IEEE P802.11
Wireless LANs

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| MAC PDT 37.15.2.1 CoBF – Part 2 |
| Date: July 10th, 2025 |
| Author(s): |
| Name | Affiliation | Address | Phone | email |
| Sherief Helwa | Qualcomm |  |  | shelwa@qti.qualcomm.com |
| George Cherian | Qualcomm |  |  |  |
| Alfred Asterjadhi | Qualcomm |  |  |  |
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 Abstract

This document contains Proposed Draft Text (PDT) for the coordinated beamforming protocol of the TGbn (UHR, Ultra High Reliability) amendment to the 802.11 standard.

Revisions:

* Rev 0: Initial version of the document.

**Explanation of the proposed changes:**

The proposed changes to the 802.11 TGbn draft within this document are based on multiple discussions among the TGbn task group members.

**Relevant passed motions:**

**[Motion #29]**

**TGbn defines multi-AP Coordinated Beamforming (Co-BF).**

**[Motion #99]**

**The Coordinated beamforming (Co-BF) transmission phase in 802.11bn shall be limited to 2 APs.**

 **[Motion #114]**

**In a Co-BF transmission, the maximum number of spatial streams given to one user will be 2.**

**[Motion #298]**

**802.11bn defines the concept of a sync-reference AP and a sync-follower AP for CFO correction in Co-BF**

* + **Sync-follower AP pre-corrections needed**
	+ **For sequential sounding:**
		- **All the NDPs sent by it during sounding phase that are sent for the purpose of sounding the STAs in the other BSS (Mandatory)**
		- **For the NDPs sent by it for sounding the STAs in its own BSS, it is recommended but not mandatory that the sync follower AP pre-correct those NDPs**
	+ **For joint sounding**
		- **All the NDPs sent by it during the sounding phase (Mandatory)**
		- **The Co-BF sync and COBF PPDU during transmission phase using the same frequency pre-correction value as the sounding phase, when it is the sharing AP**
	+ **Sync-reference AP does not pre-correct during transmission phase when it is the sharing AP**

**[Motion #299]**

**The sync-follower AP shall use the NDPA frame sent by the sync-reference AP to pre-correct the NDP frequency to be within a TBD range (e.g., 350Hz) of the sync-reference AP’s frequency**

* + **Applies to sequential and joint sounding**
	+ **The pre-correction of cross-BSS NDP and joint NDP is mandatory**
	+ **The pre-correction of in-BSS NDPs is recommended but not a mandatory requirement**

**[Motion #300]**

**The sharing AP is the AP that transmits the final sync frame before the Co-BF PPDU**

* + **Regardless of who is the sync-reference**
	+ **Note: This ensures a consistent protocol and a consistent behavior at sharing AP**

**[Motion #301]**

**The shared AP always pre-corrects Co-BF PPDU based on the final sync**

* + **To bring the two APs within a TBD frequency range of each other (e.g., ~350Hz)**
	+ **NOTE: Regardless of which AP is the sync-reference, this ensures consistent behavior at shared AP**

**[Motion #445]**

**Move to add to the TGbn SFD the following:**

* **If an eMLSR non-AP MLD that receives an ICF addressed to one of its affiliated STAs during CoBF sequences and if the affiliated STA responds with an ICR, then the eMLSR non-AP MLD shall follow the eMLSR procedure defined in 35.3.17, except that the STA shall use an extended time-out period prior to switching back upon inactivity:**
	+ **The duration of the extended time-out period shall be sufficient to cover any inactivity period within the COBF sequence, e.g. (but not limited to), from the end of the ICR to the beginning of the data PPDU, or from the DL PPDU until the beginning of the MU-BAR frame from the shared AP for STAs associated with the shared AP**
	+ **The duration of the extended timeout period is explicitly indicated to the STA in the ICF frame sent by its associated AP.**
	+ **Once the eMLSR STA(s) switch back to listen mode, they start using the default time-out period (aSIFSTime + aSlotTime + aRxPHYStartDelay) in future TXOPs unless otherwise indicated in the ICF.**
	+ **This is applicable to CoBF transmission sequence**

**[Motion #446]**

**Move to add to the TGbn SFD the following:**

* **For DPS non-AP STA(s) scheduled with CoBF in high capability mode, the same switch-back behavior as for eMLSR with extended time-out period is used**
	+ **The RTS frame shall not be used as an ICF for DPS in the CoBF Transmission sequence even when the DPS STA does not have any DPS padding required**

**NOTE: The RTS frame cannot be modified to include the extended timeout period usage and the extended timeout period duration indications.**

**[Motion #447]**

**Move to add to the TGbn SFD the following:**

* **An AP shall use the BSRP NTB Trigger frame variant for the Sounding Invite frame**
	+ **The Sounding Response frame shall be M-BA**
	+ **TBD whether there’s another frame variant allowed for the Sounding Invite/Response frame**

**[Motion #448]**

**Move to add to the TGbn SFD the following:**

* **An AP shall use the BSRP NTB Trigger frame variant for the CoBF Invite frame**
	+ **The CoBF Response frame shall be M-BA**
	+ **TBD whether there’s another frame variant allowed for the CoBF Invite/Response frame**

**[Motion #449]**

**Move to add to the TGbn SFD the following:**

* **An AP MLD that receives an ICR from a STA affiliated with an EMLSR non-AP MLD during CBF data frame exchange does not attempt to transmit to the eMLSR non-AP MLD on another link during the extended time-out periods, per baseline behavior.**

**[Motion #450]**

**Move to add to the TGbn SFD the following:**

* **Any CoBF sounding sequence that includes Cross-BSS CSI collection shall be initiated by a two-way handshake between the two APs participating in the sequence**
	+ **The two-way handshake exchange consists of a Sounding Invite frame and a Sounding Response frame.**
	+ **The Sounding Invite/Response frame exchange is used to:**
		- **Confirm the availability of both APs for CSI collection.**
		- **TBD for indication whether each AP will include ICF/ICR exchanges with its client or not.**
		- **Further information to be exchanged is TBD.**

**[Motion #451]**

**Move to add to the TGbn SFD the following:**

* **In CBF transmission phase, the Feedback User Info field in the BSRP/MU-RTS Trigger addressed to EMLSR/DPS STA carries the extended timeout period duration?**
	+ **A new feedback type value is defined for CoBF.**
	+ **An “Extended Timeout Duration” field with a TBD length is included in the Feedback user Info field**
		- **The duration value is reported with granularity of 4 us.**
		- **A value 0 of the “Extended Timeout Duration” field is an indication to the STA to follow the default eMLSR/DPS switch back behavior, i.e., do not use an extended timeout period.**
		- **Whether the field indicates maximum value or actual value is TBD**

**[Motion #452]**

**Move to add to the TGbn SFD the following:**

* **A non-AP STA is allowed to enable/disable CoBF/CoSR operation for the non-AP STA by using 11bn’s feature enabling/disabling procedure (by using Link Reconfiguration Request/Notify frame)**
	+ **There are restrictions on how often CoBF/CoSR enablement/disablement requests by the non-AP STA can be sent, those restrictions are TBD**

**[Motion #486]**

**Move to add to the TGbn SFD the following:**

* **TGbn uses the following CoBF transmission sequence to support STAs requiring ICF/ICR before data frame exchanges**
	+ **The frame sequence consists of:**
		- **A CoBF Invite/CoBF Response frame exchange between the sharing and shared APs.**
		- **CoBF Invite/Response are followed by ICF/ICR frame exchanges between the APs and their associated STAs happening sequentially across the two APs; sharing AP then shared AP.**
			* **The presence of the ICF/ICR frame exchange from each AP is conditional on the CoBF PPDU being addressed to one or more STAs requiring ICF.**
			* **The presence of the ICF/ICR frame exchange from each AP is indicated in the CoBF Invite/Response frames.**
			* **ICF1-ICR1 are exchanged between the sharing AP and its STAs**
			* **ICF2-ICR2 are exchanged between the shared AP and its STAs**
			* **The duration of the ICF/ICR frame exchange from each AP is indicated in the CoBF Invite/Response frames**
		- **Finally, a CoBF Trigger frame preceding the data PPDUs that are sent by the two APs simultaneously.**
		- **Frame sequence for Ack information polling is TBD.**
	+ **Whether the CBF-invite and ICF1 can be merged and/or CBF-response and ICF2 can be merged is TBD.**



**[Motion #491]**

**Move to add to the TGbn SFD the following:**

* **Co-BF and Co-SR transmission TXOP shall follow the same frame exchange sequence framework**
	+ **Co-SR does not need to support EHT eMLSR non-AP STA**

**Relevant SPs:**

SP1:

Do you agree to use the following sequence for acknowledgement information polling from STAs scheduled in a CoBF transmission sequence

* + MU-BAR/BA frame exchanges are used by each AP separately, i.e., sequentially.

NOTE1: The first MU-BAR frame (transmitted by the sharing AP) can be embedded in the preceding DL PPDU as in baseline.

NOTE2: The frame sequence for eliciting simultaneous ACKs from clients of both sharing and shared APs if agreed in PHY is TBD.



# Text to be adopted begins here:

**9.3.1.8.6 Multi-STA BlockAck variant**

***please change subclause 9.3.1.8.6 as follows***

The AID11 subfield carries the 11 LSBs of the AID of the non-AP STA for which the Per AID TID Info subfield is intended. The format of the Per AID TID Info subfield depends on the value of the AID11 subfield. If the Multi-STA BlockAck frame is sent to an AP, the AID11 subfield is set to 0. A value of 2045 in the AID11 subfield is used as an identifier for any unassociated STA. If the AID11 subfield is set to 2045, then the Ack Type subfield and TID subfield are set to 0 and 15, respectively. A value of 2008 in the AID11 subfield is used to identify a Per AID TID Info field that carries feedback (see 37.19.2 (Dynamic Unavailability Operation (DUO) mode)) that applies to all receiving UHR STAs.

NOTE 1—More than one Per AID TID Info subfield with the same value in the AID11 subfield but different values in the TID subfield can be present in the Multi-STA BlockAck frame.

If the AID11 subfield of the AID TID Info subfield is not set to 2045, and if the Ack Type subfield and TID subfield are not equal to 0 and 13 respectively, then the Per AID TID Info subfield has the format shown in Figure9-60 (Acknowledgment Per AID TID Info subfield format(#1035)).

***Change Figure9-60 (Acknowledgment Per AID TID Info subfield format(#1035)) including its title as follows:***

|  |  |  |  |
| --- | --- | --- | --- |
|  | AID TID Info | Block Ack Starting Sequence Control | Block Ack Bitmap |
| Octets: | 2 | 0 or 2 | 0, 4, 8, 16, 32, 64, or 128 |
| * Acknowledgment Per AID TID Info subfield format(#1035)
 |

If the AID11 subfield of the AID TID Info subfield is not 2045, and if the Ack Type subfield is equal to 0 and the TID subfield is equal to 13 then the Per AID TID Info subfield has the format shown in Figure9-60a (Feedback Per AID TID Info subfield format(#1035)).

|  |  |  |  |
| --- | --- | --- | --- |
|  | AID TID Info | Block Ack Starting Sequence Control | Feedback |
| Octets: | 2 | 0 or 2 | 0, 4, 8, 16, 32, 64 or 128(#1263) |
| * Feedback Per AID TID Info subfield format(#1035)
 |

If the AID11 subfield is not 2045, then the context and the presence of each optional subfield in a Per AID TID Info subfield in a Multi-STA BlockAck frame is defined in Table9-39 (Context of the Per AID TID Info subfield and presence of optional subfields ifthe AID11 subfield is not 2045).

|  |
| --- |
| * Context of the Per AID TID Info subfield and presence of optional subfields if the AID11 subfield is not 2045 (continued)
 |
| Ack Type subfield values | TID subfield values | Presence of Block Ack Starting Sequence Control subfield and either Block Ack Bitmap or Feedback(#897) subfields | Context of a Per AID TID Info subfield in a Multi-STA BlockAck frame |
| 0 | 0–7 | Present | Block acknowledgment context:Sent as an acknowledgment to QoS Data frames that solicit a BlockAck frame response or to a BlockAckReq frame. |
| 1 | 0–7 | Not present | Acknowledgment context:Sent as an acknowledgment to a QoS Data or QoS Null frame that solicits an Ack frame response. |
| 0 ~~or 1~~ | 8–1~~3~~2 | ~~N/A~~Present | Reserved |
| 1 | 8-12 | Not present | Reserved |
| 0 | 13 | Present | Feedback context:Sent as feedback (e.g., of unavailability information, see 37.19.2 (Dynamic Unavailability Operation (DUO) mode))(#709) |
| 1 | 13 | Not present | ICR context(#2574) |
| 0 | 14 | ~~N/A~~Present | Reserved |
| 1 | 14 | Not present | All ack context:Sent as an acknowledgment to an A-MPDU that contains an MPDU that solicits an immediate response and all MPDUs contained in the A-MPDU are received successfully. |
| 0 | 15 | ~~N/A~~Present | Reserved |
| 1 | 15 | Not present | Management/PS-Poll frame acknowledgment context:Sent as an acknowledgment to a Management or PS-Poll frame. |
| NOTE 1—Additional rules for acknowledgment, block acknowledgment and the all ack context are defined in 26.4.2 (Acknowledgment context in a Multi-STA BlockAck frame) for a multi-TID A-MPDU.NOTE 2—As HE STAs do not use HCCA (see 10.23.1), TID values from 8 to 15 are not used in QoS Data frames. |

If the Ack Type subfield is 0, the Fragment Number subfield encoding indicates the length of the BlockAck bitmap subfield or the Feedback subfield as defined in Table9-40 (Fragment Number subfield encoding for the Multi-STA BlockAck variant).

|  |
| --- |
| * Fragment Number subfield encoding for the Multi-STA BlockAck variant
 |
| Fragment Number subfield | Fragmentation level 3 (ON/OFF) | Block AckBitmap or Feedback Bitmap or Feedback  | Maximum number of MSDUs/A-MSDUs that can be acknowledged (see NOTE 2)(#1036) |
| B3 | B2–B1 | B0 |
| 0 | 0 | 0 | OFF | 8 | 64 |
| 0 | 1 | 0 | 16 | 128 |
| 0 | 2 | 0 | 32 | 256 |
| 0 | 3 | 0 | 4 | 32 |
| 0 | 0 | 1 | ON | 8 | 16 |
| 0 | 1 | 1 | 16 | 32 |
| 0 | 2 | 1 | 32 | 64 |
| 0 | 3 | 1 | 4 | 8 |
| 1 | 0 | 0 | OFF | 64 | 512 |
| 1 | 1 | 0 | 128 | 1 024 |
| 1 | 2 and 3 | 0 | Reserved | Reserved |
| 1 | Any | 1 | Reserved | Reserved |
| NOTE 1—A Multi-STA BlockAck frame with B0 of the Fragment Number subfield set to 1 cannot be sent to an HE STA, unless the HE Capabilities element received from the HE STA has the Dynamic Fragmentation Support subfield equal to 3 (see 26.3 (Fragmentation and defragmentation)).NOTE 2—The column “Maximum number of MSDUs/A-MSDUs that can be acknowledged” is applicable for the Block Ack Bitmap subfield, and this column is N/A for the Feedback subfield. (#1036)NOTE 3—For UHR, Feedback subfield. |

|  |
| --- |
| * Feedback Type subfield encoding(#1035) (continued)
 |
| Feedback Type | Feedback subfield type |
| 0 | Unavailability feedback |
| 1 | Low latency feedback |
| 2 | Co-BF feedback |
| 3 | Co-TDMA feedback |
| 4 | Co-SR feedback |
| 5-15 | Reserved |

If a Per AID TID Info field has the Ack Type subfield equal to 0 and the TID subfield equal to 13 then:

* If the Multi-STA BlockAck frame is individually addressed to the UHR non-AP STA, the AID11 subfield of the Per AID TID Info subfield is set to the 11 LSBs of the AID of a UHR non-AP STA. If the Multi-STA BlockAck frame is individually addressed to an AP, the AID11 subfield is set to 0. (#3829)
* If the Multi-STA BlockAck frame is transmitted by an AP and is group addressed, the AID11 subfield of the AID TID Info subfield is set to the AID of a UHR STA that is the intended receiver of the feedback information or to 2008 if the feedback information is intended for all addressed UHR STAs.(#3829)
* The Block Ack Starting Sequence Control subfield in the Per AID TID Info subfield has the format shown in Figure 9-48 Block Ack Starting Sequence Control subfield format.(#3829)
* The Feedback Type subfield indicates the type of feedback that is contained in the Feedback field and the encoding of the Feedback Type field is shown in Table9-40 (Feedback Type subfield encoding(#1035)).(#3829)
* (#2871)The feedback subfield length is defined in Table9-40 (Fragment Number subfield encoding for the Multi-STA BlockAck variant) and a UHR STA indicates a feedback length for unavailability feedback or low latency feedback equal to 4.(#3829)

NOTE—While a UHR STA uses length 4, it is possible to in future amendments, other feedback length might be used and as such UHR STAs are expected to parse them correctly.

More than one Per AID TID info field may be present in a Multi-STA BlockAck frame to report different types of feedback information. (#1035)

|  |  |  |  |
| --- | --- | --- | --- |
|  | B0 B3 | B4 B11 | B12 B15 |
|  | Fragment Number | Reserved | Feedback Type |
| Bits: | 4 | 8 | 4 |
| * Block Ack Starting Sequence Control subfield format if the AID11 subfield is not 2045 and if the Ack Type subfield is equal to 0 and the TID subfield is equal to 13(#1035)
 |

(#684)The Feedback Type field is set to 3 to carry Co-TDMA information as described in 37.15.2.3 (Coordinated time division multiple access (Co-TDMA)).

If the Feedback Type field is set to 3, the Feedback field has the format defined in Figure9-60c (Feedback field format if the Feedback Type field is set to 3 for Co-TDMA information).

|  |  |  |
| --- | --- | --- |
|  | B0 | B1 B31 |
|  | TXOP Sharing Solicited | Reserved |
| Bits: | 1 | 31 |
| * Feedback field format if the Feedback Type field is set to 3 for Co-TDMA information
 |

The TXOP Sharing Solicited field of the Feedback field is set to 1 if the polled AP intends to receive a time allocation from the Co-TDMA coordinating AP during the current TXOP to exchange frames of the same or higher priority ACs compared to the AC indicated in the Primary AC field in the Co-TDMA TB ICF or the Co-TDMA NTB ICF with its associated non-AP STAs, otherwise it is set to 0.

(#684)The Feedback Type field is set to 2 to carry Co-BF information as described in 37.15.2.1 (Coordinated beamforming (Co-BF)).

If the Feedback Type field is set to 2, the Feedback field will have one of two formats based on whether the Multi-STA BlockAck frame is sent as a Co-BF Sounding Response or a Co-BF Response frame. These two cases are differentiated using the 1-bit Co-BF Sub-Type field as shown in Figure 9-60d (Feedback field format if the Feedback Type field is set to 2 for Co-BF information and the frame is a Co-BF Sounding Response frame) and Figure 9-60d (Feedback field format if the Feedback Type field is set to 2 for Co-BF information and the frame is a Co-BF Response frame)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | B0 | B1 B4 | B5 | B6 | TBD | TBD | TBD | Variable |
|  | Co-BF Sub-Type(set to 0) | Invitation Response | Single-TXOP Sounding Flag | In-BSS Sounding Included | Keep Old CSI Flag | CSI Confirm | ICF/ICR Flag | Reserved |
| Bits: | 1 | 4 | 1 | 1 | TBD | TBD | 1 | Variable |

**Figure 9-60d Feedback field format if the Feedback Type field is set to 2 for Co-BF information and the frame is a Co-BF Sounding Response frame**

The Co-BF Sub-Type field is set to 0 to indicate that the feedback information included in the Feedback field is to Co-BF sounding information reported in a CoBF Sounding Response frame.

The Invitation response field indicates the sounding responding AP’s response to the Co-BF sounding invitation sent by the sounding initiating AP. The value 0 indicates sounding invitation acceptance while the values 1-15 indicate rejections with different reason codes encoded as shown in Table TBD.

The Single-TXOP Sounding Flag indicates whether the sounding responding AP will include sounding procedures of its associated STA(s) in the same TXOP or not. This field is reserved when the Single-TXOP Sounding Flag field in the MAPC User Info field of the CoBF Sounding Invite is set to 0.

The In-BSS Sounding Included field indicates whether the coordinated AP will include in-BSS sounding procedures in the current sounding TXOP. This field is reserved when the Single-TXOP Sounding Flag field in the MAPC User Info field of the CoBF Sounding Invite is set to 0 or when it is set to 1 and the In-BSS Sounding Allowed field in the MAPC User Info field of the CoBF Sounding Invite is set to 0.

The Keep Old CSI Flag field indicates whether the sounding initiating AP is required to keep the older CSI information collected for the sounding responding AP’s STAs or is allowed to flush that older information before collecting new CSI estimates. This field is reserved when the Single-TXOP Sounding Flag field in the MAPC User Info field of the CoBF Sounding Invite is set to 0 or when it is set to 1 and the Single-TXOP Sounding Flag field in this Feedback field is set to 0.

The CSI Confirm field indicates whether the initiator AP has successfully received cross-BSS CSI from the sounding responder AP’s STAs in a previous TXOP or not.

The ICF/ICR Flag field indicates whether the sounding responding AP will include an ICF/ICR frame exchange with its sounded STA(s) or not when it is going to do its sounding procedures in the same TXOP. This field is reserved when the Single-TXOP Sounding Flag field in the MAPC User Info field of the CoBF Sounding Invite is set to 0 or when it is set to 1 and the Single-TXOP Sounding Flag field in this Feedback field is set to 0.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | B0 | B1 B4 | B5 B14 | B15 B23 | B24 B26 | B27 | B28 B30 |
|  | Co-BF Sub-Type(set to 1) | Invitation Response | ICF/ICR Duration | Number of OFDM Symbols | PHY Version Identifier | Extra LTF Allowed | Numberof STAs |
| Bits: | 1 | 4 | 10 | 9 | 3 | 1 | 3 |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | B0 B11 | B12 B16 | B17 | B18 | B19 B29 | B30 B34 | B35 | B36 |  |
|  | STA 0 AID | MCS 0 | NSS 0 | 2xLDPC 0 | STA 1 AID | MCS 1 | NSS 1 | 2xLDPC 1 | … |
| Bits: | 12 | 5 | 1 | 1 | 12 | 5 | 1 | 1 |  |

**Figure 9-60d Feedback field format if the Feedback Type field is set to 2 for Co-BF information and the frame is a Co-BF Response frame**

The Co-BF Sub-Type field is set to 0 to indicate that the feedback information included in the Feedback field is to Co-BF sounding information reported in a CoBF Sounding Response frame.

The Invitation response field indicates the sounding responding AP’s response to the Co-BF sounding invitation sent by the sounding initiating AP. The value 0 indicates sounding invitation acceptance while the values 1-15 indicate rejections with different reason codes encoded as shown in Table TBD.

The ICF/ICR Duration field indicates the duration of the ICF frame sent by the coordinated AP + SIFS duration + the duration of the ICR frame sent by the coordinated AP’s scheduled STA(s) in response to its ICF. This duration is reported in units of 0.5 µs and a value 0 indicates that the no ICF/ICR frame exchange will be included by the coordinated AP in the sequence.

The Number of OFDM Symbols field indicates the suggested number of OFDM symbols by the coordinated AP to be included in the Co-BF data PPDUs.

The PHY Version Identifier field indicates the PHY Version Identifier value of the transmitted DL data PPDU.

The Extra LTF Allowed field indicates whether extra LTF is allowed or not.

The Number of STAs field indicates the number of STAs scheduled by the coordinated AP. This value dictates how many times the next four fields, i.e., STA n AID, MCS n, NSS n, 2xLDPC n, will be repeated.

The STA n AID field indicates the AID12 ID of the nth scheduled STA by the coordinated AP.

The MCS n field indicates the MCS used for STA n.

The NSS n field indicates the NSS used for STA n.

The 2xLDPC n field indicates whether LDPC encoding is used for STA n or not.

**9.3.1.22 Trigger Frame Format**

**9.3.1.22 BSRP Trigger Frame Format**

***Add the following text at the end of subclause 9.3.1.22.13:***

(#24, #3756, #2935, #1271, #2936, #2937, #3726, #25)A UHR variant BSRP Trigger frame that is individually addressed and that has the GI And UHR-LTF Type field equal to 3 is called a BSRP non-trigger based (NTB) Trigger frame. In a BSRP NTB Trigger frame(#3756, #2953, #1271):

* The Number Of UHR-LTF Symbols field, the LDPC Extra Symbol Segment field, the AP Tx Power field, the Pre-FEC Padding Factor field, the PE Disambiguity field, the UL Spatial Reuse field, the UHR P160 field, and DRU/RRU Indication field of the Common Info field are reserved.(#2936, #3756, #2935, #1271)
* The Special User Info Flag field of the UHR variant Common Info field is set to 0, indicating that a Special User Info field is present in the Trigger frame that contains the UHR variant Common Info field.(#3756, #2935, #1271)
* The PHY Version Identifier field of the Special User Info field is equal to 1, and the UL Bandwidth Extension field and NPCA Primary Channel Indication field are set as defined in 9.3.1.22.3 (Special User Info field). (#3756, #2935, #1271)
* The UHR Spatial Reuse 1 field, the UHR Spatial Reuse 2 field and the U-SIG Disregard And Validate field of the Special User Info field are reserved.(#2936)
* In the User Info field with the AID12 field set to the STA’s AID (see 9.3.1.22.1 (General))(#3726), (#2937)all the other fields of this User Info field are reserved.
* In a User Info field where the AID12 field is set to the AP ID of an AP participating in a Co-TDMA procedure (see 37.15.2.3.2 (Polling phase)), the User Info field has the format shown in Figure9-99b (User Info field format with AID12 field set to an AP ID of an AP participating in a Co-TDMA procedure).
* The Feedback Type field indicates the type of feedback carried in the Feedback Information field. The Feedback Type field is set to 3 for a Co-TDMA procedure.
* The Feedback Information field contains feedback corresponding to the type specified in the Feedback Type field. When the Feedback Type is set to 3, the Feedback Information field has the format defined in Figure Figure9-90j7 (Feedback Information field if the Feedback Type field is set to 3).

|  |  |  |  |
| --- | --- | --- | --- |
|  | B0 B11 | B12 B15 | B16 B39 |
|  | AID12 | Feedback Type | Feedback Information |
| Bits: | 12 | 4 | 24 |
| * User Info field format with AID12 field set to an AP ID of an AP participating in a MAPC procedure
 |

* In a User Info field where the AID12 field is set to the AP ID of an AP participating in a Co-BF procedure (see 37.15.2.1 (Coordinated beamforming (Co-BF))), the User Info field has the format shown in Figure9-99b (User Info field format with AID12 field set to an AP ID of an AP participating in a MAPC procedure).
* The Feedback Type field indicates the type of feedback carried in the Feedback Information field. The Feedback Type field is set to 2 for a Co-BF procedure.
* The Feedback Information field contains feedback corresponding to the type specified in the Feedback Type field. When the Feedback Type is set to 2, the Feedback Information field has the format defined in either Figure9-99c (Feedback Information field format for Co-BF Sounding) if it is included in a Sounding Invite frame or Figure9-99d (Feedback Information field format for Co-BF transmission) if it is included in a Co-BF Invite frame. These two cases are differentiated using the 1-bit Co-BF Sub-Type field as shown in the figures.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | B0 | B1 | B2 | B3 | B4 | B5 | TBD | TBD | TBD |
|  | Co-BF Sub-Type(set to 0) | ICF/ICR Flag | Sounding Scheme | In-BSS Sounding Included | Single-TXOP Sounding Flag | In-BSS Sounding Allowed | Keep Old CSI Flag | CSI Confirm | Reserved |
| Bits: | 1 | 1 | 1 | 1 | 1 | 1 | TBD | TBD | TBD |

**Figure 9-99c Feedback Information field format for Co-BF Sounding**

The Co-BF Sub-Type field is set to 0 to indicate that the BSRP NTB Trigger frame is sent for the purpose of a Co-BF sounding invitation.

The ICF/ICR Flag field is set to 1 to indicate that the sounding initiator AP will include an ICF/ICR frame exchange with one or more of its sounded STAs prior to sending the NDPA frame. The field is to 0 otherwise.

The Sounding Scheme field is to 0 to indicate sequential sounding and set to 1 to indicate joint sounding.

The In-BSS Sounding included field is set to 1 to indicate that the sounding initiator AP will include in-BSS sounding in the initiated frame sequence right after the cross-BSS sounding is concluded. The field is set to 0 otherwise.

The Single-TXOP Sounding Flag field is set to 1 to indicate that the sounding responding AP is allowed to initiate its sounding procedures within the same TXOP after the sounding initiator AP is done with its sounding. The field is set to 0 to indicate that the sounding responding AP is not allowed to do its sounding in the same TXOP.

The In-BSS Sounding Allowed field is set to 1 to indicate that the sounding responding AP is allowed to include its in-BSS sounding in the same TXOP in addition to its cross-BSS sounding. This field is applicable only for sequential sounding and if the Single-TXOP Sounding Flag field is set to 1 and is reserved otherwise.

The Keep Old CSI Flag indicates whether the sounding responding AP is required to keep the older CSI information collected for the sounding initiating AP’s STAs or is allowed to flush that older information before collecting new CSI estimates.

The CSI Confirm field indicates whether the initiating AP has successfully received cross-BSS CSI from the sounding responding AP’s STAs in a previous TXOP or not.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | B0 | B1 B10 | B11 B18 | B19 B23 |
|  | Co-BF Sub-Type(set to 1) | ICF/ICR Duration | CoBF Response Padding | Punctured Channel Info |
| Bits: | 1 | 10 | 8 | 5 |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | B0 B1 | B2 B3 | B4 B5 | B6 B14 | B15 B23 |
|  | GI-LTF Size | Max Shared AP Total NSS | Numberof STAs | Min Number of OFDM Symbols | Max Number of OFDM Symbols |
| Bits: | 2 | 2 | 2 | 9 | 9 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | B0 B10 | B11 | B12 B22 | B23 |
|  | STA 0 AID | STA 0 NSS | STA 1 AID | STA 1 NSS |
| Bits: | 11 | 1 | 11 | 1 |

|  |  |  |  |
| --- | --- | --- | --- |
|  | B0 B11 | B12 | B13 B23 |
|  | STA 2 AID | STA 2 NSS | Reserved |
| Bits: | 11 | 1 | 12 |

**Figure 9-99d Feedback Information field format for Co-BF transmission**

The CoBF Invite frame includes 3 or 4 User Info fields depending on how many STAs are scheduled by the Coordinating AP. 3 User Info fields are included in case 1 or 2 STAs are scheduled by the coordinating AP, while 4 User Info fields are included if 3 STAs are scheduled by the coordinating AP. Figure 9-90aa3 shows the format of the Feedback Information field in the possibly 4 User Info fields included in the CoBF Invite frame. When only 1 or 2 STAs are scheduled by the coordinating AP, the 4th Feedback Information field in the figure becomes irrelevant since only 3 User Info fields are needed.

NOTE — The maximum number of STAs allowed to be scheduled by a coordinating AP in a CoBF TXOP is 3.

The Co-BF Sub-Type field is set to 1 to indicate that the BSRP NTB Trigger frame is sent for the purpose of a Co-BF sounding invitation.

NOTE — The CoBF Sub-Type field only exists in the Feedback Information field of the 1st User Info field..

The ICF/ICR Duration field indicates the duration of the ICF frame sent by the coordinating AP + SIFS duration + the duration of the ICR frame sent by the coordinating AP scheduled STA(s) in response to its ICF. This duration is reported in units of 0.5 µs and a value 0 indicates that the no ICF/ICR frame exchange will be included by the coordinating AP in the sequence.

The CoBF Response Padding field indicates the padding duration requested by the coordinating AP to be included in the CoBF Response frame sent by the coordinated AP. The requested padding duration is reported in units of 2 µs.

The Number of STAs field indicates the number of STAs scheduled by the coordinating AP in the CoBF TXOP initiated by this CoBF Invite frame.

The Min Number of OFDM Symbols indicates the minimum number of OFDM symbols that will be included in the DL data PPDU transmitted by the coordinating AP.

The Max Number of OFDM Symbols indicates the maximum number of OFDM symbols that will be included in the DL data PPDU transmitted by the coordinating AP.

The STA 0 AID field indicates the AID11 address of the first STA scheduled by the coordinating AP in the CoBF TXOP initiated by this CoBF Invite frame. Similarly, the STA 1 AID and STA 2 AID fields indicate the AID11 address of the second an third STAs scheduled in the CoBF TXOP, if any.

The STA 0 NSS field indicates the number of spatial streams allocated to the first STA scheduled by the coordinating AP in the CoBF TXOP initiated by this CoBF Invite frame. Similarly, the STA 1 NSS and STA 2 NSS fields indicate the number of spatial streams allocated to the second an third STAs scheduled in the CoBF TXOP, if any.**37.15 Multi-AP coordination (MAPC) framework**

**37.15.2 Procedures for specific multi-AP coordination schemes**

**37.15.2.1 Coordinated beamforming (Co-BF) (#866)37.8.2.1.3 Frame exchange sequence for Co-BF**

(#199)A Co-BF coordinating AP shall initiate Co-BF transmission with a Co-BF coordinated AP by transmitting a Co-BF Invite frame to the Co-BF coordinated AP. The Co-BF Invite frame shall be a BSRP NTB Trigger frame. The TA field of the Co-BF Invite frame shall be set to the MAC address of the Co-BF coordinating AP, and the RA field of the Co-BF Invite frame shall be set to the MAC address of the Co-BF coordinated AP. The Co-BF invite frame solicits a Co-BF response frame from the Co-BF coordinated AP addressed by the Co-BF invite frame.

(#199)A Co-BF coordinated AP that receives a Co-BF Invite frame shall transmit a Co-BF Response frame to the Co-BF coordinating AP aSIFSTime after the end of the PPDU carrying the Co-BF Invite frame. The Co-BF Response frame shall be a Multi-STA BlockAck frame. The TA field of the Co-BF Response frame shall be set to the MAC address of the Co-BF coordinated AP, and the RA field of the Co-BF Response frame shall be set to the MAC address of the Co-BF coordinating AP.

The Co-BF coordinating or the Co-BF coordinated APs shall include an ICF-ICR frame exchange in the Co-BF transmission frame sequence whenever any of the AP’s associated STAs being scheduled for Co-BF transmission in the current TXOP operates in a mode that requires preceding frame exchanges with an ICF transmission. This is the case for DPS enabled non-AP STAs, and for non-AP STAs affiliated with an EMLSR non-AP MLD that the Co-BF transmission will immediately follow on any of its EMLSR links. The ICF frame shall not include any non-AP STA that will not be scheduled for Co-BF transmission in the next Co-BF DL PPDU.

If the ICF and ICR frame exchange is included before Co-BF transmission between the Co-BF coordinating AP and its associated recipient STAs, the Co-BF coordinating AP shall transmit the ICF aSIFSTime after the end of the PPDU carrying the Co-BF Response frame that accepts the Co-BF invite. The non-AP STAs associated with the Co-BF coordinating AP that received the ICF shall follow the rules defined in 35.3.17 (Enhanced multi-link single-radio (EMLSR) operation) and 37.17.1 (Dynamic power save (DPS) operation)to respond ICR.

If the ICF and ICR frame exchange is not included before Co-BF transmission between the Co-BF coordinating AP and its associated recipient STAs, and the ICF and ICR frame exchange is included before the Co-BF transmission between the Co-BF coordinated AP and its associated recipient STAs, the Co-BF coordinated AP shall transmit the ICF aSIFSTime after the end of the PPDU carrying the Co-BF Response frame that accepts the Co-BF invite.

If the ICF and ICR frame exchange is included before Co-BF transmission between the Co-BF coordinating AP and its associated recipient STAs, and the ICF and ICR frame exchange is included before the Co-BF transmission between the Co-BF coordinated AP and its associated recipient STAs, the Co-BF coordinated AP shall transmit the ICF 2´aSIFSTime plus the duration of the ICF and ICR frame exchange between the Co-BF coordinating AP and its associated recipient STAs that is indicated in the Co-BF Invite frame after the end of the PPDU carrying the Co-BF Response frame that accepts the Co-BF invite.

If an ICF frame is sent by any of the two APs, then the AP shall set the Duration field in the ICF frame MAC header to cover only the immediate ICR response frame.

The non-AP STAs associated with the Co-BF coordinated AP that received the ICF shall follow the rules defined in 35.3.17 (Enhanced multi-link single-radio (EMLSR) operation) and 37.17.1 (Dynamic power save (DPS) operation) to respond ICR.

A Co-BF coordinating or a Co-BF coordinated AP transmitting any ICF frame during the Co-BF transmission phase to an associated non-AP STA shall include an indication to that STA to use an extended timeout period for the following cases:

* The STA is a DPS enabled non-AP STA in which case the extended timeout period corresponds to the time the DPS STA stays in the HC mode before switching to LC mode when it is not included in any frame transmission or reception.
* The STA is operating on an EMLSR link of its affiliated non-AP MLD in which case the extended timeout period corresponds to the non-AP MLD’s switch back to listening operation event on that EMLSR link.

The duration of the extended timeout period shall be explicitly indicated by the Extended Timeout Duration field in the Feedback User Info field included in the ICF frame addressing the associated STA. The AP shall indicate a duration for the extended timeout period that is longer than the longest inactivity period the associated non-AP STA(s) will experience within the Co-BF transmission sequence.

A STA that is operating on an EMLSR link of its affiliated non-AP MLD during the Co-BF transmission phase shall follow the rules defined in 35.3.17 (Enhanced multi-link single-radio (EMLSR) operation) for switching back to listening operation except for the following:

* It uses extended timeout period instead of aSIFSTime + aSlotTime + aRxPHYStartDelay as timeout interval starting at the end of the PPDU transmitted by the non-AP STA affiliated with the non-AP MLD as a response to the most recently received frame from the AP affiliated with the AP MLD or starting at the end of the reception of the PPDU containing a frame for the non-AP STA from the AP affiliated with the AP MLD that does not require immediate acknowledgement.
* During the extended timeout period, it shall not switch back to the listening operation.

After the Co-BF coordinating or Co-BF coordinated AP receives an ICR from its associated non-AP STA operating on an EMLSR link during the Co-BF transmission phase, the other AP(s) affiliated with the AP MLD shall not transmit frames to the other non-AP STA(s) affiliated with the non-AP MLD on the other EMLSR link(s) during the extended time-out period.

When an AP transmits an ICF frame to a DPS STA that is scheduled in a Co-BF sequence, the ICF shall not be an RTS frame.

(#1578)The Co-BF coordinating AP shall transmit a Co-BF Trigger frame to the Co-BF coordinated AP prior to the two data PPDUs transmitted simultaneously by the Co-BF coordinating and Co-BF coordinated APs.

If the ICF and ICR frame exchange is not included before Co-BF transmission between the Co-BF coordinating AP and its associated recipient STAs, and the ICF and ICR frame exchange is not included before the Co-BF transmission between the Co-BF coordinated AP and its associated recipient STAs, the Co-BF coordinating AP shall transmit the Co-BF Trigger frame a aSIFSTime time after the end of the PPDU carrying the Co-BF Response frame that accepts the Co-BF invite.

If the ICF and ICR frame exchange is included before Co-BF transmission between the Co-BF coordinating AP and its associated recipient STAs, and the ICF and ICR frame exchange is not included before the Co-BF transmission between the Co-BF coordinated AP and its associated recipient STAs, the Co-BF coordinating AP shall transmit the Co-BF Trigger frame aSIFSTime after the end of the PPDU carrying the ICR transmitted by the non-AP STA(s) associated with the Co-BF coordinating AP.

If the ICF and ICR frame exchange is not included before Co-BF transmission between the Co-BF coordinating AP and its associated recipient STAs, and the ICF and ICR frame exchange is included before the Co-BF transmission between the Co-BF coordinated AP and its associated recipient STAs, the Co-BF coordinating AP shall transmit the Co-BF Trigger frame 2´ aSIFSTime plus the duration of the ICF and ICR frame exchange between the Co-BF coordinated AP and its associated recipient STAs after the end of the PPDU carrying the Co-BF Response frame that accepts the Co-BF invite. The duration of the ICF and ICR frame exchange between the Co-BF coordinated AP and its associated recipient STAs is indicated in the Co-BF Response frame.

If the ICF and ICR frame exchange is included before Co-BF transmission between the Co-BF coordinating AP and its associated recipient STAs, and the ICF and ICR frame exchange is included before the Co-BF transmission between the Co-BF coordinated AP and its associated recipient STAs, the Co-BF coordinating AP shall transmit the Co-BF Trigger frame 2´aSIFSTime plus the duration of the ICF and ICR frame exchange between the Co-BF coordinated AP and its associated recipient STAs after the end of the PPDU carrying the ICR transmitted by the non-AP STA(s) associated with the Co-BF coordinating AP. The duration of the ICF and ICR frame exchange between the Co-BF coordinated AP and its associated recipient STAs is indicated in the Co-BF Response frame.

After simultaneously transmitting the two data PPDUs, the Co-BF coordinating AP and the Co-BF coordinated AP use a sequential acknowledgement procedure to solicit the receiving status of the MSDUs/A-MSDUs in the data PPDUs from the recipient STA(s). The solicitation of the receiving status of the MSDUs/A-MSDUs in the data PPDUs shall be done by the coordinating AP first. The coordinating AP shall report the duration of its Ack polling sequence with its scheduled STA(s) to the coordinated AP in the Co-BF Trigger frame. The Ack polling sequence duration is calculated starting from the end of the DL PPDUs to the end of the BA frame sent by the coordinating AP’s scheduled STA(s).

The reported Ack polling sequence duration is used by the coordinated AP to time the initiation of its Ack polling sequence with its scheduled STA(s). The coordinated AP shall set the Ack policy to “Block Ack” and use an MU-BAR frame to solicit the BA frame response from its scheduled STA(s).

When the Ack policy set by any of the two APs is “Block Ack” and MU-BAR is used to solicit the BA frame, then the AP shall set the Duration field in the MU-BAR frame MAC header to cover only the immediate BA response frame.

NOTE — The coordinating AP needs to choose an Ack policy that allows it to report an Ack polling sequence duration information to the coordinated AP that accurately reflects the actual duration of the sequence exchanged between the coordinating AP and its scheduled STA(s).

**37.8.2.1.4 Co-BF transmission procedure**

In order to perform Co-BF transmission, a Co-BF coordinating AP and a Co-BF coordinated AP shall follow the rules defined in 37.15.2.1.3 (Frame exchange sequence for Co-BF), and shall additionally follow the rules defined in this subclause.

The Co-BF Invite frame shall include the following information:

* The minimum number of data OFDM symbols of the Co-BF transmission
* The maximum number of data OFDM symbols of the Co-BF transmission
* The PHY version of the Co-BF transmission
* The bandwidth of the Co-BF transmission
* The puncturing pattern of the Co-BF transmission
* The GI and the LTF size of the Co-BF transmission
* The maximum total number of spatial streams allowed for the Co-BF coordinated AP of the Co-BF transmission
* The number of recipient STAs of the Co-BF transmission that are associated with the Co-BF coordinating AP
* The STA ID of each recipient STA of the Co-BF transmission that is associated with the Co-BF coordinating AP
* The number of spatial streams for each recipient STA of the Co-BF transmission that is associated with the Co-BF coordinating AP
* The duration of the ICF and ICR frame exchange between the Co-BF coordinating AP and its associated recipient STAs before Co-BF transmission, which includes the SIFS between the ICF and the ICR, if the ICF and ICR frame exchange is included.
* The padding duration requested by the coordinating AP to be included in the Co-BF Response frame by the coordinated AP.

If the Co-BF coordinated AP accepts the Co-BF invite, the Co-BF Response frame shall include the following information:

* An invitation response indication whether the coordinated AP is accepting or rejecting the coordinating AP’s Co-BF invitation. The rejection reason is encoded in the value of the “Invitation response” field as indicated in 9.3.1.22.x.1 MAPC User Info field format for Co-BF.
* The suggested number of data OFDM symbols of the Co-BF transmission. (M#371)The suggested value shall not be smaller than the minimum number of data OFDM symbols indicated by the Co-BF coordinating AP in the Co-BF Invite frame.

 NOTE—The Co-BF coordinating AP might ignore the Co-BF coordinated AP’s suggestion

* The PHY version of the Co-BF transmission
* Whether extra LTF to be used in the Co-BF transmission is allowed by the Co-BF coordinated AP
* The number of recipient STAs of the Co-BF transmission that are associated with the Co-BF coordinated AP
* The STA ID of each recipient STA of the Co-BF transmission that is associated with the Co-BF coordinated AP
* The MCS for each recipient STA of the Co-BF transmission that is associated with the Co-BF coordinated AP
* The number of spatial streams for each recipient STA of the Co-BF transmission that is associated with the Co-BF coordinated AP
* Whether 2xLDPC will be used for each recipient STA of the Co-BF transmission that is associated with the Co-BF coordinated AP
* The duration of the ICF and ICR frame exchange between the Co-BF coordinated AP and its associated recipient STAs before Co-BF transmission, which includes the SIFS between the ICF and the ICR, if the ICF and ICR frame exchange is included.

If the Co-BF coordinated AP rejects the Co-BF invite, the Co-BF Response frame should include the reason for rejection.

In each of the Co-BF Invite and Co-BF Response frames, if there is information for more than one user, the users are ordered according to the number of spatial streams in non-increasing order.

The Co-BF Trigger frame is used to ensure time and frequency synchronization between the two data PPDUs, and conveys the information needed to construct a common preamble for the two data PPDUs. The Co-BF Trigger frame shall include the following information:

* The value to be set in the Length field in the L-SIG field of the PPDU of the Co-BF transmission
* The PHY version of the Co-BF transmission
* The bandwidth of the Co-BF transmission
* The puncturing pattern of the Co-BF transmission
* The BSS color of the Co-BF coordinating AP
* The BSS color of the Co-BF coordinated AP
* The TXOP duration to be set in the TXOP field in the U-SIG of the Co-BF transmission
* The number of UHR-SIG symbols of the Co-BF transmission
* The GI and the LTF size of the Co-BF transmission
* The number of UHR-LTF symbols of the Co-BF transmission
* The total number of recipient STAs of the Co-BF transmission
* The STA ID of each recipient STA of the Co-BF transmission
* Which BSS each recipient STA of the Co-BF transmission belongs to
* NOTE—the BSS is identified by the BSS color
* The MCS of each recipient STA of the Co-BF transmission
* The spatial configuration of each recipient STA of the Co-BF transmission
* Whether 2xLDPC will be used for each recipient STA of the Co-BF transmission
* The Ack polling sequence duration of the coordinating AP.

The order of user information in the Co-BF Trigger frame shall be the same as the order of users in the UHR-SIG User field for the Co-BF transmission. The ordering of user information follows the rules described in 38.3.15.9.5 (User Specific field). In addition to the above rules, the order of user information of the users associated with the Co-BF coordinating AP in the Co-BF Trigger frame shall be the same as that in the Co-BF Invite frame. The order of user information of the users associated with the Co-BF coordinated AP in the Co-BF Trigger frame shall be the same as that in the Co-BF Response frame.

The user information in the Co-BF Trigger frame and in the UHR-SIG of the Co-BF transmission corresponds to all the recipient STAs that are indicated in the Co-BF Invite and Co-BF Response frames. The number of spatial streams for each recipient STA interpreted from the spatial configuration in the Co-BF Trigger frame shall be the same as the number of spatial streams for the same STA that is indicated in the Co-BF Invite and Co-BF Response frames. The MCS and 2xLDPC bit for each recipient STA indicated in the Co-BF Trigger frame shall be the same as the MCS and 2xLDPC bit indicated in the Co-BF Response frame

The Co-BF coordinating AP and the Co-BF coordinated AP shall follow the rules defined in 38.3.24 (Transmit requirement for UHR Co-BF sounding sequence and Co-BF transmission) to apply frequency pre-correction to the PPDUs containing the Co-BF Trigger frame and the Co-BF data frames.