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Re:	IEEE 802.16m-08/053r1, "Call for Contributions on Project 802.16m Draft Amendment Content" providing text for the topic of "Downlink MIMO"
Abstract	The contribution provides DL MIMO text for the IEEE 802.16m amendment.
Purpose	To be incorporated into the initial IEEE 802.16 amendment
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Downlink MIMO Text for the IEEE 802.16m Amendment

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1. Introduction

This contribution proposes the text for DL-MIMO to be included in the 802.16m amendment. The proposed text is developed so that it can be readily combined with IEEE P802.16 Rev2/D8 [1], it is compliant to the 802.16m SRD [2] and the 802.16m SDD [3], and it follows the style and format guidelines in [4].

2. Outline

The following is a high level outline of the proposed DL MIMO text:

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15.3.10. Downlink MIMO Transmission Schemes
15.3.10.1 Antenna Configurations Supported
15.3.10.2 DL-MIMO Architecture and Data Processing
15.3.10.3 Transmission Modes for Data Channels
15.3.10.3.1 Single User MIMO
15.3.10.3.1.1 Open-Loop SU-MIMO
15.3.10.3.1.1.1 Overview of Supported Modes
15.3.10.3.1.1.2 Transmit Diversity Methods
15.3.10.3.1.1.3 Spatial Multiplexing Modes
15.3.10.3.1.1.4 Precoding the pilots and data for OL-SU-MIMO
15.3.10.3.1.1.5 Precoder Cycling over subband and subframes for OL-SU-MIMO
15.3.10.3.1.1.6 Feedback for OL-SU-MIMO
15.3.10.3.1.2 Closed Loop SU-MIMO
15.3.10.3.1.2.1 Precoding the pilots and data for CL-SU-MIMO
15.3.10.3.1.2.2 Feedback for CL-SU-MIMO
15.3.10.3.1.2.3 Codebook Feedback for SU-MIMO
15.3.10.3.1.3 Mapping the MIMO precoder output to subcarriers for SU-MIMO
15.3.10.3.2 Multi-user MIMO
15.3.10.3.2.1 Precoding Methodology
15.3.10.3.2.2 Feedback for MU-MIMO
15.3.10.3.2.3 Codebook Feedback for MU-MIMO
15.3.10.4 Transmission Modes for Control Channels
15.3.10.4.1 Broadcast Control Channels
15.3.10.4.2 Unicast Control Channels
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3. References

[1] IEEE P802.16 Rev2/D8, “Draft IEEE Standard for Local and Metropolitan Area Networks: Air Interface for Broadband Wireless Access,” Oct. 2008.

[2] IEEE 802.16m-07/002r7, “802.16m System Requirements”

[3] IEEE 802.16m-08/003r6, “The Draft IEEE 802.16m System Description Document”

[4] IEEE 802.16m-08/043, “Style guide for writing the IEEE 802.16m amendment”

Text proposal for inclusion in the 802.16m amendment

---------- Text Start ----------

Insert a new section 15:

15. Advanced Air Interface

15.3. Physical layer

15.3.5.

15.3.6.

15.3.7.

15.3.8.

15.3.9.

15.3.10. Downlink MIMO Transmission Schemes

15.3.10.1. Antenna Configurations Supported

The ABS employs a minimum of two transmit antennas. The AMS employs a minimum of two receive antennas. The antenna configurations are (N_T, N_R) = (2, 2), (4, 2), (4, 4), (8, 2), (8, 4), and (8,8) where N_T denotes the number of ABS transmit antennas and N_R denotes the number of AMS receive antennas.

15.3.10.2. DL-MIMO Architecture and Data Processing

The general architecture of downlink MIMO on the transmitter side is shown in Figure 1.

In SU-MIMO, only one AMS is scheduled in a resource allocation. In MU-MIMO, more than one AMS is scheduled in a resource allocation.

A "layer" is defined as a coding / modulation path fed to the MIMO encoder as an input. Vertical encoding is supported (Single Codeword or SCW), which means there is only one encoder block (one "layer") for each AMS assigned to the resource allocation. A "stream" is defined as an output of the MIMO encoder that is passed to a beamformer / precoder.

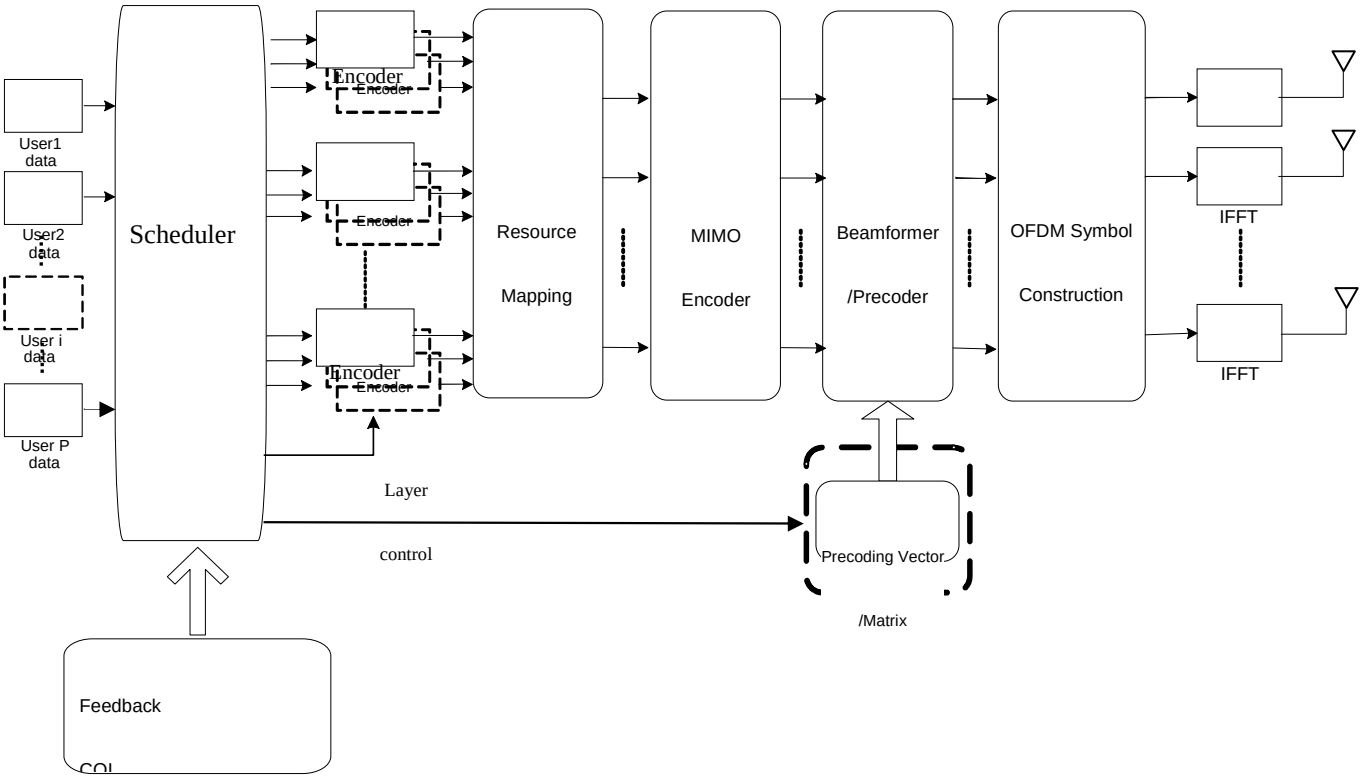

Figure 1 MIMO Architecture

The encoder block contains the channel encoder, interleaver, rate-matcher, and modulator for each layer.

The Resource Mapping block maps the modulated symbols to the corresponding time-frequency resources in the allocated resource units (RUs).

The MIMO encoder block maps the L=1 layer onto N_S (≥L) streams, which are fed to the Beamformer/Precoder block.

The Beamformer/Precoder block maps streams to antennas by generating the antenna-specific data symbols according to the selected MIMO mode.

The OFDM symbol construction block maps antenna-specific data to the OFDM symbol.

The feedback block contains feedback information such as CQI and CSI from the AMS.

The scheduler block will schedule AMSs to resource units and decide their MCS level, MIMO parameters (MIMO encoding mode), and determine the feedback to be requested from the AMS.

The mapping from layers to streams depends on the specific MIMO mode being employed by the MIMO encoder block, where the collection of supported MIMO modes will be described below. The MIMO encoder in each MIMO mode operates in batch mode on a length M vector of input modulation symbols $\mathbf{x}$ and produces a $N_S \times N_F$ STC matrix $\mathbf{z}$.

$$\mathbf{z} = \mathbf{S}(\mathbf{x}), \qquad \text{Equation 1}$$

where N_S is the number of streams, N_F is the number of subcarriers occupied by the output of the MIMO encoder, and S(x) is the mapping function of the MIMO mode.

The mapping from the N_S streams to the N_T antennas is defined by the following formula:

$$\mathbf{y} = \mathbf{W} \times \mathbf{S}(\mathbf{x}), \qquad \text{Equation 2}$$

where y is the $N_T \times N_F$ output of the precoder/beamformer, **W** is a $N_T \times N_S$ pre-coding matrix, **S(x)** is an STC matrix according to the MIMO mode, and **x** is the length M vector of input symbols.

All supported MIMO modes may be employed in contiguous or distributed resource allocations.

15.3.10.3. Transmission Modes for Data Channels

15.3.10.3.1. Single User-MIMO

15.3.10.3.1.1. Open-Loop SU-MIMO

####### 15.3.10.3.1.1.1. Overview of Supported Modes

The following table lists the MIMO encoding modes for 2 transmit antennas at the ABS.

MIMO Encoding Mode	***Type***	***Description***	N_T	**Rate**	***M***	N_S	N_F
0	TX Diversity	Rank 1 Precoder	2	1	1	1	1
1	TX Diversity	SFBC	2	1	2	2	2
2	Spatial Multiplexing	Rate 2 SM with Precoding	2	2	2	2	1

Table 1 Matrix dimensions for open-loop SU-MIMO modes for 2 transmit antennas at the ABS

The following table lists the MIMO encoding modes for 4 transmit antennas at the ABS.

MIMO Encoding Mode	***Type***	***Description***	N_T	**Rate**	***M***	N_S	N_F
0	TX Diversity	Rank 1 Precoder	4	1	1	1	1
1	TX Diversity	SFBC with Precoder	4	1	2	2	2
2	Spatial Multiplexing	Rate 2 SM with Precoding	4	2	2	2	1
3	Spatial Multiplexing	Rate 3 SM with Precoding	4	3	3	3	1
4	Spatial Multiplexing	Rate 4 SM	4	4	4	4	1

Table 2 Matrix dimensions for open-loop SU-MIMO modes for 4 transmit antennas as the ABS

The following table lists the MIMO encoding modes for 8 transmit antennas at the ABS.

MIMO Encoding Mode	***Type***	***Description***	N_T	**Rate**	***M***	N_S	N_F
0	TX Diversity	Rank 1 Precoder	8	1	1	1	1
1	TX Diversity	SFBC with Precoder	8	1	2	2	2
2	Spatial Multiplexing	Rate 2 SM with Precoding	8	2	2	2	1
3	Spatial Multiplexing	Rate 3 SM with Precoding	8	3	3	3	1
4	Spatial Multiplexing	Rate 4 SM with Precoding	8	4	4	4	1

Table 3 Matrix dimensions for open-loop SU-MIMO modes for 8 transmit antennas at the ABS

For each resource allocation (one or more LRUs), the MIMO encoding mode is signaled in the allocation grant message as described in Section (DL-Control).

15.3.10.3.1.1.2. Transmit Diversity Modes

The transmit diversity modes are the rate 1 MIMO Encoding Modes listed in Tables 1 through 3 (Modes 0 and 1 for N_T=2, 4, and 8). Mode 0 has M=1 and Mode 1 has M=2, where M is the number of modulation symbols that are batch processed by the MIMO encoder at a time.

For the transmit diversity modes with M=1, the MIMO encoder operates on one symbol at a time, and the input to MIMO encoder is x=s_1. The output of the MIMO encoder is a scalar, z=x. The output of MIMO encoder is multiplied by an $N_T \times 1$ matrix **W**, where **W** is described in Section 15.3.10.2.

$$\mathbf{y} = \mathbf{W} \times z = \begin{bmatrix} y_{1,1} \\ y_{2,1} \\ \vdots \\ y_{N_T,1} \end{bmatrix}, \quad \text{Equation 3}$$

where $y_{j,k}$ is the output symbol to be transmitted via the j-th physical antenna on the k-th subcarrier.

For the transmit diversity modes with M=2, the MIMO encoder operates on two symbols at a time, where the input to the MIMO encoder is represented a 2×1 vector.

$$\mathbf{x} = \begin{bmatrix} s_1 \\ s_2 \end{bmatrix}, \quad \text{Equation 4}$$

The output of the MIMO encoder is a Space-Frequency Block Coding (SFBC) matrix.

$$\mathbf{z} = \begin{bmatrix} s_1 & -s_2^* \\ s_2 & s_1^* \end{bmatrix}, \quad \text{Equation 5}$$

The output of the MIMO encoder is then multiplied by $N_T \times 2$ precoding matrix W, where W is described in Section 15.3.10.2.

$$\mathbf{y} = \mathbf{W} \times z = \begin{bmatrix} y_{1,1} & y_{1,2} & \cdots & y_{1,N_F} \\ y_{2,1} & y_{2,2} & \cdots & y_{2,N_F} \\ \vdots & \vdots & \ddots & \vdots \\ y_{N_T,1} & y_{N_T,2} & \cdots & y_{N_T,N_F} \end{bmatrix}, \text{ Equation 6}$$

where $y_{j,k}$ is the output symbol to be transmitted via the j-th physical antenna on the k-th subcarrier. Note N_F is the number of subcarriers used to transmit the MIMO signals derived from the input vector x. For the transmit diversity modes N_F = M=2. For open-loop SU-MIMO, the rate of a mode is defined as $R = M / N_F$.

15.3.10.3.1.1.3. Spatial Multiplexing Modes

The MIMO Modes listed in Tables 1 through 3 with rates greater than 1 are the spatial multiplexing modes (Modes 2, 3, 4 for N_T=2, 4, and 8). For the rate-R spatial multiplexing modes, the input and the output of MIMO encoder is represented by an $R \times 1$ vector

$$\mathbf{x} = \mathbf{z} = \begin{bmatrix} s_1 \\ s_2 \\ \vdots \\ s_R \end{bmatrix}, \qquad \text{Equation 7}$$

The output of the MIMO encoder is then multiplied by the $N_T \times R$ matrix **W**, where **W** is described in Section 15.3.10.2.

$$\mathbf{y} = \mathbf{W} \times \mathbf{z} = \begin{bmatrix} y_{1,1} \\ y_{2,1} \\ \vdots \\ y_{N_T,1} \end{bmatrix}, \text{ Equation 8}$$

where $y_{j,k}$ is the output symbol to be transmitted via the j-th physical antenna on the k-th subcarrier. Note N_F is the number of subcarriers used to transmit the MIMO signals derived from the input vector x and is equal to one for the spatial multiplexing modes.

15.3.10.3.1.1.4. Precoding the Pilots and Data for OL-SU-MIMO

When precoded (dedicated) pilots are used, the precoder matrix is held fixed across a PRU but may change from PRU to PRU. The pilots in the PRU that are associated with antenna i are precoded with the i^{th} column of **W**.

When non-precoded (broadcast) pilots are used, the precoding matrix **W** shall be chosen from the TBD codebook. The methodology for selecting which **W** is to be applied is TBD.

15.3.10.3.1.1.5. Precoder Cycling over subband and subframes for OL-SU-MIMO

The precoding matrix is fixed within one subband and may change from one subband to another subband. The array of precoder matrices allocated within one subframe may change from one subframe to another subframe. The array of precoder matrices allocated within one subframe repeats after N subframes, where N is configured by ABS and indicated to AMS through DL broadcast signaling.

15.3.10.3.1.1.6. Feedback for OL-SU-MIMO

As described in Section (UL-Control), to support OL-SU-MIMO in FDD systems and TDD systems, a mobile station may feedback some of the following information in open-loop SU-MIMO mode:

- Desired transmission rank. Note that for rank≥2, the rank directly equals MIMO encoding mode, but also note that MIMO encoding modes 0 and 1 are both rank 1.
- Sub-band selection
- CQI (Wideband or sub-band)

15.3.10.3.1.2. Closed-Loop SU-MIMO

For closed-loop SU-MIMO, all the MIMO encoding modes and associated descriptions in Section 15.3.10.3.1 are supported. The allocation grant indicates which MIMO encoding mode is being used on the resource

allocation. For Closed-Loop SU-MIMO, the AMS provides feedback intended to assist the ABS in determining the **W** matrix that follows the MIMO encoder. The feedback that supports Closed-Loop SU-MIMO is described in Section 15.3.10.3.1.2.2.

15.3.10.3.1.2.1. Precoding the Pilots and Data for CL-SU-MIMO

When precoded (dedicated) pilots are used, the precoder matrix is held fixed across a PRU but may change from PRU to PRU within a resource allocation. The pilots in the PRU that are associated with antenna *i* are precoded with the i^{th} column of **W**.

When non-precoded (broadcast) pilots are used, the precoding matrix **W** shall be chosen from the TBD codebook. The methodology for selecting which **W** is to be applied is TBD.

15.3.10.3.1.2.2. Feedback for CL-SU-MIMO

As described in Section (UL-Control), to support CL-SU-MIMO in FDD systems and TDD systems, a mobile station may feedback some of the following information in Closed loop SU-MIMO mode:

- Rank (Wideband or sub-band). Note that for rank≥2, the rank directly equals the MIMO encoding mode (See Table 1, Table 2, and Table 3), but also note that MIMO encoding modes 0 and 1 are both rank 1.
- Sub-band selection
- CQI (Wideband or sub-band)
- PMI (Wideband or sub-band for serving cell)
- Long-term CSI

Two forms of feedback are supported for assisting closed-loop SU-MIMO: codebook feedback and UL Channel Sounding. The UL Channel Sounding Channel is described in Section (UL Control). Codebook feedback is described in Section 15.3.10.3.1.2.3. As discussed in Section (UL-Control), the feedback information may be transmitted via a physical layer control channel or via a higher layer signaling message.

15.3.10.3.1.2.3. Codebook Feedback for CL-SU-MIMO

For codebook based precoding, two different feedback modes for the PMI are supported: standard mode and adaptive mode

In the standard mode, the PMI feedback from a mobile station shall represent an entry of the base codebook.

For 2 Tx antennas at an ABS, the base codebook is specified as follows: [TBD]

For 4 Tx antennas at an ABS, the base codebook is specified as follows: [TBD]

For 8 Tx antennas at an ABS, the base codebook is specified as follows: [TBD]

In the adaptive mode, the PMI feedback from a mobile station shall represent an entry of the transformed base codebook according to long term channel information. [Methodology TBD]

15.3.10.3.1.3. Mapping the MIMO precoder output to subcarriers for SU-MIMO

As mentioned in Section 15.3.10.2, the MIMO encoder operates on *M* modulation symbols at a time from the output of the encoder block. Each block of *M* symbols are ultimately transformed into the $N_T \times N_F$ **y** matrix

that specifies the signal to be transmitted on the N_T transmit antennas over N_F successive carriers, as described in Sections 15.3.10.3.1.1.2 and 15.3.10.3.1.1.3. Each successive block of M symbols from the encoder block is mapped to successive groups of N_F contiguous physical subcarriers belonging to the resource allocation, starting with the uppermost physical subcarrier of the first symbol interval of the resource allocation, continuing down the band to the lowermost physical subcarrier of the resource allocation, and then to the uppermost subcarrier of the second symbol of the resource allocation, and so on until the lowermost subcarrier of the last symbol interval of the resource allocation is reached.

15.3.10.3.2. Multi-User-MIMO

15.3.10.3.2.1. Precoding for MU-MIMO

For MU-MIMO, more than one AMS is assigned to a resource allocation. In MU-MIMO, the MIMO encoder operates with $M=N_s=R$, $N_F=1$, where N_s is equal to the number R of users assigned to the resource allocation. For R users being multiplexed on a resource allocation, the input and the output of MIMO encoder is represented by an $R \times 1$ vector:

$$\mathbf{x} = \mathbf{z} = \begin{bmatrix} s_1 \\ s_2 \\ \vdots \\ s_R \end{bmatrix}, \qquad \text{Equation 9}$$

where s_i is the data symbol for the i^{th} AMS assigned to the resource allocation. The output of the MIMO encoder is the multiplied by $N_T \times R$ matrix **W**,

$$\mathbf{y} = \mathbf{W} \times \mathbf{z} = \begin{bmatrix} y_{1,1} \\ y_{2,1} \\ \vdots \\ y_{N_T,1} \end{bmatrix}, \text{ Equation 10}$$

where $y_{j,k}$ is the output symbol to be transmitted via the j-th physical antenna on the k-th subcarrier. Note N_F is the number of subcarriers used to transmit the MIMO signals derived from the input vector x and is equal to one for MU-MIMO. Mapping the **y** matrix to antennas and subcarriers follows the description in Section 15.3.10.3.1.3. The **W** matrix is constant over a PRU and may change from PRU to PRU. The pilot subcarriers in the PRU are precoded in the same way as the data subcarriers, meaning that the pilot designated for antenna i is precoded with the i^{th} column of **W**. Similarly, the data symbol intended for AMS i is precoded with the i^{th} column of **W**.

For each resource allocation in which MU-MIMO is used, the number of users R and which stream is assigned to the AMS is signaled in the allocation grant.

15.3.10.3.2.2. Feedback for MU-MIMO

As specified in Section [UL Control], three forms of feedback may be used to support MU-MIMO: codebook feedback, UL Sounding, and analog-feedback. For UL Sounding-based MU-MIMO, the W matrix may be determined based on the UL sounding signal transmitted by the AMS. For analog feedback-based MU-MIMO, the **W** matrix may be determined based on the analog feedback signal transmitted by the MS. Codebook feedback for MU-MIMO is described in Section 15.3.10.3.2.3

In FDD systems and TDD systems, a mobile station may feedback some of the following information in MU-MIMO mode:

- Sub-band selection
- CQI (Wideband or sub-band, per layer)
- PMI (Wideband or sub-band for serving cell and/or neighboring cell)
- Long-term CSI

For CQI feedback, the mobile station measures the downlink pilot channel reference signal or the dedicated pilots in the allocated resource unit, computes the channel quality information (CQI), and reports the CQI on the uplink feedback channel. Both wideband CQI and subband CQI may be transmitted by a mobile station. Wideband CQI is the average CQI of a wide frequency band. In contrast, sub-band CQI is the CQI of a localized sub-band. The CQI is calculated at the mobile station assuming that the interfering users are scheduled by the serving base station using precoders orthogonal to each other and orthogonal to the reported PMI.

15.3.10.3.2.3. Codebook Feedback for MU-MIMO

For codebook based precoding, two different feedback modes for the PMI are supported: standard mode and adaptive mode.

For the standard mode, the PMI feedback from a mobile station shall represent an entry of the base codebook.

For 2 Tx antennas at an ABS, the base codebook is specified as follows: [TBD]

For 4 Tx antennas at an ABS, the base codebook is specified as follows: [TBD]

For 8 Tx antennas at an ABS, the base codebook is specified as follows: [TBD]

For the adaptive mode, the PMI feedback from a mobile station shall represent an entry of the transformed base codebook according to long term channel information. [Methodology TBD]

The MU MIMO codebook contains subsets of the unified codebook (including full set) to support both unitary and non-unitary precoding. When codebook-based feedback is used, the ABS indicates which codebook subset (including full set) will be used explicitly or implicitly.

15.3.10.4. Transmission Modes for Control Channels

15.3.10.4.1. Transmission for Broadcast Control Channel

For the broadcast channel, MIMO Encoding Modes 0 and 1 are supported for all values of N_T. The PBCH is encoded with MIMO Encoding Mode 0. As discussed in Section (DL Control), the PBCH indicates which MIMO Encoding Mode is used for the SBCH.

15.3.10.4.2. Transmission for Unicast Control Channel

For the unicast control channel, MIMO encoding Modes 0 and 1 are supported for all values of N_T.

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