IEEE P802.11
Wireless LANs

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| PDT MAC 37.8.2.1 CoBF |
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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.
* Rev 1: Adding more details after many SPs got consensus agreement.
* Rev 2: Updating the document based on more feedback received and according to the latest passed motions.

**Explanation of the proposed changes:**

The proposed changes to the 802.11 TGbn draft within this document are based on the following motions adopted by the TGbn task group in addition to straw polls that either got consensus agreement or initial wide agreement:

**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**

**Relevant SPs:**

SP1:

Do you agree to use 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.
		- Follows 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.



SP2:

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.



SP3:

Do you support that 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

# Text to be adopted begins here:

**3.2 Definitions specific to IEEE Std 802.11**

**coordinated beamforming coordinating AP:** [Co-BF coordinating AP] An AP that invites a Co-BF coordinated AP to perform Co-BF transmission in an acquired TXOP after first establishing a MAPC agreement for Co-BF.

**coordinated beamforming coordinated AP:** [Co-BF coordinated AP] An AP that is invited by a Co-BF coordinating AP to perform Co-BF transmission in an acquired TXOP after first establishing a MAPC agreement for Co-BF.

**9.3.1.8.6 Multi-STA BlockAck variant**

|  |
| --- |
| * Feedback Type subfield encoding
 |
| 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 |

**9.3.1.22.7 Feedback User Info field**

The Feedback type field indicates the type of feedback information included in the Feedback user Info field and follows the encoding shown in Table 9-45m5.

|  |
| --- |
| Table 9-46m5 Feedback Type subfield encoding |
| Feedback Type | Feedback subfield type |
| 0 | Unsolicited Unavailability feedback |
| 1 | Reserved |
| 2 | Co-BF feedback |
| 3 | Co-TDMA feedback |
| 4-15 | Reserved |

**9.3.1.22 Trigger Frame Format**

**9.3.1.22.7 Feedback User Info field**

A Feedback User Info field having the format shown in Figure 9-aa is included in the BSRP Trigger frame and MU-RTS Trigger frame that is addressed to one or more EMLSR or DPS STAs within a Co-BF transmission frame sequence. The AID12 field value is set to 2008. The Feedback Type field is set to 2 indicating to the recipient STA(s) that this BSRT Trigger frame or MU-RTS Trigger frame is sent as ICF within a Co-BF transmission sequence. The Feedback Information field has the format shown in Figure 9-bb and includes an Extended Timeout Duration field indicating the duration that the recipient STA(s) waits before initiating a switch back procedure. Switch back procedures can be either switching back to listen mode on the link of operation for EMLSR STAs or switching back to LC mode for DPS STAs. The Extended Timeout Duration is reported in units of 4 us. The value 0 indicates that an EMLSR STA should follow normal EMLSR switch back procedures as defined in 35.3.17 (Enhanced multi-link single-radio (EMLSR) operation) and a DPS STA should follow the normal DPS switch back procedures.

|  |  |  |  |
| --- | --- | --- | --- |
|  | B0   B11 | B12  B15 | B16    B39 |
|  | AID12 | Feedback Type | Feedback Information |
| Bits: | 12 | 4 | 24 |

**Figure 9-aa Feedback user Info field**

|  |  |  |
| --- | --- | --- |
|  | B0   TBD | TBD    B23 |
|  | Extended Timeout Duration | Reserved |
| Bits: | TBD | TBD |

**Figure 9-bb Feedback Information**

**9.4.2.1 General**

**9.4.2.aa3 MAPC element**

**9.4.2.aa3.2.2 Co-BF profile**

The MAPC Scheme Type field is set to the value for Co-BF as indicated in Table 9-349f.

The MAPC Scheme Parameter Set field for CoBF is defined in Figure 9-aaX.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | B0     B1 | B2     B3 | B4 | B5     B7 |
|   | Number of Supported Sounding Reports | Number of Supported Joint Sounding Reports | 2x LTF + 0.8 us GI Supported | Reserved |
| Bits:  | 2 | 2 | 1 | 3 |

Figure 9-aaX— MAPC Scheme Parameter Set field of the Co-BF profile format

The Number of Supported Sounding Reports field indicates the maximum number of OBSS Sounding Reports that the AP can store for this Co-BF pair that is equal to the value of the field minus 1.

The Number of Supported Joint Sounding Reports field indicates the maximum number of Joint Sounding Reports that the AP can store for this Co-BF pair that is equal to the value of the field minus 1. The value of the Number of Supported Joint Sounding Reports field is not larger than the value of the Number of Supported Sounding Reports field indicated between the same pair of APs.

The 2x LTF + 0.8 us GI Supported field indicates whether the AP supports the use of 2 x LTF + 0.8 GI or not while operating in Co-BF with the peer AP with which the Co-BF agreement is being established. The field is set to 1 when 2x LTF + 0.8 us GI is supported by the AP.

**37.8 Multi-AP coordination framework**

**37.8.2 Procedures for specific Multi-AP coordination schemes**

**37.8.2.1 Coordinated beamforming**

**37.13.2.1.1 General**

An AP shall not schedule non-AP STAs in Co-BF sequences including the Co-BF sounding procedures and the Co-BF data transmission procedures unless the STA has enabled Co-BF operation. A non-AP STA may enable or disable Co-BF operation by following the procedures defined in 9.4.2.X.8 (Mode Specific Parameters for Co-BF).

**37.8.2.1.3 Co-BF transmission phase**

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 coordinating AP shall use the BSRP NTB Trigger frame variant for the Co-BF invite frame. The TA field of this frame shall be set to the MAC address of the Co-BF coordinating AP, and the RA field 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. The Multi-STA BA frame shall be used for the Co-BF response frame.

If both the coordinating AP and coordinated AP need to serve EMLSR or DPS STAs in the Co-BF transmission, the ICF-ICR frame exchanges for the two APs shall be done sequentially after the transmission of the Co-BF response frame as shown in Fig. 37.x (Frame sequence for the Co-BF transmission phase). The ICF-ICR frame exchange between the Co-BF coordinating AP and its associated STA(s) shall be performed first. The coordinating AP shall transmit its ICF SIFS after the CoBF Response frame while the coordinated AP shall transmit its ICF SIFS after the ICR of the coordinating AP’s STA(s). Each of the Co-BF coordinating and 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.



Fig. 37.x—Frame sequence for the Co-BF transmission phase

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(s).

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 does not switch back to listen mode.

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

After simultaneously transmitting the two data PPDUs, the Co-BF coordinating and Co-BF coordinated APs may use the existing acknowledgment information polling mechanisms except that it is done sequentially in the two BSSs. The acknowledgment information polling process shall be performed by the Co-BF coordinating AP first.

The Co-BF transmission frame sequence described in this subclause is also used for Co-SR transmissions.

NOTE—The Co-SR frame sequence need not to support EHT EMLSR STAs.

The coordinated AP shall precorrect its transmission frequency prior to transmitting the CoBF data PPDU based to compensate for the carrier frequency offset estimated from the Co-BF Trigger frame with respect to the coordinating AP. The coordinating AP shall not do any frequency correction during the Co-BF transmission sequence.

NOTE­­—Frequency precorrection is done for CoBF data PPDU of the coordinated AP regardless of the assigned synchronization roles agreed between he two APs.