Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Double-Stage DL MU-MIMO Scheme**
Date Submitted	**2008-05-07**
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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

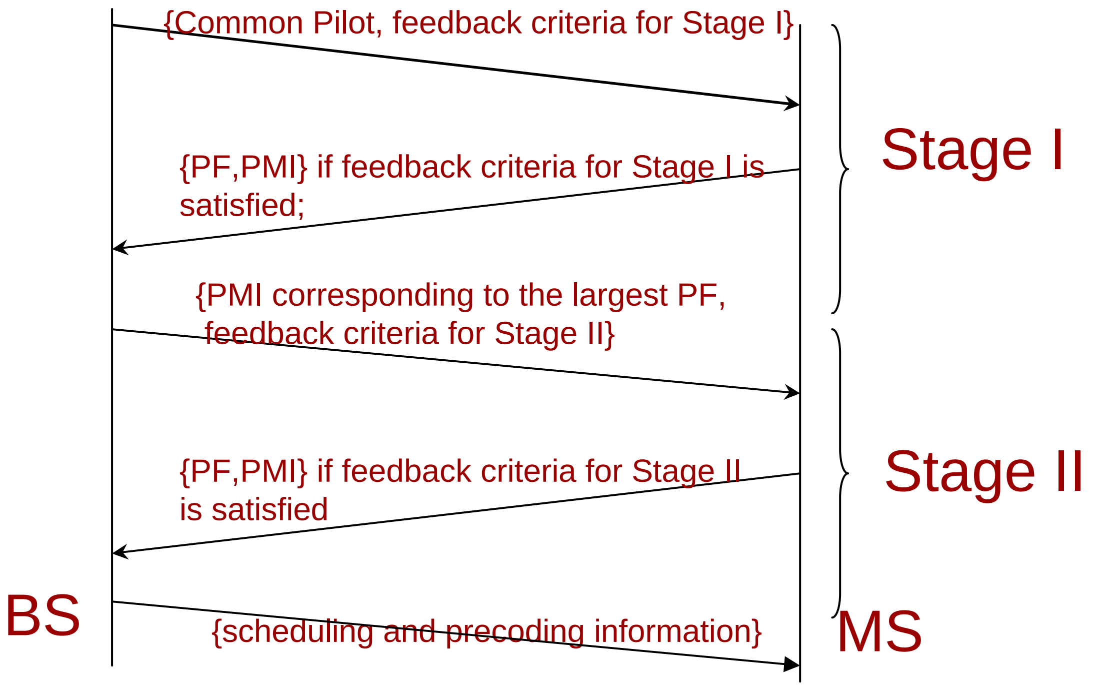
Motivation & Observations

- 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
$SNR_i = \max\left(\frac{\|hw_i'\|^2}{\sigma^2}\right) \quad w_i \in CB$	$SINR_i = \max\left(\frac{\|hw_{ip}'\|^2}{\sum_{q \neq p} \|hw_{iq}'\|^2 + \sigma^2}\right)$ $w_{ip} \in W_i$, $W_i \in CB$, I_i

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

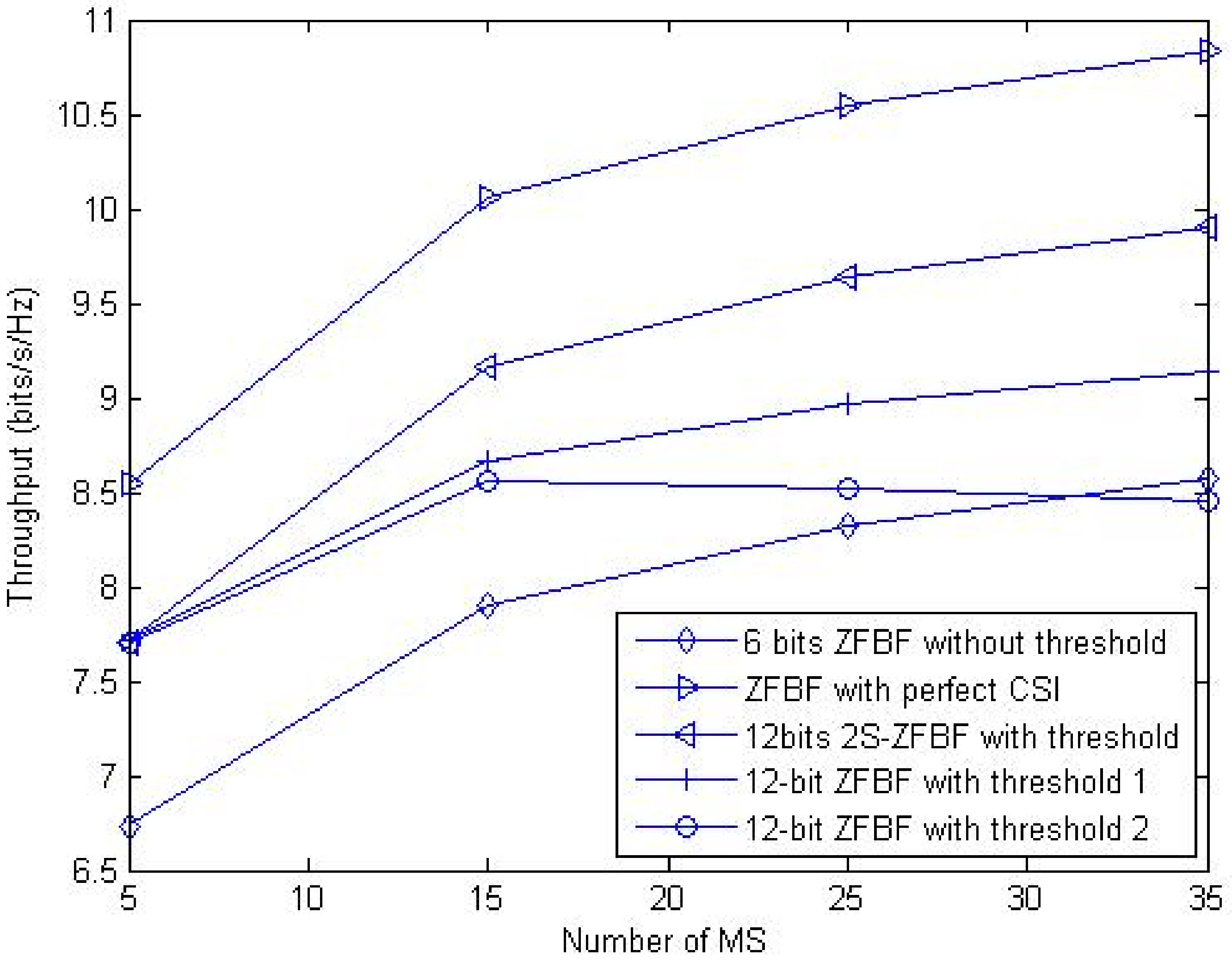
Size of Feedback Overhead (bits)

NO. of MS	12bits 2S-ZFBF With threshold	12 bits ZFBF with threshold 2	12 bits ZFBF with threshold 1	6 bits ZFBF without threshold
5	*51.3*	*52*	*50.2*	*30*
15	*53.2*	*117.5*	*55.4*	*90*
25	*48.7*	*103*	*48.1*	*150*
35	*40*	*100*	*39.7*	*210*

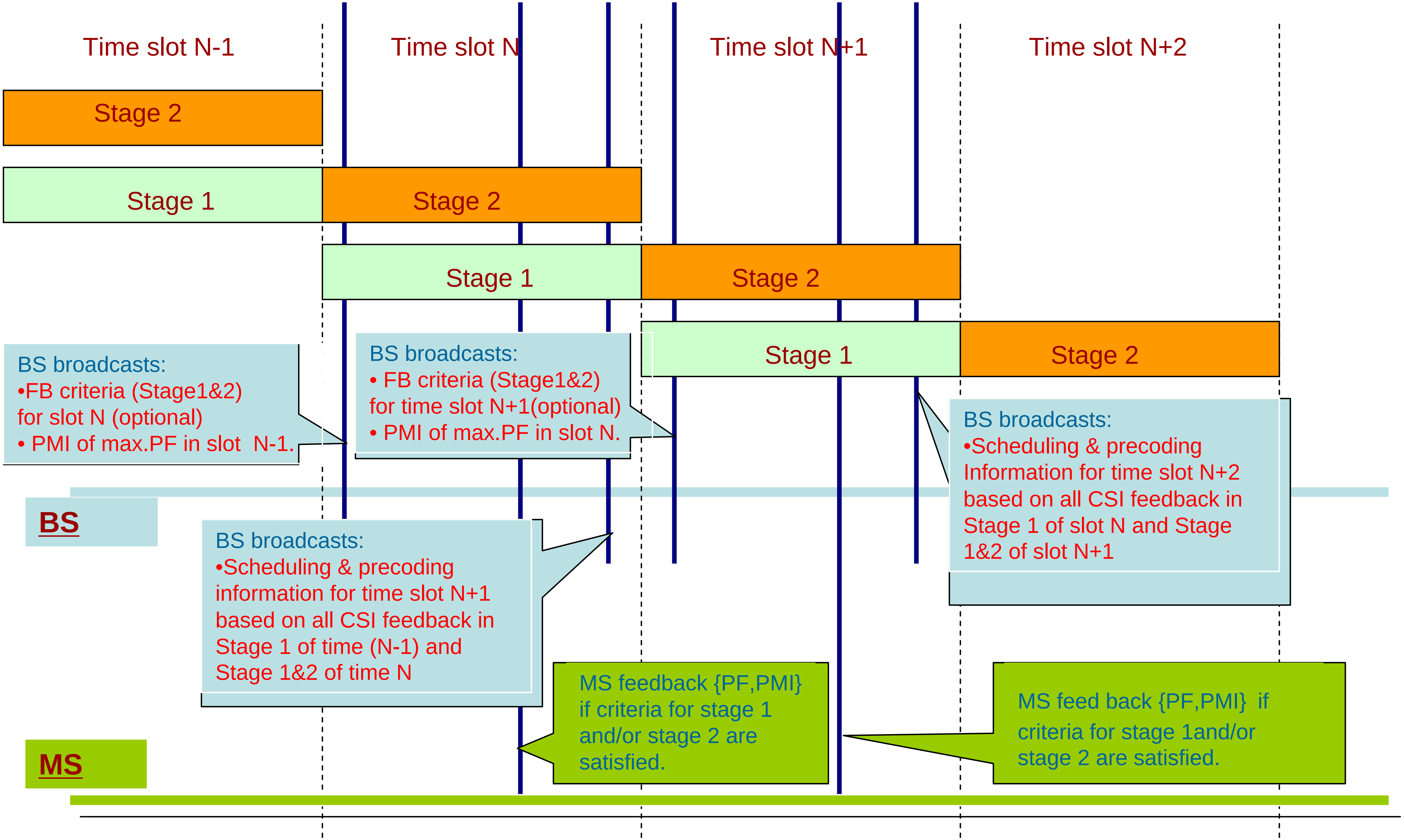
Simulation Setup:

- No. Tx Ant. = 4; No Rx Ant. = 1; No. Stream=2
- Channel Model: i.i.d. Rayleigh fading
- No. of independent channel realizations: 3000
- Code book type: Grassmannian Line Packing (6 bits/12 bits)
- SNR = 10 dB; $\alpha=1$; $\beta=0$;

Simulations 2-2

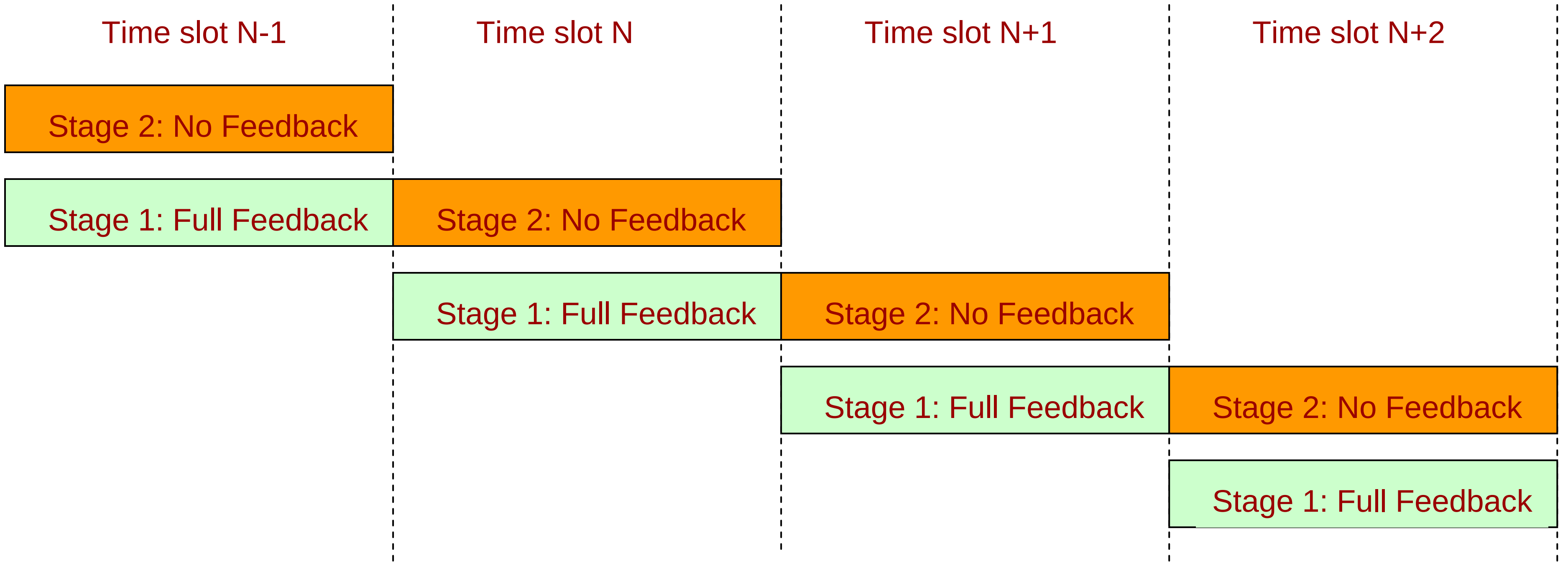


Flowchart of 2S-MU-MIMO



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 hard, if not impossible, to be directly implemented when both priority factor and PMI (for example: ZFBF) are involvedin 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…