A New Hybrid Full-Duplex Relay Scheme to support anycast applications

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***Abstract*—This paper proposes a new hybrid decode-amplify-forward (HDAF) method for full-duplex (FD) applied on a relaying network with a one source, multi-relay and multi-destination nodes. In contrast to existing schemes, we take into consideration the possible direct link between the source and destination nodes. Simulation results show that, the proposed scheme reduces significantly outage probability and achieves a higher average capacity compared to the individual amplify-and-forward (AF) and decode-and-forward (DF) schemes.**

Keywords—outage probability, relay selection, full-duplex relay, amplify-and-forward (AF), decode-and-forward (DF).

I. INTRODUCTION

Cooperative communication represents a promising technique to improve spectral efficiency, provide extensive network coverage and combat shadowing effects in next generation networks. Full-duplex relay (FDR) can receive and transmit simultaneously at the same frequency. However, the full-duplex operations are subject to self-interference (SI) due to signal leakage from the relay output to its input. Some cancellation schemes of SI have been proposed and achieved high performance but a residual self-interference (RSI) still exists [1]. In general, FDR can be implemented into two most common protocols, amplify-and-forward (AF) and decode-and-forward (DF). In AF technique, the relay simply amplifies and retransmits the received signal, without any further processing. On the other hand, in DF mode, the relay decodes the received signal, re-encodes it and forwards it to the destination [2].

In [3] the authors studied the performance of a cooperative diversity protocol signal-to-noise ratio (SNR) based hybrid decode-amplify-forward (HDAF). In [4] a HDAF with non-orthogonal multiple access transmission scheme for a cellular system was investigated. However, in all these studies, full-duplex relaying is not applied, and also the multi-destination nodes scheme is not taken into consideration. A multi-destinations scenario is a practical problem in anycast applications such as vehicular and mobile ad-hoc networks.

In this work, we propose a HDAF method focus on a multiple parallel full-duplex relays and multiple destinations system include the direct link. This paper is organized as follows. Sections II and III introduce the system model and our proposed hybrid approach. Section III presents and discusses the simulation results. Section IV concludes the paper.

II. SYSTEM MODEL

We consider a full-duplex relaying network, where one source node S intends to send the signal to one of K destination nodes D_k $(k = 1,2, \dots, K)$ via one of N candidate relay nodes R_i $(i = 1,2, \dots, N)$. We assume that the direct link between S and D_k is also used to convey information. Each relay equipped with one receive antenna and one transmit antenna operates in FD mode adaptively under the DF or AF protocol whereas the nodes S and each destination are single-antenna devices. The transmit powers of the source and all relays are denoted by P_S and P_R, respectively.

In this model, we assume that h_{SD_k}, h_{SR_i}, $h_{R_iD_k}$, h_{LI_i} denote the corresponding Rayleigh fading channel coefficients of the source to destination D_k $(S - D_k)$, source to relay R_i $(S - R_i)$, relay R_i to destination D_k $(R_i - D_k)$ links and residual loop-interference, respectively. More specifically, h_{SD_k}, h_{SR_i}, $h_{R_iD_k}$, h_{LI_i} are modeled as zero-mean complex Gaussian random variables with variances $\sigma^2_{SD_k}$,$\sigma^2_{SR_i}$,$\sigma^2_{R_iD_k}$, $\sigma^2_{LI_i}$, respectively.
Let R_i^* and D_k^* are the "best relay" and "best destination" selected, respectively.
The received signal at the relay R_i^* selected can be expressed as:

$$y_{SR_i^*}(t) = \sqrt{P_S} h_{SR_i^*} x_s(t) + \sqrt{P_R} h_{LI_i} x_{R_i^*}(t) + n_{SR_i^*} \qquad (1)$$

where x_s(t) is the signal transmitted by S at the time t, $x_{R_i^*}(t)$ is the signal transmitted by the relay R_i^*. If the DF protocol is employed $x_{R_i^*}(t) = x_s(t - \tau_d)$. For AF protocol case, $x_{R_i^*}(t) = \beta y_{SR_i^*}(t - \tau_d)$ with β is the amplification factor and τ_d is the processing delay defined as in [5]. According to the best link selected between direct and relaying links to convey information, the received signal at the destination D_k^* over relaying link selected can be expressed as:

$$y_{R_i^*D_k^*} = \sqrt{P_R} h_{R_i^*D_k^*} x_{R_i^*}(t) + n_{R_i^*D_k^*} \qquad (2)$$

Also, the received signal at the destination D_k^* over the direct link selected is given by:

$$y_{SD_k^*} = \sqrt{P_s} h_{SD_k^*} x_s(t) + n_{SD_k^*} \qquad (3)$$

where $n_{SR_i^*}$, $n_{R_i^*D_k^*}$, $n_{SD_k^*}$ are additive white Gaussian noise (AWGN) with zero mean and unit variance N_0 .The corresponding instantaneous SNRs of S-D_k , S-R_i , R_i-D_k are defined as $\gamma_{SD_k} = P_S |h_{SD_k}|^2 / N_0$,$\gamma_{SR_i} = P_S |h_{SR_i}|^2 / N_0$,

$\gamma_{R_iD_k} = P_R|h_{R_iD_k}|^2/N_0$ respectively and for loop-interference channel $\gamma_{LI_i} = P_R|h_{LI_i}|^2/N_0$, The instantaneous signal-to-interference-noise ratio (SNIR) for the relaying link S-R_i is given as $\gamma_i = \gamma_{SR_i}/(\gamma_{LI_i}+1)$.

III. PROPOSED HYBRID METHOD

Our proposed approach to enhance performance of FDR which combined DF, AF schemes with adaptive switching is presented in Fig. 1.

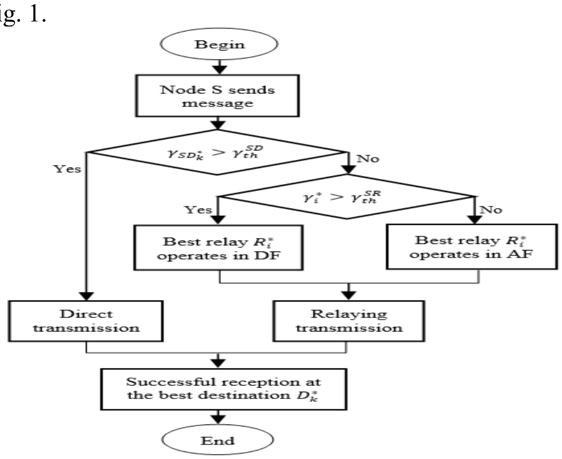

Fig.1. Illustration of the proposed scheme HDAF transmission flowchart

Firstly, the best destination D_k^* is selected based on the instantaneous SNR of the direct link between source and all the possible destinations with selection condition:

$$\gamma_{SD_k^*} = \arg\max_{1\le k\le K}\{\gamma_{SD_k}\} \quad (4)$$

Secondly, reference in work [6], the best relay R_i^* is selected based on partial relay selection criteria :

$$\gamma_i^* = \arg\max_{1\le i\le N}\left\{\frac{\gamma_{SR_i}}{\gamma_{LI_i}+1}\right\} \quad (5)$$

According to the condition $\gamma_{SD_k^*} > \gamma_{th}^{SD}$,the direct transmission will be taken, where γ_{th}^{SD} is the threshold at the destination. Otherwise, the best relay R_i^* will be chosen to send the signal to the best destination D_k^*. In this case, if $\gamma_i^* > \gamma_{th}^{SR}$, the relay R_i^* successfully decodes the message, it will be processed the message in DF protocol and forwarded to the destination. And if $\gamma_i^* < \gamma_{th}^{SR}$, the relay R_i^* uses AF protocol to send to the destination D_k^*. It is well known in [2] that the DF scheme outperforms the AF scheme.

IV. SIMULATION AND RESULTS

In this section, we present simulation results for outage probability and average capacity using BPSK modulation, AWGN with $N_0 = 1$, $\sigma_{SD_k}^2 = \sigma_{SR_i}^2 = \sigma_{R_iD_k}^2 = 1$, $\sigma_{LI_i}^2 = 0.01$ and $P_S = P_R$ is normalized to 1. The target transmission rate is set to $R_{th} = 2\ bits/s/Hz$,when threshold $\gamma_{th} = 2^{R_{th}} - 1$. Fig. 2 illustrates the outage probability, where number of relays and destinations is set to 5 and 3, respectively. Fig. 3 illustrates the average capacity under the same parameters. It is shown from Fig. 2 and Fig. 3, respectively that the outage probability of the proposed scheme is lower, and the average capacity is higher than the conventional AF and DF schemes.

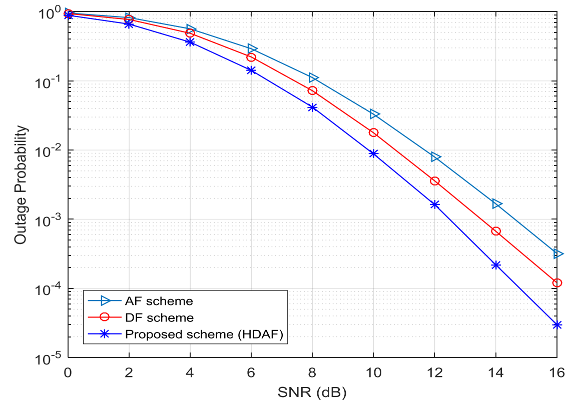

Fig. 2. Outage probability of proposed scheme compared to AF and DF schemes

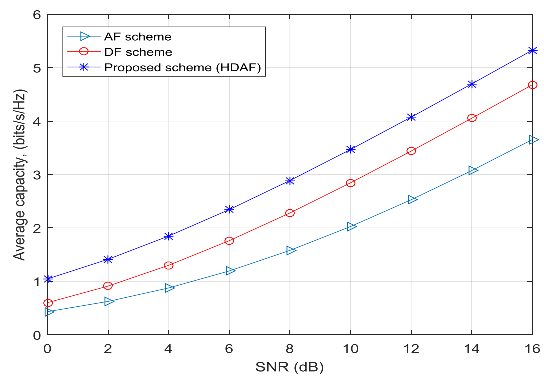

Fig. 3. Average capacity of proposed scheme compared to AF and DF schemes

V. CONCLUSION

In this paper, we propose a hybrid decode-amplify-forward approach to support anycast applications with multiple FD relays. Compared to the conventional individual AF and DF schemes, the proposed scheme as expected reduces outage probability and achieves significantly average capacity.

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