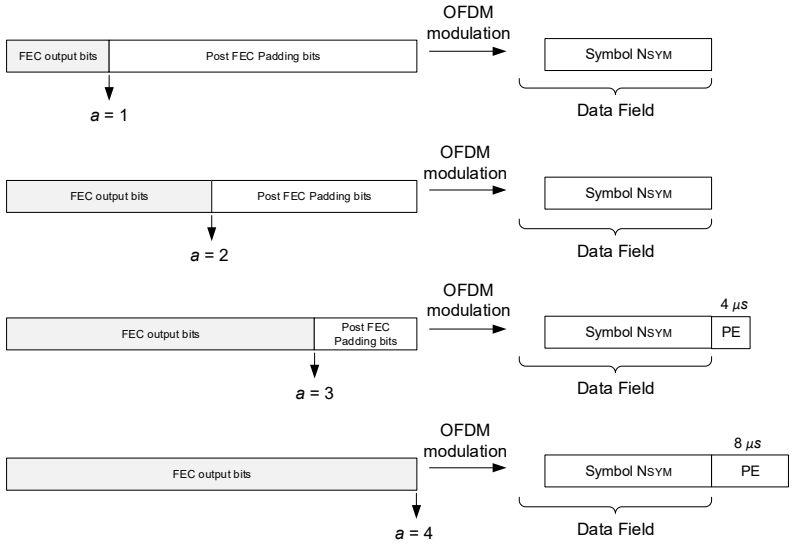


Figure 26-33—PE field when maximum PE duration is 8 µs (non STBC)

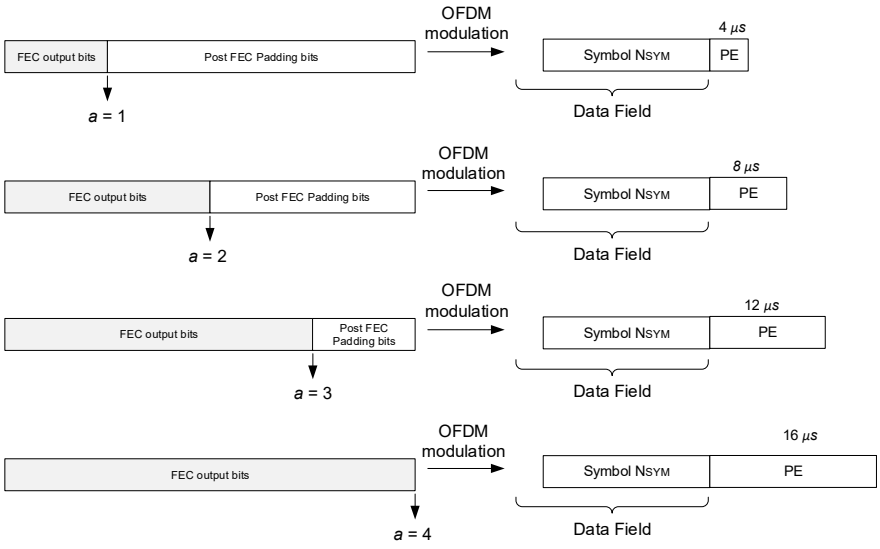


Figure 26-34—PE field when maximum PE duration is 16 µs (non STBC)

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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).

$$Tx_{pwr}^{STA} = PL_{DL} + \mathrm{Target}_{RSSI} \quad (26\text{-}121)$$

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.

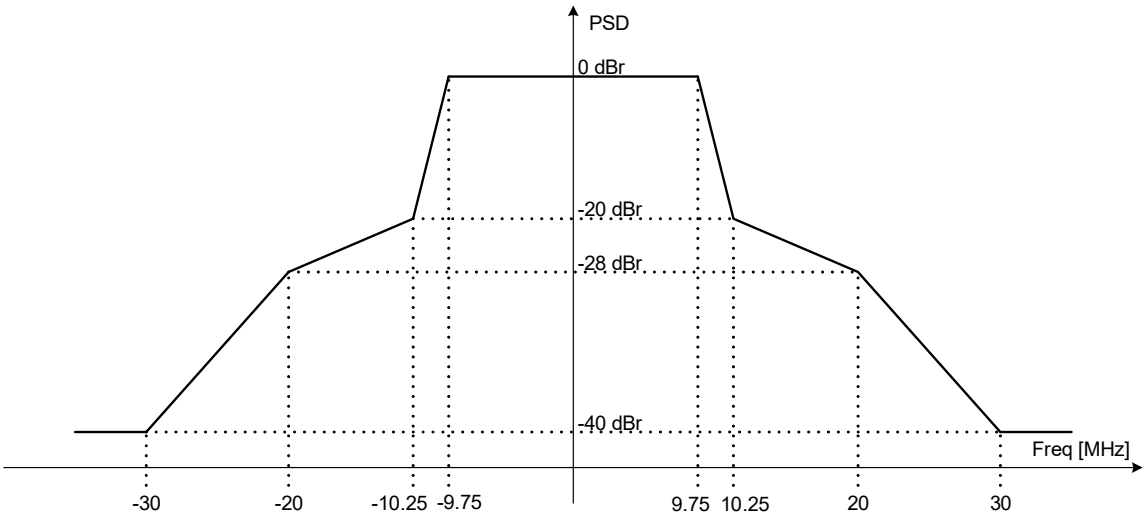


Figure 26-35—Example transmit spectral mask for a 20 MHz mask PPDU

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.

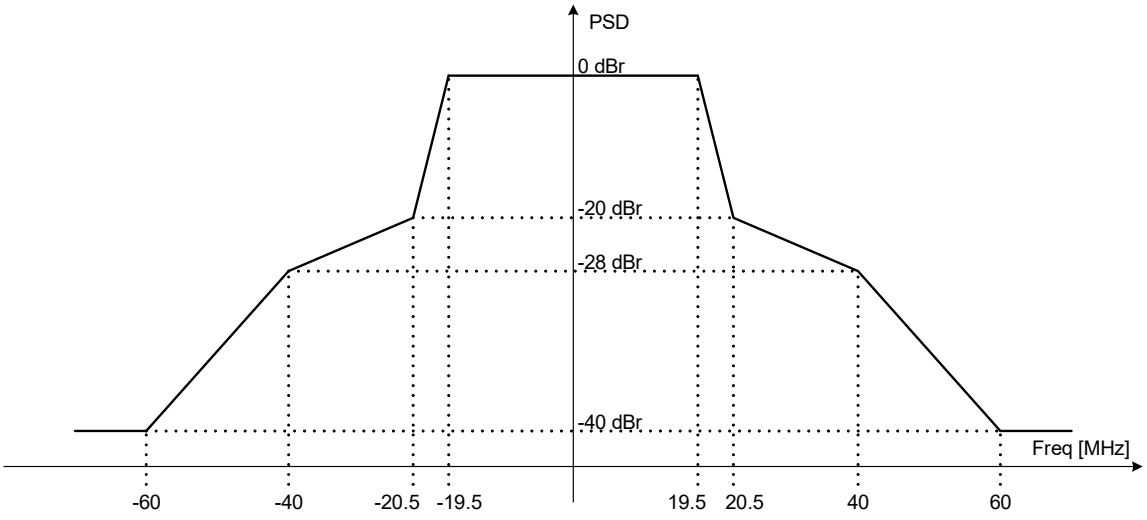


Figure 26-36—Example transmit spectral mask for a 40 MHz mask PPDU

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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.

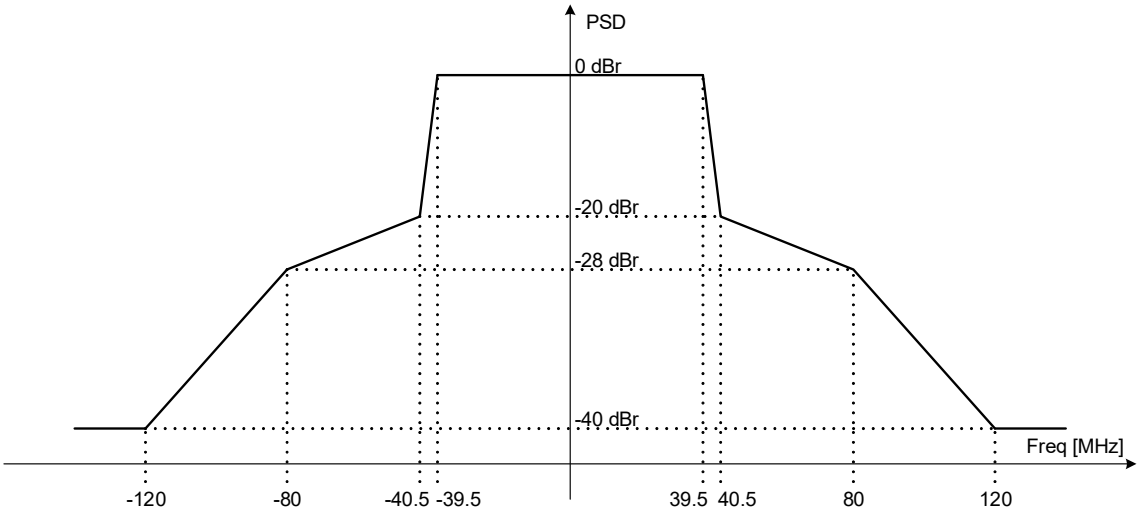


Figure 26-37—Example transmit spectral mask for a 80 MHz mask PPDU

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.

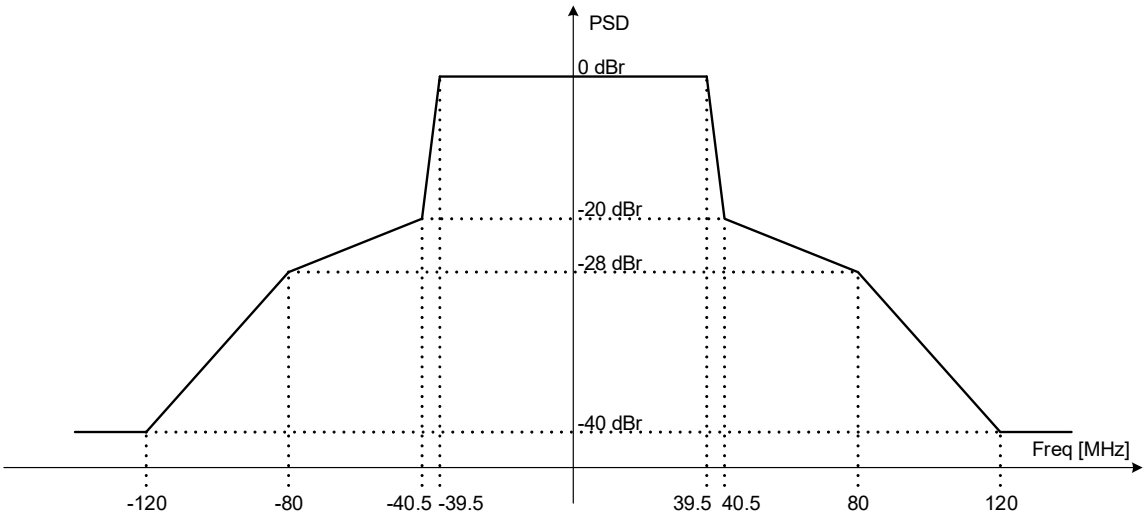


Figure 26-38—Example transmit spectral mask for a 160 MHz mask PPDU

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.

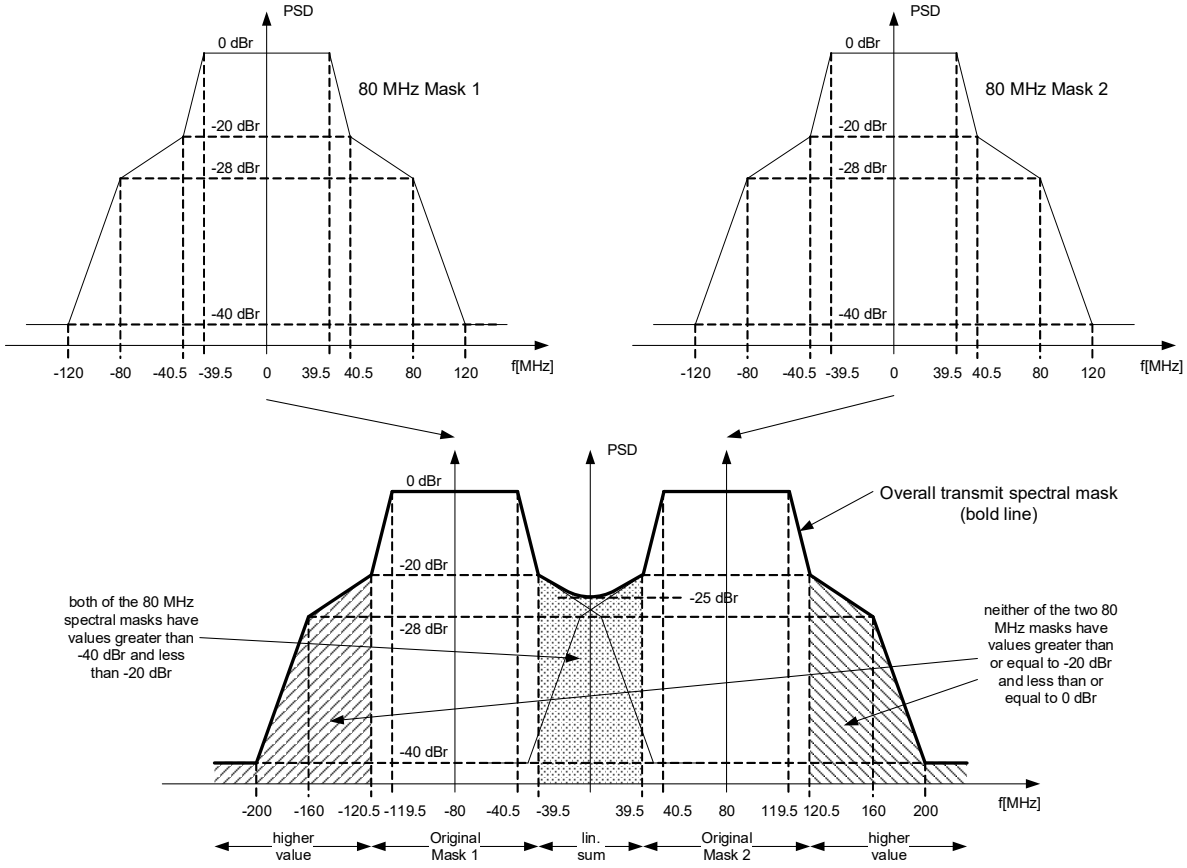


Figure 26-39—Example transmit spectral mask for a 80+80 MHz mask PPDU

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.

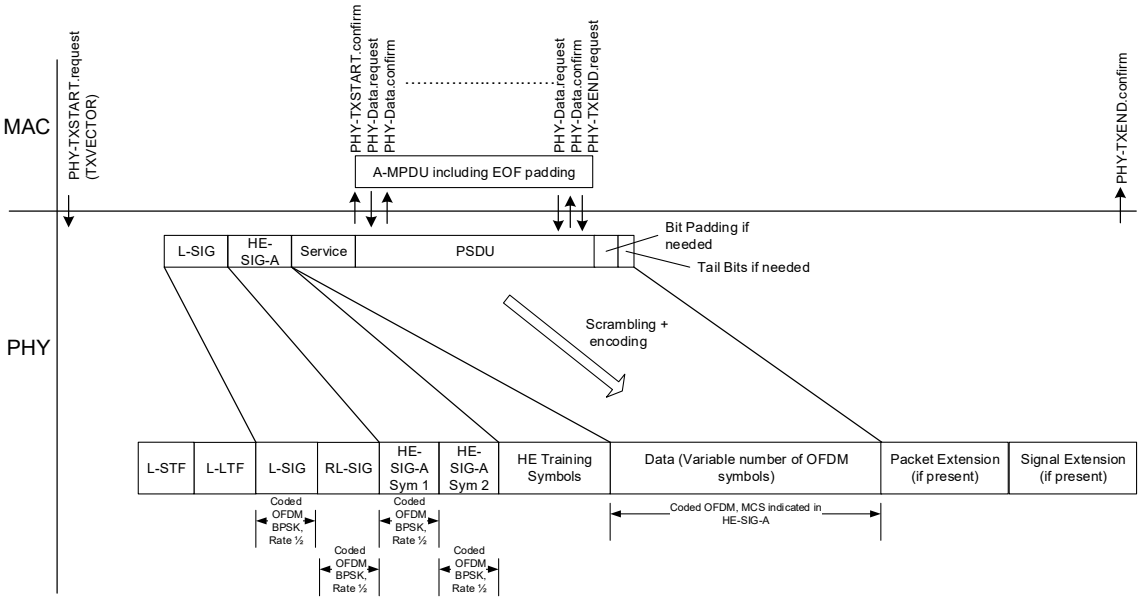
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— FIRST_TRANSITION_FIELD is L-STF.
— SECOND_TRANSITION_FIELD is L-LTF.
— TRAINING_FIELD is L-LTF windowed in a manner which should approximate the windowing described in 17.3.2.5 (Mathematical conventions in the signal descriptions) with TTR = 100 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

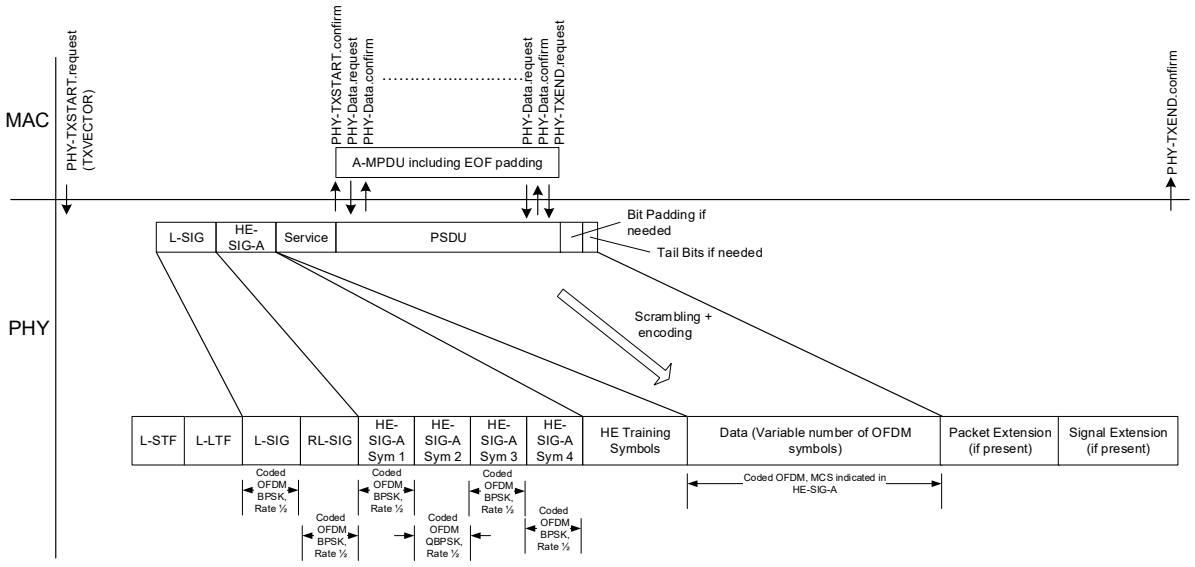
(#493)There are five options for the transmit PHY procedure. The first four options, for which typical transmit procedures are shown in Figure 26-40 (PHY transmit procedure for an HE SU PPDU), Figure 26-42 (PHY transmit procedure for an HE MU PPDU), Figure 26-41 (PHY transmit procedure for an HE extended 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.

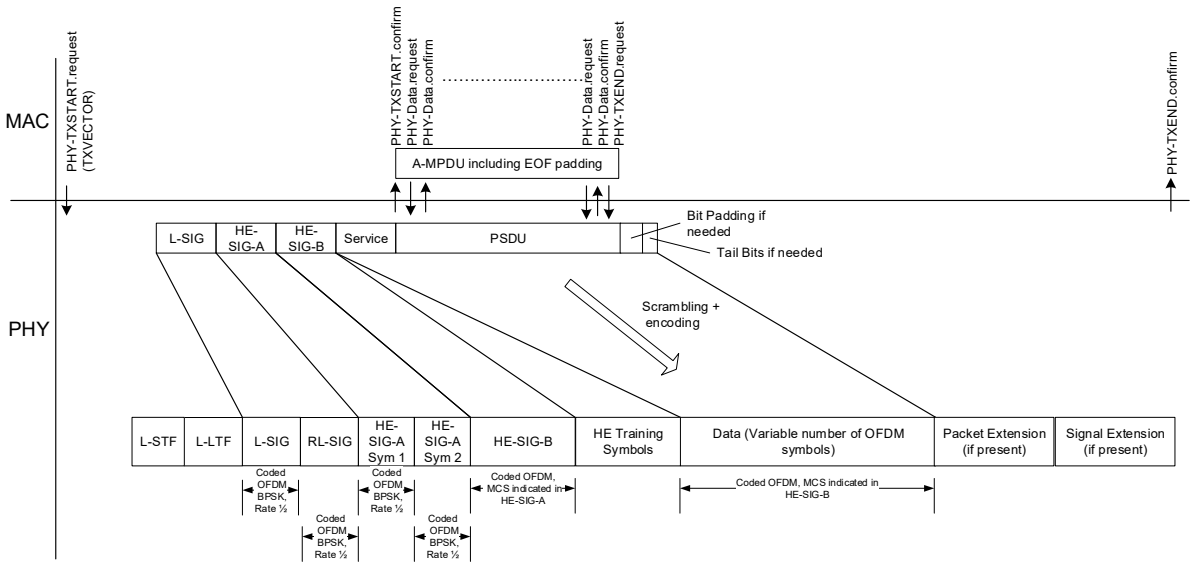
Figure 26-40—PHY transmit procedure for an HE SU PPDU

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NOTE—This procedure does not describe the operation of optional features, such as xxx.

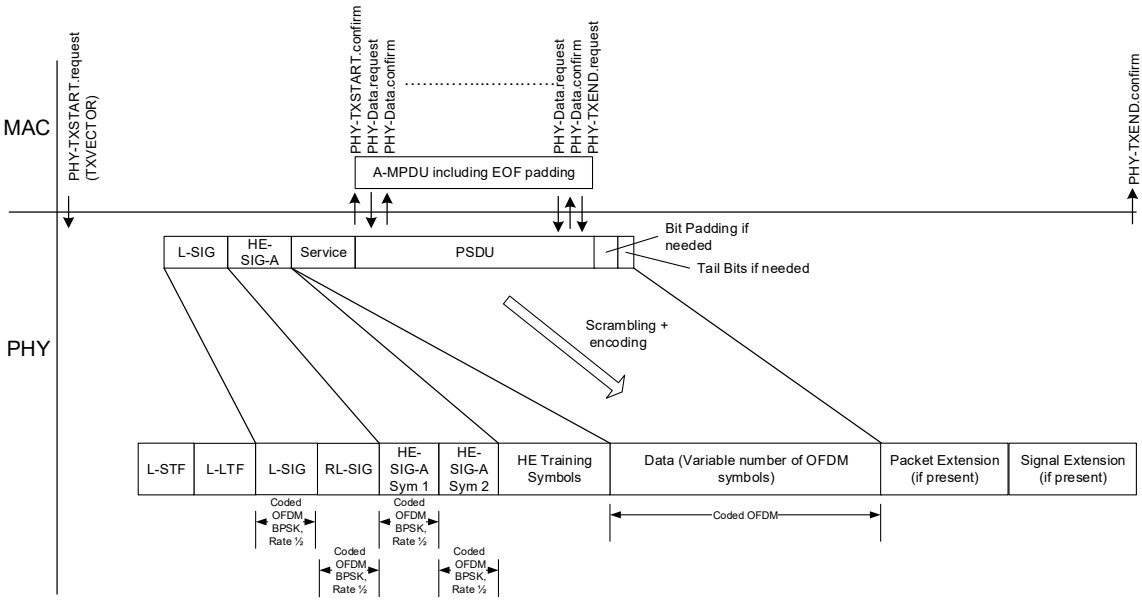
Figure 26-41—PHY transmit procedure for an HE extended range SU PPDU



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.

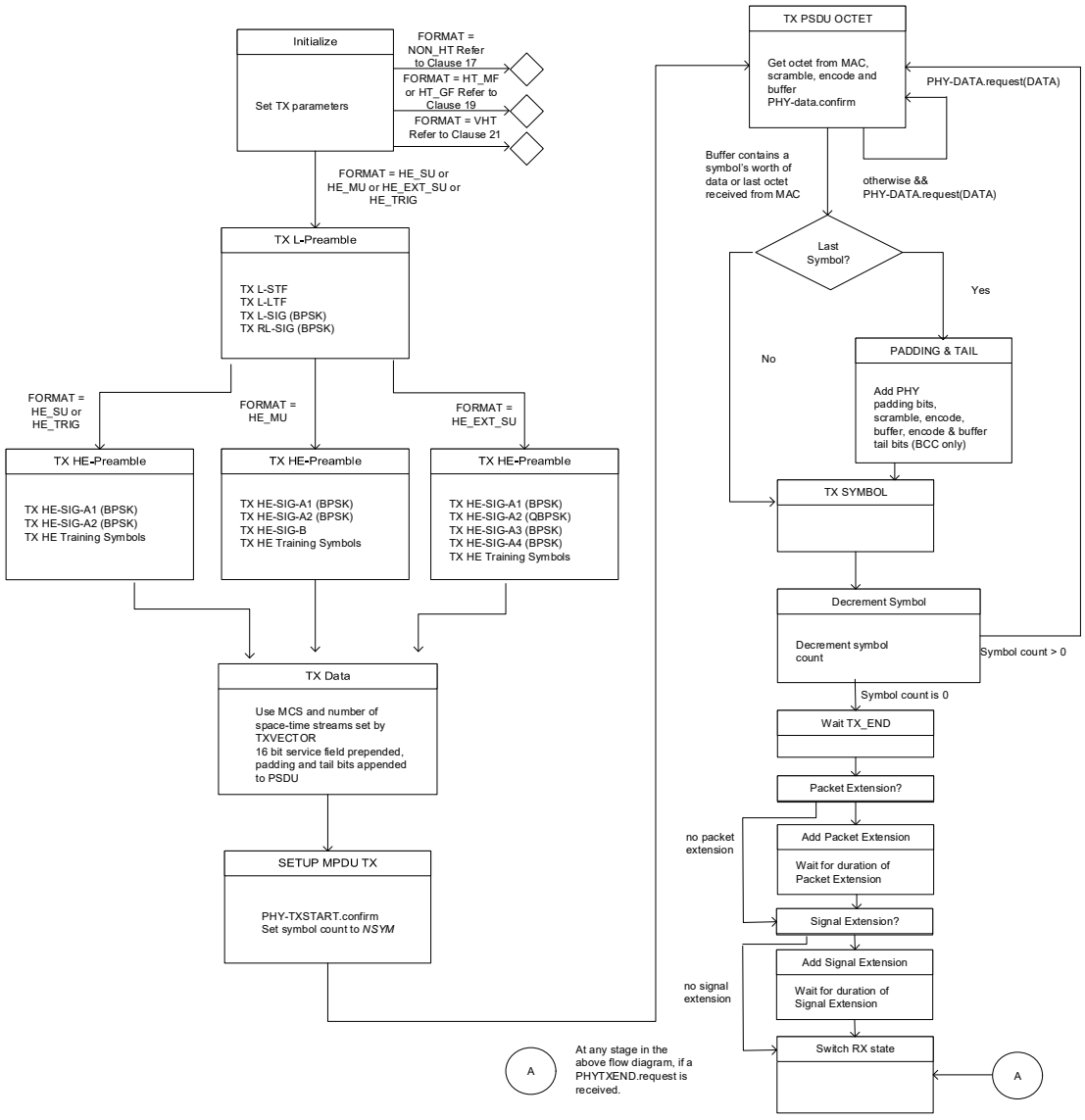


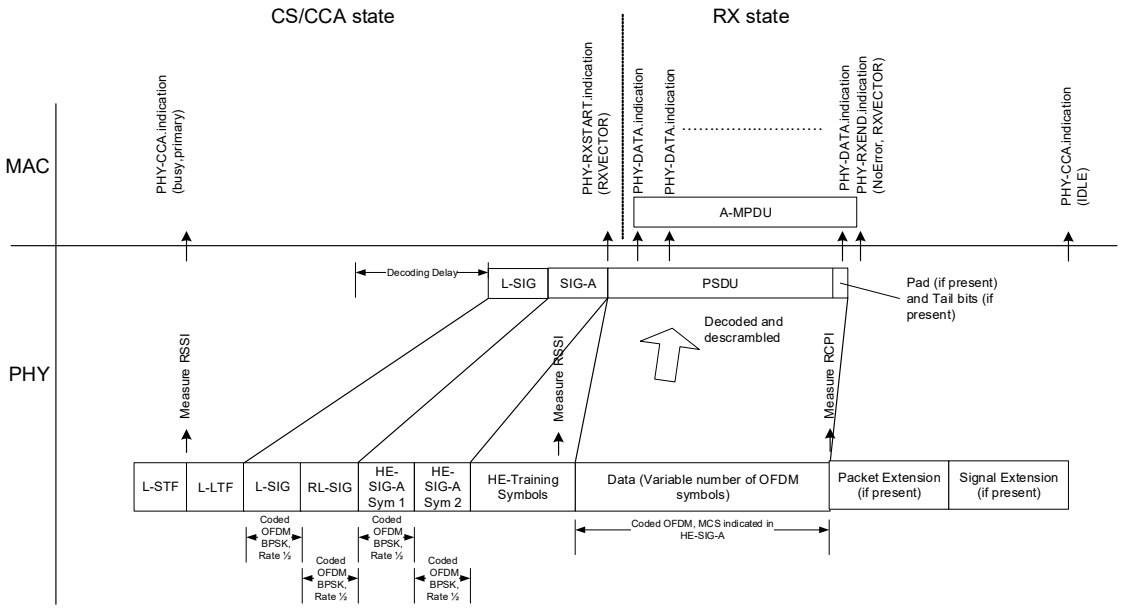
Figure 26-44—PHY transmit state machine for an HE PPDU

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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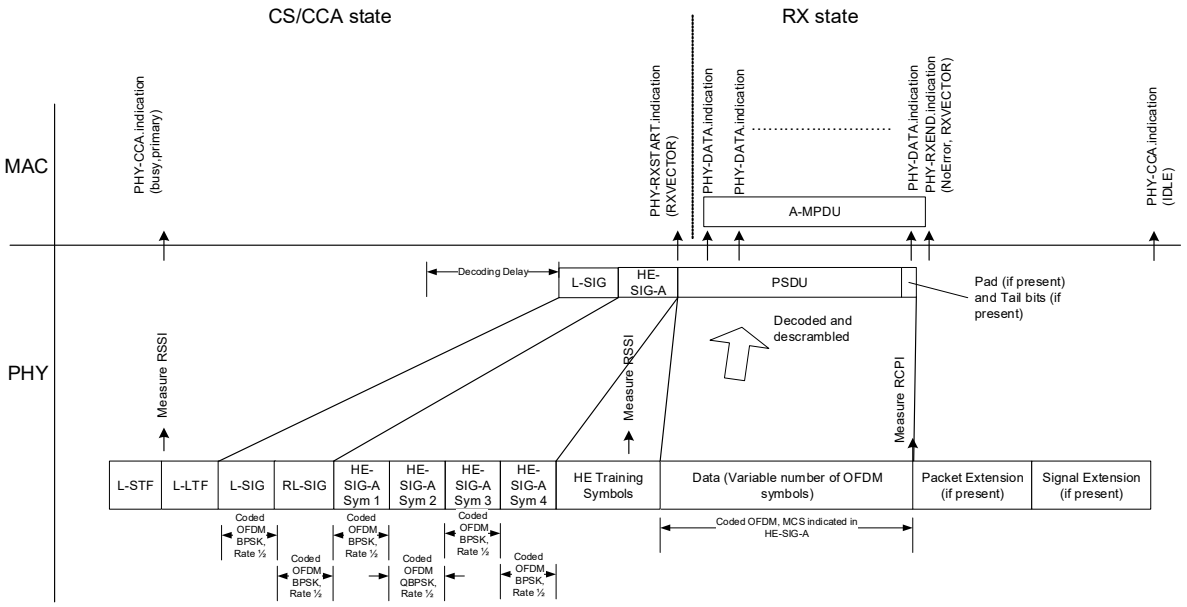
machine in Clause 19 (High Throughput (HT) PHY specification). If the detected format indicates a VHT PPDU format, refer to the receive procedure and state machine in Clause 21 (Very High Throughput (VHT) PHY specification).Through station management (via the PLME) the PHY is set to the appropriate frequency, 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.

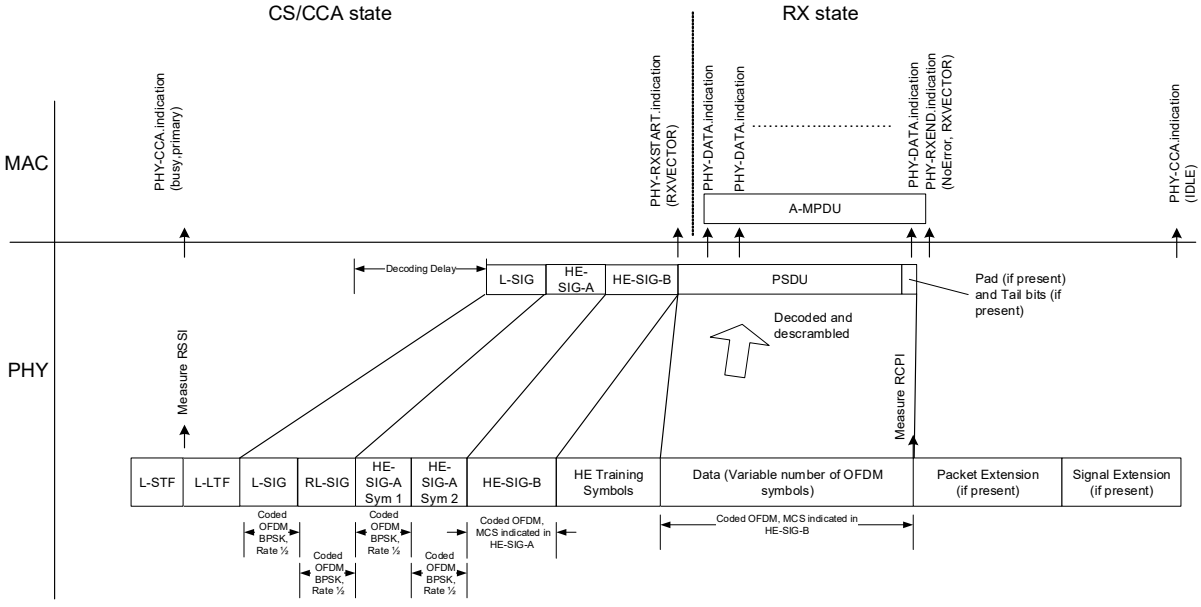
Figure 26-45—PHY receive procedure for an HE SU PPDU

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NOTE—This procedure does not describe the operation of optional features, such as xxx.

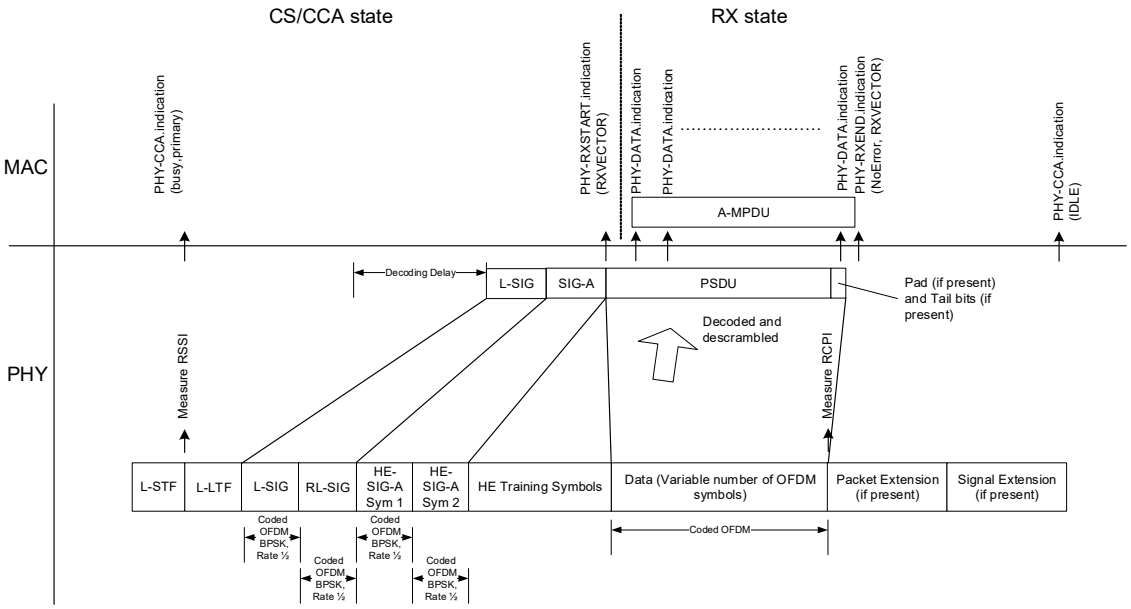
Figure 26-46—PHY receive procedure for an HE extended range SU PPDU



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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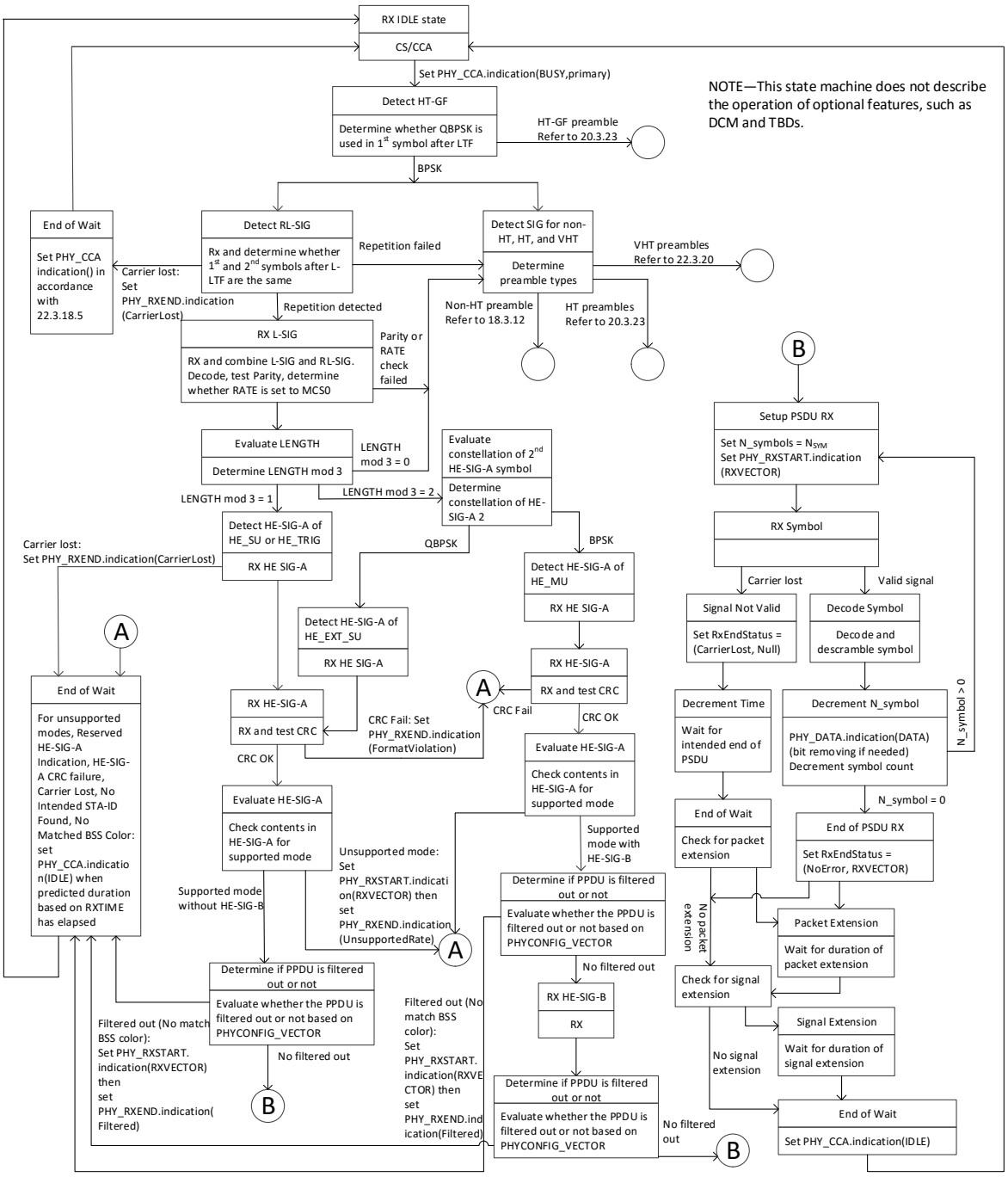


Figure 26-49—PHY receive state machine

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
Today Thursday, January 21 Pr
Loading...

Events shown in time zone: Eastern Time
Calendar

Privacy and Cookies policy.

IEEE Std 802.11, 802.11a, 802.11b, 802.11b-Cor1, 802.11d, 802.11e, 802.11F, 802.11g, 802.11h, 802.11i, 802.11j, 802.11k, 802.11m, 802.11ma, 802.11-REVma, 802.11mb, 802.11REVmb, 802.11n, 802.11p, 802.11r, 802.11s, 802.11T, 802.11v, 802.11u, 802.11w, 802.11y, 802.11z, 802.11aa, 802.11ac, 802.11ad, 802.11ae, 802.11af, 802.11ah, 802.11ai, 802.11aj, 802.11ak, 802.11aq, 802.11ax, 802.11REVmc, 802.11.1 and 802.11.2 are trademarks of the IEEE.
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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		
Author(s):	***Adrian Stephens - (Intel Corporation)***		***Jon Rosdahl - (Qualcomm)***
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			Dorothy Stanley - (HPE)
			2nd Vice-Chair, IEEE 802.11 WLANs Working Group
			Address: 1322 Crossman Ave Sunnyvale, CA 94089, USA
			Phone: +1 630-363-1389
			dstanley@arubanetworks.com
Abstract:	This document is the combined session agenda for the stated IEEE 802.11 Working Group session, including (directly or 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™

" Setting the Standards for Wireless LANs ... "

www.ieee802.org/11

Adrian Stephens - Chair IEEE 802.11 WLANS Working Group adrian.p.stephens@ieee.org

Jon Rosdahl - Vice-Chair IEEE 802.11 WLANS Working Group jrosdahl@ieee.org

Dorothy Stanley - Vice-Chair IEEE 802.11 WLANS Working Group dstanley@arubanetworks.com

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.html
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

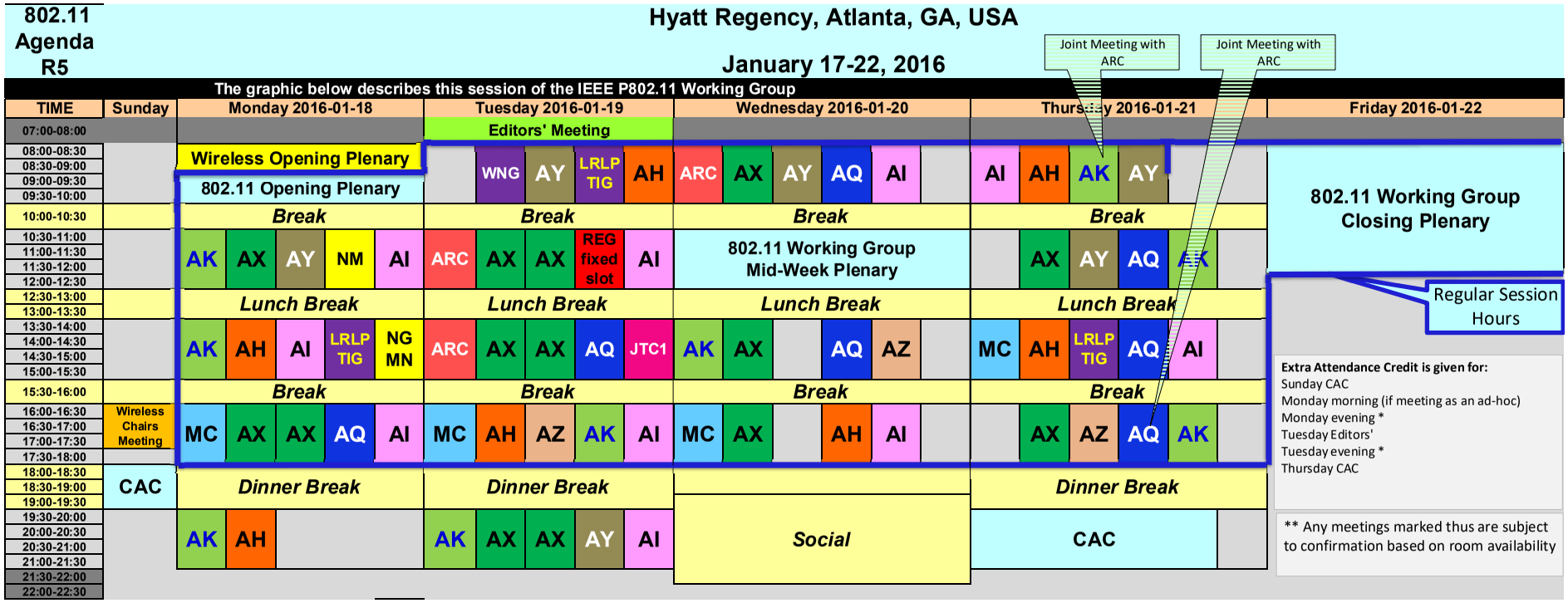
WG Session Reports	
WG Agenda	https://mentor.ieee.org/802.11/dcn/11-15-1485
Opening report	https://mentor.ieee.org/802.11/dcn/11-15-1486
Snapshots	https://mentor.ieee.org/802.11/dcn/11-15-1526
1st vice chair	https://mentor.ieee.org/802.11/dcn/11-15-1524
2nd vice chair	https://mentor.ieee.org/802.11/dcn/11-15-1527
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
Joint Meeting with ARC
Joint Meeting with ARC
The graphic below describes this session of the IEEE P802.11 Working Group
TIME
Sunday
Monday 2016-01-18
Tuesday 2016-01-19
Wednesday 2016-01-20
Thursday 2016-01-21
Friday 2016-01-22
07:00-08:00
08:00-08:30
08:30-09:00
09:00-09:30
09:30-10:00
10:00-10:30
10:30-11:00
11:00-11:30
11:30-12:00
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19:30-20:00
20:00-20:30
20:30-21:00
21:00-21:30
21:30-22:00
22:00-22:30
Editors' Meeting
Wireless Opening Plenary
802.11 Opening Plenary
Break
Lunch Break
Break
Dinner Break
Wireless Chairs Meeting
CAC
AK AX AY NM AI
AK AH AI LRLP TIG NG MN
MC AX AX AQ AI
AK AH
WNG AY LRLP TIG AH
ARC AX AX REG fixed slot AI
ARC AX AX AQ JTC1
MC AH AZ AK AI
AK AX AX AY AI
802.11 Working Group Mid-Week Plenary
Social
AI AH AK AY
AX AY AQ AK
MC AH LRLP TIG AQ AI
AX AZ AQ AK
CAC
802.11 Working Group Closing Plenary
Regular Session Hours
Extra Attendance Credit is given for:
Sunday CAC
Monday morning (if meeting as an ad-hoc)
Monday evening *
Tuesday Editors'
Tuesday evening *
Thursday CAC
** Any meetings marked thus are subject to confirmation based on room availability

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

English | Simplified Chinese (简体中文)

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APPENDIX N

Wi-Fi 6

Protocol and Network

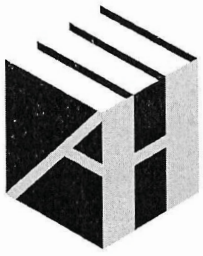
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Wi-Fi 6

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 O

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!

Add new comment

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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.

Reply

Add new comment

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About text formats

SAVE PREVIEW



Craig Mathias

Farpoint Group

Craig J. Mathias is a Principal with Farpoint Group, an advisory firm specializing in wireless networking and mobile computing. Founded in 1991, Farpoint Group works with technology developers, manufacturers, carriers and operators, enterprises, and the financial community. Craig is an internationally-recognized industry and technology analyst, consultant, conference speaker, author, columnist, and blogger. He regularly writes for *Network World, CIO.com,* and *TechTarget*. Craig holds an Sc.B. degree in Computer Science from Brown University, and is a member of the Society of Sigma Xi and the IEEE.

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APPENDIX P

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.

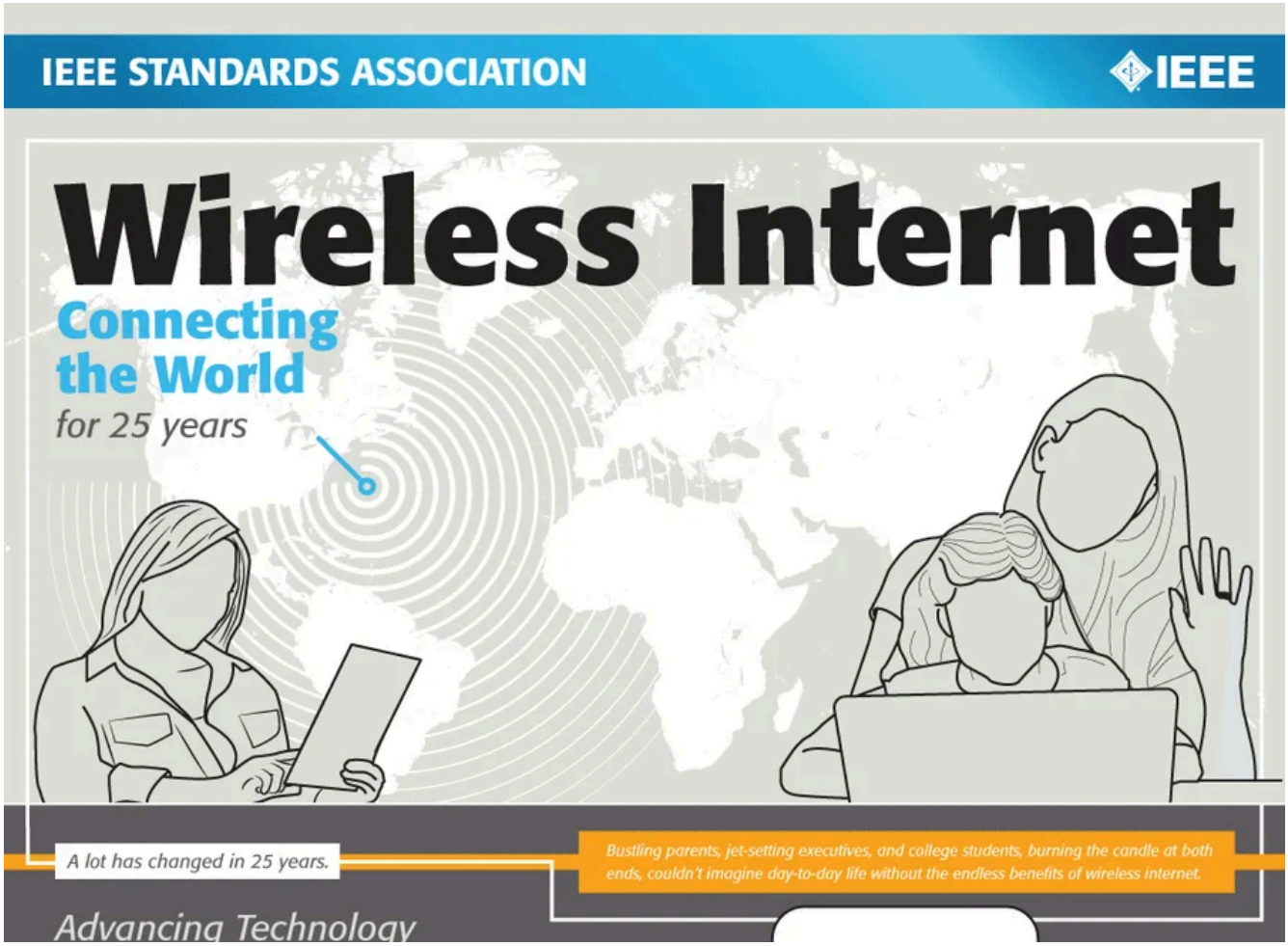
Here, the data rates are in the hundreds of kilobits range rather than in the hundreds of megabits range. But because you're operating at sub-one-gigahertz, the range is longer. The transmission range is up to a kilometer. For most smart grid or Internet of Things applications, a kilometer is more than 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.

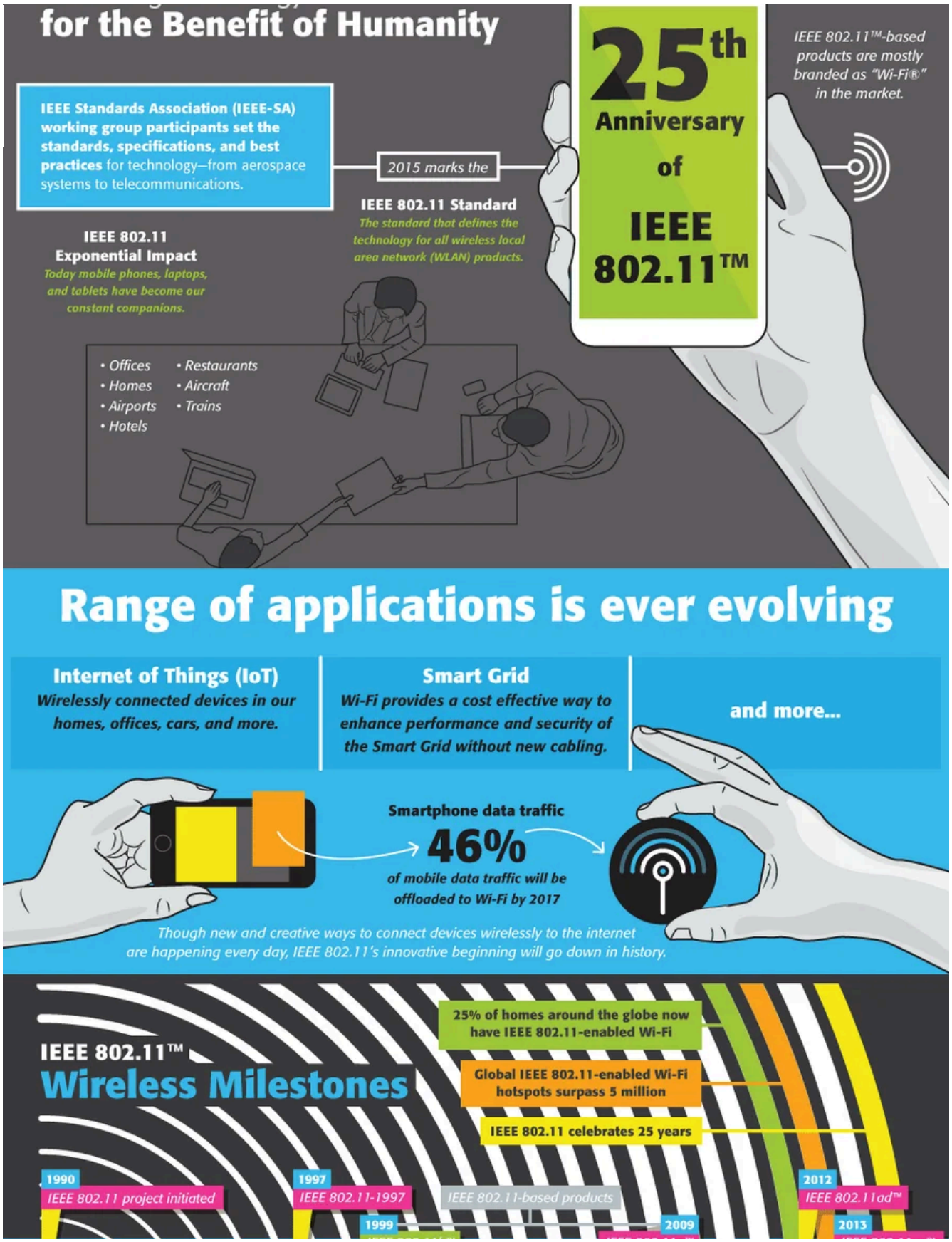
IEEE Spectrum: Why do you think the IEEE 802.11 Working Group process has been successful over the past 25 years? And do you expect the process to continue working well in the future?

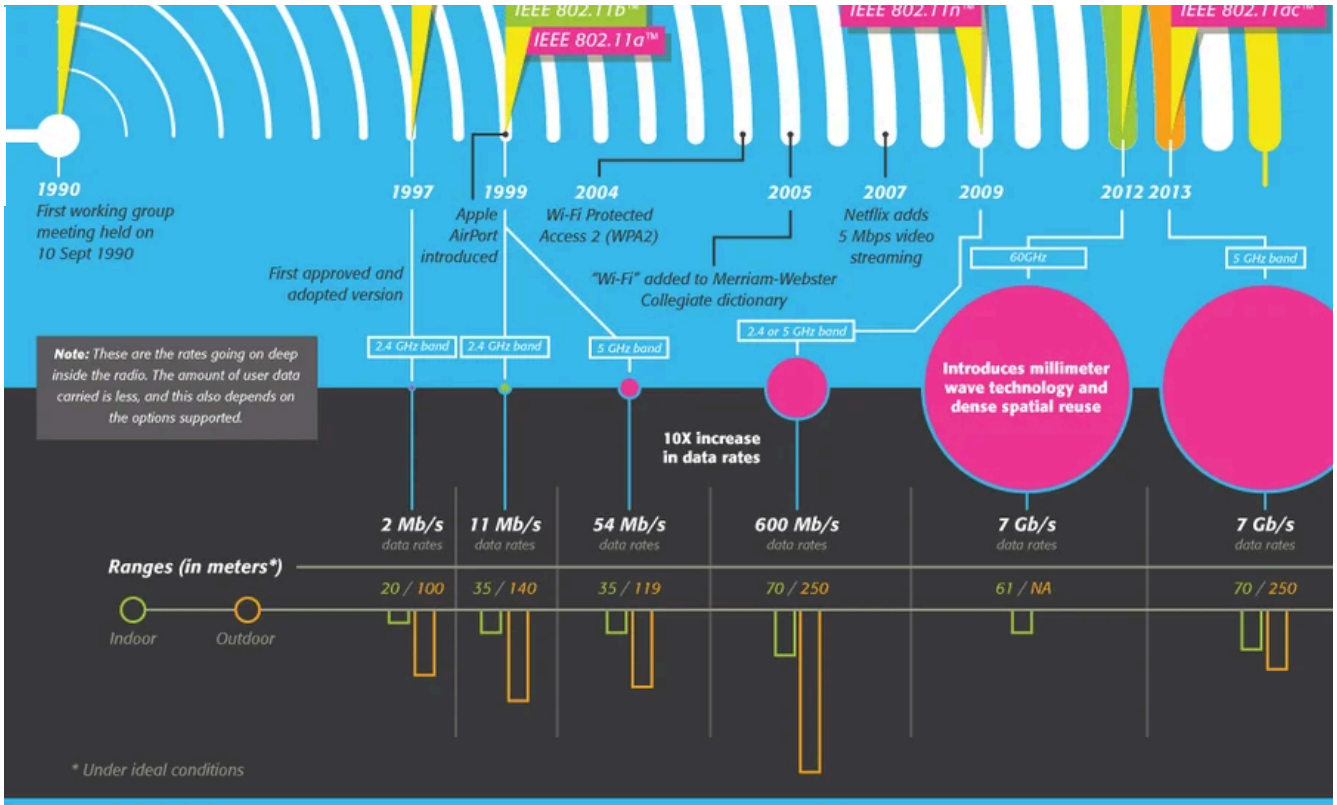
Dorothy Stanley: There is a very open, global and collaborative consensus process in place. The benefit is that you can have any people come who have technology or information to contribute. You don't have to be associated with a government; people come from new companies, established companies and academia 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.




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25th Anniversary of IEEE 802.11™
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IEEE 802.11 Standard
The standard that defines the technology for all wireless local area network (WLAN) products.
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™
Wireless Milestones
25% of homes around the globe now have IEEE 802.11-enabled Wi-Fi
Global IEEE 802.11-enabled Wi-Fi hotspots surpass 5 million
IEEE 802.11 celebrates 25 years
1990
IEEE 802.11 project initiated
1997
IEEE 802.11-1997
1999
IEEE 802.11-based products
2009
2012
IEEE 802.11ad™
2013



TODAY'S IEEE 802.11-ENABLED WI-FI PROVIDES ONLY A GLIMPSE OF

WHAT WILL BE POSSIBLE IN FUTURE GENERATIONS OF WIRELESS TECHNOLOGY.

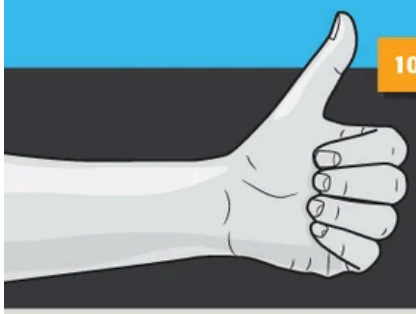
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IEEE P802.11ai™	IEEE P802.11ah™	IEEE P802.11ax™	IEEE P802.11ay™	IEEE P802.11az™
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Reduces linking time to an interesting network	Support for 900 MHz operation	High-efficiency wireless LAN improving throughput, range, and efficiency in the 1-6 GHz bands	Next-generation 60 GHz improving throughput, range, and reliability	Next generation positioning refining and extending support

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APPENDIX Q

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].

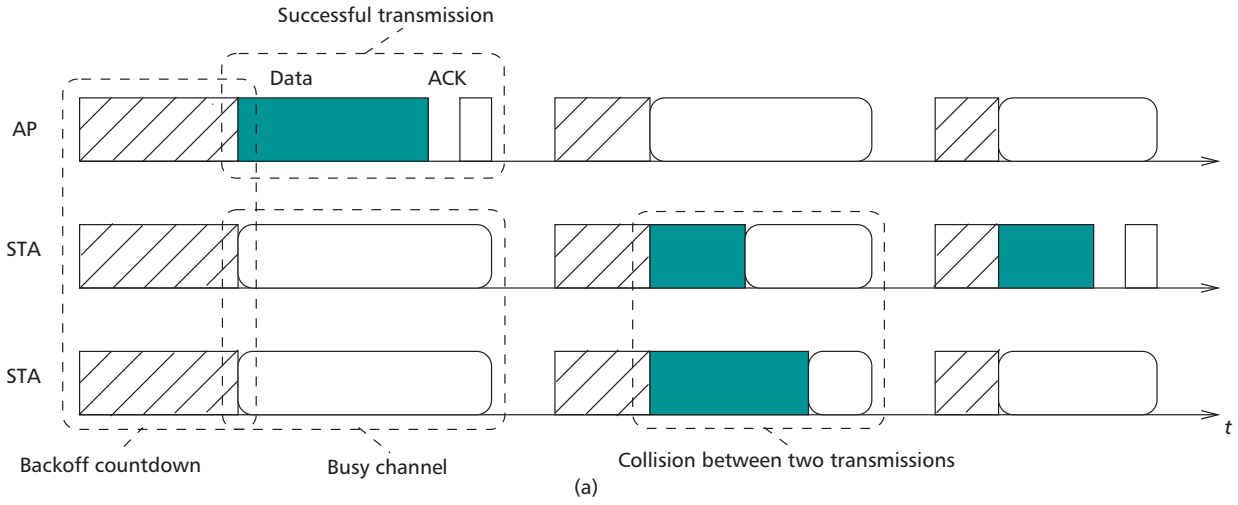
One of the most representative characteristics of WLANs is the use of carrier sense multiple access with collision avoidance (CSMA/CA) as the MAC protocol. It offers a reasonable trade-off between performance, robustness, and implementation costs. Using CSMA/CA, when a node has a packet ready for transmission, 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 m ²)	> 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.

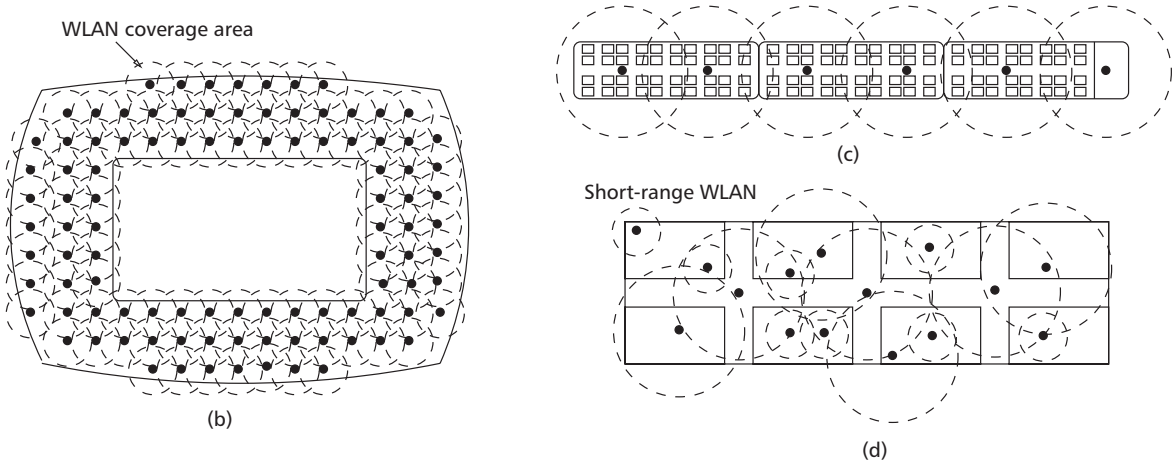


Figure 1. Key scenarios in next-generation WLANs: a) example of CSMA/CA temporal evolution with one AP and two STAs; b) stadium; c) train; d) floor of a building with several apartments.

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

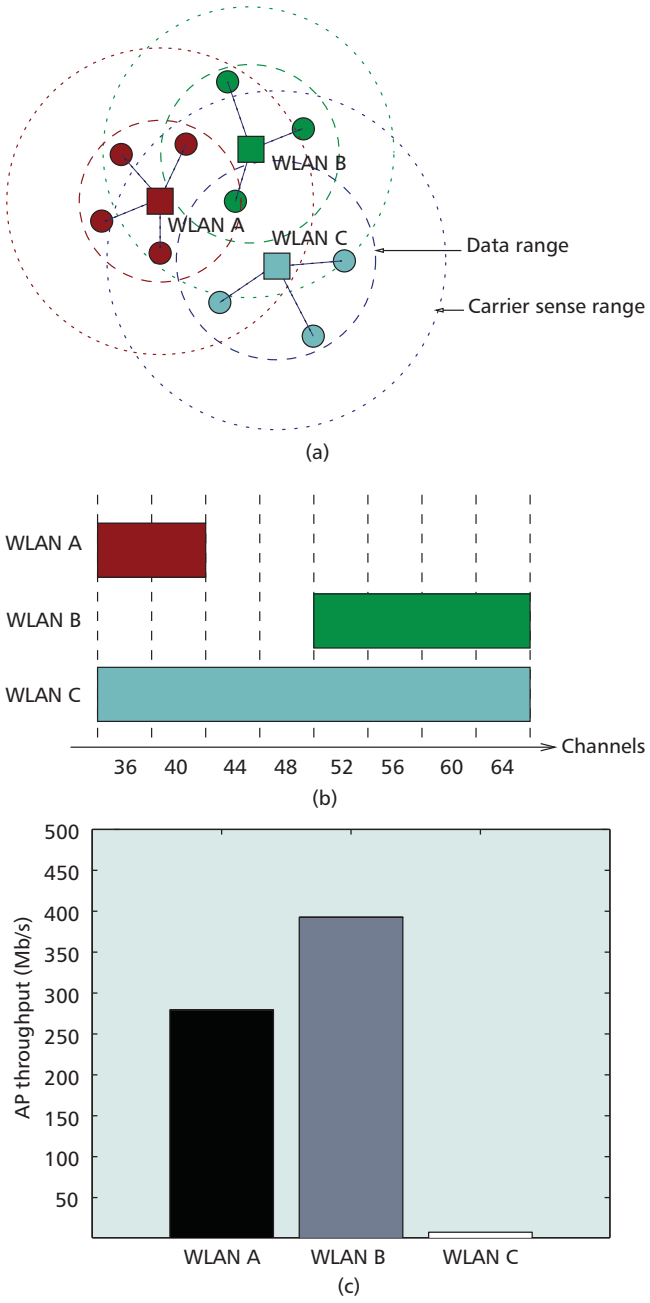


Figure 2. Throughput unfairness between overlapping WLANs: a) three overlapping WLANs; b) channel used by each WLAN; c) throughput achieved by each WLAN.

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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.

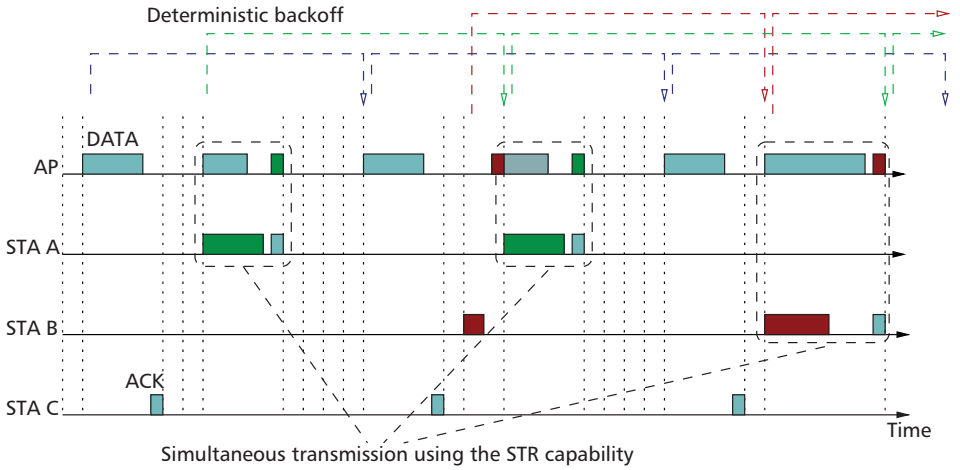


Figure 3. CSMA/ECA operation. It can be observed how the use of a deterministic backoff allows prediction of when a node will transmit again after successful transmission.

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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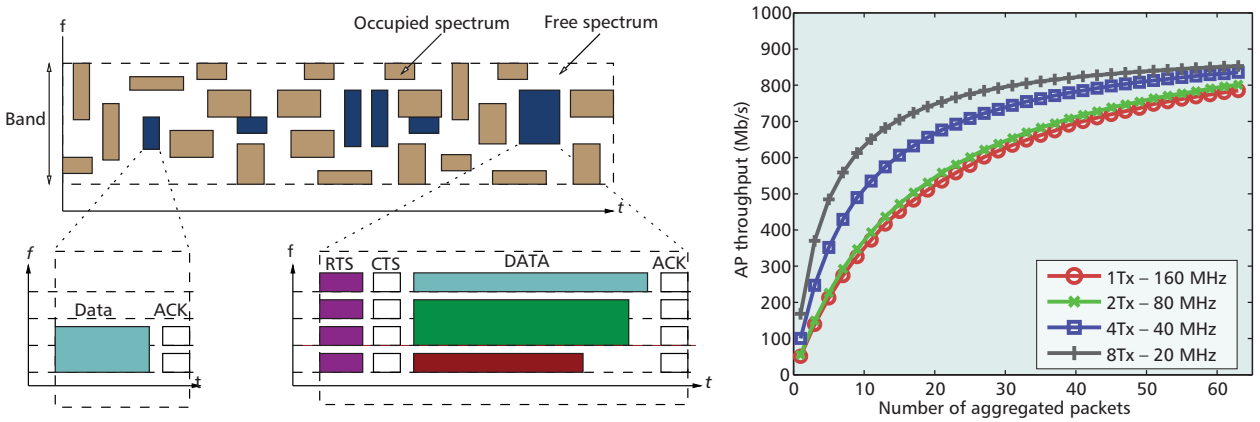


Figure 4. Dynamic spectrum access with and without OFDMA: a) dynamic channel bonding and OFDMA; b) achievable downlink throughput using a channel width of 160 MHz and OFDMA. The RTS size is $120 + 56 \cdot N_{tx}$ bits, with N_{tx} the number of OFDMA subchannels.

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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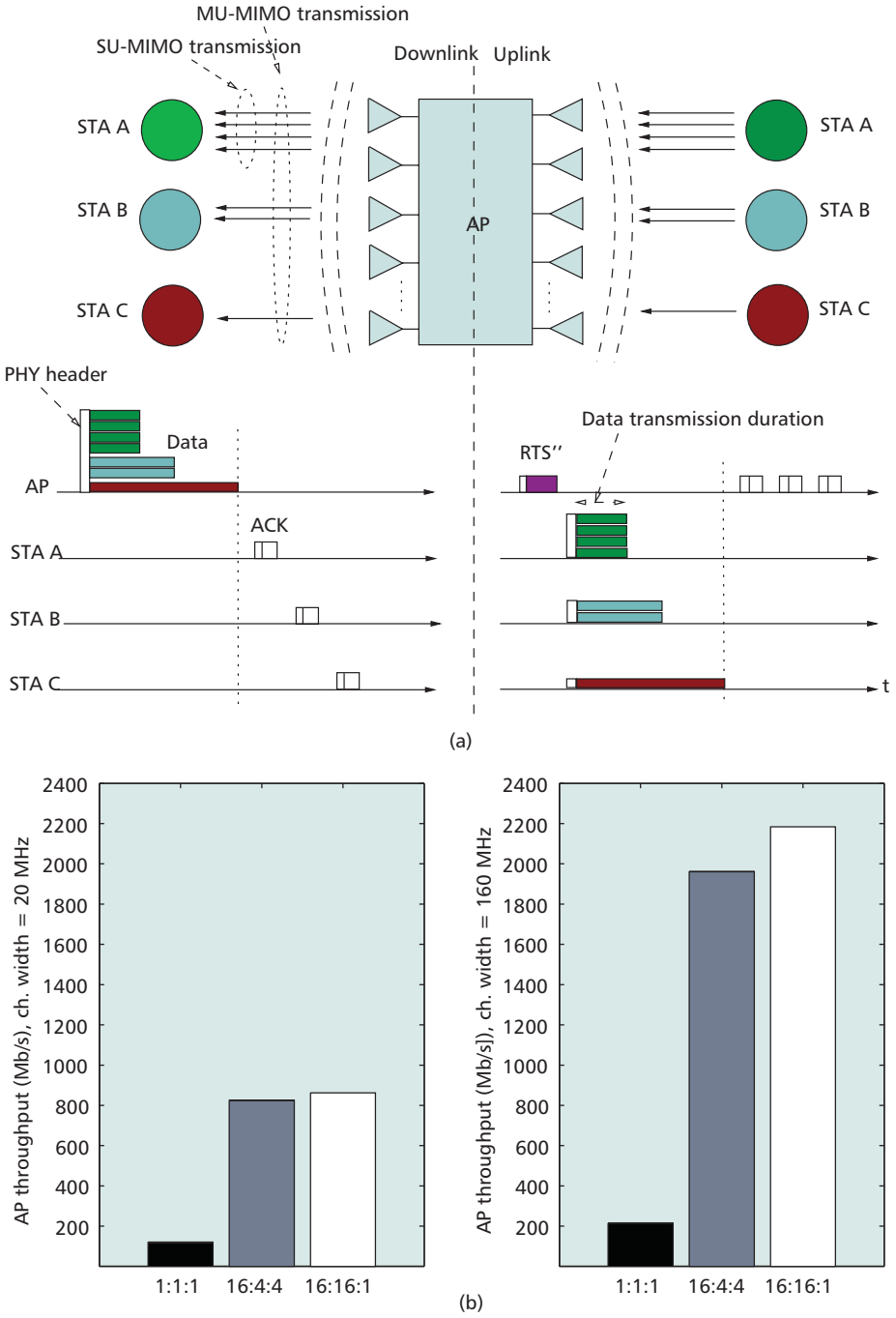
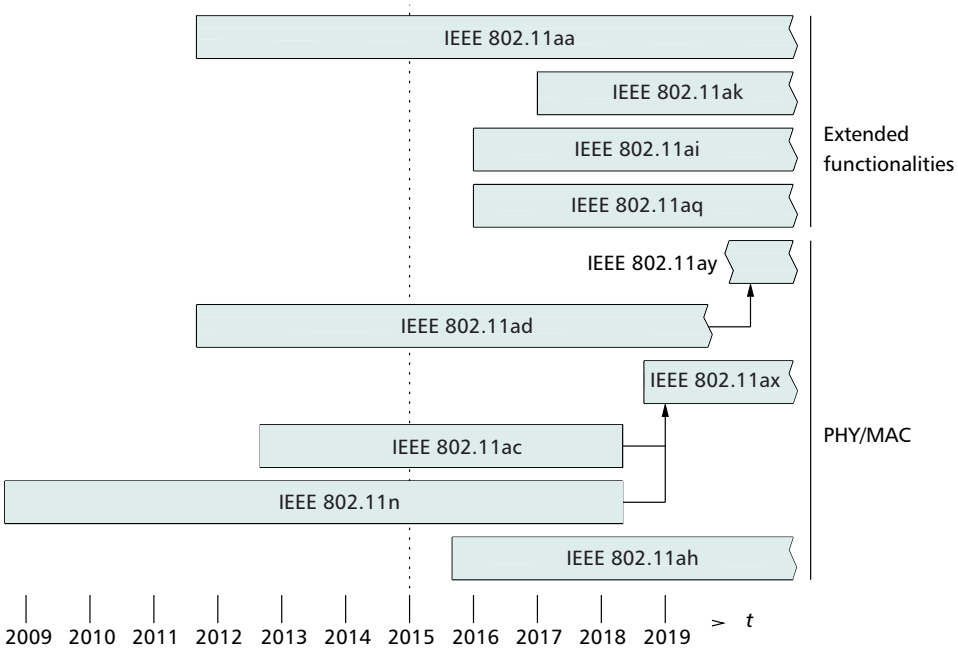


Figure 5. Multi-user spatial multiplexing: a) downlink and uplink MU-MIMO transmissions in WLANs; b) downlink throughput. The AP is equipped with 16 antennas. Each configuration is identified by the code x:y:z, where x refers to the total number of transmitted spatial streams, y the number of destinations, 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-

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.

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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 R



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.

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.

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

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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 transmissionrange,relayoperationis 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.

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APPENDIX S

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 Initial	WG Letter Ballots: Date Predicted	WG Letter Ballots: Result Recirc	Form Standards Association (SA) Ballot Pool / Reform	MEC / MDR Done	IEEE SA Ballots: Draft Initial	IEEE SA Ballots: Date Predicted	IEEE SA Ballots: Result Recirc	Final 802.11 WG Approval	Final or Conditional 802 LMSC Approval	RevCom & Standards Board Final or Continuous Process Approval	ANSI Approved	Sup Wit Sta B
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			

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 B
					2022 802.11bb-2023 802.11bc-2023 802.11-2020/Cor2-2024 802.11me 802.11bh 802.11be	Predicted	C	C	C		C	C	C	C		C	C	Sep 2025	N/A	
IEEE Std P802.11bi	A	Enhanced Data Privacy	TGbi	PDF D1.10	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	Actual	2021-02-10 [2025-12-31]	D1.0	2025-02-27	89%										
						Predicted	C	C	Jul 2025		Sep 2025	Jul 2025	Jan 2026	Mar 2026		May 2026	May 2026	Jul 2026	N/A	
IEEE Std P802.11me	A	802.11 Accumulated Maintenance Changes	TGme	PDF D7.00	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	Actual	2021-02-10 [2025-12-31]	D1.0 D2.0 D3.0 D4.0	2022-01-10 2022-11-11 2023-05-07 2023-08-30	84% 87% 93% 96%		2023-05-01	2023-07-01	D4.0 D5.0 D6.0 D7.0	2023-10-10 2024-03-05 2024-07-02 2024-08-08	85% 84% 93% 98%	2024-07-01	2024-07-01			
						Predicted	C	C	C		C	C	C	C		C	C	Sep 2024	N/A	
IEEE Std P802.11bh	A	Randomized and Changing MAC Addresses	TGbh	PDF D6.00	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	Actual	2021-02-10 [2025-12-31]	D1.0 D2.0 D3.0 D4.0	2023-07-01 2024-01-05 2024-02-24 2024-04-06	92% 94% 98% 99%		2024-02-01	2024-03-01	D4.0 D5.0 D6.0	2024-05-09 2024-07-13 2024-08-15	91% 92% 98%	2024-07-01	2024-07-01			
						Predicted	C	C	C		C	C	C	C		C	C	Sep 2024	N/A	
IEEE Std P802.11bf	A	WLAN Sensing	TGbf	PDF D8.00	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	Actual	2020-09-25 [2026-12-31]	D1.0 D2.0 D3.0 D4.0	2023-03-02 2023-08-20 2024-01-04 2024-04-26	78% 86% 93% 96%		2024-04-01	2024-03-01	D4.0 D5.0 D6.0 D7.0 D8.0	2024-06-12 2024-10-23 2024-12-11 2025-01-16 2025-04-04	90% 96% 97% 98% 98%	2025-03-12	2025-03-14			
						Predicted	C	C	C		C	C	C	C		C	C	Jun 2025	N/A	
IEEE Std P802.11be	A	Extremely High Throughput	TGbe	PDF D7.00	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	Actual	2019-03-21 [2025-12-31]	D2.0 D3.0 D4.0 D5.0	2022-07-04 2023-03-02 2023-08-13 2023-12-16	64% 80% 90% 95%		2023-10-01	2023-09-01	D5.0 D6.0 D7.0	2024-02-02 2024-05-31 2024-08-10	82% 93% 97%	2024-07-01	2024-07-01			
						Predicted	C	C	C		C	C	C	C		C	C	Sep 2024	N/A	

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: Predicted Recirc	WG Letter Ballots: Form SA Ballot Pool / Reform	WG Letter Ballots: MEC / MDR Done	IEEE SA Ballots: Draft: Predicted Initial	IEEE SA Ballots: Date: Predicted Recirc	IEEE SA Ballots: Result: Predicted Recirc	Final 802.11 WG Approval	Final or Conditional 802 LMSC Approval	RevCom & Standards Board Final or Continuous Process Approval	ANSI Approved	P
IEEE Std P802.11-2020/Cor2-2024	COR	Correct 802.11bc identifer of EBCS ANQP element	WG Tech Ed	PDF D1.00	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	Actual	2023-07-20 [2024-07-20]	D1.0	2023-10-25	100%	2023-10-01	2023-11-01	D1.0	2023-12-28	100%	2023-11-17	2024-01-09	2024-01-01		20
IEEE Std P802.11bc-2023	A	Enhanced Broadcast Service	TGbc	PDF D7.00	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	Actual	2018-12-05 [2022-12-31]	D1.0 D2.0 D3.0 D4.0	2020-12-20 2021-10-28 2022-04-28 2022-08-25	83% 90% 92% 95%	2022-09-01	2022-07-01	D4.0 D5.0 D6.0 D7.0	2022-11-04 2023-01-13 2023-02-21 2023-03-13	92% 97% 100% 100%	2023-03-01	2023-03-01	2023-06-01		20
IEEE Std P802.11bb-2023	A	Light Communications	TGbb	PDF D7.00	802.11-2020 802.11ax-2021 802.11ay-2021 802.11ba-2021 802.11-2020/Cor1-2022 802.11az-2022 802.11bd-2022	Actual	2018-03-09 [2022-12-31]	D1.0 D2.0 D3.0 D4.0	2022-01-12 2022-04-22 2022-08-31 2022-10-01	87% 94% 95% 99%	2022-03-01	2022-03-01	D4.1 D5.0 D6.0 D7.0	2022-11-07 2023-01-14 2023-02-21 2023-03-14	91% 92% 96% 100%	2023-03-01	2023-03-01	2023-06-01		20
IEEE Std P802.11bd-2022	A	Enhancements for Next Generation V2X	TGbd	PDF D8.00	802.11-2020 802.11ax-2021 802.11ay-2021 802.11ba-2021 802.11-2020/Cor1-2022 802.11az-2022	Actual	2018-12-05 [2022-12-31]	D1.0 D2.0 D3.0 D4.0	2020-11-18 2021-08-01 2021-12-16 2022-03-30	82% 88% 94% 99%	2021-12-02	2022-03-01	D4.0 D5.0 D6.0 D7.0 D8.0	2022-05-09 2022-07-05 2022-08-30 2022-09-30 2022-10-14	92% 93% 95% 97% 97%	2022-09-16	2022-10-04	2022-12-01		20
IEEE Std P802.11az-2022	A	Next Generation Positioning	TGaz	PDF D7.00	802.11-2020 802.11ax-2021 802.11ay-2021 802.11ba-2021 802.11-2020/Cor1-2022	Actual	2015-09-03 [2023-12-31]	D1.0 D2.0 D3.0 D4.0 D4.0	2019-03-09 2020-01-03 2021-02-10 2021-09-07 2021-10-01	79% 87% 88% 95% 98%	2021-08-01	2021-07-01	D4.0 D5.0 D6.0 D7.0	2021-11-05 2022-06-09 2022-09-07 2022-09-29	93% 94% 99% 100%	2022-09-16	2022-10-04	2022-12-01		20
IEEE Std P802.11-2020/Cor1-2022	COR	Correct 802.11ay Assignment of Protected Announce Support Bit	WG Tech Ed	PDF D2.10	802.11-2020 802.11ax-2021 802.11ay-2021 802.11ba-2021	Actual	2022-02-23 [2026-12-31]	D1.0 D2.1	2022-04-14 2022-06-01	99% 100%	2022-05-01	2022-06-01	D2.1	2022-07-08	100%	2022-07-01	2022-07-01	2022-09-21		20
IEEE Std P802.11ba-2021	A	Wake Up Radio	TGba	PDF D8.00	802.11-2020 802.11ax-2021 802.11ay-2021	Actual	2016-12-07 [2020-12-31]	D1.0 D2.0 D3.0 D4.0 D5.0 D6.0	2018-10-24 2019-03-03 2019-06-18 2019-10-15 2019-12-17 2020-02-01	72% 82% 84% 90% 96% 99%	2019-08-01	2019-11-01	D6.0 D7.0 D8.0	2020-03-18 2020-10-01 2020-12-21	91% 95% 98%	2020-11-01	2020-11-01	2021-03-01		20
IEEE Std P802.11ay-2021	A	Next Generation 60GHz	TGay	PDF D7.00	802.11-2020 802.11ax-2021	Actual	2015-03-26 [2021-12-31]	D1.0 D2.0 D3.0 D4.0 D5.0	2018-01-07 2018-08-31 2019-02-28 2019-07-08 2019-11-08	74% 93% 93% 98% 99%	2019-06-01	2019-07-16	D5.0 D6.0 D7.0	2020-01-09 2020-09-29 2020-12-20	89% 92% 98%	2020-11-01	2020-11-01	2021-03-01		20
IEEE Std P802.11ax-2021	A	High Efficiency WLAN	TGax	PDF D8.00	802.11-2020	Actual	2014-03-27 [2020-12-31]	D1.0 D2.0 D3.0 D4.0 D5.0 D6.0	2017-01-08 2017-11-04 2018-07-01 2019-02-25 2019-10-24 2019-12-11	58% 63% 87% 92% 94% 97%	2019-09-01	2019-05-01	D6.0 D7.0 D8.0	2020-01-24 2020-09-17 2020-11-27	82% 88% 95%	2020-09-01	2020-11-01	2021-02-01		20
IEEE Std P802.11-2020	STD	802.11 Accumulated Maintenance Changes	TGmd	PDF D5.00	802.11-2016	Actual	2017-03-23 [2021-12-31]	D1.0 D2.0 D3.0	2018-03-17 2019-01-10 2019-10-30	85% 93% 96%	2019-09-01	2019-05-01	D3.0 D4.0 D5.0 D7.0	2019-12-15 2020-09-04 2020-10-04 2024-08-08	83% 91% 97% 98%	2020-09-01	2020-10-01	2020-12-01		20

SUPERSEDED OR WITHDRAWN - 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: Predicted Recirc	WG Letter Ballots: Form SA Ballot Pool / Reform	WG Letter Ballots: MEC / MDR Done	IEEE SA Ballots: Draft: Predicted Initial	IEEE SA Ballots: Date: Predicted Recirc	IEEE SA Ballots: Result: Predicted Recirc	Final 802.11 WG Approval	Final or Conditional 802 LMSC Approval	RevCom & Standards Board Final or Continuous Process Approval	ANSI Approved	Su W S
IEEE Std P802.11aq-2018	A	Pre-Association Discovery	TGaq	PDF D14.00	802.11-2016 802.11ai-2016 802.11-2020 802.11ah-2016 802.11aj-2018 802.11ak-2018	Actual	2012-12-05 [2018-12-31]	D1.0 D3.0 D4.0 D5.0 D6.0 D7.0	2015-03-04 2015-11-07 2016-04-21 2016-07-19 2016-08-19 2016-09-25	73% 93% 93% 93% 96% 97%	2016-08-01	2016-06-01	D7.0 D8.0 D9.0 D10.0 D12.0 D13.0 D14.0 D14.0	2016-11-04 2017-03-18 2017-06-23 2017-07-29 2017-10-01 2017-10-30 2018-01-04 2018-01-31	88% 91% 94% 98% 97% 97% 98% 99%	2018-03-07	2018-03-09	2018-06-14		2
IEEE Std P802.11ak-2018	A	General Link	TGak	PDF D6.00	802.11-2016 802.11ai-2016 802.11-2020 802.11ah-2016 802.11aj-2018	Actual	2012-12-05 [2018-12-31]	D1.0 D2.0 D3.0 D4.0	2015-05-06 2016-03-10 2017-01-10 2017-03-30	85% 91% 94% 95%	2016-11-01	2016-11-01	D4.0 D5.0 D6.0	2017-05-11 2017-11-09 2018-01-01	90% 93% 97%	2018-01-19	2018-01-31	2018-03-08		2
IEEE Std P802.11aj-2018	A	China Millimeter Wave	TGaj	PDF D9.00	802.11-2016 802.11ai-2016 802.11-2020 802.11ah-2016	Actual	2012-08-01 [2018-12-31]	D1.0 D2.0 D3.0 D4.0 D5.0	2016-01-20 2016-06-30 2016-08-30 2016-12-21 2017-03-04	88% 89% 89% 92% 95%	2017-01-01	2016-11-01	D6.0 D7.0 D8.0 D9.0 D14.0	2017-06-25 2017-08-04 2017-08-24 2017-12-17 2018-01-04	98% 100% 100% 100% 98%	2017-11-10	2017-11-10	2018-01-24		2
IEEE Std P802.11-2016	STD	802.11 Accumulated Maintenance Changes	TGmc	PDF D8.00	802.11-2012 802.11ae-2012 802.11aa-2012 802.11ad-	Actual	2012-08-30 [2016-12-31]	D1.0 D2.0 D3.0 D4.0 D4.0	2013-03-02 2013-10-23 2014-06-23 2015-02-17 2015-03-26	88% 90% 90% 94% 96%	2014-09-01	2014-07-01	D4.0 D5.0 D6.0 D7.0 D8.0	2015-04-26 2016-01-26 2016-06-30 2016-08-20 2016-09-08	88% 90% 93% 97% 99%	2016-09-01	2016-10-01	2016-12-07		2

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 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	Su W S
					2012 802.11ac-2013 802.11af-2013															
IEEE Std P802.11ah-2016	A	Sub 1 GHz	TGah	PDF D10.00	802.11-2016 802.11ai-2016 802.11-2020	Actual	2010-10-04 [2016-12-31]	D1.0 D2.0 D3.0 D4.0 D5.0 D5.0	2013-11-04 2014-07-05 2014-10-25 2015-02-14 2015-04-16 2015-10-03	73% 83% 90% 93% 93% 98%	2015-04-01	2016-02-01	D5.0 D6.0 D7.0 D8.0 D9.0 D10.0	2015-11-05 2016-03-02 2016-04-14 2016-05-17 2016-09-09 2016-09-30	91% 91% 92% 95% 95% 96%	2016-09-01	2016-10-01	2016-12-07		2
IEEE Std P802.11ai-2016	A	Fast Initial Link Setup	TGai	PDF D11.00	802.11-2016	Actual	2010-12-08 [2016-12-31]	D1.0 D2.0 D3.0 D4.0 D5.0 D6.0	2013-09-12 2014-05-07 2014-10-14 2015-02-24 2015-06-26 2015-07-31	74% 85% 88% 90% 92% 97%	2015-03-01	2014-11-01	D6.0 D7.0 D8.0 D9.0 D9.0 D11.0	2015-09-15 2016-03-30 2016-07-13 2016-08-06 2016-09-09 2016-09-30	90% 89% 93% 95% 97% 95%	2016-09-01	2016-10-01	2016-12-07		2
IEEE Std P802.11af-2013	A	TV White Spaces	TGaf	PDF D6.00	802.11-2012 802.11ae-2012 802.11aa-2012 802.11ad-2012 802.11ac-2013	Actual	2009-12-09 [2013-12-31]	D1.0 D2.0 D3.0 D4.0 D5.0 D5.0	2011-02-24 2012-08-19 2013-02-08 2013-04-17 2013-06-14 2013-08-01	62% 79% 87% 92% 94% 99%	2013-06-01	2013-11-01	D5.0 D6.0 D6.0	2013-09-11 2013-10-19 2013-10-30	97% 99% 99%	2013-11-01	2013-11-01	2013-12-11		2
IEEE Std P802.11ac-2013	A	Very High Throughput 6GHz	TGac	PDF D7.00	802.11-2012 802.11ae-2012 802.11aa-2012 802.11ad-2012	Actual	2008-09-26 [2012-12-31]	D1.0 D2.0 D3.0 D4.0 D5.0 D5.0	2011-06-25 2012-02-18 2012-06-25 2012-11-01 2013-02-01 2013-04-04	74% 89% 91% 94% 95% 96%	2013-01-01	2013-01-01	D5.0 D6.0 D7.0	2013-05-05 2013-08-03 2013-10-23	93% 97% 99%	2013-11-01	2013-11-01	2013-12-09		2
IEEE Std P802.11ad-2012	A	Very High Throughput 60GHz	TGad	PDF D9.00	802.11-2012 802.11ae-2012 802.11aa-2012	Actual	2008-12-10 [2012-12-31]	D1.0 D2.0 D3.0 D4.0 D5.0 D5.0	2010-10-24 2011-04-05 2011-06-01 2011-08-09 2011-10-06 2011-11-24	87% 88% 92% 95% 94% 95%	2011-09-01	2011-07-01	D5.0 D6.0 D7.0 D8.0 D9.0 D9.0	2012-01-05 2012-03-30 2012-05-11 2012-06-16 2012-07-28 2012-08-12	86% 90% 95% 97% 98% 98%	2012-07-01	2012-07-01	2012-10-23		2
IEEE Std P802.11aa-2012	A	Video Transport Streams	TGaa	Word / PDF D9.00	802.11-2012 802.11ae-2012	Actual	2008-03-27 [2012-12-31]	D1.0 D2.0 D3.0 D4.0 D5.0 D6.0 D6.0	2010-07-10 2010-12-08 2011-02-24 2011-04-09 2011-06-17 2011-08-09 2011-08-31	78% 79% 81% 85% 90% 94% 95%	2011-06-30	2011-06-16	D6.0 D7.0 D8.0 D9.0	2011-10-12 2011-11-26 2012-01-02 2012-01-27	93% 96% 99% 100%	2012-01-28	2012-02-17	2012-06-01		2
IEEE Std P802.11ae-2012	A	Prioritization of Management Frames	TGae	PDF D8.00	802.11-2012	Actual	2009-12-09 [2010-10-15]	D1.0 D2.0 D3.0 D4.0 D5.0	2010-10-27 2011-02-18 2011-04-26 2011-06-18 2011-08-04	81% 86% 89% 96% 96%	2011-07-01	2011-05-01	D5.0 D6.0 D7.0 D8.0	2011-09-09 2011-10-29 2011-12-13 2012-01-04	95% 96% 100% 100%	2012-01-20	2012-02-17	2012-03-01		2
IEEE Std P802.11-2012	STD	802.11 Accumulated Maintenance Changes	TGmb	Frame / PDF D9.01	802.11-2007 802.11k-2008 802.11r-2008 802.11y-2008 802.11w-2009 802.11n-2009 802.11p-2010 802.11z-2010 802.11v-2011 802.11u-2011 802.11s-2011	Actual	2007-03-22 [2011-12-31]	D1.0 D2.0 D3.0 D4.0 D5.0	2009-06-27 2010-01-08 2010-04-25 2010-06-25 2010-08-19	87% 89% 89% 89% 92%	2010-09-14	2010-09-01	D6.0 D7.0 D8.0 D9.0 D10.0 D11.0 D12.0	2010-11-05 2011-02-18 2011-04-14 2011-06-22 2011-09-07 2011-10-22 2011-11-13	87% 90% 92% 93% 92% 94% 97%	2011-11-11	2011-11-11	2012-03-01		2
IEEE Std P802.11s-2011	A	Mesh Networking	TGs	PDF	802.11-2007 802.11k-2008 802.11r-2008 802.11y-2008 802.11w-2009 802.11n-2009 802.11p-2010 802.11z-2010 802.11v-2011 802.11u-2011	Actual	2004-05-13 [2010-12-31]	D1.0 D2.0 D3.0 D4.0 D5.0 D6.0 D7.0	2007-01-06 2008-05-03 2009-05-04 2010-01-08 2010-04-15 2010-06-28 2010-08-13	48% 61% 79% 85% 89% 89% 95%	2010-09-12	2010-09-29	D7.0 D8.0 D9.0 D10.0 D11.0	2010-11-01 2011-01-10 2011-03-05 2011-04-05 2011-05-07	95% 96% 95% 97% 97%	2011-07-01	2011-07-01	2011-08-01		2
IEEE Std P802.11u-2011	A	InterWorking with External Networks	TGu	Frame / PDF D13.00	802.11-2007 802.11k-2008 802.11r-2008 802.11y-2008 802.11w-2009 802.11n-2009 802.11p-2010 802.11z-2010 802.11v-2011	Actual	2004-12-08 (02/05/2008) [2010-12-31]	D1.0 D2.0 D3.0 D4.0 D5.0 D6.0 D7.0 D8.0	2007-07-08 2008-03-15 2008-07-12 2008-10-08 2009-02-20 2009-04-24 2009-06-19 2009-08-18	64% 70% 77% 78% 82% 90% 88% 93%	2009-06-01	2009-07-12	D8.0 D9.0 D10.0 D11.0 D12.0 D13.0	2009-11-07 2010-04-23 2010-07-08 2010-08-13 2010-09-12 2010-11-21	90% 92% 94% 96% 98% 99%	2010-11-01	2010-11-01	2011-02-25		2
IEEE Std P802.11v-2011	A	Wireless Network Management	TGv	Frame / PDF D16.00	802.11-2007 802.11k-2008 802.11r-2008 802.11y-2008 802.11w-2009 802.11n-2009 802.11p-2010 802.11z-2010	Actual	2004-12-08 [2010-12-31]	D1.0 D2.0 D3.0 D4.0 D5.0 D6.0 D7.0	2007-08-30 2008-03-15 2008-07-13 2008-12-19 2009-04-04 2009-06-12 2009-08-07	63% 67% 69% 81% 83% 90% 92%	2009-06-01	2009-07-12	D7.0 D9.0 D10.0 D11.0 D12.0 D13.0 D14.0 D15.0 D15.0 D16.0	2009-11-07 2010-02-17 2010-04-13 2010-06-10 2010-07-07 2010-07-28 2010-08-25 2010-10-18 2010-09-30 2010-11-15	81% 84% 87% 92% 94% 98% 98% 98% 98% 98%	2010-11-01	2010-11-01	2011-02-09		2
IEEE Std P802.11z-2010	A	Extensions to Direct Link Setup	TGz	Word / PDF D13.00	802.11-2007 802.11k-2008 802.11r-2008 802.11y-2008 802.11w-2009 802.11n-2009 802.11p-2010	Actual	2007-08-22	D1.0 D2.0 D3.0 D4.0 D5.0 D6.0	2008-05-03 2008-08-20 2008-12-18 2009-03-05 2009-06-23 2009-08-26	64% 66% 84% 88% 92% 96%	2009-06-01	2009-06-18	D6.0 D7.0 D8.0 D9.0 D11.0 D13.0	2009-11-07 2010-02-27 2010-05-04 2010-06-10 2010-08-04 2010-08-29	87% 87% 94% 95% 95% 98%	C	C	2010-10-01		2
IEEE Std P802.11p-2010	A	Wireless Access for the Vehicular Environment	TGp	N/A	802.11-2007 802.11k-2008 802.11r-2008 802.11y-2008 802.11w-2009 802.11n-2009	Actual	2004-09-23	D1.0 D2.0 D3.0 D4.0 D5.0 D6.0 D7.0 D8.0 D9.0	2006-04-11 2007-01-05 2007-09-12 2008-05-03 2008-12-05 2009-03-31 2009-06-13 2009-08-05 2009-10-10	59% 67% 74% 79% 85% 89% 85% 89% 93%	2009-06-01	2008-06-19	D9.0 D10.0 D11.0	2009-11-22 2010-02-16 2010-04-07	93% 96% 99%	C	C	2010-07-15		2
IEEE Std P802.11w-2009	A	Protected Management Frames	TGw	N/A	802.11-2007 802.11k-2008 802.11r-2008 802.11y-2008	Actual	2005-03-20	D1.0 D2.0 D3.0 D4.0 D5.0 D6.0	2006-11-19 2007-05-02 2007-10-19 2008-01-05 2008-02-20 2008-04-18	86% 89% 92% 92% 95% 97%	2007-11-13		D6.0 D7.0 D9.0 D10.0 D11.0	2008-09-24 2009-01-18 2009-05-23 2009-06-14 2009-06-28	86% 88% 92% 93% 95%	C	C	2009-09-11		2
IEEE Std P802.11n-2009	A	High Throughput	TGn		802.11-2007 802.11k-2008 802.11r-2008 802.11y-2008 802.11w-2009	Actual	2003-09-11 [2007-09-27]	D1.0 D2.0 D3.0 D4.0 D5.0 D6.0 D7.0 D7.0	2006-04-29 2007-03-09 2007-10-27 2008-04-12 2008-06-12 2008-08-05 2008-09-30 2008-12-02	47% 83% 85% 88% 90% 91% 94% 95%	2008-12-11	2008-12-11	D7.0 D8.0 D9.0 D10.0 D11.0 D11.0	2009-01-10 2009-03-06 2009-04-04 2009-05-30 2009-07-03 2009-06-20	78% 80% 81% 88% 91% 90%	C	C	2009-09-11		2
IEEE Std P802.11y-2008	A	3650-3700 MHz Operation in USA	TGy	N/A	802.11-2007 802.11k-2008 802.11r-2008	Actual	2006-03-16	D1.0 D2.0 D3.0 D4.0 D5.0 D6.0	2007-01-07 2007-05-05 2007-06-20 2007-08-21 2007-10-13 2007-12-08	76% 84% 91% 94% 96% 99%	2007-06-20	2007-07-28	D7.0 D8.0 D9.0 D10.0 D11.0	2008-01-30 2008-03-08 2008-03-27 2008-03-18 2008-06-20	93% 93% 96% 97% 97%	C	C	2008-11-06		2
IEEE Std P802.11r-2008	A	Fast Roaming	TGr	N/A	802.11-2007 802.11k-2008	Actual	2006-05-25	D1.0 D2.0 D3.0 D4.0 D5.0 D6.0	2006-01-04 2006-04-04 2006-10-14 2006-12-04 2007-04-04 2007-06-13	81% 88% 86% 92% 95% 97%		2007-04-11	D7.0 D8.0 D9.0 D9.0	2007-08-30 2007-10-07 2008-02-01 2008-01-17	86% 90% 97% 96%	C	C	2008-05-09		2
IEEE Std P802.11k-	A	Radio Resource	TGk	N/A	802.11-2007	Actual	2002-12-11		2007-09-11 2008-01-05	90% 100%		2007-04-10	D8.0 D9.0	2007-08-13 2007-10-04	90% 89%	C	C	2008-05-09		2

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2008		Measurement						D1.0 D2.0 D3.0 D4.0 D5.0 D6.0 D7.0 D7.0	2004-09-11 2005-03-15 2005-11-12 2006-03-31 2006-09-16 2006-11-16 2007-02-13 2007-05-05	95% 86% 80% 81% 85% 91% 92% 93%			D10.0 D11.0 D12.0 D12.0 D13.0	2007-12-08 2008-01-17 2008-02-14 2008-02-01 2008-03-18	91% 95% 95% 95% 97%					
IEEE Std P802.11-2007	STD	802.11 Standard Maintenance Revision	TGma	N/A	802.11-1999 802.11c 802.11a-1999 802.11b-1999 802.11b Cor1-2001 802.11d-2001 802.11g-2003 802.11h-2003 802.11i-2004 802.11j-2004 802.11e-2005	Actual	2003-03-20 [2003-03-20]	D1.0 D2.0 D3.0 D4.0	2005-05-08 2005-07-17 2005-08-19 2005-09-19	91% 94% 95% 96%	2005-08-21	2005-08-21	D5.0 D6.0 D7.0 D8.0 D9.0	2005-11-20 2006-05-10 2006-07-11 2006-09-09 2006-11-07	86% 90% 91% 96% 96%	2006-11-08	2006-11-08	2007-03-08		2
IEEE Std P802.11.2	RP	Wireless Performance	TGt			Actual	2008-12-31	D1.0	2007-05-16	76%										2
IEEE Std P802.11e-2005	A	MAC Enhancements QoS	TGe	N/A	802.11-1999 802.11c 802.11a-1999 802.11b-1999 802.11b Cor1-2001 802.11d-2001 802.11g-2003 802.11h-2003 802.11i-2004 802.11j-2004	Actual	2000-03-30	D4.0 D5.0 D6.0 D7.0 D8.0	2001-05-15 2002-01-16 2002-07-02 2003-01-08 2003-08-22 2003-12-20 2004-02-15 2004-03-10	0% 55% 49% 83% 97% 89% 93% 94%			D8.0 D9.0 D10.0 D11.0 D12.0 D13.0 D13.0	2004-05-30 2004-08-31 2004-10-08 2004-11-11 2004-12-23 2005-04-16 2005-02-18	85% 87% 92% 95% 96% 99% 96%	2005-07-22	2005-07-22	2005-09-22		2
IEEE Std P802.11j-2004	A	4.9 GHz-5 GHz Operation in Japan	TGj	N/A	802.11-1999 802.11c 802.11a-1999 802.11b-1999 802.11b Cor1-2001 802.11d-2001 802.11g-2003 802.11h-2003 802.11i-2004	Actual	2002-12-11	D1.0 D1.2 D1.3 D1.4	2003-05-12 2004-01-14 2004-03-11 2004-04-20	68% 89% 94% 95%	2004-05-13		D1.5 D1.6	2004-07-02 2004-08-14	88% 96%	C	C	2004-09-23	2005-02-02	2
IEEE Std P802.11i-2004	A	MAC Security Enhancements	TGi	N/A	802.11-1999 802.11c 802.11a-1999 802.11b-1999 802.11b Cor1-2001 802.11d-2001 802.11g-2003 802.11h-2003	Actual	2001-05-30	D3.0 D4.0 D5.0 D6.0 D7.0	2002-05-04 2003-01-12 2003-06-06 2003-08-19 2003-10-09 2003-11-04	77% 76% 78% 87% 92% 95%	2003-08-10		D7.0 D8.0 D9.0 D10.0	2003-12-20 2004-03-12 2004-04-10 2004-05-08	89% 92% 98% 98%	C	C	2004-06-24	2005-02-14	2
IEEE Std P802.11h-2003	A	Spectrum and Transmit Power Management Extensions in the 5 GHz Band in Europe	TGh	N/A	802.11-1999 802.11c 802.11a-1999 802.11b-1999 802.11b Cor1-2001 802.11d-2001 802.11g-2003	Actual	2000-12-07	D2.2	2001-09-03 2002-05-05 2002-09-01 2002-11-01	0% 76% 90% 97%	2002-07-25		D3.0 D3.11 D3.6	2003-02-06 2003-06-26 2003-04-30	92% 98% 96%	C	C	2003-09-11	2003-12-29	2
IEEE Std P802.11g-2003	A	Further Higher Data Rate Extension in the 2.4 GHz Band	TGg	N/A	802.11-1999 802.11c 802.11a-1999 802.11b-1999 802.11b Cor1-2001 802.11d-2001	Actual	2000-09-21	D5.0 D4.0 D6.1	2002-03-11 2002-09-01 2003-01-08 2002-11-01 2003-02-04	45% 83% 88% 87% 89%	2002-07-25		D6.2 D7.1 D8.2	2003-03-09 2003-04-08 2003-05-14	84% 85% 96%	C	C	2003-06-12	2003-10-20	2
IEEE Std P802.11b Cor1-2001	COR	Corrigenda to IEEE 802.11b-1999	TGb-Cor1		802.11-1999 802.11c 802.11a-1999	Actual	1999-11-27						D1.5	2001-04-13	98%	C	C	2001-10-10	2002-01-30	2
IEEE Std P802.11d-2001	A	Operation in Additional Regulatory Domains	TGd	N/A	802.11-1999 802.11c 802.11a-1999 802.11b-1999 802.11b Cor1-2001	Actual	1999-06-26		2000-04-04 2000-06-26	0% 0%	2001-11-29		D2.0 D3.0	2001-03-01 2001-04-13	93% 100%	C	C	2001-06-14	2001-10-25	2
IEEE Std P802.11b-1999	A	Higher Speed PHY Extension in the 2.4 GHz Band	TGb	N/A	802.11-1999 802.11c 802.11a-1999	Actual	1997-12-09		1998-11-09	0%						C	C	1999-09-16		2
IEEE Std P802.11a-1999	A	Higher Speed PHY Extension in the 5GHz Band	TGa	N/A	802.11-1999	Actual	1997-09-16									C	C	1999-09-16	2000-02-04	2
IEEE Std P802.11f-2003	RP	Inter-Access Point Protocol Across Distribution Systems Supporting IEEE 802.11 Operation	TGf	N/A		Actual	2000-03-30		2001-05-15 2001-09-03 2002-03-10 2002-06-16	0% 0% 82% 96%	2002-07-27		D4.0 D4.1 D5.0 D6.0	2002-10-28 2002-12-19 2003-02-17 2003-04-08	88% 95% 97% 98%	C	C	2003-06-12		2
IEEE Std P802.11-1999	STD	Part II Wireless LAN Medium Access Control MAC and Physical Layer PHY Specifications	MAC/PHY	N/A		Actual	1997-12-09							2003-01-07 2003-04-09 2003-02-02	99% 99% 99%	C	C	1999-03-18	1999-07-15	2
IEEE Std P802.11-1997	STD	IEEE Standard for Wireless LAN Medium Access Control MAC and Physical Layer PHY Specifications	MAC/PHY	N/A		Actual	1991-03-21									C	C	1997-06-26		1
IEEE Std P802.11c	A	Media Access Control MAC Bridges - Supplement for Support by IEEE 802.11 [Rolled into IEEE 802.1D]	TGc	N/A	802.11-1999	Actual	1997-12-09													

Timeline Chart Notes:

C = Stage Completed or Currently In-Process
A / COR = Amendment / Corrigendum
Predicted = Current Date Estimate
Date = Actual or Start Date
LB = Letter Ballot

N/A = Not Applicable
RP = Recommended Practice
SB = SA Ballot
STD = Standard and/or Revision
TG = Task Group

MEC = IEEE-SA Mandatory Editorial Coordination
Final 802.11 WG = Approval by 802.11 WG - Current WG Calendar
Final or Conditional 802 LMSC = Approval by 802 LMSC at Plenary Session - Current 802 LMSC Plenary Calendar
RevCom/Standards Board = Approval of RevCom / IEEE-SA Standards Board in Normal Session - Current IEEE-SA Calendar
ANSI = American National Standards Institute

MDR = 802.11 WG Mandatory Draft Review

This page is maintained by Stephen McCann . Comments are welcome.

IEEE Std 802.11, 802.11 Tech Ed , 802.11bc , 802.11bb , 802.11bd , 802.11az , 802.11 Tech Ed , 802.11ba , 802.11ay , 802.11ax , 802.11md , 802.11bq , 802.11mf , 802.11bp , 802.11bn , 802.11bk , 802.11bi , 802.11me , 802.11bh , 802.11bf , 802.11be , 802.11.1 and 802.11.2 are trademarks of the IEEE. All other names or product names are the trademarks, service marks or registered trademarks of their respective holders.

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APPENDIX T

The Wayback Machine - https://web.archive.org/web/20140702154806/http://www.ieee802.org/11/Reports/802.11_Timelines.htm

OFFICIAL IEEE 802.11 WORKING GROUP PROJECT TIMELINES - 2014-06-02

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	WG Letter Ballots: Date Predicted Initial	WG Letter Ballots: Date Predicted Recirc	WG Letter Ballots: Result	WG Letter Ballots: Form Sponsor Ballot Pool / Reform	WG Letter Ballots: MEC / MDR Done	IEEE-SA Sponsor Ballots: Draft	IEEE-SA Sponsor Ballots: Date Predicted Initial	IEEE-SA Sponsor Ballots: Date Predicted Recirc	IEEE-SA Sponsor Ballots: Result	Final 802.11 WG Approval	Final or Conditional 802 EC Approval	RevCom & Standards Board Final or Continuous Process Approval	ANSI Approved
IEEE Std P802.11ax	A	High Efficiency WLAN	TGax	None	802.11REVmc 802.11ai 802.11ah 802.11ak 802.11aq 802.11aj	Actual	2014-03-25														
						Predicted	C		Jul 2016			Jan 2018	Jan 2018		May 2018			Jan 2019	Mar 2019	Mar 2019	N/A
IEEE Std P802.11ak	A	General Link	TGak	None	802.11REVmc 802.11ai 802.11ah	Actual	2012-12-05 [2016-12-31]														
						Predicted	C		Jul 2014	Nov 2014		May 2015	Sep 2015		Nov 2015	Jan 2016		May 2016	May 2016	May 2016	N/A
IEEE Std P802.11aq	A	Pre-association Discovery	TGaq	None	802.11REVmc 802.11ai 802.11ah 802.11ak	Actual	2012-12-05 [2016-12-31]														
						Predicted	C		Nov 2014	Mar 2015		Jul 2015	Jul 2015		Nov 2015	Mar 2016		Jul 2016	Jul 2016	Jul 2016	N/A
IEEE Std P802.11aj	A	China Millimeter Wave	TGaj	PDF D0.01	802.11REVmc 802.11ai 802.11ah 802.11ak 802.11aq	Actual	2012-08-01														
						Predicted	C		Mar 2015	Jul 2015		Jul 2015	Sep 2015		Sep 2015	Jan 2016		May 2016	May 2016	Jun 2016	N/A
IEEE Std P802.11REVmc	STD	Maintenance	TGmc	PDF D2.70	802.11-2012 802.11ae-2012 802.11aa-2012 802.11ad-2012 802.11ac-2013 802.11af-2013	Actual	2012-07-20	D1.0 D2.0	2013-03-02 2013-10-23	88% 90%											
						Predicted	C		C		C	Aug 2014	Jul 2014		Nov 2014	Mar 2015		Jul 2015	Jul 2015	Dec 2015	Dec 2015
IEEE Std P802.11ai	A	Fast Initial Link Setup	TGai	PDF D1.30	802.11REVmc	Actual	2010-12-08 [2014-12-31]	D1.0 D2.0	2013-09-12 2014-05-07	74% 85%											
						Predicted	C		C		Sep 2014	Mar 2015	Nov 2014		Jul 2015	Sep 2015		Nov 2015	Nov 2015	Mar 2016	N/A
IEEE Std P802.11ah	A	Sub 1 GHz	TGah	PDF D1.20	802.11REVmc 802.11ai	Actual	2010-10-04 [2013-12-31]	D1.0	2013-11-04	73%											
						Predicted	C		C		Sep 2014	Nov 2014	Nov 2014		Feb 2015	Nov 2015		Jan 2016	Jan 2016	Mar 2016	N/A

PUBLISHED - 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	WG Letter Ballots: Date Predicted Initial	WG Letter Ballots: Date Predicted Recirc	WG Letter Ballots: Result	WG Letter Ballots: Form Sponsor Ballot Pool / Reform	WG Letter Ballots: MEC / MDR Done	IEEE-SA Sponsor Ballots: Draft	IEEE-SA Sponsor Ballots: Date Predicted Initial	IEEE-SA Sponsor Ballots: Date Predicted Recirc	IEEE-SA Sponsor Ballots: Result	Final 802.11 WG Approval	Final or Conditional 802 EC Approval	RevCom & Standards Board Final or Continuous Process Approval	ANSI Approved	Sup With Sta B
IEEE Std P802.11af-2013	A	TV White Spaces	TGaf	PDF D6.00	802.11-2012 802.11ae-2012 802.11aa-2012 802.11ad-2012 802.11ac-2013	Actual	2009-12-09 [2013-12-31]	D1.0 D2.0 D3.0 D4.0 D5.0 D5.0	2011-02-24 2012-08-19 2013-02-08 2013-04-17 2013-06-14 2013-08-01	62% 79% 87% 92% 94% 99%		2013-06-01	2013-11-01	D5.0 D6.0 D6.0	2013-09-11 2013-10-19 2013-10-30	97% 99% 99%		2013-11-01	2013-11-01	2013-12-11	2013-12-11	
IEEE Std P802.11ac-2013	A	Very High Throughput 6GHz	TGac	PDF D7.00	802.11-2012 802.11ae-2012 802.11aa-2012 802.11ad-2012	Actual	2008-09-26 [2012-12-31]	D1.0 D2.0 D3.0 D4.0 D5.0 D5.0	2011-06-25 2012-02-18 2012-06-25 2012-11-01 2013-02-01 2013-04-04	74% 89% 91% 94% 95% 96%		2013-01-01	2013-01-01	D5.0 D6.0 D7.0	2013-05-05 2013-08-03 2013-10-23	93% 97% 99%		2013-11-01	2013-11-01	2013-12-09	2013-12-11	
IEEE Std P802.11ad-2012	A	Very High Throughput 60GHz	TGad	PDF D9.00	802.11-2012 802.11ae-2012 802.11aa-2012	Actual	2008-12-10 [2012-12-31]	D1.0 D2.0 D3.0 D4.0 D5.0 D5.0	2010-10-24 2011-04-05 2011-06-01 2011-08-09 2011-10-06 2011-11-24	87% 88% 92% 95% 94% 95%		2011-09-01	2011-07-01	D5.0 D6.0 D7.0 D8.0 D9.0 D9.0	2012-01-05 2012-03-30 2012-05-11 2012-06-16 2012-07-28 2012-08-12	86% 90% 95% 97% 98% 98%		2012-07-01	2012-07-01	2012-10-23	2012-12-28	
IEEE Std P802.11aa-2012	A	Video Transport Streams	TGaa	Word / PDF D9.00	802.11-2012 802.11ae-2012	Actual	2008-03-27 [2012-12-31]	D1.0 D2.0 D3.0 D4.0 D5.0 D6.0 D6.0	2010-07-10 2010-12-08 2011-02-24 2011-04-09 2011-06-17 2011-08-09 2011-08-31	78% 79% 81% 85% 90% 94% 95%		2011-06-30	2011-06-16	D6.0 D7.0 D8.0 D9.0	2011-10-12 2011-11-26 2012-01-02 2012-01-27	93% 96% 99% 100%		2012-01-28	2012-02-17	2012-06-01	2012-05-29	
IEEE Std P802.11ae-2012	A	Prioritization of Management Frames	TGae	PDF D8.00	802.11-2012	Actual	2009-12-09 [2010-10-15]	D1.0 D2.0 D3.0 D4.0 D5.0	2010-10-27 2011-02-18 2011-04-26 2011-06-18 2011-08-04	81% 86% 89% 96% 96%		2011-07-01	2011-05-01	D5.0 D6.0 D7.0 D8.0	2011-09-09 2011-10-29 2011-12-13 2012-01-04	95% 96% 100% 100%		2012-01-20	2012-02-17	2012-03-01	2012-03-31	
IEEE Std P802.11-2012	STD	802.11 Accumulated Maintenance Changes	TGmb	Frame / PDF D9.01	802.11-2007 802.11k-2008 802.11r-2008 802.11y-2008 802.11w-2009 802.11n-2009 802.11p-2010 802.11z-2010 802.11v-2011 802.11u-2011 802.11s-2011	Actual	2007-03-22 [2011-12-31]	D1.0 D2.0 D3.0 D4.0 D5.0	2009-06-27 2010-01-08 2010-04-25 2010-06-25 2010-08-19	87% 89% 89% 89% 92%		2010-09-14	2010-09-01	D6.0 D7.0 D8.0 D9.0 D10.0 D11.0 D12.0	2010-11-05 2011-02-18 2011-04-14 2011-06-22 2011-09-07 2011-10-22 2011-11-13	87% 90% 92% 93% 92% 94% 97%		2011-11-11	2011-11-11	2012-03-01	2012-05-13	

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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	WG Letter Ballots: Date Predicted Initial	WG Letter Ballots: Date Predicted Recirc	WG Letter Ballots: Result	WG Letter Ballots: Form Sponsor Ballot Pool / Reform	WG Letter Ballots: MEC / MDR Done	IEEE-SA Sponsor Ballots: Draft	IEEE-SA Sponsor Ballots: Date Predicted Initial	IEEE-SA Sponsor Ballots: Date Predicted Recirc	IEEE-SA Sponsor Ballots: Result	Final 802.11 WG Approval	Final or Conditional 802 EC Approval	RevCom & Standards Board Final or Continuous Process Approval	ANSI Approved	Su W S
IEEE Std P802.11s-2011	A	Mesh Networking	TGs	PDF	802.11-2007 802.11k-2008 802.11r-2008 802.11y-2008	Actual	2004-05-13 [2010-12-31]	D1.0 D2.0 D3.0 D4.0	2007-01-06 2008-05-03 2009-05-04 2010-01-08	48% 61% 79% 85%		2010-09-12	2010-09-29	D7.0 D8.0 D9.0	2010-11-01 2011-01-10 2011-03-05	95% 96% 95%		2011-07-01	2011-07-01	2011-08-01		2

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: Predicted Recirc	Form Sponsor Ballot Pool / Reform	MEC / MDR Done	IEEE-SA Sponsor Ballots: Draft: Predicted Initial	IEEE-SA Sponsor Ballots: Date: Predicted Recirc	IEEE-SA Sponsor Ballots: Result: Predicted Recirc	Final 802.11 WG Approval	Final or Conditional 802 EC Approval	RevCom & Standards Board Final or Continuous Process Approval	ANSI Approved	Su W S
					802.11w-2009 802.11n-2009 802.11p-2010 802.11z-2010 802.11v-2011 802.11u-2011			D5.0 D6.0 D7.0	2010-04-15 2010-06-28 2010-08-13	89% 89% 95%			D10.0 D11.0	2011-04-09 2011-05-07	97% 97%					
IEEE Std P802.11u-2011	A	InterWorking with External Networks	TGu	Frame / PDF D13.00	802.11-2007 802.11k-2008 802.11r-2008 802.11y-2008 802.11w-2009 802.11n-2009 802.11p-2010 802.11z-2010 802.11v-2011	Actual	2004-12-08 (02/05/2008) [2010-12-31]	D1.0 D2.0 D3.0 D4.0 D5.0 D6.0 D7.0 D8.0	2007-07-08 2008-03-15 2008-07-12 2008-10-08 2009-02-20 2009-04-24 2009-06-19 2009-08-18	64% 70% 77% 78% 82% 90% 88% 93%	2009-06-01	2009-07-12	D8.0 D9.0 D10.0 D11.0 D12.0 D13.0	2009-11-07 2010-04-23 2010-07-08 2010-08-13 2010-09-12 2010-11-21	90% 92% 94% 96% 98% 99%	2010-11-01	2010-11-01	2011-02-25		2
IEEE Std P802.11v-2011	A	Wireless Network Management	TGv	Frame / PDF D16.00	802.11-2007 802.11k-2008 802.11r-2008 802.11y-2008 802.11w-2009 802.11n-2009 802.11p-2010 802.11z-2010	Actual	2004-12-08 [2010-12-31]	D1.0 D2.0 D3.0 D4.0 D5.0 D6.0 D7.0	2007-08-30 2008-03-15 2008-07-13 2008-12-19 2009-04-04 2009-06-12 2009-08-07	63% 67% 69% 81% 83% 90% 92%	2009-06-01	2009-07-12	D7.0 D9.0 D10.0 D11.0 D12.0 D13.0 D14.0 D15.0 D15.0 D16.0	2009-11-07 2010-02-17 2010-04-13 2010-06-10 2010-07-07 2010-07-28 2010-08-25 2010-10-18 2010-09-30 2010-11-15	81% 84% 87% 92% 94% 98% 98% 98% 98% 98%	2010-11-01	2010-11-01	2011-02-09		2
IEEE Std P802.11z-2010	A	Extensions to Direct Link Setup	TGz	Word / PDF D13.00	802.11-2007 802.11k-2008 802.11r-2008 802.11y-2008 802.11w-2009 802.11n-2009 802.11p-2010	Actual	2007-08-22	D1.0 D2.0 D3.0 D4.0 D5.0 D6.0	2008-05-03 2008-08-20 2008-12-18 2009-03-05 2009-06-23 2009-08-26	64% 66% 84% 88% 92% 96%	2009-06-01	2009-06-18	D6.0 D7.0 D8.0 D9.0 D11.0 D13.0	2009-11-07 2010-02-27 2010-05-04 2010-06-10 2010-08-04 2010-08-29	87% 87% 94% 95% 95% 98%	C	C	2010-10-01		2
IEEE Std P802.11p-2010	A	Wireless Access for the Vehicular Environment	TGp	N/A	802.11-2007 802.11k-2008 802.11r-2008 802.11y-2008 802.11w-2009 802.11n-2009	Actual	2004-09-23	D1.0 D2.0 D3.0 D4.0 D5.0 D6.0 D7.0 D8.0 D9.0	2006-04-11 2007-01-05 2007-09-12 2008-05-03 2008-12-05 2009-03-31 2009-06-13 2009-08-05 2009-10-10	59% 67% 74% 79% 85% 89% 85% 89% 93%	2009-06-01	2008-06-19	D9.0 D10.0 D11.0	2009-11-22 2010-02-16 2010-04-07	93% 96% 99%	C	C	2010-07-15		2
IEEE Std P802.11w-2009	A	Protected Management Frames	TGw	N/A	802.11-2007 802.11k-2008 802.11r-2008 802.11y-2008	Actual	2005-03-20	D1.0 D2.0 D3.0 D4.0 D5.0 D6.0	2006-11-19 2007-05-02 2007-10-19 2008-01-05 2008-02-20 2008-04-18	86% 89% 92% 92% 95% 97%	2007-11-13		D6.0 D7.0 D9.0 D10.0 D11.0	2008-09-24 2009-01-18 2009-05-23 2009-06-14 2009-06-28	86% 88% 92% 93% 95%	C	C	2009-09-11		2
IEEE Std P802.11n-2009	A	High Throughput	TGn		802.11-2007 802.11k-2008 802.11r-2008 802.11y-2008 802.11w-2009	Actual	2003-09-11 [2007-09-27]	D1.0 D2.0 D3.0 D4.0 D5.0 D6.0 D7.0 D7.0	2006-04-29 2007-03-09 2007-10-27 2008-04-12 2008-06-12 2008-08-05 2008-09-30 2008-12-02	47% 83% 85% 88% 90% 91% 94% 95%	2008-12-11	2008-12-11	D7.0 D8.0 D9.0 D10.0 D11.0 D11.0	2009-01-10 2009-03-06 2009-04-04 2009-05-30 2009-07-03 2009-06-20	78% 80% 81% 88% 91% 90%	C	C	2009-09-11		2
IEEE Std P802.11y-2008	A	3650-3700 MHz Operation in USA	TGy	N/A	802.11-2007 802.11k-2008 802.11r-2008	Actual	2008-12-31	D1.0 D2.0 D3.0 D4.0 D5.0 D6.0	2007-01-07 2007-05-05 2007-06-20 2007-08-21 2007-10-13 2007-12-08	76% 84% 91% 94% 96% 99%	2007-06-20	2007-07-28	D7.0 D8.0 D9.0 D10.0 D11.0	2008-01-30 2008-03-08 2008-03-27 2008-03-18 2008-06-20	93% 93% 96% 97% 97%	C	C	2008-11-06		2
IEEE Std P802.11r-2008	A	Fast Roaming	TGr	N/A	802.11-2007 802.11k-2008	Actual	2008-12-31	D1.0 D2.0 D3.0 D4.0 D5.0 D6.0	2006-01-04 2006-04-04 2006-10-14 2006-12-04 2007-04-04 2007-06-13	81% 88% 86% 92% 95% 97%		2007-04-11	D7.0 D8.0 D9.0 D9.0	2007-08-30 2007-10-07 2008-02-01 2008-01-17	86% 90% 97% 96%	C	C	2008-05-09		2
IEEE Std P802.11k-2008	A	Radio Resource Measurement	TGk	N/A	802.11-2007	Actual	2002-12-11	D1.0 D2.0 D3.0 D4.0 D5.0 D6.0 D7.0 D7.0	2007-09-11 2008-01-05 2004-09-11 2005-03-15 2005-11-12 2006-03-31 2006-09-16 2006-11-16 2007-02-13 2007-05-05	90% 100% 95% 86% 80% 81% 85% 91% 92% 93%		2007-04-10	D8.0 D9.0 D10.0 D11.0 D12.0 D12.0 D13.0	2007-08-13 2007-10-04 2007-12-08 2008-01-17 2008-02-14 2008-02-01 2008-03-18	90% 89% 91% 95% 95% 95% 97%	C	C	2008-05-09		2
IEEE Std P802.11-2007	STD	802.11 Standard Maintenance Revision	TGma	N/A	802.11-1999 802.11c 802.11a-1999 802.11b-1999 802.11b Cor1-2001 802.11d-2001 802.11g-2003 802.11h-2003 802.11i-2004 802.11j-2004 802.11e-2005	Actual	2003-03-20 [2003-03-20]	D1.0 D2.0 D3.0 D4.0	2005-05-08 2005-07-17 2005-08-19 2005-09-19	91% 94% 95% 96%	2005-08-21	2005-08-21	D5.0 D6.0 D7.0 D8.0 D9.0	2005-11-20 2006-05-10 2006-07-11 2006-09-09 2006-11-07	86% 90% 91% 96% 96%	2006-11-08	2006-11-08	2007-03-08		2
IEEE Std P802.11.2	RP	Wireless Performance	TGt			Actual	2008-12-31	D1.0	2007-05-16	76%										2
IEEE Std P802.11e-2005	A	MAC Enhancements QoS	TGe	N/A	802.11-1999 802.11c 802.11a-1999 802.11b-1999 802.11b Cor1-2001 802.11d-2001 802.11g-2003 802.11h-2003 802.11i-2004 802.11j-2004	Actual	2000-03-30	D4.0 D5.0 D6.0 D7.0 D8.0	2001-05-15 2002-01-16 2002-07-02 2003-01-08 2003-08-22 2003-12-20 2004-02-15 2004-03-10	0% 55% 49% 83% 97% 89% 93% 94%			D8.0 D9.0 D10.0 D11.0 D12.0 D13.0 D13.0	2004-05-30 2004-08-31 2004-10-08 2004-11-11 2004-12-23 2005-04-16 2005-02-18	85% 87% 92% 95% 96% 99% 96%	2005-07-22	2005-07-22	2005-09-22		2
IEEE Std P802.11j-2004	A	4.9 GHz-5 GHz Operation in Japan	TGj	N/A	802.11-1999 802.11c 802.11a-1999 802.11b-1999 802.11b Cor1-2001 802.11d-2001 802.11g-2003 802.11h-2003 802.11i-2004	Actual	2002-12-11	D1.0 D1.2 D1.3 D1.4	2003-05-12 2004-01-14 2004-03-11 2004-04-20	68% 89% 94% 95%	2004-05-13		D1.5 D1.6	2004-07-02 2004-08-14	88% 96%	C	C	2004-09-23	2005-02-02	2
IEEE Std P802.11i-2004	A	MAC Security Enhancements	TGi	N/A	802.11-1999 802.11c 802.11a-1999 802.11b-1999 802.11b Cor1-2001 802.11d-2001 802.11g-2003 802.11h-2003	Actual	2001-05-30	D3.0 D4.0 D5.0 D6.0 D7.0	2002-05-04 2003-01-12 2003-06-06 2003-08-19 2003-10-09 2003-11-04	77% 76% 78% 87% 92% 95%	2003-08-10		D7.0 D8.0 D9.0 D10.0	2003-12-20 2004-03-12 2004-04-10 2004-05-08	89% 92% 98% 98%	C	C	2004-06-24	2005-02-14	2
IEEE Std P802.11h-2003	A	Spectrum and Transmit Power Management Extensions in the 5 GHz Band in Europe	TGh	N/A	802.11-1999 802.11c 802.11a-1999 802.11b-1999 802.11b Cor1-2001 802.11d-2001 802.11g-2003	Actual	2000-12-07	D2.2	2001-09-03 2002-05-05 2002-09-01 2002-11-01	0% 76% 90% 97%	2002-07-25		D3.0 D3.11 D3.6	2003-02-06 2003-06-26 2003-04-30	92% 98% 96%	C	C	2003-09-11	2003-12-29	2
IEEE Std P802.11g-2003	A	Further Higher Data Rate Extension in	TGg	N/A	802.11-1999 802.11c 802.11a-1999 802.11b-1999	Actual	2000-09-21	D5.0	2002-03-11 2002-09-01 2003-01-08	45% 83% 88%	2002-07-25		D6.2 D7.1 D8.2	2003-03-09 2003-04-08 2003-05-14	84% 85% 96%	C	C	2003-06-12	2003-10-20	2

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	WG Letter Ballots: Date	WG Letter Ballots: Result	Form Sponsor Ballot Pool / Reform	MEC / MDR Done	IEEE-SA Sponsor Ballots: Draft	IEEE-SA Sponsor Ballots: Date	IEEE-SA Sponsor Ballots: Result	Final 802.11 WG Approval	Final or Conditional 802 EC Approval	RevCom & Standards Board Final or Continuous Process Approval	ANSI Approved	Su W S
		the 2.4 GHz Band			802.11b Cor1-2001 802.11d-2001			D4.0 D6.1	2002-11-01 2003-02-04	87% 89%										
IEEE Std P802.11b Cor1-2001	COR	Corrigenda to IEEE 802.11b-1999	TGb-Cor1		802.11-1999 802.11c 802.11a-1999	Actual	1999-11-27						D1.5	2001-04-13	98%	C	C	2001-10-10	2002-01-30	2
IEEE Std P802.11d-2001	A	Operation in Additional Regulatory Domains	TGd	N/A	802.11-1999 802.11c 802.11a-1999 802.11b-1999 802.11b Cor1-2001	Actual	1999-06-26		2000-04-04 2000-06-26	0% 0%	2001-11-29		D2.0 D3.0	2001-03-01 2001-04-13	93% 100%	C	C	2001-06-14	2001-10-25	2
IEEE Std P802.11b-1999	A	Higher Speed PHY Extension in the 2.4 GHz Band	TGb	N/A	802.11-1999 802.11c 802.11a-1999	Actual	1997-12-09		1998-11-09	0%						C	C	1999-09-16		2
IEEE Std P802.11a-1999	A	Higher Speed PHY Extension in the 5GHz Band	TGa	N/A	802.11-1999	Actual	1997-09-16									C	C	1999-09-16	2000-02-04	2
IEEE Std P802.11f-2003	RP	Inter-Access Point Protocol Across Distribution Systems Supporting IEEE 802.11 Operation	TGf	N/A		Actual	2000-03-30		2001-05-15 2001-09-03 2002-03-10 2002-06-16	0% 0% 82% 96%	2002-07-27		D4.0 D4.1 D5.0 D6.0	2002-10-28 2002-12-19 2003-02-17 2003-04-08	88% 95% 97% 98%	C	C	2003-06-12		2
IEEE Std P802.11-1999	STD	Part II Wireless LAN Medium Access Control MAC and Physical Layer PHY Specifications	MAC/PHY	N/A		Actual	1997-12-09							2003-01-07 2003-04-09 2003-02-02	99% 99% 99%	C	C	1999-03-18	1999-07-15	2
IEEE Std P802.11c	A	Media Access Control MAC Bridges - Supplement for Support by IEEE 802.11	TGc	N/A	802.11-1999	Actual	1997-12-09													2
IEEE Std P802.11-1997	STD	IEEE Standard for Wireless LAN Medium Access Control MAC and Physical Layer PHY Specifications	MAC/PHY	N/A		Actual	1991-03-21									C	C	1997-06-26		1

Timeline Chart Notes:

C = Stage Completed or Currently In-Process
A / COR = Amendment / Corrigendum
Predicted = Current Date Estimate
Date = Actual or Start Date
LB = Letter Ballot

N/A = Not Applicable
RP = Recommended Practice
SB = Sponsor Ballot
STD = Standard and/or Revision
TG = Task Group

MEC = IEEE-SA Mandatory Editorial Coordination
Final 802.11 WG = Approval by 802.11 WG - Current WG Calendar
Final or Conditional 802 EC = Approval by 802 EC at Plenary Session - Current 802 EC Plenary Calendar
RevCom/Standards Board = Approval of RevCom / IEEE-SA Standards Board in Normal Session - Current IEEE-SA Calendar
ANSI = American National Standards Institute

MDR = 802.11 WG Mandatory Draft Review

This page is maintained by Stephen McCann and Alex Ashley . Comments are welcome.

IEEE Std 802.11, 802.11af , 802.11ac , 802.11ad , 802.11aa , 802.11ae , 802.11mb , 802.11ax , 802.11ak , 802.11aq , 802.11aj , 802.11mc , 802.11ai , 802.11ah , 802.11.1 and 802.11.2 are trademarks of the IEEE. All other names or product names are the trademarks, service marks or registered trademarks of their respective holders.

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APPENDIX U

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    - LAN/MAN 802 Groups
    - Software & Systems Engineering Groups (S2ESC)
    - Standards Activities Board Groups (SAB)
    - Storage Systems (SS)
  - Computational Intelligence (CI) Groups
    - Fuzzy Markup Language
  - Industry Applications (IAS) Groups
  - Power and Energy (PE) Groups
  - SCC21 Groups
  - SCC31 Groups
  - SCC40 Groups
  - Smart Grid Groups
  - Vehicular Technology Groups (VT)
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APPENDIX V

IEEE 802.11 technical submissions

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AI Overview Learn more

IEEE 802.11 technical submissions, also known as draft standards, are **documents proposed and reviewed by the IEEE 802.11 working group to enhance the Wi-Fi technology**. Submissions are made by members and must follow specific formatting rules. These submissions are available on the "mentor" document server, which is accessible to the public. Draft standards and other members-only information are available in a password-protected area for members.

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IEEE802.org
https://www.ieee802.org › ...

IEEE 802.11, The Working Group Setting the Standards for ...

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 ...

IEEE Mentor
https://mentor.ieee.org › 802.11 › documents

IEEE Standards Association - Documents

2025, 519, 5, TGbn, Minutes for **802.11** bn PHY ad-hoc Teleconference in March to May, Dongguk Lim (LG Electronics). 29-Apr-2025 22:30:41 ET.

Wiki 12 11 14

IEEE802.org
https://www.ieee802.org › abt80211

About 802.11 and How To Participate

The draft standard is ready for final approval once it has achieved at least a 75% approval rate and met various other critria (e.g., no new Disapprove votes on ...

IEEE Standards Association
https://standards.ieee.org › ieee › 802.11

IEEE SA - IEEE 802.11-2024

Technical corrections and clarifications to **IEEE** Std **802.11** for wireless local area networks (WLANs) as well as enhancements to the existing medium access ...

Missing: ~~submissions~~ | Show results with: submissions

Wikipedia
https://en.wikipedia.org › wiki › IEEE_802

IEEE 802.11

IEEE 802.11 is used in most home and office networks to allow laptops, printers, smartphones, and other devices to communicate with each other and access the ...

Missing: ~~submissions~~ | Show results with: submissions

Scholarly articles for **IEEE 802.11 technical submissions**

IEEE 802.11 n development: history, process, and ... - Perahia - Cited by 239

The **IEEE 802.11** universe - Hiertz - Cited by 500

Creating a wireless LAN standard: **IEEE 802.11** - Jakobs - Cited by 20

People also ask

What are the IEEE 802.11 standards?

What does IEEE 802.11 apply to?

What is the difference between IEEE 802.11 A and 802.11 B?

Is 802.11a 2.4 or 5ghz?

Feedback

IEEE Standards Association
https://standards.ieee.org › beyond-standards › the-evol...

The Evolution of Wi-Fi Technology and Standards

May 16, 2023 — **IEEE 802.11**n™, or Wi-Fi 4, was introduced in 2009 to support the 2.4 GHz and 5GHz frequency bands, with up to 600 Mbit/s data rates, multiple ...

Ieee Sa Wi-Fi Timeline | Ieee Standards For Wi-Fi | Wi-Fi 7: The Next...

Missing: ~~submissions~~ | Show results with: submissions

IEEE Mentor
https://mentor.ieee.org › 802.11 › dcn › 11-09-0...

doc.: IEEE 802.11-09/0002r4

DOC

The vote by the TG to request the WG to **submit** a draft standard or a revised standard to the WG ballot group is considered to be a **technical** vote. 4.7.4 Task ...

IEEE Mentor
https://mentor.ieee.org › 802.11 › dcn › 11-14-0...

802.11 Operation Manual

DOC

Complex **technical** changes to a draft shall be in a **submission** that has been accepted by document control according to document formats specified in section 3.7 ...

Spread Spectrum Scene
http://www.sss-mag.com › pdf

A Technical Tutorial on the IEEE 802.11 Protocol

PDF

by P Brenner · 1997 · Cited by 322 — This version of the document is actualized to Draft 4.0 of the Standard. Page 3. A **Technical** Tutorial on the **IEEE 802.11** Standard. 18 July, 1996.

TechTarget
https://www.techtarget.com › searchmobilecomputing

What is 802.11? Definition from TechTarget

802.11 is a family of evolving specifications for wireless local area networks (WLANs) developed and maintained by a working group of **IEEE**.

What Is 802.11? | What Does 802.11 Mean? | How Does 802.11 Work?

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APPENDIX W

IEEE 802 Working Groups

Welcome to the information portal sponsored by the **802 Working Groups**.

- IEEE 802 Executive Committee
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- IEEE 802.1 OmniRAN Task Group and subsequently on the 802.1 OmniRAN web page
- IEEE 802.11 Wireless LAN (WLAN) Working Group
- IEEE 802.15 Wireless Speciality Network (WSN) Working Group
- IEEE 802.16 Working Group on Broadband Wireless Access
- IEEE 802.18 Radio Regulatory Technical Advisory Group
- IEEE 802.19 Wireless Coexistence WG
- IEEE 802.21 Handover Services WG
- IEEE 802.22 WRAN WG
- IEEE 802 Whitespace SG(not an active group - archive)
- IEEE 802.23 Emergency Services Working Group(not an active group - archive)
- IEEE 802.24 Smart Grid Technical Advisory Group
- IEEE 802 EC Privacy Recommendation SG and subsequently on the 802.1 Security TG Web Page

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APPENDIX X

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DCN, Title, Author or Affiliation

Created (ET) ▼	Year	DCN	Rev	Group	Title	Author (Affiliation)	Uploaded (ET)	Actions
28-Apr-2025 ET	2025	255	3	TGm	P2P TWT Harmonization	Brian Hart (Cisco Systems)	28-Apr-2025 13:34:11 ET	Download
28-Apr-2025 ET	2024	1925	6	TGm	REVmf Motions	Michael Montemurro (Huawei)	28-Apr-2025 12:17:19 ET	Download
28-Apr-2025 ET	2025	662	3	TGm	April 28 Teleconference Agenda	Michael Montemurro (Huawei)	28-Apr-2025 12:14:48 ET	Download
28-Apr-2025 ET	2025	371	1	TGm	NR-IE_6GHz_Bits	Abhishek Patil (Qualcomm)	28-Apr-2025 11:33:33 ET	Download
28-Apr-2025 ET	2025	345	5	TGm	PASN ID for MLO	Yan Li(ZTE)	28-Apr-2025 09:42:37 ET	Download
28-Apr-2025 ET	2025	676	1	TGbn	CC50 CR for CID3866	Bo Cao (ZTE)	28-Apr-2025 09:37:41 ET	Download
28-Apr-2025 ET	2025	638	2	TGbn	CRs for CID related to definitions in MAPC scheme	Chun Huang (ZTE)	28-Apr-2025 08:18:13 ET	Download
28-Apr-2025 ET	2024	2080	1	TGbn	High-Capability Protection in DPS Follow Up	Maolin Zhang (Huawei)	28-Apr-2025 06:32:10 ET	Download
28-Apr-2025 ET	2025	3	2	TGbn	NPCA follow up	Yan Li(ZTE)	28-Apr-2025 04:45:27 ET	Download
28-Apr-2025 ET	2025	5	3	TGbn	MAP discovery follow up	Jay Yang(ZTE)	28-Apr-2025 03:46:33 ET	Download
28-Apr-2025 ET	2025	576	3	TGbq	TGbq April 2025 Teleconference Call Meeting Minutes	Jonghoe Koo (Samsung Electronics)	28-Apr-2025 02:10:27 ET	Download
28-Apr-2025 ET	2025	673	3	TGbn	CR for CC50 on subclause 37.x.x.x.x Allowed settings	Hong Won Lee(LG Electronics Inc.)	28-Apr-2025 01:26:53 ET	Download
28-Apr-2025 ET	2025	727	1	TGbk	Minutes for telecons in March-APril2025	Dibakar Das (Intel)	28-Apr-2025 01:04:27 ET	Download
28-Apr-2025 ET	2025	727	0	TGbk	Minutes for telecons in March-APril2025	Dibakar Das (Intel)	28-Apr-2025 01:01:32 ET	Download
27-Apr-2025 ET	2025	723	1	TGm	802.11REVmf Editor's Report	Po-Kai Huang (Intel)	27-Apr-2025 21:29:07 ET	Download
27-Apr-2025 ET	2025	707	1	TGbn	CC50 CR for clause 6 part 2	Yan Li(ZTE)	27-Apr-2025 21:15:57 ET	Download
27-Apr-2025 ET	2024	1919	3	TGm	Protecting TSF values in Beacon frames	Henry Ptasinski (Morse Micro)	27-Apr-2025 14:18:24 ET	Download
27-Apr-2025 ET	2024	1915	4	TGm	SA Query improvements for low-transmit devices	Henry Ptasinski (Morse Micro)	27-Apr-2025 14:17:26 ET	Download
27-Apr-2025 ET	2025	726	0	TGbn	Transmit and Receive Specifications for New MCS Follow-Up	Alice Chen (Qualcomm)	27-Apr-2025 02:02:47 ET	Download
27-Apr-2025 ET	2025	725	0	TGbn	CC50 CR for UHR-SIG User Specific Field - Part 1	Mengshi Hu (Huawei)	27-Apr-2025 08:31:58 ET	Download

26-Apr-2025 ET	2025	345	4	TGm	PASN ID for MLO	Yan Li(ZTE)	26-Apr-2025 22:58:57 ET	Download
26-Apr-2025 ET	2025	260	7	TGm	Trigger, BA, BAR Protection	Po-Kai Huang (Intel)	26-Apr-2025 01:07:52 ET	Download
26-Apr-2025 ET	2025	723	0	TGm	802.11REVmf Editor's Report	Po-Kai Huang (Intel)	26-Apr-2025 00:52:03 ET	Download
25-Apr-2025 ET	2025	600	6	TGbn	PDT MAC Co-RTWT Signaling and Protocol Aspects	Giovanni Chisci, Qualcomm Technologies Inc.	25-Apr-2025 21:01:02 ET	Download
25-Apr-2025 ET	2025	599	6	TGbn	PDT MAC MAPC Signaling and Protocol Aspects	Giovanni Chisci, Qualcomm Technologies Inc.	25-Apr-2025 21:00:26 ET	Download
25-Apr-2025 ET	2025	721	0	TGbn	UHR Transmit and Receiver Specification for New MCSs-Follow Up	Juan Fang (Intel)	27-Apr-2025 01:16:00 ET	Download
25-Apr-2025 ET	2025	442	2	TGbn	CC50 CR on Trigger Frame Part 1	Alice Chen (Qualcomm)	25-Apr-2025 13:44:49 ET	Download
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25-Apr-2025 ET	2025	681	5	TGbn	PDT-CRs-Joint-sounding-procedure	You-Wei Chen (MediaTek)	25-Apr-2025 13:04:02 ET	Download
25-Apr-2025 ET	2025	719	0	PQC SG	PQC SG 21 April 2025 Teleconference Meeting Minutes	Alex LUNGU (Samsung)	25-Apr-2025 12:40:41 ET	Download
25-Apr-2025 ET	2025	717	0	TGbn	PDT JOINT Abbreviations and Acronyms	Akira Kishida (NTT)	25-Apr-2025 04:59:30 ET	Download
25-Apr-2025 ET	2025	715	0	TGbn	Discussion on Time Synchronization in MAP Framework	Qingwei Fu (TP-Link Systems Inc.)	28-Apr-2025 06:45:08 ET	Download
24-Apr-2025 ET	2024	209	14	TGbn	Specification Framework for TGbn	Ross Jian Yu (Huawei)	24-Apr-2025 23:19:58 ET	Download
24-Apr-2025 ET	2025	570	4	TGbn	CC50 CR for 38.3.4 Transmission of DRU	Eunsung Park (LG Electronics)	24-Apr-2025 19:40:18 ET	Download
24-Apr-2025 ET	2025	504	14	TGbn	mar-may-tgbn-teleconference-agenda	Alfred Asterjadhi (Qualcomm Technologies Inc.)	24-Apr-2025 18:08:24 ET	Download
24-Apr-2025 ET	2025	14	16	TGbn	tgbn-motions-list-part-2	Alfred Asterjadhi (Qualcomm Technologies Inc.)	24-Apr-2025 16:00:39 ET	Download
24-Apr-2025 ET	2025	712	0	TGbn	CC50 Section 9.4.2.aa2.3 PHYcap CIDs	Eugene Baik (Qualcomm)	25-Apr-2025 12:23:25 ET	Download
24-Apr-2025 ET	2025	711	0	TGbn	CC50 Section 38.3.1 phyintro CID	Eugene Baik (Qualcomm)	25-Apr-2025 12:20:47 ET	Download
24-Apr-2025 ET	2025	301	2	TGbn	TGbn Editor's Report	Ross Jian Yu (Huawei)	24-Apr-2025 10:22:06 ET	Download
24-Apr-2025 ET	2025	707	0	TGbn	CC50 CR for clause 6 part 2	Yan Li(ZTE)	24-Apr-2025 04:59:56 ET	Download
24-Apr-2025 ET	2025	694	1	TGbn	UHR OFDMA Sounding Limitations	Avner Epstein (Maxlinear)	24-Apr-2025 04:38:18 ET	Download
24-Apr-2025 ET	2025	637	1	TGbn	Joint PDT CR Trigger Frame Format Part 6	Alice Chen (Qualcomm)	24-Apr-2025 02:10:38 ET	Download
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24-Apr-2025 ET	2025	638	1	TGbn	CRs for CID related to definitions in MAPC scheme	Chun Huang (ZTE)	24-Apr-2025 01:54:10 ET	Download
24-Apr-2025 ET	2025	550	1	TGbn	CC50 CR for 38.3.15.11.3	Dongguk Lim (LG Electronics)	24-Apr-2025 01:36:00 ET	Download

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23-Apr-2025 ET	2025	504	13	TGbn	mar-may-tgbn-teleconference-agenda	Alfred Asterjadhi (Qualcomm Technologies Inc.)	23-Apr-2025 22:29:33 ET	Download
23-Apr-2025 ET	2025	681	4	TGbn	PDT-CRs-Joint-sounding-procedure	You-Wei Chen (MediaTek)	23-Apr-2025 18:10:10 ET	Download
23-Apr-2025 ET	2024	1095	2	TGbn	Practical MAPC Scenarios	Malcolm Smith (Cisco)	23-Apr-2025 17:29:31 ET	Download
23-Apr-2025 ET	2025	504	12	TGbn	mar-may-tgbn-teleconference-agenda	Alfred Asterjadhi (Qualcomm Technologies Inc.)	23-Apr-2025 17:24:56 ET	Download
23-Apr-2025 ET	2025	14	15	TGbn	tgbn-motions-list-part-2	Alfred Asterjadhi (Qualcomm Technologies Inc.)	23-Apr-2025 17:22:45 ET	Download
23-Apr-2025 ET	2011	270	78	802.11 WG	ANA Database	Carol Ansley (Cox)	23-Apr-2025 17:03:53 ET	Download
23-Apr-2025 ET	2025	189	2	TGbn	Elicitation of Response Transmissions in Coordinated Spatial Reuse	Hassan Omar (Huawei Technologies)	23-Apr-2025 16:48:43 ET	Download
23-Apr-2025 ET	2025	530	6	TGbi	tgbi-telecom-march-april-agenda	Carol Ansley (Cox)	23-Apr-2025 12:04:24 ET	Download
23-Apr-2025 ET	2025	662	2	TGm	April 28 Teleconference Agenda	Michael Montemurro (Huawei)	23-Apr-2025 11:39:07 ET	Download
23-Apr-2025 ET	2025	345	3	TGm	PASN ID for MLO	Yan Li(ZTE)	23-Apr-2025 04:56:27 ET	Download
23-Apr-2025 ET	2025	155	5	TGbi	SAE password identifier update	Jouni Malinen (Qualcomm)	23-Apr-2025 04:12:51 ET	Download
23-Apr-2025 ET	2025	692	2	TGbi	CIDs 9.6.42.5 9.6.42.6	Antonio de la Oliva, Interdigital	23-Apr-2025 02:56:36 ET	Download
22-Apr-2025 ET	2025	554	4	TGbi	12.16.6 comments	Po-Kai Huang (Intel)	22-Apr-2025 23:27:19 ET	Download
22-Apr-2025 ET	2025	554	3	TGbi	12.16.6 comments	Po-Kai Huang (Intel)	22-Apr-2025 23:08:17 ET	Download
22-Apr-2025 ET	2025	701	1	TGbn	PDT-PHY-MU-MIMO	Ron Porat (Broadcom)	22-Apr-2025 22:23:54 ET	Download
22-Apr-2025 ET	2025	703	0	TGbn	CC50 Comment Resolutions for 38.3.21 Coordinated Beamforming	Insik Jung (LGE)	23-Apr-2025 00:28:18 ET	Download
22-Apr-2025 ET	2025	270	4	TGm	Beacon modification for reduced ANQP exchange induced latency	Azin Neishaboori, General Motors	22-Apr-2025 17:22:52 ET	Download
22-Apr-2025 ET	2025	530	5	TGbi	tgbi-telecom-march-april-agenda	Carol Ansley (Cox)	22-Apr-2025 15:24:25 ET	Download
22-Apr-2025 ET	2025	702	0	TGbn	CR-PHY-CID 3905	Ron Porat (Broadcom)	22-Apr-2025 20:00:37 ET	Download
22-Apr-2025 ET	2025	701	0	TGbn	PDT-PHY-MU-MIMO	Ron Porat (Broadcom)	22-Apr-2025 20:00:57 ET	Download
22-Apr-2025 ET	2025	662	1	TGm	April 28 Teleconference Agenda	Michael Montemurro (Huawei)	22-Apr-2025 10:46:24 ET	Download
22-Apr-2025 ET	2025	693	1	TGbi	CIDs 9.6.42.7	Antonio de la Oliva, Interdigital	23-Apr-2025 02:36:55 ET	Download
22-Apr-2025 ET	2025	692	1	TGbi	CIDs 9.6.42.5 9.6.42.6	Antonio de la Oliva, Interdigital	22-Apr-2025 10:33:38 ET	Download
22-Apr-2025 ET	2025	699	0	TGbn	Simultaneous DL for seamless roaming	Yaoshen Cui (TP-Link)	22-Apr-2025 10:00:42 ET	Download
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22-Apr-2025 ET	2025	301	1	TGbn	TGbn Editor's Report	Ross Jian Yu (Huawei)	22-Apr-2025 05:19:27 ET	Download

22-Apr-2025 ET	2025	296	18	TGbn	IEEE 802.11bn CC50 comments on D0.1	Ross Jian Yu (Huawei)	22-Apr-2025 03:47:22 ET	Download
22-Apr-2025 ET	2025	248	1	TGbn	Partial Bandwidth Sounding for Co-BF	Qisheng Huang (ZTE)	22-Apr-2025 02:11:54 ET	Download
21-Apr-2025 ET	2025	576	2	TGbq	TGbq April 2025 Teleconference Call Meeting Minutes	Jonghoe Koo (Samsung Electronics)	21-Apr-2025 23:34:06 ET	Download
21-Apr-2025 ET	2025	519	4	TGbn	Minutes for 802.11 bn PHY ad-hoc Teleconference in March to May	Dongguk Lim (LG Electronics)	21-Apr-2025 21:20:16 ET	Download
21-Apr-2025 ET	2025	663	2	TGbn	CR-PHY-Subclause-38.3.21	Ron Porat (Broadcom)	21-Apr-2025 21:03:02 ET	Download
21-Apr-2025 ET	2025	656	1	TGbn	CC50 CR on DRU in 38.3.2.1 - Group 1	Mahmoud Kamel (InterDigital)	21-Apr-2025 20:28:16 ET	Download
21-Apr-2025 ET	2025	570	3	TGbn	CC50 CR for 38.3.4 Transmission of DRU	Eunsung Park (LG Electronics)	21-Apr-2025 19:51:42 ET	Download
21-Apr-2025 ET	2025	673	2	TGbn	CR for CC50 on subclause 37.x.x.x.x Allowed settings	Hong Won Lee(LG Electronics Inc.)	21-Apr-2025 19:31:37 ET	Download
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08-Jun-2015 ET	2015	716	2	TGaq	TGaq May to July Teleconference Minutes	Yunsong Yang (Huawei)	08-Jun-2015 20:28:53 ET	Download
08-Jun-2015 ET	2014	778	1	TGm	TGmc and REVmc-status-and-overview-presentation	Dorothy Stanley (HP-Aruba Networks)	08-Jun-2015 20:15:13 ET	Download
08-Jun-2015 ET	2015	711	1	802.11 WG	Minutes-of-IEEE-802-11-WG-meeting-May-2015-Zhuhai-china-interim-session	Dorothy Stanley (Aruba Networks)	08-Jun-2015 16:04:25 ET	Download
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APPENDIX AD

IEEE P802.11
Wireless LANs

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Author(s):				
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Abhishek Patil	Qualcomm Inc.			appatil@qti.qualcomm.com
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Abstract

This submission proposes resolutions for multiple comments received for TGax LB225 (75 CIDs):
7968, 8271, 4809, 4810, 4811, 5702, 5183, 5184, 9451, 5185, 5703, 7574, 9894, 4812, 5186, 5704, 9452, 8272, 9707, 5706, 5187, 6168, 5983, 8273, 8338, 9588, 6166, 10167, 4815, 4816, 7644, 7812, 9896, 6065, 7175, 9759, 9456, 9589, 7176, 10260, 9898, 8552, 3228, 9710, 4818, 8151, 8701, 8702, 4821, 9529, 4820, 8703, 4822, 4823, 4824, 4825, 6685, 7649, 5717, 3232, 7816, 5988, 9713, 4828, 6196, 3325*, 6695, 8705, 6696, 7817, 6697, 9917, 5997, 5998, 6701

* CID 3325 has several duplicates which are not listed or counted here. Instead, the duplicate CIDs are being tracked in document 11-17/0010 which is maintained by the TGax Editor.

Revisions:

- Rev 0: Initial version of the document.
- Rev 1:
  - Included resolution to CID 7041
  - Edits to the text on padding duration based offline feedback
  - Removed Note 2 for padding – revised text on padding covers the case
  - Minor editorial changes
- Rev 2:
  - Removed resolutions 7041, 7141, 9897 (as suggested by the group during ad-hoc session on 3/9/17)

Interpretation of a Motion to Adopt

A motion to approve this submission means that the editing instructions and any changed or added material are actioned in the TGax Draft. This introduction is not part of the adopted material.

Editing instructions formatted like this are intended to be copied into the TGax Draft (i.e. they are instructions to the 802.11 editor on how to merge the text with the baseline documents).

TGax Editor: Editing instructions preceded by "TGax Editor" are instructions to the TGax editor to modify existing material in the TGax draft. As a result of adopting the changes, the TGax editor will execute the instructions rather than copy them to the TGax Draft.

CID	Commenter	Section	Pg / Ln	Comment	Proposed Change	Resolution
7968	Mark RISON	27.5.2.1	163.19	This is normative, not just informative	Change "Non-AP STAs transmit their response frames using HE trigger-based PPDU format, in either UL OFDMA, UL MU-MIMO, or both, except when the Trigger frame is of type MU-RTS, in which case the response (CTS) is sent in a non-HT PPDU format (see 10.3.2.8a (MU-RTS/CTS procedure))." to "Non-AP STAs shall transmit their response frames using HE trigger-based PPDU format, in either UL OFDMA, UL MU-MIMO, or both, except when the Trigger frame is of type MU-RTS, in which case the response (CTS) shall be sent in a non-HT PPDU format (see 10.3.2.8a (MU-RTS/CTS procedure))."	Revised Revised text to make the sentence normative as suggested by the commenter. TGax editor please make the changes as shown in 11-17/0250r2
8271	Pascal VIGER	27.5.2.1	163.58	There is a mix of STA, HE STA, non-AP STA terms used in this section in a confusing manner. As example, page 164 line 14, "A STA shall not transmit a Trigger frame..." whereas only a AP HE STA is able to do this.	as per comment	Revised Agree with the comment Updated text to make reference to a non-AP HE STA or an HE AP. TGax editor please make the changes as shown in 11-17/0250r2
4809	Alfred Asterjadhi	27.5.2.1	163.60	"in either UL OFDMA, UL MU-MIMO, or both," is redundant since the trigger-based PPDU already defines the allowed modes	remove "in either UL OFDMA, UL MU-MIMO, or both,"	Accept Agree with the comment. Deleted the reference to UL OFDMA and UL MU-MIMO TGax editor please make the changes as shown in 11-17/0250r2
4810	Alfred Asterjadhi	27.5.2.1	164.03	use field name instad of bit number. Same in other lines	as in comment	Revised The issue pointed out by the commenter doesn't exist in D1.1. The paragraphs were updated in D1.1 as a resolution to CID 5142. The revised text refers to field names instead of bits.
4811	Alfred Asterjadhi	27.5.2.1	164.14	This para is reduntant with the next one	Remove this para and keep the next one starting at line19	Reject The two paragraphs refer to separate capabilities and neither should be deleted
5702	Guoqing Li	27.5.2.1	164.14	There is no terminology called MU-MIMO RU and UL OFDMA PPDU. I think what this sentence means is "An AP shall not ....assigning spatial streams to more than one STA in an RU in the response trigger-based PPDU when the RU does not span..."	Clarify as suggested	Revised Agree with the comment. Update the text in this paragraph to clarify that the solicited TB PPDU uses MU-MIMO, the solicited STA has indicated support for partial BW and the RU assigned to the STA spans partial BW.

						TGax editor please make the changes as shown in 11-17/0250r2
5183	Dorothy Stanley	27.5.2.1	164.14	Define "MU-MIMO RU"	as in comment	Revised Agree with the comment. The sentence was update as a resolution to CID 5702. The term MU-MIMO RU is no longer present without affecting the intention of the sentence. TGax editor please make the changes as shown in 11-17/0250r2
5184	Dorothy Stanley	27.5.2.1	164.14	Define "UL OFDMA PPDU"	as in comment	Revised Agree with the comment. The sentence was update as a resolution to CID 5702. The term OFDMA PPDU is no longer present. TGax editor please make the changes as shown in 11-17/0250r2
9451	Xiaofei Wang	27.5.2.1	164.14	there is no definition of 'UL OFDMA PPDU'	Define UL OFDMA PPDU or use other defined terminology.	Revised Agree with the comment. The sentence was update as a resolution to CID 5702. The term OFDMA PPDU is no longer present. TGax editor please make the changes as shown in 11-17/0250r2
5185	Dorothy Stanley	27.5.2.1	164.19	Define "UL MU-MIMO HE trigger-based PPDU"	as in comment	Revised Updated the sentence to clarify that this is a Trigger-based PPDU that is using UL MU-MIMO TGax editor please make the changes as shown in 11-17/0250r2
5703	Guoqing Li	27.5.2.1	164.19	There is no terminology called "UL MU-MIMO HE trigger-based PPDU"	Delete "UL MU-MIMO" from the sentence.	Revised Updated the sentence to clarify that this is a Trigger-based PPDU that is using UL MU-MIMO TGax editor please make the changes as shown in 11-17/0250r2
7574	Liwen Chu	27.5.2.1	164.24	Class A and B should also apply to UL MU also.	Change the text per the comment.	Revised Agree with the comment. Deleted text that indicated only UL OFDMA case. TGax editor please make the changes as shown in 11-17/0250r2
9894	Young Hoon Kwon	27.5.2.1	164.24	Class A/B is not limited to an UL OFDMA PPDU. It can be applied HE trigger-based PPDU including not only OFDMA but also MU-MIMO cases.	Modify the last paragraph of 27.5.2.1 to " A STA transmitting an UL trigger-based PPDU shall operate as either ...".	Revised Agree with the comment. Text is updated to indicate HE trigger based PPDU. Deleted text indicating only UL OFDMA case. Also see resolution to CID 7574.
4812	Alfred Asterjadhi	27.5.2.1	164.24	UL OFDMA PPDU is not defined. Is it meant to be triger-based PPDU with no more than one SS per user?	Define UL OFDMA PPDU or contextualy add more details to define the intended type of PPDU	Revised Agree with the comment. However, the term UL OFDMA was deleted as a resolution to CID 7574.
5186	Dorothy Stanley	27.5.2.1	164.24	Define "UL OFDMA PPDU"	as in comment	Revised Agree with the comment. However, the term UL OFDMA was deleted as a resolution to CID 7574.
5704	Guoqing Li	27.5.2.1	164.24	There is no terminology called "UL OFDMA PPDU"	Use a difined terminology	Revised Agree with the comment. However, the term UL OFDMA was deleted as a resolution to CID 7574.
9452	Xiaofei Wang	27.5.2.1	164.24	there is no definition of 'UL OFDMA PPDU'	Define UL OFDMA PPDU or use other defined terminology	Revised

						Agree with the comment. However, the term UL OFDMA was deleted as a resolution to CID 7574.
8272	Pascal VIGER	27.5.2.1	164.24	class A or class B devices are said to be defined in 28.3.14 (Transmit requirements for an HE trigger-based PPDU), whereas this seems not the case.	as per comment	Reject The sentence is not implying that the definition of class A or class B devices is in 28.3.14 but instead it is point to how a STA sending a trigger response will operate while in class A or class B. The section reference (28.3.14) is correct.
9707	Yongho Seok	27.5.2.1	164.25	"A STA that is a class A device shall set the Class A subfield in HE Capabilities elements that it transmits to 1. A STA that is a class B device shall set the Class A subfield in HE Capabilities elements that it transmits to 0." There is no Class A subfield in HE Capabilities element. Change it as the following: "A STA that is a class A device shall set the Device Class subfield in HE Capabilities elements that it transmits to 1. A STA that is a class B device shall set the Device Class subfield in HE Capabilities elements that it transmits to 0."	As per comment.	Accept Agree with the comment. Fixed text as suggested by the commenter. TGax editor please make the changes as shown in 11-17/0250r2
5706	Guoqing Li	27.5.2.1	164.50	Comparing to the first bullitin which has "one or more trigger frames", the second bullitin here says "an UL MU Response scheduling", it reads like only one MPDU in the PPDU can include an UL MU response scheduling subfield. However, I don't think that's the intention of this bullitin. Multiple MPDUs can carry the UL MU response scheduling A-Control field each addressed to differnet STAs. This needs to be clarified.	Clarify, remove "An" from beginning of the sentence.	Accept Agree with the comment Deleted 'An' from the beginning of the sentence. Also see resolution to CID 9588. TGax editor please make the changes as shown in 11-17/0250r2
5187	Dorothy Stanley	27.5.2.2.1	164.52	Define "S-MPDU"	as in comment	Reject The term S-MPDU is defined in 802.11ah spec (please see 802.11ah D10.0 page 3 line 9)
6168	Jinjing Jiang	27.5.2.2.1	164.53	What is S-MPDU? VHT single MPDU? It is not formally defined in the draft or 802.11-16; please quote the correct 10.13.8 section title; and if carried in VHT single MPDU, should "Are"-->"Is"	Define the term before use it	Reject The term S-MPDU is defined in 802.11ah spec (please see 802.11ah D10.0 page 3 line 9). Also, the 'Are' refers to the MPDUs (plural).
5983	Jarkko Kneckt	27.5.2.2.1	164.63	The standard should not encourage to put more than one Trigger frame to the A-MPDU, because multiple Trigger generate overhead and the Trigger frames will be located right after each other.	Change may to should not. Change the text to read:" More than one Trigger frame should not be aggregated..."	Reject An AP may aggregate multiple Trigger frames in an A-MPDU for the purpose of robustness and/or to replace junk with useful information (i.e., instead of adding padding to the A-MPDU, the AP can fill the frame with Trigger frames carrying the same content).
8273	Pascal VIGER	27.5.2.2.1	164.63	The purpose of following sentence is unclear: "More than one Trigger frame may be aggregated in an A-MPDU. If more than one Trigger frame is aggregated in an A-MPDU, all of them shall have the same content." What is the aim of such duplication, to replace padding ?	as per comment	Reject An AP may aggregate multiple Trigger frames in an A-MPDU for the purpose of robustness and/or to replace junk with useful information (i.e., instead of adding padding to the A-MPDU, the AP can fill the frame with Trigger frames carrying the same content).
8338	Peter Khoury	27.5.2.2.1	164.63	The sentence "More than one Trigger frame may be aggregated in an A-MPDU.	Clarify the language on situations in which trigger frames may be	Reject As described in the spec, all the Trigger

				If more than one Trigger frame is aggregated in an A-MPDU, all of them shall have the same content." Is the situation in which more than one trigger frame is aggregated is a DL MU PPDU with multiple Trigger Frames transmitted to different users in different RUs? If this is the case then this sentence is overly restrictive as information about other users is being unicasted to a single user.	aggregated. If the situation described in the comment is valid allow trigger frames to different users in an A-MPDU to differ from each other.	frames in an A-MPDU shall carry the same content. An AP may aggregate multiple trigger frames for the purpose of robustness and/or to replace junk with useful data.
9588	Yongho Kim	27.5.2.2.1	164.64	Not only Trigger frame, but also Trigger A-contol shall follow same rule.	As in comment.	Revised Agree with the comment. The rules for HT Control field in an A-MPDU are described in section 10.9 (see pg 1364 of 802.11-2016): "If the HT Control field is present in an MPDU aggregated in an A-MPDU, then all MPDUs of the same frame type (i.e., having the same value for the Type subfield of the Frame Control field) aggregated in the same A-MPDU shall contain an HT Control field. The HT Control field of all MPDUs containing the HT Control field aggregated in the same A-MPDU shall be set to the same value." Added an explanatory note with reference to section 10.9 TGax editor please make the changes as shown in 11-17/0250r2
6166	Jinjing Jiang	27.5.2.2.1	165.01	line 1-6 is a duplicate of line 18-19	As in the comments	Reject The lines are not duplicates. Lines 1-6 explain that an A-MPDU cannot carry a trigger frame and a MPDU containing UL MU Response Scheduling A-Control addressed to the same STA. While lines 18-19 imply that only an HE AP can send an MPDU that carries a Trigger frame or a UL MU Response Scheduling A-Control subfield.
10167	Yunbo Li	27.5.2.2.1	165.26	In sentence,"The AP shall apply the Trigger Frame MAC Padding field with duration corresponding to the longest value among all STAs that have requested extra MinTrigProcTime through Trigger Frame MAC Padding Duration capability", only need to consider all triggered STAs.	change "among all STAs" to "among all triggered STAs"	Accept Made the change as suggested by the comment. This clarifies that only the triggered STAs are considered. TGax editor please make the changes as shown in 11-17/0250r2
4815	Alfred Asterjadhi	27.5.2.2.1	165.27	"The AP shall apply the Trigger Frame MAC Padding field with duration corresponding to the longest value among all STAs that have requested extra MinTrigProcTime through Trigger Frame MAC Padding Duration capability." Which are "all the STAs"? even STAs that are not allocated by this trigger frame?	Clarify that the statement refers to only the STAs are allocated by this trigger frame	Revised The paragraph on trigger frame padding has been updated and includes clarification that only the triggered STAs are considered when padding length is computed. TGax editor please make the changes as shown in 11-17/0250r2
4816	Alfred Asterjadhi	27.5.2.2.1	165.31	This para is reduntant. The previous one is sufficient	Remove this para	Accept Agree with the comment. The redundant paragraph has been deleted. TGax editor please make the changes as shown in 11-17/0250r2

7644	Liwen Chu	27.5.2.2.1	165.21	This requirement must be true to the last Trigger frame in A-MPDU. Change the text accordingly.	As in comment	Revised Agree with the comment. The paragraph has been updated and includes clarification that the padding requirement applies to the last or the only trigger frame carried in the PPDU. TGax editor please make the changes as shown in 11-17/0250r2
7812	Mark Hamilton	27.5.2.2.1	165.26	This sentence is inconsistent with the next paragraph, and the previous sentence. The only rule we need, is for the AP to protect each non-AP STA's requested time. No need for a maximumizing function.	Delete this sentence.	Revised Agree with the comment Revised the paragraph on trigger frame padding to cover the case of LDPC and BCC coding and to clarify that the padding length (in time) is computed with respect to *MinTrigProcTime* specified by each triggered STA and not the longest of all the triggered STAs. Also deleted the formula in 9.3.1.23 (Trigger frame format) since it is not used for computing the size of the padding field. TGax editor please make the changes as shown in 11-17/0250r2
9896	Young Hoon Kwon	27.5.2.2.1	165.27	This sentence is somewhat misleading. An AP shall ensure that the duration from the end of the User Info field to the end of the PPDU shall be longer than the maximum MinTrigProcTime value. However, how to achieve this is an AP's implementation issue, such as using EOF padding, Trigger frame padding, or both, etc. Therefore, it is not appropriate to mention that the AP shall apply the Trigger Frame MAC Padding field with duration corresponding to the longest value among all STAs... Further clarification is needed.	As in the comment.	Revised Agree with the comment See resolution for CID 7812. Also added a note to mention that AP can use any type of padding to ensure the required amount of 'padding' time has passed. TGax editor please make the changes as shown in 11-17/0250r2
6065	Jeongki Kim	27.5.2.2.1	165.35	Because the size of AID in User Info field is 12 bits, change the value of AID for padding from the 2047 to 4095.	Change the related text as follows: 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 4095, and the remaining subfields of the Padding field are set to 1.	Reject From section 9.4.1.8 (AID field), "A non-DMG STA assigns the value of the AID in the range 1–2007; the 5 MSBs of the AID field are reserved." – i.e., bit 12 is reserved. Therefore, leaving the current text unchanged.
7175	kaiying Lv	27.5.2.2.1	165.35	The start of the Padding subfield is identified by a User Info field that has a value of the AID equal to 0XFFF,not 2047	Change "2047" to "0XFFF"	Reject From section 9.4.1.8 (AID field), "A non-DMG STA assigns the value of the AID in the range 1–2007; the 5 MSBs of the AID field are reserved." – i.e., bit 12 is reserved. Therefore, leaving the current text unchanged.
9759	Yoshio Urabe	27.5.2.2.1	165.35	The value of AID12 subfield for MAC padding of a Trigger frame is not clear. The special AID value is 2047 (i.e. 0x7FF) in 27.5.2.2.1 while the special value of STAID[11:0] is 0xFFF in 9.3.1.23.	Change "a value of the AID equal to 2047" to "a value of the AID12 subfield equal to 0xFFF".	Reject From section 9.4.1.8 (AID field), "A non-DMG STA assigns the value of the AID in the range 1–2007; the 5 MSBs of the AID field are reserved." – i.e., bit 12 is reserved. Therefore, leaving the current text unchanged.
9456	Xiaofei Wang	27.5.2.2.2	165.56	The Note is about how to set RA address in Trigger based PPDUs and it seems to be unrelated to the text above, which is on the setting of the trigger frame. It should be removed or moved to the related sections.	Remove the Note	Revised Agree with the comment Moved the note to section 27.5.2.3 which describes behavior on the responding STA. Also moved text related to RA behavior in following paragraph to 27.5.2.3.

						TGax editor please make the changes as shown in 11-17/0250r2
9589	Yongho Kim	27.5.2.2.2	165.64	GCR-MU-BAR also need to be included.	Instead of using 'MU-BAR', use '(GCR)MU-BAR)'.	Revised Agree with the comment Updated text to fix missing references to GCR MU-BAR at the location pointed out by the comment and at other locations in this section. TGax editor please make the changes as shown in 11-17/0250r2
7176	kaiying Lv	27.5.2.2.2	166.05	"destination AP" is confusing. Need to be clarified.	Change "destination AP" to "associated AP"	Reject A trigger frame may assign RA RUs for unassociated STAs. Therefore, 'destination AP' is the correct term.
10260	Yusuke Tanaka	27.5.2.2.2	166.10	This rule conflict with the rule described in P164L63. Here it says "An AP shall set all the subfields, except the Trigger Type subfield, of the Common Info field of a Trigger frame to the same value (omitted) carried in the same PPDU" but P164L63 says "If more than one Trigger frame is aggregated in an A-MPDU, all of them shall have the same content."	Resolve the conflict.	Reject Both sentences are correct. One of them is referring to Trigger frames in an A-MPDU while the other is referring to Trigger frames in a PPDU. A PPDU can carry multiple A-MPDUs. Within an A-MPDU, if there are more than one trigger frame, they shall all have the same content. Each A-MPDU (within a PPDU) could carry different types of trigger frames.
9898	Young Hoon Kwon	27.5.2.2.2	166.10	How about Trigger Dependent Common Info subfield? For example, if an AP sends GCR MU-BAR Trigger frame and MU-BAR Trigger frame together, it is not sure how to set the Trigger Dependent Common Info subfield of MU-BAR frame.	Change the txt "except the Trigger Type subfield," to "except the Trigger Type subfield and Trigger Dependent Common Info subfield,".	Reject As seen from table 9-425, an A-MPDU can aggregate one or more trigger frames where the trigger type is not GCR (which is the only type that can have a Trigger Dependent Common Info field).
8552	Rojan Chitrakar	27.5.2.2.2	166.38	"User Info field" should be "A-control subfield"?	Replace "User Info field" with "A-control subfield"	Revised Agree with the comment. Changed text to indicate STAs that receive the UL MU Response Scheduling A-Control subfield. TGax editor please make the changes as shown in 11-17/0250r2
3228	Ahmadreza Hedayat	27.5.2.2.2	166.49	Better to refer to "... HE variant HT Control fields with an UL MU Response Scheduling A-Control subfield" as "UL MU Response Scheduling A-Control field" as in the rest of 27.5.	As in the comment	Revised Agree with the comment. Fixed such reference at another location in this section. TGax editor please make the changes as shown in 11-17/0250r2
9710	Yongho Seok	27.5.2.2.2	166.62	The Multi-TID Support field is not defined in the HE MAC Capabilities Information field of the HE Capabilities element. Replace "Multi-TID Support" with "Multi-TID Aggregation Support". Also replace the same on Page 167 Line 7.	As per comment.	Accept Corrected the field name referenced in the sentences. TGax editor please make the changes as shown in 11-17/0250r2
4818	Alfred Asterjadhi	27.5.2.2.3	167.38	this para is redundant. Concepts are better explained at the previous para	Remove this paragraph	Accept Agree with the comment. The previous paragraph contains more detailed and covers the items in this one. Deleted the redundant paragraph. TGax editor please make the changes as shown in 11-17/0250r2
8151	Michael Montemurro	27.5.2.3	167.42	"STA behavior" doesn't provide much context for this subclause. Is it really TX rules?	Update the title of the clause to be something more specicic than "STA behavior"	Revised Changed the title of the clause to "STA behavior for UL MU Operation"

						TGax editor please update the section title as suggested in 11-17/0250r2. Also please update other sections in the draft to show the updated title when they make reference to 27.5.2.3.
8701	Sigurd Schelstraete	27.5.2.3	168.05	In the bullet list on page 168, sometimes we explicitly refer to the "Common field of the Trigger frame" sometimes just "The trigger Frame"	Include "Common field" in all cases	Accept Fixed reference as suggested by the comment. TGax editor please make the changes as shown in 11-17/0250r2
8702	Sigurd Schelstraete	27.5.2.3	168.06	In the bullet list on page 168, sometimes we use "solicting Trigger frame", sometimes "eliciting Trigger frame" or just "Trigger frame".	Use consistent wording	Revised Changed the two instances of 'soliciting' to 'eliciting' as 'eliciting Trigger frame' was used at all other instances in this particular clause (27.5.2.3). TGax editor please make the changes as shown in 11-17/0250r2
4821	Alfred Asterjadhi	27.5.2.3	168.27	typo on CH_BANDWITHW	remove the final W	Accept Deleted typo (extra 'W' from the word) TGax editor please make the changes as shown in 11-17/0250r2
9529	Yasuhiko Inoue	27.5.2.3	168.32	"The NUMBER_HE_LTF_SYM parameter shall be set to the value ..." There is no such a parameter in TXVECTOR nor RXVECTOR.	Clarify which parameter is referred to.	Revised Agree with the comment. Fixed the parameter name to NUM_HE_LTF TGax editor please make the changes as shown in 11-17/0250r2
4820	Alfred Asterjadhi	27.5.2.3	168.46	repeated "shall be set"	remove	Accept Deleted repeating text TGax editor please make the changes as shown in 11-17/0250r2
8703	Sigurd Schelstraete	27.5.2.3	168.46	"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 MCS is not in the Common field, but the User Info field.	Correct. Also correct typo (repetition of "shall be set to")	Accept Deleted repeating text and fixed incorrect reference (Common Info field => User Info field) TGax editor please make the changes as shown in 11-17/0250r2
4822	Alfred Asterjadhi	27.5.2.3	168.52	repeated "shall be set"	remove duplication	Accept Deleted repeating text TGax editor please make the changes as shown in 11-17/0250r2
4823	Alfred Asterjadhi	27.5.2.3	169.07	UL_TARGET_RSSI, DL_TX_POWER are not defined vectors	Remove. These are not paramters that go into the trigger-based PPDU	Accept Removed the two parameters are pointed in the comment TGax editor please make the changes as shown in 11-17/0250r2
4824	Alfred Asterjadhi	27.5.2.3	169.15	MU_MIMO_LTF_MODE is not a tx/rx vector paramter. LDPC_EXTRA is actually LTPC_EXTRA_SYMBOL; CODING_TYPE is not defined; SS_ALOCATION is not defined	Refer to the correct paramters or remove them.	Revised Renamed incorrect field reference Removed fields that are not present in the TX/RXVECTOR TGax editor please make the changes as shown in 11-17/0250r2
4825	Alfred Asterjadhi	27.5.2.3	169.26	CP_LTF_TYPE paramter does not exist	Refer to the correct paramter	Revised Fixed incorrect reference. Change CP_LTF_TYPE to HE_LTF_TYPE

						TGax editor please make the changes as shown in 11-17/0250r2
6685	John Coffey	27.5.2.3	169.41	Inconsistent terminology: here we have "the trigger-based PPDU", whereas almost everywhere else in the draft we have "the HE trigger-based PPDU". If the same thing is intended, the same term should be used.	Change to "the HE trigger-based PPDU".	Accept Text changed as suggested by the commenter TGax editor please make the changes as shown in 11-17/0250r2
7649	Liwen Chu	27.5.2.3	169.50	MAC padding of A-MPDU in HE TRIG PPDU should be in subcaluse 27	Change the padding subclause.	Revised Fixed incorrect reference. Added correct reference pointing to section 27.10.3 TGax editor please make the changes as shown in 11-17/0250r2
5717	Guoqing Li	27.5.2.3	169.52	missing "and" between the reference of 9.7.3 and 27.10.3	add "and" between the two reference sections.	Accept Added ‘and’ as suggested by the commenter TGax editor please make the changes as shown in 11-17/0250r2
3232	Ahmadreza Hedayat	27.5.2.3	169.56	Add the BQRP and GCR MU-BAR: "If the Trigger Type field of a Trigger frame is not Basic Trigger, then the STA shall include in the response A-MPDU at least one MPDU of the required type. A Beamforming Report Poll Trigger frame solicits HE Compressed Beamforming Feedback frames (see 27.6 (HE sounding protocol), an MU BAR Trigger frame solicits BlockAck frames (see 27.4 (Block acknowledgement)), and a BSRP Trigger frame solicits QoS Null frames (see 27.5.2.5 (HE buffer status feedback operation for UL MU). The MPDUs included in the response shall not solicit a response."	"If the Trigger Type field of a Trigger frame is not Basic Trigger, then the STA shall include in the response A-MPDU at least one MPDU of the required type. A Beamforming Report Poll Trigger frame solicits HE Compressed Beamforming Feedback frames (see 27.6 (HE sounding protocol), an MU BAR Trigger frame or a GCR MU-BAR frame solicits BlockAck frames (see 27.4 (Block acknowledgement)), a BSRP Trigger frame solicits QoS Null frames (see 27.5.2.5 (HE buffer status feedback operation for UL MU), and a BQRP Trigger frame solicits QoS Null frames. The MPDUs included in the response shall not solicit a response."	Revised Agree with the comment. Updated text to include GCR case and BQRP variant of TF. TGax editor please make the changes as shown in 11-17/0250r2
7816	Mark Hamilton	27.5.2.3	169.57	Clarify 'required'.	Change "required type" to "type requested by the Trigger frame". Same thing at P170L2.	Revised Agree with the comment Changed text to say requested type for the case when trigger frame type is not basic trigger. Revised the text for basic trigger case to indicate empty buffer case. TGax editor please make the changes as shown in 11-17/0250r2
5988	Jarkko Kneckt	27.5.2.3	169.61	QoS Data or QoS Null frame may be used as a response to BSRP and BQR. Currenly only QoS Null is listed.	Add QoS Data as one response frame.	Reject Only Basic Trigger specifies the minimum spacing field (i.e., the MPDU MU spacing field) and other fields like TID Aggregation Limit necessary for a data frame. Therefore TB PPDU for BSRP and BQR cannot be a QoS Data frame.
9713	Yongho Seok	27.5.2.3	169.61	"If the Trigger Type field of a Trigger frame is not Basic Trigger, then the STA shall include in the response A-MPDU at least one MPDU of the required type. A Beamforming Report Poll Trigger frame solicits HE Compressed Beamforming Feedback frames (see 27.6 (HE sounding protocol), an MU BAR Trigger frame solicits BlockAck frames (see 27.4 (Block acknowledgement)), and a BSRP	As per comment.	Revised Agree with the comment. Updated text to fix the frame name to Beacomforming and CQI frame. Included the case of BQRP variant of TF. TGax editor please make the changes as shown in 11-17/0250r2

				Trigger frame solicits QoS Null frames (see 27.5.2.5 (HE buffer status feedback operation for UL MU). The MPDUs included in the response shall not solicit a response." The HE Compressed Beamforming Feedback frame is a wrong frame name. And, the above paragraph is missing the Bandwidth Query Report Poll variant Trigger frame. Change it as the following: "...A Beamforming Report Poll Trigger frame solicits HE Compressed Beamforming And CQI frames (see 27.6 (HE sounding protocol)... a BSRP Trigger frame and a BQRP Trigger frame solicit QoS Null frames (see 27.5.2.5 (HE buffer status feedback operation for UL MU and 27.5.1.3 (HE bandwidth query report operation for DL MU))...."		
4828	Alfred Asterjadhi	27.5.2.3	170.15	double period		Accept Deleted extra period TGax editor please make the changes as shown in 11-17/0250r2
6196	John Buffington	27.5.2.5	171.39	Unknown reference in description of "(#2190, 2191)".	Please clarify reference or remove it if it's a mistake.	Accept Deleted CID reference TGax editor please make the changes as shown in 11-17/0250r2
3325	Albert Petrick	27.5.2.5	171.40	"ACs (#2190, 2191)" are remaining CID placeholders and not part of draft .11ax D1.0	Remove references to CIDs #2190, and 2191	Accept Deleted CID reference TGax editor please make the changes as shown in 11-17/0250r2
6695	John Coffey	27.5.2.5	171.41	Incomplete cross-reference: "Table 9-XX".	Add full table number.	Accept Fixed the Table number reference TGax editor please make the changes as shown in 11-17/0250r2
8705	Sigurd Schelstraete	27.5.2.5	171.41	Wrong reference: Table 9-XX	Correct reference	Accept Fixed the Table number reference TGax editor please make the changes as shown in 11-17/0250r2
6696	John Coffey	27.5.2.5	171.56	Inconsistent terminology: here we have "the trigger-based PPDU", whereas almost everywhere else in the draft we have "the HE trigger-based PPDU". If the same thing is intended, the same term should be used.	Change to "the HE trigger-based PPDU".	Accept Text changed as suggested by the commenter TGax editor please make the changes as shown in 11-17/0250r2
7817	Mark Hamilton	27.5.2.5	171.56	AID12 is equal to the least significant 12 bits of the AID	Change "the STA's AID" to "the 12 least significant bits of the STA's AID". Same thing at P181L43, P184L1. Similarly "recipient's AID" to "12 least significant bits of the reipcient's AID" at P181L44.	Revised Updated text to indicate 12 LSBs of the STA's AID. TGax editor please make the changes as shown in 11-17/0250r2
6697	John Coffey	27.5.2.5	171.59	Inconsistent terminology: here we have "the Trigger-based PPDU", whereas almost everywhere else in the draft we have "the HE trigger-based PPDU". If the same thing is intended, the same term should be used.	Change to "the HE trigger-based PPDU".	Accept Text changed as suggested by the commenter TGax editor please make the changes as shown in 11-17/0250r2

9917	Young Hoon Kwon	27.5.2.5	172.06	If the AP does not support the A-BSR Support subfield, it shall not send BSRP variant Trigger frame. Therefore, "when the AP indicated its support..." is meaningless.	Delete "when the AP has indicated its support in the A-BSR Support subfield of its HE Capabilities element" in the second sub-bullet.	Reject A non-AP STA shall not send an A-BSR in response to a trigger frame of type BSRP if the AP has not indicated support for receiving A-BSR via the A-BSR Supported field in HE Capabilities element. In such case, QoS Control field is the only option available to the STA.
5997	Jarkko Kneckt	27.5.2.5	172.19	Aggregating the BSR control frame with data, control and management frame is unlikely. It is more likely that BSR control frame is aggregated with control, data OR management frame.	Change to:" aggregated with control, data or management frames..."	Reject A Multi-TID A-MPDU can carry management frame (TID value 15), therefore, a Trigger frame of type BSRP could be aggregated with Data, Control and Management frame.
5998	Jarkko Kneckt	27.5.2.5	172.20	Unclear statements that may be interpretted differently resulting to interoperability problems.	Please clarify what is meant with "asks for acknowledgement" and "has high priority to be transmitted".	Revised Agree with the comment. The sentence is revised to clarify that the solicited A-MPDU shall carry MPDU(s) in the order specified in Table 9-425. TGax editor please make the changes as shown in 11-17/0250r2
6701	John Coffey	27.5.2.5	172.20	The statement that the acknowledgment has "high priority" doesn't seem to mean much. High compared with what? It may be that "highest" is meant, but if so, it's essential to say so, because that's not what the text says now.	Change "high" to "highest" (if this is what is intended).	Revised Agree with the comment. The sentence is revised to clarify that the solicited A-MPDU shall carry MPDU(s) in the order specified in Table 9-425. TGax editor please make the changes as shown in 11-17/0250r2

TGax Editor, please note, all references in this document to UL MU Response Scheduling A-Control are replaced with UMRS Control to be consistent with doc 11-17-238

27.5.2 UL MU operation

27.5.2.1 General

TGax Editor: Please make changes to this section (D1.1 pg 168, ln 4) as shown below:

The UL MU operation allows an HE[8271] AP to solicit simultaneous immediate response frames from one or more non-AP HE[8271] STAs. Non-AP HE[8271] STAs [7968]shall attempt to transmit their response frames using HE trigger-based PPDU format, ~~in either UL OFDMA, UL MU-MIMO, or both,~~[4809] except when the Trigger frame is of type MU-RTS, in which case the response (CTS) is sent in a non-HT PPDU format (see 10.3.2.8a (MU-RTS/CTS procedure)).

~~An~~ A non-AP[8271] HE STA with dot11ULMUMIMOOptionImplemented true shall set the Full Bandwidth UL MU-MIMO subfield of the HE PHY Capabilities Information field of the HE Capabilities element it transmits to 1, if it supports receiving a Trigger frame soliciting a HE trigger-based PPDU that uses UL MU-MIMO within an RU that spans the entire PPDU bandwidth. Otherwise, the HE STA shall set the Full Bandwidth UL MU-MIMO subfield to 0.

A non-AP HE STA with dot11ULMUMIMOOptionImplemented true shall set the Partial Bandwidth UL MU-MIMO subfield of the HE PHY Capabilities Information field of the HE Capabilities element it transmits to 1, if it supports receiving a Trigger frame soliciting a HE trigger-based PPDU that uses UL MU-MIMO within an RU that does not span the entire PPDU bandwidth. Otherwise, the HE STA shall set the Partial Bandwidth UL MU-MIMO subfield to 0.

A non-AP HE[8271] STA with dot11ULMUMIMOOptionImplemented equal to true is referred to as an UL MU capable STA.

~~An~~ A non-AP[8271] 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.

An HE AP ~~STA~~[8271] shall not transmit a Trigger frame soliciting a HE trigger-based PPDU that uses UL MU-MIMO within an RU that does not span the entire PPDU bandwidth ~~assigning an MU-MIMO RU in an UL OFDMA PPDU when the RU does not span that entire PPDU bandwidth~~ to a STA from which it has not received an HE Capabilities element with the Partial Bandwidth UL MU-MIMO subfield of the HE PHY Capabilities Information field equal to 1[5183, 5184, 5702, 9451].

An HE AP ~~STA~~[8271] shall not transmit a Trigger frame soliciting a HE trigger-based PPDU that uses UL MU-MIMO[5185, 5703] within an RU that spans the full bandwidth ~~UL MU-MIMO HE trigger based PPDU from~~ to a non-AP HE[8271] STA from which it has not received an HE Capabilities element with the Full Bandwidth UL MU-MIMO subfield of the HE PHY Capabilities Information field equal to 1.

A non-AP HE[8271] STA transmitting a~~n~~ HE trigger-based ~~UL OFDMA~~ PPDU[7574, 9894, 4812, 5186, 5704, 9452] shall operate as either a class A or class B device as defined in 28.3.14 (Transmit requirements for an HE trigger-based PPDU). An HE[8271] STA that is a class A device shall set the [9707]Device Class ~~A~~ subfield in HE Capabilities elements that it transmits to 1. An HE[8271] STA that is a class B device shall set the [9707]Device Class ~~A~~ subfield in HE Capabilities elements that it transmits to 0.

27.5.2.2 Rules for soliciting UL MU frames

27.5.2.2.1 General

TGax Editor: Please make changes to this section (D1.1 pg 168, ln 44) as shown below:

An AP shall not send to a STA an MPDU that contains an ~~UL MU Response Scheduling A-Control~~ UMRS Control subfield, unless the STA has set the UL MU Response Scheduling Support subfield to 1 in the HE Capabilities element it transmits.

An AP may transmit a PPDU that elicits an HE trigger-based PPDU from one or more STAs by including in the PPDU:

— One or more Trigger frames that includes one or more User Info fields addressed to one or more of the recipient STAs. For recipient STAs that are associated with the AP, the User Info field is addressed to a recipient STA if the value of the AID12 subfield of the User Info field is equal to the AID of the STA or to 0 (indicating a random access allocation).. A value of 0 also indicates that non-associated STAs can transmit on the allocated resource using the random access procedure as described in 27.5.2.6 (UL OFDMA-based random access).

— [5706]~~An UL MU Response Scheduling A-Control~~ UMRS Control subfield of individually addressed MPDUs contained in the HE MU PPDU that:

- Are carried in a S-MPDU format that solicits an immediate Ack frame (see 10.13.8 (Transport of S-MPDUs))
- Are carried in an A-MPDU format that solicits an immediate BlockAck frame (see 10.24.7.7 (Originator's behavior))
- Are carried in a multi-TID A-MPDU format that solicits an immediate Multi-STA BA frame (see 27.10.4 (A-MPDU with multiple TIDs))

NOTE—The AP additionally follows the rules defined in 27.3.3 (Procedure at the originator) when fragments are present in the generated MPDU(s).

More than one Trigger frame may be aggregated in an A-MPDU. If more than one Trigger frame is aggregated in an A-MPDU, all of them shall have the same content.

[9588]Note – The UMRS Control subfield within MPDUs carried in an A-MPDU have the same value (see 10.9 (HT Control field operation)).

The following two frames shall not be present in the same A-MPDU:

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

— An MPDU that contains an ~~UL MU Response Scheduling A-Control~~ UMRS Control subfield and that is addressed to the same STA

When one or more Trigger Frames are aggregated with other frames in an A-MPDU, the following ordering rules apply:

— When an Ack, BlockAck or Multi-STA BlockAck frame is not present in the A-MPDU, a Trigger frame shall be the first MPDU in the A-MPDU

— When an Ack, BlockAck or Multi-STA BlockAck frame is present in the A-MPDU, the Ack, BlockAck or Multi-STA BlockAck frame shall be the first MPDU in the A-MPDU and a Trigger frame shall follow the Ack, BlockAck or Multi-STA BlockAck frame

A non-AP STA shall not send a Trigger frame or an MPDU carrying an ~~UL MU Response Scheduling A-Control~~ UMRS Control subfield.

[7812, 9896]An AP transmitting a PPDU that contains a Trigger frame or contains an UMRS Control subfield shall ensure that the remaining time duration of the PPDU that follows B_{SYM} is larger than or equal to the *MinTrigProcTime* value specified by the non-AP STA[10167, 4815] where:

- *MinTrigProcTime* is equal to the value, in microseconds, specified by the non-AP STA in the Trigger Frame MAC Padding Duration subfield of the HE Capabilities element that it transmits
- B_{SYM} is the symbol of the PPDU that contains either the last bit of the *SCH* field when BCC is used to encode the PSDU or the last coded bit of the LDPC codeword that encodes the last bit of the *SCH* field when LDPC is used to encode the PSDU, where *SCH* is either:
  - The User Info field with the AID12 subfield corresponding to the 12 LSBs of the non-AP STA's AID of the [7644]last (or only) Trigger frame soliciting the HE trigger-based PPDU or
  - The UMRS Control subfield of the last (or only) frame soliciting the HE trigger-based PPDU.

~~A transmitted Trigger frame that contains a User Info field with the AID of a non-AP STA may contain a Padding field, whose length shall ensure that at least *MinTrigProcTime*, in microseconds, passes from the end of the User Info field that contains that AID and the end of the PPDU that contains the Trigger frame, where the *MinTrigProcTime* is equal to the value specified by the non-AP STA in the Trigger Frame MAC Padding subfield of the HE Capabilities element it transmits. The AP shall apply the Trigger Frame MAC Padding field with duration corresponding to the longest value among all STAs that have requested extra *MinTrigProcTime* through Trigger Frame MAC Padding Duration capability.~~

[4816]~~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~~ in the AID12 subfield 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).~~

NOTE 2 —The AP can use any type of padding to ensure that the duration of time passes, such as using the Padding subfield in a Trigger frame, post-EOF padding in an A-MPDU, aggregating other MPDUs in the A-MPDU etc.[9896]

27.5.2.2.2 Allowed settings of the Trigger frame fields and ~~UL MU Response Scheduling A-Control~~ UMRS Control subfields

TGax Editor: Please make changes to this section (D1.1 pg 169, ln 55) as shown below:

An AP that transmits a Trigger frame shall set the TA field of the frame to one of the following:

- The MAC address of the AP transmitting the frame when dot11MultiBSSIDActivated is false or when dot11MultiBSSIDActivated is true and the Trigger frame is directed to STAs that intend to communicate with the AP
- The MAC address of the transmitted BSSID when dot11MultiBSSIDActivated is true and the Trigger frame is directed to STAs that intend to communicate with at least two different BSSs of the multiple BSSID set and that have indicated reception support for this Trigger frame in the Multiple BSSID Control Support field of the HE Capabilities element it transmits (see 11.1.3.8 (Multiple BSSID procedure)).

~~NOTE—All MPDUs within an A-MPDU carried in an HE trigger-based PPDU have the same RA (see 9.7.3 (A-MPDU contents). The settings of the address fields of MPDUs within the A-MPDU depend on the type and subtype of the MPDU as defined in 9.3 (Format of individual frame types).~~[9456, text moved to 27.5.2.3]

If an HE AP does not receive an HE Capabilities element with the Rx Control Frame To MultiBSS field equal to 1 from a STA, the HE AP shall not send a Trigger frame whose destination STAs associate with more than one APs to the STA. ~~The RA field of the frames sent in response to a MU-RTS frame is set as defined in 9.3.1.3 (CTS frame format). The RA field of the MPDUs sent in response of a MU-BAR is set as defined in 9.3.1.9 (BlockAck frame format). BlockAck frame and Data frames whose RAs are different shall not be aggregated in one A-MPDU in responding to an MU-BAR frame. The RA field of the Data frames and Management frames sent in response to a Trigger frame shall be set to the MAC address of the destination AP.~~[9456, text moved to 27.5.2.3]

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

An AP shall set all the subfields, except the Trigger Type subfield, of the Common Info field of a Trigger frame to the same value of the corresponding subfield of the Common Info field of any other Trigger frame that is carried in the same PPDU. An AP shall set the UL PPDU Length and DL Tx Power subfields of an ~~UL MU Response Scheduling A-Control~~ UMRS Control subfield to the same value of the corresponding subfield of any ~~UL MU Response Scheduling A-Control~~ UMRS Control subfield that is carried in the same PPDU. An AP shall set the following subfields of the Common Info field of a Trigger frame accordingly if an ~~UL MU Response Scheduling A-Control~~ UMRS Control subfield is carried in an MPDU within the same PPDU:

- MU-MIMO LTF Mode and STBC are set to 0
- Number of HE-LTF Symbols is set to 1
- Spatial Reuse is set to SR_Disallowed
- GI and LTF Type is set to ~~3~~2 if the carrying PPDU TXVECTOR parameter HE~~CP~~_LTF_TYPE is 4x LTF + 3.2 μs CP or 2x LTF + 1.6 μs CP; otherwise is set to ~~2~~1[4825, also see Table 9-25c in D1.1 (pg 44, ln 34)]
- CS Required subfield is set to 0

NOTE—STAs obtain the common information either explicitly, or implicitly or both. Explicit information is obtained in the Common Info field of a Trigger frame, or in the UL PPDU Length and DL TX Power subfields of the ~~UL MU Response Scheduling A-Control~~ UMRS Control subfield contained in the soliciting PPDU. Implicit information is obtained in previously exchanged frames with the AP, e.g., in the BSS Color and the Default PE Duration subfields of the HE Operation element, or from default values specified in 27.5.2.3 (STA behavior for UL MU Operation).

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~~ UMRS Control subfield in an HE variant HT Control field to a value that is not supported by the recipient STAs of the [8552]~~User Info~~ UMRS Control subfield.

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

[3228]~~An HE variant HT Control field with an UL MU Response Scheduling A-Control~~ UMRS Control subfield shall not be included in a~~n~~ group addressed MPDU ~~that is group addressed~~.

If an AP includes one or more Trigger Frames or [3228]~~HE variant HT Control fields with an UL MU Response Scheduling A-Control~~ UMRS Control subfield, then they shall collectively elicit HE trigger-based PPDU responses such that at least one RU is allocated for each 20 MHz channel occupied by the eliciting

PPDU. An AP shall not allocate UL subchannel in any 20 MHz channel that is not occupied by the immediately preceding DL PPDU.

The responding STA shall not aggregate QoS Data frames in the multi-TID A-MPDU with a number of TIDs that exceeds the value indicated by the TID Aggregation Limit subfield in the Trigger Dependent User Info field of a Basic Trigger frame (see 9.3.1.23.1 (Basic Trigger variant)) intended to it.

The AP shall set the value in the TID Aggregation Limit subfield in the Type Dependent User Info field to 0 or 1 for an HE STA that has 0 in the Multi-TID Aggregation[9710] Support field of the HE MAC Capabilities Information field of the HE Capabilities element it transmits and is identified by the AID12 subfield of the User Info field of a Basic Trigger frame (see 9.3.1.23 (Trigger frame format)).A value 0 indicates to the STA that it shall not solicit any immediate response for the MPDUs that the STA aggregates in the HE trigger-based PPDU.A value greater than 0 indicates the number of TIDs that the STA can aggregate in the A-MPDU carried in the HE trigger-based PPDU (see 27.10.4 (A-MPDU with multiple TIDs)).

The AP may assign any value between 0 and 7 in the TID Aggregation Limit subfield in the Trigger Dependent User Info field for an HE STA that has a nonzero value in the Multi-TID Aggregation[9710] Support subfield of the HE MAC Capabilities Information field of the HE Capabilities element it transmits and is identified by the AID12 subfield of the User Info field of a Basic Trigger frame.

The AP may assign any value in the AC Preference Level subfield in the Trigger Dependent User Info field for an HE STA identified by the AID12 subfield of the User Info field of a Basic Trigger frame.

The AP may assign any value defined in Table 9-25i (Preferred AC subfield encoding) in the AC Preference Level subfield in the Trigger Dependent User Info field to 1 for an HE STA and identified by the AID12 subfield of the User Info field of a Basic Trigger frame.

NOTE—A STA follows the rules in 27.10.4 (A-MPDU with multiple TIDs) for aggregating the QoS Data frames with multiple TIDs in HE trigger-based PPDUs.

Short guard interval shall not be used for a Trigger frame transmission if the Trigger frame is transmitted using HT or VHT PPDU format. DSSS or HR/DSSS PPDU format shall not be used for Trigger frame transmission.

27.5.2.2.3 AP access procedures for UL MU operation

TGax Editor: Please make changes to this section (D1.1 pg 171, ln 44) as shown below:

When an AP receives an immediate response with at least one MPDU from at least one STA solicited by a Trigger frame, the procedures described in 9.22.2.7 (Multiple frame transmission in an EDCA TXOP) apply.

When an AP does not receive an immediate response with at least one MPDU from at least one STA solicited by a Trigger frame, i.e., transmission failure, the backoff procedure described in 9.22.2.2 (EDCA backoff procedure) applies.

An AP may use any AC for sending a PPDU that contains only Trigger frames. If the PPDU contains frames that are not Trigger frames in addition to a Trigger frame, then the AP shall follow the rules defined in 10.22.2.6 (Sharing an EDCA TXOP).

~~An AP may send the Trigger frame using any access category and follows the rules defined in 10.22.2 (HCF contention based channel access (EDCA)) for obtaining and sharing the TXOP.~~[4818]

27.5.2.3 STA behavior for UL MU Operation[8151]

TGax Editor: Please make changes to this section (D1.1 pg 172, ln 1) as shown below:

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

The inter-frame space between a PPDU that contains a Trigger frame or contains an ~~UL MU Response Scheduling A Control~~ UMRS Control field that solicits an immediate response and the HE trigger-based PPDU is SIFS.

A STA shall commence the transmission of an HE trigger-based PPDU at the SIFS time boundary after the end of a received PPDU, when all the following conditions are met

— The received PPDU contains either a Trigger frame (that is not an MU-RTS variant) with a User Info field addressed to the STA, or an MPDU addressed to the STA that contains an ~~UL MU Response Scheduling A Control~~ UMRS Control subfield. The User Info field is addressed to a STA if the AID12 subfield is equal to the AID of the STA and the STA is associated with the AP. If the STA is not associated with the AP, TBD.

— The CS Required subfield in the Trigger frame is 1 and the UL MU CS condition described in 27.5.2.4 (UL MU CS mechanism) indicates the medium is idle, or the CS Required subfield in a Trigger frame is 0.

— Otherwise, a STA shall not send an HE trigger-based PPDU

A non-AP HE STA transmitting an HE trigger-based PPDU in response to a Trigger frame sets the TXVECTOR parameter as follows:

— The FORMAT parameter shall be set to HE_TRIG

— The PE_DURATION parameter shall be set according to the value of the Packet Extension field in the ~~soliciting~~ eliciting[8702] Trigger frame

— The TXOP_DURATION parameter shall be set according the rules defined in 27.2.3 (Updating two NAVs)

— The BSS_COLOR parameter shall be set as follows:

- If the preceding Trigger frame was received in an HE PPDU, then set to the value of the RXVECTOR parameter BSS_COLOR of the HE PPDU
- If the Trigger frame was received in a non-HE PPDU, then set to the value of the BSS Color subfield of the most recently received HE Operation element for that BSS

— The L_LENGTH parameter shall be set to the value indicated by the Length subfield of the [8701]Common Info field of the eliciting Trigger frame

— The GI_TYPE and HE_LTF_TYPE parameters shall be set to the value indicated by the GI and LTF Type subfield of the Common Info field of the eliciting Trigger frame

— The NUM_STS parameter shall be set to the number of space time streams indicated by the Number Of Spatial Streams subfield of the SS Allocation field of the User Info field and STBC field in the Common Info field of the eliciting[8702] Trigger frame

— The CH_BANDWIDTH~~W~~[4821] 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 [9529]~~NUMBER_HE_LTF_SYM~~ NUM_HE_LTF parameter shall be set to the value indicated by the Number Of HE-LTF Symbols subfield of the Common Info field of the eliciting Trigger frame
- The STBC parameter shall be set to the value indicated by the STBC subfield of the Common Info field of the eliciting Trigger frame
- The LDPC_EXTRA_SYMBOL[4824] parameter shall be set to the value indicated by the LDPC Extra Symbol Segment subfield of the Common Info field of the eliciting Trigger frame
- The SPATIAL_REUSE parameter shall be set to the value of the Spatial Reuse field in the Common Info field of the eliciting Trigger frame
- The HE_SIGA_RESERVED parameter shall be set to the value of the HE-SIG-A Reserved field in the Common Info field of the eliciting Trigger frame
- The MCS parameter shall be set to~~ shall be set to~~[4820, 8703] the value of the MCS field in the [8703]~~Common~~ User Info field of the eliciting Trigger frame
- The DCM parameter shall be set to the value indicated by the DCM subfield of the User Info field of the eliciting Trigger frame
- The STARTING_STS_NUM parameter shall be set to~~ shall be set to~~[4822] the value of the Starting Spatial Stream subfield of the SS Allocation field in the ~~Common~~ User Info field of the eliciting Trigger frame
- The FEC_CODING parameter shall be set to the value indicated by the Coding Type subfield of the User Info field of the eliciting Trigger frame
- The RU_ALLOCATION parameter shall be set to the value indicated by the RU Allocation field of the User Info subfield of the eliciting Trigger frame
- The TXPWR_LEVEL_INDEX parameter shall be set to the value based on the Transmit Power Control for HE trigger-based PPDU and based on the value of the AP Tx Power subfield in the Common Info field and the Target RSSI subfield in the User Info field of the eliciting Trigger frame (28.3.14.2 (Power pre-correction)).

A STA transmitting an HE trigger-based PPDU in response to soliciting MPDU(s), containing an ~~UL MU Response Scheduling A Control~~ UMRS 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,~~ [4823]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
- [4824]HE~~MU_MIMO~~_LTF_MODE, LDPC_EXTRA_SYMBOL, ~~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~~ Default PE Duration subfield of the HE Operation element it transmits, and the pre-FEC padding factor shall be set to 4 (see 28.3.12 (Packet extension))
- TXOP_DURATION parameter shall be set according the rules defined in 27.2.3 (Updating two NAVs)

— [4825]HE~~CP~~ LTF_TYPE parameter shall be set to indicate 4x LTF + 3.2 μs CP if the RXVECTOR parameter [4825]HE~~CP~~_LTF_TYPE is 4x LTF + 3.2 μs CP or 2x LTF + 1.6 μs CP ; otherwise shall be set to indicate 2x LTF + 1.6 μs CP

NOTE 1—The HE trigger-based PPDU in this case is only sent in UL OFDMA format and CS is not required prior to its transmission (see 27.5.2.4 (UL MU CS mechanism)).

NOTE 2—The use of BCC limits the available RU sizes as defined in 28.3.11.8 (BCC interleavers).

The RA field of the frames sent in response to a MU-RTS frame is set as defined in 9.3.1.3 (CTS frame format). The RA field of the MPDUs sent in response of a [9589]GCR MU-BAR or MU-BAR is set as defined in 9.3.1.9 (BlockAck frame format). BlockAck frame and Data frames whose RAs are different shall not be aggregated in one A-MPDU in responding to an [9589]GCR MU-BAR or MU-BAR frame. The RA field of the Data frames and Management frames sent in response to a Trigger frame shall be set to the MAC address of the destination AP.

NOTE —All MPDUs within an A-MPDU carried in an HE trigger-based PPDU have the same RA (see 9.7.3 (A-MPDU contents). The settings of the address fields of MPDUs within the A-MPDU depend on the type and subtype of the MPDU as defined in 9.3 (Format of individual frame types).[9456, text moved from 27.5.2.2.2]

The STA that responds to a DL MU PPDU containing MPDU(s) addressed to it that include ~~UL MU Response Scheduling A Control~~ UMRS Control subfield(s) follows the rules defined in 10.3.2.9 (Ack procedure) for generating the Ack frame, the rules defined in 10.24.7.5 (Generation and transmission of BlockAck frames by an HT STA or DMG STA) for generating the BlockAck frame, and the rules defined in 27.4 (Block acknowledgement) for generating the Multi-STA BlockAck frame. The STA shall construct the A-MPDU carried in the HE[6685] trigger-based PPDU as defined in Table 9-428 (A-MPDU contents MPDUs in the control response context) when the A-MPDU containing the ~~UL MU Response Scheduling A Control~~ UMRS Control subfield solicits an immediate response and as defined in Table 9-426 (A-MPDU contents in the data enabled no immediate response context) when the A-MPDU does not solicit an immediate response.

NOTE—The STA additionally follows the rules defined in 27.3.3 (Procedure at the originator) when fragments are present in the soliciting (A-)MPDU(s).

The MAC padding procedure is described in ~~10.42.2.1.2~~ 27.10.3 (A-MPDU padding for an HE trigger-based PPDU)[7649].

The content of each A-MPDU in an HE trigger-based PPDU is defined in 9.7.3 (A-MPDU contents) and[5717] in 27.10.3 (A-MPDU padding for an HE trigger-based PPDU) and subject to the following additional constraints:

— If the Trigger Type field of a Trigger frame is not Basic Trigger, then the STA shall include in the response A-MPDU at least one MPDU of the [7816]~~required~~ requested type. A Beamforming Report Poll Trigger frame solicits HE Compressed Beamforming [9713]~~Feedback~~ and CQI frames (see 27.6 (HE sounding protocol), an MU BAR Trigger frame [3232]or a GCR MU-BAR frame solicits BlockAck frames (see 27.4 (Block acknowledgement)), ~~and~~ a BSRP Trigger frame solicits QoS Null frames (see 27.5.2.5 (HE buffer status feedback operation for UL MU) [3232, 9713]and a BQRP Trigger frame solicits QoS Null frames (see 27.5.1.3 (HE bandwidth query report operation for DL MU). The MPDUs included in the response shall not solicit a response.

— If the Trigger Type field of the soliciting Trigger frame is Basic Trigger and the STA does not have [7816]a frame to transmit, ~~of the required type,~~ the STA shall either not transmit a response or transmit ~~one~~ zero or more QoS Null frames.

A STA that is an intended receiver of a Trigger frame that is not a Basic Trigger frame shall construct the A-MPDU carried in the HE trigger-based PPDU as defined in 9-428 (A-MPDU contents MPDUs in the control response context). A STA that is an intended receiver of a Basic Trigger frame may include MPDUs with any TID in the HE trigger-based PPDU sent in response to a Trigger frame subject the rules of 27.10.4 (A-MPDU with multiple TIDs).

NOTE 1—An AP can include other MPDUs in a soliciting DL MU PPDU that contains Trigger frames as specified in 9.7.3 (A-MPDU contents).

NOTE 2—The frame type of MPDUs may be different across A-MPDUs within a same HE trigger-based PPDU.~~.~~[4828]

27.5.2.5 HE buffer status feedback operation for UL MU

TGax Editor: Please make changes to this section (D1.1 pg 175, ln 30) as shown below:

A non-AP STA delivers buffer status reports (BSRs) to assist its AP in allocating UL MU resources in an efficient way. The non-AP STA can either implicitly deliver BSRs in the QoS Control field or BSR A-Control field of any frame transmitted to the AP (unsolicited BSR) or explicitly deliver BSRs in any frame sent to the AP in response to a BSRP variant Trigger frame (solicited BSR).

A non-AP STA reports its buffer status (unsolicited BSR) to the AP to which it is associated using either the QoS Control field or the BSR A-Control field of frames it transmits as defined below:

— The HE STA shall report the buffer status for a given TID in the Queue Size subfield of the QoS Control field in QoS Data or QoS Null frames it transmits; except that the STA may set the Queue Size subfield to 255 to indicate an unknown/unspecified BSR for that TID.
  - The HE STA may aggregate multiple QoS Data frames or QoS Null frames in an A-MPDU to report the buffer status for different TIDs. The HE STA shall follow the A-MPDU aggregation rules defined in 27.10.4 (A-MPDU with multiple TIDs) for aggregating QoS Data frames with multiple TIDs. The HE STA does not follow the rules defined in 27.10.4 (A-MPDU with multiple TIDs) for QoS Null frames whose Ack Policy subfield is No Ack.

— The HE STA may report the buffer status in the BSR A-Control subfield of frames it transmits if the AP has indicated its support in the A-BSR Support subfield of its HE Capabilities element; otherwise the STA shall not report the buffer status in the BSR A-Control subfield.
  - The HE STA shall report the buffer status for its preferred AC, indicated by the ACI High sub-field, 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)~~ [3325, 6196]
  - The HE STA shall set the Delta TID subfield according to Table 9-~~XX~~18c[6695, 8705] (Delta TID subfield encoding), and the Scaling Factor subfield as defined in 9.2.4.6.4.5 (Buffer Status Report (BSR)).

NOTE 1—The STA can send an unsolicited BSR in response to Basic variant Trigger frames (with or without random RUs, as defined in 27.5.2.3 (STA behavior for UL MU Operation) and in 27.5.2.6 (UL OFDMA-based random access)) or it can send the unsolicited BSR after accessing the WM using EDCA.

NOTE 2—The STA can include both the QoS Control and the BSR A-Control field in the same frame and it can set the Queue Size subfield of either of them to a value of 255.

An AP can also solicit one or more non-AP STAs for their BSR(s) by sending a BSRP variant Trigger frame (see 9.3.1.23 (Trigger frame format)). The non-AP STA responds (solicited BSR) as defined below:

— The STA that receives a BSRP variant Trigger frame shall follow the rules defined in 27.5.2.3 (STA behavior for UL MU Operation) to generate the HE[6696] trigger-based PPDU when the Trigger frame contains the 12 LSBs of the[7817] STA's AID in any of the Per User Info fields; otherwise the STA shall follow the rules defined in 27.5.2.6 (UL OFDMA-based random access) to gain access to a

random RU and generate the HE[6697] t~~T~~rigger-based PPDU when the Trigger frame contains one or more random RU(s).

— The STA shall include in the HE trigger-based PPDU one or more QoS Null frames containing one or more of the following:
  - The QoS Control field(s) with Queue Size subfields for each of the TIDs for which the STA has buffer status to report to the AP.
  - The BSR A-Control field with the Queue Size All subfield indicating the queue size for all the ACs, indicated by the ACI Bitmap subfield, for which the STA has buffer status to report to the AP when the AP has indicated its support in the A-BSR Support subfield of its HE Capabilities element. The STA shall set Delta TID, SF, ACI High and Queue Size High subfields of the BSR A-Control field as defined in 9.2.4.6.4.5 (Buffer Status Report (BSR))).

— The HE STA shall not solicit an immediate response for the frames carried in the HE[6697] trigger-based PPDU (e.g., by setting the Ack Policy subfield of the frame to Normal Ack or Implicit BAR).

NOTE—Similar to unsolicited BSR, the STA can set Queue Sizes in either QoS Control or BSR A-Control field to 255 to indicate unknown/unspecified BSR for a TID, AC or all AC.

An AP may include a BSRP Trigger frame together with other control, data and management frames in one A-MPDU to a STA if the HE Capabilities element received from the STA has the BSRP A-MPDU Aggregation field equal to 1. If a STA receives a BSRP Trigger frame aggregated with control, data and management frames that ~~asks for~~ solicits an[5998] acknowledgement, the response A-MPDU shall contain MPDUs in the order as described in Table 9-425 (A-MPDU contents in the data enabled immediate response context)~~acknowledgement has high priority to be transmitted~~[5998, 6701].

27.7 TWT operation

27.7.2 Individual TWT agreements

TGax Editor: Please modify the note on pg 185, line 1 in D1.1 in this section as follows:

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 12 LSBs of the[7817] 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 [7817]12 LSBs of the recipient STA's AID in any of its Per User Info fields (see

TGax Editor, please note, all references in this document to UL MU Response Scheduling A-Control are replaced with UMRS Control to be consistent with doc 11-17-238

UL MU operation).

27.7.3.2 Rules for TWT scheduling STA

TGax Editor: Please modify the 4th paragraph (pg 187, line 5 in D1.1) in this section as follows:

A TWT scheduling STA should not include ~~a~~ the 12 LSBs of the[7817] STA's AID in a User Info field of a Trigger frame transmitted within a broadcast TWT SP unless the STA has established membership in the broadcast TWT.

APPENDIX AE

Documents

Everything | All Years | TGax (inactive)

CID

Created (ET) ▼	Year	DCN	Rev	Group	Title	Author (Affiliation)	Uploaded (ET)	Actions
09-Mar-2017 ET	2017	331	2	TGax	LB225 Comment resolution for CIDs for 28.3.11.9 Constellation mapping	Jianhan Liu (Mediatek Inc.)	09-Mar-2017 20:12:00 ET	Download
09-Mar-2017 ET	2017	332	2	TGax	LB225 Comment resolution for CIDs for 28.3.10 HE Preamble	Jianhan Liu (Mediatek Inc.)	09-Mar-2017 20:11:09 ET	Download
09-Mar-2017 ET	2017	333	1	TGax	LB225 Comment resolution for CIDs for 28.3.13 Non-HT duplicate transmission	Jianhan Liu (Mediatek Inc.)	09-Mar-2017 20:10:01 ET	Download
09-Mar-2017 ET	2017	250	2	TGax	Various CIDs in 27.5.2	Abhishek Patil (Qualcomm)	09-Mar-2017 19:49:15 ET	Download
09-Mar-2017 ET	2017	329	2	TGax	LB225 Comment resolution for CIDs for 28.3.11.5 Coding	Jianhan Liu (Mediatek Inc.)	09-Mar-2017 19:32:49 ET	Download
09-Mar-2017 ET	2017	389	0	TGax	CIDs-for-27-2-1-part1	Kaiying Lv (ZTE Corp.)	10-Mar-2017 14:31:48 ET	Download
09-Mar-2017 ET	2017	329	1	TGax	LB225 Comment resolution for CIDs for 28.3.11.5 Coding	Jianhan Liu (Mediatek Inc.)	09-Mar-2017 17:57:21 ET	Download
09-Mar-2017 ET	2017	330	1	TGax	LB225 Comment resolution for CIDs for 3 Definitions, acronyms, and abbreviations	Jianhan Liu (Mediatek Inc.)	09-Mar-2017 17:56:37 ET	Download
09-Mar-2017 ET	2017	331	1	TGax	LB225 Comment resolution for CIDs for 28.3.11.9 Constellation mapping	Jianhan Liu (Mediatek Inc.)	09-Mar-2017 17:55:38 ET	Download
09-Mar-2017 ET	2017	332	1	TGax	LB225 Comment resolution for CIDs for 28.3.10 HE Preamble	Jianhan Liu (Mediatek Inc.)	09-Mar-2017 17:54:47 ET	Download
09-Mar-2017 ET	2017	309	1	TGax	CIDs on HE Sounding (27-6-2)	Raja Banerjea (Qualcomm)	09-Mar-2017 14:08:48 ET	Download
09-Mar-2017 ET	2017	204	5	TGax	CID for 27.2.3 MU EDCA parameters	laurent cariou (Intel)	09-Mar-2017 12:46:36 ET	Download
09-Mar-2017 ET	2017	250	1	TGax	Various CIDs in 27.5.2	Abhishek Patil (Qualcomm)	09-Mar-2017 07:45:59 ET	Download
08-Mar-2017 ET	2017	370	0	TGax	some CIDs related to 20MHz operation--text	Guoqing Li (Apple)	09-Mar-2017 12:02:41 ET	Download

08-Mar-2017 ET	2017	369	0	TGax	Some CIDs related to 20MHz operation	Guoqing Li (Apple)	09-Mar-2017 12:01:58 ET	Download
08-Mar-2017 ET	2017	204	4	TGax	CID for 27.2.3 MU EDCA parameters	laurent cariou (Intel)	08-Mar-2017 13:25:08 ET	Download
08-Mar-2017 ET	2017	360	0	TGax	LB225 CR for CID5917 and CID8165	Ming Gan (Huawei)	15-Mar-2017 15:40:21 ET	Download
07-Mar-2017 ET	2017	338	0	TGax	CR for 27.5.2.4 - Physical CS CIDs	Rojan Chitrakar (Panasonic)	12-Mar-2017 17:52:18 ET	Download
07-Mar-2017 ET	2017	337	0	TGax	Explanation of CR for CID 8555	Rojan Chitrakar (Panasonic)	10-Mar-2017 12:57:36 ET	Download
07-Mar-2017 ET	2017	336	0	TGax	CR for CID 8555 - Virtual CS during UL MU CS	Rojan Chitrakar (Panasonic)	10-Mar-2017 12:58:35 ET	Download
07-Mar-2017 ET	2017	335	0	TGax	CR for CID 8142 - Random Access acronym	Rojan Chitrakar (Panasonic)	12-Mar-2017 17:57:14 ET	Download
06-Mar-2017 ET	2017	333	0	TGax	LB225 Comment resolution for CIDs for 28.3.13 Non-HT duplicate transmission	Jianhan Liu (Mediatek Inc.)	06-Mar-2017 19:55:27 ET	Download
06-Mar-2017 ET	2017	332	0	TGax	LB225 Comment resolution for CIDs for 28.3.10 HE Preamble	Jianhan Liu (Mediatek Inc.)	06-Mar-2017 19:54:08 ET	Download
06-Mar-2017 ET	2017	331	0	TGax	LB225 Comment resolution for CIDs for 28.3.11.9 Constellation mapping	Jianhan Liu (Mediatek Inc.)	06-Mar-2017 19:52:41 ET	Download
06-Mar-2017 ET	2017	330	0	TGax	LB225 Comment resolution for CIDs for 3 Definitions, acronyms, and abbreviations	Jianhan Liu (Mediatek Inc.)	06-Mar-2017 19:51:00 ET	Download
06-Mar-2017 ET	2017	329	0	TGax	LB225 Comment resolution for CIDs for 28.3.11.5 Coding	Jianhan Liu (Mediatek Inc.)	06-Mar-2017 19:49:24 ET	Download
06-Mar-2017 ET	2017	230	1	TGax	CIDs related to multi-BSSID	Abhishek Patil (Qualcomm)	06-Mar-2017 15:58:46 ET	Download
02-Mar-2017 ET	2017	309	0	TGax	CIDs on HE Sounding (27-6-2)	Raja Banerjea (Qualcomm)	06-Mar-2017 18:24:11 ET	Download
28-Feb-2017 ET	2017	204	3	TGax	CID for 27.2.3 MU EDCA parameters	laurent cariou (Intel)	28-Feb-2017 12:35:05 ET	Download
20-Feb-2017 ET	2017	204	2	TGax	CID for 27.2.3 MU EDCA parameters	laurent cariou (Intel)	20-Feb-2017 13:50:15 ET	Download
16-Feb-2017 ET	2017	204	1	TGax	CID for 27.2.3 MU EDCA parameters	laurent cariou (Intel)	16-Feb-2017 19:20:03 ET	Download
10-Feb-2017 ET	2017	250	0	TGax	Various CIDs in 27.5.2	Abhishek Patil (Qualcomm)	07-Mar-2017 19:32:05 ET	Download
10-Feb-2017 ET	2017	249	0	TGax	CIDs in 27.5.2	Abhishek Patil (Qualcomm)	04-May-2017 01:14:28 ET	Download
09-Feb-2017 ET	2017	230	0	TGax	CIDs related to multi-BSSID	Abhishek Patil (Qualcomm)	02-Mar-2017 20:12:05 ET	Download

09-Feb-2017 ET	2017	229	0	TGax	CIDs related to Random Access	Abhishek Patil (Qualcomm)	09-Mar-2017 12:12:34 ET	Download
30-Jan-2017 ET	2017	204	0	TGax	CID for 27.2.3 MU EDCA parameters	laurent cariou (Intel)	02-Feb-2017 09:57:39 ET	Download
19-Jan-2017 ET	2017	135	6	TGax	CIDs in HE Operation	Abhishek Patil (Qualcomm)	19-Jan-2017 16:05:45 ET	Download
19-Jan-2017 ET	2017	135	5	TGax	CIDs in HE Operation	Abhishek Patil (Qualcomm)	19-Jan-2017 15:50:41 ET	Download
19-Jan-2017 ET	2017	173	0	TGax	CIDs on Signaling for UL HE MU PPDU	John Son (WILUS)	19-Jan-2017 14:03:18 ET	Download
19-Jan-2017 ET	2017	137	2	TGax	CIDs in 9.4.2.222	Abhishek Patil (Qualcomm)	19-Jan-2017 12:17:03 ET	Download
19-Jan-2017 ET	2017	135	4	TGax	CIDs in HE Operation	Abhishek Patil (Qualcomm)	19-Jan-2017 12:16:36 ET	Download
18-Jan-2017 ET	2017	135	3	TGax	CIDs in HE Operation	Abhishek Patil (Qualcomm)	18-Jan-2017 17:31:42 ET	Download
18-Jan-2017 ET	2017	135	2	TGax	CIDs in HE Operation	Abhishek Patil (Qualcomm)	18-Jan-2017 07:18:52 ET	Download
17-Jan-2017 ET	2017	135	1	TGax	CIDs in HE Operation	Abhishek Patil (Qualcomm)	17-Jan-2017 16:34:59 ET	Download
17-Jan-2017 ET	2017	104	1	TGax	Discussion on CR for CID 5066	Dengyu Qiao (Huawei)	17-Jan-2017 10:40:59 ET	Download
17-Jan-2017 ET	2017	114	1	TGax	CID-Trigger frame_Part-1	Lochan Verma (Qualcomm)	17-Jan-2017 10:14:08 ET	Download
17-Jan-2017 ET	2017	140	0	TGax	Various CIDs in clause 6 & 9	Abhishek Patil (Qualcomm)	04-May-2017 01:27:26 ET	Download
17-Jan-2017 ET	2017	138	0	TGax	CIDs in 27.16.2 (part 1)	Abhishek Patil (Qualcomm)	03-Mar-2017 19:42:54 ET	Download
16-Jan-2017 ET	2017	137	1	TGax	CIDs in 9.4.2.222	Abhishek Patil (Qualcomm)	16-Jan-2017 23:06:09 ET	Download
16-Jan-2017 ET	2017	137	0	TGax	CIDs in 9.4.2.222	Abhishek Patil (Qualcomm)	16-Jan-2017 22:40:27 ET	Download
16-Jan-2017 ET	2017	72	2	TGax	CID 6124 Resolution: Remove 2x LTF+08.us GI for UL Transmission	Jianhan Liu (Mediatek Inc.)	16-Jan-2017 18:02:45 ET	Download
16-Jan-2017 ET	2017	135	0	TGax	CIDs in HE Operation	Abhishek Patil (Qualcomm)	16-Jan-2017 23:53:36 ET	Download
16-Jan-2017 ET	2017	114	0	TGax	CID-Trigger frame_Part-1	Lochan Verma (Qualcomm)	16-Jan-2017 16:20:01 ET	Download
16-Jan-2017 ET	2017	99	1	TGax	Additional background for CID 8908	Sigurd Schelstraete (Quantenna)	16-Jan-2017 10:49:36 ET	Download
16-Jan-2017 ET	2017	104	0	TGax	Discussion on CR for CID 5066	Dengyu Qiao (Huawei)	16-Jan-2017 09:24:55 ET	Download
16-Jan-2017 ET	2017	99	0	TGax	Additional background for CID 8908	Sigurd Schelstraete (Quantenna)	16-Jan-2017 09:12:14 ET	Download
15-Jan-2017 ET	2017	72	1	TGax	CID 6124 Resolution: Remove 2x LTF+08.us GI for UL Transmission	Jianhan Liu (Mediatek Inc.)	15-Jan-2017 22:38:14 ET	Download
15-Jan-2017 ET	2017	72	0	TGax	CID 6124 Resolution: Remove 2x LTF+08.us GI for UL Transmission	Jianhan Liu (Mediatek Inc.)	15-Jan-2017 22:36:40 ET	Download
14-Nov-2016 ET	2016	1522	3	TGax	CID 2147 SIGB Encoding	Hongyuan Zhang (Marvell)	14-Nov-2016 14:26:09 ET	Download
10-Nov-2016 ET	2016	1440	4	TGax	Proposed Resolutions to CID 2719	Jing Ma (NICT)	10-Nov-2016 11:58:14 ET	Download

09-Nov-2016 ET	2016	1503	2	TGax	CR HE beacon for CID 991	Yonggang Fang (ZTE TX)	09-Nov-2016 18:54:32 ET	Download
09-Nov-2016 ET	2016	1503	1	TGax	CR HE beacon for CID 991	Yonggang Fang (ZTE TX)	09-Nov-2016 16:46:50 ET	Download
09-Nov-2016 ET	2016	1522	2	TGax	CID 2147 SIGB Encoding	Hongyuan Zhang (Marvell)	09-Nov-2016 14:45:10 ET	Download
09-Nov-2016 ET	2016	1413	8	TGax	CID193 BSS Color Disabled Indication	Abhishek Patil (Qualcomm)	09-Nov-2016 11:15:01 ET	Download
09-Nov-2016 ET	2016	1413	7	TGax	CID193 BSS Color Disabled Indication	Abhishek Patil (Qualcomm)	09-Nov-2016 11:11:58 ET	Download
09-Nov-2016 ET	2016	1413	6	TGax	CID193 BSS Color Disabled Indication	Abhishek Patil (Qualcomm)	09-Nov-2016 10:01:14 ET	Download
09-Nov-2016 ET	2016	1516	1	TGax	Random Access CIDs	Reza Hedayat (Newracom)	09-Nov-2016 09:14:42 ET	Download
08-Nov-2016 ET	2016	1522	1	TGax	CID 2147 SIGB Encoding	Hongyuan Zhang (Marvell)	08-Nov-2016 23:03:50 ET	Download
08-Nov-2016 ET	2016	1522	0	TGax	CID 2147 SIGB Encoding	Hongyuan Zhang (Marvell)	08-Nov-2016 22:57:11 ET	Download
08-Nov-2016 ET	2016	1440	3	TGax	Proposed Resolutions to CID 2719	Jing Ma (NICT)	08-Nov-2016 18:08:57 ET	Download
08-Nov-2016 ET	2016	1516	0	TGax	Random Access CIDs	Reza Hedayat (Newracom)	08-Nov-2016 17:43:33 ET	Download
08-Nov-2016 ET	2016	1415	2	TGax	CID72 BSS Color change mechanism	Abhishek Patil (Qualcomm)	08-Nov-2016 12:47:21 ET	Download
08-Nov-2016 ET	2016	1387	3	TGax	Comment resolution on CID2506 and proposed changes	Jinsoo Choi (LG Electronics)	08-Nov-2016 12:33:38 ET	Download
08-Nov-2016 ET	2016	1440	2	TGax	Proposed Resolutions to CID 2719	Jing Ma (NICT)	08-Nov-2016 11:55:03 ET	Download
08-Nov-2016 ET	2016	1387	2	TGax	Comment resolution on CID2506 and proposed changes	Jinsoo Choi (LG Electronics)	08-Nov-2016 11:41:57 ET	Download
08-Nov-2016 ET	2016	1440	1	TGax	Proposed Resolutions to CID 2719	Jing Ma (NICT)	08-Nov-2016 09:52:08 ET	Download
08-Nov-2016 ET	2016	1503	0	TGax	CR HE beacon for CID 991	Yonggang Fang (ZTE TX)	09-Nov-2016 14:27:46 ET	Download
08-Nov-2016 ET	2016	1387	1	TGax	Comment resolution on CID2506 and proposed changes	Jinsoo Choi (LG Electronics)	08-Nov-2016 08:41:41 ET	Download
07-Nov-2016 ET	2016	1361	1	TGax	CC0-Remaining CIDs on MU Operation	Alfred Asterjadhi (Qualcomm Inc.)	07-Nov-2016 21:43:16 ET	Download
07-Nov-2016 ET	2016	1360	1	TGax	CC0-HE variant HT control - Some Remaining CIDs	Alfred Asterjadhi (Qualcomm Inc.)	07-Nov-2016 18:25:20 ET	Download
07-Nov-2016 ET	2016	1398	1	TGax	CR for CID 2077	Sriram Venkateswaran (Broadcom)	07-Nov-2016 18:22:39 ET	Download
07-Nov-2016 ET	2016	1374	1	TGax	Resoluction on CID495 and Removal of Unnecessary PHY TBDs	Yujin Noh (Newracom)	07-Nov-2016 17:52:42 ET	Download
07-Nov-2016 ET	2016	1375	1	TGax	Commont Resolution for CID2867 and Text Change Proposal of	Yujin Noh (Newracom)	07-Nov-2016 17:51:38 ET	Download

					26.3.10.8 HE-SIG-B			
07-Nov-2016 ET	2016	1413	5	TGax	CID193 BSS Color Disabled Indication	Abhishek Patil (Qualcomm)	07-Nov-2016 11:08:35 ET	Download
07-Nov-2016 ET	2016	1413	4	TGax	CID193 BSS Color Disabled Indication	Abhishek Patil (Qualcomm)	07-Nov-2016 10:46:25 ET	Download
07-Nov-2016 ET	2016	1415	1	TGax	CID72 BSS Color change mechanism	Abhishek Patil (Qualcomm)	07-Nov-2016 10:45:48 ET	Download
06-Nov-2016 ET	2016	1450	0	TGax	CR-for-CID 2492-section-25-9-spatial-reuse-operation	Kaiying Lv (ZTE Corp.)	07-Nov-2016 02:15:41 ET	Download
06-Nov-2016 ET	2016	1440	0	TGax	Proposed Resolutions to CID 2719	Jing Ma (NICT)	07-Nov-2016 09:59:48 ET	Download
06-Nov-2016 ET	2016	1413	3	TGax	CID193 BSS Color Disabled Indication	Abhishek Patil (Qualcomm)	06-Nov-2016 02:04:33 ET	Download
06-Nov-2016 ET	2016	1415	0	TGax	CID72 BSS Color change mechanism	Abhishek Patil (Qualcomm)	06-Nov-2016 01:53:04 ET	Download
06-Nov-2016 ET	2016	1413	2	TGax	CID193 BSS Color Disabled Indication	Abhishek Patil (Qualcomm)	06-Nov-2016 01:36:28 ET	Download
06-Nov-2016 ET	2016	1413	1	TGax	CID193 BSS Color Disabled Indication	Abhishek Patil (Qualcomm)	06-Nov-2016 01:33:15 ET	Download
06-Nov-2016 ET	2016	1413	0	TGax	CID193 BSS Color Disabled Indication	Abhishek Patil (Qualcomm)	06-Nov-2016 01:32:29 ET	Download
05-Nov-2016 ET	2016	1398	0	TGax	CR for CID 2077	Sriram Venkateswaran (Broadcom)	05-Nov-2016 19:30:50 ET	Download
05-Nov-2016 ET	2016	1392	0	TGax	comment-resolution-CID-2624-and-2738	Young Hoon Kwon (Newracom)	06-Nov-2016 20:34:35 ET	Download
05-Nov-2016 ET	2016	1389	0	TGax	Comment Resolution for CID 807	Po-Kai Huang (Intel)	05-Nov-2016 13:28:05 ET	Download
05-Nov-2016 ET	2016	1387	0	TGax	Comment resolution on CID2506 and proposed changes	Jinsoo Choi (LG Electronics)	07-Nov-2016 00:05:20 ET	Download
03-Nov-2016 ET	2016	1375	0	TGax	Commont Resolution for CID2867 and Text Change Proposal of 26.3.10.8 HE-SIG-B	Yujin Noh (Newracom)	06-Nov-2016 23:11:20 ET	Download
03-Nov-2016 ET	2016	1374	0	TGax	Resoluction on CID495 and Removal of Unnecessary PHY TBDs	Yujin Noh (Newracom)	06-Nov-2016 23:11:53 ET	Download
01-Nov-2016 ET	2016	1361	0	TGax	CC0-Remaining CIDs on MU Operation	Alfred Asterjadhi (Qualcomm Inc.)	07-Nov-2016 00:50:28 ET	Download

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APPENDIX AF

Documents

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27.5.2

Created (ET) ▼	Year	DCN	Rev	Group	Title	Author (Affiliation)	Uploaded (ET)	Actions
13-Sep-2018 ET	2018	1515	4	TGax	CR BQR section 27.5.2	Zhou Lan (Broadcom Inc.)	13-Sep-2018 15:05:59 ET	Download
13-Sep-2018 ET	2018	1515	3	TGax	CR BQR section 27.5.2	Zhou Lan (Broadcom Inc.)	13-Sep-2018 14:47:15 ET	Download
12-Sep-2018 ET	2018	1515	2	TGax	CR BQR section 27.5.2	Zhou Lan (Broadcom Inc.)	12-Sep-2018 15:07:39 ET	Download
11-Sep-2018 ET	2018	1515	1	TGax	CR BQR section 27.5.2	Zhou Lan (Broadcom Inc.)	11-Sep-2018 16:52:26 ET	Download
05-Sep-2018 ET	2018	1515	0	TGax	CR BQR section 27.5.2	Zhou Lan (Broadcom Inc.)	07-Sep-2018 12:52:29 ET	Download
12-Sep-2017 ET	2017	1091	1	TGax	Proposed resolution for comments related to CIDs in 27.5.2	Jing Ma (NICT)	12-Sep-2017 21:34:37 ET	Download
13-Jul-2017 ET	2017	1031	5	TGax	Remaining CIDs for 27.5.2.7	laurent cariou (Intel)	13-Jul-2017 08:51:40 ET	Download
12-Jul-2017 ET	2017	1031	4	TGax	Remaining CIDs for 27.5.2.7	laurent cariou (Intel)	12-Jul-2017 08:42:56 ET	Download
12-Jul-2017 ET	2017	1031	3	TGax	Remaining CIDs for 27.5.2.7	laurent cariou (Intel)	12-Jul-2017 07:38:50 ET	Download
11-Jul-2017 ET	2017	1032	3	TGax	CIDs in 27.5.2	Abhishek Patil (Qualcomm)	11-Jul-2017 14:34:44 ET	Download
11-Jul-2017 ET	2017	1032	2	TGax	CIDs in 27.5.2	Abhishek Patil (Qualcomm)	11-Jul-2017 11:07:47 ET	Download
11-Jul-2017 ET	2017	1031	2	TGax	Remaining CIDs for 27.5.2.7	laurent cariou (Intel)	11-Jul-2017 05:03:25 ET	Download
10-Jul-2017 ET	2017	1031	1	TGax	Remaining CIDs for 27.5.2.7	laurent cariou (Intel)	10-Jul-2017 11:48:59 ET	Download
10-Jul-2017 ET	2017	1032	1	TGax	CIDs in 27.5.2	Abhishek Patil (Qualcomm)	10-Jul-2017 07:41:46 ET	Download
10-Jul-2017 ET	2017	1091	0	TGax	Proposed resolution for comments related to CIDs in 27.5.2	Jing Ma (NICT)	05-Sep-2017 23:08:23 ET	Download
09-Jul-2017 ET	2017	1059	0	TGax	CR on 27.5.2.6.2 Part3	Jeongki Kim (LG Electronics)	11-Jul-2017 09:02:53 ET	Download
08-Jul-2017 ET	2017	1032	0	TGax	CIDs in 27.5.2	Abhishek Patil (Qualcomm)	08-Jul-2017 19:50:06 ET	Download
08-Jul-2017 ET	2017	1031	0	TGax	Remaining CIDs for 27.5.2.7	laurent cariou (Intel)	10-Jul-2017 05:21:13 ET	Download
10-May-2017 ET	2017	73	5	TGax	CR for 27.5.2.7 NDP feedback report	laurent cariou (Intel)	10-May-2017 04:01:45 ET	Download
09-May-2017 ET	2017	73	4	TGax	CR for 27.5.2.7 NDP	laurent cariou (Intel)	09-May-2017 22:45:32 ET	Download

					feedback report			
08-May-2017 ET	2017	645	3	TGax	CR-for-section-27.5.2.6-RAPS	Stephane Baron (Canon)	08-May-2017 23:31:26 ET	Download
08-May-2017 ET	2017	73	3	TGax	CR for 27.5.2.7 NDP feedback report	laurent cariou (Intel)	08-May-2017 03:09:21 ET	Download
05-May-2017 ET	2017	646	4	TGax	CRs-for-clause-27.5.2.6-UORA	Patrice NEZOU (Canon)	05-May-2017 02:57:13 ET	Download
05-May-2017 ET	2017	645	2	TGax	CR-for-section-27.5.2.6-RAPS	Stephane Baron (Canon)	05-May-2017 01:03:23 ET	Download
05-May-2017 ET	2017	645	1	TGax	CR-for-section-27.5.2.6-RAPS	Stephane Baron (Canon)	05-May-2017 00:59:42 ET	Download
05-May-2017 ET	2017	646	3	TGax	CRs-for-clause-27.5.2.6-UORA	Patrice NEZOU (Canon)	05-May-2017 00:29:16 ET	Download
04-May-2017 ET	2017	249	2	TGax	CIDs in 27.5.2	Abhishek Patil (Qualcomm)	04-May-2017 20:19:35 ET	Download
04-May-2017 ET	2017	708	3	TGax	CIDs in in 27.5.2.6 (Random Access)	Abhishek Patil (Qualcomm)	04-May-2017 20:19:03 ET	Download
04-May-2017 ET	2017	646	2	TGax	CRs-for-clause-27.5.2.6-UORA	Patrice NEZOU (Canon)	04-May-2017 07:55:28 ET	Download
04-May-2017 ET	2017	708	2	TGax	CIDs in in 27.5.2.6 (Random Access)	Abhishek Patil (Qualcomm)	04-May-2017 04:26:09 ET	Download
04-May-2017 ET	2017	643	1	TGax	CR on 27.5.2.6.2	Jeongki Kim (LG Electronics)	04-May-2017 03:01:38 ET	Download
04-May-2017 ET	2017	708	1	TGax	CIDs in in 27.5.2.6 (Random Access)	Abhishek Patil (Qualcomm)	04-May-2017 02:25:51 ET	Download
04-May-2017 ET	2017	249	1	TGax	CIDs in 27.5.2	Abhishek Patil (Qualcomm)	04-May-2017 01:55:03 ET	Download
03-May-2017 ET	2017	646	1	TGax	CRs-for-clause-27.5.2.6-UORA	Patrice NEZOU (Canon)	03-May-2017 21:47:35 ET	Download
03-May-2017 ET	2017	708	0	TGax	CIDs in in 27.5.2.6 (Random Access)	Abhishek Patil (Qualcomm)	04-May-2017 01:13:44 ET	Download
01-May-2017 ET	2017	73	2	TGax	CR for 27.5.2.7 NDP feedback report	laurent cariou (Intel)	01-May-2017 15:58:44 ET	Download
01-May-2017 ET	2017	646	0	TGax	CRs-for-clause-27.5.2.6-UORA	Patrice NEZOU (Canon)	03-May-2017 08:23:51 ET	Download
01-May-2017 ET	2017	645	0	TGax	CR-for-section-27.5.2.6-RAPS	Stephane Baron (Canon)	04-May-2017 21:20:26 ET	Download
30-Apr-2017 ET	2017	643	0	TGax	CR on 27.5.2.6.2	Jeongki Kim (LG Electronics)	03-May-2017 22:20:46 ET	Download
15-Mar-2017 ET	2017	448	4	TGax	Proposed resolution for comments related to CIDs in 27.5.2	Jing Ma (NICT)	15-Mar-2017 16:42:43 ET	Download
15-Mar-2017 ET	2017	448	3	TGax	Proposed resolution for comments related to CIDs in 27.5.2	Jing Ma (NICT)	15-Mar-2017 16:34:59 ET	Download

15-Mar-2017 ET	2017	338	1	TGax	CR for 27.5.2.4 - Physical CS CIDs	Rojan Chitrakar (Panasonic)	15-Mar-2017 14:28:18 ET	Download
15-Mar-2017 ET	2017	448	2	TGax	Proposed resolution for comments related to CIDs in 27.5.2	Jing Ma (NICT)	15-Mar-2017 03:44:50 ET	Download
15-Mar-2017 ET	2017	448	1	TGax	Proposed resolution for comments related to CIDs in 27.5.2	Jing Ma (NICT)	15-Mar-2017 02:01:36 ET	Download
13-Mar-2017 ET	2017	74	3	TGax	Explanations for CR on 27.5.2.7	laurent cariou (Intel)	13-Mar-2017 21:07:50 ET	Download
13-Mar-2017 ET	2017	74	2	TGax	Explanations for CR on 27.5.2.7	laurent cariou (Intel)	13-Mar-2017 13:34:35 ET	Download
13-Mar-2017 ET	2017	73	1	TGax	CR for 27.5.2.7 NDP feedback report	laurent cariou (Intel)	13-Mar-2017 13:29:27 ET	Download
13-Mar-2017 ET	2017	448	0	TGax	Proposed resolution for comments related to CIDs in 27.5.2	Jing Ma (NICT)	14-Mar-2017 00:39:31 ET	Download
13-Mar-2017 ET	2017	302	2	TGax	CR for 27.5.2.4	Po-Kai Huang (Intel)	13-Mar-2017 02:14:52 ET	Download
09-Mar-2017 ET	2017	250	2	TGax	Various CIDs in 27.5.2	Abhishek Patil (Qualcomm)	09-Mar-2017 19:49:15 ET	Download
09-Mar-2017 ET	2017	250	1	TGax	Various CIDs in 27.5.2	Abhishek Patil (Qualcomm)	09-Mar-2017 07:45:59 ET	Download
07-Mar-2017 ET	2017	338	0	TGax	CR for 27.5.2.4 - Physical CS CIDs	Rojan Chitrakar (Panasonic)	12-Mar-2017 17:52:18 ET	Download
06-Mar-2017 ET	2017	74	1	TGax	Explanations for CR on 27.5.2.7	laurent cariou (Intel)	06-Mar-2017 20:38:25 ET	Download
02-Mar-2017 ET	2017	302	1	TGax	CR for 27.5.2.4	Po-Kai Huang (Intel)	02-Mar-2017 18:47:15 ET	Download
27-Feb-2017 ET	2017	302	0	TGax	CR for 27.5.2.4	Po-Kai Huang (Intel)	27-Feb-2017 19:46:20 ET	Download
10-Feb-2017 ET	2017	250	0	TGax	Various CIDs in 27.5.2	Abhishek Patil (Qualcomm)	07-Mar-2017 19:32:05 ET	Download
10-Feb-2017 ET	2017	249	0	TGax	CIDs in 27.5.2	Abhishek Patil (Qualcomm)	04-May-2017 01:14:28 ET	Download
15-Jan-2017 ET	2017	74	0	TGax	Explanations for CR on 27.5.2.7	laurent cariou (Intel)	16-Jan-2017 11:11:37 ET	Download
15-Jan-2017 ET	2017	73	0	TGax	CR for 27.5.2.7 NDP feedback report	laurent cariou (Intel)	16-Jan-2017 11:10:53 ET	Download

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APPENDIX AG

Agent Ransack
Free File Searching Utility

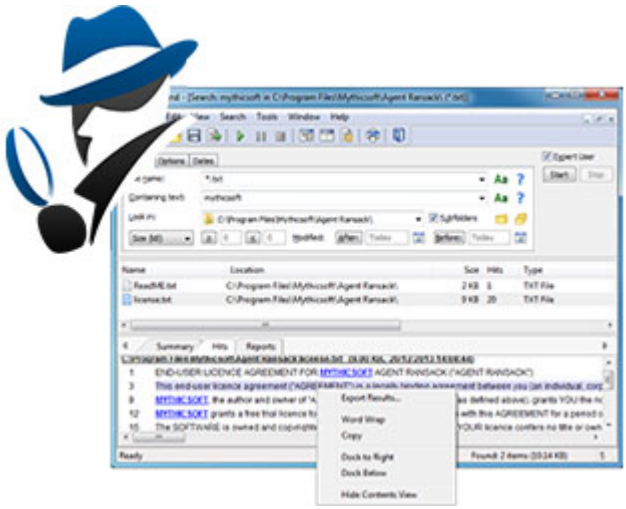
"If I were shipwrecked on a desert isle and could take only one software program with me, it would be Agent Ransack, hands down."

Testimonials (/agentransack/testimonials/)

Finding files that other search engines miss

Agent Ransack is a free file search tool for finding files on your PC or network drives. It has a Lite mode, which is **FREE** for both personal and commercial use but also a Professional mode that includes optional pay-for features (https://www.mythicsoft.com/agentransack/information/).

First released in April 2000 the Agent Ransack desktop search app has been helping people find files for over 20 years. In 2019 Agent Ransack was merged with FileLocator Pro so the two products now have exactly the same features and functionality [more] (https://qa.mythicsoft.com/21680/whats-the-difference-between-agent-ransack-and-filelocator?show=21680#q21680).



Download (//download.mythicsoft.com/flp/3517/agentransack_3517.exe)

Register (/agentransack/register/)

$ Buy Pro (/agentransack/buy)

Agent Ransack is free for both Commercial and Personal use

Download (//download.mythicsoft.com/flp/3517/agentransack_3517.exe)

Here are just some of the powerful features available



Immediate results

Found text is shown with highlighted keywords so you don't need to waste time opening each file looking for the right information.



Boolean expressions

Combine search terms using the familiar Boolean operators AND, OR, NOT.



Office formats

Support for popular Office formats including Office 2010 and OpenOffice.



Perl regex

Support for Perl compatible regular expressions.

64-bit Version

Natively compiled 64-bit version for improved compatibility.

Fast searching

Highly efficient search algorithms mean that you spend less time waiting for results.

Printing and Exporting

Results can be shared with others through reports, printing and exporting.

Corporate Version

For corporate environments we have a more ‘gentle’ branding of Agent Ransack called FileLocator Lite. It’s still free but just has a different name. See the FileLocator Lite (/filelocatorlite/download) page for more information.

Restricted Version

A ‘locked down’ version of Agent Ransack is available for environments where the end-user is not allowed to search their local PC. Please contact Sales (/support/) for more information.

Available as a single 32/64 bit installer

Download (//download.mythicsoft.com/flp/3517/agentransack_3517.exe)

Supports Windows 7 and higher

Works with Windows 7/8/10/11/2012/2016/2019/2022 and higher see Requirements (/filelocatorpro/information/#requirements) for more information.



(/filelocatorpro/information/#requirements)



(/filelocatorpro/information/#requirements)



(/filelocatorpro/information/#requirements)



(/filelocatorpro/information/#requirements)

Agent Ransack is free for both Commercial and Personal use

Download (//download.mythicsoft.com/flp/3517/agentransack_3517.exe)

Testimonials

"The best I've seen...much better than Google Desktop."

Vernon E. Rose, DrPH, LLC

"Agent Ransack is indispensable as a fast a intuitive alternative to Windows 7 search

Deb Troxel, V.P. of Technology, TigerC Technology, Inc.

See All (/agentransack/testimonials/)

Our Clients

We take great pride in providing first class customer service to all our customers from large corporations to private individuals. Our customer list is incredibly diverse and includes these household names.



All trademarks, trade names, service marks and logos belong to their respective companies.

Agent Ransack vs FileLocator Pro

FAQ

Q . Hey, I ’m confused! It looks like FileLocator Pro and Agent Ransack are now the same product and it's just whether they are in **Lite** mode or **Pro** mode, is that right?

A . Yep, apart from the name they are both the same. Honestly, it ’s the same code. During the build process an automated script runs that locates all the FileLocator Pro branding and replaces it with Agent Ransack branding and then recompiles.

Q . That's a bit odd, why have two names?

A . It is a bit odd but maybe a short history of the product will help explain:

Apr 2000 - The first version of the product was released under the name Agent Ransack.
Apr 2003 - A Pro version of Agent Ransack was released under the name FileLocator Pro.
Mar 2010 - Due to the discomfort from some people over the name Agent Ransack an alternative rebranded version named FileLocator Lite is released.
May 2018 - FileLocator Pro adds a new feature that can **downgrade** itself to 'Lite' mode.
Sep 2019 - Agent Ransack adds a new feature so that it can **upgrade** itself to 'Pro' mode.

The end result is that we now have a single code base for the product, which is much easier to maintain, but two product names, which is potentially confusing. Over the next few years we'll carefully monitor the demand for both names and hopefully retire one eventually. If you'd like more information on the change please see this blog post (https://blog.mythicsoft.com/lite-mode/).

Q . Does it matter which one I purchase for the Pro version?

A . No, the Pro license codes for FileLocator Pro and Agent Ransack are interchangable, ie you can use a FileLocator Pro license with Agent Ransack and vice-versa.

Agent Ransack is free for both Commercial and Personal use

Download (//download.mythicsoft.com/flp/3517/agentransack_3517.exe)

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APPENDIX AH

IEEE P802.11
IEEE 802.11 TGax

March 2017 Ad Hoc Meeting (non-PHY) Minutes

Date: 2017-03-12

Author(s):

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Abstract

This document contains the minutes from non-PHY session of the TGax March 2017 ad hoc meeting in San Diego, CA, from March 8th to 10th, 2017.

Minutes from the PHY session will be available in a separate document.

Rev. 0: Initial document.

IEEE 802.11 Task Group AX Ad Hoc Meeting
March 2017 in San Diego, CA
March 8th – 10th, 2017

TGax Chair Osama Aboul-Magd (Huawei Technologies)
Vice Chair Simone Merlin (Qualcomm)
Vice Chair Ron Porat (Broadcom)
TGax Secretary Yasuhiko Inoue (NTT)
TGax Technical Editor Robert Stacy (Intel)

Wednesday, March 8th, 2017, AM non-PHY Session

1. The meeting called to order by Osama Aboul-Magd (Huawei Technologies), the chair of the TGax, @10:16

2. Announcement

2.1. PHY ad hoc will be run by Hongyuan Zhang (Marvell)
2.2. Non-PHY ad hoc will be run by Simone Merlin (Qualcomm)
2.3. This is an ad hoc meeting – no motions will be conducted.
2.4. Comment resolution was the main focus. Complex comments requiring discussion from a broader group of TGax participants are to be discussed in the 802.11 interim and plenary sessions.

3. Agenda Setting.

3.1. General flow of the ad hoc meeting
- 3.1.1. Wednesday
  - 3.1.1.1. Comment resolutions (10:00 – 18:00)
  - 3.1.1.2. Recess for the day
- 3.1.2. Thursday
  - 3.1.2.1. Comment resolutions (9:00 – 18:00)
  - 3.1.2.2. Recess for the day
- 3.1.3. Friday
  - 3.1.3.1. Comment resolutions (9:00 – 16:00)
  - 3.1.3.2. Adjourn

3.2. Proposed agenda for the non-PHY session (11-17-356-00)
- 3.2.1. Call meeting to order
- 3.2.2. Patent policy, etc.
- 3.2.3. Announcement
- 3.2.4. Call for submissions
- 3.2.5. Set agenda
- 3.2.6. Presentations and comment resolutions
- 3.2.7. Recess for the day

3.3. Chair asked if there are any other items – No items proposed. Meeting will be conducted based on this order.

4. The chair reviewed the mandatory 6 slides of P&P.

4.1. Instructions for the WG Chair.
4.2. Participants, Patents, and Duty to Inform.
4.3. Patent Related Links.
4.4. Call for potentially essential patents.
4.4.1. Chair asked if anyone is aware of potentially essential patents.
4.4.2. No potentially essential patents reported.
4.5. Other Guidelines for IEEE WG Meetings.
4.6. Participation in IEEE 802 Meetings (new slide)

5. Agenda items for the week
5.1. Approve TG and Teleconference minutes since November 2016 meeting.
5.2. Comment resolution on draft D1.0
5.3. Schedule TG ad hoc meeting(s)
5.4. Schedule Teleconference times.

6. Call for submissions
6.1. Submissions are contained in the excel file attached to the agenda document.

7. Order of presentations
7.1. Laurent
7.2. Yongho
7.3. Po-Kai
7.4. Raja (4)
7.5. Alfred
7.6. Abhi (7)
7.7. George

8. Presentation
8.1. Laurent Cariou (Intel) presented "CR for 27.9.2.2 spatial reuse," based on the submission 11-17-0267-02.
8.1.1. Summary
8.1.1.1. Proposed resolutions for comments on clause 7.9.2.2 OBSS_PD
8.1.1.2. Relevant CIDs:
8.1.1.2.1. 3198, 3199, 3200, 5204, 5205, 5207, 5484, 5489, 5494, 5496, 5497, 5499, 5500, 5501, 5502, 5503, 5690, 5691, 5870, 7122, 7123, 7129, 7406, 7612, 8073, 8104, 8232, 8239, 9315,9540, 9944, 9946, 9947, 10031, 10032, 7125, 3197, 5689, 9541, 3196, 6025, 7823, 8233
8.1.1.3. This is clarification of the text in the draft. No new things are proposed.
8.1.2. Discussion
8.1.2.1. A member expressed concern to provide default values related to the OBSS_PD based spatial reuse. → It was agreed in the previous session. This is the only clarification of the text in the draft. No new things are proposed.
8.1.2.2. It becomes clear that the member has generic concern on this mechanism.
8.1.2.3. People discussed the definition of OBSS_PD.
8.1.2.4. There was a comment that it is still not clear how the OBSS_PD mechanism works.
8.1.2.5. CID#5489: A member asked for a different resolution.
8.1.3. Next Step
8.1.3.1. Discussion to be continued in the next week.

8.2. Yongho Seok (Newracom) presented "LB225 CR Sub-clause 10.22.2.2 and 10.22.2.4," based on the submission 11-17-0208-01.
8.2.1. Summary

8.2.1.1. The document 11-17-0208-01 contains resolutions for CIDs #9612 and #4832.
8.2.2. Discussion
8.2.2.1. CID #9612: There was a question – Is CW[AC] can be less than CWmin[AC]? → For the case of HE, it can.
8.2.2.2. CID #9612: People discussed the resolution and proposed changes to the text for this comment. After discussion, the resolution and proposed change to the text have been modified.
8.2.2.3. CID #4832: After long discussion, the resolution for this comment was changed from Revised to Rejected.

8.2.3. Straw Poll: Do you agree with the resolutions to CIDs 9612, 4832 in doc 11-17/0208r2?
8.2.3.1. Result: No objection.

8.3. Yongho Seok (Newracom) presented "LB225 CR Sub-clause 10.22.2.5," based on the submission 11-17-0209-01.
8.3.1. Summary
8.3.1.1. Resolutions for the following CIDs and proposed changes to the text are contained in the 11-17-0209-01.
8.3.1.2. Relevant CIDs:
8.3.1.2.1. 7667, 9693, 6529 (3 CID)
8.3.2. Discussion
8.3.2.1. People discussed CCA based on 20 MHz channel in any 20, 40, 80 and 160 MHz transmissions for the preamble puncturing case.
8.3.2.2. Discussed definition of trigger-based PPDU.
8.3.2.3. Definition of HE CCA suggested.
8.3.3. Next Step
8.3.3.1. Yongho would like to give people some tine for review.

9. Recess @ 11:58 until 13:00 local time.
9.1. Yongho still has one document to present.
9.2. Po-Kai will present his document after that.

Wednesday, March 8th, 2017, PM Non-PHY session (13:00-18:00)

10. Meeting called to order by Osama Aboul-Magd (Huawei Technologies), the chairperson of the TGax @ 13:06.

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11. Presentations
11.1. Yongho Seok (Newracom) presented "LB225 CR Sub-clause 10.22.2.7 and 10.22.2.8," based on the submission 11-17-0210-01.
11.1.1. Summary
11.1.1.1. Resolutions for comments on sub-clauses 10.22.2.7 and 10.22.2.8 and proposed text changes proposed.
11.1.1.2. Relevant CIDs: 7668, 7669, 7906, 9694, 4833, 5775, 9600, 5969, 9861, 5968, 7670, 7881, 9346, 3188 (14 CID)
11.1.2. Discussion
11.1.2.1. CID #9600: A member asked for the rationale for the resolution for this comment.

11.1.3. Straw Poll: Do you agree with the resolutions of CIDs 7668, 7669, 7906, 9694, 4833, 5775, 9600, 5969, 9861, 5968, 7670, 7881, 9346, and 3188 in doc 11-17/0210r2?

11.1.3.1. Result: No objection.

11.2. Yongho Seok (Newracom) presented "LB225 CR Sub-clause 9.7 Part 1**," based on the submission 11-17-0226-01.**

11.2.1. Summary

11.2.1.1. Resolutions for the comments on sub-clause 9.7 and proposed changes to the text explained.

11.2.1.2. Relevant CIDs: 4754, 6094, 7564, 8404, 8689, 9677, 6480, 7565, 5848, 6481, 8406, 6484, 9611 (13 CIDs)

11.2.2. Discussion

11.2.2.1. CID #6484: Discussed setting of Duration/ID field value. People also discussed related text in clause 9 (frame format) that the text in clause 9 should be removed.

11.2.2.2. CID #9611: People discussed definition of the TXTIME in the context of 802.11ax. -> Chair suggested offline work to resolve this CID.

11.2.3. Straw Poll: Do you agree with the resolutions for CIDs 4754, 6094, 7564, 8404, 8689, 9677, 6480, 7565, 5848, 6481, 8406~~, 6484, 9611~~ in document 11-17/226r1?

11.2.3.1. Result: No objection

11.2.4. Next Step

11.2.4.1. Yongho to come back with another submission for CIDs 6484 and 9611.

11.3. Po-Kai Huang (Intel) presented "11ax D1.0 MAC Comment Resolutions for 27.11.5," based on the submission 11-17-0263-02.

11.3.1. Summary

11.3.1.1. Proposed resolutions for comments of TGax Draft 1.0 with the following CIDs:

11.3.1.1.1. 8394, 5215, 7142, and 10292 (4 CIDs)

11.3.2. Discussion

11.3.2.1. CID #8394: A member asked how to respond for the HE extended-range SU with TXOP_DURATION set to UNSPCIFIED. The answer is responder responds with TXOP_DURATION value equal to "UNSPCIFIED". Some people are still confused with this spec.

11.3.3. Straw Poll: Do you agree with the resolutions of CIDs 8394, 5215, 7142, 10292 in doc 11-17/0263r3?

11.3.3.1. Result: No objection.

11.3.4. Next Step

11.3.4.1. Po-Kai to update the document.

11.4. Po-Kai Huang (Intel) presented "11ax D1.0 MAC Comment Resolution for 10.3.2.8a," based on the submission 11-17-0264-02.

11.4.1. Summary

11.4.1.1. Proposed resolutions for comments of TGax Draft 1.0 with the following CIDs:

11.4.1.1.1. 5075, 5076, 5561, 9481, 5562, 5563, 9274, 7140, 9423, 5044, 9425, 8095, 8096, 5045, 9427, 7975, 5932, 7976, 9424, 9426, 9557, 9681, 9850, 5933, 8411, 9515, 7569, 8410, 5795, 7137, 5761, 9682, 8256, 8257, 9428, 4835, 5934, 9851, and 7663.

11.4.2. Discussion

11.4.2.1. CID #9428: The relationship between puncturing and MU-RTS/CTS discussed. The resolution for this CID was modified.

11.4.3. Straw Poll: Do you agree with the resolutions of CIDs 5075, 5076, 5561, 9481, 5562, 5563, 9274, 7140, 9423, 5044, 9425, 8095, 8096, 5045, 9427, 7975, 5932, 7976, 9424, 9426, 9557, 9681, 9850, 5933, 8411, 9515, 7569, 8410, 5795, 7137, 5761, 9682, 8256, 8257, ~~9428,~~ 4835, 5934, 9851, and 7663 in document 17/264r2?

11.4.3.1. Result: No objection.

11.4.4. Next Step

11.4.4.1. Po-Kai to come back with a resolution for CID #9428.

12. Recess for 15 minutes.

13. Meeting called to order by Osama Aboul-Magd (Huawei Technologies) @ 15:30.

14. Presentation

14.1. Po-Kai Huang (Intel) presented "11ax D1.0 MAC Comment Resolution for 10.3.2.4 and 27.2.2 Part I," based on the submission 11-17-0324-00.

14.1.1. Summary

14.1.1.1. Resolutions for comments of TGax Draft 1.0 with the following CIDs proposed:

14.1.1.1.1. 10250, 10320, 10321, 10322, 10323, 10247, 10005, 10006, 10246, 9584, 9386, 9285, 8592, 8354, 8211, 7233, 6068, 6056, 5930, 5559, 5468, 5466, 5463, 5358, 5169, 3057, 8268, 8269, 7844, and 9442.

14.1.2. Discussion

14.1.2.1. A member commented it is unusual to prepare the resolution based on the editor's suggestion. → The resolution and related text in the document to be changed.

14.1.3. Straw Poll: Do you agree with the resolutions of CIDs 10250, 10320, 10321, 10322, 10323, 10247, 10005, 10006, 10246, 9584, 9386, 9285, 8592, 8354, 8211, 7233, 6068, 6056, 5930, 5559, 5468, 5466, 5463, 5358, 5169, 3057, 8268, 8269, 7844, and 9442 in document 17/324r0?

14.1.3.1. Result: No objection.

14.1.4. Next Step

14.1.4.1. Po-Kai to update the document.

14.2. George Cherian (Qulacomm) presented "CIDs: Section 9.3.1.8 & 9.3.1.9.7," based on the submission 11-17-0306-01.

14.2.1. Summary

14.2.1.1. The comments are basically on the Block Ack related spec.

14.2.1.2. Resolutions for comments of TGax Draft 1.0 with the following CIDs proposed:
14.2.1.2.1. 3006, 3010, 3112, 3162, 5047, 5058, 5067, 5403, 5926, 6075, 6076, 6184, 6272, 6273, 7044, 7134, 7311, 7312, 7314, 7475, 7733, 7734, 7735, 7736, 7737, 7934, 8113, 8157, 8186, 8187, 8474, 8475, 8477, 8478, 9362, 9363, 9364, 9625, 9626, 9642, 9814, 9815, 9816, 9817, and 9818.

14.2.2. Discussion
14.2.2.1. CID #5065: People discussed the use of M-BA as the response for PS-Poll Since current spec allows the AP to respond to PS-Poll with an ACK, George proposes to keep this sequence. Some people oppose to this idea.
14.2.2.2. CID #5403: There will be related submission on this CID. George to revisit this CID after hearing another presentation.
14.2.2.3. CID #6184 and 7044: to be discussed later.
14.2.2.4. CID #8157: excluded from this document.

14.2.3. Straw Poll: Do you agree with the resolutions of CIDs 3006, 3010, 3112, 3162, 5047, 5058, 5067, ~~5403,~~ 5926, 6075, 6076, ~~6184,~~ 6272, 6273, ~~7044,~~ 7134, 7311, 7312, 7314, 7475, 7733, 7734, 7735, 7736, 7737, 7934, 8113, ~~8157,~~ 8186, 8187, 8474, 8475, 8477, 8478, 9362, 9363, 9364, 9625, 9626, 9642, 9814, 9815, 9816, 9817, and 9818 in 17/306r2?
14.2.3.1. Result: No objection.

14.2.4. Next Step
14.2.4.1. There will be related submissions for the excluded CIDs. George to work offline with the authors of the related submissions.

14.3. George Cherian (Qulacomm) presented "CIDs: Section 27.4," based on the submission 11-17-0319-00.

14.3.1. Summary
14.3.1.1. Resolutions for the following CIDs proposed.
14.3.1.1.1. 3060, 3061, 3062, 3063, 3064, 3065, 3070, 3201, 3202, 3203, 3204, 3205, 3206, 3213, 5174, 5175, 5178, 5650, 5651, 5652, 5653, 5654, 5655, 5668, 5685, 5803, 5804, 5805, 5806, 6060, 6135, 6608, 6611, 6621, 6623, 6637, 6639, 6640, 6641, 7082, 7393, 7534, 7653, 7654, 7655, 7656, 7802, 7967, 8122, 8391, 8392, 8459, 8490, 8491, 9214, 9286, 9718, 9736, 9737, 9882, 10009, 10329, 10330, 10333
14.3.1.2. Discussion
14.3.1.2.1. CID #5175: A member has something to discuss with regards to this comment.
14.3.1.2.2. CID #5178 (S-MPDU): The comment was rejected since it has already defined in the IEEE 802.11ah-2016. There are some other comments for which the resolutions were changed for the same reason.
14.3.1.2.3.
14.3.1.3. Next Step
14.3.1.3.1. Time is up. George to continue his presentation tomorrow.

15. Recess @ 18:00 until tomorrow morning 9:00 AM.

Thursday, March 9th, 2017, TGax Ad Hoc Meeting Non-PHY Sessions (9:00-12:00)

1. The meeting called to order by Osama Aboul-Magd (Huawei Technologies), the chair of the TGax, @9:03 AM.

2. Agenda Setting.

2.1. Proposed agenda for the non-PHY session (11-17-356-01)

- 2.1.1. Call meeting to order
- 2.1.2. Reminder – IEEE 802 and 802.11 P&P, etc.
- 2.1.3. Announcement
- 2.1.4. Agenda Setting
  - 2.1.4.1. Call the meeting to order
  - 2.1.4.2. IPR Policy and Procedure
  - 2.1.4.3. 9:00 – 12:00 Comment Resolutions
  - 2.1.4.4. 12:00 – 13:00 Lunch
  - 2.1.4.5. 13:00 – 18:00 Comment Resolutions (including break)
- 2.1.5. Presentations and comment resolutions
- 2.1.6. Recess for the day

2.2. Chair asked if there are any other items – No items proposed. Meeting will be conducted based on this order.

3. Presentations

3.1. Zhou Lan (Broadcom) presented "," based on the submission 11-17-0363-02.

3.1.1. Summary

3.1.1.1. As for the resolution to the CID #5050, proposed that the Trigger frame, ACK/BlockAck/Multi-STABlockAck and Management frame transmitted by HE STAs in an A-MPDU are not subject to the minum MPDU start spacing.

3.1.2. Discussion

3.1.2.1. BlockAck has some variations and the proposal may not be applied to some of the variants such as basic Block Ack.

3.1.3. Straw Polls:

- Straw Poll #1: Do you agree to exclude control frame from the MPDU spacing constraint?

3.1.3.1. Result: Y/N/A = 11/1/22.

- Option 2: Do you agree to exclude ACK and BlockAck frames from the MPDU spacing constraint?

3.1.3.2. Result: Y/N/A = 9/0/24

- Option 3: Do you agree to change the baseline of this section saying "A STA shall not start the transmission of more than one QoS Data frame or Management frame within the time limit described in the Minimum MPDU Start Spacing field declared by the intended receiver"?

3.1.3.3. Result: Y/N/A = 16/4/17

3.1.4. Next Step

3.1.4.1. No SP on the resolution. More discussion is needed.

3.1.4.2. Zhou to come back with detailed text after offline discussion.

3.2. Raja Banerjea (Qualcomm) presented "Comment resolution for SS Allocation subfield," based on the submission 11-17-0282-02.

3.2.1.Summary

3.2.1.1. Resolutions for the comments on Spatial Stream Allocation and changes to the current text proposed.

3.2.1.2. Relevant comments:

3.2.1.2.1. 3015,3016, 3165, 7487, 8660, 8661, 9262, 9263 and 9633 (9 comments)

3.2.2.Discussion

3.2.2.1. A member commented the meaning of Starting Spatial Stream subfield.

3.2.2.2. Q: Random access – it is not covered.

3.2.2.3. People discussed the case for UL OFDMA.

3.2.2.4. There was a question for the case of UL MU-MIMO. Need to check with PHY experts.

3.2.3.Straw Poll: Do you agree to resolutions to CID; 3015,3016, 3165, 7487, 8660, 8661, 9262, 9263, 9633 in doc 11-12/0282r2?

3.2.3.1. **Result:** No SP on resolutions.

3.2.4.Next Step

3.2.4.1. Raja to check with PHY experts and come back with revised document.

3.3. Raja Banerjea (Qualcomm) presented "Comment resolution for CS Required subfield**," based on the submission 11-17-0359-01.**

3.3.1.Summary

3.3.1.1. Resolutions for the comments on CS Required and changes to the current text proposed.

3.3.1.2. Relevant comments:

3.3.1.2.1. 3012, 3019, 9648, 9837, 10162, 5189 (6 comments)

3.3.2.Discussion

3.3.2.1. A member asked for clarification of CS Required field setting for transmissions solicited by a Trigger frame to be consistent with other part of the draft.

3.3.3.Next Step

3.3.3.1. CID #3012 removed from the document. → Come back with separate submission.

3.3.3.2. CID #5189 – offline discussion suggested.

3.3.4.Straw Poll: Is there any objection to the resolutions for ~~3012,~~ 3019, 9648, 9837, 10162~~, and 5189~~ in document 17/359r2?

3.3.4.1. Result: No objection.

3.4. Raja Banerjea (Qualcomm) presented "Comment resolution for section 9.3.1.23," based on the submission 11-17-0283-02.

3.4.1.Summary

3.4.1.1. Resolutions for the comments on section 9.3.1.23 and changes to the current text proposed.

3.4.1.2. Relevant comments (19 comments):

3.4.1.2.1. 3018, 8190,
3.4.1.2.2. 3167, 3216, 5130, 8114, 8166, 8335, 8336, 8380, 8415, 8539, 8540, 9494, 9645, 9647, 6082,
3.4.1.2.3. 7484, and 9831

3.4.2. Discussion

3.4.2.1. People discussed the effectiveness of the Preferred AC.
3.4.2.2. CID #8114: There will be related submission on this comment. → CID #8114 excluded from this document.
3.4.2.3. CID #9647: It is resolved in another submission (by Po-Kai Huang). The resolution in another document is also rejected. → CID #9647 to be removed from this document.
3.4.2.4. CID #9831: Resolution was changed from "accepted, modified" to "Revised". A member asked to move the revised text to the normative part, not in the NOTE.
3.4.2.5. CID #5130: A member suggested discussion in the PHY subgroup. → The comment relates to MAC subclause and it should be discussed in MAC subgroup.

3.4.3. Straw Poll: Do you agree with the resolutions of CIDs 3018, 8190, 3167, 3216, 5130, ~~8114,~~ 8166, 8335, 8336, 8380, 8415, 8539, 8540, 9494, 9645, ~~9647~~, 6082, and 7484~~, 9831~~ in doc 11-17-0283-03?

3.4.3.1. Result: No objection.

3.5. Raja Banerjea (Qualcomm) presented "Comment resolution for HE Sounding Section 27.6.2," based on the submission 11-17-0309-01.

3.5.1. Summary

3.5.1.1. Resolutions for the comments on HE Sounding Section 27.6.2 and changes to the current text proposed.
3.5.1.2. Relevant comments (6 comments):
3.5.1.2.1. 7840, 7959, 8502, 9771, 8715, 10071

3.5.2. Discussion

3.5.2.1. CID #7840: A member suggested discussion with PHY experts for the MU case. → The comment discusses the SU case and the comment is rejected based on the discussion in resolution column.

3.5.3. Straw Poll: Do you agree with the resolutions of CIDs 7840, 7959, 8502, 9771, 8715, 10071?

3.5.3.1. Result: Straw Poll deferred.

3.6. George Cherian (Qualcomm) presented "CIDs: Section 27.4," based on the submission 11-17-0319-00.

3.6.1. Summary

3.6.1.1. This is continuation of the yesterday's presentation for the comments on Multi-STA BlockAck.

3.6.2. Discussion

3.6.2.1. CID #10330: There will be a contribution related to this comment. Matt has related contribution based on the CID #8099. The resolution for CID #10330 is unchanged ("rejected").

3.6.2.2. CID #10333:

3.6.3.Straw Poll

3.6.3.1. Do you agree with the resolutions of CIDs 3060, ~~3061, 3062,~~ 3063, 3064, 3065, ~~3070,~~ 3201, 3202, 3203, 3204, 3205, 3206, 3213, 5174, ~~5175,~~ 5178, 5650, 5651, 5652, 5653, 5654, 5655, 5668, 5685, 5803, 5804, 5805, 5806, 6060, 6135, 6608, 6611, 6621, 6623, 6637, 6639, 6640, 6641, 7082, 7393, 7534, 7653, 7654, 7655, 7656, 7802, 7967, 8122, 8391, 8392, 8459, 8490, 8491, 9214, 9286, 9718, 9736, 9737, 9882, 10009, 10329, 10330, 10333 in 17/319r1?

3.6.3.2. Discussion

3.6.3.2.1. CID #3070: Need more time to think about this comment. → Resolution for CID #3070 deferred and excluded for now.

3.6.3.2.2. Result: No objection.

3.7. Laurent Cariou (Intel) presented "," based on the submission 11-17-0204-05.

3.7.1.Summary

3.7.1.1. This is an update from the one (rev.2) presented in a teleconference.

3.7.1.2. Laurent explained the changes made after the teleconference (in r3, r4 and r5).

3.7.2.Discussion

3.7.2.1. A member asked for clarification of the modified sentence related to AIFSN value set to 0 in MU EDCA parameter set element.

3.7.2.2. CID #5853 is still open.

3.7.2.3. Clause 27.2.3: A member discussed frame sequence of Trigger – PS-Poll – MU ACK.

3.7.3.Straw Poll: Do you agree with the resolutions of CIDs 5854, 6160, 8519, 7660, 9403, 8262, 8297, ~~5853,~~ 8290 in doc 11-17/0204r5?

3.7.3.1. No objection.

3.7.4.Next Step

3.7.4.1. Laurent to upload the rev 6 after this session.

4. Recess

4.1. Recess @ 12:02 for lunch until 13:00.

Thursday, March 9th, 2017, TGax Ad Hoc Meeting Non-PHY Sessions (13:00-18:00)

5. Meeting called to order by Simone Merlin (Qualcomm) @ 13:06.

6. Presentations

6.1. Alfred Asterjadhi (Qualcomm) presented "LB225 CR Sub-clause 9.7 Part 1," based on submission 11-17-0226r2 on behalf of Yongho Seok.

6.1.1.Summary

6.1.1.1. Resolutions for two deferred CIDs from yesterday's session discussed.

6.1.1.2. Relevant CIDs: 6484 & 9611.

6.1.2.Discussion

6.1.2.1. Proposed change to the text was modified after further discussion on CID #9611.

6.1.3.Straw Poll: Do you agree with the resolutions of CIDs 6484 and 9611 in document 17/226r3?

6.1.3.1. Result: No objection.

6.2. Po-Kai Huang presented "11ax D1.0 MAC Comment Resolution for 10.3.2.8a," based on the submission 11-17-0264-03.

6.2.1.Summary

6.2.1.1. Revisit CID 9428 in 11-17-0264-03.

6.2.2.Discussion – No discussion.

6.2.3.Straw Poll: Do you agree with the resolution of CID 9428 in document 17/0264r3?

6.2.3.1. Result: No objection.

6.3. Abhishek Patil (Qualcomm) presented "Proposed resolution for comments related to Multiple BSSID set," based on submission 11-17-0230-01.

6.3.1.Summary

6.3.1.1. Resolutions for multiple comments related to TGax D1.0 with the following 31 CIDs and changes to the text proposed.

6.3.1.2. Relevant CIDs: 3060, 3061, 9444, 5175, 3062, 3071, 5708, 5709, 5710, 9709, 5711, 7177, 3072, 4817, 3136, 9821, 3075, 7552, 7972, 8533, 5455, 7163, 7164, 9378, 7165, 7841, 7169, 9379, 7146, 8280, and 8292.

6.3.2.Discussion

6.3.2.1. No discussion.

6.3.3.Straw Poll: Do you agree with the resolutions of CIDs 3060, 3061, 9444, 5175, 3062, 3071, 5708, 5709, 5710, 9709, 5711, 7177, 3072, 4817, 3136, 9821, 3075, 7552, 7972, 8533, 5455, 7163, 7164, 9378, 7165, 7841, 7169, 9379, 7146, 8280, and 8292 in document 17/230r1?

6.3.3.1. Result: No objection.

6.4. Abhishek Patil (Qualcomm) presented "Proposed resolution for comments related to Various CIDs in 27.5.2," based on submission 11-17-0250-01.

6.4.1.Summary

6.4.1.1. Resolutions for multiple comments received for TGax LB225 (78 CIDs) and changes to the current text proposed.

6.4.1.2. Relevant CIDs: 7968, 8271, 4809, 4810, 4811, 5702, 5183, 5184, 9451, 5185, 5703, 7574, 9894, 4812, 5186, 5704, 9452, 8272, 9707, 5706, 5187, 6168, 5983, 8273, 8338, 9588, 6166, 10167, 4815, 4816, 7644, 7041, 7141, 9897, 7812, 9896, 6065, 7175, 9759, 9456, 9589, 7176, 10260, 9898, 8552, 3228, 9710, 4818, 8151, 8701, 8702, 4821, 9529, 4820, 8703, 4822, 4823, 4824, 4825, 6685, 7649, 5717,

3232, 7816, 5988, 9713, 4828, 6196, 3325*, 6695, 8705, 6696, 7817, 6697, 9917, 5997, 5998, and 6701.

6.4.2. Discussion

6.4.2.1. A member discussed RU allocation for OFDMA random access and 16 us of MinTrigProcTime. OFDMA random access for unassociated STA was also discussed.

➔ After discussion, CIDs 7041, and 7141 and 9897 will be excluded from this document. These CIDs will be moved to other submission related to random access.

➔ The document was updated. Revision 2 is current document.

6.4.3. Straw Poll: Do you agree with the resolutions of CIDs 7968, 8271, 4809, 4810, 4811, 5702, 5183, 5184, 9451, 5185, 5703, 7574, 9894, 4812, 5186, 5704, 9452, 8272, 9707, 5706, 5187, 6168, 5983, 8273, 8338, 9588, 6166, 10167, 4815, 4816, 7644, ~~7041~~, ~~7141~~, ~~9897~~, 7812, 9896, 6065, 7175, 9759, 9456, 9589, 7176, 10260, 9898, 8552, 3228, 9710, 4818, 8151, 8701, 8702, 4821, 9529, 4820, 8703, 4822, 4823, 4824, 4825, 6685, 7649, 5717, 3232, 7816, 5988, 9713, 4828, 6196, 3325*, 6695, 8705, 6696, 7817, 6697, 9917, 5997, 5998, and 6701 in document 17/0250r2?

6.4.3.1. Result: No objection.

6.5. Abhishek Patil (Qualcomm) presented "Proposed resolution for comments related to Section 27.11.4 (BSS Color)," based on submission 11-17-0134-08.

6.5.1.Summary

6.5.1.1. Previous version of this document was presented in January 2017 session and the resolutions for remaining comments were proposed.

6.5.1.2. Resolutions for CIDs 3088, 9458 and 10299 proposed.

6.5.1.3. Subclause 27.16.2.2 was rewritten.

6.5.2.Discussion

6.5.2.1. A member commented that this change introduces related action for STAs and asked how often the action will be required for a STA. It is up to suggestion but the assumption is not so frequent.

6.5.2.2. A member commented the decision at the AP should be implementation dependent.

6.5.3.Straw Poll: Do you agree with the resolutions of CIDs 3084, 3085, 3086, 5387, 7166, 6786, 6779, 6777, 6781, 3088, 9458, 10299, 3087, 5476 in document 17/0134r8

6.5.3.1. Straw Poll deferred.

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7. Recess @ 15:15 until 15:30..

8. Meeting called to order by Simone Merlin (Qualcomm) @ 15:35.

9. Planning

9.1. Number of submissions and CIDs:

9.1.1. Abhi – 229 (60 CIDs)

9.1.2. Raja –

9.1.3. Alfred – 235 (CIDs), 236 (6 CIDs), 234 (52 CIDs), 238 (41 CIDs), 239 (41 CIDs), 240 (60 CIDs)

9.1.4. Jarkko
9.1.5. Zhou – (1 CID)
9.1.6. Kiseon – 349 (5 CIDs)
9.1.7. Liwen – 351 (16 CIDs)
9.1.8. …

10. Presentations.

10.1. Abhishek Patil (Qualcomm) presented "Proposed resolution for comments related to Section 27.16.2," based on submission 11-17-0138-00.

10.1.1. Summary
10.1.1.1. Resolutions for multiple comments on clause 27.16.2 proposed.
10.1.1.2. Relevant comments (11 CIDs):
10.1.1.2.1. 6787, 7131, 10300, 10301, 4910, 4911, 6789, 8356, 4909, 9703, and 4908.
10.1.2. Discussion
10.1.2.1. People discussed BSS color in a mesh network.
10.1.2.2. A member asked for the BSS color change for the Dual Beacon case. → There are some related comments which is not considered in this document.
10.1.2.3. CID #9703 (BSS color in mesh network): excluded for now.
10.1.2.4. CID #8356 (BSS color change for unassociated STA): A member commented the resolution is not enough.

10.1.3. Straw Poll: Do you agree with the resolutions of CIDs 6787, 7131, 10300, 10301, 4910, 4911, 6789, 8356, 4909, ~~9703,~~ and 4908 in document 17/138r1?
10.1.3.1. Result: Y/N/A = 12/1/2, straw poll passes.

10.2. Raja Banejea (Qualcomm) presented "Comment resolution for SS Allocation subfield," based on submission 11-17-0283-03.

10.2.1. Summary
10.2.1.1. A member requested exclusion of CID 3216 from the 11-17-0283 that will be resolved in another document.
10.2.2. Discussion
10.2.2.1.

10.2.3. Straw Poll #1: Do you agree to remove CID 3216 from the 17/283r3?
- Resolution will be provided in another document.
10.2.3.1. Result: No objection.

10.2.4. Straw Poll #2: Do you agree with the revised resolution of CID 9831 from document 17/283r3?
10.2.4.1. Result: No objection.

10.3. Raja Banejea (Qualcomm) presented "Comment resolution for CS Required subfield," based on submission 11-17-0359-02.

10.3.1. Summary
10.3.1.1. CID 5189 in 11-17-0359 revisited.
10.3.1.2. The resolution is "rejected."

10.3.2. Discussion

10.3.2.1.

10.3.3. Straw Poll: Do you agree with the resolution of CID 5189 in document 17/359r2?

10.3.3.1. Result: No objection.

10.4. Raja Banejea (Qualcomm) presented "Comment resolution for SS Allocation subfield," based on submission 11-17-0282-03.

10.4.1. Summary

10.4.1.1. Raja revised the text for 27.5.2.3 based on the discussion with PHY experts.

10.4.2. Discussion

10.4.2.1. Text in 27.5.2.3 modified after clarification.

10.4.3. Straw Poll: Do you agree to accept the resolutions for CIDs 3015, 3016, 3165, 7487, 8660, 8661, 9262, 9263, and 9633 in document 17/282r4?

10.4.3.1. Result: No objection.

10.5. Alfred Asterjadhi (Qualcomm) presented "Comment resolution in part of HE Capabilities IE (9.4.2.218)," based on submission 11-17-0235-00.

10.5.1. Summary

10.5.1.1. Resolutions for multiple comments related to TGax D1.0 with the following CIDs proposed.

10.5.1.1.1. CIDs: 4564, 4571, 4614, 7369, 8083, 8511, 8512, 9666, 9667 (9 CIDs)

10.5.2. Discussion

10.5.2.1. CID #8083:

10.5.3. Straw Poll: Is there any objection to accept the resolutions for CIDs 4564, 4571, 4614, 7369, 8083, 8511, 8512, 9666, 9667in 17/235r0?

10.5.3.1. Result: No objection

10.6. Alfred Asterjadhi (Qualcomm) presented "Comment resolutions for miscellaneous CIDs – Part 1," based on submission 11-17-0236-00.

10.6.1. Summary

10.6.1.1. Resolutions for CIDs 3132, 3175, 4720, 6919, 7228, 8308 (6 CIDs) proposed.

10.6.1.2.

10.6.2. Discussion

10.6.2.1. CID #3132: After discussion, the resolution for this CID is still revised but the explanation is updated.

10.6.3. Straw Poll: Do you agree to accept the resolutions of CIDs 3132, 3175, 4720, 6919, 7228, 8308 in document 17/236r1?

10.6.3.1. Result: No objection.

10.7. Alfred Asterjadhi (Qualcomm) presented "Comment resolutions for Selection rules (27.15)," based on submission 11-17-0237-01.

10.7.1. Summary

10.7.1.1. Resolutions for following CIDs proposed:

10.7.1.1.1. 4789, 4808, 5217, 5218, 5219, 5220, 5221, 5511, 5518, 7034, 7035, 7154, 7581, 7582, 7583, 8525, 8526, 8616, 8617, 8729, 8730, 9732, 9961, 9962, 9963, 9964 (26 CIDs)

10.7.1.1.2. 5222, 5223, 5224, 5225, 5226, 7584, 7585, 7586, 9751, 9965, 9966 11 CIDs)

10.7.1.1.3. 3256, 3354, 3461, 3775, 3858, 4301, 4925, 5227, 5228, 7587, 7588, 7589, 7590, 7591, 7592 (15 CIDs)

10.7.2. Discussion

10.7.2.1. CID #5218: Need for UL MU PPDU support is discussed. It is in current spec and it provides transmission in narrow channel bandwidth.

10.7.2.2. CID #7583: The resolution for this comment from "rejected" to "revised". The commenter thinks FTM feature should also be discussed with TGaz participants. HE PPDUs has longer GI and may not provide good accuracy. → Need to talk with 11az participants. CID #7583 is removed from this document.

10.7.3. Straw Poll on the first part of the document: Do you agree to accept the resolutions for CIDs 4789, 4808, 5217, 5218, 5219, 5220, 5221, 5511, 5518, 7034, 7035, 7154, 7581, 7582, ~~7583,~~ 8525, 8526, 8616, 8617, 8729, 8730, 9732, 9961, 9962, 9963, 9964 (25 CIDs) in document 17/237r2.

10.7.3.1. Result: No objection.

10.8. Straw Poll by Abhishek Patil (Qualcomm) on submission 11-17-0138-01 "Proposed resolution for comments related to Section 27.16.2,".

10.8.1. Summary

10.8.1.1. Resolution for CID #9703 is still rejected, but the reason is updated.

10.8.2. Discussion

10.8.3. Straw Poll: Do you agree with the resolution of CID 9703 in document 138r1?

10.8.3.1. Result: No objection.

10.9. Straw Poll by Abhishek Patil (Qualcomm) on submission 11-17-0134-09 "Proposed resolution for comments related to Section 27.11.2 (BSS Color)".

10.9.1. Summary

10.9.1.1. Based on the feedback, proposed changes to the text is updated..

10.9.2. Discussion

10.9.3. Straw Poll: Do you agree with the resolutions of CIDs 3084, 3085, 3086, 5387, 7166, 6786, 6779, 6777, 6781, 3088, 9458, 10299, 3087, 5476 in document 17/134r10.

10.9.3.1. Result: No objection.

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11. Plans for tomorrow

11.1. Start time is 9:00 AM.

12. **Recess for the day @ 18:01.**

Friday, March 10th, 2017, TGax Ad Hoc Meeting Non-PHY Sessions (9:00-12:00)

1. The meeting called to order by Osama Aboul-Magd (Huawei Technologies), the chair of the TGax, @9:03 AM.

2. Agenda Setting.

2.1. Proposed agenda for the non-PHY session (11-17-356-02)

- 2.1.1. Call meeting to order
- 2.1.2. Reminder – IEEE 802 and 802.11 P&P, etc.
- 2.1.3. Announcement
- 2.1.4. Agenda Setting
  - 2.1.4.1. Call the meeting to order
  - 2.1.4.2. IPR Policy and Procedure
  - 2.1.4.3. 9:00 – 12:00 Comment Resolutions
  - 2.1.4.4. 12:00 – 13:00 Lunch
  - 2.1.4.5. 13:00 – 16:00 Comment Resolutions (including break)
- 2.1.5. Presentations and comment resolutions
- 2.1.6. Recess for the day

2.2. Chair asked if there are any other items – No items proposed. Meeting will be conducted based on this order.

3. Reminder

3.1. IEEE 802 and 802.11 Policy & Procedure

3.2. Chair called for the potentially essential patent

3.2.1. No response.

4. Presentations

4.1. Zhou Lan (Broadcom) presented "Comment resolutions for MPDU start spacing (A-MPDU content section 10.13)" based on the submission 11-17-0363-04.

4.1.1. Summary

- 4.1.1.1. Zhou presented the changes made to the previous version of the document.
- 4.1.1.2. The requirement of minimum MPDU start spacing in this document is only for the 802.11ax devices.

4.1.2. Discussion

- 4.1.2.1. Resolution for the related comment (CID #5050) was changed to "revised" from "Accepted".

4.1.3. Straw Poll: Is there any objection to accept the resolution for CID #5050 as in document 11-17-0363-05?

- 4.1.3.1. Result: No objection.

4.2. Guoqing Li (Apple) presented "CIDs Related to 20MHz-only STAs operating on non-primary 20 MHz channels " based on the submission 11-17-0369-01.

4.2.1. Summary

- 4.2.1.1. This is a joint contribution of six companies.
  - 4.2.1.1.1. Related CIDs: 9153, 8811 and 8810.

4.2.1.2. The spec is not clear on whether and how these STAs can operate on non-primary 20MHz channel.
4.2.1.3. This contribution proposes the protocol components and some considerations that will allow these STAs to operate on non-primary 20MHz channel
4.2.2.Discussion
4.2.2.1. Slide 11 (Channel Access and Protection): A member asked for the meaning of the first bullet saying "STAs staying on non-primary 20MHz channel can only use MU transmission in uplink …" → Those STAs can of course receive DL data from the AP.
4.2.2.2. Slide 14 (Beacon Reception and Synchronization): A member commented that the third option for STAs on non-primary channel to receive Beacon and multicast frames seems to be ambiguous. → Guoqing to revise the text.
4.2.2.3. Slide 20 (Co-existence with OBSS): A member commented that it is not clear whether the proposed mechanism mitigates the OBSS issue or makes OBSS issue even worse. → Guoqing mentioned it is not changed. OBSS issue is something that the WLAN has today.

4.2.3.Straw Poll: Do you agree to allow 11ax 20MHz-only STAs to operate optionally on non-primary channel?
4.2.3.1. Discussion
4.2.3.1.1. A member expressed a concern that this mechanism could make 802.11ax spec further complicated.
4.2.3.1.2. It is not clear whether STA is allowed to operate non-primary channel, primary channel and another non-primary channel from time to time.
4.2.3.1.3. A member commented that we need to talk to PHY experts.
4.2.3.1.4. The main point will be MU-RTS/CTS procedure.
4.2.3.2. Result: Y/N/A = 16/10/13

4.3. Jarkko Kneckt (Apple) presented "Comment resolution for Opportunistic Power Save (OPS)," based on the submission 11-17-0397-00.
4.3.1.Summary
4.3.1.1. The submission is part of the opportunistic power save (OPS) comment resolutions, discussing on CID9660 and CID9841.
4.3.1.2. Two alternatives for Opportunistic power save signalling are introduced and discussed.
4.3.1.2.1. OPS element allows OPS information in Beacon, TIM, FILS Discovery and OPS TIM frames
4.3.1.2.2. New TIM element encoding and OPS SP End Time element allow the OPS information delivery in FILS Discovery frames and OPS frames
4.3.2.Discussion
4.3.2.1. Slide 13 (Alternative 1, OPS Element): A member commented that we need to be careful to creating a new mode for broadcast TWT. The commenter does not think it worth to do that.
4.3.2.2.

4.3.3.Straw Polls: Are you in favor of:
4.3.3.1. **Alternative 1: Define new OPS element to provide OPS information for HE STAs as introduced in slide 13**

	Element ID	Length	Element ID Extension	OPS SP End Time	Bitmap Control	Partial Virtual Bitmap
Octets:	1	1	1	1	1	1 - 251

4.3.3.2. Result: Y/N/A =

4.3.3.3. **Alternative 2: Use TIM element with new encoding for OPS STAs as introduced in slides 14, 15 and 16**

	Element ID	Length	DTIM Count	DTIM Period	Bitmap Control	Partial Virtual Bitmap
Octets:	1	1	1	1	1	1 - 251

	Element ID	Length	Element ID Extension	OPS SP End Time
Octets:	1	1	1	1

4.3.3.4. Result: Y/N/A =

4.3.3.5. Discussion

4.3.3.5.1. Alternative 1 proposes to include this element in FILS Discovery frame.
→ It is defined in D1.0.

4.3.3.5.2. A member is concerned by TIM frame to be transmitted outside the TWT service period.

4.3.3.6. Straw Poll was postponed.

4.4. Rojan Chitrakar (Panasonic) presented "Virtual CS during UL MU," based on the submission 11-17-0337-00.

4.4.1.Summary

4.4.1.1. Clarification CID #8555.

4.4.1.2. Proposals:

4.4.1.2.1. Non-AP STAs maintain a record of the OBSS transmission bandwidth

4.4.1.2.2. Virtual CS is considered per 20 MHz channel when the basic NAV is non-zero

4.4.1.2.3. Under certain circumstances, STA is allowed to transmit HE trigger-based PPDU even when basic NAV is set.

4.4.2.Discussion

4.4.2.1. ?

4.4.3.Straw Polls

4.4.3.1. Straw Poll #1: Do you agree that the UL MU CS mechanism should be enhanced to overcome the loss of uplink transmission opportunity described in slides 4 and 5?

4.4.3.1.1. Discussion

4.4.3.1.1.1. A member objects to this proposal. This proposal introduces additional complexity but does not resolve the issue. → Rojan agrees current issue in RTS/CTS procedure.

4.4.3.1.1.2. Another member mentioned we should talk to PHY experts.

4.4.3.1.1.3. A member is concerned that BW information is not enough for this purpose.

4.4.3.1.2. Result: Y/N/A = 6/4/20

4.5. Abhishek Patil (Qualcomm) presented "Proposed resolution for comments related to Random Access AIDs for Associated and Unassociated STAs," based on the submission 11-17-0229-01.

4.5.1.Summary

4.5.1.1. Resolutions for multiple comments received for TGax LB225 (69 CIDs) re: random access AIDs for Associated and Unassociated STAs.

4.5.1.2. Relevant CIDs: 7809, 3074, 5999, 9121, 9122, 9123, 5018, 5019, 5020, 5021, 5022, 5023, 5066, 5714, 5986, 6167, 7648, 8156, 8279, 8554, 9100, 9591, 9904, 9975, 9708, 10168, 5364, 7814, 3097, 3229, 3230, 3301*, 4819, 5035, 5094, 5190, 5370, 5713, 6195, 6677, 6999, 7097, 7845, 8276, 8299, 9528, 9711, 10169, 10010, 5810, 10012, 5365, 9916, 3073, 5411, 6188, 9405, 9919, 9258, 7745, 9827, 9630, 7329, 9997, 9998, 9826, 7041, 7141, and 9897.

4.5.2.Discussion

4.5.2.1. Re: CID #10168: People talked about the service waiting time of two M/M/1 queues and one M/M/2 queue. With regards to the AID 0, the traffic pattern is different between an associated STA and unassociated STA.

4.5.2.1.1. A member mentioned that the random access for unassociated STA is beneficial for some applications.

4.5.2.1.2. After long discussion, it eventually turned out that the commenter is okay with the resolution.

4.5.2.2. CID #5364: Removed from the document.

4.5.2.3. CID #7041: Discussed new text related to this CID.

4.5.3. Recess Abhi's presentation to be continued after lunch.

5. Recess @ 12:00 for lunch.

Friday, March 10th, 2017, TGax Ad Hoc Meeting Non-PHY Sessions (13:00-16:00)

6. Meeting called to order @ 13:01.
   6.1. Hard stop @ 16:00.

7. Presentation.
   7.1. Abhishek Patil (Qualcomm) continues his presentation of 11-17-229-01.
   7.1.1. Discussion
   7.1.1.1. CID #3073: People discuss the way to prohibit STAs with empty buffer to participate random access. → CIDs 3073, 5411, 6188, 9405 and 9919 were excluded.

7.1.2. Straw Poll: Is there any objection to accept resolutions for CIDs 7809, 3074, 5999, 9121, 9122, 9123, 5018, 5019, 5020, 5021, 5022, 5023, 5066, 5714, 5986, 6167, 7648, 8156, 8279, 8554, 9100, 9591, 9904, 9975, 9708, 10168, ~~5364,~~ 7814, 3097, 3229, 3230, 3301*, 4819, 5035, 5094, 5190, 5370, 5713, 6195, 6677, 6999, 7097, 7845, 8276, 8299, 9528, 9711, 10169, 10010, 5810, 10012, 5365, 9916, ~~3073, 5411, 6188, 9405, 9919,~~ 9258, 7745, 9827, 9630, 7329, 9997, 9998, 9826, 7041, 7141, and 9897 in document 17/229r1?

7.1.2.1. Result: No objection.

7.2. Alfred Asterjadhi (Qualcomm) presented "Comment resolutions for Selection rules (27.15)," based on the submission 11-17-0237-03.

7.2.1.Summary

7.2.1.1. The first part of this document was discussed yesterday.

7.2.1.2. Rest of the document is discussed.

7.2.1.2.1. Part 2: CIDs - 5222, 5223, 5224, 5225, 5226, 7584, 7585, 7586, 9751, 9965, 9966 11 CIDs)

7.2.1.2.2. Part 3: CIDs - 3256, 3354, 3461, 3775, 3858, 4301, 4925, 5227, 5228, 7587, 7588, 7589, 7590, 7591, 7592 (15 CIDs)

7.2.2.Discussion

7.2.2.1.

7.2.3. Straw Poll: Do you agree with the resolutions of CIDs 5222, 5223, 5224, 5225, 5226, 7584, 7585, 7586, 9751, 9965,-9966, 3256, 3354, 3461, 3775, 3858, 4301, 4925, 5227, 5228, 7587, 7588, 7589, 7590, 7591, 7592 in document 11-17-0237-03?

7.2.3.1. Result: No objection

7.3. Straw Poll by Abhishek Patil (Qualcomm) on CID 5364.

7.3.1.Straw Poll: Do you agree with the resolution of CID 5364 in document 11-17-0229-02?

7.3.1.1. Result: No objection.

7.4. Alfred Asterjadhi (Qualcomm) presented "Comment resolutions for HT Control field (9.2.4.6.X and 10.1) – Block 1," based on the submission 11-17-0238-01.

7.4.1.Summary

7.4.1.1. Resolutions for multiple comments related to TGax D1.0 with the following CIDs proposed (41 CIDs):

7.4.1.1.1. Part 1: 3004, 4725, 5436, 7715, 8175 (5 CIDs)

7.4.1.1.2. Part 2: 3378, 3483, 3812, 3896, 4358, 4425, 4727, 5025, 5438, 7471, 7713, 7714, 8176, 8643, 8644, 9801, 9984 (17 CIDs)

7.4.1.1.3. Part 3: 3153, 3381, 3487, 3817, 3902, 4365, 4433, 4734, 5051, 5122, 5123, 5439, 8177, 8645, 8646, 10334, 10335, 10336, 10337 (19 CIDs)

7.4.2.Discussion

7.4.2.1. CID #7715: A member asked clarification on the resolution of this CID.

7.4.2.2. CID #3004: Discussed the length of A-Control field. → Proposed text modified.

7.4.2.3. CID #:

7.4.3.Straw Poll: Do you agree with the resolutions of CIDs 3004, 4725, 5436, 7715, 8175, 3378, 3483, 3812, 3896, 4358, 4425, 4727, 5025, 5438, 7471, 7713, 7714, 8176, 8643, 8644, 9801, 9984, Part 3: 3153, 3381, 3487, 3817, 3902, 4365, 4433, 4734, 5051, 5122, 5123, 5439, 8177, 8645, 8646, 10334, 10335, 10336, 10337 in document 11-17-0238-02?

7.4.3.1. Result: No objection.

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8. Recess@14:15

9. Meeting reconvene @ 14:45

10. Presentations

10.1. Alfred Asterjadhi (Qualcomm) presented "Comment resolutions for HT Control field (9.2.4.6.X and 10.1) – Block 2," based on the submission 11-17-0239-00.

10.1.1. Summary

10.1.1.1. Resolutions for multiple comments related to TGax D1.0 with the following CIDs (41 CIDs) regarding HT Control field (clause 9.2.4.6 and 10.1):

10.1.1.1.1. Part 4: 4732, 4733, 5052, 5053, 5124, 5125, 5440, 5851, 7249, 7379, 7716, 7717, 8178, 8248, 9495, 9803, 9804 (17 CIDs)

10.1.1.1.2. Part 5: ~~3154,~~ 5335, 5441, 7888~~, 8369, 9094, 9619, 9805, 10140~~ (3 CIDs)

10.1.1.1.3. Part 6: 5054, 5055, 5056, 5126, 5442, 7302, 7303, 7305, 7719, 7865, 7867, 8133, 8179, 8180, 8181, 8249, 8426, 8427, 9620, 9621, 9806 (21 CIDs)

10.1.1.2. Discussion – Part 4

10.1.1.2.1. CID #5851: A member commented relationship between transmit channel width and receive channel width – the member does not agree with the resolution. CIDs 5851, 7249 and 9803 are excluded for further discussion.

10.1.1.2.2. CID #9495: CID excluded for further discussion.

10.1.1.3. Straw Poll: Is there any objection to accept the resolutions for CIDs 4732, 4733, 5052, 5053, 5124, 5125, 5440, ~~5851, 7249,~~ 7379, 7716, 7717, 8178, 8248, ~~9495, 9803,~~ 9804 (17 CIDs) in document 11-17-0239-01?

10.1.1.3.1. No objection.

10.1.1.4. Discussion – Part 5

10.1.1.4.1. No discussion.

10.1.1.5. Straw Poll: Is there any objection to accept the resolutions for CIDs 5335, 5441, 7888 (3 CIDs) in document 11-17-0239-01?

10.1.1.5.1. No objection.

10.1.1.6. Discussion – Part 6 (BSR)

10.1.1.6.1. All CIDs in this part was removed for further discussion.

10.2. Alfred Asterjadhi (Qualcomm) presented "Comment resolutions for HT Control field (9.2.4.6.X and 10.1) – Block 3," based on the submission 11-17-0240-00.

10.2.1. Summary

10.2.1.1. Resolutions for multiple comments related to TGax D1.0 with the following CIDs (60 CIDs) proposed:

10.2.1.1.1. Part 7: 3155, 3382, 3489, 3819, 3905, 4368, 4436, 5443, 7887, 8162, 8647 (11 CIDs)

10.2.1.1.1.1. Part 8: 3005, 3147, 3157, 3158, 3159, 4738, 5013, 5014, 5127, 5444, 6191, 7015, 7016, 7017, 7018, 7019, 7380, 7472, 7570, 7720, 8182, 8183, 8184, 8250, 8334, 8374, 9397, 9807, 9808, 10339 (30 CIDs)

10.2.1.1.2. Part 9: 3156, 3160, 3384, 3491, 3822, 3907, 4371, 4439, 4740, 5445, 7020, 7473, 8185, 8375, 9809, 9810, 9811, 9812 (18 CIDs)
10.2.1.1.3. Part 10: 6965 (1 CID)
10.2.2. Discussion (on Part 7 CIDs)
10.2.2.1. CID #3005: A member asked to defer for more time to think about.
10.2.2.2. Text in 9.2.4.6.4.7 (Bandwidth Query Report) was modified based on the discussion.
10.2.2.3. CID #3157:

10.2.3. Straw Poll: Is there any objection to accept the resolutions for CIDs 3155, 3382, 3489, 3819, 3905, 4368, 4436, 5443, 7887, 8162, 8647, 3005, 3147, 3157, 3158, 3159, 4738, 5013, 5014, 5127, 5444, 6191, 7015, 7016, 7017, 7018, 7019, 7380, 7472, 7570, 7720, 8182, 8183, 8184, 8250, 8334, 8374, 9397, 9807, 9808, 10339 in document 11-17-0240-01?
10.2.3.1. Result: No objection.

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11. AoB
11.1. Chair asked people planning to submit contribution to send an email to him.

12. Adjournment
12.1. TGax ad hoc meeting adjourned@16:00.

13. List of attendees
Following individuals are present in the TGax ad hoc meeting.

	Name	Affiliation
1	Osama Aboul-Magd	Huawei Technologies
2	Woojin Ahn	Wilus
3	Yaron Alpert	Intel
4	Yusuke Asai	NTT
5	Alfred Asterjadhi	Qualcomm
6	Edward Au	Huawei Technologies
7	Laurent Cariou	Intel
8	Xiaogang Chen	Intel
9	George Cherian	Qualcomm
10	Rojan Chitrakar	Panasonic
11	Jinsoo Choi	LG Electronics
12	Liwen Chu	Marvell
13	Sean Coffey	RealTek
14	Thomas Derham	Broadcom
15	yonggang Fang	ZTE
16	Matthew Fischer	Broadcom
17	Ganming (Ming)	Huawei Technolgies
18	Chittabrata Ghosh	Intel
19	Qiang Guo	Huawei Technologies
20	Reza Hedayat	Newracom
21	Frank Hsu	MediaTek
22	Chunyu Hu	Broadcom
23	Po-Kai Huang	Intel
24	Russel Huang	MediaTek

25	Yasuhiko Inoue	NTT
26	Jeongki Kim	LG Electronics
27	Suhwook Kim	LG Electronics
28	Youhan Kim	Qualcomm
29	Jarkko Kneckt	Apple
30	Geonjung Ko	Wilus
31	Young Hoon Kwon	Newracom
32	Zhou Lan	Broadcom
33	Guoqing Li	Apple
34	Yunbo Li	Huawei Technologies
35	Dongguk Lim	LG Electronics
36	Jianhan Liu	MediaTek
37	Peter Loc	Huawei Technologies
38	Kaiying Lv	ZTE
39	Jing Ma	NICT
40	Narendar Madhavan	Toshiba
41	Simone Merlin	Qualcomm
42	Saishankar Nandagopalan	Cypress
43	Patrice Nezou	Canon
44	Yujin Noh	Newracom
45	Robert Olesen	InterDigital
46	Oghenekome Oteri	InterDigital
47	Eunsung Park	LG Electronics
48	Viger Pascal	Canon
49	Abhishek Patil	Qualcomm
50	Al Petrick	InterDigital
51	Ron Porat	Broadcom
52	Zhigang Rong	Huawei Technologies
53	Kiseon Ryu	LG Electronics
54	Sigurd Schelstaete	Quantenna
55	Yongho Seok	Newracom
56	John Son	Wilus
57	Junghoon Suh	Huawei Technologies
58	Bo Sun	ZTE
59	Robert Stacey	Intel
60	Yusuke Tanaka	Sony
61	Bin Tian	Qualcomm
62	Tao Tian	Spreadtrum
63	Lochan Verma	Qualcomm
64	Huizhao Wang	Quantenna
65	James Wang	MediaTek
66	Xiaofei Wang	InterDigital
67	Lisa Ward	Rhode & Schwartz
68	Xun Yang (David)	Huawei Technologies
69	Jian Yu (Ross)	Huawei Technologies
70	Hongyuan Zhang	Marvell
71	Yan Zhang	Marvell
72	Yuval Har Zion	Celeno

APPENDIX AI

Documents

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Everything | All Years | TGax (inactive)

1415

Created (ET) ▼	Year	DCN	Rev	Group	Title	Author (Affiliation)	Uploaded (ET)	Actions
30-Sep-2020 ET	2020	1415	2	TGax	tgax-crc-teleconference-minutes-september-2020	Yasuhiko Inoue (NTT)	30-Sep-2020 08:49:36 ET	Download
28-Sep-2020 ET	2020	1415	1	TGax	tgax-crc-teleconference-minutes-september-2020	Yasuhiko Inoue (NTT)	28-Sep-2020 21:29:30 ET	Download
06-Sep-2020 ET	2020	1415	0	TGax	tgax-crc-teleconference-minutes-september-2020	Yasuhiko Inoue (NTT)	07-Sep-2020 09:47:13 ET	Download
12-Sep-2018 ET	2018	1415	2	TGax	SM power save	Po-Kai Huang (Intel)	12-Sep-2018 19:36:47 ET	Download
06-Sep-2018 ET	2018	1415	1	TGax	SM power save	Po-Kai Huang (Intel)	06-Sep-2018 13:16:22 ET	Download
13-Aug-2018 ET	2018	1415	0	TGax	SM power save	Po-Kai Huang (Intel)	04-Sep-2018 16:23:40 ET	Download
08-Nov-2016 ET	2016	1415	2	TGax	CID72 BSS Color change mechanism	Abhishek Patil (Qualcomm)	08-Nov-2016 12:47:21 ET	Download
07-Nov-2016 ET	2016	1415	1	TGax	CID72 BSS Color change mechanism	Abhishek Patil (Qualcomm)	07-Nov-2016 10:45:48 ET	Download
06-Nov-2016 ET	2016	1415	0	TGax	CID72 BSS Color change mechanism	Abhishek Patil (Qualcomm)	06-Nov-2016 01:53:04 ET	Download

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APPENDIX AJ

IEEE P802.11
Wireless LANs

Proposed Resolution for CID 72 (BSS Color Change Procedure)				
Date: 2025-06-30				
Author(s):				
Name	**Affiliation**	**Address**	**Phone**	**email**
Abhishek Patil	Qualcomm Inc.	5775 Morehouse Drive, San Diego, CA 92121	+1-858-845-4434	appatil@qti.qual-comm.com
Alfred Asterjadhi	Qualcomm Inc.	5775 Morehouse Drive, San Diego, CA 92121	+1-858-658-5302	aasterja@qti.qual-comm.com
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Abstract

This submission proposes resolution for CID 72

Interpretation of a Motion to Adopt

A motion to approve this submission means that the editing instructions and any changed or added material are actioned in the TGax Draft. This introduction is not part of the adopted material.

Editing instructions formatted like this are intended to be copied into the TGax Draft (i.e. they are instructions to the 802.11 editor on how to merge the text with the baseline documents).

TGax Editor: Editing instructions preceded by "TGax Editor" are instructions to the TGax editor to modify existing material in the TGax draft. As a result of adopting the changes, the TGax editor will execute the instructions rather than copy them to the TGax Draft.

CID	Commenter	Pg / Ln	Comment	Proposed Change	Resolution
193	Ahmadreza Hedayat	25.11	Unlike what is suggested here "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.", it'd seem logical that an AP manages its Color value so that it reduces Color collision with other neighboring APs. Since some other STAs' behaviors depend on Color value it seems logical that an AP changes its Color value to avoid unintended behaviors from its associated STAs when there is a Color collision that at least the AP is aware of.	Allow an AP to change its Color value during the existence of the BSS.	Revised – Agree in principle with the comment. Please see contribution in document 11-16-1415-00ax for more technical discussions.

9.3.3 Management frames

9.3.3.1 Beacon frame format

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

Table 9-27—Beacon frame body

Order	Information	Notes
<ANA>	BSS Color Change Announcement	The BSS Color Change Announcement element is optionally present when dot11HEOptionImplemented is true; otherwise it is not present.

9.3.3.6 Association Response frame format

TGax Editor: Insert the following new row (header row shown for convenience) into Table 9-30 (Association Response frame body):

Table 9-30—Association Response frame body

Order	Information	Notes
<ANA>	BSS Color Change Announcement	The BSS Color Change Announcement element is optionally present when dot11HEOptionImplemented is true; otherwise it is not present.

9.3.3.8 Reassociation Response frame format

TGax Editor: Insert the following new row (header row shown for convenience) into Table 9-32 (Reassociation Response frame body):

Table 9-32—Reassociation Response frame body

Order	Information	Notes
<ANA>	BSS Color Change Announcement	The BSS Color Change Announcement element is optionally present when dot11HEOptionImplemented is true; otherwise it is not present.

9.3.3.11 Probe Response frame format

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

Table 9-34—Probe Response frame body

Order	Information	Notes
<ANA>	BSS Color Change Announcement	The BSS Color Change Announcement element is optionally present when dot11HEOptionImplemented is true; otherwise it is not present.

9.6.28 HE Action frame details

9.6.28.1 HE Action field

TGax Editor: Modify Table 9-421z (HE Action field values) with the underline content as shown below:

Table 9-421z—HE Action field values

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

TGax Editor: Insert the following new section at the end of section 9.6.28:

9.6.28.3 HE BSS Color Change Announcement frame format

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

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

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

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

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

The BSS Color Change Announcement element as defined in 9.4.2.22x is always present in the frame.

No vendor-specific elements are present in HE BSS Color Change Announcement frame.

TGax Editor: Insert the following new section at the end of section 9.4.2:

9.4.2.22x BSS Color Change Announcement element

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

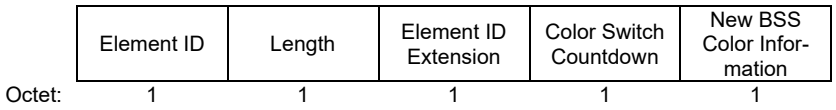


Figure Error! No text of specified style in document.**-xxx – BSS Color Change Announcement element format**

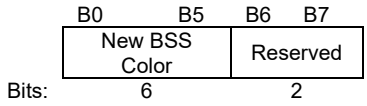


Figure Error! No text of specified style in document.**-xxx – New BSS Color Information field format**

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

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

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

The BSS Color Change Announcement element can be included in HE BSS Color Change Announcement frame, Beacon, Probe Response, and (Re-)Association Response frames. The use of BSS Color Change Announcement elements and frames is described in 25.1a.1 (Selecting and advertising a new BSS color).

TGax Editor: Insert the following new section at the end of section 25:

25.1a HE BSS Operation

25.1a.1 Selecting and advertising new BSS Color

An HE AP that sets up a BSS selects a BSS Color as defined in 25.11. An HE AP may choose to change the BSS Color under certain conditions such as when it detects that there is at least one other OBSS AP in the neighbourhood that uses the same color as the BSS Color of its BSS.

The algorithm to choose a new BSS Color is beyond the scope of this standard.

An HE AP shall announce its decision to change the BSS Color via the BSS Color Change Announcement element which is carried in the Beacon, Probe Response and (Re)Association Response frames. The AP may also advertise the BSS Color change event via the HE BSS Color Change Announcement frame. The BSS Color change announcement should be advertised for a period of time that is sufficient for all STAs in the BSS, including STAs in power save mode, to have the opportunity to receive at least one BSS Color Change Announcement element before the BSS Color change occurs.

BSS Color change TBTT is the one at which the Color Switch Countdown time has reached 0 and the BSS switches to the new color.

During the time leading up to the BSS Color change TBTT, an HE AP shall continue to advertise the existing BSS Color via the BSS Color subfield in HE Operation element.

At the BSS Color change TBTT, an HE AP shall:

- set the BSS Color Disable bit subfield value to 0 in HE Operation element
- start advertising the new BSS Color via BSS Color subfield in HE Operation element
- start using the new BSS Color

A non-AP STA that receives a BSS Color Change Announcement element shall start using the BSS Color specified in the received BSS Color Change Announcement element subsequent to the BSS Color change TBTT.

A non-AP STA in an infrastructure BSS shall not transmit the BSS Color Change Announcement element.

APPENDIX AK

Documents

Everything | All Years | TGax (inactive)

CID

Created (ET) ▼	Year	DCN	Rev	Group	Title	Author (Affiliation)	Uploaded (ET)	Actions
09-Mar-2017 ET	2017	331	2	TGax	LB225 Comment resolution for CIDs for 28.3.11.9 Constellation mapping	Jianhan Liu (Mediatek Inc.)	09-Mar-2017 20:12:00 ET	Download
09-Mar-2017 ET	2017	332	2	TGax	LB225 Comment resolution for CIDs for 28.3.10 HE Preamble	Jianhan Liu (Mediatek Inc.)	09-Mar-2017 20:11:09 ET	Download
09-Mar-2017 ET	2017	333	1	TGax	LB225 Comment resolution for CIDs for 28.3.13 Non-HT duplicate transmission	Jianhan Liu (Mediatek Inc.)	09-Mar-2017 20:10:01 ET	Download
09-Mar-2017 ET	2017	250	2	TGax	Various CIDs in 27.5.2	Abhishek Patil (Qualcomm)	09-Mar-2017 19:49:15 ET	Download
09-Mar-2017 ET	2017	329	2	TGax	LB225 Comment resolution for CIDs for 28.3.11.5 Coding	Jianhan Liu (Mediatek Inc.)	09-Mar-2017 19:32:49 ET	Download
09-Mar-2017 ET	2017	389	0	TGax	CIDs-for-27-2-1-part1	Kaiying Lv (ZTE Corp.)	10-Mar-2017 14:31:48 ET	Download
09-Mar-2017 ET	2017	329	1	TGax	LB225 Comment resolution for CIDs for 28.3.11.5 Coding	Jianhan Liu (Mediatek Inc.)	09-Mar-2017 17:57:21 ET	Download
09-Mar-2017 ET	2017	330	1	TGax	LB225 Comment resolution for CIDs for 3 Definitions, acronyms, and abbreviations	Jianhan Liu (Mediatek Inc.)	09-Mar-2017 17:56:37 ET	Download
09-Mar-2017 ET	2017	331	1	TGax	LB225 Comment resolution for CIDs for 28.3.11.9 Constellation mapping	Jianhan Liu (Mediatek Inc.)	09-Mar-2017 17:55:38 ET	Download
09-Mar-2017 ET	2017	332	1	TGax	LB225 Comment resolution for CIDs for 28.3.10 HE Preamble	Jianhan Liu (Mediatek Inc.)	09-Mar-2017 17:54:47 ET	Download
09-Mar-2017 ET	2017	309	1	TGax	CIDs on HE Sounding (27-6-2)	Raja Banerjea (Qualcomm)	09-Mar-2017 14:08:48 ET	Download
09-Mar-2017 ET	2017	204	5	TGax	CID for 27.2.3 MU EDCA parameters	laurent cariou (Intel)	09-Mar-2017 12:46:36 ET	Download
09-Mar-2017 ET	2017	250	1	TGax	Various CIDs in 27.5.2	Abhishek Patil (Qualcomm)	09-Mar-2017 07:45:59 ET	Download
08-Mar-2017 ET	2017	370	0	TGax	some CIDs related to 20MHz operation--text	Guoqing Li (Apple)	09-Mar-2017 12:02:41 ET	Download

08-Mar-2017 ET	2017	369	0	TGax	Some CIDs related to 20MHz operation	Guoqing Li (Apple)	09-Mar-2017 12:01:58 ET	Download
08-Mar-2017 ET	2017	204	4	TGax	CID for 27.2.3 MU EDCA parameters	laurent cariou (Intel)	08-Mar-2017 13:25:08 ET	Download
08-Mar-2017 ET	2017	360	0	TGax	LB225 CR for CID5917 and CID8165	Ming Gan (Huawei)	15-Mar-2017 15:40:21 ET	Download
07-Mar-2017 ET	2017	338	0	TGax	CR for 27.5.2.4 - Physical CS CIDs	Rojan Chitrakar (Panasonic)	12-Mar-2017 17:52:18 ET	Download
07-Mar-2017 ET	2017	337	0	TGax	Explanation of CR for CID 8555	Rojan Chitrakar (Panasonic)	10-Mar-2017 12:57:36 ET	Download
07-Mar-2017 ET	2017	336	0	TGax	CR for CID 8555 - Virtual CS during UL MU CS	Rojan Chitrakar (Panasonic)	10-Mar-2017 12:58:35 ET	Download
07-Mar-2017 ET	2017	335	0	TGax	CR for CID 8142 - Random Access acronym	Rojan Chitrakar (Panasonic)	12-Mar-2017 17:57:14 ET	Download
06-Mar-2017 ET	2017	333	0	TGax	LB225 Comment resolution for CIDs for 28.3.13 Non-HT duplicate transmission	Jianhan Liu (Mediatek Inc.)	06-Mar-2017 19:55:27 ET	Download
06-Mar-2017 ET	2017	332	0	TGax	LB225 Comment resolution for CIDs for 28.3.10 HE Preamble	Jianhan Liu (Mediatek Inc.)	06-Mar-2017 19:54:08 ET	Download
06-Mar-2017 ET	2017	331	0	TGax	LB225 Comment resolution for CIDs for 28.3.11.9 Constellation mapping	Jianhan Liu (Mediatek Inc.)	06-Mar-2017 19:52:41 ET	Download
06-Mar-2017 ET	2017	330	0	TGax	LB225 Comment resolution for CIDs for 3 Definitions, acronyms, and abbreviations	Jianhan Liu (Mediatek Inc.)	06-Mar-2017 19:51:00 ET	Download
06-Mar-2017 ET	2017	329	0	TGax	LB225 Comment resolution for CIDs for 28.3.11.5 Coding	Jianhan Liu (Mediatek Inc.)	06-Mar-2017 19:49:24 ET	Download
06-Mar-2017 ET	2017	230	1	TGax	CIDs related to multi-BSSID	Abhishek Patil (Qualcomm)	06-Mar-2017 15:58:46 ET	Download
02-Mar-2017 ET	2017	309	0	TGax	CIDs on HE Sounding (27-6-2)	Raja Banerjea (Qualcomm)	06-Mar-2017 18:24:11 ET	Download
28-Feb-2017 ET	2017	204	3	TGax	CID for 27.2.3 MU EDCA parameters	laurent cariou (Intel)	28-Feb-2017 12:35:05 ET	Download
20-Feb-2017 ET	2017	204	2	TGax	CID for 27.2.3 MU EDCA parameters	laurent cariou (Intel)	20-Feb-2017 13:50:15 ET	Download
16-Feb-2017 ET	2017	204	1	TGax	CID for 27.2.3 MU EDCA parameters	laurent cariou (Intel)	16-Feb-2017 19:20:03 ET	Download
10-Feb-2017 ET	2017	250	0	TGax	Various CIDs in 27.5.2	Abhishek Patil (Qualcomm)	07-Mar-2017 19:32:05 ET	Download
10-Feb-2017 ET	2017	249	0	TGax	CIDs in 27.5.2	Abhishek Patil (Qualcomm)	04-May-2017 01:14:28 ET	Download
09-Feb-2017 ET	2017	230	0	TGax	CIDs related to multi-BSSID	Abhishek Patil (Qualcomm)	02-Mar-2017 20:12:05 ET	Download

09-Feb-2017 ET	2017	229	0	TGax	CIDs related to Random Access	Abhishek Patil (Qualcomm)	09-Mar-2017 12:12:34 ET	Download
30-Jan-2017 ET	2017	204	0	TGax	CID for 27.2.3 MU EDCA parameters	laurent cariou (Intel)	02-Feb-2017 09:57:39 ET	Download
19-Jan-2017 ET	2017	135	6	TGax	CIDs in HE Operation	Abhishek Patil (Qualcomm)	19-Jan-2017 16:05:45 ET	Download
19-Jan-2017 ET	2017	135	5	TGax	CIDs in HE Operation	Abhishek Patil (Qualcomm)	19-Jan-2017 15:50:41 ET	Download
19-Jan-2017 ET	2017	173	0	TGax	CIDs on Signaling for UL HE MU PPDU	John Son (WILUS)	19-Jan-2017 14:03:18 ET	Download
19-Jan-2017 ET	2017	137	2	TGax	CIDs in 9.4.2.222	Abhishek Patil (Qualcomm)	19-Jan-2017 12:17:03 ET	Download
19-Jan-2017 ET	2017	135	4	TGax	CIDs in HE Operation	Abhishek Patil (Qualcomm)	19-Jan-2017 12:16:36 ET	Download
18-Jan-2017 ET	2017	135	3	TGax	CIDs in HE Operation	Abhishek Patil (Qualcomm)	18-Jan-2017 17:31:42 ET	Download
18-Jan-2017 ET	2017	135	2	TGax	CIDs in HE Operation	Abhishek Patil (Qualcomm)	18-Jan-2017 07:18:52 ET	Download
17-Jan-2017 ET	2017	135	1	TGax	CIDs in HE Operation	Abhishek Patil (Qualcomm)	17-Jan-2017 16:34:59 ET	Download
17-Jan-2017 ET	2017	104	1	TGax	Discussion on CR for CID 5066	Dengyu Qiao (Huawei)	17-Jan-2017 10:40:59 ET	Download
17-Jan-2017 ET	2017	114	1	TGax	CID-Trigger frame_Part-1	Lochan Verma (Qualcomm)	17-Jan-2017 10:14:08 ET	Download
17-Jan-2017 ET	2017	140	0	TGax	Various CIDs in clause 6 & 9	Abhishek Patil (Qualcomm)	04-May-2017 01:27:26 ET	Download
17-Jan-2017 ET	2017	138	0	TGax	CIDs in 27.16.2 (part 1)	Abhishek Patil (Qualcomm)	03-Mar-2017 19:42:54 ET	Download
16-Jan-2017 ET	2017	137	1	TGax	CIDs in 9.4.2.222	Abhishek Patil (Qualcomm)	16-Jan-2017 23:06:09 ET	Download
16-Jan-2017 ET	2017	137	0	TGax	CIDs in 9.4.2.222	Abhishek Patil (Qualcomm)	16-Jan-2017 22:40:27 ET	Download
16-Jan-2017 ET	2017	72	2	TGax	CID 6124 Resolution: Remove 2x LTF+08.us GI for UL Transmission	Jianhan Liu (Mediatek Inc.)	16-Jan-2017 18:02:45 ET	Download
16-Jan-2017 ET	2017	135	0	TGax	CIDs in HE Operation	Abhishek Patil (Qualcomm)	16-Jan-2017 23:53:36 ET	Download
16-Jan-2017 ET	2017	114	0	TGax	CID-Trigger frame_Part-1	Lochan Verma (Qualcomm)	16-Jan-2017 16:20:01 ET	Download
16-Jan-2017 ET	2017	99	1	TGax	Additional background for CID 8908	Sigurd Schelstraete (Quantenna)	16-Jan-2017 10:49:36 ET	Download
16-Jan-2017 ET	2017	104	0	TGax	Discussion on CR for CID 5066	Dengyu Qiao (Huawei)	16-Jan-2017 09:24:55 ET	Download
16-Jan-2017 ET	2017	99	0	TGax	Additional background for CID 8908	Sigurd Schelstraete (Quantenna)	16-Jan-2017 09:12:14 ET	Download
15-Jan-2017 ET	2017	72	1	TGax	CID 6124 Resolution: Remove 2x LTF+08.us GI for UL Transmission	Jianhan Liu (Mediatek Inc.)	15-Jan-2017 22:38:14 ET	Download
15-Jan-2017 ET	2017	72	0	TGax	CID 6124 Resolution: Remove 2x LTF+08.us GI for UL Transmission	Jianhan Liu (Mediatek Inc.)	15-Jan-2017 22:36:40 ET	Download
14-Nov-2016 ET	2016	1522	3	TGax	CID 2147 SIGB Encoding	Hongyuan Zhang (Marvell)	14-Nov-2016 14:26:09 ET	Download
10-Nov-2016 ET	2016	1440	4	TGax	Proposed Resolutions to CID 2719	Jing Ma (NICT)	10-Nov-2016 11:58:14 ET	Download

09-Nov-2016 ET	2016	1503	2	TGax	CR HE beacon for CID 991	Yonggang Fang (ZTE TX)	09-Nov-2016 18:54:32 ET	Download
09-Nov-2016 ET	2016	1503	1	TGax	CR HE beacon for CID 991	Yonggang Fang (ZTE TX)	09-Nov-2016 16:46:50 ET	Download
09-Nov-2016 ET	2016	1522	2	TGax	CID 2147 SIGB Encoding	Hongyuan Zhang (Marvell)	09-Nov-2016 14:45:10 ET	Download
09-Nov-2016 ET	2016	1413	8	TGax	CID193 BSS Color Disabled Indication	Abhishek Patil (Qualcomm)	09-Nov-2016 11:15:01 ET	Download
09-Nov-2016 ET	2016	1413	7	TGax	CID193 BSS Color Disabled Indication	Abhishek Patil (Qualcomm)	09-Nov-2016 11:11:58 ET	Download
09-Nov-2016 ET	2016	1413	6	TGax	CID193 BSS Color Disabled Indication	Abhishek Patil (Qualcomm)	09-Nov-2016 10:01:14 ET	Download
09-Nov-2016 ET	2016	1516	1	TGax	Random Access CIDs	Reza Hedayat (Newracom)	09-Nov-2016 09:14:42 ET	Download
08-Nov-2016 ET	2016	1522	1	TGax	CID 2147 SIGB Encoding	Hongyuan Zhang (Marvell)	08-Nov-2016 23:03:50 ET	Download
08-Nov-2016 ET	2016	1522	0	TGax	CID 2147 SIGB Encoding	Hongyuan Zhang (Marvell)	08-Nov-2016 22:57:11 ET	Download
08-Nov-2016 ET	2016	1440	3	TGax	Proposed Resolutions to CID 2719	Jing Ma (NICT)	08-Nov-2016 18:08:57 ET	Download
08-Nov-2016 ET	2016	1516	0	TGax	Random Access CIDs	Reza Hedayat (Newracom)	08-Nov-2016 17:43:33 ET	Download
08-Nov-2016 ET	2016	1415	2	TGax	CID72 BSS Color change mechanism	Abhishek Patil (Qualcomm)	08-Nov-2016 12:47:21 ET	Download
08-Nov-2016 ET	2016	1387	3	TGax	Comment resolution on CID2506 and proposed changes	Jinsoo Choi (LG Electronics)	08-Nov-2016 12:33:38 ET	Download
08-Nov-2016 ET	2016	1440	2	TGax	Proposed Resolutions to CID 2719	Jing Ma (NICT)	08-Nov-2016 11:55:03 ET	Download
08-Nov-2016 ET	2016	1387	2	TGax	Comment resolution on CID2506 and proposed changes	Jinsoo Choi (LG Electronics)	08-Nov-2016 11:41:57 ET	Download
08-Nov-2016 ET	2016	1440	1	TGax	Proposed Resolutions to CID 2719	Jing Ma (NICT)	08-Nov-2016 09:52:08 ET	Download
08-Nov-2016 ET	2016	1503	0	TGax	CR HE beacon for CID 991	Yonggang Fang (ZTE TX)	09-Nov-2016 14:27:46 ET	Download
08-Nov-2016 ET	2016	1387	1	TGax	Comment resolution on CID2506 and proposed changes	Jinsoo Choi (LG Electronics)	08-Nov-2016 08:41:41 ET	Download
07-Nov-2016 ET	2016	1361	1	TGax	CC0-Remaining CIDs on MU Operation	Alfred Asterjadhi (Qualcomm Inc.)	07-Nov-2016 21:43:16 ET	Download
07-Nov-2016 ET	2016	1360	1	TGax	CC0-HE variant HT control - Some Remaining CIDs	Alfred Asterjadhi (Qualcomm Inc.)	07-Nov-2016 18:25:20 ET	Download
07-Nov-2016 ET	2016	1398	1	TGax	CR for CID 2077	Sriram Venkateswaran (Broadcom)	07-Nov-2016 18:22:39 ET	Download
07-Nov-2016 ET	2016	1374	1	TGax	Resoluction on CID495 and Removal of Unnecessary PHY TBDs	Yujin Noh (Newracom)	07-Nov-2016 17:52:42 ET	Download
07-Nov-2016 ET	2016	1375	1	TGax	Commont Resolution for CID2867 and Text Change Proposal of	Yujin Noh (Newracom)	07-Nov-2016 17:51:38 ET	Download

					26.3.10.8 HE-SIG-B			
07-Nov-2016 ET	2016	1413	5	TGax	CID193 BSS Color Disabled Indication	Abhishek Patil (Qualcomm)	07-Nov-2016 11:08:35 ET	Download
07-Nov-2016 ET	2016	1413	4	TGax	CID193 BSS Color Disabled Indication	Abhishek Patil (Qualcomm)	07-Nov-2016 10:46:25 ET	Download
07-Nov-2016 ET	2016	1415	1	TGax	CID72 BSS Color change mechanism	Abhishek Patil (Qualcomm)	07-Nov-2016 10:45:48 ET	Download
06-Nov-2016 ET	2016	1450	0	TGax	CR-for-CID 2492-section-25-9-spatial-reuse-operation	Kaiying Lv (ZTE Corp.)	07-Nov-2016 02:15:41 ET	Download
06-Nov-2016 ET	2016	1440	0	TGax	Proposed Resolutions to CID 2719	Jing Ma (NICT)	07-Nov-2016 09:59:48 ET	Download
06-Nov-2016 ET	2016	1413	3	TGax	CID193 BSS Color Disabled Indication	Abhishek Patil (Qualcomm)	06-Nov-2016 02:04:33 ET	Download
06-Nov-2016 ET	2016	1415	0	TGax	CID72 BSS Color change mechanism	Abhishek Patil (Qualcomm)	06-Nov-2016 01:53:04 ET	Download
06-Nov-2016 ET	2016	1413	2	TGax	CID193 BSS Color Disabled Indication	Abhishek Patil (Qualcomm)	06-Nov-2016 01:36:28 ET	Download
06-Nov-2016 ET	2016	1413	1	TGax	CID193 BSS Color Disabled Indication	Abhishek Patil (Qualcomm)	06-Nov-2016 01:33:15 ET	Download
06-Nov-2016 ET	2016	1413	0	TGax	CID193 BSS Color Disabled Indication	Abhishek Patil (Qualcomm)	06-Nov-2016 01:32:29 ET	Download
05-Nov-2016 ET	2016	1398	0	TGax	CR for CID 2077	Sriram Venkateswaran (Broadcom)	05-Nov-2016 19:30:50 ET	Download
05-Nov-2016 ET	2016	1392	0	TGax	comment-resolution-CID-2624-and-2738	Young Hoon Kwon (Newracom)	06-Nov-2016 20:34:35 ET	Download
05-Nov-2016 ET	2016	1389	0	TGax	Comment Resolution for CID 807	Po-Kai Huang (Intel)	05-Nov-2016 13:28:05 ET	Download
05-Nov-2016 ET	2016	1387	0	TGax	Comment resolution on CID2506 and proposed changes	Jinsoo Choi (LG Electronics)	07-Nov-2016 00:05:20 ET	Download
03-Nov-2016 ET	2016	1375	0	TGax	Commont Resolution for CID2867 and Text Change Proposal of 26.3.10.8 HE-SIG-B	Yujin Noh (Newracom)	06-Nov-2016 23:11:20 ET	Download
03-Nov-2016 ET	2016	1374	0	TGax	Resoluction on CID495 and Removal of Unnecessary PHY TBDs	Yujin Noh (Newracom)	06-Nov-2016 23:11:53 ET	Download
01-Nov-2016 ET	2016	1361	0	TGax	CC0-Remaining CIDs on MU Operation	Alfred Asterjadhi (Qualcomm Inc.)	07-Nov-2016 00:50:28 ET	Download

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APPENDIX AL

Documents

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Everything | All Years | TGax (inactive)

BSS color change

Created (ET) ▼	Year	DCN	Rev	Group	Title	Author (Affiliation)	Uploaded (ET)	Actions
08-Nov-2016 ET	2016	1415	2	TGax	CID72 BSS Color change mechanism	Abhishek Patil (Qualcomm)	08-Nov-2016 12:47:21 ET	Download
07-Nov-2016 ET	2016	1415	1	TGax	CID72 BSS Color change mechanism	Abhishek Patil (Qualcomm)	07-Nov-2016 10:45:48 ET	Download
06-Nov-2016 ET	2016	1415	0	TGax	CID72 BSS Color change mechanism	Abhishek Patil (Qualcomm)	06-Nov-2016 01:53:04 ET	Download

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APPENDIX AM

IEEE P802.11
Wireless LANs

IEEE 802.11 TGax, MAC Ad hoc

November 2016 TGax MAC Ad hoc Meeting Minutes

Date: 2016-11-07

Author(s):

Name	Affiliation	Address	Phone	email
Reza Hedayat	Newracom			reza.hedayat at newracom.com

Abstract

TGax, MAC Ad Hoc meeting minutes from the IEEE 802.11, November 6th – 11th, 2016.

IEEE 802.11 Task Group ax, MAC Ad hoc
November 2016 Meeting, San Antonio, TX
November 6th – 11th, 2016

Monday, November 7th, 2016, PM2 TGax Session (16:00-18:30PM)

1. **The meeting called to order at 16:00pm by Reza Hedayat (Newracom), the co-chair of the TGax MAC Ad hoc**
   1.1. About 65 people are in the room.

2. **Announcement**
   2.1. Agenda Doc.11-16/1478 on the server. Rev. 0 is the working document.
   2.2. Meeting Protocol: The Chair asked to state name and affiliation when speaking for the first time.
   2.3. Attendance reminder.
      2.3.1. The attendance server: https://imat.ieee.org/

3. **The chair reviewed the mandatory 5 slides of P&P.**
   3.1. Instructions from the WG Chair. [reviewed~~, did not review~~]
   3.2. Participants, Patents, and Duty to Inform. [reviewed~~, did not review~~]
   3.3. Patent Related Links. [reviewed~~, did not review~~]
   3.4. Call for potentially essential patents.
      3.4.1. Chair asked if anyone is aware of potentially essential patents
         [Asked. ~~Did not ask~~]
      3.4.2. Potentially essential patents
         [None reported~~. Reported as follows~~]
   3.5. Other Guidelines for IEEE WG Meetings.

4. **The Chair called for presentations**
   4.1. No additional contributions were requested to be added to the list of contributions.

5. **The Chair asked for approval of the agenda**
   5.1. No objection raised

6. **Presentation of contributions**
   6.1. 11-16/1238r0, "Setting Quiet time period - text"
      6.1.1. Presented by Chao-Chun Wang (MediaTek)

   6.2. 11-16/1352r0, "CC23 MAC CR Miscellaneous Part-1"
      6.2.1. Presented by Yongho Seok (Newracom)
      6.2.2. Strawpoll 1:
         6.2.2.1. "Do you agree to add to the 11ax specification D0.5 the comment resolutions in document 16/1352r1 for CIDs: 1920, 2441, 2671, 2262, 2396, 2454, 2604, 2605, 1734, 118, 691, 822, 1353"
         6.2.2.2. Results: Strawpoll passed without objection

   6.3. 11-16/1354r0, "CC23 CR Annex C"

6.3.1. Presented by Yongho Seok (Newracom)
6.3.2. Strawpoll 1:
6.3.2.1. "Do you agree to add to the 11ax specification D0.5 the comment resolutions in document 16/1354r0 for CIDs: 150, 1020, 2201"
6.3.2.2. Results: Strawpoll passed without objection

6.4. 11-16/1355r0, "Spec text for 10.22.2.5 and 3.2"
6.4.1. Presented by Yongho Seok (Newracom)
6.4.2. Strawpoll 1:
6.4.2.1. "Do you agree to update the 11ax specification D0.5 according to the instructions in document 16/1355r0."
6.4.2.2. Results: Strawpoll passed without objection

6.5. 11-16/1358r0, "CC0-Remaining CIDs on BA"
6.5.1. Presented by Alfred Asterjadhi (Qualcomm)
6.5.2. Strawpoll 1:
6.5.2.1. "Do you agree to add to the 11ax specification D0.5 the comment resolutions in document 16/1358r0 for CIDs: 135, 658, 2389"
6.5.2.2. Results: Strawpoll passed without objection

6.6. 11-16/1359r0, "CC0-Some remaining CIDs related to TWT"
6.6.1. Presented by Alfred Asterjadhi (Qualcomm)
6.6.2. Strawpoll 1:
6.6.2.1. "Do you agree to add to the 11ax specification D0.5 the comment resolutions in document 16/1359r0 for CIDs: 385, 419, 458, 459, 514, 630, 741, 743, 2844, 2846"
6.6.2.2. Results: Strawpoll passed without objection

6.7. 11-16/1360r0, "CC0-HE variant HT control - Some Remaining CIDs"
6.7.1. Presented by Alfred Asterjadhi (Qualcomm)
6.7.2. Strawpoll 1:
6.7.2.1. "Do you agree to add to the 11ax specification D0.5 the comment resolutions in document 16/1360r1 for CIDs: 93, 824, 819, 989, 1067, 2388, 147, 161 "
6.7.2.2. Results: Strawpoll passed without objection

6.8. 11-16/1362r1, "CC0-Complete RTS_Enablement"
6.8.1. Presented by Alfred Asterjadhi (Qualcomm)
6.8.2. Strawpoll 1:
6.8.2.1. "Do you agree to update the 11ax specification D0.5 according to the instructions in document 16/1362r1"
6.8.2.2. Results: Strawpoll passed without objection

6.9. 11-16/1367r0, "NDP feedback report"
6.9.1. Presented by Laurent cariou (Intel)
6.9.2. Strawpoll 1:

6.9.2.1. "Do you agree to update the 11ax specification D0.5 according to the instructions in slide 16 of document 16/1367r0."
6.9.2.2. Results: Y/N/A: 29/1/18. Strawpoll passed.

6.10. 11-16/1368r1, "Follow-up on MU EDCA parameters"
6.10.1. Presented by Laurent cariou (Intel)
6.10.2. Strawpoll 1:
6.10.2.1. "Do you agree to update the 11ax specification D0.5 according to the instructions in document 16/1368r2."
6.10.2.2. Results: Strawpoll passed without objection.

Tuesday, November 8th, 2016, AM2 TGax Session (10:30-12:30PM)

1. **The meeting called to order at 10:30am by Reza Hedayat (Newracom), the co-chair of the TGax MAC Ad hoc**
   1.1. About 69 people are in the room.

2. **Announcement**
   2.1. Agenda Doc.11-16/1478 on the server. Rev. 0 is the working document.
   2.2. Meeting Protocol: The Chair asked to state name and affiliation when speaking for the first time.
   2.3. Attendance reminder.
      2.3.1. The attendance server: https://imat.ieee.org/

3. **The chair reviewed the mandatory 5 slides of P&P.**
   3.1. Instructions from the WG Chair. [reviewed~~, did not review~~]
   3.2. Participants, Patents, and Duty to Inform. [reviewed~~, did not review~~]
   3.3. Patent Related Links. [reviewed~~, did not review~~]
   3.4. Call for potentially essential patents.
      3.4.1. Chair asked if anyone is aware of potentially essential patents
         [Asked. ~~Did not ask~~]
      3.4.2. Potentially essential patents
         [None reported~~. Reported as follows~~]
   3.5. Other Guidelines for IEEE WG Meetings.

4. **The Chair called for presentations**
   4.1. No additional contributions were requested to be added to the list of contributions.

5. **The Chair asked for approval of the agenda**
   5.1. No objection raised

6. **Presentation of contributions**

6.1. 11-16/1380r0, "Proposed text changes for TWT in congested environment"
- 6.1.1. Presented by Laurent cariou (Intel)

6.2. 11-16/1381r0, "Proposed text changes for fragmentation operation"
- 6.2.1. Presented by Laurent cariou (Intel)

6.3. 11-16/1404r1, "Early TWT SP Termination in TWT Operation"
- 6.3.1. Presented by Jayh hyunhee Park (LGE)
- 6.3.2. Strawpoll 1:
  - 6.3.2.1. "Do you agree to update the 11ax specification D0.5 according to the instructions in slide 16 of document 16/1404r1"
  - 6.3.2.2. Results: Strawpoll passed without objection.

6.4. 11-16/1413r5, "CID193 BSS Color Disabled Indication"
- 6.4.1. Presented by Abhishek Patil (Qualcomm)

6.5. 11-16/1415r1, "CID72 BSS Color Change mechanism"
- 6.5.1. Presented by Abhishek Patil (Qualcomm)
- 6.5.2. Strawpoll 1:
  - 6.5.2.1. "Do you agree to update the 11ax specification D0.5 according to the instructions in document 16/1415r2 for CID 72."
  - 6.5.2.2. Results: Strawpoll passed without objection.

6.6. 11-16/1409r2, "AMSDU Fragmentation"
- 6.6.1. Presented by Matt Fischer (Broadcom)
- 6.6.2. Strawpoll 1:
  - 6.6.2.1. "Do you agree to update the 11ax specification D0.5 according to the instructions in document 16/1409r3."
  - 6.6.2.2. Results: Strawpoll passed without objection.

6.11. 11-16/1420r0, "TWT Information frames in 11ax"
- 6.11.1. Presented by Alfred Asterjadhi (Qualcomm)
- 6.11.2. Strawpoll 1:
  - 6.11.2.1. "Do you agree to update the 11ax specification D0.5 according to the instructions in slides 8, 9 and 10 in document 16/1420r0"
  - 6.11.2.2. Results: Strawpoll passed without objection

6.7. 11-16/1380r2, "Proposed text changes for TWT in congested environment"
- 6.7.1. Presented by Laurent cariou (Intel)
- 6.7.2. Strawpoll 1:
  - 6.7.2.1. "Do you agree to update the 11ax specification D0.5 according to the instructions in document 16/1380r3"
  - 6.7.2.2. Results: Strawpoll passed without objection

Wednesday, November 9th, 2016, PM1 TGax Session (1:30-3:30PM)

1. **The meeting called to order at 1:30pm by Reza Hedayat (Newracom), the co-chair of the TGax MAC Ad hoc**
   1.1. About 75 people are in the room.

2. **Announcement**
   2.1. Agenda Doc.11-16/1478 on the server. Rev. 1 is the working document.
   2.2. Meeting Protocol: The Chair asked to state name and affiliation when speaking for the first time.
   2.3. Attendance reminder.
      2.3.1. The attendance server: https://imat.ieee.org/

3. **The chair reviewed the mandatory 5 slides of P&P.**
   3.1. Instructions from the WG Chair. [reviewed~~, did not review~~]
   3.2. Participants, Patents, and Duty to Inform. [reviewed~~, did not review~~]
   3.3. Patent Related Links. [reviewed~~, did not review~~]
   3.4. Call for potentially essential patents.
      3.4.1. Chair asked if anyone is aware of potentially essential patents
         [Asked. ~~Did not ask~~]
      3.4.2. Potentially essential patents
         [None reported~~. Reported as follows~~]
   3.5. Other Guidelines for IEEE WG Meetings.

4. **The Chair called for presentations**
   4.1. No additional contributions were requested to be added to the list of contributions.

5. **The Chair asked for approval of the agenda**
   5.1. No objection raised

6. **Presentation of contributions**

6.1. 11-16/1423r0, "NAV Update Rule Considering UL MU Operation"

6.1.1. Presented by Geonjung Ko (Wilus)

6.1.2. Strawpoll 1:

6.1.2.1. "Do you agree to make the change below and include it to the next revision of the TG draft? (Clause 25.2.2 in page 118 of D0.5)

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)

— Either Tthe STA is not solicited an immediate response by the PPDU carrying the frame.(#2905) or the STA is solicited an immediate response by the PPDU carrying the frame but the STA is not able to respond to the frame. "

6.1.2.2. Results: Y/N/A: 7/10/19. Strawpoll failed.

6.2. 11-16/1424r1, "Issue on the CWmax value in MU EDCA"

6.2.1. Presented by Woojin (Wilus)

6.3. 11-16/1425r1, "Clarification on applying MU EDCA parameter set"

6.3.1. Presented by Woojin (Wilus)

6.3.2. Strawpoll 1:

6.3.2.1. "Do you agree to update the 11ax specification D0.5 according to the instructions in slide 6 of document 16/1425r2"

6.3.2.2. Results: Strawpoll passed without objection

6.4. 11-16/1454r0 and 11-16/1452r1, "Multiple BSSID and MU Discussion"

6.4.1. Presented by Liwen Chu (Marvel)

6.4.2. Strawpoll 1:

6.4.2.1. "Do you agree to update the 11ax specification D0.5 according to the instructions document 16/1452r2"

6.4.2.2. Results: Strawpoll passed without objection

6.5. 11-16/1456r0 and 11-16/1453r1, "A-MPDU content discussion"

6.5.1. Presented by Liwen Chu (Marvel)

6.5.2. Strawpoll 1:

6.5.2.1. "Do you agree to update the 11ax specification D0.5 according to the instructions document 16/1453r1"

6.5.2.2. Results: Strawpoll passed without objection

6.8. 11-16/1413r8, "CID193 BSS Color Disabled Indication"

6.8.1. Presented by Abhishek Patil (Qualcomm)

6.8.2. Strawpoll 1:

6.8.2.1. "Do you agree to update the 11ax specification D0.5 according to the instructions document 16/1413r8 for CID 193"

6.8.2.2. Results: Y/N/A: 22/0/13

6.9. 11-16/1381r2, "Proposed text changes for fragmentation operation"

6.9.1. Presented by Laurent cariou (Intel)

6.9.2. Strawpoll 1:

6.9.2.1. "Do you agree to update the 11ax specification D0.5 according to the instructions document 16/1381r2"

6.9.2.2. Results: Strawpoll passed without objection

Wednesday, November 9th, 2016, PM2 TGax Session (4:00-6:00PM)

1. **The meeting called to order at 4:00pm by Reza Hedayat (Newracom), the co-chair of the TGax MAC Ad hoc**

1.1. About 80 people are in the room.

2. **Announcement**

2.1. Agenda Doc.11-16/1478 on the server. Rev. 1 is the working document.

2.2. Meeting Protocol: The Chair asked to state name and affiliation when speaking for the first time.

2.3. Attendance reminder.

2.3.1. The attendance server: https://imat.ieee.org/

3. The chair reviewed the mandatory 5 slides of P&P.

3.1. Instructions from the WG Chair. [reviewed~~, did not review~~]
3.2. Participants, Patents, and Duty to Inform. [reviewed~~, did not review~~]
3.3. Patent Related Links. [reviewed~~, did not review~~]
3.4. Call for potentially essential patents.
3.4.1. Chair asked if anyone is aware of potentially essential patents
[Asked. ~~Did not ask~~]
3.4.2. Potentially essential patents
[None reported~~. Reported as follows~~]
3.5. Other Guidelines for IEEE WG Meetings.

4. The Chair called for presentations

4.1. No additional contributions were requested to be added to the list of contributions.

5. The Chair asked for approval of the agenda

5.1. No objection raised

6. **Presentation of contributions**

11-16/1458r0, "Comment Resolution for Sub-clause 25.13.2"

1.1.1. Presented by Chittabrata Ghosh (Intel)
1.1.2. Strawpoll 1:
1.1.2.1. "Do you agree to add to the 11ax specification D0.5 the comment resolutions in document 16/1458r0 for CIDs: 195, 723, 779, 780, 1087, 1088, 2179, 2387, 2672, 2673, and 2674"
1.1.2.2. Results: Strawpoll passed without objection

Eric Wong (Apple) is the chair during the following two contributions.

11-16/1461r0, "MU BAR comment resolutions"

1.1.1. Presented by Reza Hedayat(Newracom)
1.1.2. Strawpoll 1:
1.1.2.1. "Do you agree to add to the 11ax specification D0.5 the comment resolutions in document 16/1461r1 for CIDs: 6 and 7"
1.1.2.2. Results: Strawpoll passed without objection

11-16/1503r0, "CR for CID 991"

1.1.1. Presented by Kying(ZTE)

Reza Hedayat (Newracom) is chair during the following contributions.

11-16/1357r0 and 16/1529r0, "CC0 Remaining CIDs on sounding"

1.1.1. Presented by Alfred(Qualcomm)

1.1.2. Strawpoll 1:
1.1.2.1. "Do you agree to add to the 11ax specification D0.5 the comment resolutions in document 16/1357r0 for CIDs: 969, 1517, 1558, 1560, 1917, 2180"
1.1.2.2. Results: Strawpoll passed without objection

1.1.3. Strawpoll 2:
1.1.3.1. "Do you support to instruct the TGax editor to remove the sentence below from IEEE802.11ax D0.5 in clause 9.3.1.23
The exact location of each 20 MHz for 80 MHz BW is TBD."
1.1.3.2. Results: Strawpoll passed without objection

1.1.4. Strawpoll 3:
1.1.4.1. "Do you support to instruct the TGax Editor to make the following changes (related to HE Link adaptation A-Control format):
- Replace "TBD" with "16" in P17L21 of TGax D0.5
- Replace "TBD" with "Reserved" in P19L8 of TGax D0.5
- Replace "B6+X" with "B15" in P19L6 of TGax D0.5
- Replace "X" with "9" in P19L6 of TGax D0.5"
1.1.4.2. Results: Strawpoll passed without objection

1.1.5. Strawpoll 4:
1.1.5.1. "Do you support to instruct the TGax Editor to make the following changes as shown in 16/1529r0"
1.1.5.2. Results: Strawpoll passed without objection

11-16/1477r1, "CC23-PR-TWT"
1.1.1. Presented by Matt Fischer(Broadcom)
1.1.2. Strawpoll 1:
1.1.2.1. "Do you agree to add to the 11ax specification D0.5 the comment resolutions in document 16/1477r2 for CID 682"
1.1.2.2. Results: Strawpoll passed without objection

6.6. 11-16/1424r2, "Issue on the CWmax value in MU EDCA"
6.6.1. Presented by Woojin (Wilus)
6.6.2. Strawpoll 1: Do you support to instruct the TGax Editor to make the following changes as shown in slide 6 of document 16/1424r2
6.6.3. Results: Strawpoll passed without objection

6.7. 11-16/1503r0, "CR for CID 991"
1.1.1. Presented by Kying(ZTE)
1.1.3. Strawpoll 1:
1.1.3.1. "Do you agree to add to the 11ax specification D0.5 the comment resolutions in document 16/1503r2 for CID 991"
1.1.3.2. Results: Strawpoll passed without objection

APPENDIX AN

12-Jun-2025 13:10:44 ET

Documents

Join group

Everything | All Years | TGax (inactive)

230

Created (ET) ▼	Year	DCN	Rev	Group	Title	Author (Affiliation)	Uploaded (ET)	Actions
16-Jan-2018 ET	2018	230	0	TGax	PHY-Misc-CR-Follow-up	Ross Jian Yu (Huawei Technologies)	17-Jan-2018 20:54:29 ET	Download
06-Mar-2017 ET	2017	230	1	TGax	CIDs related to multi-BSSID	Abhishek Patil (Qualcomm)	06-Mar-2017 15:58:46 ET	Download
09-Feb-2017 ET	2017	230	0	TGax	CIDs related to multi-BSSID	Abhishek Patil (Qualcomm)	02-Mar-2017 20:12:05 ET	Download

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APPENDIX AO

IEEE P802.11
Wireless LANs

Proposed resolution for comments related to Multiple BSSID set

Date: 2025-06-30

Author(s):				
Name	**Affiliation**	**Address**	**Phone**	**email**
Abhishek Patil	Qualcomm Inc.			appatil@qti.qualcomm.com
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George Cherian	Qualcomm Inc.			gcherian@qti.qualcomm.com
Raja Banerjea	Qualcomm Inc.			rajab@qca.qualcomm.com

Abstract

This submission proposes resolutions for multiple comments related to TGax D1.0 with the following CIDs (31):

- 3060, 3061, 9444, 5175, 3062, 3071, 5708, 5709, 5710, 9709, 5711, 7177, 3072, 4817, 3136, 9821, 3075, 7552, 7972, 8533, 5455, 7163, 7164, 9378, 7165, 7841, 7169, 9379, 7146, 8280, 8292

Revisions:

- Rev 0: Initial version of the document.
- Rev 1: Revised based on offline feedback.
  - Moved the rules for STA selection for multi-BSS trigger before the rules for setting the TA field in the trigger frame.
  - Revised text for rules related to setting the TA field for single or multi-BSS case.

Interpretation of a Motion to Adopt

A motion to approve this submission means that the editing instructions and any changed or added material are actioned in the TGax Draft. This introduction is not part of the adopted material.

Editing instructions formatted like this are intended to be copied into the TGax Draft (i.e. they are instructions to the 802.11 editor on how to merge the text with the baseline documents).

TGax Editor: Editing instructions preceded by "TGax Editor" are instructions to the TGax editor to modify existing material in the TGax draft. As a result of adopting the changes, the TGax editor will execute the instructions rather than copy them to the TGax Draft.

CID	Commenter	Section	Pg / Ln	Comment	Proposed Change	Resolution
3060	Abhishek Patil	27.4.1	158.11	Current sentence is convoluted. Simplify it.	Change sentence to: "If an HE AP does not receive an HE Capabilities element with the Rx Control Frame To MultiBSS set to 1 from a STA, then the HE AP shall not send a Multi-STA Block Ack frame to the STA if the frame is destined for STAs associated with more than one AP that are part of the same multiple BSSID set."	Revised Agree with the comment. The sentence is updated to correctly capture the desired meaning. TGax editor please make the changes as shown in 11-17/0230r1
9444	Xiaofei Wang	27.4.1	158.11	The sentence "If an HE AP does not receive an HE Capabilities element with the Rx Control Frame To MultiBSS set to 1 from a STA, then the HE AP shall not send a Multi-STA Block Ack frame whose destination STAs associate with more than one APs to the STA." is not clear and very confusing; not sure which normative behavior it is describing.	Please clarify and rephrase the sentence so that it is clear which normative behavior it is describing.	Revised Agree with the comment. The sentence is updated to correctly capture the desired meaning. TGax editor please make the changes as shown in 11-17/0230r1
5175	Dorothy Stanley	27.4.1	158.15	I don't think a STA associates with a BSSID. Change "An HE non-AP STA that is associated with a nontransmitted BSSID" should be "An HE non-AP STA that is associated with BSS with a nontransmitted BSSID". Then fix the end of the sentence as well, change to "whose RA is set either to the (nontransmitted) BSSID of the BSS it is associated with"	as in comment	Revised Agree with the comment. Updated text to indicate STA is associated with an AP that corresponds to nontransmitted BSSID and the RA set to (nontransmitted) BSSID of the BSS. TGax editor please make the changes as shown in 11-17/0230r1
3062	Abhishek Patil	27.4.1	158.17	The condition in following sentence is not complete: "An HE non-AP STA that is associated with a nontransmitted BSSID and has indicated support for receiving Control frames with TA set to the Transmitted BSSID (Rx Control Frame To MultiBSS set to 1 in HE Capabilities element).."	Suggest to modify as follows: "An HE non-AP STA that is associated with a nontransmitted BSSID and has indicated support for receiving Control frames receives Control frames from a multi-BSS AP with TA set to the Transmitted BSSID (Rx Control Frame To MultiBSS set to 1 in HE Capabilities element).."	Revised Agree with the comment The sentence is updated to correctly capture the desired meaning. TGax editor please make the changes as shown in 11-17/0230r1
3072	Abhishek Patil	27.5.2.2.2	165.60	Current sentence is convoluted. Simplify it.	Change sentence to: "If an HE AP does not receive an HE Capabilities element with the Rx Control Frame To MultiBSS field equal to 1 from a STA, then the HE AP shall not send the Trigger frame to the STA if the frame is destined for STAs associated with more than one AP that are part of the same multiple BSSID set."	Revised Agree with the comment. The sentence is updated to correctly capture the desired meaning. Also moved the sentence before the paragraph that describes the rules for setting the TA field of the Trigger frame. TGax editor please make the changes as shown in 11-17/0230r1
4817	Alfred Asterjadhi	27.5.2.2.2	165.60	confusing construction of the sentence "If an HE AP does not receive an HE Capabilities element with the Rx Control	Reword the sentence	Revised Agree with the comment. The sentence is updated to correctly capture the desired

				Frame To MultiBSS field equal to 1 from a STA, the HE AP shall not send a Trigger frame whose destination STAs associate with more than one APs to the STA."		meaning. Also moved the sentence before the paragraph that describes the rules for setting the TA field of the Trigger frame. TGax editor please make the changes as shown in 11-17/0230r1
5708	Guoqing Li	27.5.2.2.2	165.47	Why both false and true conditions are in the sentence? I think only this sentence is for the case when dot11MultiBSSIDactivated is false.	remove "when dot11MultiBSSIDactivated is false"	Revised Agree with the comment. The bullet is confusing because it captures the true and false case. However, the true case had an exception that the trigger frame was meant for a single BSS (although the AP was a member of a multiple BSSID set). Revised the entire paragraph to simplify the sentence and clarify the case of Trigger frame directed to STAs from multiple BSSs or single BSS (even when dot11MultiBSSIDActivated is set to true). TGax editor please make the changes as shown in 11-17/0230r1
3071	Abhishek Patil	27.5.2.2.2	165.50	Incorrect field reference. Also, the sentence needs to be simplified.	Change the sentence to: "The MAC address of the transmitted BSSID when dot11MultiBSSIDActivated is true and the Trigger frame is destined for STAs associated with more than one AP that are part of the same multiple BSSID set and have indicated support to received such frames via the Rx Control Frame to MultiBSS field in HE Capabilities element."	Revised Agree with the comment. The sentence is revised correctly capture the desired meaning. Also see resolution to CID 5708 TGax editor please make the changes as shown in 11-17/0230r1
5709	Guoqing Li	27.5.2.2.2	165.51	"intend to communciate" is not an accurate wording. A more suitable word is "is capable of communicating"	"intend to"-->"is capable of communicating"	Revised Agree with the comment. The sentence is updated to correctly capture the desired meaning. “intend to” has been replaced with “from at least two BSSs”. Also see resolution to CID 5708 TGax editor please make the changes as shown in 11-17/0230r1
5710	Guoqing Li	27.5.2.2.2	165.54	There is no field called "multiple BSSUD support field". I think this refers to the "RX Control Frame to MultipleBSS" field in HE Capabilties Element.	change the terminology to be consistent	Revised Agree with the comment. The sentence is updated to refer to the correct subfield. Also see resolution to CID 5708 TGax editor please make the changes as shown in 11-17/0230r1
9709	Yongho Seok	27.5.2.2.2	165.53	"...that have indicated reception support for this Trigger frame in the Multiple BSSID Control Support field of the HE Capabilities element it transmits..." The Multiple BSSID Control Support field is not defined. Replace "Multiple BSSID Control Support" with "Rx Control Frame To MultiBSS".	As per comment.	Revised Agree with the comment. The sentence is updated to refer to the correct subfield. Also see resolution to CID 5708 TGax editor please make the changes as shown in 11-17/0230r1
5711	Guoqing Li	27.5.2.2.2	165.54	What is the meaning of "RX Control Frame to MultiBSS"? Is it capable to receive trigger frame destined to more than one BSS or it's the capability of the STA assocaited with non transmitted BSS to be able to receive frame with TA=transmitted BSSID?	Clarify	Revised It means both – a STA associated with a non transmitted BSS may be triggered by its own AP in which case the TA is the BSSID of the BSS the STA is associated with or the STA may be listed in a trigger frame which is intended for STAs that are associated with more than one BSSIDs of

						the multiple BSSID set. TA=transmitted BSSID serves as an address that indicated that the trigger frame is intended for the latter purpose. A STA indicates whether it supports receiving such multi-BSS trigger via the field in HE Capabilities element. The text in this section has been updated to clarify the meaning. Also see resolution to CID 5708 TGax editor please make the changes as shown in 11-17/0230r1
7177	kaiying Lv	27.5.2.2.2	165.51	It is not clear to say "STAs that intend to communicate with at least two different BSSs of the multiple BSSID set "?	Change to "The MAC address of the transmitted BSSID when dot11MultiBSSIDActivated is true and the Trigger frame is directed to STAs from at least two different BSSs of the multiple BSSID set"	Revised Agree with the comment. The sentence is revised to clearly state the two cases. Also see resolution to CID 5708 TGax editor please make the changes as shown in 11-17/0230r1
3163	Ahmadreza Hedayat	9.3.1.23	41.65	Looks like this sentence needs more description for the case of a multi-BSSID AP: "The TA field value is the address of the STA transmitting the Trigger frame."	Describe what address a multi-BSSID AP shall set this value to when the AP addresses STAs from one/several BSS	Revised Agree with the comment. Add new text to capture the case of AP belonging to single and multiple BSSID. TGax editor please make the changes as shown in 11-17/0230r1
9821	Young Hoon Kwon	9.3.1.23	41.65	Clarification is need on how to set TA field in case multiple BSSID is supported. Especially for the case that the Trigger frame schedules STAs in different virtual APs under the same physical AP.	As in the comment.	Revised Agree with the comment. Add new text to capture the case of AP belonging to single and multiple BSSID. TGax editor please make the changes as shown in 11-17/0230r1
3075	Abhishek Patil	27.6.2	176.20	Current sentence is convoluted. Simplify it.	Change sentence to: "If an HE AP does not receive an HE Capabilities element with the Rx Control Frame To MultiBSS subfield in the HE MAC Capabilities Information field equal to 1 from a STA, then the HE AP shall not send the NDP Announcement frame to the STA if the frame is destined for STAs associated with more than one AP that are part of the same multiple BSSID set."	Revised Agree with the comment. The sentence is updated to correctly capture the desired meaning. TGax editor please make the changes as shown in 11-17/0230r1
7972	Mark RISON	27.6.2	176.21	"If an HE AP does not receive an HE Capabilities element with the Rx Control Frame To MultiBSS subfield in the HE MAC Capabilities Information field equal to 1 from a STA, the HE AP shall not send a NDP Announcement frame whose destination STAs associate with more than one APs to the STA." is not clear ("APs to the STA" is especially confusing, as is "associate with more than one AP"). Also wrong pronoun before "NDP" and plurality for "APs"	Change to "If an HE AP does not receive from a STA an HE Capabilities element with the Rx Control Frame To MultiBSS subfield in the HE MAC Capabilities Information field equal to 1, the HE AP shall not send to the STA an NDP Announcement frame whose destination STAs are associated with more than one BSS."	Revised Agree with the comment. The sentence is updated as suggested to simplify it and correctly capture the desired meaning. TGax editor please make the changes as shown in 11-17/0230r1
7552	Liwen Chu	27.6.2	176.23	Remove "to the STA" from the sentence	As in comment	Revised The text “to the STA” is required since it referring to the STA that the AP is transmitting the frame to. The text was revised to simplify the sentence and correctly capture the desired meaning.