IEEE P802.11
Wireless LANs

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| **Specification Framework for TGbe** |
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Abstract

This document provides the framework from which the draft TGbe amendment will be developed. The document provides an outline of each the functional blocks that will be a part of the final amendment. The document is intended to reflect the working consensus of the group on the broad outline for the draft specification. As such it is expected to begin with minimal detail reflecting agreement on specific techniques and highlighting areas on which agreement is still required. It may also begin with an incomplete feature list with additional features added as they are justified. The document will evolve over time until it includes sufficient detail on all the functional blocks and their inter-dependencies so that work can begin on the draft amendment itself.

# Revision history

|  |  |  |
| --- | --- | --- |
| Revision | Date | Changes |
| 0 | July 15, 2019 | Initial draft version for task group review |
| 1 | July 18, 2019 | Revised draft version based on the inputs from task group members |
| 2 | July 18, 2019 | Further revised draft version based on the inputs from task group members |
| 3 | October 9, 2019 | Incorporated motions 1, 6, 10, and 11 approved in the September 2019 interim. |
| 4 | October 9, 2019 | Incorporated motion 9 approved in the September 2019 interim. |
| 5 | November 17, 2019 | Incorporated motions 14-38, 40-49 approved in the November 2019 plenary. |
| 6 | November 27, 2019 | Further revised draft version based on [the input from a task group member](http://www.ieee802.org/11/email/stds-802-11-tgbe/msg00322.html). |
| 7 | January 26, 2020 | Incorporated motions 50-63, 65-76, and 78-110 approved in the January 2020 interim. |
| 8 | February 11, 2020 | Move motions 91 and 92 from Section 2.4.5 to Section 2.3 based on [an input from a task group member](http://www.ieee802.org/11/email/stds-802-11-tgbe/msg00478.html). |
| 9 | May 6, 2020 | Update the reference of Motion 71 to the contribution 19/1822r4.Update the reference of Motion 75 to the contribution 20/0117r1.Replace “GLK” with “GTK” in Section 1. |
| 10 | June 17, 2020 | Incorporated motions 111-114 approved on June 11, 2020. |

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# Abbreviations and acronyms

BIGTK beacon integrity group temporal key

BPSK binary phase shift keying

BU bufferable unit

BSS basic service set

BW bandwidth

CCA clear channel assessment

DL downlink

DS distribution system

EHT extremely high throughput

EP emergency preparedness

GTK group temporal key

HE high efficiency

IGTK integrity group temporal key

LLC logical link control

L-LTF Non-HT Long Training field

L-SIG Non-HT SIGNAL field

L-STF Non-HT Short Training field

LTF long training field

MAC medium access protocol

MCS modulation and coding scheme

MLD multi-link device

MU multi-user

MU-MIMO multi-user multiple input, multiple output

NDP null data PPDU

NS national security

OFDM orthogonal frequency division multiplexing

PHY physical layer

PN packet number

PPDU PHY protocol data unit

PSDU PHY service data unit

RA receiver address

RL-SIG Repeated Non-HT SIGNAL field

RU resource unit

RX receive or receiver

SAP service access point

STA station

SU single user

SU-MIMO single user multiple input, multiple output

TA transmitter address

TID traffic identifier

TX transmit or transmitter

TXOP transmission opportunity

UL Uplink

U-SIG Universal SIGNAL field

WM wireless medium

# EHT PHY

1.
2.

## General

This section describes the functional blocks in the EHT PHY.

## Channelization and tone plan

### Wideband and noncontiguous spectrum utilization

802.11be supports 320 MHz and 160+160 MHz PPDU.

[Motion 10, [1] and [2]]

802.11be supports 240 MHz and 160+80 MHz transmission.

* Whether 240/160+80 MHz is formed by 80 MHz channel puncturing of 320/160+160 MHz is TBD.

[Motion 16, [3] and [4]]

240/160+80 MHz bandwidth is constructed from three 80 MHz channels which include primary 80 MHz.

[Motion 17, [3] and [5]]

802.11be reuses 802.11ax tone plan for 20/40/80/160/80+80 MHz PPDU.

For 320 MHz and 160+160 MHz PPDU, 802.11be uses duplicated HE160 for OFDMA tone plan.

[Motion 33, [3] and [6]]

***Editor’s note: This motion is expected to be updated because of Motion 112, #SP42.***

802.11be 240/160+80 MHz transmission consists of 3x80 MHz segments while the tone plan of each 80 MHz segment is the same as HE80 in 802.11ax.

[Motion 35, [3] and [6]]

***Editor’s note: This motion is expected to be updated because of Motion 112, #SP42.***

802.11be supports the following toneplan for 802.11be 80 MHz OFDMA.

* 80 MHz OFDMA = 40 MHz DUP, Table 27-8 in 802.11ax D6.0 right/left shifted by 256 tones.



Figure 1 – Tone plan for 80 MHz OFDMA

* Note
	+ The 80MHz OFDMA design applies to any RU < 996 for all modes of transmission, SU, DL MU, TB PPDU, with and without puncturing.
	+ Non-OFDMA full BW 80 MHz segment uses 996 RU design.
	+ Any punctured 80 MHz segment uses the OFDMA tone plan.
	+ For each 80MHz segment in 160 MHz, 240 MHz or 320 MHz: if it is punctured or used for OFDMA the 80 MHz OFDMA tone plan is used, if it’s used for non-OFDMA and non-punctured the 996 RU tone plan is used.

[Motion 112, #SP42, [7] and [8]]

In 160+80 MHz BSS, the 160 MHz and 80 MHz should be non-adjacent.

[Motion 111, #SP0611-01, [7] and [9]]

A 160 MHz tone plan is duplicated for the non-OFDMA tone plan of 320/160+160 MHz PPDU.

* The 160 MHz tone plan is TBD.

[Motion 18, [3] and [10]]

The 802.11be 320/160+160 MHz non-OFDMA tone plan uses duplicated tone plan of HE160.

NOTE – Puncturing design TBD.

[Motion 34, [3] and [6]]

***Editor’s note: This motion is expected to be updated because of Motion 112, #SP42.***

12 and 11 null tones are placed at the left and right edges in each 160 MHz segment for the non-OFDMA tone plan of 320/160+160 MHz PPDU.

[Motion 19, [3] and [10]]

802.11be uses the same subcarrier spacing for the data portion of EHT PPDU as 802.11ax data portion.

[Motion 11, [1] and [2]]

### Support for large bandwidth

EHT defines frequency domain aggregation of aggregated PPDUs. Aggregated PPDU consists of multiple PPDUs.

* The PPDU format combination limits to EHT and HE.
* Other combinations are TBD.
* For the PPDU using HE format, the PPDU BW TBD.
* The number of PPDUs is TBD.
* A-PPDU will be R2 feature.

[Motion 112, #SP48, [7] and [11]]

## Resource unit

### Single RU

For a single RU less than or equal to 242 tones (i.e., RU26, RU52, RU106, RU242), the BCC can be supported.

* Mandatory or Optional for BCC, TBD.
* Only for modulation up to 256 QAM (with or without DCM – if defined in 802.11be).
* Only for NSS <=4.

[Motion 112, #SP13, [7] and [12]]

### Multiple RU

#### **General**

802.11be shall allow more than one RUs to be assigned to a single STA.

Coding and interleaving schemes for multiple RUs assigned to a single STA are TBD.

Maximum number of RUs (>1) assigned to a single STA is also TBD.

[Motion 6, [1] and [13]]

Small-size RUs can only be combined with small-size RUs and large-size RUs can only be combined with large-size RUs.

RUs with equal to or more than 242 tones are defined as large-size RUs.

RUs with less than 242 tones are defined as small-size RUs.

[Motion 76, [14] and [15]]

In 802.11be, there is only one PSDU per STA for each link.

[Motion 91, [14] and [16]]

#### **Coding**

In 802.11be, for LDPC encoding each PSDU only uses one encoder.

[Motion 92, [14] and [16]]

For the combined multiple RU with the combined RU size less than 242 tones, the BCC can be supported.

* Mandatory or Optional for BCC, TBD.
* Only for modulation up to 256 QAM (with or without DCM – if defined in 802.11be).
* Only for NSS <=4.

[Motion 112, #SP12, [7] and [12]]

In case of small size MRU transmission, 802.11be supports applying a common BCC encoder and joint bit Interleaver for the combined RU.

[Motion 112, #SP14, [7] and [12]]

#### **Small-size RUs**

Combination of small-size RUs shall not cross 20 MHz channel boundary.

* The combination that includes RU106 plus center 26-tone RU case is TBD.

[Motion 69, [14] and [15]]

Only allowed small-size RU combinations are RU106+RU26 and RU52+RU26.

[Motion 78, [14] and [15]]

For 20 MHz and 40 MHz PPDU, within 20 MHz boundary, any contiguous RU26 and RU106 can be combined.

[Motion 79, [14] and [15]]

For 20 MHz and 40 MHz PPDU, the blue colored combination of RU52 and RU26 are allowed.



Figure 2 – Allowed combination of RU52+RU26 for 20 MHz and 40 MHz PPDU

[Motion 80, [14] and [15]]

For 80 MHz PPDU, the blue colored combination of RU52 and RU26 are allowed.



Figure 3 – Allowed combination of RU52+RU26 for 80 MHz PPDU

[Motion 81, [14] and [15]]

802.11be supports the following RU106+RU26 combinations as shown in orange for each 80 MHz segment in 80, 160, 240, and 320 MHz BW.



Figure 4 – Allowed combination of RU106+RU26 for each 80 MHz segment in 80, 160, 240, and 320 MHz bandwidth

[Motion 112, #SP21, [7] and [17]]

For LDPC coding, for combined RUs sent to a user with RU size less than 242-tone, a single tone mapper shall be used.

[Motion 82, [14] and [18]]

#### **Large-size RUs**

For the OFDMA transmission in 320/160+160 MHz, for one STA large size RU aggregation is allowed only within primary 160 MHz or secondary 160 MHz, respectively.

* Note that primary 160 MHz is composed of primary 80 MHz and secondary 80 MHz and secondary 160 MHz is 160 MHz channel other than the primary 160 MHz in 320/160+160 MHz.

Exception: 3×996 is supported.

3×996+484 RU combinations is TBD.

[Motion 87, [14] and [19]]

For the OFDMA transmission in contiguous 240 MHz, for one STA large size RU aggregation is allowed only within 160 MHz which is composed of two adjacent 80 MHz channels.

For the OFDMA transmission in noncontiguous 160+80 MHz, for one STA large size RU aggregation is allowed only within contiguous 160 MHz or the other 80 MHz, respectively.

2×996+484 RU combinations is TBD.

[Motion 86, [14] and [19]]

In 160 MHz OFDMA the following large RU combinations are supported.

|  |  |  |
| --- | --- | --- |
| **RU size** | **Aggregate BW** | **Notes** |
| 484 + 996 | 120 MHz | 4 options |

[Motion 98, [14] and [20]]

In 80 MHz OFDMA the following large RU combinations are supported.

|  |  |  |
| --- | --- | --- |
| **RU size** | **Aggregate BW** | **Notes** |
| 484 + 242 | 60 MHz | 4 options |

[Motion 97, [14] and [20]]

In 80 MHz non-OFDMA the following conditional mandatory (conditional on supporting puncturing) large RU combinations are supported.

* Any one of four 242 RUs can be punctured.

|  |  |  |
| --- | --- | --- |
| **RU size** | **Aggregate BW** | **Notes** |
| 484 + 242 | 60 MHz | 4 options |

[Motion 93, [14] and [20]]

In 160 MHz non-OFDMA the following conditional mandatory (conditional on supporting puncturing) large RU combinations are supported.

* Any one of eight 242 RUs can be punctured.
* Any one of four 484 RUs can be punctured.

|  |  |  |  |
| --- | --- | --- | --- |
| **80 MHz RU Size** | **80 MHz RU size** | **Aggregate BW** | **Notes** |
| 484 | 996 | 120 MHz | 4 options |
| 484 + 242 | 996 | 140 MHz | 8 options |

[Motion 94, [14] and [20]]

In 240 MHz non-OFDMA the following conditional mandatory (conditional on supporting puncturing) large RU combinations are supported.

* Any one of six 484 RUs can be punctured.
* Any one of three 996 RUs can be punctured.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **80 MHz RU size** | **80 MHz RU size** | **80 MHz RU size** | **Aggregate BW** | **Notes** |
| 484 | 996 | 996 | 200 MHz  | 6 options |
| - | 996 | 996 | 160 MHz  | 3 options |

[Motion 95, [14] and [20]]

In 320 MHz non-OFDMA the following conditional mandatory (conditional on supporting puncturing) large RU combinations are supported.

* Any one of eight 484 RUs can be punctured.
* Any one of four 996 RUs can be punctured.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **80 MHz** **RU size** | **80 MHz** **RU size** | **80 MHz** **RU size** | **80 MHz** **RU size** | **Aggregate BW** | **Notes** |
| 484 | 996 | 996 | 996 | 280 MHz | 8 options |
| - | 996 | 996 | 996 | 240 MHz | 4 options |

[Motion 96, [14] and [20]]

### Interleaving for RUs and aggregated RUs

802.11be supports joint interleaving for BCC and joint tone mapper for LDPC for RU and aggregated RU size <= 80 MHz.

[Motion 111, #SP0611-02, [7] and [21]]

The segment parser bit distribution sequence starts from the lowest frequency location to the highest frequency, just like in 802.11ac/802.11ax.

[Motion 111, #SP0611-03, [7] and [21]]

802.11be supports the following LDPC tone mapper parameters:

* for RU52+RU26: D\_TM = 4
* for RU106+RU26: D\_TM = 6
* Existing RUs: identical to 802.11ax

[Motion 111, #SP0611-04, [7] and [21]]

802.11be supports the following LDPC tone mapper parameters:

* for RU484+RU242: D\_TM = 18

[Motion 111, #SP0611-05, [7] and [21]]

For aggregated RUs and PPDU BW larger than 80 MHz, a separate LDPC tone mapper is applied in each 80 MHz segment.

[Motion 111, #SP0611-06, [7] and [22]]

802.11be uses 80 MHz segment parser with proportional round robin scheme.

[Motion 111, #SP0611-07, [7], [22], and [23]]

802.11be uses 80 MHz segment parser with the following parameters for the proportional round robin scheme:

|  |  |  |  |
| --- | --- | --- | --- |
| **RU Aggregation** | **Nsd\_total** | **Proportional Ratio (m1:m2:m3:m4)** | **Leftover bits (per symbol)** |
| 484+996 | 1448 | 1s:2s | 44\*Nbpscs on ru996 |
| 484+2\*996 | 2428 | 1s:2s:2s | 44\*Nbpscs on ru996 |
| 484+3\*996 | 3408 | 1s:2s:2s:2s | 44\*Nbpscs on ru996 |
| 2\*996 | 1960 | 1s:1s | 0 |
| 3\*996 | 2940 | 1s:1s:1s | 0 |
| 4\*996 | 3920 | 1s:1s:1s:1s | 0 |

where $s=max\left(1, \frac{N\_{BPSCS}}{2}\right) $

[Motion 111, #SP2, [7] and [24]]

The same proportional round robin is applied to left-over bits

* The same ratios are used in the entire segment parsing process except the ratios of those already filled segment becomes 0.

Leftover bits

To 1st RU

To 2nd RU

Figure 5 – Proportional round robin parser

[Motion 111, #SP3, [7] and [24]]

## EHT preamble

### L-STF, L-LTF, L-SIG, and RL-SIG

For EHT PPDU, L-STF, L-LTF and L-SIG shall be transmitted at the beginning of the EHT PPDU.

For EHT PPDU, the first symbol after L-SIG shall be BPSK modulated.

[Motion 1, [1] and [25]]

The LENGTH field in L-SIG set to a value *N* such that mod(*N*, 3) = 0.

[Motion 29, [3] and [1]]

Phase rotation is applied to the legacy preamble part of EHT PPDU.

Coefficients applied to each 20 MHz channel are TBD.

Application to the other fields is TBD.

[Motion 41, [3] and [27]]

Phase rotation is applied to legacy preamble, RL-SIG, U-SIG and EHT-SIG in EHT PPDU.

[Motion 112, #SP30, [7] and [28]]

802.11be reuses the phase rotation sequence defined in 802.11ax for 20/40/80/160/80+80 MHz PPDU.

[Motion 112, #SP31, [7] and [28]]

EHT PPDU shall have a RL-SIG field, which is a repeat of the L-SIG field, immediately following the L-SIG field.

[Motion 49, [3] and [29]]

The extra 4 subcarriers are applied to L-SIG and RL-SIG.

The indices for extra subcarriers are [-28, -27, 27, 28].

The extra subcarriers are BPSK modulated.

The coefficients [-1 -1 -1 1] as in 802.11ax are mapped to the extra subcarriers.

[Motion 107, [14] and [30]]

A PPDU that is sent to multiple user is configured as follows:

* L-STF, L-LTF, L-SIG, RL-SIG, U-SIG, EHT-SIG, EHT-STF, EHT-LTF, DATA.
* Additional fields are TBD.



[Motion 111, #SP0611-08, [7] and [30]]

EHT TB PPDU format is configured as follows:

* EHT TB PPDU consist of L-STF, L-LTF, L-SIG, RL-SIG, U-SIG, EHT-STF, EHT-LTF, DATA.
* Additional fields are TBD.



[Motion 111, #SP0611-09, [7] and [30]]

The EHT PPDU sent to a single user has the EHT-SIG field.

* A subfield that indicates preamble puncturing pattern can be present in the U-SIG and/or EHT-SIG field.

[Motion 112, #SP39, [7] and [31]]

### U-SIG

There shall be a 2 OFDM symbol long, jointly encoded U-SIG in the EHT preamble immediately after the RL-SIG.

* The U-SIG will contain version independent fields. The intent of the version independent content is to achieve better coexistence among future 802.11 generations.
* In addition, the U-SIG can have some version dependent fields.
* The size of the U-SIG for the case of an Extended Range Mode (if such a mode were to be adopted) is TBD.
* The U-SIG will be sent using 52 data tones and 4 pilot tones per-20MHz.

[Motion 27, [3] and [32]]

The U-SIG is modulated in the same way as the HE-SIG-A field of 802.11ax.

* Extended range SU mode is TBD.

[Motion 45, [3] and [33]]

The U-SIG includes Version-independent bits followed by Version-dependent bits.



Figure 6 – U-SIG

* Version-independent bits have static location and bit definition across different generations/PHY versions.
* Version-dependent bits may have variable bit definition in each PHY version.

[Motion 47, [3] and [34]]

The U-SIG shall contain the following version independent fields:

* PHY version identifier: 3 bits.
* UL/DL flag: 1 bit.

[Motion 42, [3] and [33]]

PHY version identifier field shall be one of the version independent fields in the U-SIG.

* Purpose is to simplify autodetection for future 802.11 generations, i.e., value of this field is used to identify the exact PHY version starting with 802.11be.
* Exact location of this field is TBD.

[Motion 28, [3] and [35]]

The U-SIG field includes the following bits in Version-independent bits portion:

* BSS color, number of bits TBD.
* TXOP duration, number of bits TBD.

[Motion 48, [3] and [34]]

The U-SIG shall contain Bandwidth Information, carried as a version independent field.

* This field may also convey some puncturing information.
* Number of bits for this field is TBD.

[Motion 88, [14] and [36]]

802.11be supports that U-SIG in each 80 MHz shall carry puncturing channel info for at least the specific 80 MHz where it is transmitted.

* Note: Within each 80 MHz segment, U-SIG is duplicated in every non-punctured 20 MHz.
* Whether BW/Puncturing info can be different for different 80 MHz is TBD.
* Whether BW and puncturing info in U-SIG are carried as a combined or a separate field is TBD.

[Motion 111, #SP0611-10, [7] and [37]]

802.11be signaling in U-SIG for BW/puncturing information in every non-punctured 20 MHz of an 80 MHz segment shall allow even an OBSS or unassociated device to decode the puncturing pattern of at least the specific 80 MHz that contains the 20 MHz.

[Motion 113, [7] and [38]]

802.11be supports BW field which does not include puncturing information.

[Motion 112, #SP29, [7] and [38]]

The U-SIG shall contain a PPDU type field, carried as a version dependent field.

* Number of bits for this field is TBD.

[Motion 89, [14] and [36]]

The following subfields exist in U-SIG of an EHT PPDU sent to multiple users:

* EHT-SIG MCS
* Number of EHT-SIG Symbols

[Motion 59, [14] and [39]]

The following subfield exists in U-SIG or EHT-SIG of an EHT PPDU sent to multiple users:

* GI+EHT-LTF Size

[Motion 100, [14] and [39]]

The following subfields exist in U-SIG and/or EHT-SIG of an EHT PPDU sent to single user:

* MCS
* NSTS
* GI+EHT-LTF Size
* Coding

[Motion 99, [14] and [39]]

The following subfields exist in U-SIG and/or EHT-SIG of an EHT PPDU sent to single user:

* LDPC Extra Symbol
* Beamformed
* Pre-FEC Padding Factor
* PE Disambiguity

[Motion 111, #SP0611-11, [7] and [40]]

A subfield for preamble puncturing pattern information that separates from the BW field is included in U-SIG and/or EHT-SIG for the 802.11be PPDU transmitted to a single user.

[Motion 111, #SP0611-12, [7] and [41]]

802.11be supports that preamble of primary 20 MHz channel shall not be punctured in any PPDU (except TB PPDU).

[Motion 111, #SP0611-13, [7] and [37]]

The following indication shall be the same considering symbol alignment within each segment from PHY point of view, if the fields are present in U-SIG:

* Number of EHT-SIG symbols
* GI+EHT-LTF Size
* Number of EHT-LTF symbols
* PE related parameters

[Motion 111, #SP0611-14, [7] and [42]]

A STA only needs to process up to one 80 MHz segment of the pre-EHT preamble (up-to and including EHT-SIG) to get all the assignment information for itself.

* No 80MHz segment change is needed while processing L-SIG, U-SIG and EHT-SIG.

[Motion 111, #SP0611-15, [7] and [43]]

Information in U-SIG is allowed to vary from one 80 MHz to the next in an EHT PPDU of bandwidth > 80 MHz?

* Notes:
	+ - Each STA still needs to decode only one 80 MHz segment in U-SIG.
		- Within each 80MHz, U-SIG is still duplicated in every non-punctured 20 MHz.
		- SST operation using TWT is one potential applicable scenario, other scenarios are TBD (Needs MAC discussion).

[Motion 111, #SP0611-16, [7] and [43]]

### EHT-SIG

There shall be a variable MCS and variable length EHT-SIG, immediately after the U-SIG, in an EHT PPDU sent to multiple users.

[Motion 43, [3] and [33]]

The EHT-SIG (immediately after the U-SIG) in an EHT PPDU sent to multiple users shall have a common field and user-specific field(s).

* Special case compressed modes (e.g., full BW MU-MIMO) are TBD.

[Motion 44, [3] and [33]]

An RU Allocation subfield is present in the Common field of the EHT-SIG field of an EHT PPDU sent to multiple users.

* Compressed modes are TBD.
* Contents of the RU Allocation subfield are TBD.

[Motion 57, [14] and [39]]

N RU allocation subfields are present in an EHT-SIG content channel,

* where N is the number of RU allocation subfield in common field of EHT-SIG content channel,
* N = 1 if a 20MHz or 40MHz EHT PPDU sent to multiple users is used,
* N = 2 if an 80MHz EHT PPDU sent to multiple users is used,
* N = TBD for other cases.
* The compressed modes are TBD.

[Motion 112, #SP46, [7] and [44]]

The RU allocation subfield in the EHT-SIG field of an EHT-PPDU sent to multiple users includes the RU allocation for Multiple RUs as well as Single RU.

[Motion 112, #SP45, [7] and [45]]

An RU Allocation subfield that is present in the Common field of the EHT-SIG field of an EHT PPDU sent to multiple users (except EHT TB PPDU), indicates RU assignment, including the size of the RU(s) and their placement in the frequency domain, to be used in the EHT modulated fields of the PPDU in the frequency domain.

* Compressed modes are TBD.

[Motion 112, #SP43, [7] and [46]]

There exists at least one compressed mode in which RU Allocation subfield does not exist in the Common field of the EHT-SIG field of an EHT PPDU sent to multiple users.

* Signaling method is TBD.

[Motion 58, [14] and [39]]

The minimum RU size for EHT to support MU-MIMO shall be 242-tone RU.

[Motion 112, #SP44, [7] and [46]]

For the PPDU transmitted to MU, the User field having TBD bits is contained in the user-specific field of EHT-SIG

* The User field indicates user information assigned to each RU similar to that used in HE MU PPDU.
* Detailed descriptions are TBD.

[Motion 85, [14] and [47]]

In BW ≤ 160 MHz, the EHT-SIG content channel for multiple user transmission is configured as follows:

* An EHT-SIG content channel is composed of a 20 MHz frequency segment.
* EHT-SIG content channels carry EHT-SIG common information and user-specific information.
* The EHT-SIG field consists of two EHT-SIG content channels in each 80 MHz.

The content channels (i.e., CC1 and CC2) per each 80 MHz may carry different information.

* + Where, SST operation using TWT is one potential applicable scenario, other scenarios are TBD.

[Motion 111, #SP0611-17, [7] and [48]]

802.11be STA can recognize the preamble puncturing pattern it needs by using the BW field and puncturing information of U-SIG and/or EHT-SIG field in multiple user transmission.

* Details for how to convey the puncturing information is TBD.

[Motion 111, #SP0611-18, [7] and [48]]

There is STA-ID related information in the EHT PPDU preamble sent to a single user and multiple users. TB PPDU is TBD.

[Motion 111, #SP0611-19, [7] and [37]]

EHT-SIG may carry different content in each 80 MHz.

* For PPDU BW larger than 80 MHz.
* SST operation using TWT is one applicable scenario, other scenarios are TBD.

[Motion 112, #SP1, [7] and [49]]

### EHT-STF

EHT PPDU has EHT-STF immediately after EHT-SIG.

* If EHT PPDU does not have EHT-SIG, EHT-STF is positioned immediately after U-SIG.

[Motion 112, #SP8, [7] and [50]]

802.11be supports 1x EHT-STF and 2x EHT-STF:

* 1x EHT-STF is used in EHT SU/MU PPDU.
	+ Whether SU and MU PPDU format is the same is TBD.
* 2x EHT-STF is used in EHT TB PPDU.
* TBD for any new EHT PPDU format.

[Motion 112, #SP9, [7] and [50]]

802.11be reuses 1x HE-STF and 2x HE-STF in 20/40/80/160/80+80 MHz PPDU.

[Motion 112, #SP10, [7] and [50]]

### EHT-LTF

802.11be shall include 1x EHT-LTF and 2x EHT-LTF.

[Motion 74, [14] and [51]]

802.11be shall include 4x EHT-LTF.

[Motion 75, [14] and [52]]

802.11be supports EHT-LTF for 16 spatial streams.

[Motion 83, [14] and [53]]

802.11be supports reusing 1/2/4x HE-LTF sequences for 1/2/4x EHT-LTF sequences in 20/40/80 MHz PPDU transmission.

[Motion 112, #SP11, [7] and [54]]

802.11be supports reusing 1/2/4x HE-LTF sequences for 1/2/4x EHT-LTF sequences in 80+80/160 MHz.

[Motion 112, #SP41, [7] and [54]]

P-matrix based modulation of EHT-LTFs is adopted for all spatial multiplexing modes (both UL and DL) defined in EHT.

* All spatial streams are active during EHT-LTFs on every non-zero LTF tone.
* Applicable to multi-AP transmission modes as well.

[Motion 111, #SP0611-20, [7] and [55]]

### Preamble puncture

CCA minimum BW resolution is 20 MHz.

Preamble puncturing resolution is 20 MHz.

[Motion 90, [14] and [16]]

The 802.11be amendment shall support a preamble puncture mechanism for an EHT PPDU transmitted to multiple STAs.

[Motion 30, [3] and [56]]

The 802.11be amendment shall support a preamble puncture mechanism for an EHT PPDU transmitted to a single STA.

[Motion 31, [3] and [56]]

## Modulation

802.11be shall define 4096 QAM as one of the optionally supported modulations.

[Motion 111, #SP0611-21, [7] and [57]]

The uniform constellation mapping for 4096 QAM shall be as given in 11-20/0111r0.

[Motion 111, #SP0611-22, [7] and [57]]

802.11be supports -38 dB as the Tx EVM requirement for 802.11be 4096 QAM.

[Motion 112, #SP20, [7] and [58]]

## Data field

### Scrambler

The following generator polynomial to generate the PPDU synchronous scrambler is used for EHT PPDU?

$$S\left(x\right)=x^{11}+x^{9}+1$$

• The 11 bits used for the scrambler initialization are randomly assigned by the transmitter.

• The polarity of the pilot subcarrier is derived from the same sequence as 802.11ax.

[Motion 112, #SP16, [7] and [59]]

## Beamforming

802.11be supports defining a compressed beamforming feedback in 802.11be for following cases:

* Number of streams: 1-16
* Number of antennas: 2-16
* Note: Compressed beamforming feedback is the same as defined in 802.11ax except for the new parameter values of Nc and Nr.

[Motion 111, #SP0611-23, [7] and [60]]

# EHT MAC

1.

## General

This section describes the functional blocks in the EHT MAC.

The 802.11be amendment shall define mechanism(s) for an AP to assist a STA that communicates with another STA.

[Motion 22, [3] and [61]]

802.11be supports defining a procedure for an AP to share time resource obtained in a TXOP for peer to peer (STA-TO-STA) frame exchanges.

* Whether it is in R1 or R2 is TBD.

[Motion 111, #SP0611-24, [7] and [62]]

## EHT Operation Element

802.11be supports defining an EHT Operation element with the following fields to indicate 320/160+160 MHz BSS bandwidth:

* Channel Width field
* CCFS field

[Motion 111, #SP0611-25, [7] and [63]]

802.11be supports that in 6 GHz band, an EHT AP may announce different BSS operating bandwidth to non-EHT STAs than the BSS operating bandwidth it announces to EHT STAs when EHT BW covers disallowed 20 MHz channels and/or when the announced EHT BW is not supported by non-EHT amendments. The advertised BSS operating bandwidth to EHT STA shall include the advertised BSS operating bandwidth to non-EHT STA.

[Motion 112, #SP53, [7] and [64]]

802.11be supports defining an EHT operation element to indicate the channel configuration for EHT STA, which does not need to combine with the indication of CCFS0 and CCFS1 in HE operation elements at 6 GHz.

[Motion 112, #SP54, [7] and [65]]

## TXOP

802.11be supports defining a MAC mechanism to protect TXOP for PPDUs with > 160 MHz and/or PPDUs with preamble puncturing.

[Motion 111, #SP0611-26, [7] and [66]]

802.11be supports transmitting the MU-RTS/RTS and CTS frames in a non-HT duplicate PPDU on 20 MHz subchannels which are not punctured.

[Motion 111, #SP0611-27, [7] and [67]]

## Priority access support for NS/EP services

The 802.11be amendment shall define mechanism(s) in support of priority access to a non-AP STA for national security (NS)/emergency preparedness (EP) priority service

NOTE – A non-AP STA for NS/EP priority service is a regular non-AP STA authorized to NS/EP service.

[Motion 50, [14] and [68]]

# Coexistence and regulatory rules

1.

## General

This section describes the functional blocks that support coexistence. It additionally describes, if needed, adaption to regulatory rules specific to 6 GHz spectrum.

## Coexistence feature #1

Description for coexistence feature #1

# Wideband and noncontiguous spectrum utilization

1.

## General

This section describes features related to the support of wider bandwidth and utilization of noncontiguous spectrum.

## Feature #1

Description for feature #1

# Multi-link operation

1.

## General

This section describes features related to multi-link operation.

Multi-link device (MLD): A device that has more than one affiliated STA and has one MAC SAP to LLC, which includes one MAC data service.

NOTE 1 – The device can be logical.

NOTE 2 – It is TBD for a MLD to have only one STA.

NOTE 3 – Whether the WM MAC address of each STA affiliated with the MLD is the same or different is TBD.

[Motion 23, [3] and [69]]

AP multi-link device (AP MLD): A MLD, where each STA affiliated with the MLD is an AP.

Non-AP multi-link device (non-AP MLD): A MLD, where each STA affiliated with the MLD is a non-AP STA.

[Motion 24, [3] and [69]]

## Multi-link setup

A MLD has a MAC address that singly identifies the MLD management entity.

For example, the MAC address can be used in multi-link setup between a non-AP MLD and an AP MLD.

[Motion 40, [3] and [69]]

[Motion 111, #SP0611-28, [7] and [70]]

802.11be supports that if different affiliated APs of an AP MLD have different MAC addresses, then different affiliated non-AP STAs of a non-AP MLD with more than one affiliated STA have different MAC addresses.

[Motion 112, #SP38, [7] and [70]]

An EHT MLD shall indicate its MLD MAC address during ML setup.

[Motion 112, #SP32, [7] and [71]]

The value of the RA/TA fields sent over-the-air in the MAC header of a frame is the MAC address of the STA affiliated with the MLD corresponding to that link.

[Motion 108, [14] and [72]]

The MAC address of each affiliated AP within an AP MLD shall be different from each other unless the affiliated APs cannot perform simultaneous TX/RX operation (e.g., due to near band in-device interference), in which case the MAC address properties are TBD.

NOTE – It is TBD whether we allow the operation of an AP MLD without simultaneous TX/RX operation.

[Motion 109, [14] and [72]]

802.11be defines a multi-link setup signaling exchange executed over one link initiated by a non-AP MLD with an AP MLD as follows:

* Capability for one or more links can be exchanged during the multi-link setup.
* The AP MLD serves as the interface to the DS for the non-AP MLD after successful multi-link setup.

NOTE 1 – The link identification is TBD.

NOTE 2 – Details for non-infrastructure mode of operation TBD.

[Motion 25, [3] and [73]]

802.11be defines mechanism(s) for multi-link operation that enables the following:

* Indication of capabilities and operating parameters for multiple links of an AP MLD.
* Negotiation of capabilities and operating parameters for multiple links during a single setup signaling exchange.

[Motion 32, [3] and [74]]

802.11be supports a mechanism for multi-link operation:

* An AP affiliated with an AP MLD can indicate the capabilities and operational parameters for one or more STAs of the multi-link device.
* A non-AP STA affiliated with a non-AP MLD can indicate the capabilities for one or more non-AP STAs of the non-AP MLD.
* Specific information of capabilities and operational parameters of multi-link device is TBD.

[Motion 21, [3] and [75]]

A MLD can indicate capability to support exchanging frames simultaneously on a set of affiliated STAs to another MLD.

[Motion 26, [3] and [73]]

A MLD that supports multiple links can announce whether it can support transmission on one link concurrent with reception on the other link for each pair of links.

NOTE 1 – The 2 links are on different channels.

NOTE 2 – Whether to define a capability of announcing the support transmission on one link concurrent with transmission on the other link is TBD.

[Motion 38, [3] and [76]]

A new element will be defined as a container to advertise and exchange capability information for multi-link setup.

[Motion 68, [14] and [77]]

802.11be supports that each STA of an MLD may independently select and manage its operational parameters unless specified otherwise in the 802.11be standard.

[Motion 112, #SP33, [7] and [78]]

802.11be supports that a non-AP MLD may update its ability to perform simultaneous transmission and reception on a pair of setup links after multi-link setup.

* This update for any pair of setup links can be announced by non-AP MLD on any enabled link.

NOTE – Specific signaling for update indication is TBD.

NOTE – Limitations on dynamic updating is TBD.

[Motion 112, #SP4, [7] and [79]]

802.11be shall define a mechanism to teardown an existing multi-link setup agreement.

[Motion 70, [14] and [80]]

After multi-link setup between two MLDs, different GTK/IGTK/BIGTK in different links with different PN spaces are used.

* GTK/IGTK/BIGTK in different links can be delivered in one 4-way handshake.

[Motion 71, [14] and [81]]

802.11be supports that after multi-link setup between two MLDs, the same PMK and the same PTK across links are used with the same PN space for a PTKSA.

[Motion 111, #SP0611-29, [7] and [82]]

Between two MLDs, 802.11be supports using the MLD MAC addresses to derive PMK under SAE method and PTK in 802.11be SFD.

[Motion 112, #SP40, [7] and [83]]

## TID-to-link mapping

802.11be defines a directional-based TID-to-link mapping mechanism among the setup links of a MLD.

* By default, after the multi-link setup, all TIDs are mapped to all setup links.
* The multi-link setup may include the TID-to-link mapping negotiation.
	+ TID-to-link mapping can have the same or different link-set for each TID unless a non-AP MLD indicates that it requires to use the same link-set for all TIDs during the multi-link setup phase.

 NOTE – Such indication method by the non-AP MLD is TBD (implicit or explicit).

* The TID-to-link mapping can be updated after multi-link setup through a negotiation, which can be initiated by any MLD.
	+ Format TBD.

 NOTE – When the responding MLD cannot accept the update, it can reject the TID-to- link mapping update.

[Motion 54, [14] and [84]]

At any point in time, a TID shall always be mapped to at least one link that is set up, unless admission control is used.

[Motion 101, [14] and [85]]

A link, that is setup as part of a multi-link setup, is defined as Enabled if that link can be used for frame exchange and at least one TID is mapped to that link.

NOTE – Frame exchange on a link is subject to the power state of the corresponding non-AP STA.

[Motion 105, [14] and [86]]

Management frames are allowed on all enabled links, following baseline.

[Motion 102, [14] and [85]]

If a TID is mapped in UL to a set of enabled links for a non-AP MLD, then the non-AP MLD can use any link within this set of enabled links to transmit data frames from that TID.

If a TID is mapped in DL to a set of enabled links for a non-AP MLD, then:

* The non-AP MLD can retrieve buffered BUs corresponding to that TID on any links within this set of enabled links.
* The AP MLD can use any link within this set of enabled links to transmit data frames from that TID, subject to existing restrictions for transmissions of frames that apply to those enabled links.
* An example of restriction is if the STA is in doze state.

[Motion 103, [14] and [2]]

802.11be define mechanism(s) for multi-link operation that enables the following:

* An operational mode for concurrently exchanging frames on more than one link for one or more TID(s).
* An operational mode for restricting exchanging frames of one or more TID(s) to be on one link at a time.

[Motion 9, [1] and [87]]

802.11be supports adjusting the setting of More Data subfield to fit MLD scenario.

[Motion 112, #SP51, [7] and [88]]

802.11be supports setting the More Data subfield as follows:

* When AP MLD transmit a BU in one link to a non-AP MLD, if there is at least one additional buffered BU of any TID or management frames that is mapped to this link by TID-to-link mapping or default mapping for the same non-AP MLD, the More Data subfield is set to 1, otherwise the More Data subfield is set to 0.

[Motion 112, #SP52, [7] and [88]]

## Multi-link block ack

A single block ack agreement is negotiated between two MLDs for a TID that may be transmitted over one or more links.

NOTE – The format of the setup frames is TBD.

[Motion 36, [3] and [89]]

Setup a block ack agreement for multi-link operation by using ADDBA request and ADDBA response frames.

[Motion 67, [14] and [90]]

The established block ack agreement allows the QoS Data frames of the TID, aggregated within the A-MPDUs, to be exchanged between the two MLDs on any available link.

[Motion 61, [14] and [91]]

For each block ack agreement, there exists one receive reordering buffer based on MPDUs in the MLD which is the recipient of the QoS Data frames for that block ack agreement.

The receive reordering buffer operation is based on the Sequence Number space that is shared between the two MLDs.

[Motion 62, [14] and [91]]

The receive status of QoS Data frames of a TID received on a link shall be signaled on the same link and may be signaled on other available link(s)

[Motion 63, [14] and [91]]

Sequence numbers are assigned from a common sequence number space shared across multiple links of a MLD, for a TID that may be transmitted to a peer MLD over one or more links.

[Motion 37, [3] and [89]]

After the BA agreement of a TID between two MLDs, the common reordering buffer of the TID are applied on all setup links.

[Motion 112, #SP27, [7] and [92]]

For each block ack agreement between two MLDs, there exists one transmit buffer control to submit MPDUs for transmission across links.

* TBD for separate transmit buffer control.

[Motion 112, #SP6, [7] and [93]]

802.11be extends the negotiated Block Ack buffer size to be smaller than or equal to 1024 and define 512-bits and 1024-bits BA bitmap in R1.

[Motion 112, #SP7, [7] and [93]]

802.11be extends Table 26-1 in 802.11ax D6.0 as shown below:

|  |  |  |
| --- | --- | --- |
| **Negotiated buffer size** | **Bitmap in compressed BA** | **Bitmap in multi-STA BA** |
| 1-64 | 64 | 32 or 64 |
| 65-128 | 64 or 256 | 32, 64, 128 |
| 129-256 | 64 or 256 | 32, 64, 128, or 256 |
| 257-512 | 64 or 256 or 512 | 32, 64, 128, 256, 512 |
| 513-1024 | 64 or 256 or 512 or 1024 | 32, 64, 128, 256, 512, or 1024 |

[Motion 112, #SP25, [7] and [94]]

For an M-BlockAck frame, add support for 512/1024 bitmap lengths by:

* Including new BA Bitmap lengths (of 512 and 1024 bits), where the length of the BA Bitmap field is signaled in the Per AID TID Info field addressed to an EHT STA
* The M-BA frame containing these Per AID TID Info fields is not sent as a response to an HE TB PPDU generated by at least one HE STA.

[Motion 112, #SP22, [7] and [95]]

For a Compressed BlockAck frame, use some of the reserved values of the Fragment Number field of the BlockAck frame to indicate the added bitmap lengths (512 and 1024).

[Motion 112, #SP23, [7] and [95]]

802.11be uses B3 equal to 1, B2 B1 equal to 0 and B0 equal to 0 in Fragment Number field to indicate 512 BA bitmap length and to use B3 equal to 1, B2 B1 equal to 0 and B0 equal to 1 in Fragment Number field to indicate 1024 BA bitmap length in compressed BA and multi-STA BA.

[Motion 112, #SP24, [7] and [96]]

802.11be shall define mechanism for multi-link operation that enables the following:

* A STA of a recipient MLD shall provide receive status for MPDUs received on the link that it is operating on and may provide (if available) information on successful reception of MPDUs received by another STA of that MLD.

[Motion 114, [7] and [97]]

An originator MLD of a BA agreement:

* shall update the receive status for an MPDU corresponding to the BA agreement if the received status indicates successful reception.
* shall not update the receive status for an MPDU corresponding to the BA agreement that has been already positively acknowledged.

[Motion 112, #SP26, [7] and [98]]

## Power save

For each of the enabled links, frame exchanges are possible when the corresponding non-AP STA of the enabled link is in the awake state.

NOTE 1 – A link is enabled when that link can be used to exchange frames subject to STA power states.

NOTE 2 – When a link is disabled (i.e., not enabled) by an MLD the frame exchanges are not possible.

[Motion 51, [14] and [99]]

An AP of an AP MLD may transmit on a link a frame that carries an indication of buffered data for transmission on other enabled link(s).

[Motion 52, [14] and [99]]

An AP MLD can recommend a non-AP MLD to use one or more enabled links.

* The AP’s indication could be carried in a broadcast or a unicast frame.

[Motion 106, [14] and [100]]

For a link setup between an AP MLD and a non-AP MLD, a non-AP STA operating on that link can send to an AP operating on that link an indication that (an)other non-AP STA(s) within the same non-AP MLD that has(have) transition to doze state is(are) in awake state.

[Motion 84, [14] and [101]]

A non-AP MLD monitors and performs basic operations (such as traffic indication, BSS parameter updates, etc.) on one or more link(s).

[Motion 104, [14] and [102]]

Each non-AP STA affiliated with a non-AP MLD that is operating on an enabled link maintains its own power state/mode.

[Motion 110, [14] and [86]]

Not every STA operating in PS mode in a non-AP MLD is required to receive the beacon frames periodically.

* This is an exemption besides the existing ones, such as individual TWT agreement, WNM sleep mode and NonTIM mode.

[Motion 112, #SP55, [7] and [103]]

## Multi-link group addressed data delivery

For R1, each AP affiliated with an STR AP MLD shall follow the baseline rules for scheduling Beacon frame transmissions.

[Motion 112, #SP37, [7] and [104]]

## Multi-link channel access

An MLD AP may offer differentiated quality of service over different links.

[Motion 112, #SP49, [7] and [105]]

802.11be shall allow the following asynchronous multi-link channel access:

* Each of STAs belonging to a MLD performs a channel access over their links independently in order to transmit frames.
* Downlink and uplink frames can be transmitted simultaneously over the multiple links.

[Motion 20, [3] and [106]]

802.11be shall allow a MLD that has constraints to simultaneously transmit and receive on a pair of links to operate over this pair of links.

* Signaling of these constraints is TBD.

[Motion 46, [3] and [107]]

802.11be supports the following cases in R1:

* STR AP MLD with STR non-AP MLD
* STR AP MLD with non-STR non-AP MLD
* Note: All the other cases are TBD.

[Motion 111, #SP0611-30, [7] and [108]]

802.11be supports the following PPDU transmission restriction for the constrained multi-link operation:

* If an AP MLD intends to align the ending time of DL PPDUs carrying a frame soliciting an immediate response simultaneously sent to the same non-STR non-AP MLD on multiple links, the AP MLD shall ensure that the difference between the ending times of transmitting DL PPDUs is less than TBD (< SIFS).
	+ Where the reference of the ending time of the PPDU is TBD.

[Motion 111, #SP0611-31, [7] and [109]]

802.11be supports the following constrained multi-link operation:

* When a STA in a non-STR MLD receives an RTS addressed to itself, if the NAV of the STA indicates idle but another STA in the same MLD is either a TXOP holder or a TXOP responder, the STA may not respond with a CTS frame.

[Motion 111, #SP0611-32, [7] and [110]]

## Multi-BSSID

An AP of an AP MLD can correspond to a transmitted BSSID or a nontransmitted BSSID in a multiple BSSID set on a link.

[Motion 112, #SP34, [7] and [111]]

APs belonging to the same multiple BSSID set cannot be part of the same AP MLD.

* Note: APs within a multiple BSSID set are, by definition, operating on the same channel.

[Motion 112, #SP35, [7] and [111]]

APs belonging to the same co-hosted BSSID set cannot be part of the same AP MLD.

* Note: APs within a co-hosted BSSID set are, by definition, operating on the same channel.

[Motion 112, #SP36, [7] and [111]]

802.11be supports that each AP of an AP MLD is independently configured to operate as transmitted or nontransmitted BSSID of a multiple BSSID set or as an AP of a co-hosted BSSID set or not part of either a multiple BSSID set or co-hosted BSSID set.

[Motion 112, #SP50, [7] and [112]]

# Multi-band and multichannel aggregation and operation

1.

## General

This section describes features related to multi-band and multichannel aggregation and operation.

## Feature #1

Description for feature #1

# Spatial stream and MIMO protocol enhancement

1.

## General

This section describes features related to 16 spatial stream operation and MIMO protocol enhancement.

## 16 spatial stream operation

802.11be supports a maximum of 16 spatial streams (total across all the scheduled STAs) for MU-MIMO.

[Motion 65, [14] and [113]]

802.11be defines a maximum of 16 spatial streams for SU-MIMO.

[Motion 66, [14] and [113]]

For an EHT MU-MIMO transmission, the maximum number of spatial streams allocated to each MU-MIMO scheduled non-AP STA is limited to 4.

[Motion 112, #SP15, [7] and [114]]

The maximum number of users that can be spatially multiplexed in EHT for DL transmissions is 8 per RU/MRU.

* Applicable to all transmission modes in 802.11be.

[Motion 112, #SP47, [7] and [115]]

# Multi-AP operation

1.

## General

This section describes features related to multi-AP operation.

## Setup

An EHT AP supporting the Multi-AP coordination can send a frame (e.g., Beacon or other management frame) including capabilities of Multi-AP transmission schemes.

NOTE – Multi-AP transmission schemes are TBD (e.g., Coordinated OFDMA).

[Motion 72, [14] and [116]]

An EHT AP which obtains a TXOP and initiates the Multi-AP coordination is the Sharing AP.

An EHT AP which is coordinated for the Multi-AP transmission by the Sharing AP is the Shared AP.

NOTE – The name of the Sharing AP and the Shared AP can be modified.

[Motion 73, [14] and [116]]

## Channel sounding

802.11be shall provide a joint NDP sounding scheme as optional mode for multiple-AP systems.

* Sequential sounding scheme that each AP transmits NDP independently and sequentially without overlapped sounding period of each AP can also be used in multi-AP systems.

[Motion 14, [3] and [117]]

Joint NDP sounding scheme for multi-AP system with less or equal to total 8 antennas at AP has all antennas active on all LTF tones and uses 802.11ax P matrix across OFDM symbols.

[Motion 15, [3] and [117]]

Multiple APs can sequentially use an 802.11ax-like sounding sequence to collect CSI from the in-BSS STAs and OBSS STAs.

* The sounding sequence of each AP is similar to the 802.11ax sounding protocol with multiple STAs (NDPA + NDP + BFRP TF + CSI report).

[Motion 112, #SP18, [7] and [118]]

In sequential channel sounding sequence for multi-AP, the NDPA frame and BFRP TF frame will include ID info for OBSS STA.

* The details of the NDPA, BFRP TF and the ID info are TBD.

[Motion 112, #SP19, [7] and [118]]

## Coordinated transmission

11be shall define a mechanism to determine whether an AP is part of an AP candidate set and can participate as a shared AP in coordinated AP transmission initiated by a sharing AP.

[Motion 55, [14] and [119]]

Define a procedure for an AP to share its frequency/time resources of an obtained TXOP with a set of APs.

* Set of APs is TBD.

[Motion 56, [14] and [120]]

An AP that intends to use the resource (i.e., frequency or time) shared by another AP shall be able to indicate its resource needs to the AP that shared the resource.

[Motion 53, [14] and [121]]

In all modes of operation wherein an AP shares its frequency/time resource of an obtained TXOP with a set of APs:

* Define a mechanism for the sharing AP to optionally solicit feedback from one or more APs from the AP candidate set to learn the resource needs and the intent to participate in a coordinated AP transmission.

[Motion 111, #SP0611-33, [7] and [120]]

In all modes of operation wherein an AP shares its frequency resource with a set of APs, the AP shall share its frequency resource in multiples of 20 MHz channels with a set of APs in an obtained TXOP.

* PPDU format of the transmission on the shared resource is TBD.

[Motion 111, #SP0611-34, [7] and [120]]

Coordinated OFDMA is supported in 11be, and in a coordinated OFDMA, both DL OFDMA and its corresponding UL OFDMA acknowledgement are allowed.

[Motion 60, [14] and [122]]

## Other Multi-AP coordination schemes

802.11be supports introducing a coordinated spatial reuse operation in 802.11be.

* Whether it is in R1 or R2 is TBD.

[Motion 111, #SP0611-35, [7] and [123]]

802.11be supports adding to 802.11be SFD “Joint transmission for single and multi user” under the multi-AP topic.

* Note: this feature is for R2

[Motion 111, #SP0611-36, [7] and [124]]

802.11be supports adding “Multi-AP Coordinated BF” to 802.11be SFD as one of the multi-AP coordination schemes.

Note: This feature is for R2.

[Motion 112, #SP17, [7] and [125]]

# Link adaptation and retransmission protocols

1.

## General

This section describes features related to enhanced link adaptation and retransmission protocols.

## Feature #1

Description for feature #1

# Low latency

1.

## General

This section describes features related to low latency.

## Feature #1

Description for feature #1

# Bibliography

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| --- | --- |
| [1]  | TGbe, “Compendium of motions related to the contents of the TGbe specification framework document,” *19/1755r0,* October 2019.  |
| [2]  | Alice Chen (Qualcomm), “320MHz channelization and tone plan,” *19/0797r1,* September 2019.  |
| [3]  | TGbe, “Compendium of motions related to the contents of the TGbe specification framework,” *19/1755r1,* November 2019.  |
| [4]  | Eunsung Park (LGE), “Tone plan discussion,” *19/1066r3,* November 2019.  |
| [5]  | Eunsung Park (LGE), “Discussion on 240MHz bandwidth,” *19/1889r2,* November 2019.  |
| [6]  | Bin Tian (Qualcomm), “Further thoughts on 11be tone plan,” *19/1521r2,* November 2019.  |
| [7]  | TGbe, “Compendium of motions related to the contents of the TGbe specification framework document,” *19/1755r4,* June 2020.  |
| [8]  | Ron Porat (Broadcom), “80MHz OFDMA tone plan,” *20/0666r2,* May 2020.  |
| [9]  | Sigurd Schelstraete (Quantenna/ON Semiconductor), “240 MHz channelization,” *20/0479r0,* March 2020.  |
| [10]  | Eunsung Park (LGE), “Non-OFDMA tone plan for 320MHz,” *19/1492r3,* November 2019.  |
| [11]  | Rui Cao (NXP), “Aggregated PPDU for large BW,” *20/0693r1,* May 2020.  |
| [12]  | Junghoon Suh (Huawei), “Small size MRU with different MCS and BCC,” *20/0470r1,* April 2020.  |
| [13]  | Jianhan Liu (MediaTek), “Enhanced resource allocation schemes for 11be,” *19/1126r1,* September 2019.  |
| [14]  | TGbe, “Compendium of motions related to the contents of the TGbe specification framework,” *19/1755r2,* January 2020.  |
| [15]  | Jianhan Liu (MediaTek), “Multiple RU combinations for EHT,” *19/1907r2,* January 2020.  |
| [16]  | Bin Tian (Qualcomm), “Preamble puncturing and RU aggregation,” *19/1869r2,* January 2020.  |
| [17]  | Ron Porat (Broadcom), “Small RU combinations,” *20/0667r1,* April 2020.  |
| [18]  | Ross Yu (Huawei), “Multiple RU discussion,” *19/1914r4,* January 2020.  |
| [19]  | Eunsung Park (LGE), “Multiple RU aggregation,” *20/0023r2,* January 2020.  |
| [20]  | Ron Porat (Broadcom), “Multi-RU support,” *19/1908r4,* January 2020.  |
| [21]  | Bin Tian (Qualcomm), “Thoughts on RU aggregation and interleaving,” *20/0394r1,* March 2020.  |
| [22]  | Jianhan Liu (MediaTek), “Segment parser and tone interleaver for 11be,” *20/0440r1,* March 2020.  |
| [23]  | Tianyu Wu (Apple), “Discussions on multi-RU aggregation,” *20/0495r1,* March 2020.  |
| [24]  | Jianhan Liu (MediaTek), “Update on segment parser and tone interleaver for 11be,” *20/0579r3,* April 2020.  |
| [25]  | Ross Yu (Huawei), “Preamble structure,” *19/1099r2,* September 2019.  |
| [26]  | Dongguk Lim (LGE), “Further discussion for 11be preamble,” *19/1486r9,* November 2019.  |
| [27]  | Eunsung Park (LGE), “Phase rotation for 320MHz,” *19/1493r1,* November 2019.  |
| [28]  | Eunsung Park (LGE), “Phase rotation proposal follow-up,” *20/0699r0,* May 2020.  |
| [29]  | Xiaogang Chen (Intel), “11be preamble structure,” *19/1516r4,* November 2019.  |
| [30]  | Dongguk Lim (LGE), “11be PPDU format,” *20/0019r1,* January 2020.  |
| [31]  | Dongguk Lim (LGE), “11be PPDU format,” *20/0019r4,* May 2020.  |
| [32]  | Sameer Vermani (Qualcomm), “Forward compatibility for WiFi preamble design,” *19/1519r5,* November 2019.  |
| [33]  | Sameer Vermani (Qualcomm), “Further ideas on EHT preamble design,” *19/1870r4,* November 2019.  |
| [34]  | Rui Cao (Marvell), “EHT preamble design,” *19/1540r7,* November 2019.  |
| [35]  | Dongguk Lim (LGE), “Further discussion for 11be preamble,” *19/1486r8,* November 2019.  |
| [36]  | Sameer Vermani (Qualcomm), “PPDU types and U-SIG content,” *20/0049r2,* January 2020.  |
| [37]  | Wook Bong Lee (Samsung), “SU PPDU SIG contents considerations,” *20/0285r5,* April 2020.  |
| [38]  | Wook Bong Lee (Samsung), “Further discussion on bandwidth and puncturing information,” *20/0606r2,* May 2020.  |
| [39]  | Mengshi Hu (Huawei), “Preamble structure and SIG contents,” *20/0029r3,* January 2020.  |
| [40]  | Dongguk Lim (LGE), “11be PPDU format,” *20/0019r3,* April 2020.  |
| [41]  | Dongguk Lim (LGE), “Signaling of preamble puncturing in SU transmission,” *20/0524r2,* April 2020.  |
| [42]  | Ross Yu (Huawei), “Multi-segment EHT-SIG design discussion,” *20/0545r1,* April 2020.  |
| [43]  | Sameer Vermani (Qualcomm), “U-SIG structure and preamble processing,” *20/0380r0,* March 2020.  |
| [44]  | Dongguk Lim (LGE), “Evaluation of signaling overhead for EHT-SIG,” *20/0738r2,* May 2020.  |
| [45]  | Dongguk Lim (LGE), “Signaling of RU allocation in 11be,” *20/0652r0,* April 2020.  |
| [46]  | Ross Yu (Huawei), “Further discussion on RU allocation subfield in EHT-SIG,” *20/0609r3,* May 2020.  |
| [47]  | Eunsung Park (LGE), “Consideration on 240/160+80 MHz and preamble puncturing,” *20/0022r1,* January 2020.  |
| [48]  | Dongguk Lim (LGE), “Consideration for EHT-SIG transmission,” *20/0020r3,* April 2020.  |
| [49]  | Jianhan Liu (MediaTek), “Further discussions on efficient EHT preamble,” *20/0605r0,* April 2020.  |
| [50]  | Eunsung Park (LGE), “Consideration on EHT-STF,” *20/0585r0,* April 2020.  |
| [51]  | Dandan Liang (Huawei), “EHT P matrices discussion,” *19/1980r2,* January 2020.  |
| [52]  | Dandan Liang (Huawei), “EHT-LTFs design for wideband,” *20/0117r1,* January 2020.  |
| [53]  | Jinmin Kim (LGE), “Consideration of EHT-LTF,” *19/1925r2,* January 2020.  |
| [54]  | Jinyoung Chun (LGE), “Consideration on EHT-LTF,” *20/0608r0,* April 2020.  |
| [55]  | Sameer Vermani (Qualcomm), “P-matrix based LTFs for EHT,” *20/0382r0,* March 2020.  |
| [56]  | Oded Redlich (Huawei), “Improved preamble puncturing in 802.11be,” *19/1190r3,* November 2019.  |
| [57]  | Sigurd Schelstraete (Quantenna/ON Semiconductor), “4096 QAM Straw Polls,” *20/0480r0,* March 2020.  |
| [58]  | Qinghua Li (Intel), “Tx EVM requirement for 4k QAM,” *20/0456r0,* March 2020.  |
| [59]  | Xiaogang Chen (Intel), “EHT PPDU scrambler,” *20/0563r1,* April 2020.  |
| [60]  | Wook Bong Lee (Samsung), “Further discussion on feedback overhead reduction,” *19/1495r2,* March 2020.  |
| [61]  | Stephane Baron (Canon), “Direct link MU transmissions,” *19/1117r2,* November 2019.  |
| [62]  | Dibakar Das (Intel), “EHT direct link transmission,” *19/1604r1,* January 2020.  |
| [63]  | Po-Kai Huang (Intel), “320 MHz BSS configuration,” *20/0384r1,* March 2020.  |
| [64]  | Liwen Chu (NXP), “EHT BSS with wider bandwidth,” *20/0398r3,* May 2020.  |
| [65]  | Guogang Huang (Huawei), “Operating bandwidth indication for EHT BSS,” *20/0680r0,* April 2020.  |
| [66]  | Liwen Chu (NXP), “Protection with more than 160MHz PPDU and puncture operation,” *20/0062r0,* January 2020.  |
| [67]  | Yongho Seok (MediaTek), “EHT RTS and CTS procedure,” *19/2125r2,* March 2020.  |
| [68]  | Subir Das (Perspecta Labs), “Priority access support in IEEE 802.11be: what and why?,” *19/1901r4,* January 2020.  |
| [69]  | Po-Kai Huang (Intel), “Extremely efficient multi-band operation,” *19/0822r9,* November 2019.  |
| [70]  | Po-Kai Huang (Intel), “MLD MAC address and WM address,” *20/0054r3,* March 2020.  |
| [71]  | Xiaofei Wang (InterDigital), “Follow up discussion on multi-link operations,” *20/0119r2,* May 2020.  |
| [72]  | Duncan Ho (Qualcomm), “MLA MAC addresses considerations,” *19/1899r7,* January 2020.  |
| [73]  | Po-Kai Huang (Intel), “Multi-link operation framework,” *19/0773r8,* November 2019.  |
| [74]  | Abhishek Patil (Qualcomm), “Multi-link association setup,” *19/1525r2,* November 2019.  |
| [75]  | Insun Jang (LGE), “Discussion on multi-link setup,” *19/1509r5,* November 2019.  |
| [76]  | Liwen Chu (Marvell), “Multiple link operation capability announcement,” *19/1159r5,* November 2019.  |
| [77]  | Yunbo Li (Huawei), “Multi-link association,” *19/1549r5,* January 2020.  |
| [78]  | Abhishek Patil (Qualcomm), “MLO: BSS color,” *20/0314r1,* May 2020.  |
| [79]  | Sharan Naribole (Samsung), “MLO constraint indication and operating mode,” *20/0226r5,* April 2020.  |
| [80]  | Po-Kai Huang (Intel), “Multi-link setup follow up,” *19/1823r3,* January 2020.  |
| [81]  | Po-Kai Huang (Intel), “Multi-link security consideration,” *19/1822r4,* January 2020.  |
| [82]  | Po-Kai Huang (Intel), “Multi-link security consideration,” *19/1822r7,* March 2020.  |
| [83]  | Po-Kai Huang (Intel), “Multi-link security consideration,” *19/1822r9,* May 2020.  |
| [84]  | Yongho Seok (MediaTek), “Multi-link operation management,” *19/1358r4,* January 2020.  |
| [85]  | Laurent Cariou (Intel), “Multi-link: steps for using a link,” *19/1924r1,* January 2020.  |
| [86]  | Abhishek Patil (Qualcomm), “Multi-link: link management,” *19/1528r5,* January 2020.  |
| [87]  | Abhishek Patil (Qualcomm), “Multi-link operation: dynamic TID transfer,” *19/1082r3,* September 2019.  |
| [88]  | Yunbo Li (Huawei), “Discussion of More Data subfield for multi-link,” *20/0472r2,* May 2020.  |
| [89]  | Rojan Chitrakar (Panasonic), “Multi-link acknowledgment,” *19/1512r6,* November 2019.  |
| [90]  | Yuchen Guo (Huawei), “BA setup for multi-link aggregation,” *19/1591r5,* January 2020.  |
| [91]  | Liwen Chu (NXP), “A-MPDU and BA,” *19/1856r3,* January 2020.  |
| [92]  | Yongho Seok (MediaTek), “Multi-link BA clarification,” *20/0460r3,* May 2020.  |
| [93]  | Po-Kai Huang (Intel), “Multi-link BA,” *20/0053r3,* April 2020.  |
| [94]  | Po-Kai Huang (Intel), “Multi-link BA,” *20/0053r4,* May 2020.  |
| [95]  | Duncan Ho (Qualcomm), “MLA: BA format,” *20/0441r3,* April 2020.  |
| [96]  | Liwen Chu (NXP), “Sequence number and BA operation with large BA buffer size,” *20/0397r4,* May 2020.  |
| [97]  | Abhishek Patil (Qualcomm), “MLO: acknowledgement procedure,” *20/0024r2,* April 2020.  |
| [98]  | Abhishek Patil (Qualcomm), “MLO: acknowledgement procedure,” *20/0024r3,* May 2020.  |
| [99]  | Alexander Min (Intel), “Multi-link power save operation,” *19/1544r5,* January 2020.  |
| [100]  | Abhishek Patil (Qualcomm), “MLO: link management – follow up,” *19/1904r3,* January 2020.  |
| [101]  | Jeongki Kim (LGE), “EHT power saving considering multi-link,” *19/1510r6,* January 2020.  |
| [102]  | Abhishek Patil (Qualcomm), “Multi-link operation: anchor channel,” *19/1526r3,* January 2020.  |
| [103]  | Ming Gan (Huawei), “Power save for multi-link,” *19/1988r2,* May 2020.  |
| [104]  | Duncan Ho (Qualcomm), “MLA: group addressed frames delivery,” *20/0442r1,* May 2020.  |
| [105]  | Chunyu Hu (Facebook), “Prioritized EDCA channel access over latency sensitive links in MLO,” *20/0408r4,* May 2020.  |
| [106]  | Insun Jang (LGE), “Channel access for multi-link operation,” *19/1144r6,* November 2019.  |
| [107]  | Sharan Naribole (Samsung), “Multi-link channel access discussion,” *19/1405r7,* November 2019.  |
| [108]  | Duncan Ho (Qualcomm), “MLO: Sync PPDUs,” *20/0026r4,* April 2020.  |
| [109]  | Yongho Seok (MediaTek), “Synchronous multi-link operation,” *19/1305r4,* April 2020.  |
| [110]  | Yongho Seok (MediaTek), “Constrained multi-link operation,” *19/1959r1,* March 2020.  |
| [111]  | Abhishek Patil (Qualcomm), “Multi-BSSID operation with MLO,” *20/0358r1,* May 2020.  |
| [112]  | Abhishek Patil (Qualcomm), “Multi-BSSID operation with MLO,” *20/0358r3,* May 2020.  |
| [113]  | Wook Bong Lee (Samsung), “16 Spatial Stream Support,” *19/1877r1,* January 2020.  |
| [114]  | Junghoon Suh (Huawei), “Restrictions for 16 SS based MU-MIMO scheduling,” *20/0067r1,* April 2020.  |
| [115]  | Ron Porat (Broadcom), “Number of users in MU-MIMO,” *20/0767r0,* May 2020.  |
| [116]  | Sungjin Park (LGE), “Setup for Multi-AP coordination,” *19/1895r2,* January 2020.  |
| [117]  | Jianhan Liu (MediaTek), “Joint sounding for multi-AP systems,” *19/1593r3,* November 2019.  |
| [118]  | Feng Jiang (Intel), “Channel sounding for Multi-AP CBF,” *20/0123r0,* January 2020.  |
| [119]  | Cheng Chen (Intel), “Multi-AP group formation follow-up,” *19/1931r2,* January 2020.  |
| [120]  | Lochan Verma (Qualcomm), “Coordinated AP time/frequency sharing in a transmit opportunity in 11be,” *19/1582r2,* January 2020.  |
| [121]  | Yongho Seok (MediaTek), “Coordinated OFDMA operation,” *19/1788r1,* January 2020.  |
| [122]  | Liwen Chu (NXP), “Coordinated OFDMA,” *19/1919r3,* January 2020.  |
| [123]  | Jason Yuchen Guo (Huawei), “Coordinated spatial reuse operation,” *20/0033r1,* February 2020.  |
| [124]  | Ron Porat (Broadcom), “Joint transmission for 11be,” *20/0071r1,* April 2020.  |
| [125]  | Roya Doostnejad (Intel), “Coordinated beamforming for 802.11be,” *20/0099r1,* April 2020.  |