Relaying with Distributed Interference Alignment in Multi-node Networks

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Abstract—A system with multiple transmitters (i.e. base stations) and multiple receivers (mobile nodes) is considered. The transmitter-receiver pairs are assumed to operate using the same resources without any coordination and hence the receivers unavoidably experience interference from undesired transmitters. A MIMO relaying scheme is proposed to manage the interference in the network by judiciously optimizing the relay precoding matrix and aligning the interference at each receiver simultaneously. It is shown that the proposed scheme provides a closed-form optimal precoding matrix. Moreover, the numerical results for various scenarios show that the scheme performs better than the considered baseline schemes for most of the channel conditions.

I. INTRODUCTION

The potential of relaying to combat fundamental limitations in wireless links such as fading and pathloss has put the related research in high priority in the recent decade. Cover and El Gamal [1] proposed a comprehensive achievable scheme by incorporating the decode-and-forward and compress-and-forward techniques. The application of the information theoretical techniques to wireless systems was first studied by Sendonaris et.al. [2], which initiated significant research effort that resulted in various practical relaying schemes and also novel information theoretical results (see [4] and references therein).

Interference is a fundamental paradigm in wireless communication systems and several techniques have been proposed to manage interference. Among these techniques, interference alignment has been shown to achieve the degrees of freedom upper bound for several interference limited systems such as the 3 user interference channel and X channel [8], [9]. In this scheme, each transmitter composes its signal in such a way that the interference at each destination aligns in the subspace that is orthogonal to the desired signal space. Despite its significant performance gain, the optimal schemes proposed require high complexity techniques such as transmission over several orthogonal time slots [8] or dirty-paper coding [9].

Recently, relays have been considered to manage the interference among multiple interfering nodes [5][6][7][10]. It is shown that in addition to helping direct transmission for each transmitter-receiver pair via signal relaying, relays can additionally ensure the mitigation of interference at the receivers by a novel approach called interference forwarding. However, such interference mitigation techniques require non-linear successive interference cancelation (SIC) at the receivers which brings significant complexity to the overall system.

In this work, we propose a distributed interference alignment scheme to manage interference in multiple source-destination networks. We assume that the destinations (also denoted as user-equipment, UE, throughout the paper) do not employ a SIC scheme and the transmitters, i.e., base-stations (BS), do not share information and therefore are not able to perform interference alignment. Instead, relay nodes are used to provide such an alignment at the destinations in a distributed manner. By exploiting half-duplex, decode-and-forward (DF) and MIMO relaying, we show that the composite desired and interfering signals aggregated over two time slots can be aligned such that after applying a linear filter at the receiver, the interfering signal can be eliminated completely. We further show that the corresponding precoding matrix used at the relay can be obtained in a closed form. In order to compare the throughput gain achieved by the proposed scheme, two benchmark schemes are considered. In the first scheme, which is also investigated in [11] to obtain the degrees-of-freedom of the full-duplex system, the precoding matrix at the relay is optimized to maximize the overall throughput in the system by exploiting the global channel state information (CSI). However, due to the non-convexity of the throughput expression, it is not possible to obtain a closed form expression for the optimal precoding relay matrix. The second benchmark scheme assumes that the relay does not have any CSI, and hence transmits with
a predetermined precoding matrix. We show via numerical results that, the proposed technique outperforms the benchmark schemes for most channel conditions depending on the relay power.

The paper is organized as follows. In Section II, the system model is presented. In Section III, the details of the proposed transmission technique and the two benchmark schemes are explained. Section IV is dedicated to numerical results and performance comparison. We conclude the paper in Section V.

Notation: The vectors and matrices are denoted by bold letters in the paper, i.e., $\mathbf{X}$, $\mathbf{X}^*$ is the complex conjugate and $\mathbf{X}^T$ is the transpose of the vector $\mathbf{X}$, respectively.

II. SYSTEM MODEL

We investigate a two-cell downlink scenario where the base stations (BS$_i$, $i = 1, 2$) at each cell communicate with their assigned mobile users (UE$_i$, $i = 1, 2$) as shown in Fig. 1. We assume that the adjacent cells operate in the same resource blocks, i.e. time and frequency, satisfying a frequency reuse factor of 1 and the BS and UEs are equipped with single antenna. For $i = 1, 2$, BS$_i$ wishes to send a message $W_i$ drawn uniformly from the set $[1, 2^{nR_i}]$ to its destination UE$_i$, where $n$ is the number of channel uses and $R_i$ denotes the achievable rate. An in-band relay node [2] with two antennas assists both BS and UE pairs simultaneously by operating in the resource block of the cells. The relay uses a half-duplex decode-and-forward (DF) technique [1] and hence decodes the messages transmitted by both BSs in the first time slot (Phase 1) which is defined as $[0, T_o]$. The channels between the nodes are AWGN and the received signals during the first phase, $[0, T_o]$, are given by,

\begin{align}
    \mathbf{Y}_R &= \mathbf{h}_{1R} \mathbf{X}_1 + \mathbf{h}_{2R} \mathbf{X}_2 + \mathbf{Z}_R \\
    \mathbf{Y}_1 &= \mathbf{h}_{11} \mathbf{X}_1 + \mathbf{h}_{12} \mathbf{X}_2 + Z_1 \\
    \mathbf{Y}_2 &= \mathbf{h}_{12} \mathbf{X}_1 + \mathbf{h}_{22} \mathbf{X}_2 + Z_2,
\end{align}

where $X_i$, $i = 1, 2$ is the input signal of the BS$_i$ satisfying the power constraint $E(|X_i|^2) \leq P_i$, and $Z_i$ is an iid Gaussian noise process with unit power. We represent $\mathbf{h}_{1R} = [h_{1R,1}, h_{1R,2}]$ and $\mathbf{h}_{2R} = [h_{2R,1}, h_{2R,2}]$ as the channels from BS$_1$ and BS$_2$ to the relay whereas $h_{ij}$, $i, j = 1, 2$, denote the channels between BS$_i$ and UE$_j$ and $h_{iR,a}$, $a = 1, 2$ denotes the channels between the nodes and relay antennas.

In the second time slot (Phase 2), $[T_o, T]$, we assume that the BSs do not transmit any messages and only the relay transmits its signal $\mathbf{X}_R$ which is received at the UEs as follows,

\begin{align}
    \mathbf{Y}_1' &= \mathbf{h}_{R1} \mathbf{X}_R + Z_1' \\
    \mathbf{Y}_2' &= \mathbf{h}_{R2} \mathbf{X}_R + Z_2',
\end{align}

where $\mathbf{h}_{R1} = [h_{R1,1}, h_{R1,2}]$ and $\mathbf{h}_{R2} = [h_{R2,1}, h_{R2,2}]$ are the channels between the relay and UE$_1$, UE$_2$, respectively and $[h_{Ri,1}, h_{Ri,2}]$ denotes the channel coefficients between the receive antenna of UE$_i$ and the two transmit antennas of the relay node. Here, $Z_i'$ is an iid Gaussian noise process with unit power experienced at the UEs’ during the second phase.

The relay transmit signal $\mathbf{X}_R$ satisfies the power constraint such that $\text{tr}(E(\mathbf{X}_R \mathbf{X}_R^H)) \leq P_R$. For simplicity, we assume $T_o = T/2$ throughout the analysis. It is assumed that BS$_i$ has channel state information (CSI) of the forward channels to the its desired destination and to the relay, i.e. $h_{ii}$, $h_{iR}$, respectively and the UEs have perfect channel state information of the links from both BSs. On the other hand, in order to fully capitalize on the benefits due to relaying, the relay is assumed to have CSI corresponding to BS-to-UE links, i.e. $h_{ij}$, $i, j = 1, 2$.

III. DISTRIBUTED INTERFERENCE ALIGNMENT SCHEME

As the base stations perform their transmissions independently in the first time slot without any type of coordination, the transmitted signals interfere with each other at the destinations. Due to the broadcast nature of the transmission, the relay receives the signals from both base stations. In the first time slot, the communication between the base stations and the relay can be represented as a multiple access communication and the capacity can be written as assuming $E(\mathbf{Z}_R \mathbf{Z}_R^H) = \mathbf{I}$,

\begin{align}
    R_1^* &\leq 0.5 \log \left(1 + (|h_{1R,1}|^2 + |h_{1R,1}|^2)P_1\right) \\
    R_2^* &\leq 0.5 \log \left(1 + (|h_{2R,1}|^2 + |h_{2R,2}|^2)P_2\right) \\
    R_1^* + R_2^* &\leq 0.5 \log \det (\mathbf{I} + \mathbf{HK}_S \mathbf{H}^*)
\end{align}

where $\mathbf{H} = [\mathbf{h}_{1R} \mathbf{h}_{2R}]^T$, $\mathbf{K}_S = \text{diag}(P_1, P_2)$ and $\mathbf{I}$ is the identity matrix. Assuming that the relay is able to...
decode the messages in the first time slot, it is able to perform a transmission strategy so that the desired and interfering signals can be separated by the UEs at the end of the second time slot. Such a transmission strategy is to apply precoding at the relay node and transmit a linear combination of the two messages, \( \mathbf{X}_R \). The precoding matrix is designed such that the received signals over two time slots are aligned properly at the destinations and the interfering signals may be eliminated completely by applying appropriate linear filters at the receivers. The precoding and decoding operations are explained in what follows.

Assuming that the relay successfully decodes the messages transmitted by the base stations in the first time slot \([0, T_0]\) and it then applies a precoding matrix to the conjugates of the decoded messages before transmitting the composite signals. Then, the signal transmitted by the relay node in the second time slot \([T_0, T]\) can be written as,

\[
\mathbf{X}_R = \begin{bmatrix}
t_{11}X_1^t + t_{12}X_2^t \\
t_{21}X_1^s + t_{22}X_2^s
\end{bmatrix}
\]

(9)

where \( t = \begin{bmatrix} t_{11} & t_{12} \\ t_{21} & t_{22} \end{bmatrix} \) is the precoding matrix. The received signals at UE1 and UE2, denoted as \( Y_1' \) and \( Y_2' \), respectively can then be written as,

\[
Y_1' = (h_{R1,1}t_{11} + h_{R1,2}t_{21})X_1^t + (h_{R1,1}t_{12} + h_{R1,2}t_{22})X_2^s + Z_1'
\]

(10)

\[
Y_2' = (h_{R2,1}t_{11} + h_{R2,2}t_{21})X_1^t + (h_{R2,1}t_{12} + h_{R2,2}t_{22})X_2^s + Z_2'.
\]

(11)

Over two time slots, the destinations receive signals transmitted by the base stations as shown in (1)-(3) and transmitted by the relay as shown in (4) and (5). The goal is to design the precoding matrix \( t \) such that when these two signals are combined appropriately, the interfering signal is eliminated completely. To achieve this goal, it is sufficient for the following equations to hold

\[
\begin{bmatrix} h_{R1,1} & h_{R1,2} \\ h_{R2,1} & h_{R2,2} \end{bmatrix} \begin{bmatrix} t_{11} & t_{12} \\ t_{21} & t_{22} \end{bmatrix} = k \begin{bmatrix} h_{21} & -h_{11} \\ h_{22} & -h_{12} \end{bmatrix}
\]

(12)

where \( k \) is a parameter used to satisfy the total power constraint of the relay node. Then, the received signals at the UEs in Phase 2 can be written as,

\[
Y_1' = kh_{21}X_1^t - kh_{11}X_2^s + Z_1'
\]

(13)

\[
Y_2' = kh_{22}X_1^s - kh_{12}X_2^s + Z_2'.
\]

(14)

Combining (2), (3), (13), and (14), the overall received signals at the destinations over two time slots is then written as,

\[
\begin{bmatrix} Y_1' \\ Y_1'' \end{bmatrix} = \begin{bmatrix} X_1 & X_2 \\ -kX_2^* & kX_1^* \end{bmatrix} \begin{bmatrix} h_{11} & [Z_1] \\ h_{21} & [Z_1'] \end{bmatrix} + \begin{bmatrix} Z_1 \\ Z_1' \end{bmatrix}
\]

(15)

\[
\begin{bmatrix} Y_2' \\ Y_2'' \end{bmatrix} = \begin{bmatrix} X_1 & X_2 \\ -kX_2^* & kX_1^* \end{bmatrix} \begin{bmatrix} h_{12} & [Z_2] \\ h_{22} & [Z_2'] \end{bmatrix} + \begin{bmatrix} Z_2 \\ Z_2' \end{bmatrix}
\]

(16)

**Decoding at the UEs:**

Before applying a receive filter to the overall signal, the UEs first apply a conjugate operation on the signals received in the second time slot resulting on (13), and (14) to be modified as follows

\[
\begin{bmatrix} Y_1' \\ Y_1''' \end{bmatrix} = \begin{bmatrix} h_{11} & h_{21} \\ kh_{21} & -kh_{11} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + \begin{bmatrix} Z_1 \\ Z_1' \end{bmatrix}
\]

(17)

\[
\begin{bmatrix} Y_2' \\ Y_2''' \end{bmatrix} = \begin{bmatrix} h_{12} & h_{22} \\ kh_{22} & -kh_{12} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + \begin{bmatrix} Z_2 \\ Z_2' \end{bmatrix}
\]

(18)

From (17) and (18) we see that \( X_1 \) and \( X_2 \) can be extracted interference free at UE1 and UE2, respectively, by applying such linear filters that the interfering signal components are cancelled completely. To this end, the following receive processing can be employed at the UE1 and UE2, respectively,

\[
[kh_{11}, h_{21}] \begin{bmatrix} Y_1' \\ Y_1''' \end{bmatrix} = k(\sqrt{|h_{11}|^2 + |h_{21}|^2})X_1 + kh_{11}Z_1 + h_{21}Z_1^*
\]

(19)

\[
[kh_{22}, -h_{12}] \begin{bmatrix} Y_2' \\ Y_2''' \end{bmatrix} = k(\sqrt{|h_{22}|^2 + |h_{12}|^2})X_2 + kh_{12}Z_2 + h_{21}Z_2^*
\]

(20)

From (19) and (20), it can be seen that the interfering signal is cancelled completely and only the desired signal and the noise remain after the filtering operation. Note that in the special case when \( k=1 \), the transmission becomes similar to Alamouti coding.

Assuming \( E(|Z_1|^2) = E(|Z_2|^2) = 1 \), and that Gaussian inputs are used at the transmitters, the achievable rates can be written as follows from (19) and (20),

\[
R_1^{UE}(k) \leq 0.5 \log \left( 1 + \frac{|k|^2 (|h_{11}|^2 + |h_{21}|^2)^2 P_1}{|kh_{11}|^2 + |h_{21}|^2} \right)
\]

(21)

\[
R_2^{UE}(k) \leq 0.5 \log \left( 1 + \frac{|k|^2 (|h_{22}|^2 + |h_{12}|^2)^2 P_2}{|kh_{22}|^2 + |h_{12}|^2} \right)
\]

(22)

The objective is to maximize the sum rate \((R_1 + R_2)\) which is constrained by the multiple-access rates at the relay given in (6)-(8) and the achievable rates at the
receivers in (21) and (22) subject to the relay power constraint,
\[
\max_k \left( R_i^r + R_{2i}^r, \min \left( R_{1i}^r, R_{1i}^{UE}(k) \right) + \min \left( R_{2i}^r, R_{2i}^{UE}(k) \right) \right) \leq P_R.
\]  
(23)

While maximizing the sum rate, the first constraint is due to maximum total power of the relay which can be written as,
\[
\left( |t_{11}|^2 P_1 + |t_{12}|^2 P_2 + |t_{21}|^2 P_1 + |t_{22}|^2 P_2 \right) \leq P_R \tag{24}
\]
and the second constraint is due to the design of the precoding matrix from (12) which can be written as,
\[
\begin{bmatrix}
    t_{11} & t_{12} \\
    t_{21} & t_{22}
\end{bmatrix} = \begin{bmatrix}
    h_{R1,1} & h_{R1,2} \\
    h_{R2,1} & h_{R2,2}
\end{bmatrix}^{-1} \begin{bmatrix}
    h_{21} & -h_{11} \\
    h_{22} & -h_{12}
\end{bmatrix}.
\]  
(25)

It is possible to obtain the closed form precoding matrix satisfying the desired conditions to align the interference as follows. From (21) and (22) we observe that the throughputs expressions are increasing functions of \( k \) and hence the largest \( k \) value satisfying (24) and (25) is in fact optimal which gives the optimal precoding matrix. Clearly from (25), each \( t_{ij}, i, j = 1, 2 \) can be explicitly written as a function of \( k \), so that (24) should be satisfied with equality which will lead to largest \( k \) value.

Remark: Note that it is possible to improve the achievable rates in (21) and (22) by incorporating selection relaying proposed in [1]. In particular, for the cases where transmitter-to-relay channels limit the transmission rates even with respect to direct transmission without the relay, the transmitters may choose not to exploit the relay and resume transmission in the second time slot. However in this work, we consider the cases where relaying is beneficial over direct communications only. Also, another possible way to improve the achievable rates is to allow the transmitters (base stations) to transmit during Phase 2. However, we assume no direct transmission takes place in this phase to clearly demonstrate the proposed distributed interference alignment scheme.

A. Baseline Schemes

In order to see the performance gain offered by the proposed distributed alignment scheme, we analyze two baseline schemes. The first baseline scheme preserves the CSI assumptions as in the proposed scheme, i.e. full CSI at the relay, whereas in the second scheme the relay does not have any CSI of the forward channels. The first baseline scheme is also considered in [12], where a full-duplex MIMO relay in an interference channel is analyzed. By optimizing the precoding matrix of the relay, the authors obtain the degrees-of-freedom of the considered model.

Baseline Scheme 1: Beamforming at the Relay

We generalize the achievable scheme given in [11] to account for half-duplex nature of the relay. Due to half-duplex nature in the system, the signal reception at the nodes during Phase 1 is given in (1)-(3), and similarly the decoding constraint at the relay remains as denoted in (6)-(8). However, during Phase 2, i.e where the relay transmits to the destination nodes as in (4)-(5), the relay is assumed to transmit using a precoding matrix,
\[
X_R = \begin{bmatrix}
    t_{11}X_1 + t_{12}X_2 \\
    t_{21}X_1 + t_{22}X_2
\end{bmatrix}
\]  
(26)
such that the received signals at UE1 and UE2 in the second phase \([T_0, T]\) are given by,
\[
Y_1' = (h_{R1,1} t_{11} + h_{R1,2} t_{12}) X_1 + (h_{R1,1} t_{12} + h_{R1,2} t_{22}) X_2 + Z_1' \tag{27}
\]
\[
Y_2' = (h_{R2,1} t_{11} + h_{R2,2} t_{21}) X_1 + (h_{R2,1} t_{12} + h_{R2,2} t_{22}) X_2 + Z_2'.
\]  
(28)
The destinations combine the signals received over two time slots \([0, T_0]\) and \([T_0, T]\), as given in (1)-(3), (27), and (28) using Maximal Ratio Combining (MRC) and assuming Gaussian inputs are used at the transmitters and \( E(Z_1'^2) = E(Z_2'^2) = 1 \), the following rates are achievable,
\[
R_1^{bf} \leq 0.5 \log \left( 1 + SNR_{11} + SNR_{12} \right) \tag{29}
\]
\[
R_2^{bf} \leq 0.5 \log \left( 1 + SNR_{21} + SNR_{22} \right)
\]  
(30)
where \( SNR_{11} = \frac{|h_{11}|^2 P_1}{|h_{21}|^2 P_2 + 1} \), \( SNR_{12} = \frac{|h_{12}|^2 P_2}{|h_{21}|^2 P_1 + 1} \), \( SNR_{21} = \frac{|h_{21}|^2 P_1}{|h_{22}|^2 P_2 + 1} \), and \( SNR_{22} = \frac{|h_{22}|^2 P_2}{|h_{21}|^2 P_1 + 1} \).

Then, the achievable sum rate, \( R_{tot}^{bf} \) is determined by,
\[
\max_{t_{11}, t_{12}, t_{21}, t_{22}} \left( R_1^r + R_2^r, \min \left( R_1^r, R_1^{bf} \right) + \min \left( R_2^r, R_2^{bf} \right) \right)
\]  
(31)
s.t. \( tr\{E(X_R X_R^*)\} \leq P_R \).

Baseline Scheme 2: Standard Relaying

In this scheme, we assume that the relay does not have forward CSI, and hence is not able to optimize its precoding matrix respectively. Therefore, a fixed precoding matrix is applied for relay transmission where
\[
t_{11}^r = 0.5 \sqrt{\frac{P_1}{P_T}}, \quad t_{12}^r = 0.5 \sqrt{\frac{P_2}{P_T}}, \quad t_{21}^r = 0.5 \sqrt{\frac{P_1}{P_T}}, \quad t_{22}^r = 0.5 \sqrt{\frac{P_2}{P_T}}.
\]  
(32)
and \( t_{22}^r = 0.5 \sqrt{\frac{P_2}{P_T}}. \) Then, the following sum rate is achievable for fixed precoding at the relay,
\[
R_{tot}^{bf} = R_{tot}^{bf}|_{t_{11}=t_{11}^r, t_{12}=t_{12}^r, t_{21}=t_{21}^r, t_{22}=t_{22}^r}.
\]
IV. NUMERICAL RESULTS

In this section, we evaluate the performance of the proposed scheme via numerical results. The proposed scheme given in Sec. III is compared with two baseline models discussed in Sec. III-A. The simulations are performed for Rayleigh fading channels with $h_{ij} = \sqrt{d_{ij}^{-\alpha}} A_{ij}$, $i, j = 1, 2$, where $A_{ij}$ is a complex Gaussian random variable with unit variance and zero mean, composed of iid. imaginary and real parts. $d_{ij}$ denotes the distance between the nodes $i$ and $j$, and we assume $\alpha = 4$.

In Fig. 2, we consider a symmetric system model with distances $d_{11} = d_{22} = 1$, $d_{1R,1} = d_{2R,2} = 0.5$, $d_{1R,2} = d_{2R,1} = 0.5$, $d_{R1,1} = d_{R2,2} = 0.5$, $d_{R1,2} = d_{R2,1} = 0.7$, and $P_1 = P_2 = P_R = 10$. The throughput of the proposed scheme in (23) (denoted by Dist. Alignment) is compared with the throughput of the baseline schemes as given in (31), (32). Initially, it can be observed that the gain due to CSI availability at the relay is substantial, which essentially provides precoding matrix optimization at the relay as discussed in Sec. III and III-A. On the other hand, when the CSI is available at the relay, the distributed alignment scheme outperforms joint precoding matrix optimization at the relay for $d_{12} > 0.5$. It should be noted that joint precoding matrix optimization does not lead to explicit solution for the optimal precoding values due to the non-convex throughput function (31), hence the corresponding throughput in Fig. 2 is obtained by exhaustive search. Note that this may lead to extensive delay which may not be practical in most scenarios. However, the distributed alignment technique provides explicit optimal $k$ value given in (24) satisfying the power constraint in (25) as discussed in Sec. III. One can observe that the benefit due to distributed alignment becomes more substantial with increasing $d_{12}$ up to $d_{12} = 1.5$. This is due to the fact that the relay precoding matrix aligns the desired signal in the direction of interfering link $d_{12}$ as opposed to the optimized precoding scheme where all signals in the interfering link direction is observed as interference. However, for $d_{12} > 1.5$, the relay power constraint in (24) becomes limiting factor for the $k$ value, hence the throughput gain diminishes with increasing $d_{12}$.

In Fig. 3, the throughput of the proposed scheme in (23) and baseline model given in (31) are compared for different $P_R$ values. For clarity, we omit the baseline model in (32). The schemes are evaluated for the distances given by $d_{11} = d_{22} = 1$, $d_{1R,1} = d_{2R,2} = 0.3$, $d_{1R,2} = d_{2R,1} = 0.5$, $d_{R1,1} = d_{R2,2} = 0.6$, $d_{R1,2} = d_{R2,1} = 0.8$, and $P_1 = P_2 = 10$, whereas $P_R \in \{1, 10, 100\}$. As argued, the larger $P_R$ value provides larger $k$ in (23) which leads to better throughput gains as in Fig. 3. Hence, it is possible to preserve the monotonically increasing characteristic of the proposed scheme with $d_{12}$ as the relay is allowed to transmit with higher powers. As Fig. 3 suggests, the sum rate increases with increasing interfering channel amplitude as long as the relay power is not limited. This result is the inline with the interesting approach reported in [12] where feedback of the decoded interfering message to the transmitter at the end of the first time slot was used.

![Fig. 2. Throughput comparison of the proposed scheme (23) with the baseline schemes (31) and (32). We assume a symmetric system with $d_{11} = d_{22} = 1$, $d_{1R,1} = d_{2R,2} = 0.5$, $d_{1R,2} = d_{2R,1} = 0.5$, $d_{R1,1} = d_{R2,2} = 0.5$, $d_{R1,2} = d_{R2,1} = 0.7$, $P_1 = P_2 = P_R = 10$, and $d_{12} = d_{21}$.](image1)

![Fig. 3. Throughput comparison of the proposed scheme (23) with the baseline scheme (31) for different relay powers, $P_R \in \{1, 10, 100\}$. We assume a symmetric system with $d_{11} = d_{22} = 1$, $d_{1R,1} = d_{2R,2} = 0.3$, $d_{1R,2} = d_{2R,1} = 0.5$, $d_{R1,1} = d_{R2,2} = 0.6$, $d_{R1,2} = d_{R2,1} = 0.8$, $P_1 = P_2 = 10$, and $d_{12} = d_{21}$.](image2)
to investigate the degrees of freedom of an interference channel with feedback.

V. CONCLUSION

In this paper, we proposed a distributed relaying scheme for multiple source-destination networks operating in the same resource block, hence affected by interference. The MIMO relay signal is designed to effectively align the interfering source signals in an orthogonal subspace of the desired signal at each destination. The proposed scheme provides higher throughput than the standard relaying schemes such as beamforming in certain channel condition. Moreover, the technique lends itself to a closed form optimized relay precoding matrix which reduces complexity at the relay transmitter. As future steps, it is possible to explore the performance of the proposed scheme for multiple antennas at the transmitters and receivers, in which case the relay similarly aligns the interference and desired signals in orthogonal subspaces. Moreover, the performance of the proposed scheme for limited channel state information at the relay and transmitters is another possible future direction.

REFERENCES