Interference-Aware Decentralized Precoding for Multicell MIMO TDD Systems

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Abstract—**Multiple-input multiple-output (MIMO) precoding scheme is developed for time division duplex (TDD) systems in a multicell environment. The proposed scheme is designed to maximize the total achievable rate, and to work in the decentralized manner with only locally available channel state information (CSI) at each transmitter. We first establish and solve a decentralized optimization problem for the case of multiple-input single-output (MISO) channels. We introduce a new precoding design metric called *signal to generating interference plus noise ratio* (SGINR). Based on the SGINR metric, the MISO precoding scheme is extended to general MIMO channels. Simulation results confirm that proposed precoding scheme offers significant throughput enhancement in multicell environments.**

I. INTRODUCTION

Multiple-input multiple-output (MIMO) is widely accepted as a key technology for enabling high quality wireless access. Most of works on MIMO have focused on capacity or diversity improvement in a single cell scenario [1]-[4]. Recently, there has been increasing interest in the effective use of multiple antennas in a multicell environment [5]-[9]. Due to mutual interference among cells, performance features of MIMO in a multicell environment are quite different from those in a single cell environment [5]-[7]. For example, spatial multiplexing gain significantly decreases when MIMO is employed in a multicell environment [5]. Accordingly, the design of MIMO transmission scheme should reflect the intercell interference to take full advantage of MIMO in multicell environments.

In [6], an optimal MIMO transmission strategy was studied in a multicell scenario, when the channel state information (CSI) is not available at the transmitter. It was shown that each transmitter has to either put the whole power into a single transmit antenna or distribute power equally into each transmit antenna in order to maximize the achievable rate. The transmitter needs to switch between the two modes depending on the operating signal to noise ratio (SNR) and interference to noise ratio (INR).

For the case when the CSI is available at the transmitter, a transmit antenna subset selection was proposed in [7], and precoding schemes were proposed in [8] and [9]. The precoding scheme in [8] attempts to maximize the achievable rate of the own cell without accounting for the interference caused to the other cells, and thus fails to maximize the total achievable rate. On the contrary, the precoding scheme in [9] maximizes the sum of the achievable rates of all the cells. However, it works in the centralized manner, requiring a lot of feedback and huge signaling overhead among cells.

In this paper, we develop a MIMO precoding scheme in a multicell environment, when the CSI is available at each transmitter. In order to maximize the total achievable rate, the proposed scheme is designed to determine a precoding matrix considering not only the desired signal power but also the interference caused to adjacent cells. We begin with a rather simple case of multiple-input single-output (MISO) channels to establish a decentralized optimization problem. As a result of the optimization, we derive a new precoding design metric called *signal to generating interference plus noise ratio* (SGINR). The precoding vector that maximizes the SGINR at each transmitter is found to satisfy our optimality criterion in the case of MISO channels. Then, we propose an SGINR-based precoding scheme for general MIMO channels by extending the result of MISO channels.

In the proposed precoding scheme, each transmitter calculates its precoding matrix or vector with locally available CSI which can be obtained by exploiting the channel reciprocity of time division duplex (TDD) systems. Remarkably and differently from the scheme in [9], however, the proposed scheme works in the decentralized manner, and thus eliminates the need for feedback and signaling among cells. Simulation results will be provided to validate the performance improvement of the proposed precoding scheme in multicell environments.

The rest of this paper is organized as follows. Section II describes the system model and formulates an optimization problem. In Section III, we propose a new precoding scheme for MISO channels in a multicell environment. In Section IV, we extend the MISO precoding to general MIMO channels. Simulation results are presented in Section V, and conclusions are drawn in Section VI.

We define here some notation used throughput this paper. We use boldface capital letters and boldface small letters to denote matrices and vectors, respectively, $(\cdot)^T$ and $(\cdot)^H$ to denote transpose and conjugate transpose, respectively, $\det(\cdot)$ to denote determinant of a matrix, $\mathrm{tr}(\cdot)$ to denote trace of a matrix, $(\cdot)^{-1}$ to denote matrix inversion, $\|\cdot\|$ to denote norm of a vector, $\|\cdot\|_F$ to denote Frobenius norm of a matrix, $\mathbf{I}_N$ to denote the $N\times N$ identity matrix, $\mathrm{diag}(a_1, a_2, \cdots, a_N)$ to denote an $N\times N$ diagonal matrix whose diagonal elements are $a_1, a_2, \cdots, a_N$, and $(x)^+$ to denote $\max(x, 0)$.

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II. SYSTEM MODEL AND PROBLEM FORMULATION

A. System Model

We consider a MIMO system comprised of L cells. It is assumed that there is only one active communication pair per cell with N_t transmit antennas and N_r receive antennas. The i-th transmitter (the transmitter in the i-th cell) communicates with the i-th receiver (the receiver in the i-th cell) by transmitting $N_s^{(i)}$ streams over N_t transmit antennas using an $N_t \times N_s^{(i)}$ linear precoding matrix $\mathbf{W}_i$.

The received signal vector $\mathbf{y}_i$ at the i-th receiver can be expressed as

$$\mathbf{y}_i = \sqrt{\rho_i}\mathbf{H}_{i,i}\mathbf{W}_i\mathbf{x}_i + \sum_{j=1, j\neq i}^{L} \sqrt{\eta_{i,j}}\mathbf{H}_{i,j}\mathbf{W}_j\mathbf{x}_j + \mathbf{n}_i \quad (1)$$

where $\mathbf{H}_{i,j}$ denotes $N_r \times N_t$ channel matrix between the i-th receiver and the j-th transmitter. $\mathbf{x}_i$ denotes $N_s^{(i)} \times 1$ symbol vector transmitted from the i-th transmitter. We assume that the elements of $\mathbf{H}_{i,j}$ and $\mathbf{x}_i$ are independent and identically distributed (i.i.d.) circularly symmetric complex Gaussian random variables with zero mean and unit variance. $\mathbf{n}_i$ denotes the additive white Gaussian noise (AWGN) vector at the i-th receiver with each element having unit variance. ρ_i represents the SNR for the i-th cell, and $\eta_{i,j}$ represents the INR for the interference that the j-th transmitter causes to the i-th receiver.

We define the *desired channel* $\mathbf{H}_{\mathrm{D}}^{(i)}$ and *interference generating channel* $\mathbf{H}_{\mathrm{GI}}^{(i)}$ at the i-th transmitter as

$$\mathbf{H}_{\mathrm{D}}^{(i)} \triangleq \sqrt{\rho_i}\mathbf{H}_{i,i}, \quad (2)$$

$$\mathbf{H}_{\mathrm{GI}}^{(i)} \triangleq \begin{bmatrix} \sqrt{\eta_{1,i}}\mathbf{H}_{1,i} \\ \vdots \\ \sqrt{\eta_{i-1,i}}\mathbf{H}_{i-1,i} \\ \sqrt{\eta_{i+1,i}}\mathbf{H}_{i+1,i} \\ \vdots \\ \sqrt{\eta_{L,i}}\mathbf{H}_{L,i} \end{bmatrix}. \quad (3)$$

We assume that the i-th transmitter can obtain $\mathbf{H}_{\mathrm{D}}^{(i)}$ and $\mathbf{H}_{\mathrm{GI}}^{(i)H}\mathbf{H}_{\mathrm{GI}}^{(i)}$ by exploiting the channel reciprocity of TDD systems. In the uplink case, for example, the mobile station of the i-th cell can obtain $\mathbf{H}_{\mathrm{D}}^{(i)}$ through downlink pilot signal that comes from the i-th base station. Similarly, the mobile station can obtain $\mathbf{H}_{\mathrm{GI}}^{(i)H}\mathbf{H}_{\mathrm{GI}}^{(i)}$ by estimating the covariance matrix of aggregate interference signals that come from adjacent cells during the downlink period.

B. Problem Formulation

From (1), the achievable rate of the i-th cell can be computed as

$$\mathrm{C}^{(i)} = \log_2 \det\left(\mathbf{I}_{N_r} + \mathbf{K}_{\mathrm{D}}^{(i)}(\mathbf{K}_{\mathrm{N}}^{(i)})^{-1}\right), \quad (4)$$

where $\mathbf{K}_{\mathrm{D}}^{(i)}$ denotes the covariance matrix of the desired signal, and $\mathbf{K}_{\mathrm{N}}^{(i)}$ denotes the covariance matrix of the noise plus interference signal at the i-th receiver. These matrices can be expressed as

$$\mathbf{K}_{\mathrm{D}}^{(i)} = \rho_i(\mathbf{H}_{i,i}\mathbf{W}_i)(\mathbf{H}_{i,i}\mathbf{W}_i)^H, \quad (5)$$

$$\mathbf{K}_{\mathrm{N}}^{(i)} = \mathbf{I}_{N_r} + \sum_{j\neq i}\eta_{i,j}(\mathbf{H}_{i,j}\mathbf{W}_j)(\mathbf{H}_{i,j}\mathbf{W}_j)^H. \quad (6)$$

An optimization problem for finding precoding matrices that maximize the achievable rate summed over the L cells can be formulated as

$$\begin{aligned}(\mathbf{W}_{\mathrm{opt}}^{(1)}, \mathbf{W}_{\mathrm{opt}}^{(2)}, \cdots, \mathbf{W}_{\mathrm{opt}}^{(L)}) &= \underset{(\mathbf{W}^{(1)},\mathbf{W}^{(2)},\cdots,\mathbf{W}^{(L)})}{\arg\max} \sum_{i=1}^{L} C^{(i)} \\ &\text{s.t. } \mathrm{tr}(\mathbf{W}^{(i)}\mathbf{W}^{(i)H}) \le 1 \text{ for all } i.\end{aligned} \quad (7)$$

Since this is a non-convex problem, it is impossible to find a closed-form solution. Note that the scheme in [9] corresponds to a locally optimal algorithm based on the gradient projection method.

III. PRECODING FOR MISO CHANNELS

In this section, we derive a decentralized precoding scheme for MISO channels where $N_r = N_s^{(i)} = 1$. To further simplify the optimization problem in (7), we first consider a special case of $L = 2$. Then the optimal precoding vectors can be expressed as

$$\begin{aligned}\left(\mathbf{w}_{\mathrm{opt}}^{(1)}, \mathbf{w}_{\mathrm{opt}}^{(2)}\right) &= \underset{(\mathbf{w}^{(1)},\mathbf{w}^{(2)})}{\arg\max}\left(C^{(1)} + C^{(2)}\right) \\ &= \underset{(\mathbf{w}^{(1)},\mathbf{w}^{(2)})}{\arg\max}\left(\log_2(1+\mathrm{SINR}^{(1)}) + \log_2(1+\mathrm{SINR}^{(2)})\right) \\ &= \underset{(\mathbf{w}^{(1)},\mathbf{w}^{(2)})}{\arg\max}\begin{pmatrix}\log_2\left(1+\dfrac{\|\mathbf{H}_{\mathrm{D}}^{(1)}\mathbf{w}^{(1)}\|^2}{1+\|\mathbf{H}_{\mathrm{GI}}^{(2)}\mathbf{w}^{(2)}\|^2}\right) + \\ \log_2\left(1+\dfrac{\|\mathbf{H}_{\mathrm{D}}^{(2)}\mathbf{w}^{(2)}\|^2}{1+\|\mathbf{H}_{\mathrm{GI}}^{(1)}\mathbf{w}^{(1)}\|^2}\right)\end{pmatrix} \\ &\text{s.t. } \left\|\mathbf{w}^{(1)}\right\|^2 = \left\|\mathbf{w}^{(2)}\right\|^2 = 1.\end{aligned} \quad (8)$$

To make a decentralized optimization tractable, we apply an approximation $\log_2(1+\mathrm{SINR}^{(i)}) \approx \log_2(\mathrm{SINR}^{(i)})$, $i = 1, 2$ assuming $\mathrm{SINR}^{(i)} \gg 1$, $i = 1, 2$. Then, (8) can be simplified to

$$\begin{aligned}\left(\mathbf{w}_{\mathrm{opt}}^{(1)}, \mathbf{w}_{\mathrm{opt}}^{(2)}\right) &\approx \underset{(\mathbf{w}^{(1)},\mathbf{w}^{(2)})}{\arg\max}\left(\log_2(\mathrm{SINR}^{(1)}) + \log_2(\mathrm{SINR}^{(2)})\right) \\ &= \underset{(\mathbf{w}^{(1)},\mathbf{w}^{(2)})}{\arg\max}\left(\log_2\left(\frac{\|\mathbf{H}_{\mathrm{D}}^{(1)}\mathbf{w}^{(1)}\|^2}{1+\|\mathbf{H}_{\mathrm{GI}}^{(2)}\mathbf{w}^{(2)}\|^2}\right)\left(\frac{\|\mathbf{H}_{\mathrm{D}}^{(2)}\mathbf{w}^{(2)}\|^2}{1+\|\mathbf{H}_{\mathrm{GI}}^{(1)}\mathbf{w}^{(1)}\|^2}\right)\right) \\ &= \underset{(\mathbf{w}^{(1)},\mathbf{w}^{(2)})}{\arg\max}\left(\log_2\left(\frac{\|\mathbf{H}_{\mathrm{D}}^{(1)}\mathbf{w}^{(1)}\|^2}{1+\|\mathbf{H}_{\mathrm{GI}}^{(1)}\mathbf{w}^{(1)}\|^2}\right)\left(\frac{\|\mathbf{H}_{\mathrm{D}}^{(2)}\mathbf{w}^{(2)}\|^2}{1+\|\mathbf{H}_{\mathrm{GI}}^{(2)}\mathbf{w}^{(2)}\|^2}\right)\right) \\ &\text{s.t. } \left\|\mathbf{w}^{(1)}\right\|^2 = \left\|\mathbf{w}^{(2)}\right\|^2 = 1\end{aligned} \quad (9)$$

which can be separated into

$$\mathbf{w}_{\text{opt}}^{(i)} = \arg\max_{\mathbf{w}^{(i)}} \left(\gamma_{\text{SGINR}}^{(i)}(\mathbf{w}^{(i)}) \right),\ i = 1,2$$
$$\text{s.t. } \left\| \mathbf{w}^{(1)} \right\|^2 = \left\| \mathbf{w}^{(2)} \right\|^2 = 1 \tag{10}$$

where $\gamma_{\text{SGINR}}^{(i)}(\mathbf{w}^{(i)})$ is defined as

$$\gamma_{\text{SGINR}}^{(i)}(\mathbf{w}^{(i)}) \triangleq \frac{\| \mathbf{H}_{\text{D}}^{(i)} \mathbf{w}^{(i)} \|^2}{1 + \| \mathbf{H}_{\text{GI}}^{(i)} \mathbf{w}^{(i)} \|^2} . \tag{11}$$

We refer to this metric as *signal to generating interference plus noise ratio (SGINR)* of the i-th transmitter. Note that the numerator of $\gamma_{\text{SGINR}}^{(i)}(\mathbf{w}^{(i)})$ represents the desired signal power at the desired receiver, and that the denominator consists of noise and generating interference to adjacent cells by the i-th transmitter.

We call the solution of (10) the *MAX-SGINR precoding*, since it maximizes the SGINR at each transmitter. The solution can be obtained using the generalized eigenproblem [11]. If we define the *effective SGINR matrix* $\mathbf{K}_{\text{SGINR}}^{(i)}$ of the i-th transmitter as

$$\mathbf{K}_{\text{SGINR}}^{(i)} = (\mathbf{I}_{N_t} + \mathbf{H}_{\text{GI}}^{(i)H} \mathbf{H}_{\text{GI}}^{(i)})^{-1} (\mathbf{H}_{\text{D}}^{(i)H} \mathbf{H}_{\text{D}}^{(i)}) , \tag{12}$$

then the MAX-SGINR precoding vector corresponds to the eigenvector associated with the largest eigenvalue of $\mathbf{K}_{\text{SGINR}}^{(i)}$. Note that each transmitter can calculate its precoding vector in the decentralized manner with only locally available CSI, $\mathbf{H}_{\text{D}}^{(i)}$ and $\mathbf{H}_{\text{GI}}^{(i)H} \mathbf{H}_{\text{GI}}^{(i)}$. Although the MAX-SGINR precoding scheme has been derived under the scenario of two interfering cells, it can be applied to arbitrary number of cells without any modification: we simply need to account for all $L-1$ interfering cells when constructing the interference generating channel $\mathbf{H}_{\text{GI}}^{(i)}$ in (3).

IV. Precoding for MIMO Channels

In this section, we consider MIMO channels where more than one streams can be transmitted, i.e., $N_s^{(i)} \geq 1$. In Section IV-A, we extend the MAX-SGINR scheme derived in Section III to MIMO channels, to propose a generalized SGNR-based precoding scheme. In Section IV-B, we briefly discuss two previously proposed MIMO precoding schemes.

A. SGINR-based Precoding

The precoding matrix can be decomposed into two matrices: beamforming matrix and power allocation matrix. To construct a beamforming matrix, we express $\mathbf{K}_{\text{SGINR}}^{(i)}$ in (12) using the eigenvalue decomposition as

$$\begin{aligned} \mathbf{K}_{\text{SGINR}}^{(i)} &= \sum_{k=1}^{N_t} d_{\text{SGINR},k}^{(\text{i})} \mathbf{v}_{\text{SGINR},k}^{(i)} \mathbf{v}_{\text{SGINR},k}^{(i)}{}^{H} \\ &= \mathbf{V}_{\text{SGINR}}^{(i)} \mathbf{D}_{\text{SGINR}}^{(i)} \mathbf{V}_{\text{SGINR}}^{(i)}{}^{-1} \end{aligned} \tag{13}$$

where $d_{\text{SGINR},k}^{(\text{i})}$ and $\mathbf{v}_{\text{SGINR},k}^{(i)}$, respectively, denote the k-th eigenvalue and the k-th unit-norm eigenvector of $\mathbf{K}_{\text{SGINR}}^{(i)}$. Correspondingly, $\mathbf{V}_{\text{SGINR}}^{(i)}$ and $\mathbf{D}_{\text{SGINR}}^{(i)}$, respectively, denote the $N_t \times N_t$ eigenvector matrix and the eigenvalue matrix of $\mathbf{K}_{\text{SGINR}}^{(i)}$. We propose to use $\mathbf{V}_{\text{SGINR}}^{(i)}$ as a beamforming matrix for possibly transmitting up to N_t streams. Note that, according to the definition of SGINR in (11), the SGINR of the stream associated with the beamforming vector $\mathbf{v}_{\text{SGINR},k}^{(i)}$ is equal to the k-th eigenvalue of $\mathbf{K}_{\text{SGINR}}^{(i)}$: $\gamma_{\text{SGINR}}^{(\text{i})}(\mathbf{v}_{\text{SGINR},k}^{(i)}) = d_{\text{SGINR},k}^{(i)}$. With beamforming matrix $\mathbf{V}_{\text{SGINR}}^{(i)}$, the SGINR-based precoding matrix $\mathbf{W}^{(i)}$ can be written as

$$\mathbf{W}^{(i)} = \mathbf{V}_{\text{SGINR}}^{(i)} \mathbf{P}^{(i)1/2} \tag{14}$$

where $\mathbf{P}^{(i)} \triangleq \text{diag}(p_1^{(i)}, p_2^{(i)}, ..., p_{N_t}^{(i)})$ is a power allocation matrix with the constraint $\sum_{k=1}^{N_t} p_k^{(i)} = 1$. The power allocation matrix maximizing the achievable rate can be obtained using a water-filling over the SGINR values. Specifically, the power allocated to the k-th stream is given as

$$p_k^{(i)} = \left(\lambda^{(i)} - \frac{1}{d_{\text{SGINR},k}^{(i)}} \right)^+ \tag{15}$$

where $\lambda^{(i)}$ is chosen to satisfy power constraint.

The proposed SGINR-based precoding scheme allocates more power to a stream with higher SGINR due to the inherent nature of water-filling algorithm. This is a reasonable policy from the total system perspective, since low SGINR stream will provide low signal power to the desired receiver or cause high level of interference to adjacent cells. It should be noted that the SGINR-based precoding scheme in (14) can be regarded as a generalized version of the MAX-SGINR scheme.

B. D-SVD and P-SVD Precoding

For comparison purpose, we briefly discuss two previously proposed precoding schemes in [12]: Direct-channel singular value decomposition (D-SVD) and Projected-channel SVD (P-SVD). In the D-SVD scheme, the precoding matrix is given as

$$\mathbf{W}_{\text{D-SVD}}^{(i)} = \mathbf{V}_{\text{D-SVD}}^{(i)} \mathbf{P}_{\text{D-SVD}}^{(i)}{}^{1/2} \tag{17}$$

where $\mathbf{V}_{\text{D-SVD}}^{(i)}$ is the matrix composed of right singular vectors of the desired channel $\mathbf{H}_{\text{D}}^{(i)}$, and $\mathbf{P}_{\text{D-SVD}}^{(i)}$ is the power allocation matrix. The power allocation is determined by the water-filling over the SNR of each stream. Note that the D-SVD scheme does not consider the interference generated to adjacent cells. When applied to MISO channels, the D-SVD scheme maximizes the SNR of the desired signal as in [10], and thus we call the D-SVD scheme the MAX-SNR scheme in MISO systems.

In the P-SVD scheme, on the other hand, the precoding matrix is given as

$$\mathbf{W}_{\text{P-SVD}}^{(i)} = \mathbf{V}_{\text{NULL}}^{(i)} \mathbf{B}_{\text{P-SVD}}^{(i)} \mathbf{P}_{\text{P-SVD}}^{(i)}{}^{1/2} \tag{18}$$

where $\mathbf{V}_{\text{NULL}}^{(i)}$ is a nulling matrix such that $\mathbf{H}_{\text{GI}}^{(i)} \mathbf{V}_{\text{NULL}}^{(i)} = \mathbf{0}$, $\mathbf{B}_{\text{P-SVD}}$ is the matrix composed of right singular vectors $\mathbf{H}_{\text{D}}^{(i)} \mathbf{V}_{\text{NULL}}^{(i)}$, and $\mathbf{P}_{\text{P-SVD}}^{(i)}$ is the water-filling power allocation matrix. Note that the P-SVD scheme generates no interference to adjacent cells. However, in order to use the P-SVD scheme, each transmitter needs to be equipped with transmit antennas as many as the whole receive antennas in adjacent cells.

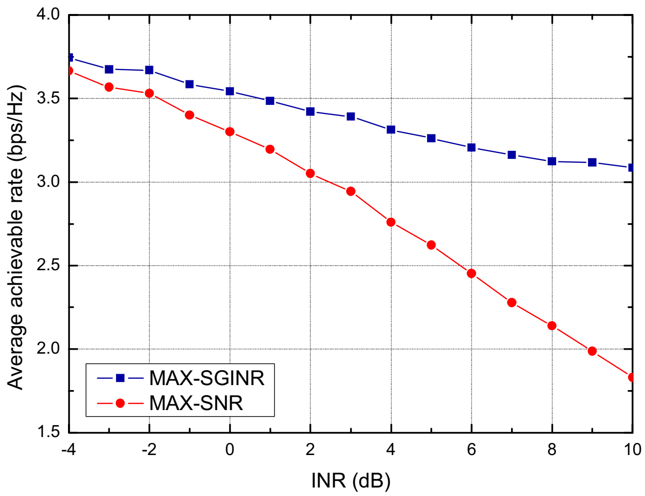

Fig. 1. Average achievable rate vs. INR for $L = 2$, $N_t = 2$, $N_r = 1$, and SNR = 10dB.

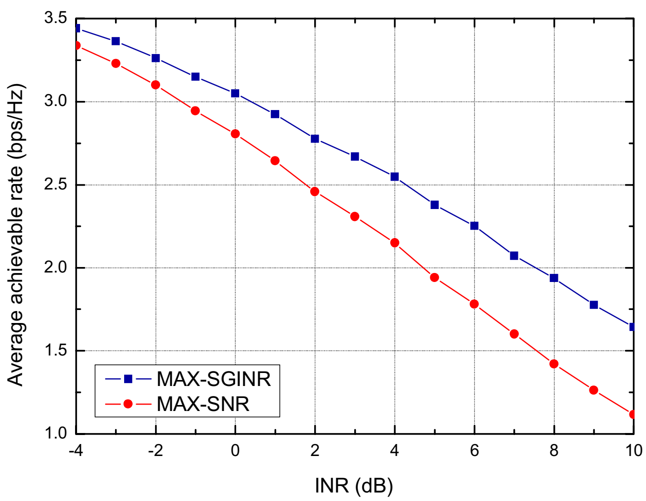

Fig. 2. Average achievable rate vs. INR for $L = 3$, $N_t = 2$, $N_r = 1$, and SNR = 10dB.

There is some interesting relationship between the proposed scheme and the D-SVD/P-SVD scheme. When INR goes to zero, the proposed scheme is equivalent to the D-SVD scheme. On the contrary, when INR goes to infinity, the proposed scheme is equivalent to the P-SVD scheme. The proofs are omitted due to page limitation.

V. Simulation Results

In this section, we evaluate the performance of the precoding schemes discussed in Sections III-IV using computer simulations. We consider a symmetric system except for Fig. 7; in other words, ρ_i and $\eta_{i,j}$ in (1) are assumed to be the same for all i and j in Figs. 1-6.

Figs.1-2 show the average achievable rate per cell vs. INR in a MISO system with $N_t = 2$, $N_r = 1$ for two cells and three cells, respectively. The SNR is fixed to 10dB. As expected, the proposed MAX-SGINR scheme provides higher achievable rate than the MAX-SNR scheme for all INR regions, and the performance difference becomes larger with INR increasing.

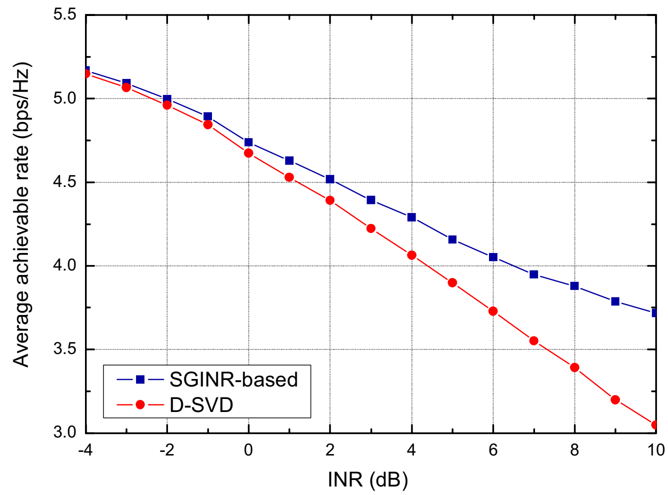

Fig. 3. Average achievable rate vs. INR for $L = 2$, $N_t = 2$, $N_r = 2$, and SNR = 10dB.

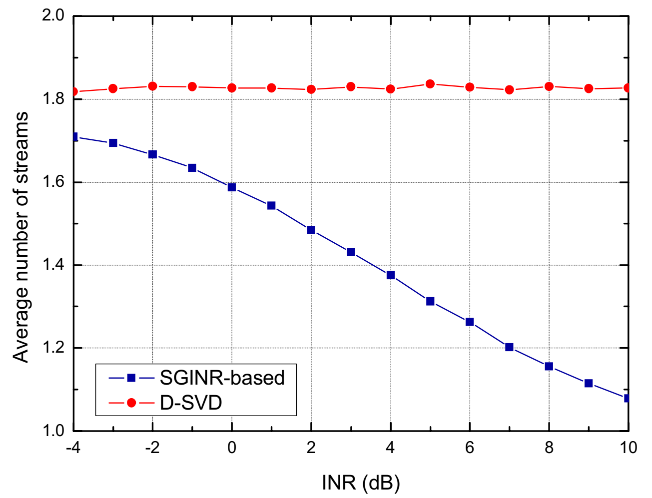

Fig. 4. Average number of streams vs. INR for $L = 2$, $N_t = 2$, $N_r = 2$, and SNR = 10dB.

Fig. 3 depicts the average achievable rate per cell vs. INR in a two-cell MIMO system with $N_t = N_r = 2$, and SNR = 10dB. It is shown that the proposed SGINR-based precoding scheme outperforms the D-SVD scheme in all INR regions. Note that the P-SVD scheme is not applicable to this MIMO configuration due to the lack of the number of transmit antennas. Fig. 4 shows the average number of transmit streams vs. INR under the same condition as Fig. 3. It is observed that the SGINR-based scheme tends to reduce transmit number of steams as INR increases, while the number of streams for the D-SVD scheme is independent of INR. This property of the SGINR-based scheme is consistent with the principle of the optimal centralized transmission scheme in [9].

Figs. 5-6 depict the average achievable rate per cell vs. the number of transmit antennas in a three-cell MIMO system with $N_r = 2$ at a relatively low INR (-5dB) and at a relatively high INR (10dB), respectively. Note that the P-SVD scheme is applicable as long as $N_t \geq 6$. It is found that the D-SVD outperforms the P-SVD at the low INR value, whereas the P-SVD

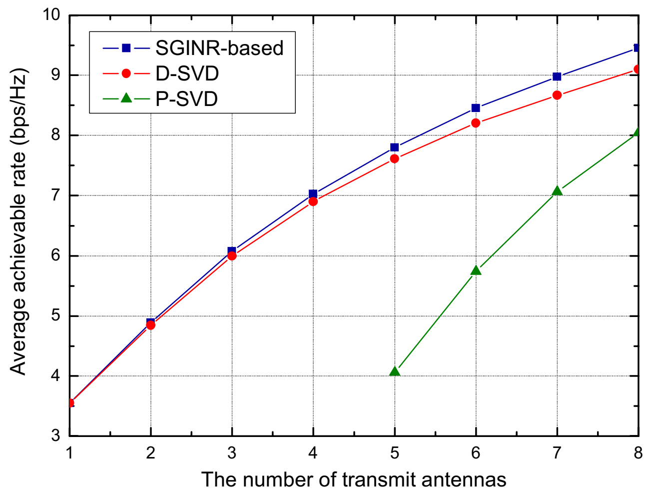

Fig. 5. Average achievable rate vs. N_t for $L = 3$, $N_r = 2$, SNR = 10dB, and INR = −5dB.

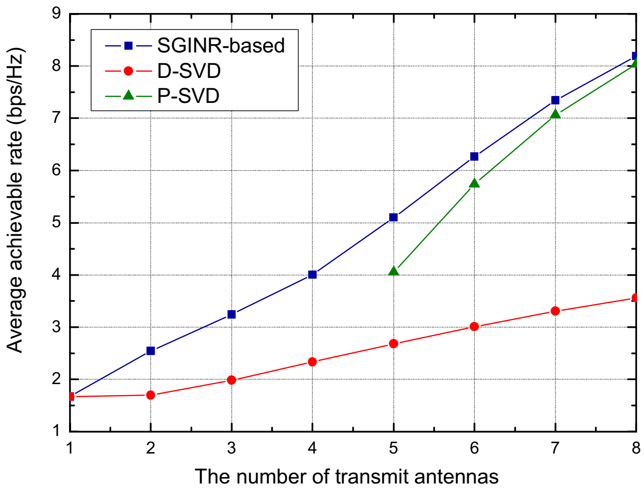

Fig. 6. Average achievable rate vs. N_t for $L = 3$, $N_r = 2$, SNR = 10dB, and INR = 10dB.

outperforms the D-SVD at the high INR value. The proposed SGINR-based scheme is found to always outperform both the D-SVD and P-SVD schemes.

Fig. 7 shows the achievable rate per cell vs. the number of transmit antennas in a non-symmetric system with $L = 3$ and $N_r = 2$, where the SNR and INR of each link are randomly generated with uniform distribution between 0dB and 10dB. The SGINR-based scheme still outperforms both the D-SVD and P-SVD schemes.

VI. Conclusions

In this paper, we have developed a practical and effective solution to deal with intercell interference problems for multi-cell MIMO systems. We have formulated an optimization problem for finding a precoding matrix that maximizes the total achievable rate in the decentralized manner. In order to solve the problem, we have introduced a design metric called SGINR that is related to the desired signal channel and interference generating channels. Based on the SGINR metric, we

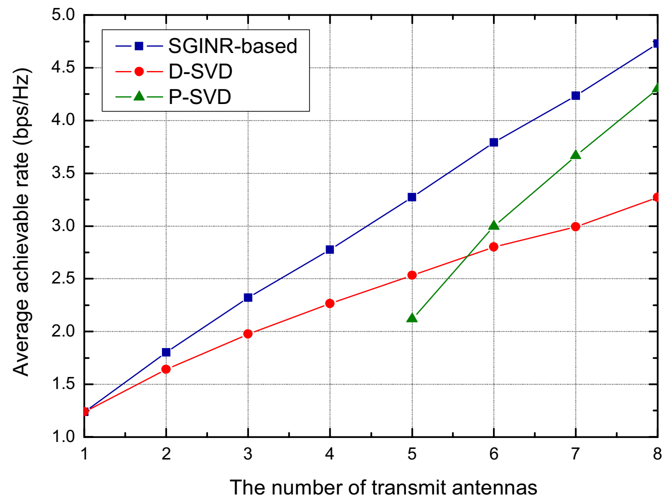

Fig. 7. Average achievable rate vs. N_t for $L = 3$ and $N_r = 2$, where SNR and INR are randomly generated with uniform distribution between -5dB and 10dB.

have proposed precoding schemes for MISO and MIMO systems. Simulation results have shown that the proposed MAX-SGINR and SGINR-based schemes offer significant performance gain over the previously proposed D-SVD and P-SVD schemes in terms of the achievable rate. Furthermore, the SGINR-based scheme has been found to provide more robust performance than the two schemes against the INR variation.

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