Beamforming in Multiuser MIMO Downlink Systems: Non-cooperative and cooperative approaches

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Abstract—**In this paper, joint transmitter and receiver beamforming algorithms are proposed for downlink in multiuser multi-input multi-output (MIMO) communication systems. The proposed beamforming algorithms are developed based on non-cooperative and cooperative utility functions. In non-cooperative approach, utility function of each user is defined based on the performance of the user without considering the impact of the user's action on the others. However in cooperative approach, in addition to the performance of the user, the impact of user's action on the other users is considered in the user's utility function. Two iterative algorithms are derived by maximizing the utility function of the user in order to estimate transmitter and receiver beamforming vectors. The performances of the proposed algorithms are evaluated by computer simulations and compared with that of the duality method-based minimum mean square error (DM-MMSE) beamforming algorithm. Simulation results show the superiority of our proposed cooperative beamforming algorithm regarding the bit error rate (BER) performance and convergence rate.**

***Index Terms*— Multiuser, MIMO systems, non-cooperative beamforming, cooperative beamforming**

I. INTRODUCTION

Purpose of each multiuser communication system is to provide appropriate quality of service (QoS) for all users. Due to sharing environment by all users in multiuser scenario, however, the QoS of each user is affected by the QoSs of other users. Multi-input multi-output (MIMO) system is a technology that improves the user's QoS by increasing the link reliability. Thus the MIMO technology becomes an attractive method in multiuser systems. However, transmitted signals by different users cause interference that is a challenging issue. Employing beamformer at transmit and receive sides is a method that is able to eliminate the interference in multiuser MIMO systems.

Different utility functions have been proposed in the literature for beamforming algorithm design in order to mitigate multiuser interference [1]-[6]. In [1] and [2], beamforming algorithm has been designed based on maximizing the SINR for MIMO CDMA systems. Mean Square error (MSE) and mutual information criteria have been used as the utility functions for transceiver design in [3] and [4], respectively.

A minimum mean square error (MMSE) criterion developed based on duality between uplink and downlink in the MIMO channel has been proposed in [5] and [6] as the utility function for joint transceiver beamforming design.

In this paper we consider joint transmitter and receiver beamforming design for downlink in multiuser MIMO systems. Two new beamforming algorithms are developed based on non-cooperative and cooperative utility functions. In the non-cooperative beamforming algorithm, the power of the received signals (desired user and other users) is considered in the utility function. In the cooperative beamforming algorithm, in addition to the power of the (desired and undesired) received signals, the power of interference signals that have impact on the other users is also considered in the utility function of each user. Bit error rate (BER) performance evaluations show that the cooperative beamforming algorithm outperforms the non-cooperative and the duality method based MMSE [6] beamforming algorithms.

The reset of this paper is organized as follows. In Section II we model a downlink multiuser MIMO system. The non-cooperative and cooperative beamforming algorithms are developed in Section III and Section IV, respectively. Computer simulation results are presented in Section V and finally we conclude the paper in Section VI.

II. SYSTEM MODEL

Consider a downlink multiuser MIMO system with K users where the base station (BS) has N transmitting antenna and each user has M receiving antennas. For each user J data streams can be transmitted where $J \leq N$. The transmitted signal vector of the mth user is $\mathbf{d}_m = [d_{m,1}, d_{m,2}, ..., d_{m,J}]^T$ such that $E[\mathbf{d}_m \mathbf{d}_m^H] = \mathbf{I}_N$ where I_N is $N \times N$ unitary matrix and $(.)^H$ represents complex conjugate operation.

For transmitting $d_{m,j}$, the normalized beamforming vector $\mathbf{f}_{T,m,j}$ is used in the BS such that $\mathbf{f}_{T,m,j}^H \mathbf{f}_{T,m,j} = 1$ and $\mathbf{F}_{T,m} = \left[\mathbf{f}_{Tm,1}, \mathbf{f}_{T,m,2}, ..., \mathbf{f}_{T,m,J}\right]$ beamforming matrix is employed to transmit the data vector $\mathbf{d}_m$ for mth user. Thus, the transmitted signal from the BS is given as

$$\mathbf{s} = \sum_{m=1}^{K} \mathbf{s}_m = \sum_{m=1}^{K} \mathbf{F}_{T,m} \mathbf{d}_m = \sum_{m=1}^{K} \sum_{j=1}^{J} \mathbf{f}_{T,m,j} d_{m,j} \tag{1}$$