IEEE P802.11
Wireless LANs

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Abstract

This document proposes changes on the 11ay draft D0.3 regarding the MIMO phase of SU-MIMO beamforming and MU-MIMO beamforming.

***Make the following changes on D0.21:***

* + - * 1. SU-MIMO beamforming

10.38.9.2.3.3 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 45 and consists of four subphases: an SU-MIMO BF setup subphase, an initiator SU-MIMO BF training (SMBT) subphase, a responder SMBT subphase, and an SU-MIMO BF feedback subphase. Each subphase shall be separated by an MBIFS.



Figure 45—The MIMO phase

It is mandatory to perform the SU-MIMO BF setup subphase. In the SU-MIMO BF 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 SMBT 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 SMBT training time. This can be achieved by setting the L-RX subfield to a reduced value in the corresponding MIMO BF 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 SMBT 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 SMBT training time. This can be achieved by setting the L-RX subfield to a reduced value in the corresponding MIMO BF Setup frame.

In the SU-MIMO BF setup subphase, the initiator shall send a MIMO BF Setup frame to communicate to the responder the number of BRP frames to be transmitted in the following initiator SMBT 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 BF Setup frame shall also contain the number of receive sector training units requested for the following responder SMBT subphase. The responder shall send a MIMO BF Setup frame a SIFS following the reception of the MIMO BF Setup frame from the initiator. The MIMO BF Setup frame shall contain the number of receive sector training units requested for the following initiator SMBT subphase. The MIMO BF Setup frame shall also contain the number of BRP frames to be transmitted in the following responder SMBT 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 BF setup subphase should be sent using the DMG control mode.

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

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

If the initiator is the decision maker for the initiator link, the initiator shall send a MIMO BF Feedback frame to the responder a SIFS following the reception of the MIMO BF Feedback frame from the responder. Otherwise the initiator shall not send a MIMO BF Feedback frame to the responder a SIFS following the reception of the MIMO BF Feedback frame from the responder. The EDMG Channel Measurement Feedback element in the MIMO BF 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 SMBT 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.

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10.38.9.2.4 MU-MIMO beamforming

10.38.9.2.4.3 MIMO phase

The initiator shall start the MIMO phase MBIFS following the end of the SISO phase. The MIMO phase is shown in Figure 47 and consists of four subphases, namely, a MU-MIMO BF setup subphase, a MU-MIMO BF training subphase, a MU-MIMO –BF feedback subphase, and a MU-MIMO BF selection subphase. Each subphase shall be separated by MBIFS.

In the MU-MIMO BF setup subphase, the initiator shall transmit a MIMO BF Setup frame to each intended responder. The MIMO BF Setup frame indicates the AID of each responder in the MU group, the training type (i.e., MU-MIMO BF training), an unique dialog token identifying MU-MIMO BF training, the number of simultaneous TX DMG antennas employing orthogonal waveforms, the order in which transmit sectors are trained. To reduce the MU-MIMO BF training time, the initiator may select a subset of TX sectors for each DMG antenna and the number of receive training fields based on the feedback from responders. The initiator should transmit the minimum number of MIMO BF Setup frames to reach all responders. All frames transmitted during the MU-MIMO BF setup subphase should be sent using the DMG control mode.

In the MU-MIMO BF training subphase, the initiator shall transmit BRP frames using the EDMG PHY. Each transmitted BRP frame is used to train one or more transmit sectors and, for each transmit sector, a number of receive AWVs. In each BRP frame the initiator shall include, for each selected sector, TRN-Units in the TRN field for intended responders to perform receive sector training. The number of TRN-Unit included in the TRN field should be the maximum number of receive sectors across all intended responders based on the feedback from the SISO phase. An initiator may transmit a BRP frame with orthogonal waveforms to train multiple (up to 4) transmit DMG antennas simultaneously through the same BRP frame and hence reduce the training time. The MU-MIMO BF training subphase is performed by setting, for a BRP frame, the TXVECTOR parameter EDMG\_TRN\_LEN to a value greater than zero and the parameter RX\_TRN\_PER\_TX\_TRN to a value greater than one.

In the MU-MIMO BF Feedback subphase, the initiator shall transmit a MIMO BF Feedback Poll frame to poll each intended responder to collect MU-MIMO BF feedback from the preceding MU-MIMO BF training subphase. Each MIMO BF Feedback Poll frame and MIMO BF Feedback frame sent back by the responder shall be separated by SIFS. Each MIMO BF Feedback Poll frame carries the dialog token that identifies the MU-MIMO BF training. The MIMO BF Feedback frame carries the list of received initiator’s transmit DMG antennas/sectors, each with its corresponding responder’s receive DMG antenna/sector and the associated quality indicated.

In the MU-MIMO BF selection subphase, the initiator shall transmit MIMO BF Selection frame to each responder in the MU group containing the dialog token identifying the MU-MIMO BF training, one or multiple sets of the MU transmission configurations, and the intended recipient STAs for each MU transmission configuration. The final set of selected responders in the MU group contained in the MIMO BF Selection frame does not have to be the same as the initial set of intended responders. The initiator should transmit the minimum number of MIMO BF Selection frames to selected responders.



Figure 47—The MIMO phase