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QRD Based Precoder Design for Coordinated Multipoint Downlink Transmission

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Abstract- *This paper the performance of two precoding methods for Co-ordinated Multipoint (CoMP) Downlink transmission systems, Singular value decomposition and the QR decomposition is being studied and finally compared. In this we propose to study the performance of the two precoding scheme using Rayleigh fading channel. The Bit Error Rate (BER) performance of CoMP system is studied through different algorithms for improvement of system performance. The improvement of BER performance is based on SVD and QRD algorithm. Basically these precoding schemes are adopted from the multiple input multipoint output (MIMO).Computer simulations show that, in the case for different MIMO like 2x2, 4x4, 8x8 QRD performs better than SVD but at the cost of computational complexity. MATLAB simulations are used to evaluate the performance of the studied precoders in terms of QRD and SVD for CoMP Downlink systems with MIMO.*

Keywords *-Co-ordinated Multipoint, SVD, QRD*

I. INTRODUCTION

Multiple-input-multiple-output (MIMO) technology has attracted extensive attention due to its capability of offering significant increase in data throughput and improved link reliability without incurring extra bandwidth or transmission Power [1].It has been recognized as one of the most significant technical breakthroughs in modern communications. MIMO technology has been adopted in a wide range of wireless communication standards such as IEEE 802.11n, the 3rd Generation Partnership Project (3GPP) Long Term Evolution (LTE) and Worldwide Interoperability for Microwave Access (WiMAX) [3]. In cellular system, geographically separated users may experience different communication quality caused by a variety of factors such as propagation pathloss, log-normal shadowing, multipath fading and other cell interference (OCI).Specifically, in comparison with cell-center users, cell-edge users tend to have lower received signal strength and are more vulnerable to OCI. In conventional cellular system as illustrated in Fig. 1, each user equipment (UE) receives useful signal from its serving base station (BS) as well as interference from the neighbouring BS. Therefore, the downlink capacity of the conventional cellular system is limited by inter-cell interference (ICI). By Contrast, as a distributed MIMO technology, coordinated multipoint (CoMP) joint processing scheme is capable of mitigating ICI through coordination ofmultiple BSs [3].Hence the spectral efficiency (SE) can be improved and, in particular, the experience of the cell-edge users can be enhanced.

Downlink CoMP transmission schemes are mainly categorized into two types: joint processing (JP) and coordinated Scheduling/beamforming (CS/CB)

To elaborate further, JP-CoMP can be divided into two classes, namely coherent JP-CoMP (CJP CoMP) and non-coherent JP-CoMP (NCJP-CoMP). In Joint-processing transmission schemes, data to a single UE is simultaneously transmitted from multiple transmission points in the coordination area in such a way that signal can be coherently or non-coherently added to the UE to improve the received signal quality actively interference from transmissions intended for other UEs[1]. CJP-CoMP is capable of achieving improved performance in terms of system average and cell-edge SE at the cost of higher backhaul capability and increased signal overhead, which is induced by huge CSI exchange among the cooperation BSs.By contrast, NCJP-CoMP incurs less constraints on backhaul due to no requirement of cell-to-cell CSI exchange in the CoMP cluster. Specifically, procoder design algorithms based on Singular Value Decomposition (SVD) QR decomposition (QRD) are developed in order to improve the cell-edge performance.

The rest of the paper is organized as follows: Section II provides an introduction to the system model and non-CoMP precoder design algorithm for NCJP-CoMP. In Section III, we discuss an existing precoding algorithm based on QRD and our proposed precoding algorithm based on PD for NCJP-CoMP. Section IV presents the system level simulation assumptions and results. Finally, a conclusion is given in Section V.

Notation: $(.)^*, (.)^T, (.)^H$ denote conjugate, transpose and Hermitian transpose operations, respectively $|\cdot|$and $||\cdot||$ represent the absolute value and norm of a vector or matrix

II.SYSTEM MODEL

We consider a downlink cellular system containing multiple sites with 3 sectors per site. The sectors of a site are created by employment of directional antennas associated with the antenna gain as

$$A(\theta)_{db} = -\min\left[12\left(\frac{\theta}{\theta_{3\,db}}\right), A_m\right]$$

Where,$\theta\epsilon[-180°, 180°]$ is the direction of the UE with respect to the broadside direction of the BS, $\theta_{3\,db}$, is the 3 dB beam width indicating the angle where the antenna gain is 3 dB lower than the broadside direction, while Am=20dB represents the maximum attenuation for the side lobe lower than the broadside direction, while Am=20dB represents the maximum attenuation for the side lobe.The NCJP-CoMP system model is depicted in Fig 2, where a UE is located in the cell edge of its serving cell. Without loss of generality, the size of the cluster is assumed to take a value of two. Note that in practice only a small number of adjacent BSs are preferred to perform CoMP transmission, since the relative aim of increasing the cluster size tend to diminish due to weak signals received from long-distance coop1ration BSs. The CoMP setup mechanism is as follows.

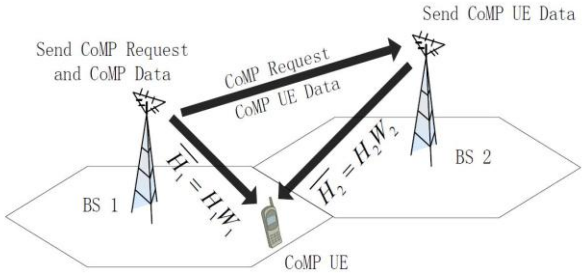

Fig 1.NCJP-CoMP System Model

Firstly, the UE measures the serving channel from BS 1 and the interference channel from BS 2. Based on the measurement, if the UE could make a judgement that the CoMP transmission would bring more gains (in terms of, for example, SINR or throughput) to itself and the overall system, it will then trigger a CoMP request to the serving BS 1. When the serving BS 1 decides to perform CoMP transmission to the UE, it will send a CoMP request to BS 2. Once the BS 2 decides to cooperate, the CoMP cluster is setup and the both BSs will jointly transmit data to the UE, whichisnowreferredtoasCoMPUE.Notethatthe CoMP setup requires communications among cooperation BSs within the cluster via X2 interface [13] supported by radio over air or optical fiber, which is beyond the scope of this contribution. In the following discussion.We assume that each BS is equipped with M transceiver antennas, while the UE is equipped with N transceiver antennas. We assume that the transmitter precoding matrix at BS i (i =1, 2) is denoted asW_i, which is a M × k dimensional matrix with k being the transmit rank for the CoMP UE. Furthermore,each BS decides it's transmit precoding matrix independently and there is no CSI exchange between the CoMP BSs in the NCJP-CoMP scenario.

Let $\boldsymbol{s}$ be a $k \times 1$ data vector to be transmitted to the UE, where $\boldsymbol{s}$ is assumed to obey$E[ss^H] = I$. Under the cluster size L and equal power allocation among the BSs, the signals received at the CoMP UE can be expressed as

$$r = \rho_0 \sum_{i=1}^{L} H_i W_i s + z + n$$

$$=\rho_0 \bar{H} s + z + n$$

Where $H_i(i = 1 \ldots\ldots L)$ is a $N \times M$ channel matrix in association with BS $i(i = 1 \ldots\ldots L)$,$\rho_0 = \frac{P_0}{k}$with P_0 being the total transmission power at each BS, z accounts for the intra- and inter-cluster interference, $n = [n_1 \ldots\ldots n_N]^T$ represents an additivecomplex-valued white Gaussian noise vector with identity covariance matrix, and finally Equivalent Precoded Channel Gain is given by

$$H_I(n.m) = \alpha_i^{(n,m)} \sqrt{\beta_i A(\theta_i^m)(\frac{d_i}{d_o})^{-\gamma}}$$

Various parameters like log normal shadowingβ_i, antenna gain$A(\theta_i^m)$, pathloss exponent γ are considered for our system model as above the equation. Rayleigh fading channel as mentioned as $\alpha_i^{(n,m)}$is used for spanning channel matrix.$d_i$is the distance between BS i and the CoMP UE and d_0 is the reference distance between the cell center and the cell vertex.

III.COMP PRECODER DESIGN

A.SVD based precoder design

The optimal precoder in the non-CoMP scenario can be designed based on the singular value decomposition (SVD) [8] of the channel matrix associated with each BS.Singular value decomposition mainly used for decompose MIMO channel into single user SISO channel. Upon applying SVD algorithm to channel matrix $H_i = U_i S_i V_i^H$, precoder at BS i is obtained as

$$W_i^{svd} = V_i(:,1:k)$$

Where u and v are unitary or semi unitary matrix, S is diagonal matrix.The above-mentioned SVD-based precoder is optimal from the perspective of each individual BS. However, if W_i^{svd} is adopted in NCJP-CoMP, the EPCH matrix $\overline{H}$ can be enhanced only when the channel matrices associated with each BS are in phase, which may be invalid in practice. Therefore, appropriate precoder for the NCJP-CoMP scenario should be designed in order to improve the equivalent precoded channel gain.In this section, a precoder design for the NCJP-CoMP based on QRD is introduced.

B.QRD Based Precoder Design for NCJP-CoMP

The basic idea of QRD-based precoder is to utilize prophase-adjustment based on QR decomposition in order for the CoMP user to achieve enhanced equivalent precoded channel $\overline{H}$.QR Decomposition of H_i is given as

$$\mathrm{H_i} = \mathrm{R_i Q_i^H}$$

Where, Q_i unitary or semi-unitary matrix and R_i which is lower triangular matrix. R_i is given as follows

$$R_i = \begin{bmatrix} r^i_{(1,1)} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ r^i_{(N,1)} & \cdots & r^i_{(N,N)} \end{bmatrix}$$

Prephase adjustment of R_i is applied by diagonal matrix F_i , which is given by,

$$F_i = \begin{bmatrix} \frac{(r^i_{(1,1)})^*}{|r^i_{(1,1)}|} & 0 \cdots & 0 \\ 0 & \frac{(r^i_{(2,2)})^*}{|r^i_{(2,2)}|} \ddots & \vdots \\ 0 & \cdots & \frac{(r^i_{(k,k)})^*}{|r^i_{(k,k)}|} \end{bmatrix}$$

Then QRD based precoder is defined and is given by,

$$w_i^{qrd} = Q_i(:,1:k)F_i$$

Consequently, the equivalent precoded channel matrix for the CoMP UE can be obtained as

$$\overline{\mathrm{H}} = \begin{bmatrix} \sum_{i=1}^{2} |r_{1,1}^{(i)}| & \cdots & 0 \\ \vdots & \ddots & \vdots \\ \sum_{i=1}^{2} r_{N,1}^{(i)} \frac{(r_{1,1}^{(i)})^*}{|r_{1,1}^{(i)}|} & \cdots & \sum_{i=1}^{2} r_{N,k}^{i} \frac{(r_{k,k}^{i})^*}{|r_{k,k}^{(i)}|} \end{bmatrix}$$

It can be seen from above that the effective channel gain with respect to each receive antenna is enhanced upon employing phase adjustment. Specifically, when a successive interference cancellation receiveris implemented at the CoMP UE, the effective channel gain corresponding to thenth receive antenna can be expressed as

$$g_n = \sum_{i=1}^{L} |r_i^{(n,n)}|$$

IV. SIMULATION RESULTS

In this section, we provide a range of simulation results to evaluate the performance of SVD, QRD and PD based NCJP-CoMP. Figs. 2, 3 and 4 exploit the BER vs SNR analysis based on SVD and QRD algorithm for NCJP-CoMP over flat Rayleigh fading channels. The transmit power is assumed to be 0 dB, while the number of receive antennas and transmit antenna pair (2, 2), (4, 4), (8, 8) for Figs. 2, 3 and 4, respectively.For BER vs SNR analysis in CoMP system, we have taken n=10000 no of symbols and transmitted through Rayleigh fading channel for no. of BS=2, for users 5 for one bs-1 and 10 for bs-2.Rayleigh fading channel is generated for the number of symbols with the BPSK modulation scheme.SVD and QRD algorithm are applied to channel matrix, then the decomposition of channel is obtained in the form of precoded matrix, unitary matrix and diagonal matrix. Obtained precoded matrix is multiply with the Channel matrix and randomly generated data is transmitted through it.Additive Gaussian noise is added to the transmitted signal. To measure BER, No of change of bits at the receiver side after precoding were calculated for different level of SNR value it can be shown

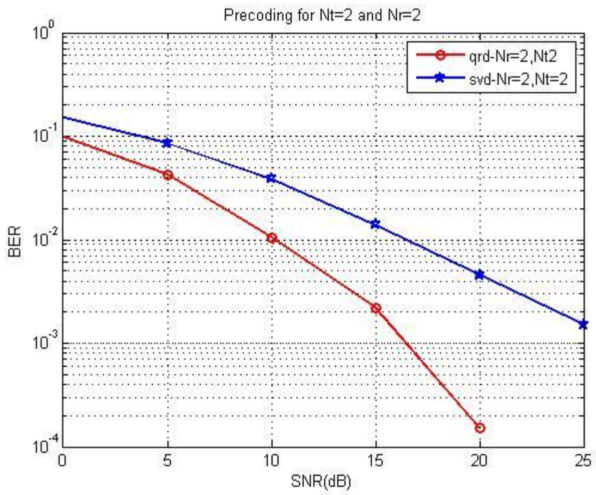

Fig 2.BER Performance for Nt=2, Nr=2

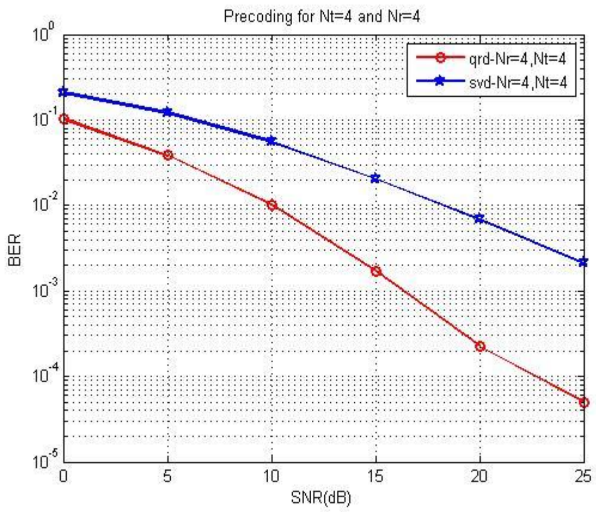

Fig 3.BER Performance for Nt=4, Nr=4

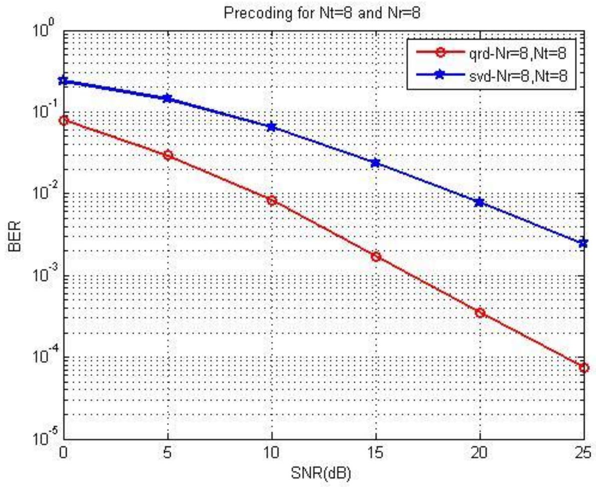

Fig 4.BER Performance for Nt=8, Nr=8

Table I Simulation parameter

Number of antennas (Tx,Rx)	(2,2),(4,4),(8,8)
Modulation technique	BPSK
Pathloss exponent γ	3.5
Lognormal shadowing	8 db.
Maximum attenuation A_m	20 db.
Beam width θ	$[-180^{\circ}, 180^{\circ}]$

V. CONCLUSION

In this paper, we proposed a precoder design based on SVD and QRD for the NCJP-CoMP. We first provided simulation results in terms of the BER for comparison of SVD and QRD based precoder algorithms. Specifically, the QRD based precoder is capable of achieving higher EPCH gain so that the QRD based precoder gives decreased BER.Implementation results shows that QRD based algorithm gives the better performance than the SVD.As per the no. of antenna increases ,the BER is going to decrease for the particular SNR value provided to it.QRD and SVD are the Precoding scheme which are applied to the channel matrix formulation to decompose it in the metrical form in such way that precoder matrix is easily obtained to manage interference.

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