Interference Relay Channel in 4G Wireless Networks

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***Abstract*—In the next generation cellular systems, such as LTE-A (Release 10 and beyond), relay node (RN) deployment has been adopted due to its potentials in enlarging coverage and increasing system throughput, even with primitive relaying functionalities. For example, in LTE-A Release 10 only Type-I (non-transparent) RNs are considered wherein no cooperative transmission to the Donor evolved-NodeBs (DeNBs) is allowed. In this paper, we would like to add more functionalities to the RNs and see the advantages of using cooperative relaying, i.e., Type-II RNs. In particular, we study an interference relay channel (IRC) consisting of two single-antenna transmitter-receiver pairs and a shared multiple-antenna RN, which is exploited in a way that interferer's signal components at each receiver node are eliminated. Specifically, at the RN a transmit filtering is performed such that the compound received signal at each user equipment (UE) has a structure similar to the receiver structure for Alamouti's space-time coding [1]. We also show that it is not always required to have more complex receiver structure at the RN in order to achieve better spectral efficiencies.**
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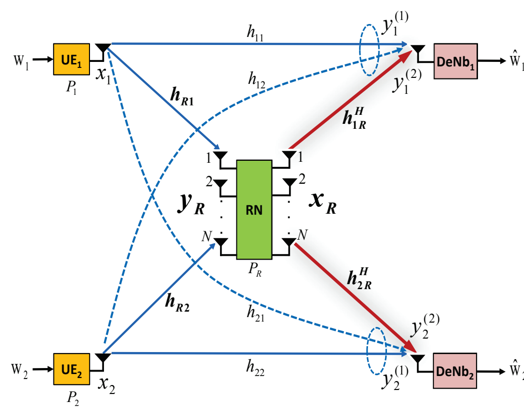

Fig. 1. The IRC with multiple-antenna half-duplex RN.

I. Introduction

In cellular systems, intra/inter-cell interference is the one of the performance limiting factors and cooperative communication or relaying has been identified as one of the important tools in combating this. Beside these tools, coordinated multi-point (CoMP) transmission/reception technique has also being densely studied towards eliminating the interference effect at the UEs close to the cell-edges. Although CoMP technique offers high performance gains, it might not always be feasible to perform CoMP transmission/reception since the need for full channel state information (CSI) and data exchange between the cooperating DeNBs via limited capacity backhaul. Another drawback with CoMP technique is the received power levels at the receiving terminals due to path-loss which might surpass the gain achieved by CoMP.

Toward this end, we exploit a shared multiple antenna relay node (RN) that can be used by the DeNBs to realize the same benefits as in CoMP in order to combat interference by using multi-user multiple-input multiple-output (MU-MIMO) tools, such as precoding and scheduling. Furthermore, the respective MIMO operations at the RN are developed with the special attention paid to the signaling aspect, e.g. limited feedback of CSI.

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One specific model to be considered in this case, is the interference relay channel (IRC) - a RN in an interference channel setting has been shown to be beneficial in improving the degrees of freedom of the system [2]. In addition to this, it has been recently shown that RNs can be exploit for both signal and interference forwarding purposes in the multiple-source multiple-destination networks [3]–[5]. However, in most of these works complex transmitter and receiver structures, e.g., rate splitting at the sources [6] and successive interference cancelation (SIC) at the destinations, are assumed which make them be unattractive. In our work, we will also pay attention to this issue and assume single-user decoder at each receiver.

A multi-antenna RN, shared by multiple source-destination pairs, is particularly interesting since it can simultaneously forward information and/or interference to aid the receivers. Recently, in [7] a half-duplex multi-antenna RN is used to enable distributed interference alignment in an IRC set-up for decode-and-forward (DF) relaying. Inspired by [7], we will explore the achievable rates for Layer-1 relaying strategies (Amplify-and-Forward (AF) and Quantize-and-Forward (QF)), due to their proved performance improvement for various relaying networks and being less complex compared to the Layer-2/3 (e.g., DF) relaying strategies. Our aim is to study performance of linear beamforming or precoding techniques for an IRC, with an aim to compare this system against classical CoMP techniques.

II. THE SYSTEM AND SIGNAL MODEL

We consider an IRC consisting of two single-antenna UEs, one multi-antenna RN and two single-antenna DeNBs where each UE wants to communicate with its associated DeNB with the assistance of the RN. The system model is depicted in Figure-1.

We assume half-duplex RN, i.e., it can not transmit and receive at the same time on the same frequency band. The communication from the UEs to the DeNBs takes place in two phases, where in the first phase the UEs transmit while the RN and DeNBs receive and during the second phase the UEs stay silent while the RN transmits towards the DeNBs. We note that allowing the UEs transmit during the second phase might provide more spectral efficiency; but, in order to be able to exhibit our ideas clearly, we neglect this possibility.

We study the IRC shown in Figure-1 where two UEs want to communicate with their respective DeNBs with the assistance of a RN equipped with N antennas. We assume no cooperation neither among the UEs nor among the DeNBs. Each UE encodes its message $w_t \in [1, 2^{nR_t}]$, where R_t is the transmission rate of the t-th UE, into the codeword $x_t^n(w_t)$, $t = 1, 2$. All UE channel inputs are independent of each other.

The received signal, respectively, at the DeNBs and the RN in the first phase of the communication is given by

$$y_1^{(1)} = h_{11}x_1 + h_{12}x_2 + z_1^{(1)} \tag{1}$$

$$y_2^{(1)} = h_{21}x_1 + h_{22}x_2 + z_2^{(1)} \tag{2}$$

$$\mathbf{y}_R = \mathbf{h}_{R1}x_1 + \mathbf{h}_{R2}x_2 + \mathbf{z}_R \tag{3}$$

where $\mathbb{E}[\|x_i\|^2] \leq P_i$, $i = 1, 2$, and h_{ji} is the channel coefficient between transmitter i and receiver j and $\mathbf{y}_R, \mathbf{h}_{R1}, \mathbf{h}_{R2} \in \mathbb{C}^{N\times 1}$.

Let $\mathbf{x}_R \in \mathbb{C}^{N\times 1}$ be the signal vector transmitted by the RN in second phase, which obeys the power constraint at the RN $\mathbb{E}[\|\mathbf{x}_R\|^2] \leq P_R$. Then, the received signals at the DeNBs after the second phase of the communication are given by

$$y_1^{(2)} = \mathbf{h}_{1R}^H \mathbf{x}_R + z_1^{(2)} \tag{4}$$

$$y_2^{(2)} = \mathbf{h}_{2R}^H \mathbf{x}_R + z_2^{(2)} \tag{5}$$

where $\mathbf{h}_{iR} \in \mathbb{C}^{N\times 1}$ is the channel coefficient between the RN and and the i-th DeNB. All noise terms are assumed to be circularly symmetric complex Gaussian random variables (temporarily and spatially independent) with zero mean and unit variance.

III. DF RELAYING

In this section, we generalize the results of [7] to the case where $N \geq 2$. We assume that the total communication time is equally divided between the first and second phases. In the first phase, the RN can decode the UEs' messages if the following is satisfied [8]:

$$R_1 \leq \frac{1}{2}\log_2\left(1 + \|\mathbf{h}_{R1}\|^2 P_1\right) \tag{6}$$

$$R_2 \leq \frac{1}{2}\log_2\left(1 + \|\mathbf{h}_{R2}\|^2 P_2\right) \tag{7}$$

$$R_1 + R_2 \leq \frac{1}{2}\log_2\left|\mathbf{I} + \mathbf{H}\mathbf{Q}\mathbf{H}^H\right| \tag{8}$$

where $\mathbf{H} = [\mathbf{h}_{R1}\ \mathbf{h}_{R2}]$, $\mathbf{Q} = \mathrm{diag}\{P_1, P_2\}$, $|.|$ is used for determinant operation and the pre-log term is due to the half-duplex relaying with equal time duration on the first and second phase of the communication.

Once the RN successfully decodes the both messages in the first phase, then it applies a precoded matrix to the decoded messages and sends the following signal vector

$$\mathbf{x}_R = \mathbf{A}\mathbf{x} \tag{9}$$

where $\mathbf{A} \in \mathbb{C}^{N\times 2}$ and $\mathbf{x} = [x_1\ x_2]^T$.

In [7], the precoding matrix $\mathbf{A}$ is proposed such that when (1)-(3) and (4)-(5) are combined properly, the interfering signal is completely eliminated. If the following set of equations holds, then it is sufficient to achieve this goal

$$\begin{bmatrix} \mathbf{h}_{1R}^H \\ \mathbf{h}_{2R}^H \end{bmatrix} \mathbf{A} = k \begin{bmatrix} h_{12}^* & -h_{11}^* \\ h_{22}^* & -h_{21}^* \end{bmatrix} \tag{10}$$

where k is a scaling parameter used to satisfy the transmit power constraint at the RN. For the following we define

$$\mathbf{G} = \begin{bmatrix} \mathbf{h}_{1R} & \mathbf{h}_{2R} \end{bmatrix}^H \in \mathbb{C}^{2\times N},$$

$$\mathbf{T} = \begin{bmatrix} h_{12}^* & -h_{11}^* \\ h_{22}^* & -h_{21}^* \end{bmatrix} \in \mathbb{C}^{2\times 2}.$$

Assuming that there is an $\mathbf{A}$ satisfying (10) for $N \geq 2$, then for each DeNB we can write the received signals in the first and second phases in the vector form as follows

$$\begin{bmatrix} y_1^{(1)} \\ y_1^{(2)} \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ kh_{12}^* & -kh_{11}^* \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} z_1^{(1)} \\ z_1^{(2)} \end{bmatrix} \tag{11}$$

$$\begin{bmatrix} y_2^{(1)} \\ y_2^{(2)} \end{bmatrix} = \begin{bmatrix} h_{21} & h_{22} \\ kh_{22}^* & -kh_{21}^* \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} z_2^{(1)} \\ z_2^{(2)} \end{bmatrix}. \tag{12}$$

We apply the following receiver filters to the overall signal at each DeNB, which cancel the interfering signal components completely,

$$\begin{aligned} &\begin{bmatrix} kh_{11}^* & h_{12} \end{bmatrix} \begin{bmatrix} y_1^{(1)} \\ y_1^{(2)} \end{bmatrix} \\ &= k(|h_{11}|^2 + |h_{12}|^2)x_1 + kh_{11}^* z_1^{(1)} + h_{12} z_1^{(2)} \end{aligned} \tag{13}$$

$$\begin{aligned} &\begin{bmatrix} kh_{22}^* & -h_{21} \end{bmatrix} \begin{bmatrix} y_2^{(1)} \\ y_2^{(2)} \end{bmatrix} \\ &= k(|h_{21}|^2 + |h_{22}|^2)x_2 + kh_{22}^* z_2^{(1)} - h_{21} z_2^{(2)}. \end{aligned} \tag{14}$$

Then, the both DeNB can successfully decode if the transmission rates satisfy

$$R_1 \leq \frac{1}{2}\log_2\left(1+\frac{|k|^2(|h_{11}|^2+|h_{12}|^2)^2 P_1}{|kh_{11}|^2+|h_{12}|^2}\right) \quad (15)$$

$$R_2 \leq \frac{1}{2}\log_2\left(1+\frac{|k|^2(|h_{22}|^2+|h_{21}|^2)^2 P_2}{|kh_{22}|^2+|h_{21}|^2}\right). \quad (16)$$

The precoding matrix $\mathbf{A} \in \mathbb{C}^{N\times 2}$ takes the following closed form [7], for $N \geq 2$,

$$\mathbf{A} = k\,\mathbf{G}^H\left(\mathbf{G}\mathbf{G}^H\right)^{-1}\mathbf{T} \quad (17)$$

where scaling factor k can be ultimately calculated from $\mathbb{E}[\|\mathbf{A}\mathbf{x}\|^2] = P_R$ as follows

$$k = \sqrt{\frac{P_R}{\mathrm{Tr}\left\{\left(\mathbf{G}\mathbf{G}^H\right)^{-1}\mathbf{T}\mathbf{Q}\mathbf{T}^H\right\}}}. \quad (18)$$

IV. AF Relaying

For the AF relaying, we assume the received signal is first conjugated and then multiplied by a precoding matrix $\mathbf{W} \in \mathbb{C}^{N\times N}$. The RN transmit signal is given by

$$\begin{aligned}\mathbf{x}_R &= \mathbf{W}\mathbf{y}_R \\ &= \mathbf{W}\mathbf{h}_{R1}x_1 + \mathbf{W}\mathbf{h}_{R2}x_2 + \mathbf{W}\mathbf{z}_R. \quad (19)\end{aligned}$$

And the corresponding receiving signal at each DeNB is given by,

$$y_1^{(2)} = \mathbf{h}_{1R}^H\mathbf{W}\mathbf{H}\begin{bmatrix}x_1\\x_2\end{bmatrix} + \mathbf{h}_{1R}^H\mathbf{W}\mathbf{z}_R + z_1^{(2)} \quad (20)$$

$$y_2^{(2)} = \mathbf{h}_{2R}^H\mathbf{W}\mathbf{H}\begin{bmatrix}x_1\\x_2\end{bmatrix} + \mathbf{h}_{2R}^H\mathbf{W}\mathbf{z}_R + z_2^{(2)} \quad (21)$$

As in DF case, in order to be able to cancel interfering signals completely, we select the precoding matrix $\mathbf{W}$ such that the following set of equations are satisfied

$$\mathbf{G}\mathbf{W}\mathbf{H} = k\mathbf{T} \quad (22)$$

We can solve (22) for $\mathbf{W}$ as follows:

$$\begin{aligned}\mathrm{vec}(\mathbf{G}\mathbf{W}\mathbf{H}) &= k\ \mathrm{vec}(\mathbf{T}) \\ (\mathbf{H}^T\otimes\mathbf{G})\mathrm{vec}(\mathbf{W}) &= k\ \mathrm{vec}(\mathbf{T}) \\ (\mathbf{H}^T\otimes\mathbf{G})\mathbf{w} &= k\ \mathbf{t} \quad (23)\end{aligned}$$

where $\mathbf{w} = \mathrm{vec}(\mathbf{W}) \in \mathbb{C}^{N^2\times 1}$ and $\mathbf{t} = \mathrm{vec}(\mathbf{T}) \in \mathbb{C}^{4\times 1}$ and the symbol $\otimes$ represents the Kronecker product. And then a solution for $\mathbf{w}$ is given by

$$\mathbf{w} = k\ (\mathbf{H}^T\otimes\mathbf{G})^H((\mathbf{H}^T\otimes\mathbf{G})(\mathbf{H}^T\otimes\mathbf{G})^H)^{-1}\mathbf{t}, \quad (24)$$

which can then be converted to $\mathbf{W}$, since $\mathbf{w} = \mathrm{vec}(\mathbf{W})$.

With this assumptions, as in the DF case, the achievable rates can be expressed as

$$R_1 \leq \frac{1}{2}\log_2\left(1+\frac{|k|^2(|h_{11}|^2+|h_{12}|^2)^2 P_1}{|kh_{11}|^2+|h_{12}|^2(1+\|\mathbf{h}_{1R}^H\mathbf{W}\|^2)}\right) \quad (25)$$

$$R_2 \leq \frac{1}{2}\log_2\left(1+\frac{|k|^2(|h_{22}|^2+|h_{21}|^2)^2 P_2}{|kh_{22}|^2+|h_{21}|^2(1+\|\mathbf{h}_{2R}^H\mathbf{W}\|^2)}\right). \quad (26)$$

Note that the achievable rates are increasing function of k. Hence, the power constraint at the RN should be satisfied with equality for maximum rates.

V. QF Relaying

For the QF relaying strategy, we assume that the RN first applies two different filters to the received signal. And then the outcome of each filter is quantized with quantization rate lower then the link capacity between the RN and each DeNB. First, the RN perform two receiver filter, where outcome of each filter is intended for one of the DeNB, as follows

$$s_1 = \mathbf{d}_1^H\mathbf{y}_R \quad (27)$$

$$s_2 = \mathbf{d}_2^H\mathbf{y}_R. \quad (28)$$

For each outcome the RN generates the corresponding quantized codeword according to the distribution $f(\hat{s}_i|s_i) \sim \mathcal{CN}(s_i, D_i)$ for $i = 1, 2$, where D_i is the noise variance due to the distortion in reconstructing s_i, i.e.,

$$\hat{s}_1 = s_1 + z_{q,1} \quad (29)$$

$$\hat{s}_2 = s_2 + z_{q,2} \quad (30)$$

where $z_{q,i} \sim \mathcal{CN}(0, D_i)$.

The RN sends symbols x_{q1} and x_{q2} carrying the quantization messages $w_{q1} \in [1, 2^{nR_{bc,1}}]$ and $w_{q2} \in [1, 2^{nR_{bc,2}}]$, to the corresponding DeNB with rate $R_{bc,i}$ which is (considering (29) and (30))

$$\begin{aligned}\mathrm{I}(\hat{s}_i; s_i) &= \frac{1}{2}\log_2\left(1+\frac{|\mathbf{d}_i^H\mathbf{h}_{R1}|^2P_1+|\mathbf{d}_i^H\mathbf{h}_{R2}|^2P_2+\|\mathbf{d}_i\|^2}{D_i}\right) \\ &\leq R_{bc,i} \quad (31)\end{aligned}$$

or in terms of distortion, $\forall i \in \{1, 2\}$,

$$D_i \geq \frac{|\mathbf{d}_i^H\mathbf{h}_{R1}|^2P_1+|\mathbf{d}_i^H\mathbf{h}_{R2}|^2P_2+\|\mathbf{d}_i\|^2}{2^{2R_{bc,i}}-1}. \quad (32)$$

To be able to send the quantization messages (or bits) reliably to the DeNBs, the RN should select the quantization rates, $R_{bc,i}$, according to the broadcast (BC) rate region. For simplicity, we assume that the RN performs zero-forcing (ZF) beamforming, which is a linear transmit beamformer. The transmit ZF filter, $\mathbf{W}$, is given by

$$\mathbf{W} = \rho\ \mathbf{G}^H\left(\mathbf{G}\mathbf{G}^H\right)^{-1} \quad (33)$$

where $\rho \in \mathbb{R}_+$ is the scaling factor for the power constraint at the RN which is given by

$$\rho = \sqrt{\frac{P_R}{\mathrm{Tr}\left\{\left(\mathbf{G}\mathbf{G}^H\right)^{-1}\right\}}} \tag{34}$$

where we assume $\mathbb{E}[|x_{q1}|^2] = \mathbb{E}[|x_{q2}|^2] = 1$. Then, the following rates are achievable for the BC channel

$$R_{bc,1} = R_{bc,2} = \frac{1}{2}\log_2\left(1+\rho^2\right). \tag{35}$$

Once (35) is satisfied, each DeNB can calculate the reconstruction signals (29) and (30) with distortion

$$D_i \geq \frac{|\mathbf{d}_i^H \mathbf{h}_{R1}|^2 P_1 + |\mathbf{d}_i^H \mathbf{h}_{R2}|^2 P_2 + \|\mathbf{d}_i\|^2}{\rho^2}. \tag{36}$$

Then by putting the received signal in the first phase and the reconstructed signal at each DeNB, we have

$$\begin{bmatrix} y_1^{(1)} \\ \hat{s}_1 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ \mathbf{d}_1^H \mathbf{h}_{R1} & \mathbf{d}_1^H \mathbf{h}_{R2} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} z_1^{(1)} \\ \mathbf{d}_1^H \mathbf{n}_R + z_{q,1} \end{bmatrix} \tag{37}$$

$$\begin{bmatrix} y_2^{(1)} \\ \hat{s}_2 \end{bmatrix} = \begin{bmatrix} h_{21} & h_{22} \\ \mathbf{d}_2^H \mathbf{h}_{R1} & \mathbf{d}_2^H \mathbf{h}_{R2} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} z_2^{(1)} \\ \mathbf{d}_2^H \mathbf{n}_R + z_{q,2} \end{bmatrix}. \tag{38}$$

As in the previous section, we select $\mathbf{d}_1^H$ and $\mathbf{d}_2^H$ as follows

$$\mathbf{d}_1^H \mathbf{H} = \left[\begin{array}{cc} h_{12}^* & -h_{11}^* \end{array}\right], \tag{39}$$

$$\mathbf{d}_2^H \mathbf{H} = \left[\begin{array}{cc} h_{22}^* & -h_{21}^* \end{array}\right] \tag{40}$$

The solutions for $\mathbf{d}_1^H$ and $\mathbf{d}_2^H$, for $N \geq 2$, are given by

$$\mathbf{d}_1^H = \left[\begin{array}{cc} h_{12}^* & -h_{11}^* \end{array}\right] \left(\mathbf{H}^H \mathbf{H}\right)^{-1} \mathbf{H}^H, \tag{41}$$

$$\mathbf{d}_2^H = \left[\begin{array}{cc} h_{22}^* & -h_{21}^* \end{array}\right] \left(\mathbf{H}^H \mathbf{H}\right)^{-1} \mathbf{H}^H \tag{42}$$

With these selection of $\mathbf{d}_1^H$ and $\mathbf{d}_2^H$, and we apply the following receiver filters to the overall signal at each DeNB, which cancel the interfering signal components completely,

$$\begin{aligned} &\begin{bmatrix} h_{11}^* & h_{12} \end{bmatrix} \begin{bmatrix} y_1^{(1)} \\ \hat{s}_1 \end{bmatrix} \\ &\quad = (|h_{11}|^2 + |h_{12}|^2) x_1 + h_{11}^* z_1^{(1)} + h_{12}(\mathbf{d}_1^H \mathbf{n}^R + z_{q,1}), \\ &\begin{bmatrix} h_{22}^* & -h_{21} \end{bmatrix} \begin{bmatrix} y_2^{(1)} \\ \hat{s}_2 \end{bmatrix} \\ &\quad = (|h_{21}|^2 + |h_{22}|^2) x_2 + h_{22}^* z_2^{(1)} + h_{21}(\mathbf{d}_2^H \mathbf{n}^R + z_{q,2}). \end{aligned}$$

Then, the achievable rates for the QF relaying strategy are given by

$$R_1 \leq \frac{1}{2}\log_2\left(1 + \frac{(|h_{11}|^2 + |h_{12}|^2)^2 P_1}{|h_{11}|^2 + |h_{12}|^2(\|\mathbf{d}_1\|^2 + D_1)}\right) \tag{43}$$

$$R_2 \leq \frac{1}{2}\log_2\left(1 + \frac{(|h_{22}|^2 + |h_{21}|^2)^2 P_2}{|h_{22}|^2 + |h_{21}|^2(\|\mathbf{d}_2\|^2 + D_2)}\right). \tag{44}$$

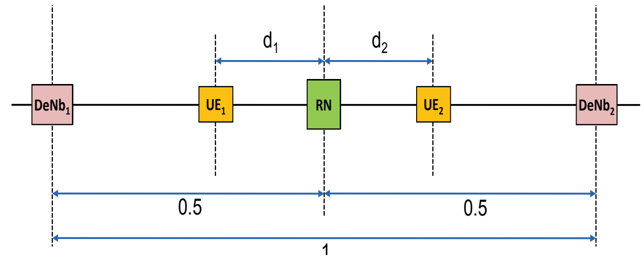

Fig. 2. Simulation set-up for the IRC.

VI. Numerical Results

All channel components consists of path-loss and fast fading, e.g., $h_{ij} = d_{ij}^{-\frac{\alpha}{2}} \phi_{ij}$ where d_{ij} is the distance between transmitter i and receiver j, α is the path-loss exponent and $\phi_{ij} \sim \mathrm{CN}(0,1)$. For the system model we assume there is line-of-sight (LOS) between the RN and each DeNB. Hence, the channel gains for the links between the RN and the DeNBs follow Rician distribution with a factor $K = 8$[dB]. Moreover, we assume all nodes have single antenna except the RN, which is equipped with $N = 2$ antennas.

We consider the simple setup depicted in Figure-2, which embraces all the characteristics of interference relay channels, e.g., by adjusting the distance parameters $d_1 \in [0, 0.5]$ and $d_2 \in [0, 0.5]$ we can emulate strong, medium and weak interference scenarios. For the setup, we assume that the RN is placed on the mid-point of the line connecting the DeNBs with a distance $d_{RN \to DeNB_1} = d_{RN \to DeNB_2} = 0.5$.

Here, we evaluate average achievable rates for the DF, AF and QF relaying strategies. In Figure-3, we plot achievable average sum-rates versus distance between UE1 and the RN for fixed UE2 position at $d_2 = 0.2$ and $P_s = 1$[Watt], $P_r = 10$[Watt]. From the figure, we can see that the DF relaying, which require more complexity at the RN due to full decoding of the UE messages, has the worst achievable rate performance. One of the reason is the particular geometric model that we have selected due to the its close resemblance to the real cellular networks. Moreover, the results show that the achievable rate performance does not suffer from being oblivious to the codebooks used at the UEs, e.g., the QF relaying achieves the best performance.

In Figure-4, we plot achievable average sum-rates versus transmit power P_s used at each UE for fixed UE1 and UE2 positions at $d_2 = 0.1$, $d_2 = 0.3$, respectively, and $P_r = 10$[Watt]. The selected parameters allows us to understand the behavior of the relaying strategies under asymmetric channel conditions, which is the case in real scenarios. From the figure we can see the same achievable rate behavior as in Figure-3. One more thing to note is that with increasing transmit power at the UEs the gap between the DF and AF performances goes to zero; however, the QF relaying still outperforms the others.

VII. Conclusions

In this paper, we study the interference relay channel consisting of two single-antenna transmitter-receiver pairs and a

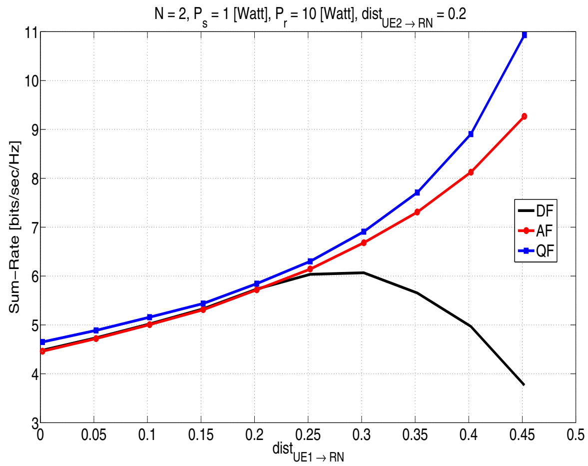

Fig. 3. Achievable average rates versus distance between UE1 and the RN for fixed UE2 position at $d_2 = 0.2$ and $P_s = 1$[Watt], $P_r = 10$[Watt].

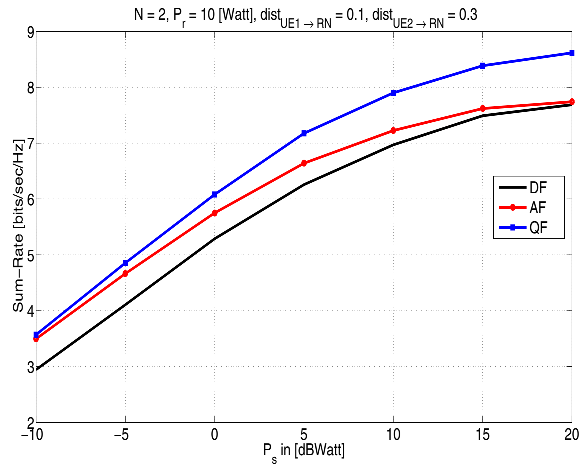

Fig. 4. Achievable average sum-rates versus transmit power P_s used at each UE for fixed UE1 and UE2 positions at $d_2 = 0.1$, $d_2 = 0.3$, respectively, and $P_r = 10$[Watt].

shared multiple-antenna relay node. We proposed, for different relaying strategies, to eliminate interferer's signal components at each receiver node by subtly exploiting multiple-antennas at the RN. In particular, the RN, before transmission, performs a transmit filter such that the compound received signal, which corresponds to the signals received in the first and second phases, at each UE has a structure similar to the receiver structure for Alamouti's coding. We also showed that it is not always required to have more complex receiver structures at the RN in order to achieve better spectral efficiencies, e.g., the QF relaying, where the RN is oblivious to the codebooks used at the UEs, has less complexity than the DF relaying, where the RN tries to fully decode the UE messages.

The focus of this paper is the IRC consisting of two communication pairs with simple transmit and receiver structures at the UEs and the DeNBs. Possible future studies might be the extension of the proposed methods to multi-pair case (more than two). Also, allowing for rate-splitting approaches and successive-interference cancelation (SIC) receiver structures would be another interesting horizon to explore in the IRC domain.

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