Proposal for IEEE 802.16m DL MIMO Schemes

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Sophie Vrzic, Jun Yuan, Mo-Han Fong, Dongsheng Yu, Robert Novak, Sang-Youb Kim, Kathiravetpillai Sivanesan

Nortel Networks E-mail: svrzic@nortel.com, mhfong@nortel.com, junyu@nortel.com

*<http://standards.ieee.org/faqs/affiliationFAQ.html>

Re: IEEE 802.16m-08/016 – Call for Contributions on Project 802.16m System Description Document (SDD), on the topic of "Downlink MIMO Schemes"

Purpose: Adopt the proposal into the IEEE 802.16m System Description Document

Scope

- This contribution proposes an overall DL MIMO scheme for IEEE 802.16m
- The details of DL SDMA, DL Network MIMO and an enhanced codebook feedback scheme for DL MIMO are presented in separate contributions (see C802.16m-08/345 "Proposal for IEEE 802.16m SDMA and Beamforming", C802.16m-08/346 “Proposal for IEEE 802.16m DL Network MIMO” and C802.16m-08/347 "Proposal for IEEE 802.16m Differential Encoding/Decoding for CL-MIMO Codebook feedback").

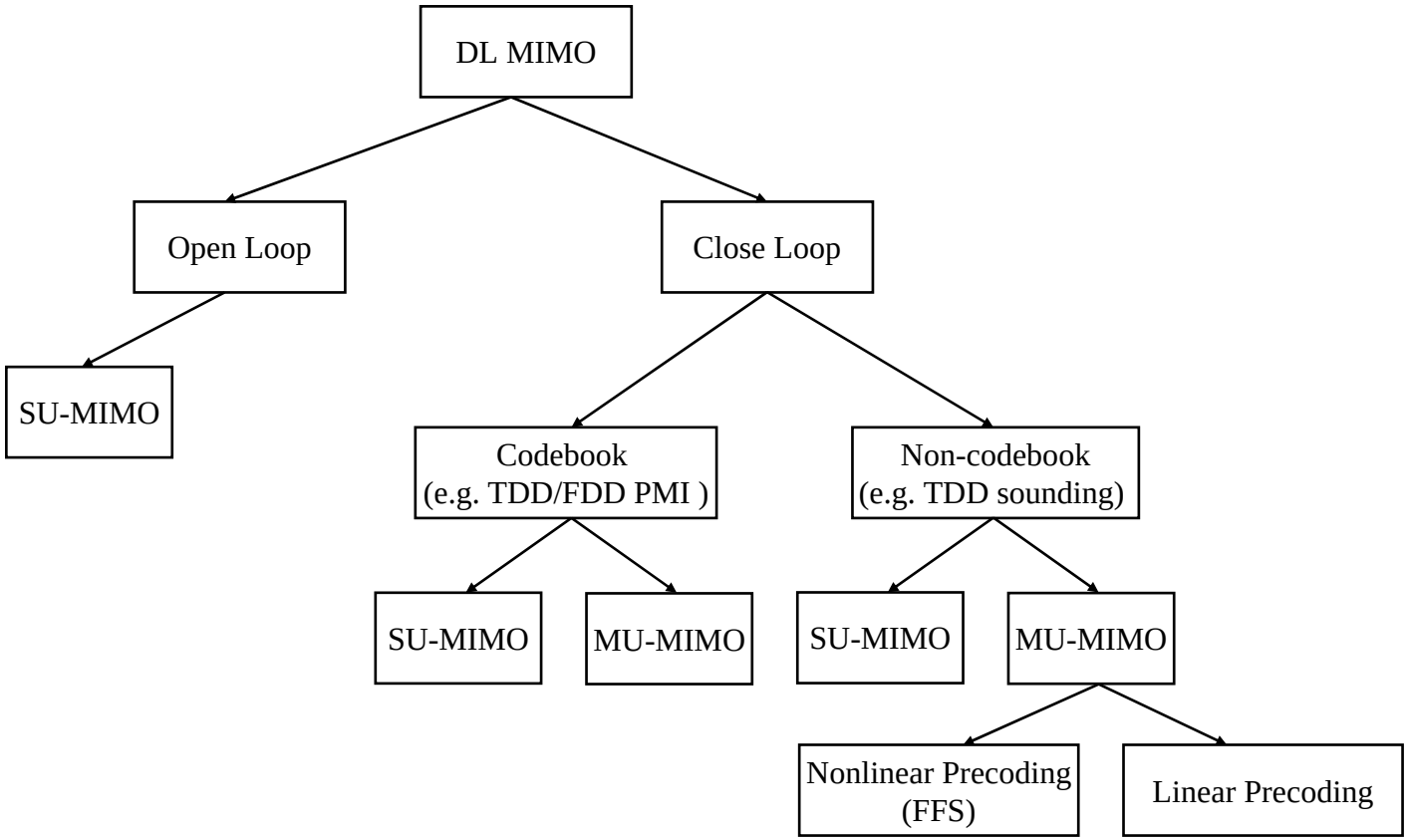
IEEE 802.16m System Requirements

- The TGm SRD (IEEE 802.16m-07/002r4) specifies the following requirements:
  - Section 5.2 Complexity
    - IEEE 802.16m should minimize complexity of the architecture and protocols and avoid excessive system complexity. It should support low cost devices.
  - Section 5.7 Support of Advanced Antenna techniques
    - IEEE 802.16m shall support MIMO, beamforming operation or other advanced antenna techniques.
    - IEEE 802.16m shall further support single-user and multi-user MIMO techniques.
- The proposed DL MIMO schemes target the above requirements.

DL MIMO Overview

- The proposed DL MIMO scheme supports a number of different MIMO modes and configurations. These include
  - Open loop MIMO
    - For STTD Rate 1 and 2, we propose to reuse matrix A and matrix B in 16e
    - SM: We propose to reuse matrix B and matrix C in 16e. Both single codeword (or vertical encoding) and multi-code word (or horizontal encoding) are supported.
  - Closed loop MIMO
    - Single user MIMO (SCW and MCW)
    - Multi-user MIMO
    - We propose to reuse the existing codebook in 16e.
- No separate zone is required for DL MIMO.
  - Open loop MIMO transmission can be in both diversity and localized zones.
  - Closed loop MIMO transmission is restricted to localized zones.
- Up to four MIMO streams are supported for the case of open loop MIMO and closed loop MIMO.
- For open loop MIMO and codebook based CL-MIMO, the maximum number of effective physical transmit antennas supported at the BS is four. For sounding based CL-MIMO, there is no hard limit on the number of effective physical transmit antennas at the BS.

DL MIMO Overview



Rank adaptation can be applied to all of the above schemes

Open Loop MIMO

- Open loop MIMO can be applied in either a localized zone or a distributed zone.
- Common pilots are used for data demodulation (see contribution C802.16m-08/172r1 “Proposal for IEEE 802.16m DL Pilot Design”).
- In a distributed zone, a broadband C/I is reported by the MS.
- In a localized zone, a sub-band C/I is reported for a number of best bands. The number of best bands is configured by the BS.
- Both high speed and low speed mobiles can use open loop MIMO.
  - Sub-band scheduling in the localized zone is reserved for slow moving mobiles.

Closed Loop MIMO

- CL MIMO transmission occurs in a localized zone using dedicated pilots.
- In order to support closed loop MIMO, two types of pre-coding feedback are considered
  - Pre-coding matrix index (PMI) feedback for FDD and TDD systems
  - Channel sounding for TDD systems (see contribution C802.16m-08/349 “Proposal for IEEE 802.16m UL Sounding Pilot”)
- Since sounding requires more overhead, it is only considered for slow moving (e.g. up to 3 km/h) users, where the required feedback rate is lower (e.g. every 20 ms)
- For higher speeds (e.g. up to 30 km/h), PMI feedback is used.

Open Loop and Closed Loop Comparison

- Open loop and closed loop MIMO can be applied in different scenarios.
- The table below summarizes the different usage scenarios.

	Open Loop MIMO	Closed Loop MIMO
Number of users	Single user	Single or multiple users
User speed	Any	Low
Channelization	Distributed / localized	Localized
Pilot	Common for both channel measurement and data demodulation	Dedicated for data demodulation Common for channel measurement
Transmission mode	STTD or SM	Rank 1 to 4

Closed Loop MIMO Feedback

- To support closed loop MIMO transmissions, channel information feedback is required from MS to BS.
- There are two types of feedback
  - Codebook based feedback
    - PMI + CQI feedback + rank (can be implied through PMI)
  - Non-codebook based feedback
    - Sounding channel + interference feedback or
    - Sounding channel + CQI feedback
- The comparison in terms of performance, delay, and complexity is given in the table below.

	Performance	Feedback Delay	Feedback Overhead
PMI	Good	Long	Low
Sounding	Better	Short	High

Feedback Overhead Comparison Between PMI and Channel Sounding

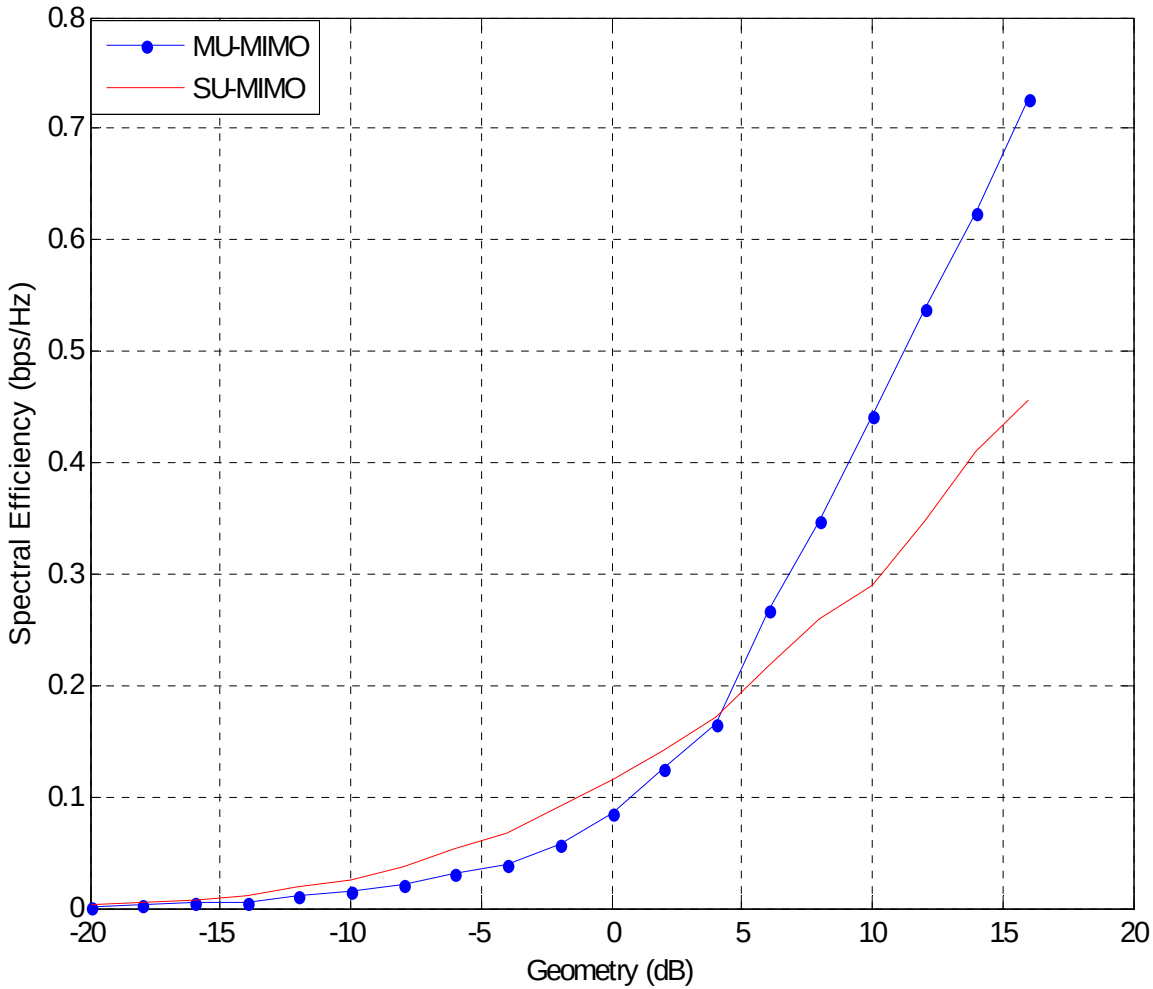
- The pre-coding feedback overhead depends on the type of feedback and on the frequency of the feedback.
- PMI feedback can be sent more often than channel sounding since it requires less overhead.
- The table below compares the number of users that can be supported for the two feedback methods with the following assumptions
  - Feedback overhead is less than 10%
  - There are 12 sub-bands (sub-band size = 36x6)
  - CQI Feedback = 4 bits
  - Interference Feedback = 4 bits
  - Sounding feedback: 4 tones per antenna for each sub-band, MS has 4 antennas
- The comparison below shows that sounding is only feasible when the feedback interval is 20 ms or more.

Feedback Interval (ms)	Number of Users (Sounding + CQI)	Number of Users (Sounding + Interference)	Number of Users (PMI + CQI)
5	15	21	48
10	31	43	86
20	62	86	176
100	314	431	860

Closed Loop Multi-User MIMO

- Multi-user MIMO (MU-MIMO) supports multiple user transmissions over the same resource unit (time-frequency), and employs pre-coding techniques to maximize per-user SNR and minimize inter-user interference.
- Downlink MU-MIMO significantly increase system throughput. It has the following advantages
  - Utilizes multi-user diversity
  - Supports low-complexity MS in the case of a TDD system with UL sounding
    - In this case, the MS does not have to compute its rank or preferred PMI and the BS can determine the appropriate pre-coding vectors such that the interference between the interfering layers is minimized (MMSE is optional at the MS).
- MU-MIMO performance improves when
  - The number of users in a sector is large,
  - High geometry users are multiplexed

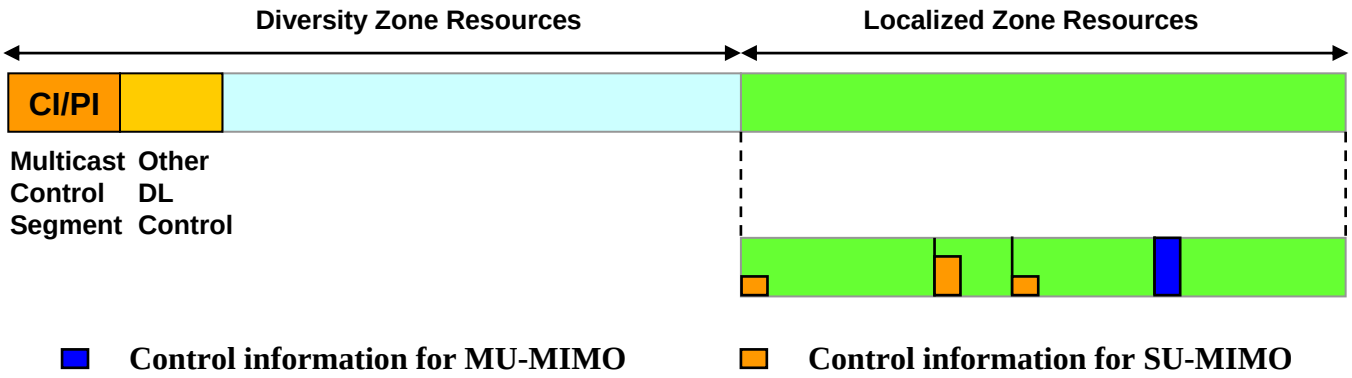
MU-MIMO vs. SU-MIMO Based on Sounding Feedback



DL Control Structure to Support DL MIMO (1/2)

- For open loop and for CL SU-MIMO, the control information is unicast to the scheduled user.
- For MU-MIMO, the control information is multicast to the scheduled users, using STTD with common pilots in one or more control tiles (see contribution C802.16m-08/172r1 “Proposal for IEEE 802.16m DL Pilot Structure”)
- Control information includes
  - Number of layers
  - MCS per layer
  - User ID per layer
- PMI information is not signaled to the MS since dedicated pilots are used for data demodulation.

Control Channel Structure to Support DL MIMO (2/2)



	Type I (SU-MIMO)	**Type II (SU-MIMO)**	**Type III (MU-MIMO)**
Tx Mode # of layers	STTD / SM 1, 2, 3, 4 (3 bits)	CL-MIMO 1, 2, 3, 4 (2 bits)	CL-MIMO 1, 2, 3, 4 (2 bits)
Layer Encoding	Vertical	Horizontal	Horizontal
MCS	4 bits	4 bits / layer	4 bits / layer
User ID	Scrambled	Scrambled	9 bits / layer
CRC	16 bits	16 bits	16 bits
Pilot for control / data	Common / Common	Common / Dedicated	Common / Dedicated
Control Information (QPSK 1/3)	Unicast Embedded with data No separate control tile is needed	Unicast Embedded with data Need to define a control tile	Multicast Embedded with data Need to define a control tile

DL CL MU-MIMO
Linear vs. Nonlinear Precoding

- Linear precoding has less complexity than nonlinear precoding at both BS and MS.
- This contribution focuses on linear precoding techniques for CL MU-MIMO.
- Nonlinear precoding technique (e.g. dirty paper coding) of MU-MIMO is for further study (FFS).

Summary

- The proposed DL MIMO scheme satisfies the requirements of the TGm SRD.
- The new design efficiently supports both open loop and closed loop MIMO.
  - For CL MIMO, both single user and multi-user MIMO are supported.
- The design also provides support for two different feedback methods for CL MIMO, which can be configured by the BS
  - Sounding can be used in a TDD system when the required feedback interval is large (nomadic or slow moving MS)
  - PMI feedback is used in an FDD system and a TDD system when the mobile's speed is higher.

Proposed Text for SDD

- Section 11.x DL MIMO
  - [*Add content of slides 6, 7, 9, 13 and 14 to this section*]
- Section 11.x.1 DL Multi-user MIMO
  - [*Add content on slides 13 and 14 to this section*]
  - [*Add figure on slide 14 to this section*]