IEEE P802.11  
Wireless LANs

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| PDT PHY Co-BF | | | | |
| Date: 2025-01-06 | | | | |
| Author(s): | | | | |
| Name | Affiliation | Address | Phone | email |
| Ron Porat | Broadcom Inc |  |  | ron.porat@broadcom.com |
| Sameer Vermani | Qualcomm |  |  | svverman@qti.qualcomm.com |
| You-Wei Chen | MediaTek |  |  | you-wei.chen@mediatek.com |
| Alice Chen | Qualcomm |  |  |  |
| Srinath Puducheri | Broadcom |  |  |  |
| Juan Fang | Intel |  |  |  |
| Karim Toussi | Broadcom |  |  |  |
| Jianhan Liu | MediaTek |  |  |  |
| Qinghua Li | Intel |  |  |  |
| Hari Ram Balakrishnan | NXP |  |  |  |
| Tianyu Wu | Apple |  |  |  |
| Wook bong Lee | Apple |  |  |  |
| Mengshi Hu | Huawei |  |  |  |
| Aniruddh Rao | Samsung |  |  |  |
| Bin Tian | Qualcomm |  |  |  |
| Aiguo Yan | Samsung |  |  |  |
| Shimi Shilo | Huawei |  |  |  |
| Junghoon Suh | Huawei |  |  |  |
| Jason Yuchen Guo | Huawei |  |  |  |
| Youhan Kim | Qualcomm |  |  |  |
| Sigurd Schelstraete | Maxlinear |  |  |  |
| Yeon-Geun Lim | Newracom |  |  |  |
| Leonardo Lanante | Offino |  |  |  |
| Insik Jung | LGE |  |  |  |
| Qinglai Liu | Panasonic |  |  |  |
| Xiaogang Chen | Spreadtrum |  |  |  |
| Jay Yang | ZTE |  |  |  |
| Kosuke Aio | Sony |  |  |  |
| Rui Cao | NXP |  |  |  |
| Dana Ciochina | Sony |  |  |  |
| Ying Wang | Interdigital |  |  |  |
| Genadiy Tsodik | Huawei |  |  |  |
| Ross Yu | Huawei |  |  |  |
| Mahmoud Kamel | Interdigital |  |  |  |

Abstract

This document contains Proposed Draft Text (PDT) for PHY aspects of the Co-BF feature of the proposed TGbn (UHR, Ultra High Reliability) amendment to the 802.11 standard and is limited to sections 38.x.

# Revision information

The following is a summary of the important changes that occurred within each revision of this document:

|  |  |
| --- | --- |
| **Revision** | **Major changes** |
| 0 | Initial revision |
| 1 | Resolve comments from Wook bong, Qinglai, Leonardo, Xiaogang, Jay |
| 2 | Resolve comments from Leonardo, Qinglai, Insik, Kosuke |
| 3 | Resolve comments from Rui Cao |
| 4 | Resolve comments from Shimi, Dana, Ying, Genadiy, Ross, Mahmoud |
| 5 | Typo, added a period in one sentence |

# 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 passing PHY motions in doc 24/0171 [1]:

[Motion #29, [1]]

Move to add the following text to the TGbn SFD:

•      Define a multi-AP Coordinated Spatial Reuse at TxOP-level with power control

•      Define multi-AP Coordinated Beamforming

•      Other multi-AP coordination modes are TBD

[Motion #99, [1]]

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

Motion #103, [1]]

* In the UHR sounding process for COBF, for the joint sounding case as well as for the sequential sounding case, the NDP shall always carry the BSS color of the AP which transmitted the NDPA.

[Motion #111, [1]]

Move to add to the TGbn SFD the following:

The pre-UHR portion (the portion up-to and including UHR-SIG) of the COBF PPDU shall be transmitted in a non-beamformed (omni) manner.

[Motion #112, [1]]

Move to add to the TGbn SFD the following:

* The pre-UHR portion of a COBF PPDU shall have identical content across two APs.

[Motion #114, [1]]

Move to add to the TGbn SFD the following:

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

Motion #115, [1]]

* For the maximum number of spatial streams supported for reception of sounding NDP in UHR and the maximum total number of streams (across all users) supported for reception in UHR DL MU-MIMO and COBF PPDUs:
  + 4 is mandatory except for a non-AP STA with 20 MHz-Only Limited Capabilities Support subfield equal to 1.
  + 8 is optional for DL MU-MIMO and sounding NDP (Note: More than 4 is not allowed for COBF PPDUs

# Text to be adopted begins here:

***TGbn editor: Please add the following new subclauses for Co-BF to the 802.11bn draft D0.1:***

#### **38.1 Introduction**

#### **38.1.1 Introduction to the UHR PHY**

A UHR AP may support the following features:

* Full bandwidth and partial bandwidth UHR sounding as defined in 37.6.2 (UHR sounding protocol).

A non-AP UHR STA shall support the following features:

* Responding with requested beamforming feedback in a UHR sounding procedure with up to 4 spatial streams in the EHT sounding NDP if the non-AP STA supports Co-BF, except for a 20 MHz-only non-AP STA with 20 MHz-Only Limited Capabilities Support subfield equal to 1.
* Full bandwidth UHR sounding as defined in 37.6.2 (UHR sounding protocol) if the non-AP STA supports Co-BF.

# 38.3.14 UHR preamble

## 38.3.14.1 Introduction

The UHR preamble consists of pre-UHR modulated fields and UHR modulated fields. The pre-UHR modulated fields for the three UHR PPDU formats are the following:

— L-STF, L-LTF, L-SIG, RL-SIG, and U-SIG fields of a UHR TB PPDU

— L-STF, L-LTF, L-SIG, RL-SIG, U-SIG, and UHR-SIG fields of a UHR MU PPDU

— L-STF, L-LTF, L-SIG, RL-SIG, U-SIG, and ELR-MARK fields of a UHR ELR PPDU

The UHR modulated fields in the preamble for the UHR TB PPDU and UHR MU PPDU formats are the UHR-STF and UHR-LTF fields.

For a UHR MU PPDU using Co-BF, the pre-UHR modulated fields are non-beamformed and the UHR modulated fields including the UHR-STF and UHR-LTF fields are beamformed using the same beamforming steering matrix as the Data field.

For a UHR MU PPDU using Co-BF, the pre-UHR modulated fields shall have identical content across all participating APs and shall be transmitted by all participating APs.

38.3.20 Coordinated Beamforming

38.3.20.1 Introduction

Coordinated Beamforming (Co-BF) is a technique used by multiple APs, each with multiple antennas (acting as a beamformer), to steer signals using knowledge of the channel in order to improve throughput, reliability and to reduce latency. With SU-MIMO beamforming all spatial streams in the transmitted signal are intended for reception at a single STA. With DL MU-MIMO beamforming, disjoint subsets of the spatial streams are transmitted from a single AP and are intended for reception at different non-AP STAs. With Co-BF, disjoint subsets of spatial streams are transmitted from different APs, where each AP’s subset of streams may be further divided into the streams intended for reception at one or more non-AP STAs associated with that AP.

Depending on the channel knowledge available and the number of antennas available at the APs, the steering matrices used by all the APs may ensure a minimal signal strength of an AP’s spatial streams at either all the receive antennas of all the OBSS AP’s recipients or, if those recipients have more than a single receive antenna, over a subspace of the eigen-modes of the channels to the OBSS AP’s recipients.

The sounding procedure needed for obtaining the channel information for performing the steering for Co-BF is described in 37.6 UHR sounding operation.

For Co-BF, the receive signal vector in subcarrier *k* at recipient *u*, , is shown in Equation (21-101), where  denotes the transmit signal vector in subcarrier *k* for all *Nuser* recipients, with being the transmit signal for recipient *u*.



where

***H****k,u* is the compound channel matrix from the beamformers to recipient *u* in subcarrier *k* with dimensions , where NTX is the total number of transmit chains across all the participant beamformers

 is the number of receive chains at recipient *u*

 is a steering matrix for recipient *u* in subcarrier *k* with dimensions x and it has zero entries for the rows corresponding to antennas of APs that the recipient *u* is not associated with.

*Nuser* is the number of Co-BF PPDU recipients (see Table 21-6 (Frequently used parameters))

***n*** is a vector of additive noise and may include interference

The Co-BF steering matrix  is composed of sections (disjoint sets of rows) which are calculated by different beamformers using the beamforming feedback matrices *Vk,u* for subcarrier *k* from recipient *u*, and SNR information *SNRk,u* for subcarrier *k* from recipient *u*, where

 .

Note, that all the APs participating in a Co-BF transmission need to have the channel state information to all the recipients to make this calculation possible. The process for obtaining this information is described in 37.6 UHR sounding operation.

38.3.20.2 Beamforming Feedback Matrix *V* during UHR sounding operation

Upon reception of an EHT sounding NDP as part of a UHR TB sounding sequence, the beamformee shall follow the procedure as described in 27.3.16.2 (Beamforming feedback matrix V), to calculate the compressed beamforming feedback matrix in the form of angles which are sent to the beamformers in the CSI feedback*.* When sounding is performed for the purpose of a Co-BF transmission, the feedback shall be of type MU. The beamformee shall generate the beamforming feedback matrices with the number of rows (*Nr*) equal to the *NSTS* of the sounding NDP. CSD removal guidelines, quantization requirements, tone-grouping options and codebook sizes shall also follow the description in section 27.3.16.2.

After receiving the angle information, the beamformers reconstruct *Vk,u* using Equation (19-79). For Co-BF, the participating beamformers may calculate the corresponding portion of the overall steering matrix  using *Vk,u* and *SNRk,u* () in order to suppress crosstalk between participating beamformees. The method used by the beamformers to calculate the portions of the steering matrix *Qk* is implementation specific.

In UHR sounding, the tone grouping and codebook size to be used in the compressed beamforming report of the beamforming feedback matrix *V* are defined by the the AP transmiting the UHR NDP Announcement frame (even if the sounding NDP is sent by another AP).

38.3.20.3 Supported RU sizes in Co-BF

Co-BF transmissions in UHR are applicable only to non-OFDMA DL transmissions

38.3.20.4 Number of APs, STAs and spatial streams in a Co-BF PPDU

The number of participating APs in a UHR Co-BF transmission shall be 2. The total number of recipient STAs across the 2 APs in a Co-BF transmission shall be less than or equal to 4. The maximum number of spatial streams per recipient STA in Co-BF is 2.

Co-BF transmissions are defined only for a UHR AP that can transmit 4 or more spatial streams.

The maximum total number of spatial streams in a Co-BF PPDU across all recipients shall be 4.

#### **38.3.21 EHT sounding NDP for UHR TB sounding sequence**

The EHT sounding NDP is a variant of the EHT MU PPDU as defined in 36.3.18 (EHT sounding NDP). An EHT sounding NDP for UHR TB sounding sequence is indicated by setting the PHY Version Identifier to 0 (EHT), PPDU Type And Compression Mode field to 1, the EHT-SIG MCS field to 0, and the Number Of EHT-SIG Symbols field to 0 in the U-SIG field. The format of an EHT sounding NDP for UHR TB sounding sequence is illustrated in Figure 38-x (EHT sounding NDP format for UHR TB sounding sequence).



#### **Figure 38-x—EHT sounding NDP format for UHR TB sounding sequences**

The BSS Color in the U-SIG of the EHT sounding NDP for UHR TB sounding is set to the BSS Color of the transmitter of the most recent UHR NDP Announcement frame.

In a sounding NDP used for Co-BF, the number of spatial streams is set to four or eight spatial streams.

In a sounding NDP used for Co-BF, the number of EHT-LTF Symbols is set to four or eight. Other values are disallowed.

GI+LTF size is set to either 2 EHT-LTF with 0.8 µs GI or 2 EHT-LTF with 1.6 µs GI. The other combinations of EHT-LTF type and GI duration are disallowed.