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On Partners and Channel Signal-to-Interference-Plus-Noise Ratio (SINR) in Cooperative Communications

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ABSTRACT

Cooperative communication or cooperative diversity, as it is sometimes called, is a relatively new technique aimed at improving the channel capacity of wireless networks, through the enhancement of transmit and spatial diversity. This is brought about by an exploitation of the antennas on wireless devices. A major benefit of this technique is that this gain in diversity is achieved without the physical installation of these multiple antennas at the transmitter or even the receiver. In this paper, we attempt to investigate the effect of employing the use of relaying partners on the signal-to-interference-plus-noise ratio (SINR) on each of the channels involved in cooperative cooperation, that is, source-destination, source-relay, relay-destination and source-relay-destination; making use of the amplify-and-forward cooperative diversity scheme. Implementation was also carried out with multiple relays as a means of comparing with a single-relay scenario. The findings show that the SINR with the help of the relaying partner in cooperation is approximately 10^4 times than that without the help of a relaying partner node.

Keywords: *diversity, SINR, source, partner, destination, relays*

1. INTRODUCTION

Cooperative diversity, or otherwise called user cooperation is a very novel and veritable technique for addressing the high data-rate coverage demand in the next generation wireless communication systems like the Long Term Evolution (LTE) and the 4G cellular systems. The basic notion behind this technique is that apart from the direct transmission from the transmitter to the receiver, there can be other nodes, used in enhancing the diversity by relaying the signal from the source to the destination. Some of the benefits of cooperative diversity include increasing signal-to-noise ratio (SNR), transmission reliability and capacity, lowering the bit-error rate, and increasing the achievable transmission range. Moreover, spatial diversity is achieved by using relay nodes as virtual antennas, and as a result, mitigating fading effects [1].

There are three main schemes commonly employed in implementing cooperation in wireless networks. These are the Amplify-and-Forward (also called unregenerative), the Decode-and-Forward (also known as regenerative) and Coded Cooperation. In the amplify-and-forward scheme, the relay (or partner) amplifies the incoming signal before retransmitting it onward to the destination, while in the decode-and-forward scheme, the relay detects (or decodes) the signal and then retransmits it. [1] In coded cooperation, there is an integration of relay cooperation with channel coding. Instead of merely repeating the received information, as in the previous protocols, the relay node decodes the partner's transmission and transmits additional parity symbols to the destination node.

The work in [2] worked on cooperative communication without the use of relaying partner. But in [3], the authors showed that cooperative communication with the help of partners (or relays) provides better resource usage efficiency than communication without a relay. In [4], the authors proposed an adhoc network model which uses mobile clients as relays to route peer-to-peer traffic within the network, but it lacks availability guarantee. The work of [6] revolved around the issue of selecting partners (or relays) using power allocation scheme, but it focused on cellular networks.

The work in [7] addressed the issue of selecting the optimal relay, with power allocation as the metric and under the influence of interference, and using game theory. The work in [8] also investigated the performance of cooperative diversity, through the selection of best relays in the network, and with the decode- and –forward cooperative diversity (CD) scheme as the protocol. In [9], a coded cooperative system under Rayleigh fading and path loss was considered, where a novel algorithm for partner selection and optimal power allocation was presented. The authors in [10] provided a simple optimal rate allocation algorithm for two cooperating node pairs and closed-form optimal rate allocations for some cases.

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In the work of [11], a system with a single base station communicating with multiple users over orthogonal channels while being assisted by multiple relays was considered, in which, using the sum rate as the design metric, a convex optimization problem that provides an extremely tight upper bound on performance was developed. And still on cooperative diversity cum relay selection, in [12], a novel network architecture that incorporates cooperative diversity techniques to increase the cellular network throughput was proposed

The work in this paper is in two folds: firstly, we attempt to evaluate how the introduction of partners for relaying information would affect the signal-interference-plus-noise ratio, in quantitative terms, by comparing the SINR without a partner's help and the SINR with the help of a partner. Secondly, we move from one-relay scenario to multi-relay to investigate the effect of increasing the number of relays on the overall capacity of the channel, from the source to the destination, with the help of a relaying partner.

The rest of this paper is organised as follows: Section II discusses the model of the concept and its mathematical formulation. In section III, the simulation platform is discussed while the simulation results are explained in section IV. Section V gives the conclusion of the paper.

2. SYSTEM MODEL AND MATHEMATICAL FORMULATION

Fig. 1 shows a model of a 3-node cooperative communication scheme. Fig. 1a shows a 3-node multi-hop cooperative diversity, with the source node (S), relay node (R) and destination node (D), while Fig. 1b shows a model of cooperative diversity with multiple relays, where the number of relays is denoted by r_i ($i \in L$), where L is the number of relays used in cooperation. During the first time slot, the source node transmits signal directly to the destination and also to the relay, while during the second time slot, the relay, employing the amplify-and-forward cooperative diversity strategy scheme, retransmits the signal received from the source node to the destination.

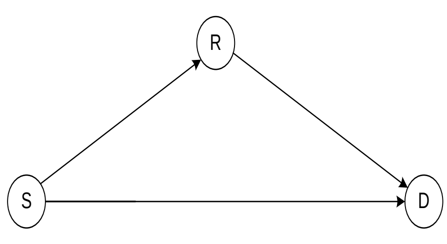

Fig. 1a. Two-hop transmission with cooperative diversity

A very important attribute of wireless networks, i.e their broadcast nature, makes them prone to interference from neighbours. It is thus assumed that the relay and the destination nodes suffer from interference. This is because the nodes are usually located within clusters, and as such, there would always be interference from neighbouring clusters during transmission.

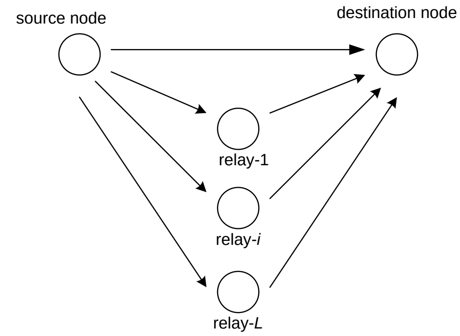

Fig. 1b. Cooperative diversity in a multi-relay scenario

As said previously, during the first time slot, the source node transmits signal to the destination and the relay. So the received signal, R at the destination node from this source node is given as

$$R_{sd} = \sqrt{P_s G_{sd}}\, x + N_{sd} + \omega_d \,, \qquad (1)$$

the received signal at the relay, from the source is given as (2)

$$R_{sr} = \sqrt{P_s G_{sr}}\, x + N_{sr} + \omega_r \qquad (2)$$

and the received signal at the destination, from the relay is denoted as

$$R_{rd} = \frac{\sqrt{P_r G_{rd}}\left(\sqrt{P_s G_{sr}}\, x + N_{sr} + \omega_r\right)}{\sqrt{P_s G_{sr} + \sigma_n + \sigma_{\text{int}}}} + N_{rd} + \omega_d \qquad (3)$$

where P_s = transmit power of the source node, G_{sd}, G_{sr} and G_{rd} represent the channel gains between the source node and destination node, between the source and the relay nodes and between the relay node and the destination node, respectively; N represents the additive white Gaussian noise (AWGN) having zero mean and variance σ_n in the relay and destination nodes. ω_r and ω_d represent the interference from the neighbouring clusters in the relay and destination nodes, respectively [5].

The Central Limit Theorem states that, given certain conditions, the mean of a sufficiently large number of independent random variables, each with finite mean and variance, will be approximately normally distributed, and the interference can be modelled as a zero mean Gaussian distributed variable, with a variance σ_{int}.

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Now considering the signal-to-interference-plus-noise ratio (SINR), which refers to the ratio of the transmitted signal to the noise plus interference, then the SINR at the destination node from the source node is given by

$$SINR_{sd} = \frac{P_s G_{sd}}{\sigma_n + \sigma_{\text{int}}} \quad (4)$$

while at the relay from the source, the SINR is given by

$$SINR_{sr} = \frac{P_s G_{sr}}{\sigma_n + \sigma_{\text{int}}} \quad (5)$$

Also, from the relay to the destination, we have

$$SNR_{rd} = \frac{P_r G_{rd}}{\sigma_n + \sigma_{\text{int}}} \quad (6)$$

Combining (5) and (6), we obtain the SNR at the destination node from the source node, via the relay node is given as (7)

$$SINR_{srd} = \frac{P_r P_s G_{rd} G_{sr}}{(\sigma_n + \sigma_{\text{int}})(P_r G_{rd} + P_s G_{sr} + \sigma_n + \sigma_{\text{int}})} \quad (7)$$

Furthermore, from Shannon's equation for transmission capacity, given that C_{sr} is the source-relay link capacity, the capacity of transmission link at the destination node from the relay node is given by

$$C_{srd} = W \log_2(1 + SINR_{rsd}) \quad (8)$$

where W is the bandwidth of transmission.

However, since this work set out to evaluate a multi-relay scenario, with L as the total number of available nodes we assume that M relay nodes were to be used by the source node where $M \in L$, then the total transmission capacity at the destination node is given by (8)

$$C_{srd} = W \log_2(1 + SINR_{sd} + \sum_{i \in M} SINR_{srd}) \quad (9)$$

3. COMPUTATION PROCESS AND RESULTS

In this work, the computation was carried out on the MATLAB 2008b platform. The work was done in two phases. In the first phase, the source node power was varied with the signal-to-interference-plus-noise ratio (SINR) on the source-destination channel, source-relay channel and the source-relay-destination channel. In the second phase, a variation of source power with the transmission link capacity under a multi-relay situation was carried out to ascertain the effect of increasing the number of relaying partners on the link capacity.

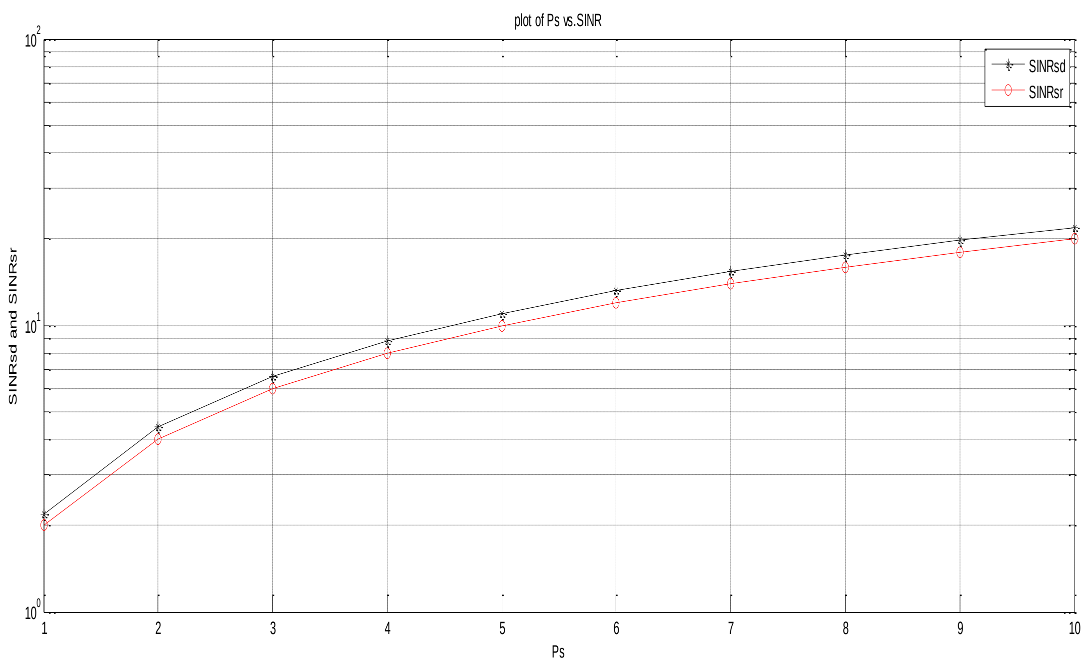

Fig.2 Plots of source power vs SINR for source-destination and source-relay channels

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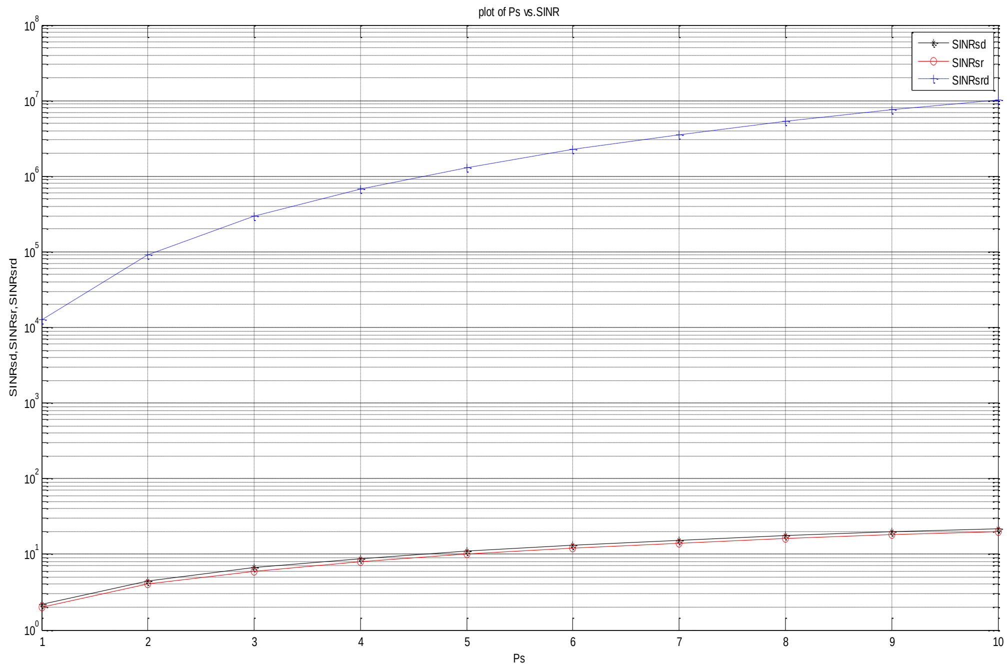

Fig.3. Plots of source power vs SINR for the three channels: source-destination, source-relay and source-relay-destination

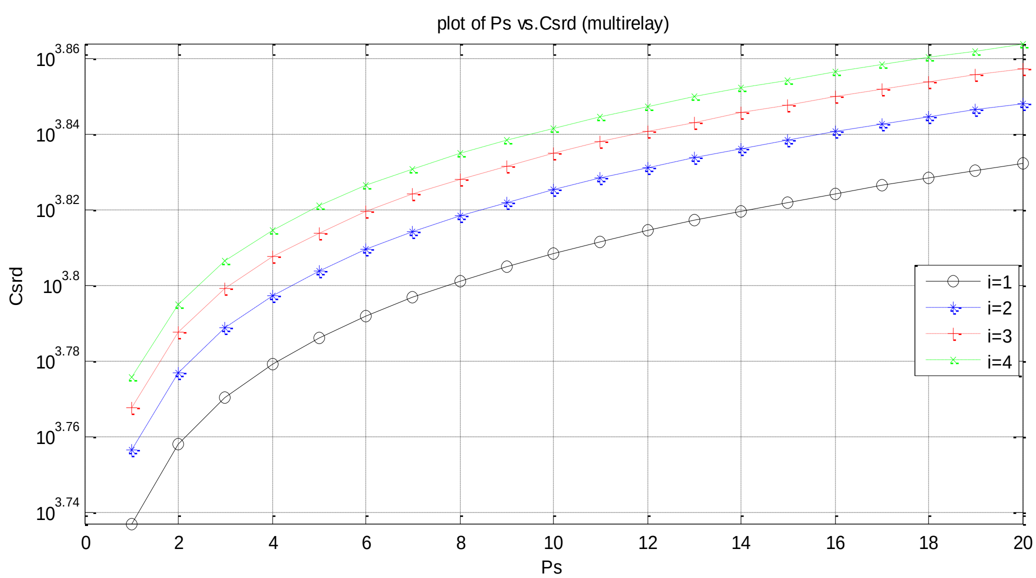

Fig.4. Plots of source power vs. Transmission link capacity, with varying number of relays

4. DISCUSSION OF RESULTS

The first phase of the work investigated the SINR while the second phase was on the transmission capacity of the channel. Fig.2 shows the plots of the source power Ps vs. SINR for the source-destination and source-relay channels. It can be observed from the plots that as the source power is increased, there is a corresponding increase in the SINR of the channel (in this case, source-destination). An observation of the plots shows that the two plots are quite similar. An explanation for this is that both transmissions are direct, the one from the source node to the destination node and the other from the source node to the relay node; the relay in this case not helping to forward the information to the destination, unlike what obtains in Fig. 3, where a combination of SINRs for the three channels, namely, source-destination, source-relay and source-relay-destination is shown, but in the case of the source-relay-destination channel, the relay is helping to forward the information from the source node to the destination node. It can be seen from this figure that the SINR with the help of the relaying partner in cooperation is approximately 10^4 times than that without the help of a relaying partner node.

From the results above, it can be seen that additional nodes improve channel diversity. The reason is because, unlike direct transmission from a single node, signals are transmitted on independent fading paths towards the destination node, in cooperative cooperation; and at the destination, there is a combining to get back the original signal, and as such the signal-to-noise ratio (SNR) is improved on.

The plots in Fig.4 give the result of the second phase of this work, where the number of relays is varied. The figure shows the plots of the source power P_s vs. link capacity C_{srd} for the source-relay-destination channel while varying the number of relaying partners. The figure depicts that the higher the number of relaying partners involved in cooperation, the higher the transmission link capacity of the channel. This obviously corroborates the already established notion that the presence of relaying partners increases the transmission capacity of the channel

5. CONCLUSION

We have been able, through this paper, to verify in quantitative terms, the effect of employing the use of relays or partners in cooperative communication; that the use of relays leads to an increase of about 10^4 in the Signal-to-Interference-plus-Noise Ratio (SINR). Moreso we were able to ascertain that employing the use of multiple relays also yields increases in the transmission link capacity.

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