Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Double-Stage DL MU-MIMO Scheme**
Date Submitted	**2008-05-13**
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Re:	IEEE 802.16m-08/016r1: Call for Contributions on Project 802.16m System Description Document (SDD). Target topic: “Downlink MIMO Schemes” and “Uplink control Structures”.
Abstract	This contribution proposes multi user MIMO scheme for downlink transmission
Purpose	For discussion and approval by TGm
Notice	
Release	
Patent Policy	

Outline

- Motivation and observations
- Proposed double stage MU-MIMO
- Selected simulations
- Remarks and conclusions

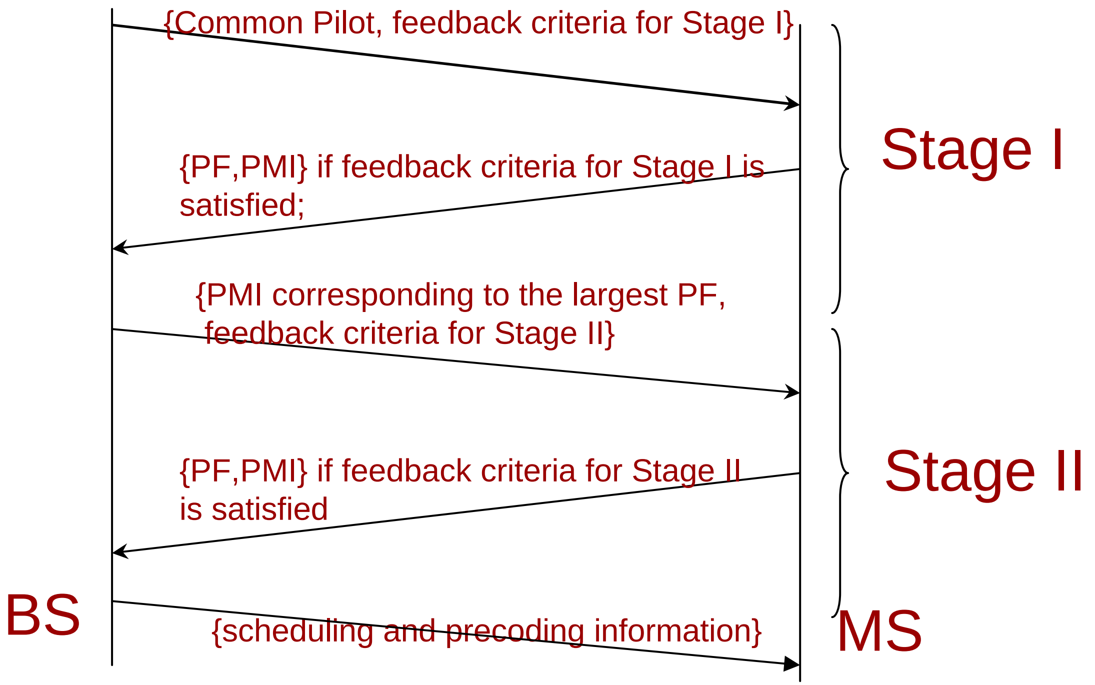
Motivation & Observations

- Motivation and Observations:
  - MU-MIMO potentially provide higher throughput compared to SU-MIMO.
  - More precise channel quantization is required for MU-MIMO compared to SU-MIMO. (This indicates the necessity of a large codebook and large feedback overhead per MS)
  - Due to feedback channel capacity is limited, high feedback overhead may prevent MU-MIMO from being useful in real applications.
  - Only a few active MSs are scheduled. It is wasteful to make every MS feed back channel state information.
  - If only small portion of active MSs feed back CSI to BS, large feedback overhead per MS does not mean large overall feedback overhead.

Double-stage MU-MIMO (2S-MU-MIMO)

- Objectives:

1. Increase channel quantization accuracy by applying large codebook(>10 bits).
2. Limit the overall feedback overhead without sacrificing system performance.
3. Maintain the attractive properties of MU-MIMO techniques.



2S-MU-MIMO: Stage I (2-1)

- **Feedback criteria for Stage I:**

Priority factor PF_I^i of MS *i* is no less than the predetermined threshold.

$$PF_I^i = \frac{\log 2(1+SNR_i)^{\alpha}}{R_i^{\beta}} \geq T$$

where parameters α and β tune the fairness of scheduler, R_i is average throughput of MS *i* and *T* is broadcasted threshold information for Stage I. SNR_i is MU-MIMO precoding technique specific. For example, for non-unitary and unitary precoding, are respectively defined as follow:

Non-unitary precoding	Unitary precoding
$SNR_i = \max\left(\frac{\lvert hw_i' \rvert^2}{\sigma^2}\right) \quad w_i \in CB$	$SINR_i = \max\left(\frac{\lvert hw_{ip}' \rvert^2}{\sum_{q \neq p} \lvert hw_{iq}' \rvert^2 + \sigma^2}\right) \quad w_{ip} \in W_i \quad W_i \in CB$

2S-MU-MIMO: Stage I (2-2)

MS

- If feedback criteria for Stage I is satisfied, MS picks up a codeword in predefined codebook for Stage I, which has minimum chordal distance from its own channel state information. The corresponding PF and PMI are fed back to BS;

- Otherwise, MS keeps idle;

BS

- Compare all feedbacks.

- Broadcast PMI associated with the largest priority factor and corresponding codeword is denoted by $w_{\max - I}$.

- Broadcast feedback criteria for Stage II.

2S-MU-MIMO: Stage II (2-1)

- **Feedback criteria for Stage II:**

1. Refined priority factor PF_{II}^{i} of MS *i* is no less than the predetermined threshold;

$$PF_{II}^{i} = \frac{\log 2(1+SINR_{i-II})^{\alpha}}{R_i^{\beta}} \geq T_{II}$$

where T_{II} is broadcasted threshold information for Stage II.

2. PF_{II}^{i} related CSI has not been feedback in Stage I .

$SINR_{i-II}$ is MU-MIMO precoding technique specific. For example, when non-unitary precoding and unitary precoding techniques are used, $SINR_{i-II}$ can be obtain as follow

Non-unitary precoding	Unitary precoding
$SNR_{i-II} = \frac{\lvert h_i w_i^H \rvert^2}{N}$ $w_i = \frac{h_i - w_{\max-I}(w_{\max-I} h_i^H)}{\lvert h_i - w_{\max-I}(w_{\max-I} h_i^H) \rvert}$	$SNR_{i-II} = \frac{\lvert h_i w_i^H \rvert^2}{I_i + N}$ w_i and $w_{\max-I}$ belong to same unitary matrix codeword U I_i represent the interference associated with U

2S-MU-MIMO: Stage II (2-2)

MS

- If feedback criteria for Stage II is satisfied, MS picks up a codeword in predefined codebook for Stage II, which has minimum chordal distance from its own channel state information. The corresponding PF and PMI are feed back to BS;
- Otherwise, MS keeps idle;

BS

- Broadcast the scheduled MS information
- Determine precoding matrix based on all feedback (Stage I&II)

Simulations 2-1

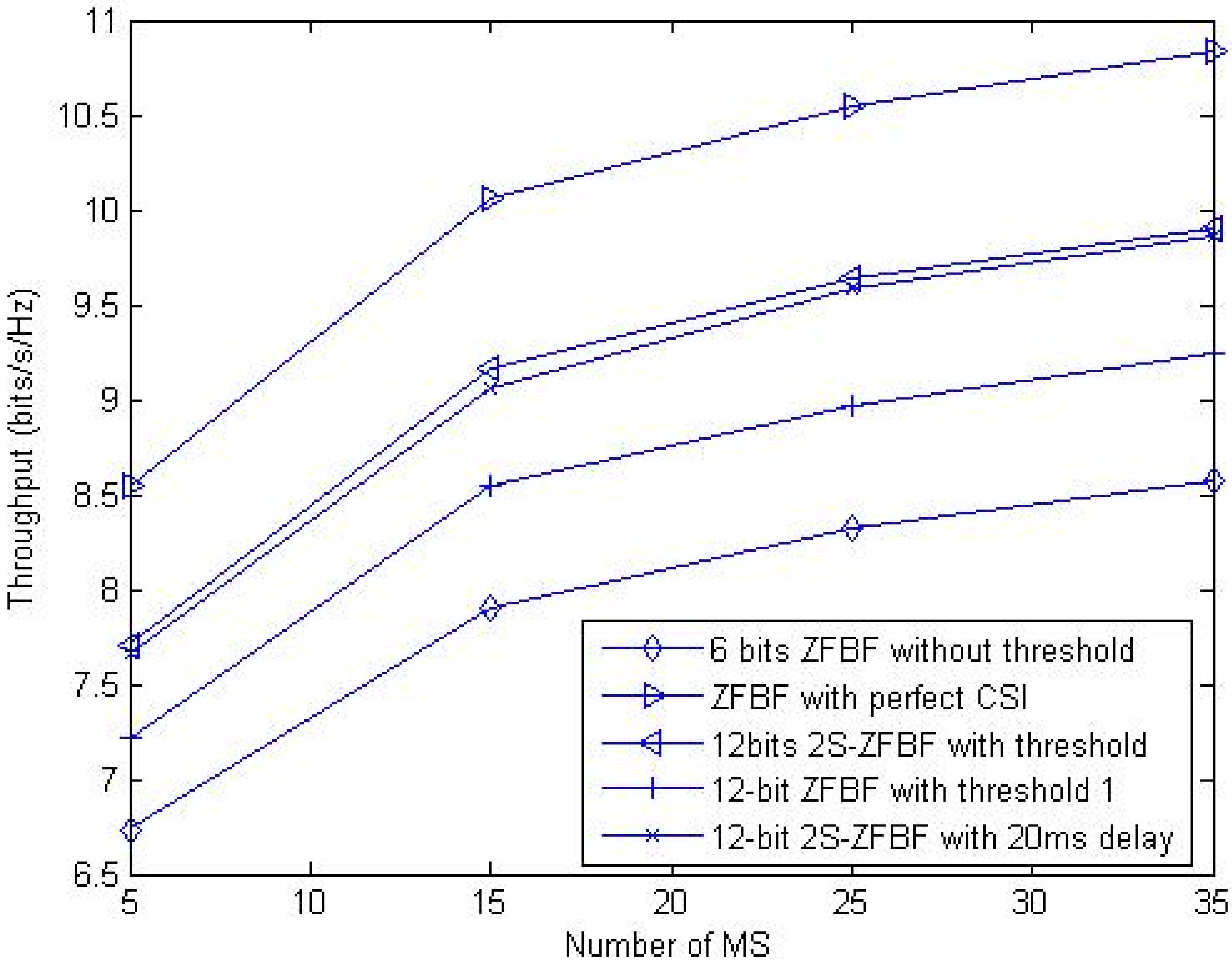
Size of Feedback Overhead (bits)

NO. of MS	12bits 2S-ZFBF With threshold	12 bits ZFBF with threshold	6 bits ZFBF without threshold
5	*43.7*	*45.2*	*30*
15	*39.8*	*41.2*	*90*
25	*40.7*	*40.2*	*150*
35	*40*	*39.7*	*210*

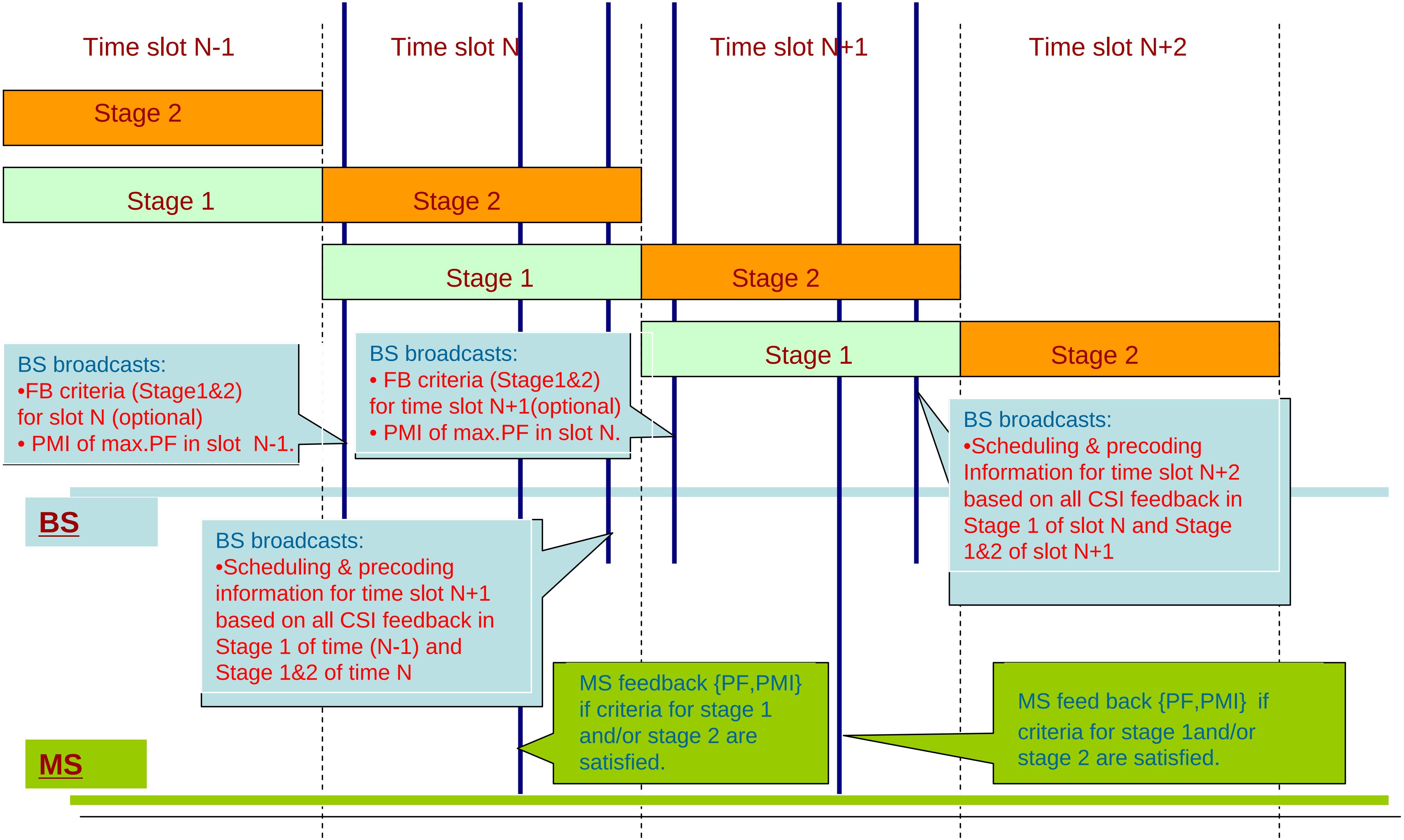
Simulation Setup:

- No. Tx Ant. = 4; No Rx Ant. = 1; No. Stream=2
- Center frequency: 2.5G; Transmission BW:10MHz; FFT size:1024; Num. of SC/RU=18
- Channel Model: SCM
- Velocity: Up to 3km/s
- No. of independent channel realizations: 3000
- Code book type: Grassmannian Line Packing (6 bits/12 bits)
- average SNR = 10 dB; $\alpha=1$; $\beta=0$;

Simulations 2-2

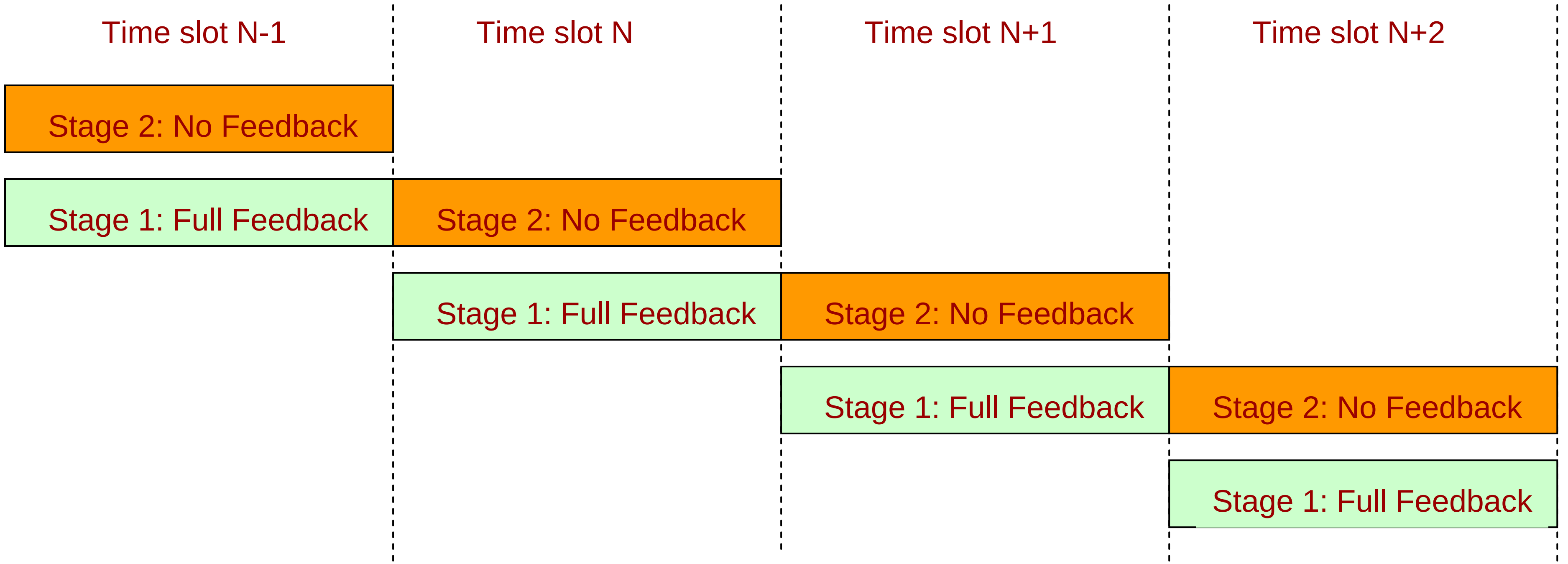


Flowchart of 2S-MU-MIMO



Compatibility of 2S-MU-MIMO

- 2S-MU-MIMO can be easily converted into conventional MU-MIMO by adjusting the threshold. (e.g. T=0 and TII=inf.)



Conclusions:

1. Threshold based algorithm is simple and can significantly reduce feedback overhead, especially when number of MS is large. However, it is not efficient to be directly implemented when both PF/CQI and PMI (for example: ZFBF) are involved in scheduling.

2. Highly accurate channel quantization is a must requirement for MU-MIMO. Simulations suggest that large codebook (10+ bits) should be adopted for MU-MIMO, especially for uncorrelated MIMO.

3. When only a few MS feed back CSI to BS, large feedback overhead per MS would not mean large overall feedback overhead any more.

Advantages of 2S-MU-MIMO

1. 2S-MU-MIMO makes threshold based algorithm work more efficiently than it does in conventional single stage MU-MIMO.

2. 2S-MU-MIMO adopts large codebook for each selected MS and, at the same time, maintains low overall feedback overhead by implementing threshold based algorithms.

3. 2S-MU-MIMO can be easily converted to conventional MU-MIMO with special threshold setting.

Text proposal

Insert the following text in Chapter 11 (Physical Layer):

11.Z1 Codebook design for DL MIMO

…11.Z1.X1 Codebook for MU-MIMO

To fulfill the potential of MU-MIMO over SU-MIMO, codebook of MU-MIMO shall be specifically defined...

11.Z2 DL Control Channel

11.Z3.X3 Broadcasting Channel

11.Z3.X31 Broadcasting Channel for double-stage MU-MIMO

Feedback criteria for both stage I and II should be broadcasted in periodical and/or event driven manner……..

In stage 1, BS shall broadcast scheduling information made in stage 1 and corresponding PMI….

In stage 2, BS shall broadcast updated scheduling information made in stage 2 and precoding matrix information…

11.Z3.X4 Feedback Channel

The CSI feedback channel should support CDM based multiple access…

MS shall feed back CSI based on feedback criteria (stage 1 and 2) broadcasted by BS…