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Re:	Response to Recirculation Sponsor Ballot
Abstract	An closed loop MIMO based antenna groping method is presented
Purpose	To incorporate the changes here proposed into the 802.16e D6 draft.
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Antenna Grouping Based Closed-Loop MIMO

1 Introduction

For the mobility application, when vehicular speed is high, open loop MIMO has advantages, in this case, for the DL reception, it is desirable that the number of receive antennas N at MSS is equal or larger than the number of transmit antennas M at BS. However, when the number of transmit antennas at BS is larger than the number of receive antennas at MSS, the closed-loop MIMO is preferable, on the other hand, closed-loop feedback information (aging) will be no longer valid after the BS demodulates the feedback. In this contribution, we present a simple procedure for antenna grouping transmission with minimum feedback singling required. Furthermore, we also demonstrate that by using the antenna grouping strategy, we can achieve similar performance for the SVD based closed-loop MIMO.

2 Background

For the BS point to multi-point transmission, to exploit the multi-user diversity, the selection to schedule a burst can be based on the user with the best CQI for the particular AMC band, in addition, we can also select the number of antenna and the MIMO transmission formats. In this contribution, for a specific user assigned to a band AMC sub-channel, we discuss the strategy to perform the antenna selection and MIMO transmission format selection.

For a fixed SS, to further enhance the channel capacity, water-filling can be applied to each layer based on the eigenvalue distribution. However, for moving mobiles, it can be shown that equal power allocation is the optimum solution. In other words, when the feedback delay is long, water-filling will be no longer beneficial, and even be detrimental.

A MIMO system can be defined by

$$\vec{r} = H\vec{s} + \vec{n}\,, \qquad (1)$$

then with equal power allocation, its channel capacity is given by

$$C = \sum_{i=1}^{L} \log_2\left(1 + \gamma_0 \lambda_i\right), \qquad (2)$$

where $\gamma_0 = \dfrac{P}{M\sigma^2}$, P is the total transmitted power, σ^2 is the noise power (per receive antenna), L is the number of eigenvalues of HH'.

When the MIMO channel is perfectly know to the transmitter, the joint singular value decomposition (SVD) and water-filling power allocation provides the optimum solution. However, this is at the cost of a great amount of feedback in the UL. In addition, feedback quantization and sensitivity of SVD to channel aging will quickly diminish the SVD gain, and may even result in a loss (vs. an open-loop system due to mismatched power allocation).

In this contribution, we propose antenna selection for the closed-loop MIMO OFDMA system, the object of antenna grouping is to maintain the robustness of the channel condition at the price of reduced layers. The criterion in antenna selection is by eliminating the weakest layers, which is, equivalently, maximizing the condition of channel matrix.

Assuming that $\alpha_1, \alpha_2, \ldots, \alpha_L$ are L nonzero singular values of H_s, and $\lambda_1, \lambda_2, \ldots, \lambda_L$ are L eigenvalues of $H_s'H$, then $\lambda_i = \alpha_i^2$. Therefore, to select a subsystem from H is to find the sub-matrix Γ which maximizes

$$\Gamma = \arg\max_{H_s \in H} \sum_{i=1}^{L} \log_2\left(1 + \gamma_0 \alpha_i^2\right) \qquad (3)$$

or equivalently

$$\Gamma = \arg\max_{H_s \in H} \prod_{i=1}^{L} \left(1+\gamma_0 \alpha_i^2\right). \qquad (4)$$

When SNR is high, equation (4) can be written as

$$\begin{aligned}\Gamma &\approx \arg\max_{H_s \in H} \prod_{i=1}^{L} \alpha_i^2 \\ &= \arg\max_{H_s \in H} \prod_{i=1}^{L} \lambda_i\end{aligned} \quad . \qquad (5)$$

Since

$$\det\left(H_s{}' H_s\right) = \prod_{i=1}^{L} \lambda_i \ , \qquad (6)$$

Equation (5) can be written as

$$\Gamma = \arg\max_{H_s \in H} \det\left(H_s' H_s\right). \qquad (7)$$

From equation (7), the selection process is very simple, and no SVD or eigen-value decomposition is required. Since $N \geq M$, $M > L$, and $H_s' H_s$ is a square matrix of size $L \times L$, the determinant calculation is limited to small size matrixes.

The matrix H_s is a matrix consists of L columns of H . The number of candidate sets is

$$\mathrm{K} = \frac{M!}{L!\left(M-L\right)!}. \qquad (8)$$

3 Proposed Solution

The MSS compute the antenna grouping criterion by computing the sub-MIMO channel determinants of all possible antenna group combinations. And select the sub-MIMO channel for the antenna grouping with the maximum determinant value. The un-selected antennas are muted from transmission for a particular sub-channel and for a particular user. The power is add onto the active antennas with boosted power.

3.1 Advantages

The proposed antenna grouping based SM has the following advantages:

- Very light feedback is needed
  - only antenna group index is fed back maximum 3 bits
- No channel/pre-coding matrix quantization error.
- Resistant to channel aging
  - due to even layer energy distribution and equal transmit power allocation
- Applicable to *all* the sub-channelization

4 Simulation Results

The simulation methodology is compliant with the CL-MIMO harmonization group requirements.

4.1 Simulation Set Up

The simulation parameters and conditions are listed in Table 1.

Table 1 Simulation Set Up

Configurations	Parameters	Comments
Optional BAND AMC sub-channel		The band allocation in time-direction shall be fixed at center band
Coding Modulation Set	CC coding , K=3, TB	Coded Symbol Puncture for MIMO Pilot
	QPSK ½, QPSK, ¾, 16QAM ½, 16QAM R=¾, 64QAM R=1/2, 64QAM R= 3/4	
Code Modulation Mapping	Single encoder block with uniform bit-loading	
MIMO Receiver	MMSE-one-shot for SVD MLD receiver for OL and CL SM	
FFT parameters	Carrier 2.6GHz, 10MHz, 1024-FFT Guard tone 79 left, 80 right CP=11.2ms, Sampling rate = 8/7, Sub-carrier spacing = 11.2kHz	
Frame Length	5ms frame, DL:UL=2:1	
Feedback delay	2 frames	
MIMO Configurations	4x2	
Channel Model	ITU-PA, 3km/h, ITU-VA, 30km/h Antenna Correlation: 20% Perfect Channel Estimation	
Feedback	SVD: perfect pre-coding matrix V without quantization SM: antenna selection matrix index	

The simulation results are shown in Figure 1, where the open loop SM, the antenna grouping 4x2 SM and the 4x2 perfect SVD are presented in the hull curve representation.

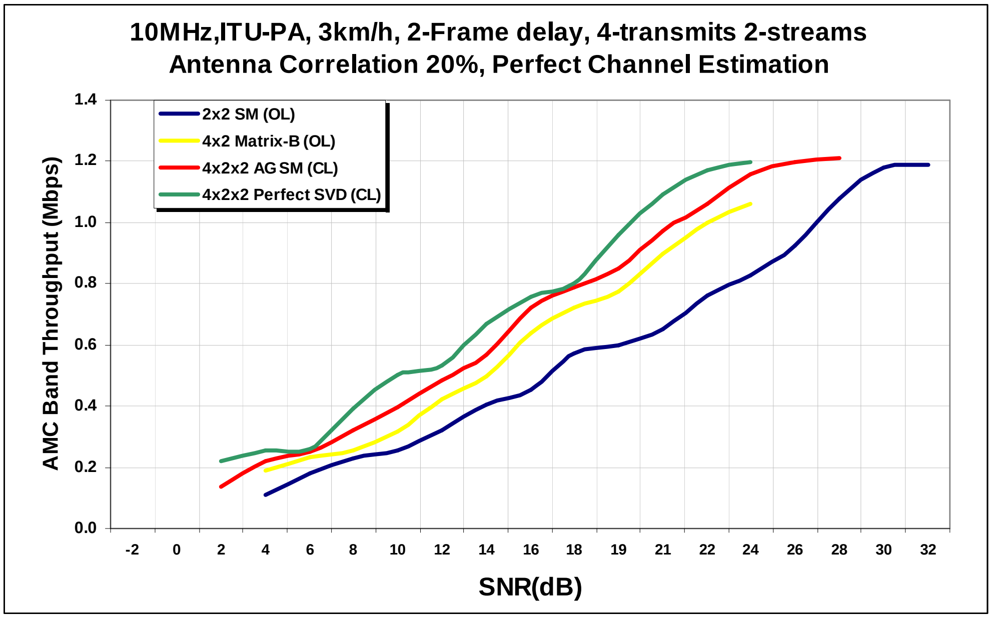

Figure 1 Hull curve PA-3km/h

It can be seen that for the fixed and slow nomadic case, antenna grouping MIMO and the closed loop SVD have about 4~6dB gain over the basic open loop 2x2 SM. In addition, the performance of antenna grouping SM is very close to the perfect SVD closed loop SM. The practical SVD requires compression of the pre-coding V matrix in general will introduce the quantization loss, for the antenna grouping, such a loss can be avoided.

4.2 Impact of Mobility Speed

The mobility has a significant impact on the performance of closed loop based MIMO, especially on the SVD based methods, In Figure 4, the significant ~3dB loss of closed loop perfect SVD is observed at 30km/h mobility (if the mobility speed is higher than 10km/h, the SVD closed loop performance gain is diminished).

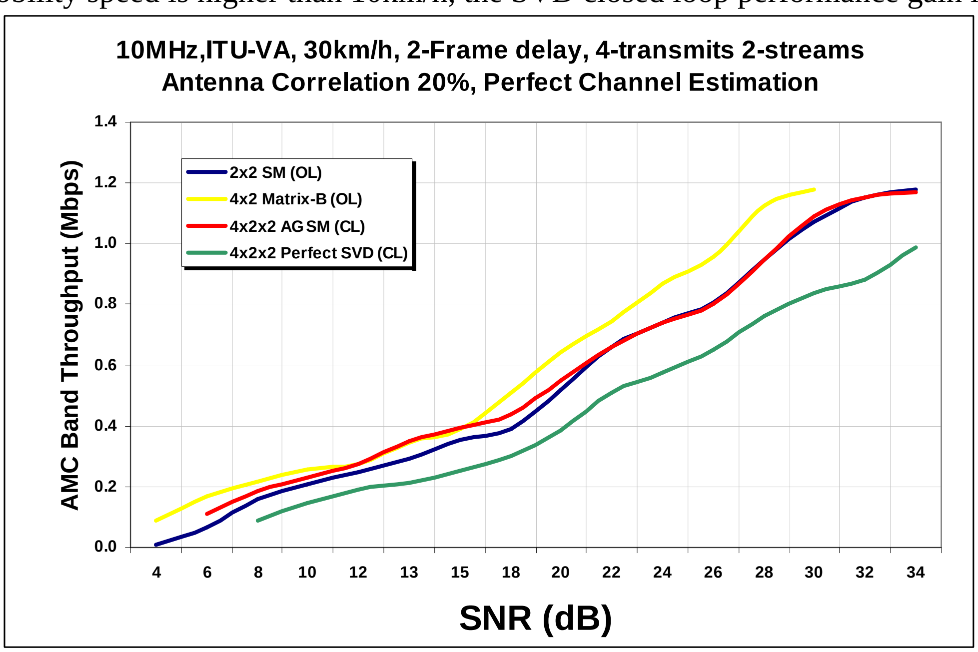

Figure 4 Comparison of Aging Effect

As we can see, the most the gain of the closed loop MIMO can be achieved by simple antenna grouping while avoiding the pre-coding matrix feedback penalty in the UL. In addition, the antenna grouping based closed loop MIMO requires a small among addition computing complexity

5 Feedback Requirement

2~3 bit are required per AMC band

6 Complexity

The complexity of antenna selection mainly consists of the computing the determinant defined by equation (7). For 4x2 antenna grouping case, maximum108 multiplications are required.

7 Summary

The proposed antenna grouping SM can achieve the performance gain close to the perfect channel feedback SVD pre-coding with the following merits:

- Requires small feedback resource
- Applicable to all the sub-channelization
- Robust t feedback aging and no performance degradation worse than open loop transmission
    - However for the SVD based pre-coding, significant performance loss for the mobility speed larger than 10km/h

8 Text Proposal

Start text proposal

[Add a new section 8.4.8.3.4.1 as follows]

8.4.8.3.4.1 3 Antenna Grouping for 3 and 4 Transmit Antennas for Matrix C

For the transmission matrix C, when k sub-streams are configured, $x_i=[s_1,s_2,..s_k]$, k=1,2,.M, M=3,4, the transmit antennas can be pre-coded as $x=W_n x_i$.

For 3-transmit antennas BS, the pre-coding matrix is listed in Table xxx, where the mapping of the matrix W_n to the CQICH is shown. The active antenna is power boosted.

Table xxx The Mapping of the Pre-coding matrix and CQICH for 3 Transmit Antennas

	CQICH			
Streams, k	0b110000	0b110001	0b110010	Power boosting
1	$W_1 = c\begin{bmatrix}1\\0\\0\end{bmatrix}$	$W_2 = c\begin{bmatrix}0\\1\\0\end{bmatrix}$	$W_3 = c\begin{bmatrix}0\\0\\1\end{bmatrix}$	$c = 1$

2	$W_1 = c\begin{bmatrix}1 & 0\\0 & 1\\0 & 0\end{bmatrix}$	$W_2 = c\begin{bmatrix}1 & 0\\0 & 0\\0 & 1\end{bmatrix}$	$W_3 = c\begin{bmatrix}0 & 0\\1 & 0\\0 & 1\end{bmatrix}$	$c = 1/\sqrt{2}$

For 4-transmit antennas BS, the pre-coding matrix is listed in Table yyy, where the mapping of the matrix W_n to the CQICH is shown. The active antenna is power boosted.

Table yyy The Mapping of the Pre-coding matrix and CQICH for 4 Transmit Antennas

Streams, k	CQICH						Power boosting
	0b110000	0b110001	0b110010	0b110011	0b110100	0b110101	
1	$W_1 = c\begin{bmatrix}1\\0\\0\\0\end{bmatrix}$	$W_2 = c\begin{bmatrix}0\\1\\0\\0\end{bmatrix}$	$W_3 = c\begin{bmatrix}0\\0\\1\\0\end{bmatrix}$	$W_4 = c\begin{bmatrix}0\\0\\0\\1\end{bmatrix}$			$c = 1$
2	$W_1 = c\begin{bmatrix}1 & 0\\0 & 1\\0 & 0\\0 & 0\end{bmatrix}$	$W_2 = c\begin{bmatrix}1 & 0\\0 & 0\\0 & 1\\0 & 0\end{bmatrix}$	$W_3 = c\begin{bmatrix}1 & 0\\0 & 0\\0 & 0\\0 & 1\end{bmatrix}$	$W_4 = c\begin{bmatrix}0 & 0\\1 & 0\\0 & 1\\0 & 0\end{bmatrix}$	$W_5 = c\begin{bmatrix}0 & 0\\1 & 0\\0 & 0\\0 & 1\end{bmatrix}$	$W_6 = c\begin{bmatrix}0 & 0\\0 & 0\\1 & 0\\0 & 1\end{bmatrix}$	$c = 1/\sqrt{2}$
3	$W_1 = c\begin{bmatrix}1 & 0 & 0\\0 & 1 & 0\\0 & 0 & 1\\0 & 0 & 0\end{bmatrix}$	$W_2 = c\begin{bmatrix}1 & 0 & 0\\0 & 1 & 0\\0 & 0 & 0\\0 & 0 & 1\end{bmatrix}$	$W_3 = c\begin{bmatrix}1 & 0 & 0\\0 & 0 & 0\\0 & 1 & 0\\0 & 0 & 1\end{bmatrix}$	$W_4 = c\begin{bmatrix}0 & 0 & 0\\1 & 0 & 0\\0 & 1 & 0\\0 & 0 & 1\end{bmatrix}$			$c = 1/\sqrt{3}$

End text proposal

9 Reference:

[1] IEEE P802.16-REVd/D5-2004 Draft IEEE Standards for local and metropolitan area networks part 16: Air interface for fixed broadband wireless access systems