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Comparative Analysis of Fixed-Gain Relaying Schemes for Inter-relay Communication over Nakagami-m Fading Channel

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Abstract: Analysis of Fixed-Gain relaying schemes for three time slot transmission protocol over Nakagami-m is presented. In this paper a profound analysis of two relaying schemes for inter-relay communication has been simulated and compared under different performance metrics. The performance is analyzed considering various relay locations in order to investigate the best relay location. The parameters used to analyze the system are Bit Error Rate, Outage capacity and Outage probability (BER).

Keywords: Cooperative Networks, Relaying Schemes, Nakagami Fading, Network protocols.

1. INTRODUCTION

Cooperative communication provides us the best possible solution to tackle the three main challenges of Next generation wireless networks. The size, cost and hardware limitations of antennas restrict the use of multiple antennas diversity techniques. Cooperative networks solve the challenges caused by the MIMO (Multiple Input- Multiple Output) systems as virtual multiple antenna arrays are established in cooperative networks by using the intermediate nodes called relays (Nosratinia *et al.*, 2004). Apart from solving the challenges caused by multiple antenna diversity techniques, cooperative networks are helpful in achieving high data rates as the affect of fading is reduced which greatly affects the wireless communication (Anghel and Kavin, 2004). Before transmitting a signal further, the relay node either amplify or decodes the incoming signal received from the source node. Among the two relaying schemes, Amplify and Forward (AF) and Decode and Forward (DF), the former works based on the signal amplification at the relay before transmission while the latter performs decoding and then modulation of the input signal prior to transmission. It has been proven in the study of (Tanoli *et al*., 2011) that AF outperforms DF by experiencing less processing speed. We have considered DF mode as well as AF mode in our work as the comparison of both these gives different BER and outage probability performances. For accessing the shared medium, techniques have been proposed by the various researchers such as Division Multiple Access (TDMA), Frequency Division Multiple Access (FDMA) and Code Division Multiple Access (CDMA) (Mark and Zhuang, 2003), (Jiang and Zhuang, 2004), (Jiang *et al.*, 2006)

The work presented in this paper considers the comparison between two fixed gain relaying protocols i.e. AF and DF. In (Al-Qahtani *et al.,* 2011), analysis of dual hop AF systems over Nakagami-m fading channels is presented. The performance bounds of multi-relay DF cooperative networks over Nakagami-m fading is presented in (Huang *et al.,* 2011). In (Salhab *et al*., 2012), analysis of dual-hop AF system considering Nakagami and Rician fading channels is performed. In (Khan *et al.*, 2009), the authors have presented the SER Analysis by considering the Nakagami-m fading model in a scenario of diversity of users Cooperation in hybrid FDMA-TDMA access setup. Bit Error Rate along with outage analysis has not yet been explored for DF as well AF modes, considering Nakagami-m fading channels and inter-relay communication. In (Tanoli *et al*., 2011), a three time slot inter-relay communication TDMA based protocol is analyzed considering Nakagami fading channels. The inter-relay communication based protocol showed better performance than two time slot TDMA protocol considering AF mode. The authors in (Tanoli *et al.*, 2012) investigated the inter-relay based protocol for DF mode for Nakagami fading channel.

In this paper, we have simulated and analyzed the results of three time slot inter-relay based transmission protocol for both Amplify and forward and Decode and forward considering Nakagami-m fading channels. The performance metrics used to analyze the system are BER, Outage Capacity and Outage probability. Optimal relay location is also find in our work for analyzing the system performance at various locations. The relays are placed at various locations between source and destination to investigate the change

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in BER and Outage probability performance. Rest of the paper is organized as follows: Section 2 discusses the materials and methods, where the system model has been presented. In-depth discussion on the simulation results has been presented in the Section 3. Finally, the Section 4 concludes this paper.

2. MATERIALS AND METHODS

System Model

A source, destination and two relays have been considered in our system as show in the **(Fig. 1)**. Relays can communicate and transmit system in both the ways. Single antenna is considered on each of the intermediate node and both DF and AF have been analyzed. The modulation scheme used is Binary Phase Shift Keying (BPSK). Maximal ration combining technique is used at the destination to get the received signals.

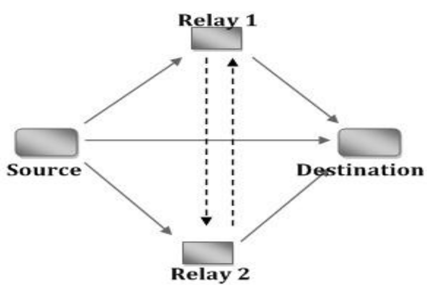

Fig.1: Inter-relay communication based protocol based on Three time slots.

Transmission Protocol

The transmission protocol used here is a three time slot transmission protocol with an extra time slot for the exchange of information between the two relays. Fig 1 shows our intended system model in which two relays are used to forward the information of the source to the destination. The signal received at destination is a composition of noise white Gaussian noise and the fading. In our work Nakagami-m fading channels have been considered. **(Table. 1)** shows the transmission protocol used for the transmission. As shown in the **(Table. 1)**, the source, in the 1st time slot, transmits the signal to both the relays and the destination which can be mathematically represented as follows, after first time slot:

$$y_{SR1} = h_{SR1}x + n_{SR1} \quad (1a)$$

and

$$y_{SR2} = h_{SR2}x + n_{sR2} \quad (1b)$$

Where h_{SR1} and h_{SR2} in the Equations (1a) and (1b) represent the (Source-R1) and (Source-R2) fading channels, respectively. n_{SR1} and n_{sR2} are the Additive White Gaussian Noise (AWGN) at the receivers.

The signal at the destination will be:

$$y_{SD} = h_{SD}x + n_{SD} \quad (2)$$

Where h_{SD} in the Equation (2) represents the Source-Destination fading, while n_{SD} is the added AWGN at the receiver.

Table. 1: TDMA based protocol based on Three time slots

Time Slot 1	Time Slot 2	Time Slot 3
S→R1,S→R2	R1→D, R2→D	R1→D
S→D	R1→R2, R2→R1	R2→D

As clear from the **(Table. 1)**, in the 2nd time slot, the received signals at R1 and R1 are sent to the destination. Meanwhile, an information exchange takes place between the relays R1 and R2. This mutual sharing of signals between R1 and R1 is the inter-relay communication. A Hybrid TDMA-FDMA based protocol is created as the signal exchanged is of two different frequencies. At destination following signals will be received:

$$y_{R1D} = h_{R1D}y_{SR1} + n_{R1D} \quad (3a)$$

and

$$y_{R2D} = h_{R2D}y_{SR2} + n_{R2D} \quad (3b)$$

The parameters, $\mathrm{h_{R1D}}$ and $\mathrm{h_{R2D}}$ in the Equations (3a) and (3b) represent the (Destination-R1) and (Destination-R2) fading, respectively. While n_{R1D} and n_{R2D} represent the AWGN added on the receive antennas.

The received signal at R1 from R2, in the 2nd time slot is represented by:

$$y_{R2R1} = h_{R2R1}y_{SR2} + n_{R2R1} \quad (4)$$

Where n_{R2R1} in the Equation (4) is the value for AWGN and h_{R2R1} shows the effect of fading on the signal while transmitting from the Relay 2 to Relay 1. Accordingly, the signal received at Relay 2 from Relay1 is expressed as:

$$y_{R1R2} = h_{R1R2}y_{SR1} + n_{R1R2} \quad (5)$$

Where h_{R1R2} shows the effect of fading on the signal while transmitting from the Relay1 to the Relay 2 and is the fading and n_{R1R2} is the AWGN.
Accordingly, the signal received from Relay 1 at the destination is represented by:

$$y'_{R1D} = h_{R1D} y_{R2R1} + n'_{R1D} \quad (6)$$

Where the parameters h_{R1D} and n'_{R1D} in the Equation (6) represent the fading and noise added at the receiver.

Accordingly, the signal received at the destination from Relay 2 is represented by:

$$y'_{R2D} = h_{R2D} y_{R1R2} + n'_{R2D} \quad (7)$$

Where the parameters h_{R2D} and n'_{R2D} in the Equation (7) represent the amount of fading experienced by the signal and AWGN added during transmission and at reception, respectively.

(Table. 1) shows the summery of the three time slot protocol used during the inter-relay communication based.

Relay Optimization

Relay optimization results in enhancing the performance of the relaying system. As shown in the **(Fig. 2)**, a summary of two dimensional relay model has been presented. The parameter asd_t shows the assumed distance between the source and the destination. The protocol B has been considered for the system model, where Relay 1 is fixed at position equal to $0.1d_t$, while the position of Relay 2 varies from $0.1d_t$ to $0.9d_t$. To investigate the performance of Outage probability and Gain, the Relay R2 is placed at distance equal to $0.1d_t$ initially and is moved in the range of $0.1d_t$ to $0.9d_t$. The received signal, in the first time slot, from source at R1 and R2 will be:

$$y_{SR1} = (d_{SR1})^{-\alpha} h_{SR1} x + n_{SR1} \quad (8a)$$

$$y_{SR2} = (d_{SR2})^{-\alpha} h_{SR2} x + n_{SR2} \quad (8b)$$

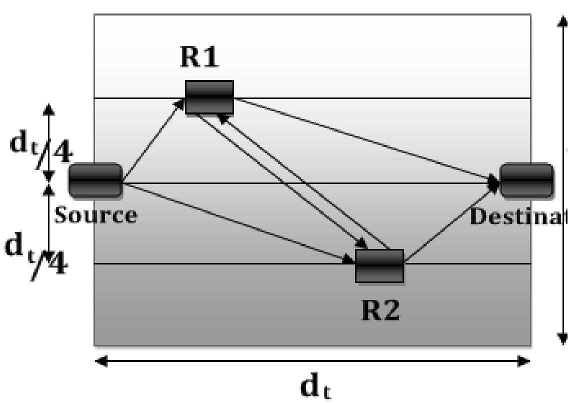

Fig. 2: System Model

Where d_{SR1} and d_{SR2} shows the distances between the Source and the relays (R1 R2), respectively. While the parameter ∝ shows the path loss exponent. The received signal at the destination, being transmitted from the source, during the 1st time slot is represented by:

$$y_{SD} = (d_{SD})^{-\alpha} h_{SD} x + n_{SD} \quad (9)$$

Where the parameter d_{SD} in the Equation (9) represents source to destination distance.

The Equation (10) is the mathematical representation of the received signal from Relay 1and Relay 2, measured at the destination:

$$y_{R1D} = (d_{R1D})^{-\alpha} h_{R1D} y_{SR1} + n_{R1D} \quad (10a)$$

$$y_{R2D} = (d_{R2D})^{-\alpha} h_{R2D} y_{SR2} + n_{R2D} \quad (10b)$$

Where d_{R1D} and d_{R2D} in the Equations (10a) and (10b) are the Relay 1 and Relay 2 distances from the Destination, respectively.

The signals received from Relay 1 to Relay 2, and vice versa, is represented by:

$$y_{R2R1} = (d_{R2R1})^{-\alpha} h_{R2R1} y_{SR2} + n_{R2R1} \quad (11a)$$

and

$$y_{R1R2} = (d_{R2R1})^{-\alpha} h_{R1R2} y_{SR1} + n_{R1R2} \quad (11b)$$

Where d_{R2R1} shows the distance from Relay 2 to the Relay 1.

The received signal at the destination from Relay 1 and 2, in the third time slot, is represented as:

$$y'_{R1d} = (d_{R1d})^{-\alpha} h_{R1d} y_{R2R1} + n'_{R1d} \quad (12a)$$

and

$$y'_{R2d} = (d_{R2d})^{-\alpha} h_{R2d} y_{R1R2} + n'_{R2d} \quad (12b)$$

3. RESULTS AND DISCUSSION

The system model considered in the previous section is simulated and the results are described in this section in detail. BER, Outage capacity and Outage probability are the two performance metrics used to show the performance of both AF and DF. To modulate the signal, the technique, Binary Phase Shift Keying is performed while the AWGN samples are real Gaussian variables with zero mean and unit variance.

BER Analysis **(Fig. 3)** shows BER results where Nakagami-m channel has been considered in order to compare the two relaying schemes. It is obvious from the results that Decode and Forward perform better as compared to Amplify and Forward scheme. Both schemes show same performance for lower SNR values, however, when SNR value goes up, the AF starts showing better performance than DF and at 12 SNR. For the value of m=1, the Nakagami channel a similar behavior as that of Rayleigh fading channel; Further, with an increase in the value of m, the system shows better performance, here we have considered m=1,

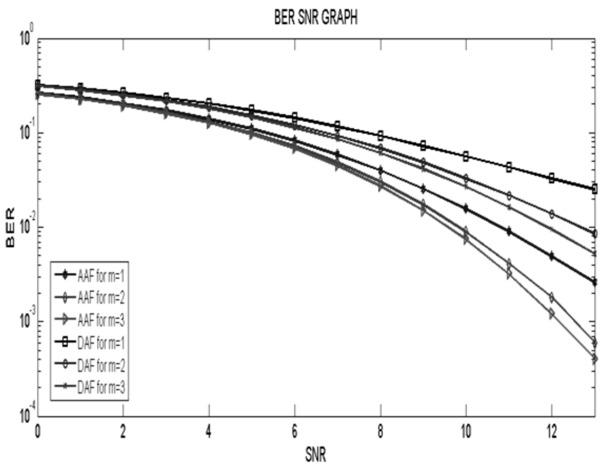

Fig. 3: BER Comparison for AF and DF

2 and 3. A simulation is performed for the system model, as shown in the **(Fig. 1)**, to calculate the Bit Error Rate. A comparative result of Bit Error Rate against the SNR is plotted. 10^5 number of symbols have been simulated for plotting the BER curves. **(Fig. 4)** shows 3D graph for BER in which the comparison of AF and DF is shown for various locations of both the relays. AF shows better performance than DF as clearly observed from the figure. DF shows better performance only when both the relays are at middle of source and destination.

Outage Probability

The characterization of the system performance is measured by the outage probability. Simulation has been performed for measuring the outage probability. **(Fig. 5)** shows the comparison of both AF and DF. The results showed better performance for DF as compared to AF. As it is cleared from **(Fig. 5)** that outage probability is same for AF and DF for SNR values lower than 10 but at 20 SNR value an increased performance for DF is observed. **(Fig. 6)** shows 3D graph for outage probability results for various locations of both the relays as explained in the previous section. Projection of relays means the relative distance of relays from the source.

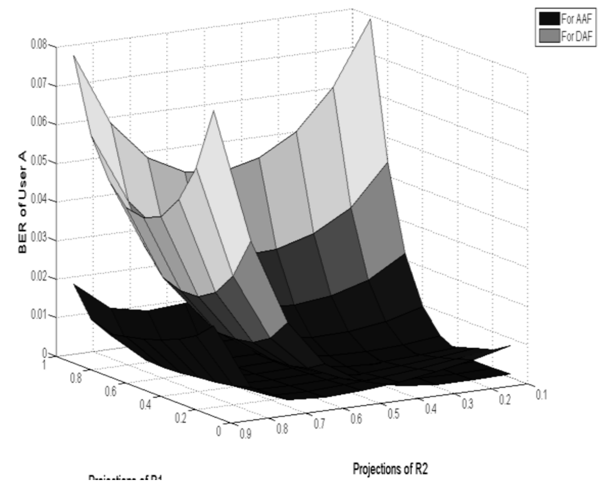

Fig. 4: Comparison between AF and DF

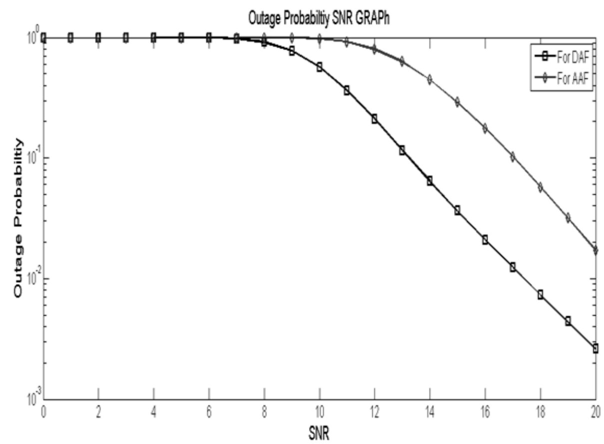

Fig. 5: Comparison between AF and DF

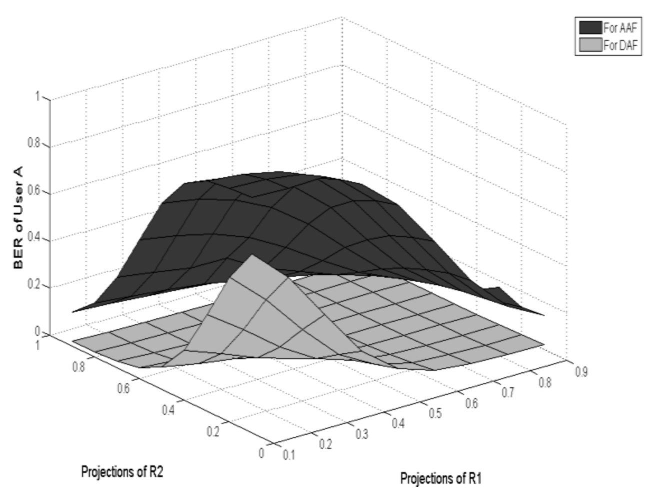

Fig. 6: Outage probability analysis for relay optimization

Here, we can see that DF shows better performance when the relays are closed to source or destination but the performance of AF is not good for and the values of Outage probability is large.

Outage Capacity

Outage capacity curves are shown in **(Fig. 7)**. The results clearly show that outage performance is better for DF as compared to AF. Both the schemes show This section can be summarized by discussing the scope of our results.

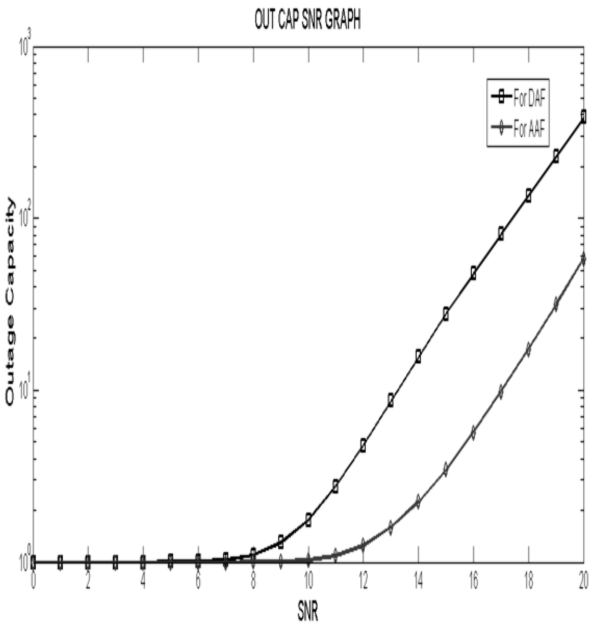

Fig. 7: Outage Capacity For Nakagami-m fading channel with relay optimization

This section provided us the comparison of two relaying schemes. The results clearly showed that for outage analysis DF shows better performance while BER performance is better for AF. Both schemes show the same performance up to 8 SNR value but as the SNR value is increased AF starts performing better.

4. CONCLUSION

Two relaying schemes for different parameters have been investigated and compared in our work. For the considered inter-relay communication based protocol DF showed better performance than AF for outage analysis while AF performs better while considering BER analysis. The work also presents the optimal relay location analysis which helped in showing that what is the best relay location. In our future work, the mathematical modelling of the proposed system will be considered. An improvement in the network performance can be achieved with multiple relays consideration and relaxing some of the assumption made in the current work.

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