IEEE P802.11
Wireless LANs

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| SC Precoding Indications |
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Abstract

This document proposes draft changes to BRP and MIMO frames to accommodate digital beamforming training. Changes are based on Draft 0.5.

Discussion

Digital BF Computation

* For OFDM: Computation at receiver based on SVD per subcarrier and is known to be optimal
* For SC:
	+ Computation can be performed at the transmitter:
		- based on channel measurement included in the EDMG Channel Measurement
		- does not consider the receiver structure
		- does not consider all channel information available at the receiver
	+ Computation can be performed at the receiver
		- unique optimal solution in point of achievable rate w.r.t. to a given equalizer exists, only known at the receiver
		- various suboptimal solutions considering averaging over frequency can be easily derived and are only available at the receiver
		- suboptimal solution in time domain based on SVD on best tap MIMO channel

Signaling and Protocol Requirements:

* Indication that digital bf training will be performed
* Indication of whom is performing the bf matrix computation
* Indication of the digital bf matrices
	+ (optionally) the format and required parameters of the digital precoders
* Sounding requirement: analog beam combinations can be taken based on rougher channel estimates than digital beamformers. Furthermore, high tap resolution can have large feedback overhead and therefore would in many cases not be used. Therefore in most cases computing a precoder based on only the channel measurement in the MIMO feedback after the MIMO setup is not feasible and finer channel estimates are needed.

Motivation for using BRP frames to request digital BF computation and type of BF feedback:

* Allows flexibility as BF computation can be made independent of MIMO training
* In many cases loss of digital BF is related to loss of analog BF; using BRP makes possible the restablishment of both beamformers within one flow
* Sending MIMO feedback with tracking request to allow computation of digital BF can be inconvenient as this frame is sent in control mode (so only SC SISO TRNs can be sent staggered). Also, the antenna selection is only known at the receiver to allow precoder computation after the RTS. Thus first data packets cannot be sent beamformed, if digital BF can only be requested by tracking.
* MCSs with analog only and joint analog and digital BF can vary significantly even for SC

Motivation for using MIMO Feedback to contain Digital BF Feedback

* Natural solution especially when feedback sent as part of tracking process, as in most cases both information will be required at the same time

9.4.2.255 EDMG BRP Request element

The EDMG BRP Request element provides BRP configuration in addition to the BRP configuration provided in the BRP Request field. The EDMG BRP Request element is defined in Figure 45.

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | B0 B7 | B8 B15 | B16 B23 | B24 B31 | B32 B39 | B40 B50 | B51 B52 | B53 B56 | B57 B58 |
|  | Element ID | Length | Element ID Extension | L-RX | L-TX-RX | TX Sector ID | EDMG TRN-Unit P | EDMG TRN-Unit M | EDMG TRN-Unit N |
| Bits: | 8 | 8 | 8 | 8 | 8 | 11 | 2 | 4 | 2 |

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| --- | --- | --- | --- | --- | --- | --- | --- |
|  | B59 | B60 | B61 B69 | B70 B75 | B76 B83 | B84 | B85 B87 |
|  | TXSS-REQ | TXSS-REQ-RECIPROCAL | TXSS-SECTORS | BRP CDOWN | TX Antenna Mask | Digital BF Request | Reserved |
| Bits: | 1 | 1 | 9 | 6 | 8 | 1 | 3 |

1. —EDMG BRP Request element format

The Element ID, Length and Element ID Extension fields are defined in 9.4.2.1.

The L-RX field indicates the number of TRN-R subfields requested by the transmitting STA as part of beam refinement.

The L-TX-RX field indicates the requested number of consecutive TRN-Units for which the transmit AWV remain with the same AWV configuration.

The TX Sector ID field indicates the sector ID that is used when transmitting the packet. If the packet is transmitted using a pattern that is not a sector that has been used in the sector sweep, the value of this field is set to 2047.

The EDMG TRN-Unit P field indicates the requested number of TRN subfields at the start of a TRN-Unit that use the same AWV. A value of zero indicates zero requested TRN subfields, a value of one indicates one requested TRN subfield, a value of two indicates two requested TRN subfields and a value of three indicates four requested TRN subfields.

The value of the EDMG TRN-Unit M field plus one indicates the requested number of TRN subfields within a TRN-Unit that can change the AWV configuration. The value of this field is an integer multiple of the value of the EDMG TRN-Unit N field.

The EDMG TRN-Unit N field indicates the requested number of TRN subfields per EDMG TRN-Unit M field. A value of zero indicates one requested TRN subfield, a value of one indicates two requested TRN subfields, a value of two indicates three requested TRN subfields if EDMG TRN-Unit M field is equal to 3, 6, 9 or 12, a value of two indicates eight requested TRN subfields if EDMG TRN-Unit M field is equal to 8 or 16, and a value of three indicates four requested TRN subfields.

The TXSS-REQ field is set to one to indicate the request to perform the BRP TXSS training defined in 10.38.9.5. Otherwise, this field is set to zero.

If the TXSS-REQ field is equal to one, the TXSS-REQ-RECIPROCAL field set to one indicates the request for reciprocal BRP TXSS training (see 10.38.9.5), otherwise it is set to zero. If the TXSS-REQ field is equal to zero, the TXSS-REQ-RECIPROCAL field is reserved.

If the TXSS-REQ field is equal to one, the TXSS-SECTORS field indicates the total number of transmit sectors the transmitter of this element uses in the BRP TXSS procedure combined over all of its DMG antennas. Otherwise if the TXSS-REQ field is equal to zero, the TXSS-SECTORS field is reserved.

The BRP CDOWN field is a down-counter indicating the number of remaining EDMG BRP packet transmissions to the end of the BF training.

The TX Antenna Mask field is a bitmap that indicates whether each of eight TX DMG antennas is used in the transmission of the EDMG BRP packet. The first bit (i.e., the least significant bit) corresponds to the first TX DMG antenna, the second bit corresponds to the second TX DMG antenna, and so on. A bit is set to 1 to indicate the associated TX DMG antenna is used in the transmission of the EDMG BRP packet; otherwise the bit is set to 0

If Digital BF Request is equal to one, it indicates a request for performing digital beamforming. Otherwise this field is set to 0. When Digital BF Request is set to one, feedback will be sent in MIMO Feedback frames and will contain precoding information or MIMO Channel Measurement, depending on the values indicated in the DMG Beam Refinement Element,

9.4.2.130 DMG Beam Refinement element

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | B0 B7 | B8 B15 | B16 | B17 | B18 | B19 | B20 | B21 B26 | B27 B28 | B29 B33 |
|  | Element ID | Length | Initiator | TX-train-response | RX-train-response | TX-TRN-OK | TXSS-FBCK-REQ | BS-FBCK | BS-FBCK Antenna ID | FBCK-REQ |
| Bits: | 8 | 8 | 1 | 1 | 1 | 1 | 1 | 6 | 2 | 5 |

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| --- | --- | --- | --- | --- | --- | --- |
|  | B34 B51 | B52 | B53 | B54 B55 | B56 B59 | B60 |
|  | FBCK-TYPE | MID Extension | Capability Request | Reserved | BS-FBCK MSB | BS-FBCK Antenna ID MSB |
| Bits: | 18 | 1 | 1 | 2 | 4 | 1 |

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | B61 B64 | B65 | B66 | B67 | B68 | B69 | B70 | B71 |
|  | Number of Measurements MSB | EDMG Extension Flag | EDMG Channel Measurement Present | Short SSW Packet Used | BRP-TXSS-OK | BRP-TXSS-response | DBFFBCK REQ  | Reserved |
| Bits: | 4 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

The definition of the BS-FBCK field depends on the value of the EDMG Extension Flag field. If the EDMG Extension Flag field is set to 1, the BS-FBCK MSB field is prepended to the BS-FBCK field to form a single BS-FBCK field of size 10 bits. Otherwise, the BS-FBCK MSB field is reserved.

If the EDMG Extension Flag field is set to 0, the BS-FBCK field indicates the index of the TRN-T field that was received with the best quality in the last received BRP-TX PPDU, where the first TRN-T field in the PPDU is defined as having an index equal to 1.If the EDMG Extension Flag field is set to 1, the BS-FBCK field indicates the AWV feedback ID of the TRN subfields transmitted with the same AWV that were received with the best quality in the last received EDMG BRP-TX packet or EDMG BRP-RX/TX packet as defined in 30.9.2.2.5. If the last received PPDU was not a BRP-TX PPDU, an EDMG BRP-TX packet or an EDMG BRP-RX/TX packet, this field is set to 0. The determination of best quality is implementation dependent.

*Insert the following paragraph before the 9th paragraph*

The definition of the BS-FBCK Antenna ID field depends on the value of the EDMG Extension Flag field. If the EDMG Extension Flag field is set to 1, the BS-FBCK Antenna ID MSB field is prepended to the BS-FBCK Antenna ID field to form a single BS-FBCK Antenna ID field of size 3 bits. Otherwise, the BS-FBCK Antenna ID MSB field is reserved.

The definition of the DBF FBCK REQ field depends on the value of the Digital BF Request field within the EDMG Request Element. If Digital BF Request= 1 and DBF FBCK-Req is set to 1, digital beamforming matrix information is requested as part of a following MIMO Feedback Frame. If Digital BF Request = 1 and DBF FBCK-REQ=0, MIMO channel measurement is present as part of a following MIMO Feedback frame. If Digital BF Request=0, the value of DBF FBCK-Req is reserved.

9.4.2.x MIMO Feedback Control element

The MIMO Feedback Control element, as shown in Table 9-xxx (MIMO Feedback Control element format), is used to carry configuration information for accompanying Channel Measurement Feedback element and EDMG Channel Measurement Feedback element.

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| Table 9-xxx MIMO Feedback Control element format  (11ad) |
| Field | Size | Meaning |
| Element ID | 8 bits |  |
| Length | 8 bits |  |
| Element ID Extension | 8 bits |  |
| SU/MU | 1 bit | Sets to 1 to indicate SU-MIMO beamforming and sets to 0 to indicate MU-MIMO beamforming. |
| Link Type | 1 bit | Sets to 1 to indicate initiator link and sets to 0 otherwise. This field shall be set to 1 when the SU/MU field is set to 0. |
| MIMO FBCK-TYPE | 11 bits |  |

The Element ID, Length and Element ID Extension fields are defined in 9.4.2.1 (General).

The MIMO FBCK-TYPE field is defined in Figure 9-x and is described in Table 9-xxxx.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Channel Measurement Present | Tap Delay Present | Number of Taps Present | Number of TX Sector Combinations Present | Precoder Information Present |
| Bits: | 1 | 1 | 2 | 6 | 1 |

Figure 9-x-MIMO FBCK-TYPE field format

Table 9-xxxx-MIMO FBCK-TYPE field description

|  |  |
| --- | --- |
| **Subfield** | **Meaning** |
| Channel Measurement Present | If set to 1, the Channel Measurement subfield is present as part of the MIMO BF feedback. Otherwise, set to 0.  |
| Tap Delay Present | If set to 1, the Tap Delay subfield is present as part of the MIMO BF feedback. Otherwise, set to 0.  |
| Number of Taps Present | Number of taps in each channel measurement. |
| Number of TX Sector Combinations Present | The value of this field plus one indicates the number of TX sector combinations, *N*tsc, for the MIMO BF feedback. The number of measurements, *N*meas, is *N*TX×*N*RX multiples of the number of TX sector combinations, *N*tsc. |
| Precoding Information Present | If set to 1, the precoding information is present as part of the MIMO BF Feedback. Otherwise it is set to 0. |

SP: Do you agree to add the changes in document 11-17-1452-00-00ay to the current specification draft?