International Journal of Engineering and Technical Research (IJETR)
ISSN: 2321-0869 (O) 2454-4698 (P), Volume-4, Issue-1, January 2016

User scheduling for beam forming MU – MISO - OFDM Systems

Najoua Achoura, Ridha Bouallegue

***Abstract*—The use of multi-user multiple-input multiple-output (MU-MIMO) transmission is an attractive strategy to increase spectral efficiency in wireless systems such as 3GPP Long-Term Evolution (LTE) and LTE-Advanced. In this work, we investigate beamforming and scheduling strategies in the downlink of limited feedback MU-MIMO systems. Modeling transmission under orthogonal frequency-division multiplexing (OFDM) using the achievable sum rate as performance measure, numerical results show that PU2RC achieves higher throughput and is more robust against CSI quantization errors than the popular alternative of FZ beamforming if the number of users is sufficiently large.**

***Index Terms*— MIMO-OFDM, beamforming, ZF,Greedy, PU2RC.**

I. INTRODUCTION

The combination of beamforming multiple –input -single-output (MISO) and orthogonal frequency multiplexing (OFDM) provides a robust communications link in fading environments by maximizing received signal strength via beam-steering, and has been incorporated in standards such as WiMAX and 3GPP Long Term Evolution. A MISO-OFDM system is often characterized by a single base station with multiple antennas transmitting simultaneously to a number of individual users. More practical downlink algorithms are based on transmit beamforming, including zero forcing [1]–[4], a signal-to-interference-plus-noise-ratio (SINR) constraint [5], minimum mean squared error (MMSE) [6]. These boadcast algorithms can be combined with multiuser scheduling to further increase the throughput by exploiting multiuser diversity, which refers to scheduling only a subset of users with good channels for each transmission [7]–[8]. Both scheduling and beamforming in a broadcast system require channel state information (CSI) at the base station. Unfortunately, CSI feedback from each user potentially incurs excessive overhead because of the multiplicity of channel coefficients. Therefore, this paper focuses on downlink transmission that supports efficient CSI feedback and uses CSI for joint beamforming and scheduling

II. SYSTEM MODEL

The downlink or broadcast system is described as follows. The base station with N_t antennas transmits data simultaneously to Nt active users chosen from a total of U users, each with one receive antenna. The base station separates the multiuser data streams by beamforming, i.e. assigning a beamforming vector to each of the N_t active users. The beamforming vectors $\{w_n\}_{n=1}^{Nt}$ are selected from multiple sets of unitary orthogonal vectors following the beam and user selection algorithm. Equal power allocation over scheduled users is considered. The received signal of the u^th scheduled user is expressed as:

$$y_u = \sqrt{\frac{P}{Nt}} h_k^* \sum_{n \in A} w_n x_n + v_u \qquad u \in A \qquad (1)$$

Where we use the following notation:
N_t :number of transmit antennas and also number of scheduled users; h_u (Nt × 1 vector) downlink channel; x_u transmitted symbol with $E[|xu|^2] = 1$; y_u received symbol; w_u (Nt × 1 vector) beamforming vector, A The index set of scheduled users, P :transmission power;

III. MULTI-USER MISO-OFDM DOWNLINK CHANNEL

A. *Zero-Forcing Beamforming*

Zero-forcing (ZF) decomposes the channel into several parallel scalar channels with only additive noise, and the interference is removed completely by transmit beamforming techniques[10]. Suppose a base station with Nt transmit antennas transmits information to K users, each user is equipped with one single receive antenna. The received signal by the kth user is

$$y_k = h_k^H v_k x_k + h_k^H \sum_{j=1, j \neq k}^{K} v_j x_j + n_k \qquad 1 \leq k \leq K \quad (2)$$

ZF method transmits the signals towards the intended user with nulls steered in the direction of the other users, i.e., ($h_j^H v_k = 0 \ \forall j \neq k$) .The users will receive only the desired signal without any interference because of the perfect nulling. In this case, the received data at the kth user can be written

$$y_k = h_k^H v_k x_k + n_k \qquad (3)$$

The corresponding vector equation is

$$y = H^h V x + n \qquad (4)$$

Therefore, if the normalized transmit beamforming vector of the kth user is selected

$$v_k' = \frac{h_k^{(\dagger)}}{\sqrt{\left\| h_k^{(\dagger)} \right\|_F^2}} \qquad (5)$$

where h(y)k is the kth column of the pseudo inverse of H, denoted as H(y). Then it is shown that the interference can be canceled completely. In this case, the SNR of the kth user is

$$SNR_k = \frac{|h_k^H v_k'|^2 p_k}{\sigma^2} \qquad (6)$$

B. *Channel Vector Quantization*

In [9], authors analyzed the channel capacity with perfect channel knowledge at the receiver, but with limited channel

---

Najoua Achoura, National Engineering School Of Tunis, SUP'COM, Innov'Com Laboratory
Ridha Bouallegue, High School Of Communication Of Tunis, SUP'COM, Innov'Com Laboratory, Carthage University

knowledge at the transmitter. Specifically, the optimal beamformer is quantized at the receiver, and the quantized version is relayed back to the transmitter. Given the quantization codebook $C = \{w_1, \cdots w_{2^B}\}$, which is also known a priori at the transmitter, and the channel H, the receiver selects the quantized beamforming vector to maximize the instantaneos rate, [9]

$$w(H) = \arg\max_{v_j \in V} \left\{ \log(1 + \rho \left\| H w_j \right\|^2) \right\}$$

where $\rho = 1/\sigma_n^2$ is the background signal-to-noise ratio (SNR). The (uncoded) index for the rate-maximizing beamforming vector is relayed to the transmitter via an error-free feedback link. The capacity depends on the beamforming codebook V and B. With unlimited feedback (B→ ∞) the w(H) that maximizes the capacity is the eigenvector of H*H, which corresponds to the maximum eigenvalue.

We will assume that the codebook vectors are independent and isotropically distributed over the unit sphere. It is shown in [12], that this RVQ scheme is optimal (i.e., maximizes the achievable rate) in the large system limit in which (B,Nt,Nr)→∞ with fixed normalized feedback B = B/Nt and Nr = Nr/Nt. (For the MISO channel Nr = 1). Furthermore, the corresponding capacity grows as log(ρNt), which is the same order-growth as with perfect channel knowledge at the transmitter. Although strictly speaking, RVQ is suboptimal for a finite size system, numerical results indicate that the average performance is often indistinguishable from the performance with optimized codebooks [12], [14].

IV. SCHEDULING

In the case of K > Nt a multiuser diversity can be achieved by performing user scheduling before applying ZF-BF. Multiuser diversity is a form of selection diversity among users; when the number of users is large, the base station can schedule its transmission to those users with favorable channel fading conditions to improve the system throughput. When full CSI is available, a better choice of beamforming directions can be made and it provides fairly good performance under the zero-forcing strategy. Namely, the transmitter can choose a group of users with high channel magnitudes and for which their channel directions are matched to zero forcing beam directions.

A. Greedy Scheduling

1. *Initialization phase:*

- Setb=1.

Let $r_{1,k} = h_k^H h_k$,$\forall k$. Find the best user a1, according to its channel gain a1 such that

$$a_1 = arg \max_{k \in \mathcal{R}} r_{1,k} \qquad (7)$$

Then BS knows its first selected user, and the set of selected users will be $\mathcal{A}_1 = \{a_1\}$

2. *Sum rate calculation phase:*

- Forb=2 to Nt repeat:

– The objective is to find users who are orthogonal to the selected ones. Therefore, we project each remaining channel vector onto the orthogonal complement of the subspace spanned by the channels of the selected users.

The projector matrix is obtained by

$$\mathrm{P}_\mathrm{b}^\perp = \mathrm{I}_{\mathrm{N_t}} - \mathrm{H}(\mathcal{A}_{\mathrm{b-1}})^{\mathrm{H}}[\mathrm{H}(\mathcal{A}_{\mathrm{b-1}})\mathrm{H}(\mathcal{A}_{\mathrm{b-1}})^{\mathrm{H}}]^{-1}\mathrm{H}(\mathcal{A}_{\mathrm{b-1}}) \qquad (8)$$

where I_{N_t} , is the $N_t \times N_t$ identity matrix, and $H(\mathcal{A}_{b-1})$ denotes the matrix consisting of the channel vectors of the users selected in the first b-1 steps as $\mathrm{H}(\mathcal{A}_{\mathrm{b-1}}) = [\mathrm{h}_{\mathrm{a}_1} \cdots \mathrm{h}_{\mathrm{a}_{\mathrm{b-1}}}]^{\mathrm{H}}$.

– From all the orthogonal users, we select the user who maximizes the sum rate (according to the projection properties) as

$$r_{b,k} = h_k^H \mathrm{P}_\mathrm{b}^\perp h_k \qquad (9)$$

– Find user a_b such that

$$a_b = arg \max_{k \in \mathcal{R} \setminus \mathcal{A}_{\mathrm{b-1}}} r_{b,k} \qquad (10)$$

Set $\mathcal{A}_b = \mathcal{A}_{\mathrm{b-1}} \cup \{a_b\}$.

3. *Beamforming:*

Apply the ZF transmit beamforming as previously described by using the selected user set

B. *PU2RC*

Having collected quantized CSI from all U users, the base station schedules Nt users for transmission and computes their beamforming vectors. To maximize the throughput, Nt scheduled users must be selected through an exhaustive search, which is infeasible for a large user pool [5]. Therefore, we adopt a simpler joint scheduling and beamforming algorithm. This algorithm schedules a subset of users with orthogonal quantized channel shapes, and furthermore applies these channel shapes as the scheduled users' beamforming vectors. It is elaborated as follows. First, each member of the codebook F, which is a potential beamforming vector, is assigned a user with the maximum SINR. Consider an arbitrary vector, for instance $v_n^{(m)}$, which is the th member of the m^th^ orthonormal subset $V^{(m)}$of the codebook F. This vector can be the quantized channel shapes of multiple users, whose indices are grouped in a set defined as $I_n^{(m)} = \left\{1 \le u \le U{:}\, \hat{s}_u = v_n^{(m)}\right\}$

where $\hat{s}_u$ is the uth user's quantized channel shape. $I_n^{(m)}$can be equivalently defined as:

$$I_n^{(m)} = \left\{1 \le u \le U | d(s_u, v_n^{(m)}) < d(s_u, v) \forall\, v \in F \; and \; v \neq \right\} v_n^{(m)}$$

Among the users in $I_n^{(m)}, v_n^{(m)}$ is associated with the one providing the maximum SINR, which is feasible since the SNRs are known to the base station through feedback. The index $i_n^{(m)}$ and SINR $\xi_n^{(m)}$ of this user associated with $v_n^{(m)}$(m) can be written as

$$i_n^{(m)} = arg \max_{u \in I_n^{(m)}} SINR_u \; and \; \xi_n^{(m)} = \max_{u \in I_n^{(m)}} SINR_u \qquad (11)$$

In the event that the vector $I_n^{(m)} = \emptyset$ the vector $v_n^{(m)}$ is associated with no user and the maximum SINR $\xi_n^{(m)}$ is set as zero.

Second, the orthonormal subset of the codebook that maximizes throughput is chosen, whose index is $m^* = arg\, \max_{1 \le m \le M} \sum_{n=1}^{Nt} \log(1 + \xi_n^{(m)})$. Thereby, the users associated with this chosen subset, specified by the indices $i_n^{(m^*)} | 1 \le n \le N_t$, are scheduled for simultaneous transmission using beamforming vectors from the (m*)th orthonormal subset.

V. SIMULATIONS RESULTS

In Figure 1, the sum rates of ZF and PU2RC (with randomly generated codebooks) are compared for various values of

Tfb; for each strategy, B has been optimized separately. It is seen that ZF maintains a significant advantage over PU2RC for Nt = 4. At small value of Tfb, both schemes perform similarly, but ZF maintains an advantage compared to PU2RC. Intuitively, difference with perfect CSIT case in term of sum rates is understandable if we consider the impact of the multiuser interference penalty term and the non-optimality of these algorithms in the other hand.

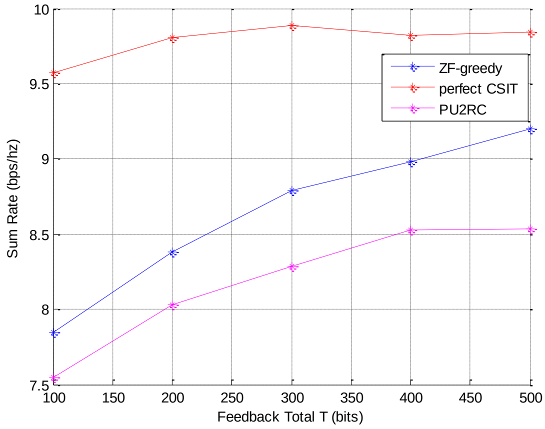

Fig1. Comparison between Greedy end PU2RC with perfect case

Figure 2 compares the throughput of PU2RC and ZF for an increasing SNR. The number of transmit antennas is Nt = 4 and the codebook size is N = 64. As observed from this figure for the number of users U = 20, PU2RC achieves lower throughput than ZF over the range of SNR under consideration (0 ≤ SNR ≤ 20 dB). Nevertheless, for larger numbers of users (U = 40 or 80), PU2RC outperforms ZF for a subset of the SNRs. Specifically, the throughput versus SNR curves for PU2RC and ZF crosses at SNR=7 dB for U = 40 and at SNR=18 dB for U = 80. The above results suggest that in the practical range of SNR, PU2RC is preferred to ZF only if the user pool is sufficiently large.

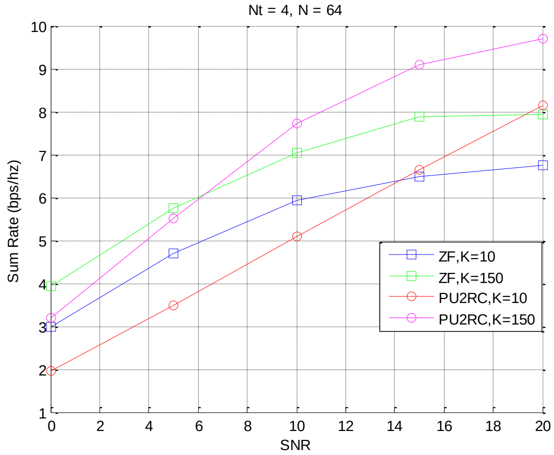

Fig. 2. PU2RC and ZF

VI. CONCLUSION

This paper presents asymptotic throughput scaling laws for downlink transmission with orthogonal beamforming known as PU2RC. In the normal SNR or noise-limited regimes, the throughput of PU2RC is found to scale double logarithmically with the number of users and linearly with the number of antennas at the base station. Numerical results showed that PU2RC can achieve significant gains in throughput with respect to Zero Forcing method for the same amount of CSI feedback. This paper focuses on the scheduling criterion of maximizing throughput. The design and performance analysis of PU2RC based on the criterion of proportional fairness is a topic under investigation. As perspective, we can consider other scheduling algorithms and compare their performance with PU2RC and ZF algorithms.

REFERENCES

[1] Hojae Lee, Sanghoon Lee “Joint precoding selection diversity with limited feedback “ Digital Signal Processing, Volume 30, July 2014, Pages 141-153

[2] Wang Li, Yang Ke, Hu Han-ying and Cui Wei-jia “Robust joint linear transceiver design for MU-MIMO with imperfect CSI,” Proc. GMC, pp. 1-6, Oct. 2010.

[3] C. Siriteanu, S. D. Blostein, A. Takemura, H. Shin, S. Yousefi, and S. Kuriki, “Exact MIMO zero-forcing detection analysis for transmitcorrelated Rician fading,” IEEE Transactions on Wireless Communications, vol. 13, no. 3, pp. 1514–1527, March 2014

[4] G. Dimic and N. D. Sidiropoulos, “On downlink beamforming with greedy user selection: performance analysis and a simple new algorithm,” *IEEE Trans. on Signal Processing*, vol. 53, pp. 3857–68, Oct. 2005.

[5] P.drayi K. Nagaraju“Modelling, Simulation of Multi-User Diversity with Channel State Information in MIMO Systems” IRACST – International Journal of Computer Networks and Wireless Communications (IJCNWC), ISSN: 2250-3501Vol.4, No5, October 2014

[6] Yan Yang, Hui Yue « Efficient beamforming method for downlink MU-MIMO broadcast channels » International Journal of Electronics and Communications, Volume 69, Issue 3, March 2015, Pages 636-643

[7] M. Jung, Y. Kim, J. Lee, and S. Choi, “Optimal number of users in zeroforcing based multiuser MIMO systems with large number of antennas,” Journal of Communications and Networks, vol. 15, no. 4, pp. 362–369, 2013

[8] Z. Shen, R. Chen, J. G. Andrews, R. W. Heath Jr., and B. L. Evans, “Low complexity user selection algorithms for multiuserMIMO systems with block diagonalization,” IEEE Trans. on Signal Processing, vol. 54, pp. 3658–63, Sept. 2006.

[9] W. Santipach, M.L. Honig “Optimization of Training and Feedback Overhead for Beamforming over Block Fading Channels” IEEE Trans. Info. Theory, August 2009

[10] G. Caire, N. Jindal, M. Kobayashi, and N. Ravindran, Multiuser MIMO Achievable Rates with Downlink Training and Channel State Feedback, IEEE Trans. Information Theory, Vol. 56, No. 6, pp. 2845-2866, June 2010