Joint Partial Relay and Antenna Selection for Full-Duplex Amplify-and-Forward Relay Networks

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Abstract. In this paper, a joint partial relay and antenna selection (PRAS) scheme is proposed to further improve the capacity of full-duplex (FD) amplify-and-forward (AF) relay networks. The exact capacity expression for PRAS is derived. Furthermore, the simulation for the PRAS considering loop-interference and the relay numbers is analyzed by systems' capacity while making a comparison with primary relay selection schemes, e.g. optimal relay selection (ORS) and partial relay selection (PRS) scheme. The results show that the PRAS scheme can even get a capacity gain about 14% while it's 19% under the ORS comparing to the PRS scheme and presents the characteristic among the primary policies as well.

Keywords: Full-duplex · Amplify-and-forward · Capacity · Relay selection

1 Introduction

Full-duplex (FD) relay selection is seen as a promising technology to improve systems' capacity of wireless transmissions significantly, but the loop-interference (LI) caused by the signal leakage between the output and input antennas of the relay limits its development [1–3]. Fortunately, many LI cancellation projects including the antenna separation [4], directional antennas [5] and the time domain interference cancellation [6] etc. make that the residual loop-interference (RLI) on the FD relay can be nearly modeled as an additional noise, which means that FD relay networks can be possibly came true. As for existing relay selection policies, they mainly focus on an optimal relay selection (ORS) policy under a global CSI and three suboptimal relay selection policies such as Max-Min relay selection (MM); Partial relay selection (PRS), and Max-Min with Loop-Interference relay selection (MMLI) [2, 3, 7]. However, almost all the existing works for kinds of FD relay selection policies are analyzed by outage probability, the analysis on FD relay systems' capacity remains virtually unknown. For the antenna selection, a technology about antenna pair selection on the relay is analyzed in [8]. In [9, 10], they investigate an antenna selection at the relay based on the ORS scheme, which needs global CSI and leads to the increase of the system overhead.

In this paper, we proposed a joint relay and antenna partial selection (PRAS) scheme to improve the performance of PRS scheme from the aspect of saving resources

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efficiently. Also the performance for the primary selection policies are investigated in terms of a new aspect about systems' capacity from the ability of loop-interference attenuation and the number of relays.

The remainder of this paper is organized as follows: Sect. 2 gives the system model and the capacity analysis; Sect. 3 shows the details of the proposed relay selection policies and primary policies. Simulation and analytical results are presented in Sect. 4. A brief conclusion is given in Sect. 5.

2 System Model

We assume a clustered network topology consisting of one half-duplex (HD) source (S), N FD relays (R_i with $1 \leq i \leq N$) and one HD destination (D). The communication can be established only via the relays [2]. Each relay employ an AF protocol and is equipped with two antennas (one for receiving and one for transmitting) that enable a full-duplex operation. All wireless links are non-selective rayleigh block fading and an imperfect interference cancellation scheme is used at each relay. During one slot, we assume all fading channel coefficients $h_{A,B}$ (for the A → B link) remain constant and only one relay is selected, but change independently from one slot to another.

Assuming that the ith relay node R_i is activated to forward the signal, the received signal at R_i is given as

$$y_i[n] = h_{S,R_i} x[n] + h_{R_i} x_i[n] + n_i[n] \tag{1}$$

Where h_{S,R_i} is the channel fading coefficient for the link S → R_i, and h_{R_i} represents the channel coefficients of residual loop-interference (RLI) on the ith relay. n_i is the additive white Gaussian noise (AWGN) with the power σ^2, $x[n]$ and $x_i[n]$ are the nth transmitting signal belongs to the S and the ith relay with a fixed transmit power P_t in one transmission slot.

The retransmit signal at the AF FD relay node can be expressed as

$$x_i[n] = \beta y_i[n - \tau] \tag{2}$$

Where β is the power amplification factor and τ is the processing delay.

The amplification factor β ensures that the average power of signal $x_i[n]$ satisfies the power constraint. Therefore, the factor β can be obtained as

$$\beta = \sqrt{\frac{P_t}{\left|h_{S,R_i}\right|^2 P_t + \left|h_{R_i}\right|^2 P_t + \sigma^2}} \tag{3}$$

The received signal at the destination is given by

$$y_D[n] = h_{R_i,\mathrm{D}} x_i[n] + n_D[n] \tag{4}$$

Where $h_{R_i,\mathrm{D}}$ is the channel fading coefficient from R_i to D, and $n_D[n]$ is the AWGN with power σ^2. Then the end-to-end SINR considering the amplification factor β can be obtained.

Therefore, if an optimal amplification factor is employed for the AF process, the instantaneous end-to-end capacity of the ith FD relay is expressed as

$$C_{R_i}^{FD} = 2\log_2\left(1 + \frac{\frac{\gamma_{SR_i}}{\gamma_{R_i+1}}\gamma_{R_iD}}{\frac{\gamma_{SR_i}}{\gamma_{R_i+1}} + \gamma_{R_iD} + 1}\right) \tag{5}$$

Where $\gamma_{SR_i} = P_t\left|h_{S,R_i}\right|^2/\sigma^2$, $\gamma_{R_i} = \alpha P_t\left|h_{R_i}\right|^2/\sigma^2$, and $\gamma_{R_iD} = P_t\left|h_{R_i,\mathrm{D}}\right|^2/\sigma^2$.

3 Relay Selection Policies

In this section, we show the details of the proposed joint partial relay and antenna selection (PRAS) scheme, besides the primary relay selection policies. These schemes refer to a centralized architecture where a central unit decides the selected relay based on the available CSI.

3.1 Joint Partial Relay and Antenna Selection (PRAS)

In order to improve systems' capacity more effectively, we apply antenna selection technology to the existing PRS scheme and proposed a joint partial relay and antenna selection (PRAS) scheme. The policy consider a joint antenna and relay selection scheme, where the optimal relay and its transmit and receive antenna configuration are selected jointly based on the instantaneous channel conditions. The selection process is similar to the partial relay selection (PRS), which selects the relay that has the maximum SINR on the S → R_i link considering LI, but each relay will adaptively select the optimal transmit antenna and receive antenna according to the condition on the link of S → R_i in advance. The RLI remains unchanged despite of the configuration of the transmit/receive mode for the two antennas. Therefore, the policy activates the relay that satisfies the following condition

$$l_{i,AS} = \arg\max_i \left\{\gamma_{SR_i,T_1\to T_2}, \gamma_{SR_i,T_2\to T_1}\right\} \tag{6}$$

Where T_1 and T_2 denote the two antennas of the ith relay node, $\gamma_{SR_i,T_1\to T_2}$ denotes the SINR at the receiving terminal of relay when the ith relay node chooses the antenna T_1 as the receiving antenna and T_2 as the transmitting antenna in the next transmission and it's similar for $\gamma_{SR_i,T_2\to T_1}$ that the SINR at the receiving terminal of relay when the antenna T_2 is used to receive the signal from the source node, and T_1 is used to retransmit the signal to the destination.

Therefore, PARS scheme can be formulated as

$$K_{PRAS} = arg \max_i \left\{ \frac{\gamma_{SR_i}}{\gamma_{R_i} + 1} \right\} \tag{7}$$

Where $\gamma_{SR_i} = \max_i \left\{ \gamma_{SR_i,T_1 \to T_2}, \gamma_{SR_i,T_2 \to T_1} \right\}$.

3.2 The Primary Relay Selection Policies

Optimal Relay Selection (ORS): The ORS policy is based on the instantaneous capacity expression. Thus, it activates the relay with the optimal SINR

$$\mathrm{K} = \arg \max_i \left\{ \gamma_i \right\} \tag{8}$$

Partial Relay Selection (PRS): Activate the relay that has the maximum SNR on the $\mathrm{S} \to R_i$ link considering LI and is written as

$$\mathrm{K} = \arg \max_i \left\{ \frac{\gamma_{SR_i}}{\gamma_{R_i} + 1} \right\} \tag{9}$$

Max−Min Relay Selection (MM): Select the relay with the best end-to-end link without considering the LI and can be expressed as

$$\mathrm{K} = \arg \max_i \min \left\{ \gamma_{SR_i}, \gamma_{R_iD} \right\} \tag{10}$$

Max-Min with Loop-Interference Relay Selection (MMLI): This scheme is an improvement of the MM scheme and takes into account the LI. The selection metric is similar with the MM policy but updates the first branch with the SINR

$$\mathrm{K} = \arg \max_i \min \left\{ \frac{\gamma_{SR_i}}{\gamma_{R_i+1}}, \gamma_{R_iD} \right\}. \tag{11}$$

4 Simulation Results

In this section, we illustrate the performance of the above all relay selection policies with systems' capacity from the ability of loop-interference attenuation (α) and the number of relays (L) finding the differences between FD relay selection policies. The proposed PRAS scheme is compared with the PRS especially.

Figures 1 and 2 give numerical examples about capacity for primary FD relay selection schemes. Figure 1 plots system capacity versus L where α = 4 dB. The important observation is that the capacity of all policies increase with the growth of L and ORS is the best one while PRS outperforms MM with the growth of SNR. This is because that the performance of PRS mainly focuses on the condition of R → D link. Figure 2 plots system capacity versus the α, where L = 4. It is worth noting that for this scenario, the intersection of MM > PRS move to a higher α while the signal noise to ratio (SNR) on the channel is fixed and α is growing, besides the main observations follow our previous remarks. For this result, we find the links that MM considered is more efficient than PRS.

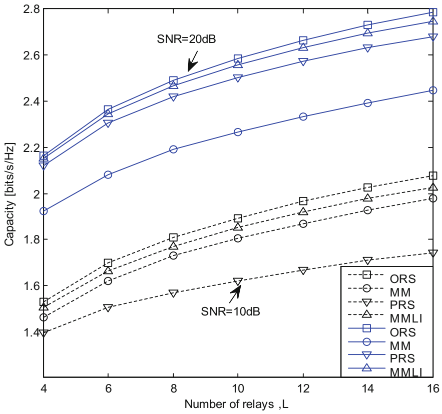

Fig. 1. System capacity versus the L

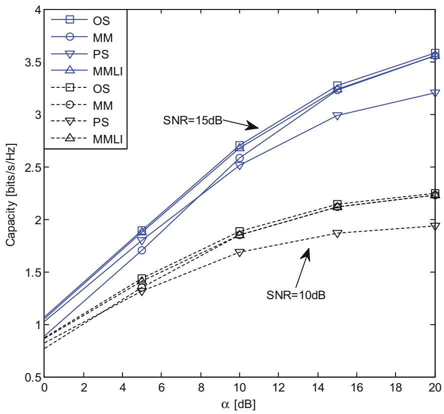

Fig. 2. System capacity versus the α

Therefore, we can conclude that ORS is the best one; the performance of the MMLI is almost same with the ORS; and the other two policies can nearly get the performance of ORS in some particular scenario, especially when unstable links conditions of the scenario can be considered by corresponding suboptimal policies efficiently.

Figures 3 and 4 show the simulation results among PRAS, PRS, and ORS from aspects about α and L. Figure 3 plots system capacity versus L, where SNR = 10 dB, α = 4 dB. Figure 4 plots system capacity versus the α, where L = 4.

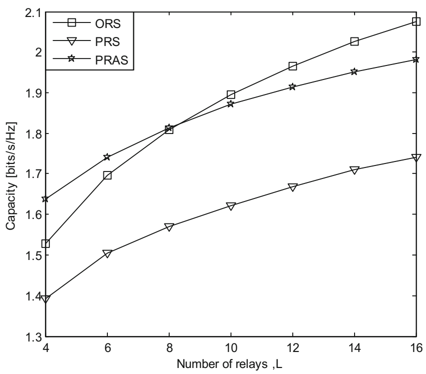

Fig. 3. System capacity versus the L

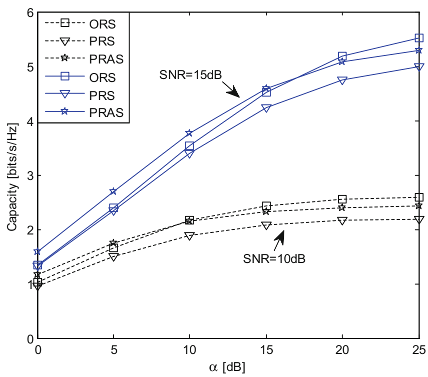

Fig. 4. System capacity versus the α

As can be seen, the performance of the proposed PRAS scheme is superior to PRS in all aspects and the PRAS is even better than the ORS in some specific scenarios, such as $L < 8$ in Fig. 3. From Fig. 3, we can also see that the PRAS can get a capacity gain about 14% while the gain of ORS is 19% ($L = 16$) comparing to the PRS scheme. And in Fig. 4 the capacity gain that the PRAS can get is about 15% while the ORS is similar to the PRS under a low loop-interference attenuation ($\alpha = 5$ dB, SNR = 15 dB).

5 Conclusion

In this paper, the proposed PRAS and the primary AF FD relay selection schemes have been analyzed in terms of systems' capacity. The numerical results reveal that the proposed PRAS scheme outperforms conventional PRS policy and it can even show better performance than the ORS in some particular scenarios. The ORS scheme is the best one among the primary policies and others will be similar to the ORS in some special scenarios.

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