IEEE P802.11  
Wireless LANs

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| **Specification Framework for TGbe** | | | | |
| **Date:** 2020-09-20 | | | | |
| **Author(s):** | | | | |
| **Name** | **Affiliation** | **Address** | **Phone** | **email** |
| Edward Au | Huawei | 400-303 Terry Fox Drive,  Ottawa, ON, K2K 3J1 |  | [edward.ks.au@gmail.com](mailto:edward.ks.au@gmail.com) |

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. |
| 11 | July 11, 2020 | Incorporated motions 115, 116, and 118 approved on July 9, 2020. |
| 12 | August 1, 2020 | Incorporated motion 119 approved on July 30, 2020. |
| 13 | August 20, 2020 | Incorporated motion 120 approved on August 20, 2020. |
| 14 | September 5, 2020 | Incorporated motions 124, 125, and 126 approved on September 3, 2020. |
| 15 | September 20, 2020 | Incorporated motions 131 and 133 approved on September 17, 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



## General

This section describes the functional blocks in the EHT PHY.

802.11be AP is mandatory to support the following:

* 160 MHz operating channel width in 6 GHz band
* 80 MHz operating channel width in 5 GHz band
* 20 MHz operating channel width in 2.4 GHz band

NOTE – “soft AP” is TBD.

[Motion 124, #SP178, [1] and [2]]

It is mandatory for a non-AP STA to support 80 MHz operating channel width in 5 and 6 GHz bands.

* Except for 20 MHz only client (if defined in EHT)

[Motion 124, #SP179, [1] and [2]]

802.11be defines 20 MHz-only client in 2.4/5 GHz band only.

[Motion 124, #SP180, [1] and [2]]

## Subcarriers and resource allocation

### Wideband and noncontiguous spectrum utilization

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

[Motion 10, [3] and [4]]

802.11be supports defining 320 MHz channels as any two adjacent 160 MHz channels.

[Motion 119, #SP115, [5] and [6]]

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, [7] and [8]]

No 240 MHz channelization is defined in 802.11be.

* NOTE – 240/160+80 MHz entry in BW field is TBD.

[Motion 119, #SP116, [5] and [9]]

There is no 240/160+80 MHz PPDU BW entry in the BW field of U-SIG in 802.11be.

* The 240 MHz transmission is defined as 320 MHz PPDU with 80 MHz punctured.

[Motion 122, #SP165, [10] and [11]]

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

[Motion 17, [7] and [12]]

802.11be reuses 802.11ax tone plan for 20/40 MHz PPDU and, with the exception of pilot locations, for 80/160/80+80 MHz in non-OFDMA PPDU. For 320 MHz and 160+160 MHz PPDU, 802.11be uses duplicated EHT160.

[Motion 33, [7] and [13]]

[Motion 118, [14] and [15]]

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 EHT80.

[Motion 35, [7] and [13]]

[Motion 118, [14] and [15]]

240/160+80 MHz transmission is subjected to 320/160+160 MHz PPDU mask plus additional puncturing mask.

320/160+160 MHz transmission is subjected to 320/160+160 MHz PPDU mask, additional puncturing mask can be applied according to the puncturing patterns and MRUs.

Details of the masks are TBD.

[Motion 119, #SP117, [5] and [16]]

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 80 MHz 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, [17] and [18]]

For 80 MHz NDP or each 80 MHz segment of > 80 MHz bandwidth NDP,

* If not punctured, non-OFDMA 80 MHz tone plan is used.
* If punctured, OFDMA 80 MHz tone plan is used.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **RU & Tone Indices** | **1x LTF Tones** | **2x LTF Tones** | **4x LTF Tones** |
| Non-punctured | RU996, [-500:-3, 3:500] | A=[-500:4:-4, 4:4:+500] | A=[-500:2:-4, 4:2:500] | A=[-500:-3, 3:500] |
| 1st 20MHz punctured | RU242+484, [-253:-12, 12:253, 259:500] | B1=[-252:4:-12, 12:4:252, 260:4:500] | B1=[-252:2:-12, 12:2:252, 260:2:500] | B1=[-253:-12, 12:253, 259:500] |
| 2nd 20MHz punctured | RU242+484, [-500:-259, 12:253, 259:500] | B2=[-500:4:-260, 12:4:252, 260:4:500] | B2=[-500:2:-260, 12:2:252, 260:2:500] | B2=[-500:-259, 12:253, 259:500] |
| 3rd 20MHz punctured | RU242+484, [-500:-259, -253:-12, 259:500] | B3=[-500:4:-260, -252:4:-12, 260:4:500] | B3=[-500:2:-260, -252:2:-12, 260:2:500] | B3=[-500:-259, -253:-12, 259:500] |
| 4th 20MHz punctured | RU242+484, [-500:-259, -253:-12, 12:253] | B4=[-500:4:-260, -252:4:-12, 12:4:252] | B4=[-500:2:-260, -252:2:-12, 12:2:252] | B4=[-500:-259, -253:-12, 12:253] |
| 1st 40MHz punctured | RU484, [12:253, 259:500] | C1=[12:4:252, 260:4:500] | C1=[12:2:252, 260:2:500] | C1=[12:253, 259:500] |
| 2nd 40MHz punctured | RU484, [-500:-259, -253:-12] | C2=[-500:4:-260, -252:4:-12] | C2=[-500:2:-260, -252:2:-12] | C2=[-500:-259, -253:-12] |

[Motion 131, #SP201, [19] and [20]]

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

[Motion 111, #SP0611-01, [17] and [21]]

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, [7] and [22]]

The 802.11be 320/160+160 MHz non-OFDMA tone plan uses duplicated tone plan of EHT160.

[Motion 34, [7] and [13]]

[Motion 118, [14] and [15]]

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, [7] and [22]]

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

[Motion 11, [3] and [4]]

### Support for large bandwidth

802.11be supports that 80 MHz and 160 MHz operating STA shall be able to participate in a higher BW DL and UL OFDMA transmission.

* STA shall be able to decode the preamble and its assigned RU (some restrictions TBD).
* No capability bit as in 802.11ax.

[Motion 115, #SP75, [14] and [23]]

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, [17] and [24]]

802.11be supports the design of allowing multiplexing STAs of different amendments in one transmission with OFDMA using frequency domain A-PPDU.

* STAs of different amendments may include HE, EHT
  + Post-EHT STA is TBD;
  + The BW allocated to different STAs that can be mixed in one transmission is TBD;
* This feature is targeted for R2.

[Motion 122, #SP156, [10] and [25]]

### 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, [17] and [26]]

### 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, [3] and [27]]

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, [28] and [29]]

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

[Motion 91, [28] and [30]]

#### **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, [28] and [29]]

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

[Motion 78, [28] and [29]]

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

[Motion 79, [28] and [29]]

For 20 MHz and 40 MHz PPDU, combination of RU52 and RU26 are allowed only in locations shown in rows marked by RU78.



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

[Motion 80, [28] and [29]]

[Motion 118, [14] and [15]]

For 80 MHz PPDU, combination of RU52 and RU26 are allowed only in locations shown in rows marked by RU78.



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

[Motion 81, [28] and [29]]

[Motion 118, [14] and [15]]

802.11be supports the following RU106+RU26 combinations as shown in the row marked RU132 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, [17] and [31]]

[Motion 118, [14] and [15]]

802.11be supports the following mandatory RU combinations for small-size RUs:

* {RU26+RU52, RU106+RU26} for non-AP STA only and in OFDMA only.

[Motion 115, #SP71, [14] and [32]]

#### **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, [28] and [33]]

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, [28] and [33]]

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

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

[Motion 98, [28] and [34]]

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

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

[Motion 97, [28] and [34]]

For OFDMA, MRUs allowed in 80 MHz PPDU shall be allowed in each 80 MHz segment of 160 MHz/80 MHz + 80 MHz, 240 MHz/160 MHz + 80 MHz and 320 MHz/160 MHz + 160 MHz PPDU.

[Motion 115, #SP73, [14] and [35]]

For OFDMA, MRUs (996+484) are allowed in the following cases:

* Contiguous 160 MHz in 240 MHz/160 MHz + 80 MHz
* Primary 160 MHz and secondary 160 MHz in 320 MHz/160 MHz + 160 MHz

[Motion 115, #SP74, [14] and [35]]

802.11be supports the following mandatory RU combinations:

* Conditioned on device supporting 80, 160, 240 and 320 MHz transmissions
* BW support for 802.11be AP and non-AP STA is TBD
* NOTE – Currently in the SFD under OFDMA, 2×996+484 and 3×996+484 are TBD

|  |  |  |
| --- | --- | --- |
| **BW** | **RU** | **Mandatory in OFDMA for:** |
| 80 MHz | 484+242 | Non-AP STA only |
| 160 MHz | 996+484 | Non-AP STA only |
| 240 MHz | 2×996+484 | Non-AP STA only |
| 320 MHz | 3×996+484, 3×996 (any 3) | Non-AP STA only |

[Motion 115, #SP72, [14] and [32]]

802.11be supports the mandatory RU combinations for large-size MRUs as shown in the table below:

* Conditioned on device supporting 80, 160, 240 and 320 MHz transmissions
* BW support for 11be AP and non-AP STA is TBD

|  |  |  |
| --- | --- | --- |
| **BW** | **RU** | **Mandatory in Non-OFDMA for:** |
| 80 MHz | 484+242 | AP, STA |
| 160 MHz | 996+484 | AP, STA |
| 996+(484+242) | AP, STA |
| 240 MHz | 3×996, 2×996+484, 2×996 (any 2) | AP, STA |
| 320 MHz | 4×996, 3×996+484, 3×996 (any 3) | AP, STA |

[Motion 115, #SP71, [14] and [32]]

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, [28] and [34]]

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, [28] and [34]]

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, [28] and [34]]

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, [28] and [34]]

MRU 996×2 shall not straddle two 160 MHz channels.

[Motion 122, #SP164, [10] and [11]]

The table below defines 12 options for MRU 996×2+484 in 320 MHz BSS.

* 240/160+80 MHz BW entry is TBD
* NOTE – Shaded area in the table is punctured.



[Motion 122, #SP166, [10] and [11]]

## MU-MIMO

802.11be agrees with the following MU-MIMO support:

* DL MU-MIMO
  + Mandatory support for AP with >=4 antennas
  + Mandatory support for client
  + At least for full BW.  RU/M-RU support TBD
* UL MU-MIMO
  + Mandatory support for AP with >=4 antennas
  + Mandatory support for client
  + At least for full BW.  RU/M-RU support TBD

[Motion 124, #SP181, [1] and [2]]

Support of Nss\_total = 4 is mandatory for 802.11be STA in receiving both sounding NDP and DL MU-MIMO, i.e., beamformee STS capability.

[Motion 124, #SP182, [1] and [2]]

## EHT PPDU formats

The format of the EHT MU PPDU is configured as follow:

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

****

NOTE –This PPDU format is used for 802.11be PPDU transmitted to a single user or multiple users. There is no EHT SU PPDU.

There are two modes in the EHT MU PPDU.

* Compressed mode:
  + Non-OFDMA
  + No RU Allocation subfield in the Common field of the EHT-SIG.
* Non-compressed mode:
  + OFDMA
  + RU Allocation subfield(s) in the Common field of the EHT-SIG.

[Motion 111, #SP0611-08, [17] and [36]]

[Motion 122, #SP140, [10] and [37]]

The format of the EHT TB PPDU is configured as follow:

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

****

NOTE – This format is used for a transmission that is a response to a triggering frame from an AP.

[Motion 111, #SP0611-09, [17] and [36]]

[Motion 122, #SP141, [10] and [37]]

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, [17] and [38]]

## EHT modulation and coding schemes (EHT-MCSs)

### OFDM modulation

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

[Motion 111, #SP0611-21, [17] and [39]]

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

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Coordinate** | **Bits** | | | | | |
| -63 | 0 | 0 | 0 | 0 | 0 | 0 |
| -61 | 0 | 0 | 0 | 0 | 0 | 1 |
| -59 | 0 | 0 | 0 | 0 | 1 | 1 |
| -57 | 0 | 0 | 0 | 0 | 1 | 0 |
| -55 | 0 | 0 | 0 | 1 | 1 | 0 |
| -53 | 0 | 0 | 0 | 1 | 1 | 1 |
| -51 | 0 | 0 | 0 | 1 | 0 | 1 |
| -49 | 0 | 0 | 0 | 1 | 0 | 0 |
| -47 | 0 | 0 | 1 | 1 | 0 | 0 |
| -45 | 0 | 0 | 1 | 1 | 0 | 1 |
| -43 | 0 | 0 | 1 | 1 | 1 | 1 |
| -41 | 0 | 0 | 1 | 1 | 1 | 0 |
| -39 | 0 | 0 | 1 | 0 | 1 | 0 |
| -37 | 0 | 0 | 1 | 0 | 1 | 1 |
| -35 | 0 | 0 | 1 | 0 | 0 | 1 |
| -33 | 0 | 0 | 1 | 0 | 0 | 0 |
| -31 | 0 | 1 | 1 | 0 | 0 | 0 |
| -29 | 0 | 1 | 1 | 0 | 0 | 1 |
| -27 | 0 | 1 | 1 | 0 | 1 | 1 |
| -25 | 0 | 1 | 1 | 0 | 1 | 0 |
| -23 | 0 | 1 | 1 | 1 | 1 | 0 |
| -21 | 0 | 1 | 1 | 1 | 1 | 1 |
| -19 | 0 | 1 | 1 | 1 | 0 | 1 |
| -17 | 0 | 1 | 1 | 1 | 0 | 0 |
| -15 | 0 | 1 | 0 | 1 | 0 | 0 |
| -13 | 0 | 1 | 0 | 1 | 0 | 1 |
| -11 | 0 | 1 | 0 | 1 | 1 | 1 |
| -9 | 0 | 1 | 0 | 1 | 1 | 0 |
| -7 | 0 | 1 | 0 | 0 | 1 | 0 |
| -5 | 0 | 1 | 0 | 0 | 1 | 1 |
| -3 | 0 | 1 | 0 | 0 | 0 | 1 |
| -1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 3 | 1 | 1 | 0 | 0 | 0 | 1 |
| 5 | 1 | 1 | 0 | 0 | 1 | 1 |
| 7 | 1 | 1 | 0 | 0 | 1 | 0 |
| 9 | 1 | 1 | 0 | 1 | 1 | 0 |
| 11 | 1 | 1 | 0 | 1 | 1 | 1 |
| 13 | 1 | 1 | 0 | 1 | 0 | 1 |
| 15 | 1 | 1 | 0 | 1 | 0 | 0 |
| 17 | 1 | 1 | 1 | 1 | 0 | 0 |
| 19 | 1 | 1 | 1 | 1 | 0 | 1 |
| 21 | 1 | 1 | 1 | 1 | 1 | 1 |
| 23 | 1 | 1 | 1 | 1 | 1 | 0 |
| 25 | 1 | 1 | 1 | 0 | 1 | 0 |
| 27 | 1 | 1 | 1 | 0 | 1 | 1 |
| 29 | 1 | 1 | 1 | 0 | 0 | 1 |
| 31 | 1 | 1 | 1 | 0 | 0 | 0 |
| 33 | 1 | 0 | 1 | 0 | 0 | 0 |
| 35 | 1 | 0 | 1 | 0 | 0 | 1 |
| 37 | 1 | 0 | 1 | 0 | 1 | 1 |
| 39 | 1 | 0 | 1 | 0 | 1 | 0 |
| 41 | 1 | 0 | 1 | 1 | 1 | 0 |
| 43 | 1 | 0 | 1 | 1 | 1 | 1 |
| 45 | 1 | 0 | 1 | 1 | 0 | 1 |
| 47 | 1 | 0 | 1 | 1 | 0 | 0 |
| 49 | 1 | 0 | 0 | 1 | 0 | 0 |
| 51 | 1 | 0 | 0 | 1 | 0 | 1 |
| 53 | 1 | 0 | 0 | 1 | 1 | 1 |
| 55 | 1 | 0 | 0 | 1 | 1 | 0 |
| 57 | 1 | 0 | 0 | 0 | 1 | 0 |
| 59 | 1 | 0 | 0 | 0 | 1 | 1 |
| 61 | 1 | 0 | 0 | 0 | 0 | 1 |
| 63 | 1 | 0 | 0 | 0 | 0 | 0 |

[Motion 111, #SP0611-22, [17] and [39]]

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

[Motion 112, #SP20, [17] and [40]]

802.11be devices shall mandatorily support the following modulation order:

* Up to 64 QAM for 20 MHz-only non-AP STA (if defined in EHT)
* Up to 256QAM for all other devices

[Motion 124, #SP176, [1] and [2]]

802.11be agrees that:

* MCS numbering for BSPK – 1024QAM is the same as 802.11ax
* 4096 QAM is defined with R=3/4 and R=5/6
* MCS numbering for 4096 QAM is 12 and 13.

[20/1290r1 (PDT-PHY-Parameters-for-EHT-MCSs, Yujin Noh, Newracom), SP#1, Y/N/A: 42/1/3]

[Motion 131, #SP209, [19] and [41]]

### DCM

DCM+MCS0 for Nss=1 as defined in 802.11ax is a MCS in 802.11be.

* The detailed MCS number for DCM+MCS0 is TBD.
* This is an R1 feature.

[Motion 122, #SP147, [10] and [42]]

802.11be agrees to define a DUP mode for non-punctured 80 MHz, 160 MHz and 320 MHz PPDUs transmitted to a single user, limited to {MCS0+DCM, Nss=1}.

* 80 DUP = 40 (RU 484) duplicated.
* 160 DUP = 80 (RU 996) duplicated.
* 320 DUP = 160 (RU 2×996) duplicated.
* PAPR reduction scheme is TBD.
* Additional diversity scheme is TBD.
* This is an R1 feature.

The mode defined above is limited to 6 GHz.

* NOTE – Whether to further limit this to LPI mode is TBD.

The duplication in the mode defined above is done only on the data tones of the payload portion and that EHT-STF/LTF are based on the total BW.

In this mode,

* For 80 MHz PPDU, the EHT-STF, EHT-LTF and pilot are same as transmitting both RU1 and RU2 of 484-tone RU.
* For 160/320 MHz PPDU, the EHT-STF, EHT-LTF and pilot are same as the non-OFDMA 160/320 MHz PPDU.

PAPR reduction scheme is TBD.

NOTE – pre-EHT modulated fields are TBD.

[Motion 122, #SP162, [10] and [43]]

[Motion 122, #SP163, [10] and [43]]

[Motion 122, #SP170, [10] and [44]]

## EHT preambles

### 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, [3] and [45]]

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

[Motion 29, [7] and [46]]

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, [7] and [47]]

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

[Motion 112, #SP30, [17] and [48]]

802.11be supports the following phase rotation sequence for legacy preamble, RL-SIG, U-SIG and EHT-SIG in 320/160+160 MHz PPDU:

* + [1 -1 -1 -1 1 -1 -1 -1 -1 1 1 1 -1 1 1 1]

[Motion 115, #SP81, [14] and [49]]

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

[Motion 112, #SP31, [17] and [48]]

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, [7] and [50]]

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, [28] and [36]]

### 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-20 MHz.

[Motion 27, [7] and [51]]

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, [7] and [52]]

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



Figure 5 – 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, [7] and [53]]

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

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

[Motion 42, [7] and [52]]

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, [7] and [54]]

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, [7] and [53]]

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, [28] and [55]]

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, [17] and [56]]

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, [17] and [57]]

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

[Motion 112, #SP29, [17] and [57]]

The preamble puncture indication field in U-SIG of an OFDMA transmission in an EHT MU PPDU indicates the preamble puncturing patterns of only the 80 MHz where the U-SIG is being sent.

[Motion 131, #SP194, [19] and [58]]

Regarding preamble puncture flexibility for OFDMA, up to one hole per 80 MHz segments is supported. If punctured, the puncture pattern of each segment shall be one of the followings:

* X212
* 1X12
* 12X2
* 121X
* XX12
* 12XX
* 1XX2

NOTE – Left-to-right represents low-to-high 20MHz channels.

[Motion 131, #SP195, [19] and [58]]

Within one EHT PPDU, the BW field in U-SIG shall indicate the same PPDU bandwidth across different 80MHz segments.

[Motion 122, #SP142, [10] and [59]]

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, [28] and [55]]

A subfield for indication of compressed mode is included in U-SIG as version dependent field.

[Motion 124, #SP183, [1] and [60]]

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, [28] and [61]]

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

* GI+EHT-LTF Size

[Motion 100, [28] and [61]]

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, [28] and [61]]

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, [17] and [62]]

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, [17] and [63]]

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, [17] and [64]]

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

[Motion 111, #SP0611-13, [17] and [56]]

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, [17] and [65]]

The Number of EHT-SIG Symbols field always exists in U-SIG of a PPDU that is not an EHT TB PPDU.

* The field is not reinterpreted as the number of MU-MIMO users.

[Motion 122, #SP138, [10] and [66]]

The bitwidth of the Number of EHT-SIG Symbols field is 5 in U-SIG of a PPDU that is not an EHT TB PPDU.

[Motion 122, #SP139, [10] and [66]]

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 80 MHz segment change is needed while processing L-SIG, U-SIG and EHT-SIG.

[Motion 111, #SP0611-15, [17] and [67]]

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

* NOTE –
  + - 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, [17] and [67]]

### 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, [7] and [52]]

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, [7] and [52]]

A 3-bit subfield for the indication of the number of non-OFDMA users is included in EHT-SIG common field of an EHT MU PPDU for the compressed mode.

[Motion 124, #SP184, [1] and [60]]

The common field of EHT SIG in EHT PPDU that is sent to multiple user includes the CRC and tail bits.

* The number of bits for CRC is TBD.
* The number of tail bits is 6.
* The configuration of the common field is TBD.

[Motion 119, #SP107, [5] and [68]]

The user-specific field of EHT SIG in EHT PPDU that is sent to multiple user consists of the user block field(s) that is made up of 2 user fields except for the last user block.

* The last user block may have one or two user field(s).
* The user block field includes the CRC and tail bits. The number of bits for CRC is 4. The number of tail bits is 6.

[Motion 119, #SP108, [5] and [68]]

The user field in EHT PPDU that is sent to multiple user includes the subfield that indicates the number of spatial streams for each user.

* For MU-MIMO allocation
  + Spatial Configuration
    - Indicates the number of spatial streams for a user in MU-MIMO allocation.
* For non-MU-MIMO allocation
  + NSTS

[Motion 119, #SP120, [5] and [69]]

The spatial configuration subfield of the user field for MU-MIMO allocation consists of 6 bits.

[Motion 119, #SP122, [5] and [69]]

The spatial configuration subfield is defined as described in slide 17~19 of 20/0930r3.







[Motion 119, #SP123, [5] and [69]]

Do you agree that the Nsts subfield of user field for non-MU-MIMO allocation consist of four bits and can indicate 1 to 16 streams consists of 4 bits.

[Motion 119, #SP121, [5] and [69]]

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, [28] and [61]]

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 20 MHz or 40 MHz EHT PPDU sent to multiple users is used,
* N = 2 if an 80 MHz EHT PPDU sent to multiple users is used,
* N = TBD for other cases.
* The compressed modes are TBD.

[Motion 112, #SP46, [17] and [70]]

The number of RU Allocation subfields, when present, in a common field in the EHT-SIG field of EHT PPDU sent to multiple users is 4 and 8 in each content channel for 160 MHz and 320 MHz PPDU, respectively.

[Motion 122, #SP132, [10] and [71]]

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, [17] and [72]]

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, [17] and [73]]

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, [28] and [61]]

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

[Motion 112, #SP44, [17] and [73]]

The RU allocation subfield includes large size of RU aggregation for OFDMA transmission as follows:

* For 80 MHz
  + 484 + 242
* For 160 MHz
  + 484 + 996
* For 320 MHz
  + 3x996
* Other cases are TBD.
* NOTE – Specific RU allocation indication is TBD

[Motion 115, #SP57, [14] and [74]]

For non-compressed mode, each RU Allocation subfield in an EHT-SIG content channel corresponding to a 20 MHz frequency segment indicates the 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 EHT PPDU sent to multiple users in the frequency domain, also indicates information needed to compute the number of users allocated to each RU.

[Motion 115, #SP84, [14] and [75]]

The mapping from the TBD-bit RU Allocation subfield to the RU assignment contains the following entries:

* Other entries TBD
* Compressed mode TBD
* NOTE – Not all the 106+26-tone and 52+26 tone MRU are applicable when PPDU BW is greater than or equal to 80 MHz.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **order** | **#1** | | **#2** | | **#3** | **#4** | **#5** | **#6** | **#7** | | **#8** | **#9** | **Number of entries** |
| TBD | 26 | | 26 | | 26 | 26 | 26 | 26 | 26 | | 26 | 26 | 1 |
| TBD | 26 | | 26 | | 26 | 26 | 26 | 26 | 26 | | 52 | | 1 |
| TBD | 26 | | 26 | | 26 | 26 | 26 | 52 | | | 26 | 26 | 1 |
| TBD | 26 | | 26 | | 26 | 26 | 26 | 52 | | | 52 | | 1 |
| TBD | 26 | | 26 | | 52 | | 26 | 26 | 26 | | 26 | 26 | 1 |
| TBD | 26 | | 26 | | 52 | | 26 | 26 | 26 | | 52 | | 1 |
| TBD | 26 | | 26 | | 52 | | 26 | 52 | | | 26 | 26 | 1 |
| TBD | 26 | | 26 | | 52 | | 26 | 52 | | | 52 | | 1 |
| TBD | 52 | | | | 26 | 26 | 26 | 26 | 26 | | 26 | 26 | 1 |
| TBD | 52 | | | | 26 | 26 | 26 | 26 | 26 | | 52 | | 1 |
| TBD | 52 | | | | 26 | 26 | 26 | 52 | | | 26 | 26 | 1 |
| TBD | 52 | | | | 26 | 26 | 26 | 52 | | | 52 | | 1 |
| TBD | 52 | | | | 52 | | 26 | 26 | 26 | | 26 | 26 | 1 |
| TBD | | 52 | | | 52 | | 26 | 26 | 26 | | 52 | | 1 |
| TBD | | 52 | | | 52 | | 26 | 52 | | | 26 | 26 | 1 |
| TBD | | 52 | | | 52 | | 26 | 52 | | | 52 | | 1 |
| TBD | | 26 | | 26 | 26 | 26 | 26 | 106 | | | | | 1 |
| TBD | | 26 | | 26 | 52 | | 26 | 106 | | | | | 1 |
| TBD | | 52 | | | 26 | 26 | 26 | 106 | | | | | 1 |
| TBD | | 52 | | | 52 | | 26 | 106 | | | | | 1 |
| TBD | | 106 | | | | | 26 | 26 | 26 | | 26 | 26 | 1 |
| TBD | | 106 | | | | | 26 | 26 | 26 | | 52 | | 1 |
| TBD | | 106 | | | | | 26 | 52 | | | 26 | 26 | 1 |
| TBD | | 106 | | | | | 26 | 52 | | | 52 | | 1 |
| TBD | | 52 | | | 52 | | -- | 52 | | | 52 | | 1 |
| TBD | | Punctured 242-tone RU | | | | | | | | | | | 1 |
| TBD | | Unassigned 242-tone RU | | | | | | | | | | | 1 |
| TBD | | 242-tone RU; contributes zero User fields to the User Specific field in the same EHT-SIG content channel as this RU Allocation subfield and is not unallocated | | | | | | | | | | | 1 |
| TBD | | 484-tone RU; contributes zero User fields to the User Specific field in the same EHT-SIG content channel as this RU Allocation subfield and is not unallocated | | | | | | | | | | | 1 |
| TBD | | 996-tone RU; contributes zero User fields to the User Specific field in the same EHT-SIG content channel as this RU Allocation subfield and is not unallocated | | | | | | | | | | | 1 |
| TBD | | 106 | | | | | 26 | 106 | | | | | 1 |
| TBD | | 242 | | | | | | | | | | | 8 |
| TBD | | 484 | | | | | | | | | | | 8 |
| TBD | | 996 | | | | | | | | | | | 8 |
| TBD | | 2\*996 | | | | | | | | | | | 8 |
| TBD | 26 | | | 26 | 26 | 26 | 26 | 52+26 | | | | 26 | 1 |
| TBD | 26 | | | 26+52 | | | 26 | 26 | 26 | | 26 | 26 | 1 |
| TBD | 26 | | | 26+52 | | | 26 | 26 | 26 | | 52 | | 1 |
| TBD | 26 | | | 26+52 | | | 26 | 52 | | | 26 | 26 | 1 |
| TBD | 26 | | | 26 | 52 | | 26 | 52+26 | | | | 26 | 1 |
| TBD | 26 | | | 26+52 | | | 26 | 52+26 | | | | 26 | 1 |
| TBD | 26 | | | 26+52 | | | 26 | 52 | | | 52 | | 1 |
| TBD | 52 | | | | 26 | 26 | 26 | 52+26 | | | | 26 | 1 |
| TBD | 52 | | | | 52 | | 26 | 52+26 | | | | 26 | 1 |
| TBD | 52 | | | | 52+26 | | | 52 | | 52 | | | 1 |
| TBD | 26 | | 26 | | 26 | 26 | 26+106 | | | | | | 1 |
| TBD | 26 | | 26+52 | | | | 26 | 106 | | | | | 1 |
| TBD | 26 | | 26 | | 52 | | 26+106 | | | | | | 1 |
| TBD | 26 | | 26+52 | | | | 26+106 | | | | | | 1 |
| TBD | 52 | | | | 26 | 26 | 26+106 | | | | | | 1 |
| TBD | 52 | | | | 52 | | 26+106 | | | | | | 1 |
| TBD | 106+26 | | | | | | | 26 | 26 | | 26 | 26 | 1 |
| TBD | 106+26 | | | | | | | 26 | 26 | | 52 | | 1 |
| TBD | 106+26 | | | | | | | 52 | | | 26 | 26 | 1 |
| TBD | 106 | | | | | | 26 | 52+26 | | | | 26 | 1 |
| TBD | 106+26 | | | | | | | 52+26 | | | | 26 | 1 |
| TBD | 106+26 | | | | | | | 52 | | | 52 | | 1 |
| TBD | 106+26 | | | | | | | 106 | | | | | 1 |
| TBD | 106 | | | | | | 26+106 | | | | | | 1 |

* STA ID 2046 is indicating unallocated RU for smaller than 242-tone RU.
* Whether STA ID 2046 can be used to indicated unallocated RU for equal or larger than 242-tone RU or not is TBD

NOTE – Punctured RU 242 shall be used when the preamble portion of corresponding 20 MHz is punctured.

[Motion 115, #SP58, [14] and [76]]

[Motion 119, #SP103, [5] and [77]]

[Motion 119, #SP104, [5] and [77]]

[Motion 119, #SP105, [5] and [77]]

[Motion 119, #SP106, [5] and [78]]

[Motion 122, #SP134, [10] and [79]]

[Motion 122, #SP135, [10] and [79]]

[Motion 122, #SP136, [10] and [80]]

[Motion 131, #SP200, [19] and [81]]

RU996+484 is not supported in two contiguous 80 MHz segments that cross two 160MHz channels.

[Motion 122, #SP137, [10] and [80]]

No entry in the RU allocation subfield table is defined for 4×996 RU.

[Motion 131, #SP131, [10] and [82]]

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, [28] and [83]]

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, [17] and [64]]

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, [17] and [56]]

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, [17] and [84]]

### 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, [17] and [85]]

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

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

[Motion 112, #SP9, [17] and [85]]

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

[Motion 112, #SP10, [17] and [85]]

1× and 2× 320/160+160 MHz EHT-STF sequences are designed by repeating 1× and 2× 80 MHz HE-STF sequences, respectively.

* Additional coefficients for phase rotation are TBD.

[Motion 115, #SP56, [14] and [86]]

1× EHT-STF sequence for contiguous 320 MHz PPDU

* *EHTS*-2032:16:2032 = {*M*, 1, -*M*, 0, -*M*, 1, -*M*, 1\*(0, *M*, 1, -*M*, 0, -*M*, 1, -*M*) , -1\*(0, *M*, 1, -*M*, 0, -*M*, 1, -*M*), -1\*(0, *M*, 1, -*M*, 0, -*M*, 1, -*M*)} \* (1+j) / sqrt(2)

1× EHT-STF sequence for non-contiguous 160+160 MHz PPDU

* Low 160 MHz: *EHTS*-1008:16:1008 = {*M*, 1, -*M*, 0, -*M*, 1, -*M*, 0, *M*, 1, -*M*, 0, -*M*, 1, -*M* }\*(1+j) / sqrt(2)
* High 160 MHz: *EHTS*-1008:16:1008 = {-*M*, -1, *M*, 0, *M*, -1, *M*, 0, -*M*, -1, *M*, 0, *M*, -1, *M* }\*(1+j) / sqrt(2)

where *M* = {-1, -1, -1, +1, +1, +1, -1, +1, +1, +1, -1, +1, +1, -1, +1}

[Motion 115, #SP82, [14] and [86]]

2× EHT-STF sequence for contiguous 320 MHz PPDU

* *EHTS*-2040:8:2040 = {*M*, -1, *M*, -1, -*M*, -1, *M*, 0, -*M*, 1, *M*, 1, -*M*, 1, -*M*, 1\*(0, *M*, -1, *M*, -1, -*M*, -1, *M*, 0, -*M*, 1, *M*, 1, -*M*, 1, -*M*), -1\*(0, *M*, -1, *M*, -1, -*M*, -1, *M*, 0, -*M*, 1, *M*, 1, -*M*, 1, -*M*), -1\*(0, *M*, -1, *M*, -1, -*M*, -1, *M*, 0, -*M*, 1, *M*, 1, -*M*, 1, -*M*)}\*(1+j) / sqrt(2)
  + *EHTS*-2040 = *EHTS*-1032 = *EHTS*-1016 = *EHTS*-8 = *EHTS*8 = *EHTS*1016 = *EHTS*1032 = *EHTS*2040 = 0

2× EHT-STF sequence for non-contiguous 160+160 MHz PPDU

* Low 160 MHz: *EHTS*-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* }\*(1+j) / sqrt(2)
  + *EHTS*-1016 = *EHTS*-8 = *EHTS*8 = *EHTS*1016 = 0
* High 160 MHz: *EHTS*-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*}\*(1+j) / sqrt(2)
  + *EHTS*-1016 = *EHTS*-8 = *EHTS*8 = *EHTS*1016 = 0

where *M* = {-1, -1, -1, +1, +1, +1, -1, +1, +1, +1, -1, +1, +1, -1, +1}

[Motion 115, #SP83, [14] and [86]]

### LTF

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

[Motion 74, [28] and [87]]

802.11be shall include 4× EHT-LTF.

[Motion 75, [28] and [88]]

802.11be supports EHT-LTF for 16 spatial streams.

[Motion 83, [28] and [89]]

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

[Motion 112, #SP11, [17] and [90]]

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

[Motion 112, #SP41, [17] and [90]]

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, [17] and [91]]

In a 320 MHz transmission using 1× EHT-LTF, the 1× EHT-LTF sequence is given as below.

*EHTLTF*-2036,2036= {*LTF*80MHz\_1st\_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\_2nd\_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\_3rd\_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\_4th\_1x}

*LTF*80MHz\_1st\_1x = { *LTF*80MHz\_left\_1x, 0, *LTF*80MHz\_right\_1x}

*LTF*80MHz\_2nd\_1x = { *LTF*80MHz\_left\_1x, 0, *LTF*80MHz\_right\_1x}

*LTF*80MHz\_3rd\_1x = { -*LTF*80MHz\_left\_1x, 0, -*LTF*80MHz\_right\_1x}

*LTF*80MHz\_4th\_1x = { -*LTF*80MHz\_left\_1x, 0, -*LTF*80MHz\_right\_1x}

*LTF*80MHz\_left\_1x and *LTF*80MHz\_right\_1x are used as it is in 802.11ax.

[Motion 122, #SP146, [10] and [92]]

### Preamble puncture

CCA minimum BW resolution is 20 MHz.

Preamble puncturing resolution is 20 MHz.

[Motion 90, [28] and [30]]

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

[Motion 30, [7] and [93]]

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

[Motion 31, [7] and [93]]

## Data field

### Scrambler

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

• 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, [17] and [94]]

802.11be supports using the first 11 LSB bits in SERVICE field for 802.11be scrambling seed initialization and keeping the remaining 5 bits as reserved.



Figure 6 – SERVICE field

[Motion 124, #SP172, [1] and [95]]

802.11be supports using the first 7 LSB bits of the SERVICE field in MU-RTS to scramble the CTS data and fill in the first 7 LSB bits of the SERVICE field of the CTS, when MU-RTS is transmitted using an EHT PPDU.

[Motion 124, #SP173, [1] and [95]]

802.11be supports to disallow the 7 LSB bits of the SERVICE field in MU-RTS transmitted using an EHT PPDU to be all zeros.

[Motion 124, #SP174, [1] and [95]]

### Pilot subcarriers

802.11be supports the following pilot indices for 26/52/106/242/484 RU in 80/160/320 MHz PPDU:

* in a OFDMA/non-OFDMA with puncturing 80MHz EHT PPDU
  + [Pilot indices in 40 MHz]-256, [Pilot indices in 40 MHz]+256
* in a OFDMA/non-OFDMA with puncturing 160MHz EHT PPDU
  + [Pilot indices in 80 MHz]-512, [Pilot indices in 80 MHz]+512
* in a OFDMA/non-OFDMA with puncturing 320MHz EHT PPDU
  + [Pilot indices in 160 MHz]-1024, [Pilot indices in 160 MHz]+1024

[Motion 116, [14] and [96]]

802.11be supports the following pilot indices for n×996RUs (n ≥ 1):

* In a OFDMA/non-OFDMA 80 MHz EHT PPDU
  + Pilot indices of 996-tone RU: P996 = {-468, -400, -334, -266, -220, -152, -86, -18, 18, 86, 152, 220, 266, 334, 400, 468}
* In a OFDMA/non-OFDMA 160 MHz EHT PPDU
  + Pilot indices of 996-tone RU: {P996 -512}, {P996 + 512}
  + Pilot indices of 2×996-tone RU: {P996 -512, P996 + 512}
* In a OFDMA/non-OFDMA 320 MHz EHT PPDU
  + Pilot indices of 996-tone RU: {P996 -1536}, {P996 -512}, {P996 + 512}, {P996 + 1536}
  + Pilot indices of 2×996-tone RU: {P996 -1536, P996 -512}, {P996 + 512, P996 + 1536}
  + Pilot indices of 4×996-tone RU: {P996 -1536, P996 -512, P996 + 512, P996 + 1536}

[Motion 115, #SP78, [14] and [97]]

802.11be supports that pilot subcarriers for small/large RU combinations includes the pilot subcarriers of each RU.

[Motion 115, #SP80, [14] and [97]]

All 802.11be PPDUs use single stream pilots in the data section for SU, DL/UL OFDMA as well as DL/UL MU-MIMO transmissions.

[Motion 122, #SP143, [10] and [98]]

802.11be pilot values are shifted on pilot tones in the data section from symbol to symbol for each RU, which is the same as 802.11ax.

[Motion 122, #SP144, [10] and [98]]

802.11be supports to define the following pilot mapping and values.

* For all size of RUs under 2×996-tone RU, pilot mapping and values of 802.11ax are reused.
* For 3×996-tone RU, pilot mapping and values for 996-tone RU are triplicated
* For 4×996-tone RU, pilot mapping and values for 2×996-tone RU are duplicated
* Pilot mapping and values of RU combinations follow each RU’s.

[Motion 122, #SP145, [10] and [98]]

### Segment parser

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

[Motion 111, #SP0611-07, [17], [99], and [100]]

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

[Motion 111, #SP2, [17] and [101]]

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 7 – Propotional round robin parser

[Motion 111, #SP3, [17] and [101]]

802.11be uses 80 MHz segment parser with the following parameters for (242+484)+996:

|  |  |  |  |
| --- | --- | --- | --- |
| **RU Aggregation** | **Nsd\_total** | **Proportional Ratio (m1:m2:m3:m4)** | **Leftover bits (per symbol)** |
| (242+484)+996 | 1682 | 3s:4s | 44×Nbpscs on RU996 |

where

[Motion 115, #SP70, [14] and [102]]

802.11be supports the following DCM scheme for RU/M-RU size > 80 MHz.

* Use segment parser to distribute coded bits to each 80 MHz segment.
* Within each 80 MHz, perform DCM mapping using per 80 MHz Nsd\_k, k is the index of 80 MHz segment.
* This is for R1.

[Motion 122, #SP150, [10] and [103]]

## Coding

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

[Motion 92, [28] and [30]]

Mandatory support requirement of LDPC in 802.11be is the same as in 802.11ax.

[Motion 124, #SP177, [1] and [2]]

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, [17] and [26]]

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, [17] and [26]]

## Interleaving for RUs and aggregated RUs

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, [28] and [104]]

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, [17] and [99]]

802.11be supports the following BCC interleaver parameters for RU78:

* NOTE – The parameters are defined without considering DCM.

|  |  |
| --- | --- |
| **RU78** | **Parameters** |
| Nsd | 72 |
| Ncol | 18 |
| Nrow | 4\*Nbpscs |

[Motion 115, #SP66, [14] and [105]]

802.11be supports the following BCC interleaver parameters for RU132:

* NOTE – The parameters are defined without considering DCM.

|  |  |
| --- | --- |
| **RU132** | **Parameters** |
| Nsd | 126 |
| Ncol | 21 |
| Nrow | 6\*Nbpscs |

[Motion 115, #SP67, [14] and [105]]

802.11be supports the following BCC interleaver parameters for RU52+RU26:

* NOTE – The parameters are defined without considering DCM.

|  |  |
| --- | --- |
| **RU52+RU26** | **Parameters** |
| Nrot | 18 |

[Motion 115, #SP68, [14] and [105]]

802.11be supports the following BCC interleaver parameters for RU106+RU26:

* NOTE – The parameters are defined without considering DCM.

|  |  |
| --- | --- |
| **RU106+RU26** | **Parameters** |
| Nrot | 31 |

[Motion 115, #SP69, [14] and [105]]

The following BCC interleaver and LDPC DTM parameters are defined for DCM.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | NSD | | BCC NCOL | | BCC NROT | | LDPC DTM | |
|  | No DCM | DCM | No DCM | DCM | No DCM | DCM | No DCM | DCM |
| RU78 | 72 | 36 | 18 | **12** | 18 | - | 4 | **3** |
| RU132 | 126 | 63 | 21 | 21 | 31 | - | 6 | 3 |
| RU726 | 702 | 351 | - | - | - | - | 18 | 9 |

* This is for R1.

[Motion 122, #SP149, [10] and [103]]

802.11be supports one padding bit is added after 2 × NDBPS coded bit when BCC is used for RU132 with DCM.

* This is for R1.

[Motion 122, #SP151, [10] and [103]]

802.11be supports define DCM for RU/M-RU size <= 996×2 plus RU 996×3 and 996×4.

* This is for R1.

[Motion 122, #SP148, [10] and [103]]

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, [17] and [106]]

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, [17] and [106]]

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, [17] and [106]]

802.11be supports the following LDPC tone mapper parameters:

* for RU484+RU242: D\_TM = 18

[Motion 111, #SP0611-05, [17] and [106]]

## 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, [17] and [107]]

# EHT MAC



## 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, [7] and [108]]

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, [17] and [109]]

## TXOP

### Bandwidth signaling

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, [17] and [110]]

802.11be supports indicating BW larger than 160 MHz through scrambler sequence in non-HT or non-HT duplicated frames.

[Motion 115, #SP102, [14] and [111]]

### Preamble puncturing

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, [17] and [112]]

## 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, [28] and [113]]

The NS/EP Priority Service if supported by a non-AP STA, shall use an action frame to indicate the need for priority access to its associated AP STA and to be included in Release 1 specification.

NOTE 1 – The identification of the need is outside the scope of this specification.

NOTE 2 – The container of the TID is TBD.

[Motion 115, #SP90, [14] and [114]]

[Motion 126, [1] and [115]]

The Priority Service Information shall be defined in EHT MAC Capability Information Element to exchange the NS/EP Priority Service capability information between AP STA and non-AP STA.

NOTE – It is an R1 feature.

[Motion 131, #SP207, [19] and [115]]

# Coexistence and regulatory rules



## 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



## General

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

## Subchannel selective transmission

802.11be supports extending the SST mechanism so that an 80 MHz/160 MHz (20 MHz TBD) operating STA can operate in the secondary 160 MHz channel in R2.

[Motion 119, #SP129, [5] and [116]]

## A-control subfield

802.11be supports indicating the channel availability up to 320 MHz channel in the A-control subfield.

* NOTE – The detailed solution is TBD.

[Motion 119, #SP128, [5] and [117]]

802.11be supports to indicate the channel availability of 320 MHz channel by carrying two BQR Control subfields in A-control subfield in R2.

[Motion 124, #SP171, [1] and [118]]

# Multi-link operation



## 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, [7] and [119]]

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, [7] and [119]]

## Multi-link discovery

### Discovery procedures and RNR

802.11be shall define mechanism(s) for an AP of an AP MLD to advertise complete or partial information of other links:

* Partial information to prevent frame bloating.
* For example, frames exchanged during ML setup are expected to carry complete information while Beacon frame is expected to carry partial information.
* The exact set of elements/fields that constitute partial information is TBD.

[Motion 115, #SP93, [14] and [120]]

All APs that are part of the same MLD as a reporting AP and that are collocated with the reporting AP shall be reported in the RNR element that is included in the beacons and the broadcast probe responses transmitted by the reporting AP when the reporting AP is either not part of a multiple BSSID set or corresponds to a transmitted BSSID in a multiple BSSID set.

* NOTE 1 – An AP is not included if it is not discoverable.
* NOTE 2 – RNR provides basic information (e.g., operating class, channel, BSSID, short SSID).

[Motion 115, #SP95, [14] and [121]]

802.11be agrees to include in a TBTT Information field of the RNR, corresponding to a reported AP that is part of the same MLD as the reporting AP, an indication that the reported AP is part of the same MLD as the reporting AP when the reporting AP is either not part of a multiple BSSID set or corresponds to a transmitted BSSID in a multiple BSSID set.

* NOTE – Signaling of that indication is TBD.

[Motion 115, #SP96, [14] and [121]]

All APs that are part of the same MLD as a non-transmitted BSSID and that are collocated with the non-transmitted BSSID shall be reported in the RNR element that is included in the beacons and the broadcast probe responses transmitted by the transmitted BSSID that is in the same Multiple BSSID set as the non-transmitted BSSID.

If a reporting AP is part of an AP MLD and is in the same collocated set as APs affiliated with another AP MLD for which there are no affiliated APs operating on the same channel as the reporting AP, each AP of the other AP MLD shall be reported in the RNR element that is included in the beacons and the broadcast probe responses transmitted by the reporting AP if at least one AP of the other AP MLD is in the same multiple BSSID set as an AP affiliated with the AP MLD of the reporting AP, unless the APs of the other AP MLDs are already reported in beacons and the broadcast probe responses transmitted by an AP in the same collocated set as the reporting AP on the same channel as the reporting AP.

[Motion 119, #SP127, [5] and [122]]

802.11be agrees to define a mechanism for a STA of a non-AP MLD to send a probe request frame to an AP belonging to an AP MLD, which enables to request a probe response from the AP that includes the complete set of capabilities, parameters and operation elements of other APs affiliated to the same MLD as the AP

* The complete information is defined as all elements that would be provided if the reported AP was transmitting that same frame (exceptions TBD).
* It is TBD if the AP is mandated or not to respond with the requested information.
* NOTE 1 – Such a directed probe request requesting complete MLO information for one or more APs of the MLD is referred to as an ML probe request.
* NOTE 2 – A probe response sent in response to an ML probe request containing complete MLO Information for the requested AP(s) is referred to as an ML probe response.

[Motion 115, #SP97, [14] and [121]]

[Motion 119, #SP109, [5] and [123]]

802.11be agrees to add MLD-index to the TBTT Information field of the RNR element, which is used to indicate the ID of the AP MLD in which the reported AP is if the reported AP in an AP MLD.

* MLD-Index is set to BSSID Index of a non-transmitted BSSID if the reported AP is the in the same MLD as the non-transmitted BSSID and the reporting AP is the same multiple BSSID set as the non-transmitted BSSID.
* MLD-Index is set to zero if the reported AP is in the same MLD as the reporting AP.
* MLD-Index of the AP MLD in which the reported AP is shall be unique in the frame sent by the reporting AP.

[Motion 124, #SP185, [1] and [124]]

802.11be agrees to carry Link ID in the TBTT Information field of the RNR element, which is used to indicate the identifier of the reported AP if the reported AP is in an AP MLD.

* The link identifier (Link ID) uniquely identifies a link (tuple consisting of Operational Class, Channel, BSSID) within an MLD.

[Motion 124, #SP186, [1] and [124]]

### ML element structure

802.11be defines mechanism(s) to include MLO information that a STA of an MLD provides in its mgmt. frames, during discovery and ML setup, as described below:

* MLD (common) Information
  + Information common to all the STAs of the MLD.
* Per-link information
  + Capabilities and Operational parameter of other STAs of the MLD other than the advertising STA.

[Motion 115, #SP91, [14] and [120]]

802.11be supports that the MLO framework should follow an inheritance model when advertising complete information of other link(s):

* NOTE – Inheritance mechanism is similar to that defined in 802.11ax for multiple BSSID feature.

[Motion 115, #SP92, [14] and [120]]

802.11be agrees to define a new Multi-Link element (MLE) to report/describe multiple STAs of an MLD with at least the following characteristics:

* MLD-level information may be included
* A STA profile subelement is included for each reported STA (if any) and is made of a variable number of elements describing this STA

NOTE 1 – A control field for the element is not considered as MLD-level information.

NOTE 2 – Name can be changed.

[Motion 115, #SP98, [14] and [125]]

802.11be supports that, for the ML element, an inheritance model is defined to prevent frame bloating when advertising complete information of other links.

* Define the inheritance mechanism, similar to 802.11ax, so that the value of an element of a reported STA that is not present in a STA profile of a ML element in a frame sent by a reporting STA is the same as the element of the reporting STA, present elsewhere in the frame.
* Define the inheritance mechanism, similar to 802.11ax, so that the value of an element of a reported STA that is not present in a STA profile of a ML element, if any, included in a non-transmitted BSSID profile of a non-transmitted BSSID in a multiple BSSID element in a frame sent by a reporting STA is the same as the element of the non-transmitted BSSID, present elsewhere in the frame or as the element of the reporting STA, present elsewhere in the frame.
* Note: an “element of a STA” refers in the text above to the instance of the element describing the capabilities/operation/functionalities of that STA, in a frame where multiple instances of the element can be found for other STAs.
* NOTE – Some elements may not be inherited, signaling TBD.

[Motion 115, #SP99, [14] and [125]]

An AP shall not include a RNR element in a STA profile subelement of a Multi-Link element.

An AP shall not include a MBSSID element in a STA profile subelement of a Multi-Link element.

An ML element shall not be included in a STA profile subelement of another Multi-Link element.

NOTE – It is an R1 feature.

[Motion 131, #SP193, [19] and [126]]

802.11be agrees to include a Control field in Multi-Link element to indicate the presence of certain fields.

[Motion 119, #SP124, [5] and [127]]

### Usage and rules of ML information element in the context of discovery

The Multi-Link element when included in a Beacon or non-ML Probe Response frame should carry only MLD-level/common information.

* NOTE 1 – Exact name for the element is TBD.
* NOTE 2 – Whether the Multi-Link element is always present in the Beacon and non-ML Probe Response frames or is optionally present is TBD.
* NOTE 3 – MLD-Level/Common information includes at least MLD Address, and other information (TBD).

[Motion 119, #SP111, [5] and [123]]

## Multi-link setup

### Procedure

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, [7] and [119]]

[Motion 111, #SP0611-28, [17] and [128]]

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, [17] and [128]]

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, [28] and [129]]

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, [28] and [129]]

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 1 – Specific signaling for update indication is TBD.

NOTE 2 – Limitations on dynamic updating is TBD.

[Motion 112, #SP4, [17] and [130]]

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, [7] and [131]]

If a MLD can support transmission on link 1 concurrent with reception on link2, but cannot support transmit on link2 concurrent with reception on link1, this pair of links will be non-STR.

[Motion 122, #SP167, [10] and [132]]

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

[Motion 26, [7] and [133]]

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, [7] and [133]]

802.11be agrees to define the following mechanism:

* A STA of a non-AP MLD can request a peer AP of AP MLD a part of complete information of other APs of the same AP MLD.
* The signaling for requesting the part of complete information is TBD.
* NOTE – As an example, the part of complete information may be information that is not included on the beacon frame sent from the peer AP.

[Motion 131, #SP190, [19] and [134]]

802.11be supports the following:

* Existing frames are reused for discovering APs that are affiliated with AP MLD.
* Association Request and Association Response frames are reused for multi-link setup.
* NOTE – After association, new signaling to query AP link specific parameters or AP MLD parameters by using Protected Management Frames (PMF) encrypted Management frames is TBD.

[Motion 115, #SP76, [14] and [135]]

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

[Motion 70, [28] and [136]]

802.11be supports the following:

* Reuse disassociation frame for multi-link teardown.
* Reuse authentication frame for multi-link SAE exchange and multi-link Open System authentication.

[Motion 115, #SP88, [14] and [137]]

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, [17] and [138]]

TGbe shall define a multi-link resetup mechanism to resetup with another AP MLD or changing configuration of existing multi-link setup with an AP MLD.

* Reassociation Request/Response frame is used for this purpose.

[Motion 115, #SP86, [14] and [139]]

When a non-AP MLD that has multi-link setup with current AP MLD sends a Reassociation Request frame to a new AP MLD, AP MLD MAC address of the current AP MLD is used in Current AP Address field of the frame.

[Motion 115, #SP87, [14] and [139]]

When a STA of a non-AP MLD that has multi-link setup with current AP MLD sends a Reassociation Request frame to a new AP that is not affiliated with an AP MLD, AP MLD MAC address of the current AP MLD is used in Current AP Address field of the frame.

* NOTE – Only the STA that sends the Reassociation Request frame can associate with the new AP.

[Motion 115, #SP94, [14] and [139]]

### MLD transition

After a successful multi-link (re)setup between a non-AP MLD and an AP MLD, the non-AP MLD is in associated state and is (re)associated with the AP MLD, and the non-AP MLD to the AP MLD mapping is provided to the DS by the AP MLD.

* For each setup link, the corresponding non-AP STA affiliated with the non-AP MLD is in the same associated state as the non-AP MLD and is associated with the corresponding AP affiliated with the AP MLD, without providing the corresponding non-AP STA to the corresponding AP mapping to the DS, and enables the functionalities between a non-AP STA and its associated AP unless the functionalities have been extended to MLD level and specified otherwise.

After a successful multi-link tear down between a non-AP MLD and an AP MLD, the non-AP MLD is in unassociated state and is disassociated with the AP MLD.

* All the non-AP STAs affiliated with the non-AP MLD are in the unassociated state.

NOTE – A non-AP MLD needs to perform successful multi-link (re)setup with AP MLD before the non-AP MLD is allowed to send/receive MSDU(s) via the AP MLD to the DS.

[Motion 131, #SP192, [19] and [140]]

Define ML transition\* as follows:

* A non-AP MLD movement from being associated with one AP MLD in one ESS to be reassociated with another AP MLD within the same ESS.
* A non-AP MLD movement from being associated with one AP MLD in one ESS to become a non-AP STA that is reassociated with an AP within the same ESS.
* A non-AP STA movement from being associated with one AP in one ESS to become a non-AP MLD that is reassociated with an AP MLD with the same ESS.

Define fast ML transition\* as follows:

* A ML transition\* that establishes the state necessary for data connectivity before the reassociation rather than after the reassociation.

NOTE 1 – \* the name can be changed.

NOTE 2 – It is an R1 feature.

[Motion 131, #SP196, [19] and [141]]

802.11be supports to reuse existing frame exchange of over-the-air fast BSS transition (FT) for fast ML transition in R1.

[Motion 131, #SP197, [19] and [141]]

For a non-AP MLD and an AP MLD in a FT initial mobility domain operation, use non-AP MLD address as S1KH-ID and S0KH-ID and AP MLD address as R1KH-ID. Use AP MLD address and non-AP MLD address to compute PMKID, PTK, and PTKName.

For a non-AP MLD and a target AP MLD in an over-the-air FT operation, use non-AP MLD address as S1KH-ID and AP MLD address as R1KH-ID. Use AP MLD address and non-AP MLD address to compute PMKID, PTK, and PTKName.

NOTE – It is an R1 feature.

[Motion 131, #SP203, [19] and [142]]

For a non-AP MLD and an AP MLD in a FT initial mobility domain operation, different GTK/IGTK/BIGTK of different setup links are delivered in one FT 4-way handshake.

For a non-AP MLD and a target AP MLD in an over-the-air FT operation, different GTK/IGTK/BIGTK of different setup links are delivered in FTE of reassociation response of the over-the-air FT protocol.

NOTE – It is an R1 feature.

[Motion 131, #SP204, [19] and [142]]

### Security

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, [28] and [143]]

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, [17] and [144]]

### Usage and rules of ML Information element

802.11be supports the following:

* An AP that is part of an AP MLD that supports SAE authentication shall include the MLD address in beacon and probe response frames it transmits.
* EHT MLD shall indicate its MLD MAC address during authentication request/response exchange.

[Motion 115, #SP89, [14] and [137]]

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

[Motion 112, #SP32, [17] and [145]]

802.11be supports that a non-AP MLD may initiate multi-link setup with an AP MLD to setup more than one link with subset of APs affiliated with the AP MLD. This is for R1.

[Motion 122, #SP133, [10] and [146]]

During multi-link setup, a non-AP MLD includes in a Multi-Link element included in Association Request frame the complete information of affiliated non-AP STAs corresponding to the links requested for setup.

NOTE – It is an R1 feature.

[Motion 131, #SP202, [19] and [147]]

During multi-link setup, when an AP MLD accepts the association request of a non-AP MLD, the AP MLD provides in a Multi-Link element included in Association Response frame the complete information of affiliated APs corresponding to the links that are accepted by the AP MLD and requested by the non-AP MLD.

NOTE – It is an R1 feature.

[Motion 131, #SP205, [19] and [147]]

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, [7] and [148]]

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, [7] and [149]]

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

[Motion 68, [28] and [150]]

802.11be supports that an STA of an MLD can provide MLD-level information that is common to all STAs affiliated with the MLD and per-link information that is specific to the STA on each link in management frames during multi-link setup.

* The specific information is TBD.

[Motion 115, #SP65, [14] and [135]]

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, [17] and [151]]

## TID-to-link mapping and link management

### Default mode and enablement

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, [28] and [152]]

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, [28] and [153]]

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

[Motion 102, [28] and [152]]

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, [28] and [152]]

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

[Motion 112, #SP51, [17] and [154]]

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, [3] and [155]]

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, [17] and [154]]

### 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, [28] and [156]]

### Individual addressed data delivery

After multi-link setup, the following is enabled to deliver individual addressed QoS traffic of a TID without BA negotiation across links, where the TID is mapped, in R1.

* For Transmitter:
  + Expand Table 10-5—Transmitter sequence number spaces to have a new entry Indexed by <destined MLD Address, TID> .
  + Continue to transmit the failed QoS Data frame until the retry counter is met.
  + Cannot transmit other QoS Data frame from the same TID in any link until the current frame finish transmission or dropped.
* For Receiver:
  + Maintain at least the most recent record of <peer MLD address, TID, sequence number>.
  + Drop the frame with retry bit set and record match.

[Motion 122, #SP158, [10] and [157]]

### Retransmission

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.

NOTE – QoS Data frames that are not fragments might be retransmitted on any available link.

[Motion 61, [28] and [158]]

[Motion 115, #SP85, [14] and [159]]

## Multi-link block ack

### Procedures

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, [7] and [160]]

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

[Motion 67, [28] and [161]]

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, [28] and [158]]

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, [28] and [158]]

802.11be supports allowing an EHT STA to use HE SU PPDU to carry the solicited BA if the transmit time of HE SU PPDU is less than the PPDU duration of a non-HT PPDU containing the Control frame sent at the primary rate.

[Motion 115, #SP63, [14] and [162]]

802.11be supports allowing an EHT SU PPDU to carry the solicited BA if the transmit time of EHT SU PPDU is less than the PPDU duration of a non-HT PPDU containing the Control frame sent at the primary rate and the soliciting PPDU is EHT PPDU.

[Motion 115, #SP64, [14] and [162]]

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, [17] and [163]]

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, [17] and [164]]

### Sharing and extension of SN space

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, [7] and [160]]

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, [17] and [165]]

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, [17] and [166]]

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, [17] and [166]]

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, [17] and [167]]

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, [17] and [168]]

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, [17] and [168]]

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 1 and B0 equal to 0 in Fragment Number field to indicate 1024 BA bitmap length in compressed BA and multi-STA BA.

[Motion 112, #SP24, [17] and [169]]

[Motion 133, [19]]

## Power save

### Traffic indication

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, [28] and [170]]

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, [28] and [171]]

A bit in a partial virtual bitmap of a TIM element that corresponds to a non-AP MLD is set to 1 if any individually addressed BUs for the non-AP MLD are buffered by the AP MLD.

[Motion 115, #SP61, [14] and [172]]

When a non-AP MLD made a multi-link setup with an AP MLD, one AID is assigned to the non-AP MLD across all links.

[Motion 115, #SP62, [14] and [172]]

A non-AP MLD shall have the same U-APSD Flag value for each AC across all links that multi-link is setup. This is for R1.

[Motion 122, #SP157, [10] and [173]]

### Power state indication

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, [28] and [174]]

### BSS parameter update

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, [28] and [175]]

A non-AP MLD shall maintain a record of the most recently received change sequence number for each reported APs in the AP MLD with which it has multi-link setup.

[20/0503r2 (BSS parameter update for Multi-link Operation, Ming Gan, Huawei), SP#2, Y/N/A: 51/7/14]

[Motion 115, #SP101, [14] and [176]]

An AP in an AP MLD shall provide BSS specific parameters update indication for one or more other APs in the same AP MLD.

* The detail for BSS specific parameters update indication is TBD.

[Motion 115, #SP59, [14] and [177]]

802.11be supports that an AP within an AP MLD shall include in the Beacon and Probe Response frames it transmits the Change Sequence fields that indicate changes of system information for the transmitting AP and other APs within the same AP MLD, where the change sequence field value for each AP is initialized to 0, and is incremented when there is a critical update to the operational parameters for that AP.

* TBD field(s) to carry the change sequence(s) of the transmitting AP and of non-transmitted BSSIDs (if any).
* The change sequence information for another AP of the MLD shall be carried in a field in the TBTT Information field of the Reduced Neighbor Report element corresponding to that AP.
* A TBD subfield in the Capability Information field of the Beacon frame shall provide an early indication of an update to change sequence information in the RNR for any AP of the reporting AP’s MLD.
  + NOTE – For an AP corresponding to nontransmitted BSSID in a multiple BSSID set, the early indication is carried in the Nontransmitted BSSID Capability field (which has the same structure as the Capability Information field) and signals the update to change sequence information in RNR for APs corresponding to the MLD to which the nontransmitted BSSID is affiliated with.
* The critical updates are defined in 11.2.3.15 (TIM Broadcast) and the additional update can be added if needed.
* The field is at most 1 octet in length and the value carried in the field is modulo of the maximum value.
* NOTE – It is optional for non-AP MLD to decode the subfield in the Capability Information field carrying the early indication.

[Motion 115, #SP77, [14] and [178]]

[Motion 131, #SP191, [19] and [179]]

### TWT

Individual TWT agreement(s) could be set up on a setup link for more than one setup link.

[Motion 115, #SP60, [14] and [177]]

### Other procedures

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, [28] and [170]]

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, [28] and [153]]

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, [17] and [180]]

The MLD Max Idle Period of an AP MLD applies at the MLD level and not at the STA level.

The MLD Max Idle Period of an AP MLD indicates, for a non-AP MLD, the time period during which a non-AP MLD can be inactive (i.e., refrain from transmitting frames to the AP MLD on any of the setup links) without the Multi-link setup to be torn down.

A non-AP MLD is considered inactive if none of the APs of the AP MLD have received a Data frame, PS-Poll frame, or Management frame (protected or unprotected) of a frame exchange sequence initiated by a STA from the non-AP MLD for a time period greater than or equal to the time specified by the MLD Max Idle Period of the AP MLD.

If the non-AP MLD is inactive for a duration greater than the MLD Max Idle Period, then the AP MLD may tear down the multi-link setup for that non-AP MLD.

[Motion 115, #SP100, [14] and [181]]

## Multi-link group addressed frame delivery

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

[Motion 112, #SP37, [17] and [182]]

802.11be supports the following group addressed frames delivery mechanism in R1:

* An AP MLD should not cause a STA affiliated to a non-STR non-AP MLD to transmit an MPDU that overlaps with group addressed frames in a constrained link if another STA affiliated to the same non-STR non-AP MLD is expected to be receiving group addressed frames.

[Motion 122, #SP155, [10] and [183]]

802.11be supports the following loopback prevention mechanism of the group address frame in the MLO in R1.

* An AP MLD that broadcasts the group addressed MPDU received from a non-AP MLD with which it has done multi-link setup shall set the SA field of the broadcast group addressed MPDU to the MLD MAC address of the non-AP MLD.
* A non-AP MLD filters out the group addressed MPDU with the SA field set to the MLD MAC address of the non-AP MLD.

[Motion 131, #SP199, [19] and [184]]

802.11be agrees that each AP in an AP MLD shall independently transmit all bufferable group addressed Management frames after every DTIM beacon in R1.

[Motion 131, #SP206, [19] and [185]]

## Multi-link channel access

### STR: General

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, [7] and [186]]

### Non-STR: General

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, [17] and [187]]

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, [17] and [188]]

### Capability signaling

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, [7] and [189]]

### End PPDU alignment

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 or equal to 8 μs ((aSIFSTime + aSignalExtension)/2).
  + Where the reference of the ending time of the PPDU is not including the Signal Extension field.

[Motion 111, #SP0611-31, [17] and [190]]

[Motion 122, #SP152, [10] and [191]]

802.11be supports the following Trigger frame transmission rule in the MLO:

* An AP in the AP MLD shall not send a Trigger frame with the CS Required subfield set to 1 to a STA in a non-STR non-AP MLD, when at least one PPDU from other STAs affiliated to the same non-STR non-AP MLD is scheduled for transmission before (aSIFSTime + aSignalExtention – aRxTxTurnaroundTime) has expired after the PPDU containing the Trigger frame.
  + NOTE 1 – In the above, aRxTxTurnaroundTime is 4 μs.
  + NOTE 2 – The ending time of a first PPDU that carrying a frame soliciting an immediate response frame cannot be earlier more than aRxTxTurnaroundTime of the ending time of a second PPDU containing a Trigger frame with the CS Required subfield set to 1.
  + NOTE 3 – The AP STA still follows the CS Required rule defined in 802.11ax.

[Motion 122, #SP153, [10] and [192]]

802.11be supports the following Trigger frame transmission rule in the MLO in R1:

* When an AP MLD triggers simultaneously TB PPDUs from more than one STAs affiliated to the same non-STR non-AP MLD and allows the frames in the TB PPDUs to solicit control response frames from the AP MLD, then the UL Length subfield values in the soliciting Trigger frames shall be set to the same value.

[Motion 122, #SP154, [10] and [192]]

An AP MLD shall align the end of DL PPDUs (that contain QoS data soliciting an immediate UL response) that are sent simultaneously on multiple links to the same non-STR non-AP MLD, in such a way that the response to any of the PPDUs will not overlap with any of the DL PPDUs in R1.An exception is that a high priority DL PPDU sent on one link may not be aligned with another DL PPDU sent on the other link.

[Motion 122, #SP159, [10] and [193]]

802.11be supports that the padding procedures of 802.11ax can be used when transmitting a Trigger frame to extend the frame length to meet the ending time requirement of the PPDU carrying the Trigger frame in the MLO.

* NOTE – The Padding field in the Trigger frame is also included in the padding procedure.

[Motion 122, #SP168, [10] and [194]]

### STA ID indication

802.11be supports that the STA ID field in a downlink EHT SU PPDU sent from an EHT AP to an EHT STA identifies the recipient EHT STA.

* NOTE – The size and encoding of the STA ID field in the downlink EHT SU PPDU is TBD.

[Motion 122, #SP160, [10] and [195]]

802.11be supports that the STA ID field in an uplink EHT SU PPDU sent from an EHT STA to an EHT AP identifies the transmitter EHT STA.

* NOTE – The size and encoding of the STA ID field in the uplink EHT SU PPDU is TBD.

[Motion 122, #SP161, [10] and [195]]

## Multi-BSSID operation

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, [17] and [196]]

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, [17] and [196]]

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, [17] and [196]]

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, [17] and [197]]

## Quality of service for latency sensitive traffic

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

[Motion 112, #SP49, [17] and [198]]

802.11be supports to define a mechanism so that an EHT AP MLD can provide information about traffic conditions of each link (e.g., DL transmit Delay, BSS load).

* Signaling details is TBD.

[Motion 119, #SP110, [5] and [199]]

## Multi-link single radio operation

Single-link/radio (TBD) non-AP MLD: A non-AP MLD that supports operation on more than one link but can only receive, or transmit frames on one link at a time.

[Motion 119, #SP118, [5] and [200]]

[Motion 119, #SP125, [5] and [201]]

802.11be supports the multi-link operation for a non-AP MLD that is defined as follows to be included in R1.

* A non-AP MLD that can: 1) transmit or receive data/management frames to another MLD on one link at a time, and 2) listening on one or more links.
  + The “listening” operation includes CCA as well as receiving initial control messages (e.g., RTS/MU-RTS).
  + The initial control message may have one or more additional limitations: spatial stream, MCS (data rate), PPDU type, frame type.
  + Link switch delay may be indicated by the non-AP MLD.

[Motion 119, #SP126, [5] and [202]]

## Enhanced multi-link operation mode

802.11be shall define a mechanism that in R1 a non-AP MLD indicates maximum number of spatial streams that it is capable of transmitting or receiving at a time, while operating in any of the links within the specified set of links in which the enhanced multi-link operation mode is applied.

* Each STA in the non-AP MLD operating in any of the links within the specified set of links shall support the indicated maximum number of spatial streams.
* The enhanced multi-link operation mode is optional mechanism.

NOTE – The name of the enhanced multi-link operation mode can be changed.

[Motion 124, #SP187, [1] and [203]]

## Soft AP for MLD operation

802.11be defines mechanisms to support the operation of a Non-STR AP MLD in R1. The mechanisms are limited to instantiate a Non-STR Non-AP MLD as a Soft AP that could utilize all its links under TBD conditions. The exact language to govern such scope is TBD.

[Motion 125, [1] and [204]]

# Multi-band and multichannel aggregation and operation



## 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



## 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, [28] and [205]]

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

[Motion 66, [28] and [205]]

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, [17] and [206]]

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, [17] and [207]]

# Multi-AP operation



## 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, [28] and [208]]

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, [28] and [208]]

802.11be supports the following:

* Sharing AP and Shared AP may not have the same primary 20 MHz channel.
* The primary 20 MHz channel of the shared AP shall be within the BSS operating channel width of the sharing AP.
* The primary 20 MHz channel of the sharing AP shall be within the BSS operating channel width of the shared AP.

[Motion 119, #SP113, [5] and [209]]

802.11be supports defining the modes of AP coordination that share frequency resources with one or more APs within the AP candidate set only for 20 MHz channels allocated by a sharing AP to a shared AP within the BSS operating channel of the shared AP.

* NOTE – 20 MHz channels allocated by a sharing AP within the 20 MHz channels on which the sharing AP gained channel access.

[Motion 119, #SP114, [5] and [209]]

## 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, [7] and [210]]

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, [7] and [210]]

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, [17] and [211]]

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, [17] and [211]]

In sequential channel sounding sequence for multi-AP, 802.11be supports the following:

* STA can process the NDPA frame and the BFRP Trigger frame received from the OBSS AP.
* If polled by the BFRP trigger frame from the OBSS AP, the STA responds with the corresponding channel state information (CSI) to the OBSS AP

NOTE 1 – Details of the CSI report are TBD.NOTE 2 – The OBSS AP belongs to the multi-AP set serving the STA and the details regarding formulation of the multi-AP set are TBD.NOTE 3 – This feature is for R2.

[Motion 119, #SP119, [5] and [212]]

## Coordinated transmission

802.11be shall define an AP candidate set\* as follows:

* An AP candidate set is a set of APs that can initiate or participate in Multi-AP Coordination.
* An AP in an AP candidate set can participate as a shared AP in Multi-AP Coordination initiated by a sharing AP in the same AP candidate set.
* At least one AP in an AP candidate set shall be capable of being a sharing AP.
* NOTE – The name\* can be changed.

[Motion 55, [28] and [213]]

[Motion 124, #SP188, [1] and [214]]

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, [28] and [215]]

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, [28] and [216]]

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, [17] and [215]]

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, [17] and [215]]

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

[Motion 60, [28] and [217]]

802.11be will adopt Coordinated UL MU-MIMO as a Multi-AP Coordination scheme for UL transmissions in R2.

* NOTE – Not for joint reception.

[Motion 124, #SP189, [1] and [218]]

802.11be believes the hidden node problem in multi-AP environments (e.g. coordinated AP transmission) should be addressed.

[20/0933r1 (Hidden Node Protection in Coordinated AP Transmissions, Dennis Sundman, Ericsson), SP#1, Y/N/A: 87/4/24]

[Motion 131, #SP208, [19] and [219]]

## 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, [17] and [220]]

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, [17] and [221]]

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, [17] and [222]]

# Link adaptation and retransmission protocols



## General

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

## Feature #1

Description for feature #1

# Low latency



## General

This section describes features related to low latency.

## Feature #1

Description for feature #1

# Frame Format

## General

This section describes features related to frame format.

## 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, [17] and [223]]

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, [17] and [122]]

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, [17] and [224]]

# Security

## General

This section describes features related to security.

An EHT RSNA STA shall support GCMP-256.

[Motion 119, #SP130, [5] and [225]]

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