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Performance Analysis of Relaying Protocol for Cooperative Communication System over Nakagami-m Channels

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***ABSTRACT*:** Cooperative Communication is a scheme that combines the benefits of MIMO systems with relay techniques and forms a virtual distributed MIMO system. The relaying techniques used in this paper are Amplify and Forward and Decode and Forward. The performance of Amplify and Forward protocol is analysed using single relay and two relays and compared to direct link. The QPSK modulation technique is used and signals are combined using maximum ratio combining at receiver. The performance of Decode and Forward protocol is also analysed using a number of relays. The signal is decoded and re-encoded at one relay and how the signal is transmitted when error occur and when error does not occur has been shown and its comparison to direct link has been done.

Keywords: Amplify and Forward, Cooperative Communication, Decode and Forward, MIMO, QPSK.

I. INTRODUCTION

The idea of Cooperation firstly was presented by Vander Meulen 1971.The foundation of the relay channel was established there. In Cooperative communication the neighbouring node overhear the source's signal due to broadcast nature of wireless medium and sends the information to the destination. In this way, the cooperating nodes create a virtual antenna array [1]. With cooperation it is possible to obtain the cooperative diversity benefits of MIMO systems without the cost of having a physical antenna array at each terminal. Thus, because of these benefits cooperative communication is a promising technique which can be widely used in next-generation wireless networks [2].

When a mobile user wishes to communicate with the base station, but if the link between them is too weak then the nearby mobile user cooperates shares their antenna and aids n direct communication. Using relays the coverage and capacity of cellular network can be increased without any increase in extra bandwidth and mobile transmit power [3].The transmission in which a source and relay cooperate to send a message to a destination is cooperative transmission and it can provide spatial diversity against fading in wireless networks. The analytical expressions for the error probability of amplify-and-forward (AF), decode-and-forward (DF), and a new hybrid AF/DF relaying protocol in Rayleigh fading channels has been derived for systems using strong forward error correction [4].

The Cooperative Communication can be utilized to mitigate channel estimation error which is the main cause of performance degradation. Two performance criteria used to study it are outage probability and signal to noise gap ratio. Using Cooperative Communication the SNR gap ratio is lowered and outage probability is also reduced [5].The performance of fixed decode-and-forward cooperative networks with relay selection over independent but not identically distributed for severity parameter m was analysed. Closed-form expressions the symbol error probability and the outage probability are derived using the statistical characteristic of the signal-to-noise ratio [6].

The rest of the paper is organized as follows. In section II Proposed model, amplify and forward protocol and decode and forward protocol are explained. In section III Experiments and Results are presented. In section IV Conclusion is given.

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II. PROPOSED MODEL

The Cooperative communication system consists of a source S, destination D and a number of relays are placed in between of them. Each node is equipped with single antenna and all of them can not transmit or receive at the same time. The fading channel coefficients between source and destination, source and relay and relay and destination are denoted by h_{sd}, h_{sr} and h_{rd} respectively, where they are modelled as Nakagami-m distributed random variables with parameters shaping factor, m and spreading factor, Ω. The relays are using parallel transmission topology. Thus, the probability density function is given by

$$F(x;m,\Omega) = \frac{2m^m x^{2m-1} \exp(-mx^2/\Omega)}{\Gamma(m)\Omega^m} \quad (1)$$

Thus the system models for Amplify and Forward cooperative communication and Decode and Forward cooperative communication is as shown in Fig 1 and Fig 2.

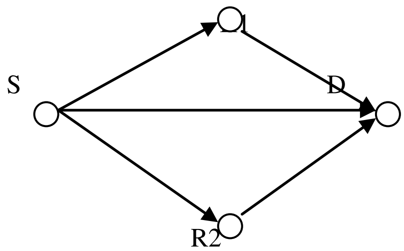

Fig.1 System model for Amplify and Forward Cooperative Communication.

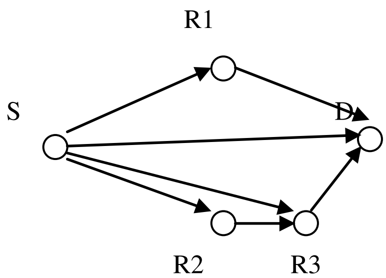

Fig.2 System model for Decode and Forward Cooperative Communication.

A. Amplify and Forward protocol

As shown in Fig. 1 a source is transmitting data to the destination. The transmission of the data from the source to the destination terminal is accomplished in two phases. In the first phase, the source broadcasts data to the destination and also to relay. In the second phase, the relay after receiving data amplifies the received data and retransmits it to the destination. The relay receives the information signal appended by the channel gain and noise. The amplified signal is sent to the destination. Now, the receiver can decode the combined signal using Maximal Ratio Combining (MRC) [7]. In the first phase, the source broadcasts its information with transmission power P to destination and relays

$$Y_{sr} = \sqrt{P}\, h_{sr}\, x + n_{sr} \quad (2)$$

$$Y_{sd} = \sqrt{P}\, h_{sd}\, x + n_{sd} \quad (3)$$

Then, all the relays will forward the scaled versions of the received signal to D in the matched phases. Thus, at the destination terminal, the received signals from the relay R can be written as

$$Y_{rd} = \beta_k h_{rd} Y_{sr} + n_{rd} \quad (4)$$

where, $\beta_k = \sqrt{[P_k / (P\,|h_{sr}|^2 + N_o)]}$ and P_k is the transmit power of any relay. The source-to-relay and the relay-to destination paths are separately estimated [8].

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B. Decode and Forward protocol

In decode and forward protocol processing occurs at the relay node. The relay decodes the received signal, re-encode it, and then retransmit it to the receiver. The decoded signal at the relay may be incorrect. If an incorrect signal is forwarded to the destination, the decoding at the destination is meaningless.

The received signal at the destination in Phase 2 can be modelled as

$$Y_{s,d} = \sqrt{P_2}\, h_{s,d}\, x + n_{s,d} \tag{5}$$
$$Y_{r,d} = \sqrt{P_2}\, h_{r,d}\, x + n_{r,d} \tag{6}$$

With knowledge of the channel coefficients $h_{s,d}$(between the source and the destination) and $h_{r,d}$(between the relay and the destination), the destination decodes the transmitted symbols and the signals are received as $Y_{s,d}$ from the source and $Y_{r,d}$ from the relay. As shown in Fig.2 the decoding of signal occurs at R2. Here, the signal is decoded and checked for error if error=1 then the signal is transmitted by R3 to destination and if error=0 then the signal is re-encoded and transmitted through R1 to destination.

C. SNR and BER analysis

The equivalent SNR of MRC output is

$$\gamma = \frac{[|A|^2 + \sum_{i=1}^{n} |B_i|^2]}{N_o} \tag{7}$$

It can be transformed as

$$\gamma = \gamma_1 + \gamma_2 \tag{8}$$

Where γ_1 and γ_2 are

$$\gamma_1 = |A|^2 / N_o \tag{9}$$
$$\gamma_1 = P_1 \, |h_{s,d}|^2 / N_o \tag{10}$$
$$\gamma_2 = \frac{\sum_{i=1}^{n} |B_i|^2}{N_o} \, i=1,2 \tag{11}$$
$$\gamma_2 = \sum_{i=1}^{n} \gamma_i \tag{12}$$

Thus,

$$\gamma_i = \frac{1}{N_o} \frac{P_1 \, P_{ri,d} \, |h_{s,ri}|^2 \, |h_{ri,d}|^2}{P_1 |h_{s,ri}|^2 + P_{ri,d} |h_{ri,d}|^2} \tag{13}$$

γ_1 is the SNR of MRC output formed by signal's transmitting from source node to destination node. γ_i is the SNR of MRC output formed by signal's transmitting through the *i*-th relay-assisted channel. *n* is the total number of relay nodes. γ_2 is the total SNR of all relay links. γ_i can be tightly upper bounded as

$$\gamma_i < \breve{\gamma}_i = \frac{1}{N_o} \frac{P_1 \, P_{ri,d} \, |h_{s,ri}|^2 \, |h_{ri,d}|^2}{P_1 |h_{s,ri}|^2 + P_{ri,d} |h_{ri,d}|^2} \tag{14}$$

which is the harmonic mean of two exponential random variables $P_1 \, |h_{s,ri}|^2 / N_o$ and $P_{ri,d} \, |h_{ri,d}|^2 / \, N_o$. If we approximate the SNR a $Y = Y_{s,d} + \sum_{k=1}^{N} \gamma_i$. The conditional SER of AF cooperation systems with MPSK modulations can be given as follows [

$$P_{psk} \approx \frac{1}{\pi} \int_0^{\frac{(M-1)\pi}{M}} \exp\left(\frac{-b_{psk}}{\sin^2\theta}\gamma\right) d\theta \tag{15}$$

III. EXPERIMENTS AND RESULTS

The performance of Amplify and Forward protocol is analyzed when direct link is used for transmission of signals, when single relay is used and when two relays are used and all signals are combined at receiver. Matlab 7.8 software platform is use to perform the experiment.

This is done by taking different values of shape parameter i.e. m=1 and m=2. The graph shows that BER is reduced when single relay is taken as compared to direct link. The performance also improves when two relays are taken as compared to direct link. Using two relays instead of one provides a diversity gain.

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The performance of Decode and Forward protocol is analysed when direct link is used for transmission of signals and compared after applying decode and forward at decoding relay. The results have been analysed taking different values of m i.e. m=1 and m=2.

In Fig.3 direct link is compared with amplify and forward with single relay. In Fig.4 direct link is compared with amplify and forward with two relays. In Fig.5 direct link, amplify and forward with single relay and with two relays are compared for m=1. In Fig.6 direct link, amplify and forward with single relay and with two relays are compared for m=2. In Fig.7 and Fg.8 decode and forward protocol is compared with direct link for m=1 and m=2.

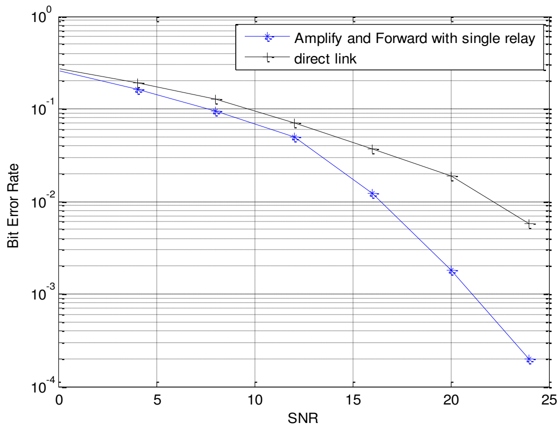

Fig.3 Comparison of direct link with Amplify and Forward with single relay.

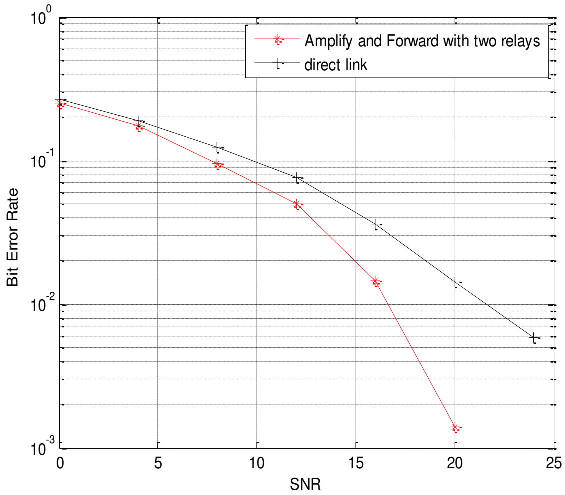

Fig.4 Comparison of direct link with Amplify and Forward with two relays .

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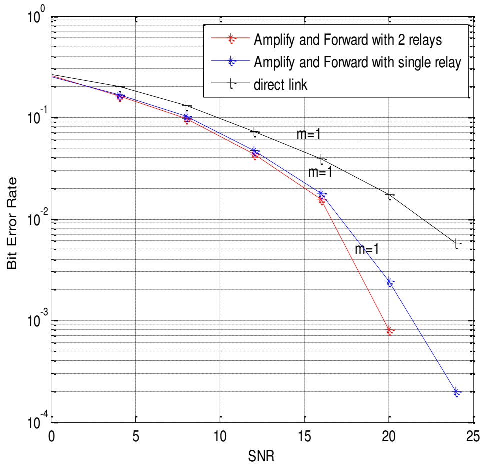

Fig.5 Comparison of direct link with Amplify and Forward with single relay and Amplify and Forward with two relays for m=1.

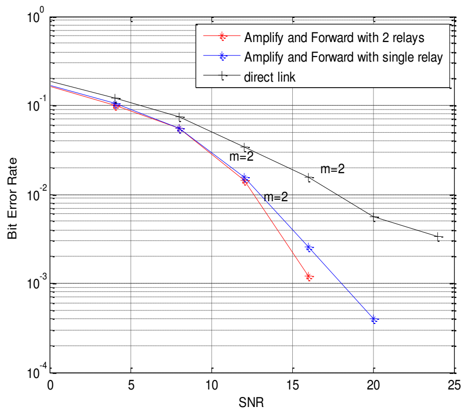

Fig.6 Comparison of direct link with Amplify and Forward with single relay and Amplify and Forward with two relays for m=2.

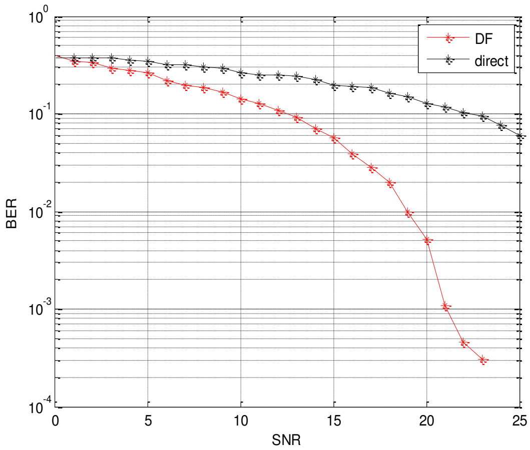

Fig.7 Comparison of direct link with Decode and Forward relays for m=1.

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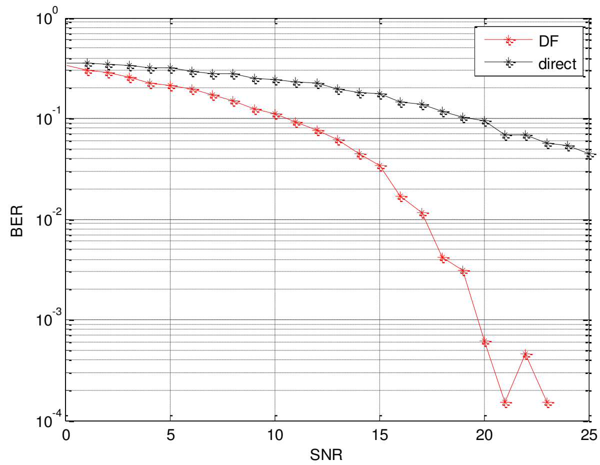

Fig.8 Comparison of direct link with Decode and Forward relays for m=2.

TABLE I
SIMULATION PARAMETERS FOR AMPLIFY AND FORWARD

Amplify and Forward		
S.no.	**Parameter**	**Value**
1	Signal to Noise Ratio	0-25(varying)
2	Number of symbols	5000
3	Modulation technique	QPSK
4	Channel used	Nakagami-m channel
5	Shape parameter, m	1,2
6	Controlling spread, Ω	2
7	Software	Matlab
8	version	7.8

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TABLE II
SIMULATION PARAMETERS FOR DECODE AND FORWARD

Decode and Forward		
S.no.	**Parameter**	**Value**
1	Signal to Noise Ratio	0-25(varying)
2	Number of symbols	100
3	Modulation technique	8-PSK
4	Channel used	Nakagami-m channel
5	Shape parameter, m	1,2
6	Controlling spread, Ω	2
7	Software	Matlab
8	version	7.8

IV. CONCLUSION

In this paper the performance of Amplify and Forward and Decode and Forward cooperative communication systems is analysed. It is seen that in Amplify and Forward when single relay is used instead of direct link, there is a reduction in bit error rate. When two relays are used instead of direct link, there is a reduction in bit error rate. Thus, using two relays instead of single relay is providing improved performance. Moreover, the performance also improves when m=2 compared to m=1.

It is also observed that the performance of Decode and Forward cooperative communication systems improves compared to direct link. Moreover, the performance also improves when m=2 compared to m=1.

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BIOGRAPHY

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