An SINR Balancing Technique for a Cognitive Two-Way Relay Network

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***Abstract*—We propose a two-way relay based spatial multiplexing technique for a cognitive radio relay network (CR). The relay coefficients and the transmission powers are optimized to maximize the worst-case user signal-to-interference and noise ratio (SINR), while ensuring interference leakage from the relays to the primary users (PUs) in the network is below a threshold. We solve this problem through an iterative procedure that uses semidefinite and geometric programming along with bisection search method. We evaluate the performance of the proposed scheme in terms of the mean SINR for different number of relays and transmission power at the relays.**

I. Introduction

CR [1] is a promising solution to the problem of spectrum scarcity in wireless communications. The basic idea of CR is to allow secondary (unlicensed) users (SUs) to opportunistically utilize the spectrum of PUs (licensed), provided that the SU transmission do not harmfully affect the PUs. In this paper, we focus on the underlay CR approach, where the SUs access the spectrum occupied by the PUs, given that the interference they cause to the PUs is less than a certain threshold such that the Quality-of-Service (QoS) of the PUs can be ensured.

Cooperative networks have been the focus of many research activities in the area of wireless communications [2], [3], [4], [5]. In the context of CR networks, cooperative transmission between SUs aims to increase the secondary throughput, while ensuring the PU terminals are not affected harmfully.

Processing at the relays can be non-regenerative (e.g. amplify-forward (AF)) [6], [7], or regenerative (e.g. compress-forward (CF) [8], and decode-forward (DF) [9]). Among these schemes, the AF approach is of particular interest as it can be easily implemented. In this paper, we consider a two-way AF relaying scenario, where the relays cooperate with each other to establish a connection between multiple transceivers. Both transceivers and relay nodes are cognitive terminals and we assume that all transceivers are equipped with single antenna, while relay nodes consist of multiple antennas. Employing multiple antennas at the relays allows beamforming techniques to be used that will improve the quality of the signal transmission. Several papers have considered multiple antennas based relaying schemes. In [10], a non-regenerative multiple antenna relaying strategy is developed through maximization of the capacity between the source and the destination. Recently, there has been increasing attention to the design of decentralized beamforming for relaying schemes with the aim of designing optimal beamforming coefficients with respect to particular criteria. In [11], the authors have proposed to determine the beamforming vector of a two-way relay network with two users by minimizing the total power of the network or by maximizing the worst-user signal-to-noise ratio (SNR) under certain constraints. The latter optimization problem is sometimes referred to as SNR balancing because its solutions tend to equalize all user SNRs. This problem is of particular interest since the user SNRs are directly related to common performance measures like system capacity and bit error rates. This problem has been solved by finding the matched-filter of the combined forward and backward links. Hence, the problem reduces to determine the amplitudes of the complex weights.

Compared to [11], this paper focuses on a two-way AF relaying scheme with multiple source-destination pairs of SUs and relays with multiple antennas. It aims to obtain the relay beamforming complex coefficients using an SINR balancing approach. More specifically, we aim to maximize the worst-case SU SINR subject to the total transmit power budget while ensuring that the interference leakage to PUs is below specific thresholds. An iterative algorithm is proposed by solving two subproblems. In the first subproblem, using a semidefinite relaxation approach, we convert our power minimization problem into a semidefinite programming (SDP) optimization problem and we maximize the worst-case user SINR. In the second subproblem, for a given set of relay weight coefficients, we optimize the transmission power at the sources and we balance the transceivers' SINR by applying a geometric programming approach.

Notation: Lowercase letters are used for scalars. Vectors and matrices are denoted by boldface lowercase and uppercase letters respectively. We denote complex conjugate, transpose, and Hermitian transpose by $(\cdot)^*$, $(\cdot)^T$ and $(\cdot)^H$. We use $\mathrm{E}\{\cdot\}$ to denote statistical expectation, $\mathrm{tr}\{\cdot\}$ and $\mathrm{Rank}(\cdot)$ represent the trace and rank of a matrix respectively and $\mathrm{Vec}(\cdot)$ is an operator that forms a vector by stacking the columns of a matrix. $\mathrm{blkdiag}\{\mathbf{S}_1, \cdots, \mathbf{S}_M\}$ denotes a block-diagonal square matrix with $\mathbf{S}_1, \cdots, \mathbf{S}_M$ as the diagonal square matrices.

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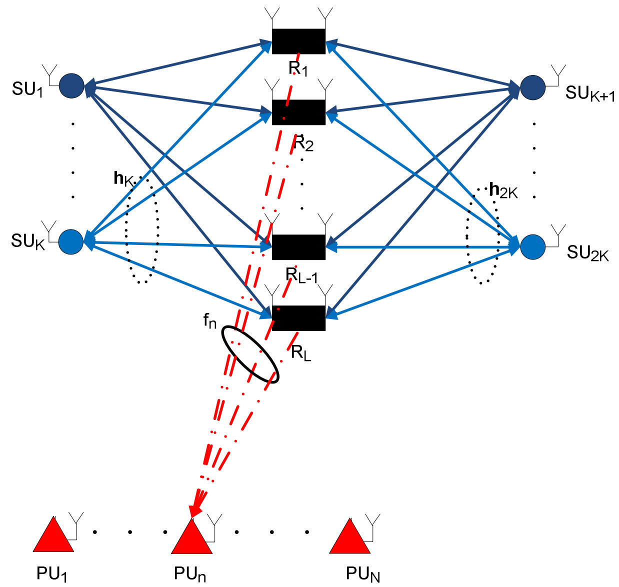

Fig. 1. The two-way multi-antenna relay channel with multiple users

$\mathbf{S} \succeq 0$ means that $\mathbf{S}$ is a positive semidefinite matrix. $\mathbf{I}$ and $\mathbf{0}$ denote the identity and the all zero matrix respectively. $||\mathbf{x}||$ denotes the Euclidean norm of a complex vector $\mathbf{x}$, while $|z|$ denotes the norm of a complex number z.

II. System Model

We consider a wireless two-way cognitive relay network, which consists of K single-antenna source-destination pairs and L multiple-antenna relay nodes, each equipped with M antennas, all operating in the same frequency band allocated to N single-antenna primary users PU_n $n = 1, \ldots, N$. The pair of sources k and $K+k$ exchange messages through the set of L relays. We assume that all the channels are independent, frequency-flat Rayleigh block-fading and the channel links are established through a two-step AF cooperative scheme. In the first step, the $2K$ sources transmit simultaneously their source information to the L relays. In the second step, the L relays amplify their respective faded mixtures of their received signals and relay them to the destination receivers.

Let s_k be the information symbol transmitted by the kth source, which transmits with power p_k, i.e. $E\{|s_k|^2\} = p_k$ for $k = 1, \ldots, 2K$. It should hold that

$$\mathbf{1}^T \mathbf{p} \leq P_1 \tag{1}$$

where $\mathbf{p} \triangleq [p_1 \ldots p_{2K}]^T$ and P_1 is the total power available at the sources. Let $\mathbf{h}_{lk} \triangleq [h_{1lk}, \ldots, h_{Mlk}]^T$ stand for the channel between the kth source and the lth relay, then we introduce $\mathbf{h}_k \triangleq [\mathbf{h}_{1k}^T, \ldots, \mathbf{h}_{Lk}^T]^T$. Thus, the $(ML \times 1)$ received signal vector at the relays is given by

$$\mathbf{y}_R = \sum_{k=1}^{2K} \mathbf{h}_k s_k + \mathbf{n}_R \tag{2}$$

where $\mathbf{n}_R \triangleq [\mathbf{n}_1^T \ldots \mathbf{n}_L^T]^T$ contains the noise components present at the relay and the noise components are assumed to be zero-mean, spatially uncorrelated and unity variance. The lth relay multiplies its received signal by a processing matrix $\mathbf{W}_l$. Thus, the vector of signals transmitted by all relays is given by

$$\mathbf{x}_R = \mathbf{W}\mathbf{y}_R \tag{3}$$

where $\mathbf{W} = \text{blkdiag}\{\mathbf{W}_1 \ldots \mathbf{W}_L\}$. From (2) and (3) the relays' total transmit power is given by

$$\begin{aligned} P_r = E\{\mathbf{x}_R^H \mathbf{x}_R\} = & \sum_{k=1}^{2K} ||\mathbf{W}\mathbf{h}_k||^2 p_k + tr(\mathbf{W}\mathbf{W}^H) \\ = & \sum_{k=1}^{2K} ||\mathbf{A}_k \mathbf{b}||^2 p_k + tr(\mathbf{b}\mathbf{b}^H) \end{aligned} \tag{4}$$

where $\mathbf{A}_k = \text{blkdiag}\{\mathbf{A}_{k1} \ldots \mathbf{A}_{kL}\}$, for $k = 1, \ldots, 2K$, $\mathbf{A}_{kl} = \text{blkdiag}\overbrace{\{\mathbf{h}_{kl} \ldots \mathbf{h}_{kl}\}}^{Mtimes}$, $\mathbf{b} = [\mathbf{w}_1^T \ldots \mathbf{w}_L^T]^T$ and $\mathbf{w}_l = \text{Vec}(\mathbf{W}_l)$. It is also required that

$$P_r \leq P_2 \tag{5}$$

where P_2 is the upper-bound on the relays' total transmit power. Let $\mathbf{f}_{nl} = [f_{1nl} \ldots f_{Mnl}]^T$ denote the channel gains between the lth relay and the nth primary user, $\mathbf{f}_n = [\mathbf{f}_{n1}^T \ldots \mathbf{f}_{nl}^T]^T$ the channel gain between all the relays and the nth primary user and I_n^R is the acceptable interference power threshold caused by the relays on PU_n, then it should hold that

$$\begin{aligned} E\{|\mathbf{f}_n^T \mathbf{x}_R|^2\} = & \sum_{k=1}^{2K} |\mathbf{f}_n^T \mathbf{W}\mathbf{h}_k|^2 p_k + ||\mathbf{W}\mathbf{f}_n||^2 + \sigma_p^2 \\ = & \sum_{k=1}^{2K} |\mathbf{t}_k^T \mathbf{b}|^2 p_k + ||\mathbf{F}_n \mathbf{b}||^2 + \sigma_p^2 \leq I_n^R \\ & \text{for } n = 1, 2, \ldots, N \end{aligned} \tag{6}$$

where $\mathbf{t}_k = [(\mathbf{h}_{1k}^T \otimes \mathbf{f}_n^T) \ldots (\mathbf{h}_{Lk}^T \otimes \mathbf{f}_n^T)]$ has been obtained by applying the Kronecker product identity $\text{Vec}(\mathbf{AXB}) = (\mathbf{B}^T \otimes \mathbf{A})\text{Vec}(\mathbf{X})$ and $\mathbf{F}_n = \text{blkdiag}\{\mathbf{F}_{n1} \ldots \mathbf{F}_{nL}\}$, for $n = 1, \ldots, N$, $\mathbf{F}_{nl} = \text{blkdiag}\overbrace{\{\mathbf{f}_{nl} \ldots \mathbf{f}_{nl}\}}^{Mtimes}$.

The received signal at the kth destination is given by

$$y_k = \mathbf{h}_k^T \mathbf{x}_R + n_k = \mathbf{h}_k^T \mathbf{W} \sum_{i=1}^{2K} \mathbf{h}_i s_i + \mathbf{h}_k^T \mathbf{W}\mathbf{n}_R + n_k \tag{7}$$

where n_k is the noise at the kth destination. Note that the first term of the above equation contains the self-interference $\mathbf{h}_k s_k$. Assume that h_k is known at kth user via training-based estimation [10] before data transmission. Thus, kth receiver can subtract its self-interference from y_k. From (7), subtracting the self-interference, we obtain:

$$\widetilde{y}_k = \mathbf{h}_k^T \mathbf{W} \sum_{\substack{i=1 \\ i \neq k}}^{2K} \mathbf{h}_i s_i + \mathbf{h}_k^T \mathbf{W}\mathbf{n}_R + n_k$$

$$= \mathbf{h}_k^T \mathbf{W} \mathbf{h}_j s_j + \mathbf{h}_k^T \mathbf{W} \sum_{\substack{i=1 \\ i \neq k,j}}^{2K} \mathbf{h}_i s_i$$
$$+ \mathbf{h}_k^T \mathbf{W} \mathbf{n}_R + n_k \quad (8)$$

where

$$j = \begin{cases} K + k & \text{if } k \leq K \\ -K + k & \text{if } k > K \end{cases}$$

The first term of (8) is the desired signal, the second is the interference and the last two terms describe the total noise received at the kth destination.

Thus, the received signal and interference power at the kth receiver may be represented as:

$$\begin{aligned} P_s^k &= |\mathbf{h}_k^T \mathbf{W} \mathbf{h}_j|^2 p_k = |\mathbf{d}_k \mathbf{b}|^2 p_k \\ P_i^k &= \sum_{\substack{i=1 \\ i \neq k,j}}^{2K} |\mathbf{h}_k^T \mathbf{W} \mathbf{h}_i|^2 p_i = \sum_{\substack{i=1 \\ i \neq k,j}}^{2K} |\mathbf{q}_i \mathbf{b}|^2 p_i \end{aligned} \quad (9)$$

where $\mathbf{d}_k = [(\mathbf{h}_{1j}^T \otimes \mathbf{h}_{1k}^T) \dots (\mathbf{h}_{Lj}^T \otimes \mathbf{h}_{Lk}^T)]$ and $\mathbf{q}_i = [(\mathbf{h}_{1i}^T \otimes \mathbf{h}_k^T) \dots (\mathbf{h}_{Li}^T \otimes \mathbf{h}_{Lk}^T)]$.

The aggregated noise power received at the kth destination is

$$\begin{aligned} P_n^k &= ||\mathbf{W} \mathbf{h}_k||^2 + \sigma_k^2 \\ &= ||\mathbf{N}_k \mathbf{b}||^2 + \sigma_k^2 \end{aligned} \quad (10)$$

where $\mathbf{N}_k = \text{blkdiag}\{\mathbf{N}_{k1} \dots \mathbf{N}_{kL}\}$, for $k = 1, \dots, 2K$ and $\mathbf{N}_{kl} = \text{blkdiag}\overbrace{\{\mathbf{h}_{kl} \dots \mathbf{h}_{kl}\}}^{M times}$.

Using (9), (10) the SINR at kth destination is:

$$\text{SINR}_k(\mathbf{p}, \mathbf{b}) = \frac{|\mathbf{d}_k \mathbf{b}|^2 p_k}{\sum_{\substack{i=1 \\ i \neq k,j}}^{2K} |\mathbf{q}_i \mathbf{b}|^2 p_i + ||\mathbf{N}_k \mathbf{b}||^2 + \sigma_k^2} \quad (11)$$

III. Optimization Problem

Our design goal is to jointly adjust the relay coefficient weights $\mathbf{b}$ and the transmission power vector $\mathbf{p}$ to maximize the worst user SINR (i.e. SINR balancing), while keeping both the interference leakage to the primary users and the total transmit and relays' powers below a certain threshold. Thus, the problem is formulated as P1:

$$\begin{aligned} \text{P1}: \max_{\mathbf{p} \succeq 0, \mathbf{b}} \quad & \min_{1 \leq k \leq 2K} \text{SINR}_k(\mathbf{p}, \mathbf{b}) \\ \text{s.t.} \quad & \mathbf{1}^T \mathbf{p} \leq P_1 \\ & \sum_{k=1}^{2K} ||\mathbf{A}_k \mathbf{b}||^2 p_k + tr(\mathbf{b}\mathbf{b}^H) \leq P_2 \\ & \sum_{k=1}^{2K} |\mathbf{t}_k^T \mathbf{b}|^2 p_k + ||\mathbf{F}_n \mathbf{b}||^2 + \sigma_p^2 \leq I_n^R, \\ & \text{for } n = 1, 2 \dots N \end{aligned} \quad (12)$$

The above optimization problem is not convex with respect to both design parameters $\mathbf{b}$, $\mathbf{p}$ and is thus difficult to solve jointly via standard convex optimization techniques. Therefore we need to break the above problem into two subproblems P1(a) and P1(b).

The first P1(a) aims to maximize the worst-case user SINR over all possible relay beamforming weights $\mathbf{b}$ for a given sources' transmit power.

$$\begin{aligned} \text{P1}(a): \max_{\mathbf{b}} \quad & \min_{1 \leq k \leq 2K} \text{SINR}_k \\ \text{s.t.} \quad & \sum_{k=1}^{2K} ||\mathbf{A}_k \mathbf{b}||^2 p_k + tr(\mathbf{b}\mathbf{b}^H) \leq P_2 \\ & \sum_{k=1}^{2K} |\mathbf{t}_k^T \mathbf{b}|^2 p_k + ||\mathbf{F}_n \mathbf{b}||^2 + \sigma_p^2 \leq I_n^R, \\ & \text{for } n = 1, 2 \dots N \quad (13) \end{aligned} \quad (14)$$

while the second P1(b), aims to balance all the users' SINR over all possible transmission powers for the given beamforming vectors.

$$\begin{aligned} \text{P1}(b): \max_{\mathbf{p} \succeq 0} \quad & \min_{1 \leq k \leq 2K} \text{SINR}_k \\ \text{s.t.} \quad & \mathbf{1}^T \mathbf{p} \leq P_1 \\ & \sum_{k=1}^{2K} ||\mathbf{A}_k \mathbf{b}||^2 p_k + tr(\mathbf{b}\mathbf{b}^H) \leq P_2 \\ & \sum_{k=1}^{2K} |\mathbf{t}_k^T \mathbf{b}|^2 p_k + ||\mathbf{F}_n \mathbf{b}||^2 + \sigma_p^2 \leq I_n^R, \\ & \text{for } n = 1, 2 \dots N \end{aligned} \quad (15)$$

Introducing $\mathbf{B} = \mathbf{b}\mathbf{b}^H$, $\mathbf{D}_k = \mathbf{d}_k \mathbf{d}_k^H$, $\mathbf{Q}_k = \mathbf{q}_i \mathbf{q}_i^H$, $\mathbf{N} = \widetilde{\mathbf{N}}_k \widetilde{\mathbf{N}}_k^H$, $\mathbf{R}_k = \mathbf{A}_k \mathbf{A}_k^H$ and $\mathbf{T}_k = \mathbf{t}_k \mathbf{t}_k^H + \mathbf{F}_n \mathbf{F}_n^H$ the first subproblem P1(a) can be written equivalently as:

$$\begin{aligned} \max_{\mathbf{B}, t} \quad & t \\ \text{s.t.} \quad & \frac{\text{tr}(\mathbf{D}_k \mathbf{B}) p_k}{\sum_{\substack{i=1 \\ i \neq k,j}}^{2K} p_i \text{tr}(\mathbf{Q}_k \mathbf{B}) + \text{tr}(\mathbf{N}\mathbf{B}) + \sigma_k^2} \geq t, \\ & \text{for } k = 1, \dots, 2K \\ & \sum_{k=1}^{2K} p_k \text{tr}(\mathbf{R}_k \mathbf{B}) + \text{tr}(\mathbf{B}) \leq P_2 \\ & \sum_{k=1}^{2K} p_k \text{tr}(\mathbf{T}_k \mathbf{B}) + \sigma_p^2 \leq I_n^R, \\ & \text{for } n = 1, 2 \dots N \\ & \text{rank}(\mathbf{B}) = 1, \ \mathbf{B} \succeq 0. \end{aligned} \quad (16)$$

Due to the constraint rank($\mathbf{B}$)= 1, the optimization problem in (16) is not convex. Hence we remove the rank constraint so that the problem is relaxed into SDP [12], [13] as follows:

$$\begin{aligned} \max_{\mathbf{B}, t} \quad & t \\ \text{s.t.} \quad & \frac{\text{tr}(\mathbf{D}_k \mathbf{B}) p_k}{\sum_{\substack{i=1 \\ i \neq k,j}}^{2K} p_i \text{tr}(\mathbf{Q}_k \mathbf{B}) + \text{tr}(\mathbf{N}\mathbf{B}) + \sigma_k^2} \geq t, \end{aligned}$$

$$\begin{aligned}
&\text{for } k = 1, \dots, 2K \\
&\sum_{k=1}^{2K} p_k \text{tr}(\mathbf{R}_k \mathbf{B}) + \text{tr}(\mathbf{B}) \leq P_2 \\
&\sum_{k=1}^{2K} p_k \text{tr}(\mathbf{T}_k \mathbf{B}) + \sigma_p^2 \leq I_n^R, \\
&\text{for } n = 1, 2 \dots N \\
&\mathbf{B} \succeq 0
\end{aligned} \tag{17}$$

For any given $t = t_r$ the feasible set in (17) is convex. Given the convexity of the above SDP problem, the optimal solution could be efficiently found by using bisection method. By solving (17), we obtain the maximum value of t that satisfies the constraints and the corresponding value of $\mathbf{B}$.

SDP relaxation usually leads to an optimal B with rank one for the problem in (17). However, if rank of the matrix B turns out to be greater than one, randomization techniques [14] can be used to obtain a rank one solution.

Note that the above subproblem only maximized the worst case user SINR. However, if the number of the relays is substantially higher than the number of users, the resulting SINR will tend to be equal for all users. This is because, unlike transmit beamforming techniques [15], the relay transceivers has the inability to control the power usage for each user separately at the relays. Therefore, in order to balance the SINR of all users, we need to control the transmission power at the source level.

For this purpose, we solve problem P1(b):

$$\begin{aligned}
\max_{\mathbf{p} \succeq 0} \quad & \min_{1 \leq k \leq 2K} \frac{\text{tr}(\mathbf{D}_k \mathbf{B}) p_k}{\sum_{\substack{i=1 \\ i \neq k,j}}^{2K} p_i \text{tr}(\mathbf{Q}_k \mathbf{B}) + \text{tr}(\mathbf{N}\mathbf{B}) + \sigma_k^2} \\
\text{s.t.} \quad & \mathbf{1}^T \mathbf{p} \leq P_1 \\
& \sum_{k=1}^{2K} p_k \text{tr}(\mathbf{R}_k \mathbf{B}) + \text{tr}(\mathbf{B}) \leq P_2 \\
& \sum_{k=1}^{2K} p_k \text{tr}(\mathbf{T}_k \mathbf{B}) + \sigma_p^2 \leq I_n^R, \\
& \text{for } n = 1, 2 \dots N
\end{aligned} \tag{18}$$

The above problem can be rewritten as:

$$\begin{aligned}
\max_{\mathbf{p} \succeq 0, \widetilde{t}} \quad & \widetilde{t} \\
\text{s.t.} \quad & \mathbf{1}^T \mathbf{p} \leq P_1 \\
& \widetilde{t} \left(\sum_{\substack{i=1 \\ i \neq k,j}}^{2K} p_i \text{tr}(\mathbf{Q}_k \mathbf{B}) + \text{tr}(\mathbf{N}\mathbf{B}) + \sigma_k^2 \right) \leq \text{tr}(\mathbf{D}_k \mathbf{B}) p_k \\
& \sum_{k=1}^{2K} p_k \text{tr}(\mathbf{R}_k \mathbf{B}) + \text{tr}(\mathbf{B}) \leq P_2 \\
& \sum_{k=1}^{2K} p_k \text{tr}(\mathbf{T}_k \mathbf{B}) + \sigma_p^2 \leq I_n^R, \\
& \text{for } n = 1, 2 \dots N
\end{aligned} \tag{19}$$

The problem (18) is convex and belongs to the class of geometric programming [16] . As a result, it can be efficiently solved using interiorpoint methods [17].

Based on the above we get the following algorithm that optimizes $\mathbf{p}$ and $\mathbf{b}$:

Algorithm 1 :Optimization of the relays' beamforming vectors and sources' power

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- **Initialize** $\mathbf{p} \geq 0$
- **Repeat**
  1) Solve problem (17) to obtain optimal value of $\mathbf{B}$
     - if $\mathbf{B}$ is rank-one, then the principal eigenvector of $\mathbf{B}$ is $\mathbf{b}$
     - if $\mathbf{B}$ is of higher rank we use randomization techniques to obtain $\mathbf{b}$
  2) Solve problem (19) to obtain optimal value of $\mathbf{p}$, for given $\mathbf{b}$
  3) Update the old values of $\mathbf{p}$, before solving (17)
- **Until** $\text{SINR}_{\text{current}} - \text{SINR}_{\text{previous}} \leq \varepsilon$, where ε is a small positive constant for controlling the accuracy of the algorithm. The converged value of SINR is the optimal solution of SINR in (12).

IV. Numerical Results

We consider three numerical examples on the achievable mean SINR of the above network scheme with different number of users, relays and relay powers. For convenience, we assume that all primary and secondary users' channel coefficients $\mathbf{h}_k$, $\mathbf{f}_n$ are modeled as Gaussian random variables. Fig. 2 shows the mean SINR for different number of maximum allowable transmit power at the relays for a network with 2 secondary users on both sides, 2 relays, each of which is equipped with 2 antennas and 1 primary user. Moreover, in all the simulations the noise power at the relays and at the transceivers is assumed to be equal to 1 and 0.1 respectively. It is observed that the achievable SINR is increased as the maximum allowable transmit power gets larger. In Fig. 3, we show the achievable mean SINR for different number of secondary users, for a network with 2 relays, each equipped with 2 antennas and one primary user. As the number of users decreases, the performance at the transceivers is improved. The maximum allowable transmit power at the relays is 10W. Finally in Fig.4 the mean SINR versus different number of relays is plotted. The maximum allowable transmit power at the relays is set to 5W and each of the relays is equipped with one antenna.

V. Conclusion

We proposed a two-way relay based multi-user spatial multiplexing technique for a CR relay network. The relay coefficients and transmission powers are optimized in order to maximize the worst-case user SINR (namely SINR balancing). As optimization of relay coefficients alone will not be able

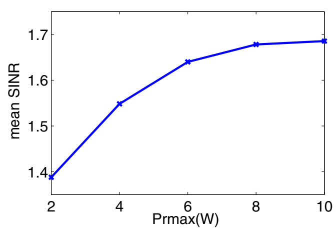

Fig. 2. The mean SINR versus the maximum allowable relay transmit power P_2 at the relays for a network with 2 users on both sides, 2 relays, equipped with 2 antennas each and P_1=7W.

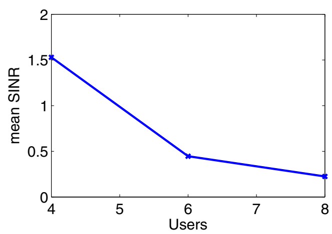

Fig. 3. The mean SINR versus different number of users for a network with 2 relays, each with two antennas and maximum allowable transmit power P_2=10W and I_1^R=7W.

to balance SINR of each user, we have proposed to design relay coefficients and determine transmit power for each user iteratively. The transmitter power was optimized using geometric programming. We have found that by controlling the power of each user, we are able to obtain a balanced SINR over all users. Simulation results validate the efficiency of the algorithm.

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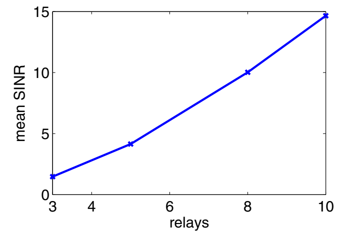

Fig. 4. The mean SINR versus different number of relays for a network with maximum allowable transmit power P_2=5W and I_1^R=7W.

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