On the Performance of the Scheduling Scheme for MU-MIMO BC System With Two-Stage Feedback

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Abstract-Multi-user Multiple Input Multiple Output (MU-MIMO) broadcast channel (BC) deployed with multiple transmit antennas at the base station (BS) and multiple receive antennas at each user is considered. The channel state information (CSI) from each user is quantized at the user side and the CSI at the transmitter (CSIT) required to obtain the throughput for the system is obtained in terms of the feedback bits only. The main objective is to reduce the feedback load. Transmitter architecture is proposed based on the zero-forcing beam forming (ZFBF) semi-orthogonal user selection (SUS) algorithm. In the proposed system, a two-stage feedback scheme is used along with the SUS scheduling algorithm so as to minimize the feedback load. The Maximum expected SINR combiner (MESC) is exploited so that only a limited number of users convey their feedback. These methods efficiently eliminate users from transmission in feedback and scheduling process, resulting in optimum use of scarce resources. The simulation results bring us to a conclusion that SUS user selection method gives significant reduction in feedback bits and the required effective throughput is achieved.

*Keywords***:** Multi-user MIMO, Channel state information, SUS user selection, MESC, throughput.

I INTRODUCTION

MU-MIMO (*Gesbert , Kountorious, Heath, Chae and Salzer,2008*) enhances for Multi-user Multiple Input Multiple Output which enables independent radio terminals for accessing the system where multiple users access the same channel using spatial degrees of freedom. MIMO-BC (*Spencer, Peel , Swindlehurst and Haardt,2004*) represents a downlink in which a single sender sends data to multiple receiver wireless networks. In MU-MIMO high throughput can be achieved using high SNR value. Such networks have wide spread-access in wireless networks. The examples of application include multi-cell networks with multiple access channels where co-ordination among base station (BS) is established. The main aim is to co-ordinate and mitigates the effect of interfering cells.

For transmit processing of these signals, the channel state information at the transmitter (CSIT) must be known so as to achieve high throughput and improvement in multiplexing gain. If transmitter knows the downlink, channel state information at the transmitter (CSIT) perfectly, the capacity can be achieved almost when there are large numbers of users. If there is limited CSIT then the accuracy depends on accuracy of CSIT. These CSIT results play a significant role in throughput loss because of interference factors.

The codebook **C** is available at the transmitter and the receiver. B bits per feedback interval are used so as to index the codebook with 2^B vectors. A well-defined codebook contains codewords which span the set of MIMO experience by the users. The increased feedback associates with the number of users and SNR values. The feedback (*Hassel , Gesbert, Alouini, and Qien,2007*) is interpreted by two-stages: the first stage necessitates quantized CDI of user scheduling and the second stage accumulates CDI for user scheduling for beamforming. The sum-rate performance (*Murakami , Kudo , Asai , Kumagai and Mizoguchi,2011*) relies upon the quantization validity in design and the amount of nominated users, feedback bits are adequately assigned at each stage. For generation of codebooks in relevance to any antenna design for different spatial configuration, various highly adaptive techniques (*Benvenuto and Cherubin,2002*) (*Benvenuto, Conte, Tomasin and Trivellato,2007*) are available.

To reduce the feedback, a fraction of users which have their SNR higher than the system-defined threshold are authorized to emit their channel information. In the second stage; threshold is a function of amount of users, the amount of transmitting antennas, quantization size and othogonality criterion used. An optimum threshold value is used so that it decreases the intermediate feedback load which is a requirement for the paper to be implemented.

In this paper we propose a scheduling algorithm combined with the two-stage feedback for a Multi-user Multiple Input Multiple Output (MU-MIMO) which earlier existed for Single user Multiple Input Multiple Output (SU-MIMO) system. The SUS algorithm and the two-stage feedback systems combine together to perform better as the feedback load is reduced. The feedback load enhances the throughput of the system directly. The need to combine these two systems originated, for the number of users

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eliminated in the SUS algorithm is not large. On combining the scheduling algorithm (*Gesbert and Alouini,2008*) with the feedback system the number of users are effectively reduced.
The paper is organized as follows. In section II , we describe the system model. Section III describes the scheduling algorithm and the feedback in detail. Section IV describes the performance analysis of the proposed system with different feedback bits used. The section V concludes with the comparison of the results of the system.

II SYSTEM MODEL

The multi-antenna broadcast (BC) channel in a MU-MIMO system is considered with K users. The base station (BS) consists N_t transmit antennas and each user has N_r number of receive antennas with the assumption that $K \times N_r >> N_t$. The complex base-band received signal is represented as

$$\mathbf{y}_k = \mathbf{H}_k \mathbf{x} + \mathbf{n}_k$$

where $\mathbf{H}_k$ is the N_r x N_t channel matrix of k^{th} user, **x** is the transmitted signal vector of size N_t x 1 and n_k is the complex Gaussian noise component for the k^{th} user. Individual components h_{ij} of the channel matrix **H** are assumed to Rayleigh fading coefficients, i.e. they are complex Gaussian random variable with zero mean and unit variance ~ CN(0,1).The assumption is taken that the channel information is known to each user. In case of multiple receiver antennas, each user has spatial data stream. We assume a equal power allocation mechanism, i.e each selected user is allocated a power of P/N_t where P is the total transmit power. In practical cellular systems where K>>N_t, this restriction is through empirical observation under ideal CSIT, limiting the feedback per user provides justification for the restriction done.

The base station (BS) serves a particular set of users i.e S ϵ {1,2…….K}. This set of users is selected using the zero-forcing beam-forming (ZFBF) (*Yoo and Goldsmith*) with semi-orthogonal user selection (SUS) combined with two-stage feedback which attains both the multiplexing and multi-diversity gains. The channel directional information (CDI) is also combined with this scheme. Because of limited degrees of freedom, the numbers of users are restricted S ≤ N_t. The limited feedback ZFBF-SUS system needs both CQI (Channel Quality Information) and CDI to attain the sum capacity growth rate for perfect CSIT. The scheme was deployed for different feedback bits and the performance was monitored. An optimum threshold was used so as to minimize the intermediate feedback load. This threshold is considered as a function of number of transmit antennas, number of users, the number of quantization size, and the orthogonality criterion in the second stage. With this the feedback load is reduced significantly without hampering the performance of the ZFBF-SUS algorithm.

III COMBINED SCHEDULED TWO-STAGE FEEDBACK

Before deploying the SUS algorithm for all the users we need to calculate the expected SINR value. For the CQI feedback, the expected SINR (*Trivellato, Boccardi, and Huang,2008*)is:-

$$\gamma_k = \frac{\rho \left| \mathbf{u}_k \mathbf{H}_k \hat{\mathbf{v}}_k \right|^2}{1 + \rho \left\| \mathbf{u}_k^H \mathbf{H}_k - (\mathbf{u}_k^H \mathbf{H}_k \hat{v}_k) \hat{v}_k^H \right\|^2} \quad (1)$$

with ρ=P/Nt, where $\mathbf{u}_k = (I + \mathbf{B}_k)^{-1} \sqrt{\rho} \mathbf{H}_k \mathbf{c}_i$; where $\mathbf{u}_k$ represents N dimensional unit norm vector and $\mathbf{c}_i$ represents the codebook of the system.

$$\mathbf{A}_k = \rho(\mathbf{H}_k \mathbf{c}_i \mathbf{c}_i^H)\mathbf{H}_k^H \, ; \; \mathbf{B}_k = \rho[\mathbf{H}_k (I - \mathbf{c}_i \mathbf{c}_i^H)\mathbf{H}_k^H].$$

The CQI is expected using the Maximum expected SINR combiner (MESC).

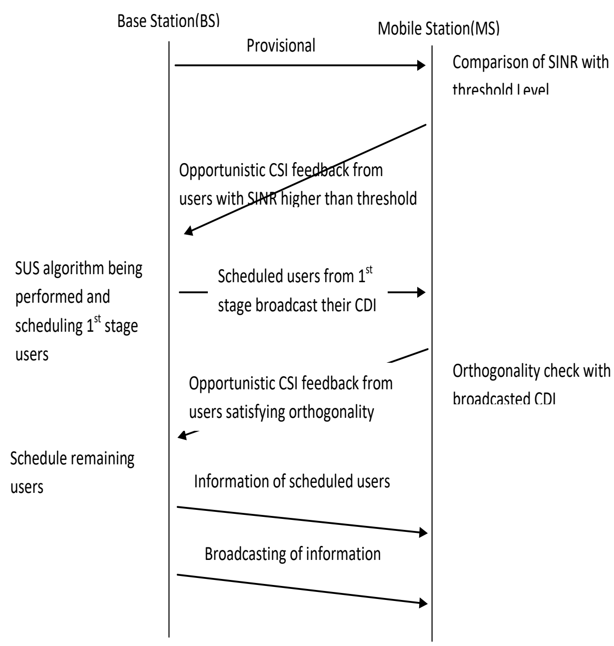

Fig.1 Proposed scheme timing diagram

IV SUS ALGORITHM

For selection of the adequate number of users, the BS executes the SUS Algorithm (*Yoo,Jindal and Goldsmith,2007*) is performed as follows:-

Step 1) Initialize U_o with the index of all the users

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U_o=[1,2…….k] .

Step 2) A user is selected on the basis of the given condition

$$\phi(i) = \arg\max_{k \in k_{i-1}} \gamma_k$$

The set of users satisfying this condition are collected.

Step 3) The remaining user-set is updated which satisfy

$$U_i = \{ j \in k_{i-1} : \left| \hat{\mathbf{v}}_k^H \hat{\mathbf{v}}_{\phi(i)} \right| \leq \in \}$$

Step 4) Repetation of 2) and 3) is done until the user reaches N_t .Considering U_i should not be an empty matrix.

The selected users are quantized using he quantization vectors, in S = {ϕ(1),ϕ(2)………..ϕ(M)}; where M ≤ N_t and the ZFBF vectors as:-

$$\hat{\mathbf{H}} = [\hat{h}_{\phi(1)} \hat{h}_{\phi(2)} \ldots\ldots\ldots\ldots \hat{h}_{\phi(M)}]$$

$$W(s) = \hat{\mathbf{H}}(\hat{\mathbf{H}}^H \mathbf{H})^{-1}$$

On normalizing W(s), the beam forming vector $\hat{W}_k$ is obtained for k € S. The selected users from the SUS algorithm are the appropriate users which will be used for the ZFBF-based transmission having low complications from steps 2) and 3). Since all the users are not appropriate for the ZFBF, the unwanted users are excluded from the SUS algorithm. K feedback bits are required for CDI for a perfect CQI. The procedure has disadvantages as it consumes important resources such as bandwidth, time and transmission energy as we increase the number of users i.e K. For reduction in the transmission load and the computational load, we exclude users before the feedback and scheduling process. The feedback strategy is proposed so as to avoid the unwanted ZFBF transmission, of the users from reporting the CDI and CQI. The users using approximate SINR γ_k and orthogonality are the ones selected for the ZFBF transmission. For this we use both the CQI and CDI for the feedback considers the feedback. The two stage feedback considers the feedback from SINR during the 1^{st} stage and orthogonality criterion at the 2^{nd} stage (*Min, Kim, and Hong,2013*).

V Two-stage feeback system

Stage 1: SUS combined with SINR-based appropriate feedback

The exploitation of the SINR feedback is done, to reduce the overhead feedback. Each user transmits its CQI and CDI and the CQI value γ_k is compared to the threshold value. Comparison is done by each user, it compares the SINR value i.e. γ_k with γ_t and decides the transmission of the CSI (CQI and CDI) or not. From this, the selected users are collected as:-

$$\mathbf{M}_1 = \{ k \in K : \gamma_k > \gamma_t \}$$; where k={1,2………K} .

On reception of selected users in M_1, the SUS is partially performed on these by the selected users. ϕ(1), ϕ(2)………ϕ() using the steps of SUS algorithm. The initialization of the SUS algorithm is swiped from U_o to M_1. If in case =N_t, the BS skips the second stage and jumps to the downlink. Else the numbers of selected users are sent to the feedback stage for further processing.

Stage 2: SUS combined with orthogonality criterion

To diminish the complexness of user selection, the orthogonality criterion is implemented on the user. Step 3) of SUS algorithm is used to exploit the orthogonality criterion in second stage. The non orthogonal users are eliminated in this stage. The orthogonality is calculated between the quantization vector and the broadcast codeword vectors, the users satisfying this condition transmit their CSI. Using the above criterion, the selected users are collected as:

$$\mathbf{M}_2 = \{ k \in K - \mathbf{M}_1 : \left| \hat{h}_k^H \hat{h}_{\phi(j)} \right| \leq \in, 1 \leq \forall j \leq N_s^1 \} .$$

If N_s^1 (Number of selected users in stage 1)=0; all users transmit their CSI. Also, we can minimize the number of feedback bits. Codebook indices for both BS and the users are known; thus the codebooks do not satisfy this orthogonality criterion is eliminated. Thus now the codebook is reduced to:-

$$C_2 = \{ \mathbf{c} \in \mathbf{C} : \left| \mathbf{c}^H \hat{\mathbf{h}}_{\phi(j)} \right| \leq \in, 1 \leq \forall j \leq N_s^1 \}$$

C_2 is known to the BS and selected users of stage 2 i.e. M_2 can quantize CDI with reduced codebook C_2 and feedback quantization index. On performing the SUS algorithm partially the set of selected user S={ϕ(1),ϕ(2)…………….ϕ(M)}. Now the BS constructs the ZFBF vectors and the broadcasting is done. Since the two-stages are related as $\lceil M_2 \rceil$ is subset of $\lceil M_1 \rceil$ as it depends on the selected users in stage 1).

VI RESULTS AND DISCUSSION

Our prime focus is to reduce the feedback load, for this we investigate the intermediate values for the feedback bits. The performance for B=4 and B=8when N_t=N_r=4 and also with N_t=4 and N_r=1 has been simulated. This system can be implemented for various values of N_t and N_r. Primarily the SUS algorithm was implemented solely and the results were obtained. Then the system is extended for two-stage feedback scheduling combined with the SUS algorithm.

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The comparison of the results for the feedback bits 4 and 8 when the SUS algorithm was implemented for N_t=4 and N_r=1 is given in Fig. 2.

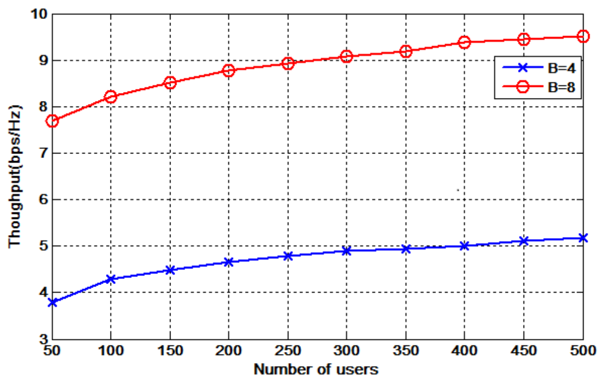

Fig. 2. Comparison of achieved throughput for B=4 and B=8 with Nt=4 and Nr=1 using SUS user selection algorithm.

The comparison of the results for the feedback bits 4 and 8 when the SUS algorithm was implemented for N_t=4 and N_r=4 is given in Fig. 3.

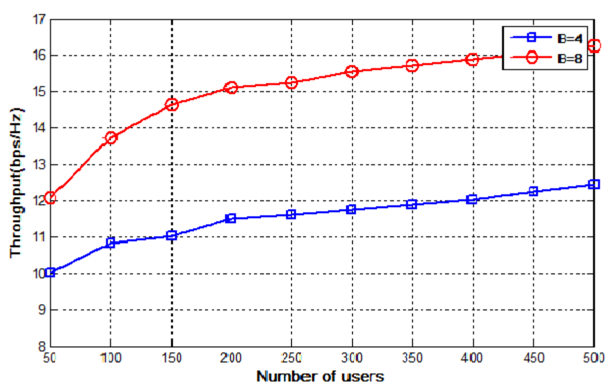

Fig. 3. Comparison of achieved throughput for B=4 and B=8 with Nt=4 and Nr=4 using SUS user selection algorithm.

The comparison of results when the SUS algorithm was combined with the two-stage feedback was implemented for feedback bits 4 and 8 for N_t=4 and N_r=1 is given in Fig. 4.

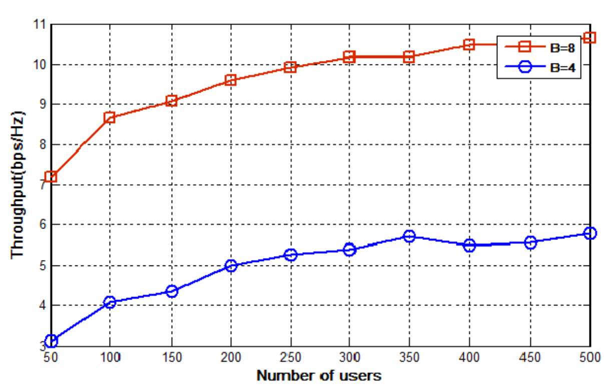

Fig. 4. Comparison of achieved throughput for B=4 and B=8 with Nt=4 and Nr=1 using SUS user selection algorithm combined with two-stage feedback.

From the above simulation results, it is evident that on combining the two systems though the number of users have reduced evidently but this does not affect the throughput of the system. The above graphs clearly show that the throughtput is not affected even though the number of users emitting the channel information is reduced.

The comparison of results when the SUS algorithm was combined with the two-stage feedback was implemented for feedback bits 4 and 8 for N_t=4 and N_r=4 is given in Fig. 5.

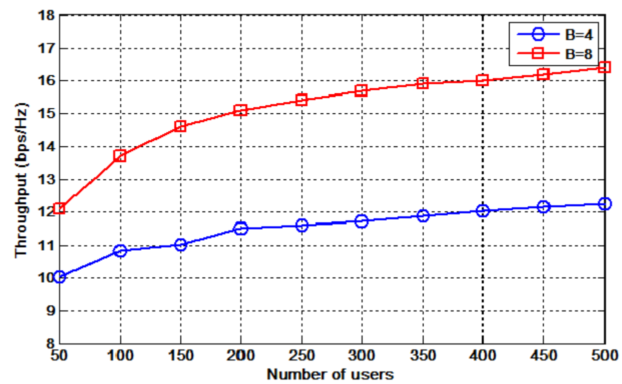

Fig. 5. Comparison of achieved throughput for B=4 and B=8 with Nt=4 and Nr=4 using SUS user selection algorithm combined with two-stage feedback.

When we compare the results of SUS user selection algorithm and the two-stage feedback then, it is concluded that the feedback bit 8 has better results when compared with 4 feedback bits. This is due to the fact that when we increase the number of quanization bits then the quantization error is reduced. Similarly, if we implement the it for 12 feedback bits then the results will be much better as compared to 8 feedback bits.

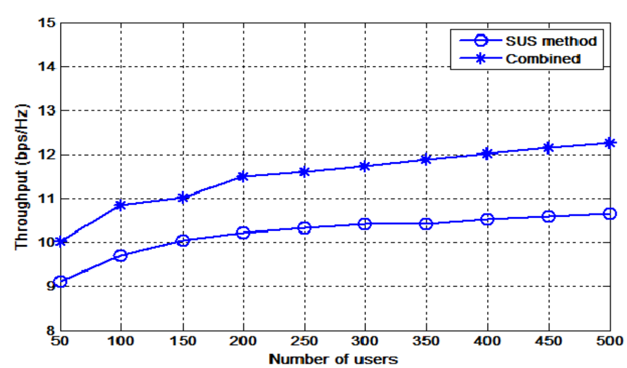

Fig. 6. Comparison of results for B=4, when SUS user selection algorithm was implemented and when SUS was combined with two-stage feedback system where Nt=4 and Nr=4.

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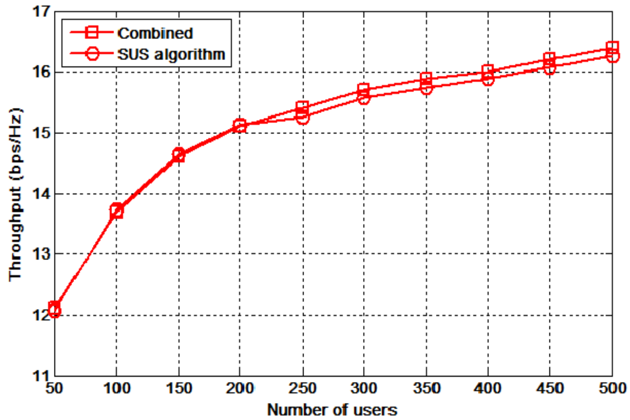

Fig. 7. Comparison of results for B=8, when SUS user selection algorithm was implemented and when SUS was combined with two-stage feedback system where Nt=4 and Nr=4.

VII CONCLUSION

The proposed MU-MIMO scheduling scheme ahows that the SUS user selection method is a better method to achieve the required throughput. In case of SUS user selection method we use the entire feedback and then the algorithm is performed on it. But this is not in case of the two-stage feedback system. In the two-stage feedback system the reduction in feedback bits lead to a significant reduction in the information at the transmitter. This lesser information at thetransmitter side helps in simulating the things in faster and a better way. When the two schemes are combined the system performance is better since the feedback load is reduced in this case.

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