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| Draft Spec Text for SU MIMO Beamforming | | | | |
| Date: 2016-12-21 | | | | |
| Author(s): | | | | |
| Name | Affiliation | Address | Phone | email |
| Lei Huang | Panasonic Corporation |  |  | lei.huang@sg.panasonic.com |
| James Wang | MediaTek |  |  |  |
| Carlos Cordeiro | Intel Corporation |  |  |  |
| Dejian Li | Huawei Technologies |  |  |  |
| Motozuka Hiroyuki | Panasonic Corporation |  |  |  |
| Wee Gaius | Panasonic Corporation |  |  |  |

Abstract

This document proposes specification text for subcaluse 3.3 of the 11ay SFD describing SU-MIMO beamforming.

***Insert the following new clause***

10.38.9 SU-MIMO beamforming(11ad)

**10.38.9.1 General**

The SU-MIMO beamforming protocol supports beamforming training for transmission and reception of multiple spatial streams between a SU-MIMO capable initiator and a SU-MIMO capable responder. The SU-MIMO beamforming protocol enables the determination of transmit antenna settings and the corresponding receive antenna settings for simultaneous transmission of multiple spatial streams from the initiator to the responder or vice versa.

Both the initiator and the responder shall declare SU-MIMO capability during capability exchange by setting the SU-MIMO Support subfield in the EDMG Capabilities element to 1. The SU-MIMO capability means support of both SU-MIMO transmission and reception. The SU-MIMO beamforming protocol shall be performed in the DTI and shall not be initiated unless the initiator and the responder have a valid SISO beamformed link between them.

The SU-MIMO beamforming protocol can also be used to enable transmit beamforming operation of multiple DMG antennas between the initiator and the responder in which a single spatial stream is transmitted through multiple DMG antennas.

The SU-MIMO beamforming protocol comprises the following consecutive phases:

* SISO phase, and
* MIMO phase

**10.38.9.2 SISO phase**

The objective of the SISO phase is to enable the initiator to collect feedback of the last initiator TXSS from the responder and also enables the responder to collect feedback of the last responder TXSS from the initiator. During the SISO phase, all transmissions should use the DMG control mode.

Figure 1 depicts the SISO phase, which consists of three subphases: an optional initiator TXSS subphase, an optional responder TXSS subphase, and an SISO Feedback subphase. If both the initiator TXSS subphase and the responder TXSS subphase are present in the SISO phase, the SISO Feedback subphase shall be separated from the responder TXSS subphase by an MBIFS, which in turn shall be separated from the initiator TXSS subphase by an MBIFS.

The initiator may perform the initiator TXSS subphase to start the SISO phase. During the initiator TXSS subphase, the initiator performs an initiator TXSS (see 10.38.2.2.2 Initiator TXSS). The Short SSW frame shall be used during the initiator TXSS. In each Short SSW frame transmitted as part of the initiator TXSS, the initiator shall set the Packet Type field to 0, set the Direction field to 0, and set the Addressing Mode field to 0. In addition, the CDOWN field in each transmitted Short SSW frame shall contain the total number of Short SSW frame transmissions remaining until the end of the initiator TXSS, including any LBIFS if required, such that the last Short SSW frame transmission of the initiator TXSS has the CDOWN field set to 0.

If the initiator TXSS subphase was present in the SISO phase, the responder shall initiate the responder TXSS subphase following the completion of the initiator TXSS subphase. Otherwise the responder shall not initiate the responder TXSS subphase following the completion of the initiator TXSS subphase. During the responder TXSS subphase, the responder performs a responder TXSS (see 10.38.2.3.2 Responder TXSS). The Short SSW frame shall be used during the responder TXSS. In each Short SSW frame transmitted as part of the responder TXSS, the responder shall set the Packet Type field to 0, set the Direction field to 1 and set the Addressing Mode field to 0. The CDOWN field in each transmitted Short SSW frame shall contain the total number of Short SSW frame transmissions remaining until the end of the responder TXSS, including any LBIFS if required, such that the last Short SSW frame transmission of the responder TXSS has the CDOWN field set to 0. In addition, the Short SSW Feedback field in each transmitted Short SSW frame shall contain the value of the CDOWN field of the Short SSW frame that was received with best quality in the immediately preceding initiator TXSS.

It is mandatory to perform the SISO Feedback subphase. In the SISO Feedback subphase, the initiator shall send an SISO Feedback frame to the responder. The SISO Feedback frame shall contain a list of CDOWN values and SNRs of the transmit sectors received during the last responder TXSS. The responder shall send an SISO Feedback frame to the initiator a SIFS following the reception of the SISO Feedback frame from the initiator, which shall contain a list of CDOWN values and SNRs of the transmit sectors received during the last initiator TXSS.



**Figure 1-The SISO phase**

**10.38.9.3 MIMO phase**

The MIMO phase enables the training of transmit and receive sectors and DMG antennas to determine best combinations of transmit and receive sectors and DMG antennas for SU-MIMO operation. The initiator shall start the MIMO phase an MBIFS following the end of the SISO phase. The MIMO phase is shown in Figure 2 and consists of four subphases: an SU-MIMO setup subphase, an initiator SU-MIMO training (SMT) subphase, a responder SMT subphase, and an SU-MIMO feedback subphase. Each subphase shall be separated by an MBIFS.

It is mandatory to perform the SU-MIMO setup subphase. In the SU-MIMO setup subphase, based on the SNRs of the transmit sectors collected from the responder in the SISO Feedback subphase of the SISO phase, the initiator may select a subset of candidate transmit sectors per DMG antenna to reduce the initiator SMT training time. Each DMG antenna should have the similar number of candidate transmit sectors in order to avoid biasing a DMG antenna. If the initiator has antenna pattern reciprocity, the initiator may also reduce the number of receive sector training units to reduce the responder SMT training time. This can be achieved by setting the L-RX subfield to a reduced value in the corresponding MIMO Setup frame. Additionally, based on the SNRs of the transmit sectors collected from the initiator in the SISO Feedback subphase of the SISO phase, the responder may select a subset of candidate transmit sectors per DMG antenna to reduce the responder SMT training time. Each DMG antenna should have the similar number of candidate transmit sectors in order to avoid biasing a DMG antenna. If the responder has antenna pattern reciprocity, the responder may also reduce the number of receive sector training units to reduce the initiator SMT training time. This can be achieved by setting the L-RX subfield to a reduced value in the corresponding MIMO Setup frame.

In the SU-MIMO setup subphase, the initiator shall send a MIMO Setup frame to communicate to the responder the number of BRP frames to be transmitted in the following initiator SMT subphase, the candidate transmit sectors to be used for each transmitted BRP frame, the information on simultaneous transmit antenna training for each transmitted BRP frame, the number of transmit and receive sector combinations requested for the initiator link *NI*, the feedback type for the initiator link (e.g., SINR or time domain channel response) and the decision maker for the initiator link. The information on simultaneous transmit antenna training specifies how orthogonal waveforms are used in each transmitted BRP frame to train multiple transmit DMG antennas simultaneously. The decision maker indicates whether the initiator or the responder is responsible for determining transmit and receive antenna settings for SU-MIMO operation. Additionally, the MIMO Setup frame shall also contain the number of receive sector training units requested for the following responder SMT subphase. The responder shall send a MIMO Setup frame a SIFS following the reception of the MIMO Setup frame from the initiator. The MIMO Setup frame shall contain the number of receive sector training units requested for the following initiator SMT subphase. The MIMO Setup frame shall also contain the number of BRP frames to be transmitted in the following responder SMT subphase, the candidate transmit sectors to be used for each transmitted BRP frame, the information on simultaneous transmit antenna training for each transmitted BRP frame, the number of transmit and receive sector combinations requested for the responder link *NR*, the feedback type for the responder link (e.g., SINR or time domain channel response). All frames transmitted during the MIMO setup subphase should be sent using the DMG control mode.

The initiator shall perform the initiator SMT subphase. In the initiator SMT subphase, the initiator shall transmit BRP frames using the EDMG control mode. In each transmitted BRP frame, the initiator shall include the TRN field to enable training of multiple transmit and receive sectors for SU-MIMO operation of the initiator link. This is indicated by using the EDMG TRN Length field and RX TRN-Units per Each TX TRN-Unit field in the EDMG-Header-A of the EDMG control mode PPDU. If simultaneous transmit antenna training is enabled for a BRP frame, the TRN units of the BRP frame transmitted through multiple transmit DMG antennas are masked with orthogonal sequences.

The responder shall perform the responder SMT subphase following the completion of the initiator SMT subphase. In the responder SMT subphase, the responder shall transmit BRP frames using the EDMG control mode. In each transmitted BRP frame, the responder shall include the TRN field to enable training of multiple transmit and receive sectors for SU-MIMO operation of the responder link. This is indicated by using the EDMG TRN Length field and RX TRN-Units per Each TX TRN-Unit field in the EDMG-Header-A of the EDMG control mode PPDU. If simultaneous transmit antenna training is enabled for a BRP frame, the TRN units of the BRP frame transmitted through multiple transmit DMG antennas are masked with orthogonal sequences.

It is mandatory to perform the SU-MIMO feedback subphase. All frames transmitted during the SU-MIMO feedback subphase should be sent using the DMG control mode. In the SU-MIMO feedback subphase, the initiator shall send a MIMO Feedback frame to the responder. If the responder is the decision maker for the responder link, the EDMG Channel Measurement Feedback element in the MIMO Feedback frame shall contain the SU-MIMO beamforming training feedback for the responder SMT subphase according to the feedback type specified by the responder in the SU-MIMO setup subphase. Otherwise the EDMG Channel Measurement Feedback element in the MIMO Feedback frame shall contain *NR* best transmit and receive sector combinations, which are determined based on channel measurement data captured from the responder SMT subphase.

The responder shall send a MIMO Feedback frame to the initiator a SIFS following the reception of the MIMO Feedback frame from the initiator. If the initiator is the decision maker for the initiator link, the EDMG Channel Measurement Feedback element in the MIMO Feedback frame shall contain the SU-MIMO beamforming training feedback for the initiator SMT subphase according to the feedback type specified by the initiator in the SU-MIMO setup subphase. Otherwise the EDMG Channel Measurement Feedback element in the MIMO Feedback frame shall contain *NI* best transmit and receive sector combinations, which are determined based on channel measurement data captured from the initiator SMT subphase. Additionally, if the responder is the decision maker for the responder link, the EDMG Channel Measurement Feedback element in the MIMO Feedback frame shall also contain *NR* best transmit and receive sector combinations for the responder link, which are determined based on the received SU-MIMO beamforming training feedback for the responder SMT subphase.

If the initiator is the decision maker for the initiator link, the initiator shall send a MIMO Feedback frame to the responder a SIFS following the reception of the MIMO Feedback frame from the responder. Otherwise the initiator shall not send a MIMO Feedback frame to the responder a SIFS following the reception of the MIMO Feedback frame from the responder. The EDMG Channel Measurement Feedback element in the MIMO Feedback frame shall contain *NI* best transmit and receive sector combinations for the initiator link, which are determined based on the received SU-MIMO beamforming training feedback for the initiator SMT subphase.

The *NI* best transmit and receive sector combinations for initiator link and the *NR* best transmit and receive sector combinations for responder link shall be determined in such a way that no determined transmit or receive sectors come from the same DMG antenna. The algorithms for determining the *NI* best transmit and receive sector combinations for the initiator link and for determining the *NR* best transmit and receive sector combinations for the responder link are implementation dependent.



**Figure 2- The MIMO phase**

**References:**

1. IEEE Std 802.11™-2016, Dec 2016