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# MAC Enhancement to Support OFDMA MIMO

## 1 Introduction

This document describes the MAC enhancements to support the MIMO-OFDMA PHY. The following MAC features are proposed:

- DL burst assignment to support adaptive MIMO transmission
- UL burst assignment to support adaptive MIMO transmission
- Fast feedback channel operation to support SS dynamic feedback of MIMO mode and permutation selection

## 2 Proposed MAC Enhancement

### *2.1 DL Burst Assignment to Support Adaptive MIMO Transmission*

To support adaptive MIMO mode, i.e. STTD and spatial multiplexing (SM), we introduce a new DL-MAP extended information element, MIMO_DL_Basic_IE, to perform DL burst assignment with specific MIMO configuration.

*[Add a new section 8.4.5.3.8]*

8.4.5.3.8 MIMO DL Basic IE format

In the DL-MAP, a MIMO-enabled BS may transmit DIUC=15 with the MIMO_DL_Basic_IE() to indicate the MIMO configuration of the subsequent downlink allocation to a specific MIMO-enabled SS' CID. The MIMO mode indicated in the MIMO_DL_Basic_IE() shall only apply to the subsequent downlink allocation until the end of frame.

Table x - MIMO DL Basic IE

| Syntax | Size | Notes |
|---|---|---|
| MIMO_DL_Basic_IE () { | | |
| Extended DIUC | 4 bits | 0x05 |
| Length | 4 bits | Length in bytes |
| Num_Region | 4 bits | |
| for ( i = 0; i< Num_Region; i++) { | | |
| OFDMA Symbol offset | 10 bits | |
| Subchannel offset | 5 bits | |
| Boosting | 3 bits | |
| No. OFDMA Symbols | 9 bits | |
| No. subchannels | 5 bits | |
| Matrix_indicator | 2 bits | STC matrix (see 8.4.8.4.)<br><br>Transmit_diversity = transmit diversity mode indicated in the latest TD_Zone_IE().<br><br>if (Transmit_Diversity == 01)<br>{<br>00 = Matrix A<br>01 = Matrix B<br>10 – 11 = Reserved<br>}<br>elseif (Transmit_Diversity == 10)<br>{<br>00 = Matrix A<br>01 = Matrix B<br>10 = Matrix C<br>11 = Reserved<br>} |
| Num_layer | 2 bits | |
| for (j = 0; j< Num_layer; j++) { | | |
| if (INC_CID == 1) { | | |
| CID | 16 bits | |
| } | | |
| Layer_index | 2 bits | |
| DIUC | 4 bits | 0-11 burst profiles |
| } | | |
| } | | |

*[Add the following text below the table]*

**Num_Region**

This field indicates the number of the regions defined by OFDMA_Symbol_offset, Subchannel_offset, Boosting, No._OFDMA_Symbols and No._subchannels in this IE.

**Matrix_indicator**

The values of these two bits indicate the STC matrix (see 8.4.8.4).

**Num_layer**

The value of these 2 bits plus one indicate the number of MIMO transmission layers.

**Layer_index**

This field specifies the layer index.

## 2.2 UL Burst Assignment to Support Adaptive MIMO Transmission

We introduce a new extended information element, MIMO_UL_Basic_IE, to include information on the MIMO mode associated with the UL burst allocation.

*[Add a new section 8.4.5.4.10]*

8.4.5.4.10 MIMO UL Basic IE format

In the UL-MAP, a MIMO-enabled BS may transmit UIUC=15 with the MIMO_UL_Basic_IE() to indicate the MIMO mode of the subsequent uplink allocation to a specific MIMO-enabled SS' CID. The MIMO mode indicated in the MIMO_UL_Basic_IE() shall only apply to the subsequent uplink allocation until the end of frame.

Table x - MIMO UL Basic IE

| Syntax | Size | Notes |
|---|---|---|
| MIMO_UL_Basic_IE () { | | |
| Extended UIUC | 4 bits | 0x02 |
| Length | 4 bits | Length in bytes |
| Num_Assign | 4 bits | Number of burst assignment |
| For ( i = 0; i < Num_assign; i++ ) { | | |
| CID | 16 bits | SS basic CID |
| UIUC | 4 bits | |
| MIMO_Control | 1 bit | For dual transmission capable SS 0: STTD; 1: SM<br>For Collaborative SM capable SS<br>0: pilot pattern A; 1: pilot pattern B |
| Duration | 10 bits | In OFDMA slots (see 8.4.3.1) |
| } | | |
| } | | |

*[Add the following text below the table]*

**Num_assign**
This field specifies the number of assignments in this IE.

**MIMO_Control**
MIMO_Control field specifies the MIMO mode of UL burst. For a dual transmission capable SS, the value of 0 indicates STTD mode, the value of 1 indicates SM mode; For a collaborative SM capable SS, the value of 0 indicates pilot pattern A, the value of 1 indicates pilot pattern B.

## 2.3 Fast Feedback Channel Operation

The fast feedback channel can be used to report CQI as well as MIMO channel coefficient as described in IEEE 802.16d/D4. In addition, we propose to use the fast feedback channel to indicate the selection of MIMO mode, i.e. between STTD and SM, by the SS. We also propose to use the fast feedback channel to indicate the selection between PUSC/FUSC and adjacent-subcarrier permutation, by the SS.

For the abovementioned selection indications, we propose to support both slow reporting for fixed application as well as fast periodic reporting for mobile application.

### 2.3.1 MIMO and Permutation Modes Switch Indication

Slow mode switching can be implemented by BS polling the SS for its modes selection. The FAST-FEEDBACK subheader with feedback_type field of '11' is used for BS to obtain the indication of MIMO mode and permutation mode of a SS. The polling interval is implementation dependent. Once a SS receives such a FAST-FEEDBACK sub-header, the SS shall send its indication on its assigned fast feedback channel.

*[Modify Section 6.4.2.3.7]*

6.4.2.3.7 FAST-FEEDBACK allocation subheader
The format of the FAST-FEEDBACK allocation subheader is specified in Table 13. The FAST-FEEDBACK allocation subheader, when used, shall always be the last per-PDU subheader as specified in 6.4.2.3. The support of the FAST-FEEDBACK allocation subheader is PHY specification specific.

**Table 13 FAST-FEEDBACK allocation subheader format**

| Syntax | Size | Notes |
|---|---|---|
| FAST-FEEDBACK allocation Subheader { | | |
| Allocation offset | 6 bits | |
| Feedback_type | 2 bits | 00 – Fast DL measurement<br>01 – Fast MIMO feedback, antenna #0<br>10 – Fast MIMO feedback, antenna #1<br>11 – MIMO mode and permutation mode feedback |
| } | | |

*[Add a new section 8.4.5.4.9.3]*

**8.4.5.4.9.3 Mode Selection Feedback**

When the FAST-FEEDBACK subheader Feedback Type field is '11' or at a specific frame indicated in the CQICH_Alloc_IE(), the SS shall send its selection in terms of MIMO mode (STTD versus SM) or permutation mode on the assigned Fast-feedback channel. Table XX shows the encoding of payload bits.

Table XX. Encode of payload bits when Feedback_type = '11' in FAST-FEEDBACK subheader.

| Value | Description |
|---|---|
| 0000 | STTD and PUSC/FUSC permutation |
| 0001 | STTD and adjacent-subcarrier permutation |
| 0010 | SM and PUSC/FUSC permutation |
| 0011 | SM and adjacent-subcarrier permutation |
| 0100 - 1111 | reserved |

## 2.3.2 Dynamic CQICH Allocation with Fast Periodic MIMO / Permutation Feedback

The number of available CQICHs on the uplink is dependent on the amount of uplink sub-carriers and OFDM symbols allocated for the CQICHs. The fast CQI feedback represents non-negligible overhead on the uplink and therefore the CQICH resource should be dynamically allocated and de-allocated to different SSs. The dynamic allocation and de-allocation to different SSs should be done without incurring too much downlink signaling overhead. We therefore propose to allow the option of allocating/de-allocating the CQICH on a multiple-burst basis rather than on a per-burst basis.

A new UL-MAP IE, **CQICH_Alloc_IE()**, is introduced to dynamically allocated or de-allocated a CQICH to a SS. Once allocated, the SS transmit channel quality information on the assigned CQICH on every subsequent frames, until the SS receives a **CQICH_Alloc_IE()** to de-allocate the assigned CQICH. Fast periodic (with period specified in CQICH_Alloc_IE()) MIMO mode and permutation mode feedback is supported on the assigned CQICH.

When a SS is assigned a CQICH, there is a one-to-one mapping between the SS and the CQICH assigned. Therefore, we can replace the 16-bit basic CID by the smaller size CQICH_ID when allocating DL burst to the SS. We introduce a new information element on the DL-MAP, i.e. **MIMO_DL_Enhanced_IE()** to use CQICH_ID instead of CID to assign DL burst to the SS.

*[Add a section 8.4.5.4.10 to allow the option of dynamic allocation/de-allocation of the CQICH on a multiple-burst basis]*

8.4.5.4.10 CQICH Allocation IE Format

CQICH_Alloc_IE(), is introduced to dynamically allocate or de-allocate a CQICH to a SS. Once allocated, the SS transmit channel quality information on the assigned CQICH on every subsequent frames, until the SS receives a CQICH_Alloc_IE() to de-allocate the assigned CQICH.

Table x – CQICH_Alloc_IE()

| Syntax | Size | Notes |
|---|---|---|
| CQICH_Alloc_IE() { | | |
| Extended UIUC | 4 bits | 0x03 |
| Length | 4 bits | Length in bytes of following fields |
| CQICH_ID | *variable* | Index to uniquely identify the CQICH resource assigned to the SS<br><br>The size of this field is dependent on system parameter defined in DCD. |
| Allocation offset | 6 bits | Index to the fast feedback channel region marked by UIUC = 0. |
| Period (=p) | 2 bits | A CQI feedback is transmitted on the CQICH every 2p frames. |
| Frame offset | 3 bits | The SS starts reporting at the frame of which the number has the same 3 LSB as the specified frame offset. If the current frame is specified, the SS should start reporting in 8 frames |
| Duration (=d) | 3 bits | A CQI feedback is transmitted on the CQI channels indexed by the CQICH_ID for 10 x 2^d frames. If d == 0, the CQI-CH is de-allocated. If d == 111, the SS should report until the BS command for the SS to stop. |
| MIMO_permutation_feedback_cycle | 2 bits | 00 = No MIMO and permutation mode feedback<br><br>01 = the MIMO and permutation mode indication shall be transmitted on the CQICH indexed by the CQICH_ID every 4 frames. The first indication is sent on the 8th CQICH frame.<br><br>10 = the MIMO mode and permultation mode indication shall be transmitted on the CQICH indexed by the CQICH_ID every 8 frames. The first indication is sent on the 8th CQICH frame.<br><br>11 = the MIMO mode and permultation mode indication shall be transmitted on the CQICH indexed by the CQICH_ID every 16 frames. The first indication is sent on the 16th CQICH frame. |

| | | |
|---|---|---|
| Padding | *Variable* | The padding bits is used to ensure the IE size is integer number of bytes. |
| } | | |

*[add the following text below the table]*

**CQICH_ID**
The CQICH_ID uniquely identifies a fast feedback channel on which a SS can transmit fast feedback information. With this allocation, a one-to-one relationship is established between the CQICH_ID and the SS.

**MIMO_permutation_feedback_Cycle**
This field specifies the MIMO and permutation mode fast feedback cycle. See Section 8.4.5.4.9.3 for fast feedback channel payload encoding for MIMO and permutation feedback.

[*Add a new section 8.4.5.3.9 to use CQICH_ID for DL burst assignment]*

8.4.5.3.9 MIMO DL Enhanced IE format

In the DL-MAP, a MIMO-enabled BS may transmit DIUC=15 with the MIMO_DL_Enhanced_IE() to indicate the MIMO mode of the subsequent downlink allocation to a specific MIMO-enabled SS identified by the CQICH_ID previously assigned to the SS. The MIMO mode indicated in the MIMO_DL_Enhanced_IE() shall only apply to the subsequent downlink allocation until the end of frame.

Table x - MIMO DL Enhanced IE

| Syntax | Size | Notes |
|---|---|---|
| MIMO_DL_Enhanced_IE () { | | |
| Extended DIUC | 4 bits | 0x06 |
| Length | 4 bits | Length in bytes |
| Num_Region | 4 bits | |
| for ( i = 0; i< Num_Region; i++) { | | |
| OFDMA Symbol offset | 10 bits | |
| Subchannel offset | 5 bits | |
| Boosting | 3 bits | |
| No. OFDMA Symbols | 9 bits | |
| No. subchannels | 5 bits | |
| Matrix_indicator | 2 bits | STC matrix (see 8.4.8.4.)<br><br>Transmit_Diversity = transmit diversity mode indicated in the latest TD_Zone_IE().<br>if (Transmit_Diversity == 01)<br>{<br>00 = Matrix A<br>01 = Matrix B<br>10 – 11 = Reserved<br>}<br>elseif (Transmit_Diversity == 10)<br>{<br>00 = Matrix A<br>01 = Matrix B<br>10 = Matrix C<br>11 = Reserved<br>} |
| Num_layer | 2 bits | |
| for (j = 0; j< Num_layer; j++) { | | |

| | | |
|---|---|---|
| if (INC_CID == 1) { | | |
| CQICH_ID | *variable* | Index to uniquely identify the CQICH resource assigned to the SS<br><br>The size of this field is dependent on system parameter defined in DCD. |
| } | | |
| Layer_index | 2 bits | |
| DIUC | 4 bits | 0-11 burst profiles |
| } | | |
| } | | |

*[Add the following text below the table]*

**Num_Region**

This field indicates the number of the regions as defined by OFDMA_Symbol_offset, Subchannel_offset, Boosting, No._OFDMA_Symbols and No._subchannels in this IE.

**Matrix_indicator**

The values of these three bits indicate the STC matrix (see section 8.4.8.4).

**CQICH_ID**

This is the CQICH_ID assigned to a SS in the CQICH_Alloc_IE(). The CQICH_ID is used to uniquely identify a SS that is assigned a CQICH.

**Num_layer**

The values of these 2 bits indicate the number of MIMO transmission layers.

**Layer_index**

This field specifies the layer index.

*[Add the following rows to table 312]*

Table 312 DCD channel encodings

| Name | Type | Length | Value |
|---|---|---|---|
| Size of CQICH_ID field | 17 | 1 | 0 = reserved<br>1 = 3 bits<br>2 = 4 bits<br>3 = 5 bits<br>4 = 6 bits<br>5 = 7 bits<br>6 = 8 bits<br>7 = 9 bits |