IEEE P802.11  
Wireless LANs

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| PDT MAC and CR Coordinated Beamforming Protocol | | | | |
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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: Editorial changes.
* Rev 2: Editorial changes based on the comments received during the conference call and from offline. Change the definition to align with Co-SR.
* **Introduction**

Interpretation of a Motion to Adopt

A motion to approve this submission means that the editing instructions and any changed or added material are actioned in the TGbn Draft. The abstract, revision information, introduction, explanation of the proposed changes and references sections are not part of the adopted material.

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

**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:

**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 #135]**

**The sharing AP, that transmits a Trigger frame as part of a transmission sequence in a Multi-AP coordinated transmission scheme, identifies the shared AP via an AP ID carried in the AID12 field of the User Info field of the frame**

* **Note: the name of "sharing AP" and "shared AP" are TBD**
* **Note: Multi-AP coordinated transmission schemes are Co-SR, Co-BF and Co-TDMA**

**[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 #311]**

**The Co-BF Sync frame carries the following information**

* + **How to indicate the information is TBD**

|  |  |
| --- | --- |
| Category | Information |
| Control | ‘Co-BF Sync’ |
| PHY Common Info | Length |
| PHY Version Identifier |
| Bandwidth |
| Punctured Channel Information |
| BSS Color 1, BSS Color 2 |
| TXOP |
| Number of UHR-SIG Symbols |
| GI+LTF Size |
| Number Of UHR-LTF Symbols |
| Number of Co-BF Users |
| Per-User Info in Both BSS | STA ID |
| BSS Color Indication |
| MCS |
| Spatial Configuration |
| 2xLDPC |

**[Motion #312]**

**In each of the Co-BF Invite, Response and Sync frames, if there is information for more than one users, the users are ordered according to NSS in non-increasing order**

* + **The order of users in the sharing BSS in the Sync frame is aligned with that in the Invite frame.**
  + **The order of users in the shared BSS in the Sync frame is aligned with that in the Response frame.**

**[Motion #316]**

**The order of user information in the Sync frame is aligned with the order of users in the UHR-SIG User field for Co-BF transmission.**

**[Motion #327]**

**The Co-BF Invite frame carries the following information.**

* + **How to indicate the information is TBD.**

|  |  |
| --- | --- |
| Category | Information |
| Control | ‘Co-BF Invite’ |
| PHY Common Info | Minimum Number of Data OFDM Symbols |
| Maximum Number of Data OFDM Symbols |
| PHY Version Identifier |
| Bandwidth |
| Punctured Channel Information |
| GI+LTF Size |
| Maximum Total Nss Allowed for shared AP |
| Number of Co-BF Users in sharing BSS |
| Per-User Info in Sharing BSS | STA ID |
| Nss |

**[Motion #328]**

**The Co-BF Response frame carries at least the following information.**

* + **How to indicate the information is TBD.**

|  |  |
| --- | --- |
| Category | Information |
| Control | ‘Co-BF Acceptance’ |
| PHY Common Info | Suggested Number of Data OFDM Symbols |
| PHY Version Identifier |
| Extra LTF Allowed |
| Number of CoBF Users in shared BSS |
| Per-User Info in Shared BSS | STA ID |
| MCS |
| Nss |
| 2xLDPC |

**[Motion #371]**

**The following information shall be exchanged before Co-BF PPDU:**

* + **Min-Nsym and Max-Nsym indication about the COBF PPDU length sent in the COBF invite frame**
  + **Suggested Nsym indication in the Co-BF response frame from shared AP** 
    - **Sharing AP is allowed to ignore the shared AP’s suggestion**
    - **Suggested value shall not be smaller than the Min-Nsym value from sharing AP**

**Relevant CIDs (Part I):**

**199 777 984 1578 2457 2802 3482**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| CID | Commenter | Clause | Page | Comment | Proposed Change | Resolution |
| 199 | Chunyu Hu | 37.8.2.1 | 72.13 | What would be the Co-BFed PPDU that would achieve the goal of Co-BF as mentioned in 37.8.2.1.1 with the sounding results. Does an AP need to know the other AP's DL traffic info in order to properly construct the PPDU? If so, how exactly? | Need to provide text to address the questions raised in the comment. | Revised –  Agree in principle with the commenter. A polling phase is added for the AP to know the other AP’s intent to participate in the Co-BF transmission.  TGbn Editor:  Please implement the changes in this document tagged as #199 |
| 777 | Seongho Byeon | 37.8.2.1 | 72.21 | Since Co-BF aims to minimize mutual interference between two APs and their recipient STAs, the general term "interference to OBSS STA" may not be appropriate. Suggest modifying it to "interference between each other" or "interference in between each recipient STA". | As in comment. | Revised –  Agree in principle with the commenter.  TGbn Editor:  Please implement the changes in this document tagged as #777 |
| 984 | Arik Klein | 37.8.2.1.1 | 72.24 | Need to add a clear requirement for the required Channel state information/ Compressed Beamforming/CQI reports that are mandatory for each AP to obtain prior to its participation in a Co-BF transmission. Note: The sentence in P72L24) only refers to the UHR Sounding procedure as a means to obtain these reports. | As in comment | Revised –  Agree in principle with the commenter.  TGbn Editor:  Please implement the changes in this document tagged as #984 |
| 1578 | Jinsoo Choi | 37.8.2.1 | 72.26 | The Co-BF transmission needs to be initiated by an AP that obtains a TXOP (i.e. sharing AP) with a Co-trigger/Sync frame to notify and align the start of Co-Bfed PPDU transmission. Needs to describe how to initiate a Co-BF transmission. In addition, the overall procedure for Co-BF including discovery of candidate APs, parameters negotiation, initiating Co-BF transmission, and transmitting Co-BFed PPDUs, etc., also needs to be defined. Some part (e.g. discovery, negotiation) that is common for all multi-AP schemes may be covered as in general multi-AP coordinatio framework (37.8.1). | See the comment. | Revised –  Agree in principle with the commenter. A subclause for Co-BF negotiation is added and a place holder for the Co-BF transmission phase is added. The details of the data transmission procedure will be added after related motions are approved. Besides, terminologies of Co-BF coordinating AP and Co-BF coordinated AP are defined to describe the procedure more efficiently.  TGbn Editor:  Please implement the changes in this document tagged as #1578 |
| 2457 | Yanjun Sun | 37.8.2.1.1 | 72.19 | Suggest to change this to "STAs associated with each of the APs" | as in comment | Revised –  Agree in principle with the commenter.  TGbn Editor:  Please implement the changes in this document tagged as #2457 |
| 2802 | RUI YANG | 37.8.2.1.1 | 72.19 | "to each AP's associated STAs" and "to OBSS STAs" are confusing terms in the sentence. | Change the sentence to "The objective of coordinated beamforming (Co-BF) is to allow more efficient medium usage by enabling concurrent transmissions of two APs with multiple antennas to the designated receiving STAs associated with each AP while minimizing interference to the designated receiving STAs in the OBSS by using the CSI of the channels between each AP and all designated receiving STAs associated with one of the two APs." | Revised –  Agree in principle with the commenter.  TGbn Editor:  Please implement the changes in this document tagged as #2457 and #777 |
| 3482 | ron porat | 37.8.2.1.1 | 72.24 | In addition to maximum number of spatial streams per recipient STA being restricted to 2, the maximum total number of spatial streams across all recipient STAs of both participating APs is limited to 4 for CoBF (Motion #115). This should be captured here. | Include the following: "The maximum total number of spatial streams of the Co-BF transmission summed over all recipient STAs of both participating APs shall  be 4." | Accepted. |

# Text to be adopted begins here:

**3.2 Definitions specific to IEEE Std 802.11**

**(#1578) coordinated beamforming coordinating access point:** [Co-BF coordinating AP] A coordinating AP that initiates Co-BF transmission with other APs.

**(#1578) coordinated beamforming coordinated access point:** [Co-BF coordinated AP] A coordinated AP that participates in Co-BF transmission initiated by the Co-BF coordinating AP.

**37.8 Multi-AP coordination framework**

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

**37.8.2.1 Coordinated beamforming**

**37.8.2.1.1 General**

The objective of coordinated beamforming (Co-BF) is to allow more efficient medium usage by enabling concurrent transmissions of two APs with multiple antennas to (#2457)non-AP STAs associated with the two APs, whereby each AP transmits to the non-AP STA(s) within its BSS while minimizing interference to (#777) the non-AP STA(s) associated with the other AP by using the CSI of the channels between each AP and the recipient STAs of the other AP of the Co-BF transmission. The number of participating APs in a Co-BF transmission shall be 2. The maximum number of spatial streams for each recipient STA of the Co-BF transmission shall be 2. (#984)The APs shall obtain the CSI required for performing the Co-BF transmission as described in 37.7 (UHR sounding operation).

(#1578)(M#300)A Co-BF coordinating AP is an AP with dot11CoBFOptionImplemented equal to true that obtains a TXOP and transmits a Co-BF Invite frame to invite another AP to perform Co-BF transmission. A Co-BF coordinated AP is an AP with dot11CoBFOptionImplemented equal to true that receives a Co-BF Invite frame from the Co-BF coordinating AP to perform Co-BF transmission. The Co-BF transmission sequence shall be initiated by the Co-BF coordinating AP. An AP shall not perform a Co-BF transmission to a STA with dot11CoBFOptionImplemented equal to false.

(#1578)An AP shall not initiate Co-BF transmission sequence with another AP unless the two APs have established a MAPC agreement for Co-BF according to the procedure defined in 37.8.2.1.2 (Co-BF negotiation).

**(#1578) 37.8.2.1.2 Co-BF negotiation**

A MAPC requesting AP shall follow the rules defined in 37.8.1.3 (MAPC agreement negotiation) to establish, update, or tear down a Co-BF agreement with a MAPC responding AP and additional rules defined in this subclause. An AP that responds to a MAPC requesting AP in a MAPC agreement negotiation for a Co-BF agreement shall follow the rules defined in 37.8.1.3 (MAPC agreement negotiation) and additional rules defined in this subclause.

In order to perform Co-BF transmission, a MAPC requesting AP shall transmit a MAPC Negotiation Request frame carrying a MAPC element including a Co-BF profile to a MAPC responding AP. The MAPC Operation Type field in the Co-BF profile shall be set to 0 to establish a new Co-BF agreement, or to 1 to update an existing Co-BF agreement.

After receiving the MAPC Negotiation Request frame, the MAPC responding AP shall transmit a MAPC Negotiation Response frame carrying a MAPC element including a Co-BF profile to the MAPC requesting AP. The MAPC Operation Type field in the Co-BF profile shall be set to 3 to accept the Co-BF agreement, to 4 to reject the Co-BF agreement, or to 5 to reject the Co-BF agreement with a suggestion of alternative parameters.

After a Co-BF agreement has been established between two APs, if one AP intends to tear down the Co-BF agreement, the AP shall transmit a MAPC Negotiation Request frame carrying a MAPC element that includes a Co-BF profile to the other AP, where the MAPC Operation Type field in the Co-BF profile shall be set to 2.

**37.8.2.1.3 Co-BF transmission phase**

(#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. (M#327)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

(#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. (M#328)If the Co-BF coordinated AP accepts the Co-BF invite, the Co-BF Response frame shall include the following information:

* 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 shared 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

(M#312)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.

(#1578)A Co-BF coordinating AP shall transmit a Co-BF Trigger frame to a Co-BF coordinated AP prior to the Co-BF transmission with the Co-BF coordinated AP.

(M#311)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
* 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

(M#316)The order of user information in the Co-BF Trigger frame shall be the same with 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 38.3.15.9.6 (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 with 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 with that in the Co-BF Response frame.

(M#298)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.