ISITC | 2017 SHIJIAZHUANG

Proceeding of International Symposium on Information Technology Convergence

October 19-21, 2017

Shijiazhuang Tiedao University, China

Session 3: Data and Web

14:45 - 17:50, October 20, 2017. Location: Classroom 206, No1 Teaching Building, STDU. Session Chairs:

Prof. Zhaohui Qi (Shijiahzuang Tiedao University, China)

Dr. Jianzheng Liu (Tianjin University of Science and Technology, China)

ID.3. Joint Design of Interference Spin and Linear Transceivers for Two-Way Multi-Link Interference Networks

Junbeom Kim, Changyun Lee, Daesung Yu, Seok-Hwan Park and Yongchae Jeong

Chonbuk National University

ID.29. Design of a Wideband Amplifier Using a Cascode Structure and Feedback Network

Jongsik Lim[1], Heeyoun Choi[1], Dal Ahn[1], Yongchae Jeong[2], Sang-Min Han[1] and Won-Sang Yoon[3]

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ID.51. Enh-Code: An Enhanced Erasure Code Algorithm in Distributed Storage Systems

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ID.104. A Pheromone-Heuristic Artificial Bee Colony Algorithm for Web Service Instantiation

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ID.54. Data Arrangement Algorithm for CAN Compression

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ID.103. A Planetary Data System (PDS) in Data Management for Deep Space Exploration

Lijing Ren, Zhengxu Zhao, Denghui Zhang and Weihua Zhao

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ID.50. Improving Network Lifetime with the Load Balancing Routing Metrics

Joint Design of Interference Spin and Linear Transceivers for Two-Way Multi-Link Interference Networks

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***Abstract*—Recently, the joint optimization of two-way communication links in ultra-dense interference network has been actively studied due to its important application to massive device-to-device (D2D) communication systems. Motivated by this trend, this work tackles the joint optimization of the interference scheduling, also known as interference spin, and linear transceivers with the goal of maximizing the minimum user rate for a two-way K interfering links. In order to tackle the formulated problem which is challenging due to the inclusion of binary spin variables, a rank-relaxation based iterative algorithm is proposed, and some link-level simulation results validate the advantages of the proposed scheme as compared to more conventional approaches.**

***Index Terms*—Interference channel, beamforming, interference scheduling, two-way.**

I. Introduction

While traditional works on wireless cellular communication systems prescribed the separation of a two-way communication link into two independent one-way links, some recent works studied dynamic time division duplexing (TDD) mode in which the uplink and downlink communication links are jointly optimized (see, e.g., [1]). Specifically, the works [2] and [3] tackle the problem of optimizing the interference scheduling for two-way multi-link interference networks under the assumption that the traffic load is balanced between the two transmission directions. Both in [2] and [3], the interference scheduling policy is referred to as *interference spin*.

In this work, we discuss the joint optimization of the interference spin and the linear transceiver filters for a two-way multiple-input multiple-output (MIMO) K-link interference network with the goal of maximizing the minimum achievable rate of the $2K$ communication links (accounting for the both directions). The same system model was also considered in [3] but with a different optimization criterion of minimizing the sum of interference leakage powers. We mathematically formulate the optimization problem and propose an efficient iterative algorithm based on a change of variable and rank-relaxation. Via link-level simulation results, we confirm the effectiveness of the proposed joint design compared to more conventional schemes.

This work was supported in part by the Creative Korea (CK-1) Program, National Research Foundation (NRF) of Korea.

II. System Model

We consider a two-way K-link interference network which was also studied in [3]. Each two-way link k is equipped with $N_{L,k}$ and $N_{R,k}$ antennas at the left-hand and the right-hand nodes, respectively, for $k \in \mathcal{K} \triangleq \{1, \ldots, K\}$, and operates in TDD mode. We define the notations $\mathcal{L} \triangleq \{L_1, \ldots, L_K\}$ and $\mathcal{R} \triangleq \{R_1, \ldots, R_K\}$ to denote the sets of the left-hand nodes and right-hand nodes, respectively.

We define a binary spin variable $S_k \in \{-1, 1\}$ that determines the direction of the communication of the kth link. The spin $S_k = -1$ means that the kth link operates in the directions $L_k \rightarrow R_k$ and $R_k \rightarrow L_k$ in the odd and even slots, respectively. Similarly, the spin $S_k = 1$ means that the kth link operates in the directions $R_k \rightarrow L_k$ and $L_k \rightarrow R_k$ in the odd and even slots, respectively.

The signal $\mathbf{y}_{R_k} \in \mathbb{C}^{N_{R_k} \times 1}$ received by the node R_k in an odd slot is given by

$$\mathbf{y}_{R_k} = \mathbf{H}_{R_k,L_k}\mathbf{x}_{L_k} + \sum_{j \in \mathcal{K}\setminus\{k\}} u(S_k, S_j)\mathbf{H}_{R_k,L_j}\mathbf{x}_{L_j} + \sum_{j \in \mathcal{K}\setminus\{k\}} u(S_k, -S_j)\mathbf{H}_{R_k,R_j}\mathbf{x}_{R_j} + \mathbf{z}_{R_k}, \quad (1)$$

where $\mathbf{x}_{L_k} \in \mathbb{C}^{N_{L_k} \times 1}$ and $\mathbf{x}_{R_k} \in \mathbb{C}^{N_{R_k} \times 1}$ are the vectors transmitted by the nodes L_k and R_k, respectively; $\mathbf{H}_{R_k,L_j} \in \mathbb{C}^{N_{R_k} \times N_{L_j}}$ and $\mathbf{H}_{R_k,R_j} \in \mathbb{C}^{N_{R_k} \times N_{R_j}}$ are the channel response matrices from the nodes L_j and R_j to the node R_k, respectively; and $\mathbf{z}_{R_k} \sim \mathcal{CN}(\mathbf{0}, \mathbf{I})$ is the noise signal at the node R_k. We also define the function $u(a, b) = 1 - (a-b)^2/4$ for binary variables $a, b \in \{-1, 1\}$ that returns 1 if $a = b$ and 0 otherwise. The signal $\mathbf{y}_{L_k} \in \mathbb{C}^{N_{L_k} \times 1}$ received by the node L_k in an even slot is similarly given with the definition of the channel matrices $\mathbf{H}_{L_k,R_j} \in \mathbb{C}^{N_{L_k} \times N_{R_j}}$ and $\mathbf{H}_{L_k,L_j} \in \mathbb{C}^{N_{L_k} \times N_{L_j}}$.

The node L_k generates a message $M_{L_k} \in \{1, \ldots, 2^{n\mathtt{R}_{L_k}}\}$ to be communicated to the node R_k, where n is a coding block length and $\mathtt{R}_{L_k}$ is the rate of message M_{L_k}. The message M_{L_k} is then encoded to produce a codeword $\mathbf{s}_{L_k} \in \mathbb{C}^{d_{L_k} \times 1}$, where d_{L_k} is the number of data streams with $d_{L_k} \leq \min(N_{L_k}, N_{R_k})$. For simplicity, we assume a Gaussian encoding such that the signal $\mathbf{s}_{L_k}$ is distributed as $\mathbf{s}_{L_k} \sim \mathcal{CN}(\mathbf{0}, \mathbf{I})$. Also, the message $M_{R_k} \in \{1, \ldots, 2^{n\mathtt{R}_{R_k}}\}$ intended for the node L_k is generated and encoded by the node

R_k to create the encoded signal $\mathbf{s}_{R_k} \in \mathbb{C}^{d_{R_k}\times 1}$ distributed as $\mathbf{s}_{R_k} \sim \mathcal{CN}(\mathbf{0},\mathbf{I})$ with $d_{R_k} \le \min(N_{R_k}, N_{L_k})$.

In order to enable inter-link interference management, the node L_k performs linear precoding as $\mathbf{x}_{L_k} = \mathbf{F}_{L_k}\mathbf{s}_{L_k}$, where $\mathbf{F}_{L_k} \in \mathbb{C}^{N_{L_k}\times d_{L_k}}$ is the precoding matrix. We impose a transmit power constraint as $E\left[\|\mathbf{x}_{L_k}\|^2\right] = \mathrm{tr}\left(\mathbf{F}_{L_k}\mathbf{F}_{L_k}^\dagger\right) \le P_{L_k}$. The linear precoding process and the power constraint at the node R_k can be similarly described as $\mathbf{x}_{R_k} = \mathbf{F}_{R_k}\mathbf{s}_{R_k}$ and $\mathrm{tr}\left(\mathbf{F}_{R_k}\mathbf{F}_{R_k}^\dagger\right) \le P_{R_k}$, respectively.

Based on the received signal $\mathbf{y}_{R_k}$, the node R_k performs linear decoding to obtain an estimate $\hat{\mathbf{s}}_{L_k}$ of $\mathbf{s}_{L_k}$ as $\hat{\mathbf{s}}_{L_k} = \mathbf{G}_{R_k}^\dagger\mathbf{y}_{R_k}$, where $\mathbf{G}_{R_k} \in \mathbb{C}^{N_{R_k}\times d_{L_k}}$ is the decoding matrix. Similarly, the node L_k linearly processes its received signal $\mathbf{y}_{L_k}$ to obtain $\hat{\mathbf{s}}_{R_k} = \mathbf{G}_{L_k}^\dagger\mathbf{y}_{L_k}$, with the decoding matrix $\mathbf{G}_{L_k} \in \mathbb{C}^{N_{L_k}\times d_{R_k}}$.

III. Problem Description and Optimization

To express the achievable rates, we define the mean squared error (MSE) matrix for the signal $\mathbf{s}_{L_k}$ as

$$\begin{aligned}
&\mathbf{E}_{L_k}(\mathbf{F},\mathbf{G},\mathbf{S}) \triangleq E\left[(\hat{\mathbf{s}}_{L_k} - \mathbf{s}_{L_k})(\hat{\mathbf{s}}_{L_k} - \mathbf{s}_{L_k})^\dagger\right] \\
&= \mathbf{Q}\left(\mathbf{G}_{R_k}^\dagger\mathbf{H}_{R_k,L_k}\mathbf{F}_{L_k} - \mathbf{I}\right) + \mathbf{Q}(\mathbf{G}_{R_k}^\dagger) \\
&+ \sum_{j\in\mathcal{K}\setminus\{k\}} u(S_k,S_j)\mathbf{Q}\left(\mathbf{G}_{R_k}^\dagger\mathbf{H}_{R_k,L_j}\mathbf{F}_{L_j}\right) \\
&+ \sum_{j\in\mathcal{K}\setminus\{k\}} u(S_k,-S_j)\mathbf{Q}\left(\mathbf{G}_{R_k}^\dagger\mathbf{H}_{R_k,R_j}\mathbf{F}_{R_j}\right),
\end{aligned} \tag{2}$$

where we have defined the function $\mathbf{Q}(\mathbf{X}) \triangleq \mathbf{X}\mathbf{X}^\dagger$ and the variables $\mathbf{F} \triangleq \{\mathbf{F}_{L_k}, \mathbf{F}_{R_k}\}_{k\in\mathcal{K}}$, $\mathbf{G} \triangleq \{\mathbf{G}_{L_k}, \mathbf{G}_{R_k}\}_{k\in\mathcal{K}}$ and $\mathbf{S} \triangleq [S_1\, S_2\, \ldots\, S_K]^T$. The MSE matrix $\mathbf{E}_{R_k}(\mathbf{F},\mathbf{G},\mathbf{S})$ for the signal $\mathbf{s}_{R_k}$ can be similarly defined.

For given precoders $\mathbf{F}$ and spin variables $\mathbf{S}$, the optimal decoding matrices $\mathbf{G}_{R_k}^*(\mathbf{F},\mathbf{S})$ and $\mathbf{G}_{L_k}^*(\mathbf{F},\mathbf{S})$ that minimize the sums $\mathrm{tr}(\mathbf{E}_{L_k}(\mathbf{F},\mathbf{G},\mathbf{S}))$ and $\mathrm{tr}(\mathbf{E}_{R_k}(\mathbf{F},\mathbf{G},\mathbf{S}))$ of MSEs are given as

$$\begin{aligned}
&\mathbf{G}_{R_k}^*(\mathbf{F},\mathbf{S}) \\
&= \left(\begin{array}{c} \mathbf{Q}\left(\mathbf{H}_{R_k,L_k}\mathbf{F}_{L_k}\right) + \mathbf{I} + \\ \sum_{j\in\mathcal{K}\setminus\{k\}} \left(\begin{array}{c} u(S_k,S_j)\mathbf{Q}\left(\mathbf{H}_{R_k,L_j}\mathbf{F}_{L_j}\right) + \\ u(S_k,-S_j)\mathbf{Q}\left(\mathbf{H}_{R_k,R_j}\mathbf{F}_{R_j}\right) \end{array}\right) \end{array}\right)^{-1} \\
&\times \mathbf{H}_{R_k,L_k}\mathbf{F}_{L_k},
\end{aligned} \tag{3}$$

$$\begin{aligned}
&\mathbf{G}_{L_k}^*(\mathbf{F},\mathbf{S}) \\
&= \left(\begin{array}{c} \mathbf{Q}\left(\mathbf{H}_{L_k,R_k}\mathbf{F}_{R_k}\right) + \mathbf{I} + \\ \sum_{j\in\mathcal{K}\setminus\{k\}} \left(\begin{array}{c} u(S_k,S_j)\mathbf{Q}\left(\mathbf{H}_{L_k,R_j}\mathbf{F}_{R_j}\right) + \\ u(S_k,-S_j)\mathbf{Q}\left(\mathbf{H}_{L_k,L_j}\mathbf{F}_{L_j}\right) \end{array}\right) \end{array}\right)^{-1} \\
&\times \mathbf{H}_{L_k,R_k}\mathbf{F}_{R_k}.
\end{aligned} \tag{4}$$

Then, the maximum achievable rate $\mathtt{R}_{L_k}$ of the message M_{L_k} without interference decoding is known as (see, e.g., [4])

$$\mathtt{R}_{L_k} = f_{L_k}(\mathbf{F},\mathbf{S}) \triangleq I\left(\mathbf{s}_{L_k};\mathbf{y}_{R_k}\right) = \log_2\det\left(\mathbf{E}_{L_k}^{-1}(\mathbf{F},\mathbf{G}^*,\mathbf{S})\right), \tag{5}$$

where we defined the notation $\mathbf{G}^* \triangleq \{\mathbf{G}_{L_k}^*(\mathbf{F},\mathbf{G}), \mathbf{G}_{R_k}^*(\mathbf{F},\mathbf{G})\}_{k\in\mathcal{K}}$. Similarly, the maximum achievable rate $\mathtt{R}_{R_k}$ of the message M_{R_k} is given as $\mathtt{R}_{R_k} = f_{R_k}(\mathbf{F},\mathbf{S}) \triangleq \log_2\det\left(\mathbf{E}_{R_k}^{-1}(\mathbf{F},\mathbf{G}^*,\mathbf{S})\right)$.

We aim at optimizing the spin variables $\mathbf{S}$ and linear precoding matrices $\{\mathbf{F}_{L_k}, \mathbf{F}_{R_k}\}_{k\in\mathcal{K}}$ with the goal of maximizing the minimum rate $\mathtt{R}_{\min}$ defined as

$$\mathtt{R}_{\min} = \min_{i\in\mathcal{L}\cup\mathcal{R}} \mathtt{R}_i, \tag{6}$$

while satisfying the power and rate constraints. The problem is stated as

$$\begin{aligned}
&\underset{\mathbf{F},\mathbf{S},\mathtt{R}_{\min}}{\text{maximize}}\ \mathtt{R}_{\min} && \text{(7a)}\\
&\text{s.t.}\ \ \mathtt{R}_{\min} \le f_i(\mathbf{F},\mathbf{S}),\ i\in\mathcal{L}\cup\mathcal{R}, && \text{(7b)}\\
&\qquad \mathrm{tr}\left(\mathbf{F}_i\mathbf{F}_i^\dagger\right) \le P_i,\ \ i\in\mathcal{L}\cup\mathcal{R}, && \text{(7c)}\\
&\qquad S_k \in \{-1,1\},\ k\in\mathcal{K}, && \text{(7d)}
\end{aligned}$$

where we have defined the variable $\mathtt{R} \triangleq \{\mathtt{R}_{L_k}, \mathtt{R}_{R_k}\}_{k\in\mathcal{K}}$.

It is difficult to solve the problem (7) since it requires an exhaustive search with respect to the binary spin variables $\mathbf{S} \in \{-1,1\}^K$. To resolve this problem, as in [5], we adopt a change of variable $\tilde{\mathbf{S}} = \mathbf{S}\mathbf{S}^\dagger$ to model the binary constraints on the vector $\mathbf{S}$ as

$$\mathrm{rank}(\tilde{\mathbf{S}}) = 1, \tag{8}$$

$$\tilde{\mathbf{S}} \succeq \mathbf{0},\ \mathrm{diag}(\tilde{\mathbf{S}}) = \mathbf{1}. \tag{9}$$

Then, with the aim of obtaining a tractable problem, we adopt a rank-relaxation by removing the condition (8) (see, e.g., [5, Sec. III]) which is non-convex with respect to the variable $\tilde{\mathbf{S}}$. We also note that the functions $u(S_k,S_j)$ and $u(S_k,-S_j)$ can be expressed with respect to $\tilde{\mathbf{S}}$ as

$$u(S_k,tS_j) = \tilde{u}_{k,j,t}(\tilde{\mathbf{S}}) \triangleq 1 - \frac{1}{4}(\mathbf{e}_k - t\mathbf{e}_j)^\dagger\tilde{\mathbf{S}}(\mathbf{e}_k - t\mathbf{e}_j), \tag{10}$$

for $t \in \{-1,1\}$, where we defined the vector $\mathbf{e}_k \in \mathbb{C}^{K\times 1}$ as the kth column of an identity matrix of dimension K. We also define the modified MSE functions $\mathbf{E}_{L_k}(\mathbf{F},\mathbf{G},\tilde{\mathbf{S}})$ and $\mathbf{E}_{R_k}(\mathbf{F},\mathbf{G},\tilde{\mathbf{S}})$ which are obtained by replacing the functions $u(S_k,S_j)$ and $u(S_k,-S_j)$ with $\tilde{u}_{k,j,1}(\tilde{\mathbf{S}})$ and $\tilde{u}_{k,j,-1}(\tilde{\mathbf{S}})$, respectively, in the original MSE matrices $\mathbf{E}_{L_k}(\mathbf{F},\mathbf{G},\mathbf{S})$ and $\mathbf{E}_{R_k}(\mathbf{F},\mathbf{G},\mathbf{S})$. The optimal decoding matrices $\tilde{\mathbf{G}}_{R_k}^*(\mathbf{F},\tilde{\mathbf{S}})$ and $\tilde{\mathbf{G}}_{L_k}^*(\mathbf{F},\tilde{\mathbf{S}})$ with respect to $\tilde{\mathbf{S}}$ are similarly defined from (3) and (4), respectively.

For the rate constraints (7b) which are also non-convex, we apply the Fenchel Conjugate lemma [6] to obatin equivalent constraints

$$\mathtt{R}_i \le \max_{\mathbf{\Omega}_i\succeq\mathbf{0}} g_i\left(\mathbf{F},\mathbf{G}^*,\tilde{\mathbf{S}},\mathbf{\Omega}_i\right),\ i\in\mathcal{L}\cup\mathcal{R}, \tag{11}$$

with the functions $g_i(\mathbf{F},\mathbf{G}^*,\tilde{\mathbf{S}},\mathbf{\Omega}_i)$, $i\in\mathcal{L}\cup\mathcal{R}$, defined as

$$\begin{aligned}
g_i\left(\mathbf{F},\mathbf{G}^*,\tilde{\mathbf{S}},\mathbf{\Omega}_i\right) =& -\frac{1}{\ln 2}\mathrm{tr}\left(\mathbf{\Omega}_i\tilde{\mathbf{E}}_i(\mathbf{F},\mathbf{G}^*,\tilde{\mathbf{S}})\right) \\
&+ \log_2\det(\mathbf{\Omega}_i) + \frac{1}{\ln 2}d_i.
\end{aligned}$$

Algorithm 1 Alternating update algorithm for problem (13)

1. Initialize the precoding matrices $\mathbf{F}^{(t)}$ such that the power constraints (13c) are satisfied.
2. Initialize the spin matrix $\tilde{\mathbf{S}}^{(t)} = \mathbf{I}$ and set $t \leftarrow 1$.
3. Update the decoding matrices $\mathbf{G}^{(t+1)}$ according to (3) and (4) with $u(S_k, S_j)$ and $u(S_k, -S_j)$ with $\tilde{u}_{k,j,1}(\tilde{\mathbf{S}}^{(t)})$ and $\tilde{u}_{k,j,-1}(\tilde{\mathbf{S}}^{(t)})$, respectively.
4. Update the variables $\mathbf{\Omega}^{(t+1)}$ according to (12).
5. Update the precoding matrices $\mathbf{F}^{(t+1)}$ as a solution of the convex problem (13) for fixed $\mathbf{G} = \mathbf{G}^{(t+1)}$, $\mathbf{\Omega} = \mathbf{\Omega}^{(t+1)}$ and $\tilde{\mathbf{S}} = \tilde{\mathbf{S}}^{(t)}$.
6. Update the spin matrix $\tilde{\mathbf{S}}^{(t+1)}$ as a solution of the convex problem (13) for fixed $\mathbf{G} = \mathbf{G}^{(t+1)}$, $\mathbf{\Omega} = \mathbf{\Omega}^{(t+1)}$ and $\mathbf{F} = \mathbf{F}^{(t+1)}$.
7. Go to Step 8 if a convergence criterion is satisfied. Otherwise, set $t \leftarrow t+1$ and go back to Step 3.
8. Get a feasible spin vector $\mathbf{S}$ from $\tilde{\mathbf{S}}^{(t+1)}$ such that $||\tilde{\mathbf{S}}^{(t+1)} - \mathbf{S}\mathbf{S}^{\dagger}||_F^2$ is minimized, and update the variables $\mathbf{G}$, $\mathbf{\Omega}$ and $\mathbf{F}$ by repeating the Steps 2, 3 and 5.

We note that the right-hand sides in (11) are maximized when the matrices $\mathbf{\Omega}_i$ are given as

$$\mathbf{\Omega}_i = \tilde{\mathbf{E}}_i(\mathbf{F}, \mathbf{G}^*, \tilde{\mathbf{S}})^{-1}. \quad (12)$$

As a result, we obtain the problem stated as

$$\underset{\mathbf{F},\mathbf{G},\tilde{\mathbf{S}},\mathbf{\Omega},\mathtt{R}_{\min}}{\text{maximize}} \quad \mathtt{R}_{\min} \quad (13a)$$

$$\text{s.t.} \quad \mathtt{R}_{\min} \leq g_i\left(\mathbf{F}, \mathbf{G}, \tilde{\mathbf{S}}, \mathbf{\Omega}_i\right), \ i \in \mathcal{L} \cup \mathcal{R}, \quad (13b)$$

$$\text{tr}\left(\mathbf{F}_i \mathbf{F}_i^{\dagger}\right) \leq P_i, \ i \in \mathcal{L} \cup \mathcal{R}, \quad (13c)$$

$$\tilde{\mathbf{S}} \succeq \mathbf{0}, \ \ \text{diag}(\tilde{\mathbf{S}}) = \mathbf{1}. \quad (13d)$$

where we define the variables $\mathbf{\Omega} \triangleq \{\mathbf{\Omega}_{L_k}, \mathbf{\Omega}_{R_k}\}_{k \in K}$. Note that we have removed the superscript $*$ in the decoding matrices $\mathbf{G}$ by including them into the optimization variables.

The problem (13) is still non-convex, but solving it with respect to one of the variables $\mathbf{F}$, $\mathbf{G}$, $\mathbf{\Omega}$ and $\tilde{\mathbf{S}}$ for fixed others is convex. Based on this observation, we propose an iterative algorithm which alternately updates the variables $\mathbf{F}$, $\mathbf{G}$, $\mathbf{\Omega}$ and $\tilde{\mathbf{S}}$ at each iteration to obtain monotonically non-decreasing objective values with respect to the number of iterations. The detailed algorithm is described in **Algorithm 1**.

IV. Numerical Results

Fig. 1 shows link-level simulation results by plotting the average minimum rate $\mathtt{R}_{\min}$ versus the signal-to-noise ratio (SNR) P for a two-way interference network with $N_{L_k} = N_{R_k} = 1$ and $d_{L_k} = d_{R_k} = 1$. For simulation, we consider 100m$\times$100m rectangular area in which $2K$ nodes $\mathcal{L} \cup \mathcal{R}$ are randomly located with the condition that each pair (L_k, R_k) has the distance of 10m. We assume a Rayleigh fading channel with the path loss model $1/(1+(D/D_{\text{ref}})^3)$ with the reference distance $D_{\text{ref}} = 50$m, where D represents the propagation distance.

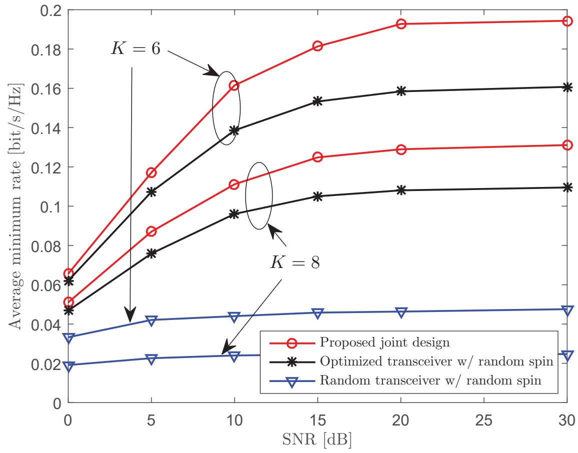

Figure 1. Average minimum rate $\mathtt{R}_{\min}$ versus the SNR P for a two-way interference network with $N_{L_k} = N_{R_k} = 1$ and $d_{L_k} = d_{R_k} = 1$.

For comparison, we show the performance of some conventional schemes: i) *Optimized transceiver with random spin* in which the spin variables $\mathbf{S}$ are randomly fixed and then the linear transceiver variables are optimized according to **Algorithm 1** for the fixed spin; ii) *Random transceiver with random spin* in which both the spin and linear transceiver variables are randomly set. It is seen that, as the SNR increases, the advantage of the proposed joint design compared to the conventional schemes is more pronounced. Also, it is worth noting that the achievable minimum rate $R_{\min}$ is degraded as the number K of interfering links increases due to the increased number of constraints in (13b).

V. Conclusion

We have studied the joint optimization of the interference scheduling and linear transceiver matrices with the criterion of maximizing the worst-link achievable rate while satisfying the power constraints at all the transmitting nodes. Since it is hard to tackle the problem due to the discrete binary constraints, we proposed change of variables and rank-relaxation to derive an efficient iterative algorithm and confirmed the advantages of the proposed algorithm via link-level simulation results.

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