INTERNATIONAL RESEARCH JOURNAL OF ENGINEERING AND TECHNOLOGY (IRJET) E-ISSN: 2395 -0056
VOLUME: 03 ISSUE: 06 | JUNE-2016 WWW.IRJET.NET P-ISSN: 2395-0072

Performance Enhancement of Multi-cell Multiuser MIMO

Rahul N Solanki[1], Vinay Soni[2], Kuldeep B Tandel[3]

[123]PG Student, ME, Wireless Communication ,S & SS Gandhy college, Surat, Gujarat, India

***Abstract*—Multiple-input Multiple-output (MIMO) system uses multiple transmit and receive antennas to utilize spatial diversity in the channel, this enables the transmitted data to use the same time and frequency slots. In Multiuser MIMO system inter-user interference degrade the performance of the system. Solutions to this can be found using Precoding techniques. I analyze precoding techniques for the downlink of multiuser MIMO system. Simulation results shows the BER performance of the different linear precoding schemes.**

***Index Terms*—MU-MIMO; Multiuser Interference; Precoding; SDMA.**

I. INTRODUCTION

Multiple-input multiple-output (MIMO) antenna systems can greatly improve the spectral efficiency in wireless communication systems. In a multiple-input multiple-output (MIMO) system, space division multiple access (SDMA) can be applied at the base-station (BS) to concurrently multiplex data streams for multiple mobile-stations (MS). Information theory reveals that under certain conditions, there is a linear relationship between the channel capacity and the number of antennas of MIMO systems. Such systems have received a lot of attention in the context of emerging cellular systems, such as the 3GPP long term evolution (LTE). With appropriate downlink. precoding techniques at the BS, SDMA can significantly improve the system spectral efficiency. The research on downlink precoding for a multiple-input multiple-output (MIMO) system has been an active area for many years. if there is full CSI at the transmitter (CSIT) and at the receiver (CSIR), the optimum transmit scheme for the MU-MIMO broadcast channel involves a theoretical pre-interference cancellation technique known as dirty paper coding (DPC) [1]. DPC has been proved to be the capacity achieving multi-user precoding strategy. However, due to its high complexity implementation that involves random nonlinear encoding and decoding, DPC only remains as a theoretical benchmark.

In MU-MIMO systems, CSIT allows for multi-user spatial multiplexing and thus increases the system throughput. It can be achieved by exploiting channel reciprocity in a time division duplex (TDD) system. But in a frequency division duplex (FDD) system, different carrier frequencies are used for uplink and downlink. Perfect CSIT is almost impossible to achieve. However, it is possible to obtain partial CSIT by means of a limited feedback channel. There are two different ways to feed back the necessary information to build the precoding matrix. The one is based on an extension of the limited feedback single-user MIMO (SU-MIMO) scheme to a MU system, as proposed in [2]. Users determine their preferred precoding vectors based on a codebook index with the quality of the chosen precoding vector. The base station (BS) just need to find the high quality users which have chosen different vectors of the same precoding matrix, and schedule them for transmission. The other is based on channel vector quantization (CVQ) using a finite channel codebook as proposed in [3]. Each user quantizes its channel based on the codebook and feeds back the corresponding index with an approximative signal to interference and noise ratio (SINR) value. Finally, the BS uses the available SINR values to schedule the users by maximizing the sum rate or any other criteria, and uses the quantized channel information to derivate the precoding matrix based on its precoding scheme.

In this paper, I describe the MU-MIMO system model firstly. Then I analyzed linear precoding schemes such as zero forcing (ZF), regularized channel inversion (also called MMSE), block diagonalization (BD) and signal to leakage noise ratio (SLNR) and measure the BER performance of each technique and compare them.

II. MU-MIMO SYSTEM MODEL

First, I describe a system model of the MU-MIMO downlink channel. The BS employs M transmit antennas and communicates with K users simultaneously. User k, (k = 1,…,K), has N_k receive antennas. The channel model from the BS to the k-th user is represented by a $N_k \times M$ channel matrix H_k.

Let $s_k \in N_k \times 1$ denote the k-th user transmit symbol vector. The user k employs a linear transmit precoding matrix $W_k \in M \times N_k$, which transforms the data vector s_k to the $M \times 1$ transmitted vector $W_k \times s_k$. The received signal vector of the k-th user is given by

$$y_k = H_k W_k s_k + H_k \sum_{i \neq k} W_i s_i + n_k \qquad (1)$$

Where, $n_k = [\, n_{k,1}, \ldots, n_{k,N_k}]^T$ denotes the noise vector for the k-th user. The components $n_{k,i}$ of the noise vector n_k are i.i.d. with zero mean and variance σ^2 for k = 1,..,K and i=1,..,Nk . Note that both the desired signal $H_k W_k s_k$ and the interference $H_k \sum_{i \neq k} W_i s_i$ are received by the user *k*.

Defining the network channel as:

$$H = \left[H_1^T \cdots H_K^T \right]^T \qquad (2)$$

The corresponding signals at all the users can be arranged as

$$y = H\,W\,s + n \qquad (3)$$

Where,

$y = \left[y_1^T \cdots y_K^T \right]^T$,

$W = \left[W_1^T \cdots W_K^T \right]^T$,

$s = \left[s_1^T \cdots s_K^T \right]^T$ *and* ,

$n = \left[n_1^T \cdots n_K^T \right]^T$.

The purpose of the linear precoder is to design the precoding matrix **W** based on the channel knowledge, so that the performance of the MU-MIMO system can be improved.

III. LINEAR PRECODING TECHNIQUES

The different inear precoding schemes of MU-MIMO downlink channel will be introduced in this section. Matlab simulation will be done to compare the BER performance of the different precoding techniques.

A. *Zero Forcing*

The Zero Forcing algorithm is the simplest precoding technique studied and as such has the lowest computational complexity. Here, the multiuser interference is driven to zero. This is achieved by projecting each data stream onto the orthogonal space of the co-channel interference. The precoding matrix is simply an inversion of the channel matrix. This inverted channel matrix can then serve as a weighting for the transmitting signal vector.

Mathematically, the precoding matrix, W, is given by the Moore-Penrose pseudoinverse of H.

$$W = H^{\dagger} = H^H (H\,H^H)^{-1} \qquad (4)$$

Where, H is the channel between the Base Station and the Mobile Users and ( )^H is the Hermitian operator. H is a (K×M) matrix with complex Gaussian distributed entries. The Hermitian operator is equivalent to the conjugate transpose of the matrix. The conjugate transpose is used to preserve signal power as the channel matrix values are complex. Furthermore, the transpose also ensures the precoding matrix is of correct dimensions (M × K). Therefore, when the inverse of the channel matrix $H^H (H\,H^H)^{-1}$ is multiplied by the channel (H.W), an identity matrix, I is formed.

$$A.A^{-1} = I \qquad (5)$$

The identity matrix has the same dimensions as the channel matrix (K × M). Therefore, when the symbols (dimensions K×1) are multiplied by the identity matrix, the symbols are returned exactly the same.

Other factors which limit the viability of Zero Forcing methods is that complete knowledge of the channel (full CSI) is required at the transmitter. Otherwise the algorithm performs sub-optimally[6]. Moreover, the complete nulling of the co-channel interference at the base station imposes the constraint that the number of transmit antennas must be greater than or equal to the sum of all receive antennas (M ≥K). This condition is necessary in order to provide sufficient Degrees Of Freedom for the Zero Forcing solution to force the CCI to zero at each user.

In summary, the major disadvantage of Zero Forcing is that it neglects the effect of AWGN in the channel. Thus, theoretically, it will operate ineffectively under noise-limited scenarios (low SNR).

Assuming equal power allocation over the users and user codes drawn from an i.i.d. Gaussian distribution, the achievable sum rate is given by

$$R_{ZF} = \sum_{k=1}^{K} \log_2 \left(1 + \frac{P}{K\sigma^2} \left| h_k w_k \right|^2 \right) \qquad (6)$$

B. *Block Diagonalisation*

The Block Diagonalisation method is an improvement on the Zero Forcing method by increasing the spatial diversity of each transmission. The symbols to be transmitted are combined and sent from all transmitters. The Block Diagonalization process at the receiver then decodes the received signal to cancel unwanted symbols and other interference at the receiver.

Under the BD scheme, the system can be equivalently regarded as a single-user MIMO environment. The system channel matrix $\tilde{H}_k$ as:

$$\tilde{H}_k = \left[H_1^T \cdots H_{k-1}^T H_{k+1}^T \cdots H_K^T \right]^T \qquad (7)$$

Let the singular value decomposition (SVD) of $\tilde{H}_k$ be:

$$\tilde{H}_k = \tilde{U}_k \tilde{D}_k \left[\tilde{V}_k^{(1)}\, \tilde{V}_k^{(0)} \right]^T \qquad (8)$$

Where $\tilde{U}_k$ and $\tilde{D}_k$ are the left singular vector matrix and the matrix of singular values of $\tilde{H}_k$, respectively, and $\tilde{V}_k^{(1)}$ and $\tilde{V}_k^{(0)}$ denote the right singular matrices each corresponding to non-zero singular values and zero singular values. Thus, the last $\left(\text{M-}\operatorname{rank}\left(\tilde{H}_k\right)\right)$ right singular vectors forms an $\tilde{V}_k^{(0)}$ orthogonal basis for the null space of $\tilde{H}_k$. Any precoder $\mathbf{W}_k$ which is a linear combination of the columns of $\tilde{V}_k^{(0)}$ will lie in the null space of $\tilde{H}_k$.

When using the BD scheme under ideal conditions, the system can be equivalently regarded as a single-user MIMO environment so that each user would experience no multiuser interference. But the computational complexity of BD scheme is slightly higher. Because the users need to know the equivalent channel to achieve detection, the BS needs to insert specific pilot frequently and it will reduce the effective information transmission rate in practice[10]. The sum rate of BD with equal power allocation is given by

$$R_{BD} = \sum_{k=1}^{K} \log_2 \left| \mathrm{I} + \frac{P}{K} \mathrm{H}_k \mathrm{W}_k \mathrm{W}_k^H \mathrm{H}_k^H \right| \qquad (9)$$

C. Minimum Mean Square Error

The Minimum Mean Square Error (MMSE) algorithm operates similarly to the Zero Forcing technique by using a channel inversion. However, the MMSE method takes the AWGN into account and aims to minimise the mean-square error between the estimate and the transmitted signal. Remember the Zero Forcing method does not take this AWGN in the channel into account.

$$W = H^H \left(H.H^H + \frac{\sigma}{ea}.I \right)^{-1} \qquad (8)$$

The $\frac{\sigma}{ea}.I$ term accounts for the AWGN in the channel as a function of power. In the above equation, ea denotes the power (in Watts) of one transmitter and σ denotes the variance of the AWGN. It is equivalent to the combined power of all the transmitters divided by the signal to noise ratio of the channel.

The algorithm also uses spatial diversity to improve reliability like Block Diagonalisation. Therefore, theoretically, MMSE should outperform both Zero Forcing and Block Diagonalisation as it uses diversity and accounts for the AWGN in the channel[10].

The achievable sum rate is given by

$$R_{MMSE} = \sum_{k=1}^{K} \log_2 \left(1 + \frac{\left| h_k w_k \right|^2}{\sum_{j \neq k} \left| h_k w_j \right|^2 + \frac{K\sigma^2}{P}} \right) \qquad (9)$$

where w_k is the normalized k-th column of the precoder.

D. Signal to Leakage Noise Ratio

The Signal to Leakage Noise Ratio algorithm uses an alternative approach to the other three algorithms studied. Here, a new concept of signal leakage is considered. Leakage refers to the interference caused by the signal intended for a desired user that is '*leaked'* onto undesired users. This is an inefficient waste of power as the leaked power just acts as interference upon undesired receivers. The aim of the algorithm is to minimise this leaked power as close to zero as possible. Therefore, instead of trying to perfectly cancel out the interference at each user (like for example Zero Forcing), SLNR precoding chooses beamforming coefficients to maximise the Signal to Leakage Noise Ratio (SLNR) for all users simultaneously. Compared with other schemes, signal to leakage ratio (SLNR) scheme is an alternative approach, based on maximizing the signal to leakage ratio for designing transmit beamforming vectors in a multi-user system without eliminating the multi-user interference [10].

The SLR expression can be written as:

$$SLNR = \frac{W_k^H H_k^H H_k W_k}{W_k^H \tilde{H}_k^H \tilde{H}_k W_k} \qquad (9)$$

Then the precoding matrices are:

$$W_k^{\circ} \alpha \max \textit{generalized eigenvector} \left(H_k^H H_k \tilde{H}_k^H \tilde{H}_k \right)$$

This scheme can maximize the SLR at each user and it does not impose a restriction on the system configuration in terms of the number of antennas. But it is different from other schemes which can serve multiple-streams for each user simultaneously, the SLR scheme can only serve singlestream for each user at the same time without employing some improvements such as orthogonal space-time coding.

IV. SIMULATION RESULT

In this section, the MU-MIMO system introduced in the previous sections is investigated by computer simulation. In the simulation, quadrature-phase-shift keying (QPSK) is utilized. The flat fading MIMO channel, whose elements are i.i.d. zero mean complex Gaussian random variables with variance one, is fixed for 100 symbols and more than 10 000 independent channels are used to obtain each bit-error-rate simulation. Throughout this section, I consider a K-user system with M transmit antennas at the BS and N

receive antennas at each MS ($N_1=N_2=\cdots=N_K=N$), and I will refer to it as a ($M,[N_1,N_2,..,N_K]$) system. In order to satisfy the sufficient condition for the existence of a nonzero precoding
matrix solution, I assume $M > (K-1)N$. Also, I assume that the number of data streams is equal to L for each user ($L_1=L_2=\cdots=L_K=L$). I denote a single-user system with transmit antennas at the BS and receive antennas at each MS as a (M,N) system.

Fig.1 shows the BER performance of the MU-MIMO with different precoding schemes. Fig.2 shows the sum capacity of the MU-MIMO with different precoding schemes

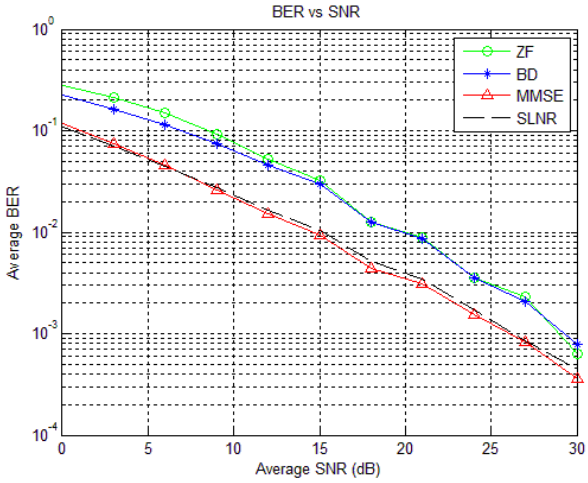

Fig. 1. Comparison of BER performance of precoding techniques.

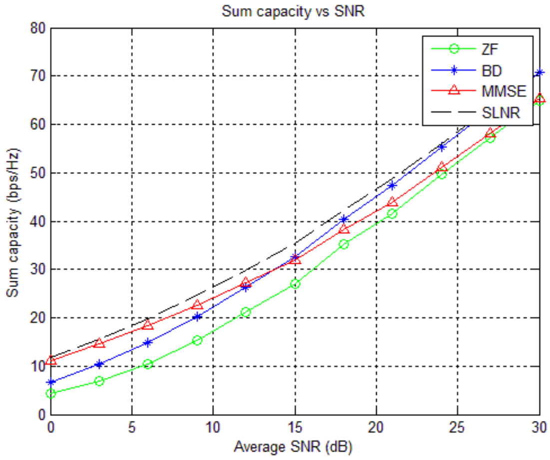

Fig. 2. Comparison of sumcapacity of MU- MIMO with differenct precoding schemes Conclusion

In this paper, five different MU-MIMO linear precoding schemes are analyzed. The ZF and MMSE schemes have been widely concerned for their high performance. The BD and SLNR schemes are high performance but high computational complexity too. And the SLNR scheme can only serve single-stream for each user simultaneously, although it does not impose a restriction on the system configuration in terms of the number of antennas. There are two important criteria need to be considered when using and designing MU-MIMO systems. Spatial separation of users has a very strong impact on the performance of linear precoding schemes In particular, the performance of the ZF precoder drops significantly when the users are close together. Therefore it is necessary to design proper scheduling algorithms that select users with different spatial signatures.

ACKNOWLEDGMENT

I have taken efforts in this work .However it would not have been possible without the kind support and help of many individual. I would like to extend my sincere thanks to all of them. I am highly indebted to Prof. K.G.Bhuva for her enlightening guidance, enthusiasm and constant supervision. I really appreciate her effort to review my report, give insightful comments and discuss with me when I am confused.

REFERENCES

[1] Caire, G.; Shamai, S., "On the achievable throughput of a multiantenna Gaussian broadcast channel," in *Information Theory, IEEE Transactions on* , vol.49, no.7, pp.1691-1706, July 2003.

[2] Lai-U Choi; Murch, R.D., "A transmit preprocessing technique for multiuser MIMO systems using a decomposition approach," in *Wireless Communications, IEEE Transactions on* , vol.3, no.1, pp.20-24, Jan. 2004.

[3] Philips, "Comparison between MU-MIMO codebook-based channel reporting techniques for LTE downlink", Oct. 2006, 3GPP TSG-RAN WG1 #46 R1-062483.

[4] Peng Cheng; Meixia Tao; Wenjun Zhang, "A New SLNR-Based Linear Precoding for Downlink Multi-User Multi-Stream MIMO Systems," in Communications Letters, IEEE , vol.14, no.11, pp.1008-1010, November 2010.

[5] Kaviani, S.; Simeone, O.; Krzymien, W.A.; Shamai, S., "Linear MMSE Precoding and Equalization for Network MIMO with Partial Cooperation," in Global Telecommunications Conference (GLOBECOM 2011), 2011 IEEE , vol., no., pp.1-6, 5-9 Dec. 2011.

[6] Wiesel, A.; Eldar, Y.C.; Shamai, S., "Zero-Forcing Precoding and Generalized Inverses," in Signal Processing, IEEE Transactions on , vol.56, no.9, pp.4409-4418, Sept. 2008.

[7] Shim, S.; Jin Sam Kwak; Heath, R.W.; Andrews, J.G., "Block diagonalization for multi-user MIMO with other-cell

interference," in Wireless Communications, IEEE Transactions on , vol.7, no.7, pp.2671-2681, July 2008.

[8] Yuyuan Chang; Araki, K., "Robust design for multiuser block diagonalization MIMO downlink system with CSI feedback delay," in *Personal, Indoor and Mobile Radio Communications, 2009 IEEE 20th International Symposium on* , vol., no., pp.3089-3093, 13-16 Sept. 2009.

[9] Karaa, H.; Adve, R.S.; Tenenbaum, A.J., "Linear Precoding for Multiuser MIMO-OFDM Systems," in *Communications, 2007. ICC '07. IEEE International Conference on* , vol., no., pp.2797-2802, 24-28 June 2007.

[10] Karaa, H.; Adve, R.S.; Tenenbaum, A.J., "Linear Precoding for Multiuser MIMO-OFDM Systems," in *Communications, 2007. ICC '07. IEEE International Conference on* , vol., no., pp.2797-2802, 24-28 June 2007.

BIOGRAPHIES

Rahul Solanki,Student at S& SS Gandhy College Surat , Pursing ME in Wireless communication Signal And Fading.