Performance Analysis of Cooperative Networks with Inter-Relay Communication over Nakagami-m and Rician Fading Channels

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***Abstract*—Time Division Multiple Access (TDMA) based transmission protocols have been proposed previously by various research communities, however, the analysis of these protocols are not considered for both Nakagami-m and Rician fading channels with inter-relay communication. We present a detailed and profound analysis of TDMA based protocols for cooperative networks with inter-relay communication over both Nakagami-m and Rician fading channels considering path loss effect. The Gain of the network over various locations of the relays is also presented. Bit error rate (BER) and Cooperation Gain are the parameters used to analyze the network.**

***Keywords*—**TDMA, Cooperative Networks, Rician Fading, Nakagami-m and Network Protocols

I. INTRODUCTION

The rapid development of wireless communication technology leads to the next generation (xG) wireless network. xG will appear as an ultra-high speed broad band wireless technology [1]. There are three main challenges to be addressed to attain the desired data rate for wireless communication i.e. power on terminals, complexity and spectral efficiency. Multiple antenna diversity techniques in combination with time and frequency diversity are generally used to enhance the system capacity and transmission reliability. Due to size, cost, or hardware limitations, a wireless agent may not be able to support multiple transmit antennas and hence Cooperative networks is the promising alternating solution to these challenges [2]. In cooperative networks, the number of paths between source and destination is equal to the diversity that can be obtained [3].

Multipath fading is another factor that degrades the performance of wireless communication networks. To mitigate the multipath fading and system capacity issues Cooperative networks in combination with other diversity techniques are recently used [4]-[6].

The intermediate relay decodes or amplifies the signal received from the source and forwards it to the destination. In decode-and-forward (DF), the relay decodes the signal. Whereas in Amplify-and-forward (AF), the relay amplifies the signal received from the source [6]-[7]. In AF the relay simply retransmits the noisy version of received signal after amplifying it. AF mode experiences less processing speed but on the other hand can outperform the latter [7].

Different conventional access techniques have been proposed and used by the researchers such as time-division multiple access (TDMA), frequency-division multiple access (FDMA) and code-division multiple access (CDMA) [8]-[10]. In [11], Nabaret al. proposed three different TDMA based protocols for the transmission of signal from source to destination.

The performance of two TDMA based protocols is analyzed over Nakagami-m fading channels [13]. Hybrid FDMA-TDMA allocation technique with transparent relaying scheme is analyzed in terms of bit error rate (BER) and symbol error rate (SER) over Rician and Nakagami-mfading channels [14,15].A three time slot TDMA based transmission protocol with the third time slot for an inter-relay communication over Rayleigh fading channels [12].

To the best of our knowledge, the inter-relay three time slots transmission protocol have not been investigated over Nakagami-m and Rician Fading channel. In this paper, the cooperative network is analyzed for various relays location over Nakagami-m and Rician fading channels. The transmission is made in three time slots with inter-relay communication. The performance of the network is examined in term of Bit Error Rate (BER) and Cooperation Gain. Relaying schemes i.e. AF will be considered at the relays. Relay optimization is also considered in our work with different locations of both the relays. The development of three time slots transmission protocol with inter-relay communication is capable of providing an improved BE performance as compared with the two time-slots non-inter-relay communication protocols.

The remaining paper is organized as follow: Section II describes the detailed system model under consideration for two time slot and three time slot transmission protocols. Optimal relay location is also discussed in detail in this section

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for Nakagami-m fading channel. Performance analysis of the intended system model is discussed in section III. Fading channels used are Nakagami-m and Rician fading channel, Amplify and forward scheme is used at relays. Section V presents the conclusion of the paper and future work.

II. SYSTEM MODEL

A cooperative network with multiple relay is considered, as illustrated in Fig. 1. The system model consists of a source, multiple fixed relays and a destination. All terminals are equipped with single antenna. The relays are operating in AF mode. The destination uses MRC to extract the required signal.

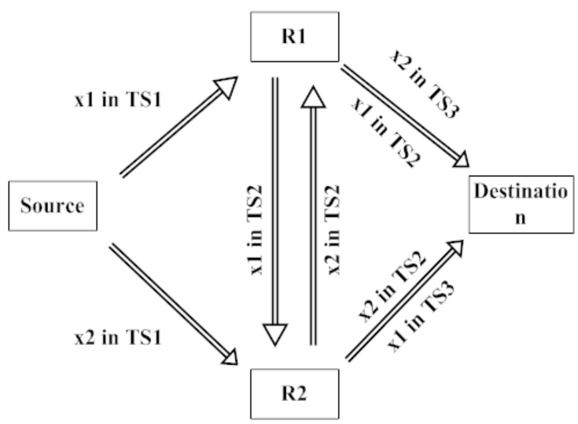

Fig. 1: Protocol B (Three time Slot Inter-relay communication Protocol)

A. *Transmission Protocol A*

Consider a wireless system where n numbers of relays are used for cooperation. For simplicity let us assumed n=2. The two time slots TDMA based protocol proposed in [11] is analyzed for two relays over Nakagami-m and Rician fading channels. In this protocol, source broadcasts signal x1 and x2 to the relays R1 and R2 respectively in the first time slot. The signal is amplified at the relays and forwarded to the destination. The signals received at the destination are given by:

$$y'_{R1d} = G'_1 h'_{R1d} y'_{sR1} + n'_{R1d}$$

And

$$y'_{R2d} = G'_2 h'_{R2d} y'_{sR2} + n'_{R2d}$$

Where y'_{sR1} and y'_{sR2} are the signals received at R1 and R2 in 1st time slot, respectively. h'_{R1d} and h'_{R2d} are the fading channels from R1 to destination and R2 to destination, respectively. n'_{R1d} and n'_{R2d} are the Additive White Gaussian Noise (AWGN) added to the signals received at the destination from R1 and R2, respectively. G is the gain for AF relaying scheme. Table 1 shows the summarized form of the transmission protocol [11] of the system model discussed above.

TABLE 1: TWO TIME SLOT TDMA BASED TRANSMISSION PROTOCOL

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

B. *Transmission Protocol B (Inter-relay communication)*

Fig. 1 shows a system model in which the signal is transmitted to destination in three time slots. Table 2 shows the summarized form of the protocol [12]. In the first time slot the signal x is broadcasted to both the relays. The received signals at R1 and R2 are y_{sR1} and y_{sR2}, respectively and given by:

$$y_{sR1} = h_{sR1} x + n_{sR1}$$

And

$$y_{sR2} = h_{sR2} x + n_{sR2}$$

Where h_{sR1} and h_{sR2} are the fading channels from source to R1 and R2 respectively. x is the signal transmitted by the source.

When both the signals are received at R1 and R2 respectively in the first time slot, both the relays interchange their respective signals in the second time slot. R1 and R2 will also send the amplified signals to the destination in the same time slot. The output signal at destination from R1and R2 will be:

$$y_{R1d} = G_1 h_{R1d} y_{sR1} + n_{R1d}$$

And

$$y_{R2d} = G_2 h_{R2d} y_{sR2} + n_{R2d}$$

R1and R2 exchange signals $G_1 y_{sR1} G_2 y_{sR2}$, respectively.
The received signal at R1 from R2 is

$$y_{R2R1} = G_2 h_{R2R1} y_{sR2} + n_{R2R1}$$

Where h_{R2R1} the fading is channel from R1 and R2 and n_{R2R1} is the AWGN. Similarly the receivedsignal at R2 from R1 will be

$$y_{R1R2} = G_1 h_{R1R2} y_{sR1} + n_{R1R2}$$

TABLE 2: THREE TIME SLOTS TDMA BASED TRANSMISSION PROTOCOL

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

In the third time slot R1 will transmit y_{R2R1} to the destination while R2 will send y_{R1R2} to the destination. The received signal at the destination from R1 will be

$$y_{R1d} = G_3 h_{R1d} y_{R2R1} + n_{R1d}$$

Similarly the received signal at destination from R2 will be:

$$y_{R2d} = G_4 h_{R2d} y_{R1R2} + n_{R2d}$$

MRC (Maximum ratio Combining) is used to extract the required signal at destination.

C. *Relay Optimization*

Relay optimization is one of the important factors for enhancing system performance; this section briefly describes the relay optimization system model presented in this paper.

Fig 2 shows a system model in which R1 and R2 have been placed in various locations to find the optimal relay location that gives the best system performance. The total distance between source and destination isd_t, R1 is set at fixed location $0.1d_t$ and R2 is moved along the axis to change the location of R2 from $0.1d_t$ to $0.9d_t$.

Similarly R2 is then set at $0.2d_t$ and R1 is placed at different locations to check the best relay location.

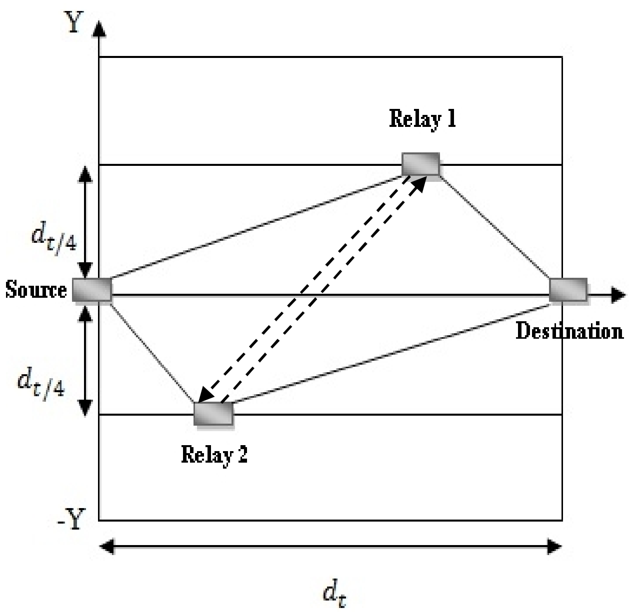

Fig 2: Relay Optimization

While considering relay location three time slot transmission protocol with inter-relay communication is used. Now the input/output equations will be as follows:

The received signal in the first time slot from source at R1 and R2 will be:

$$y_{sR1} = (d_{sR1})^{-\alpha} h_{sR1} x + n_{sR1}$$

$$y_{sR2} = (d_{sR2})^{-\alpha} h_{sR2} x + n_{sR2}$$

Where d_{sR1} and d_{sR2} are the distances between source to R1 and source to R2, respectively.∝is the path loss exponent.The received signal at destination from R1and R2can be expressed as:

$$y_{R1d} = G_1 (d_{R1d})^{-\alpha} h_{R1d} y_{sR1} + n_{R1d}$$

And

$$y_{R2d} = G_2 (d_{R2d})^{-\alpha} h_{R2d} y_{sR2} + n_{R2d}$$

Where$d_{R1d}$and d_{R2d} are the distances from R1 to destination and R2 to destination.

The received signals at R1 from R2 and at R2 from R1 can be expressed as:

$$y_{R2R1} = G_2 (d_{R2R1})^{-\alpha} h_{R2R1} y_{sR2} + n_{R2R1}$$

$$y_{R1R2} = G_1 (d_{R2R1})^{-\alpha} h_{R1R2} y_{sR1} + n_{R1R2}$$

Here d_{R2R1} is the distance from R2 to R1.
The received signals in the third time slot at destination from R1 and R2 will be

$$y_{R1d} = G_3 (d_{R1d})^{-\alpha} h_{R1d} y_{R2R1} + n_{R1d}$$

$$y_{R2d} = G_4 (d_{R2d})^{-\alpha} h_{R2d} y_{R1R2} + n_{R2d}$$

As discussed in previous section, the MRC will be used to extract the required signal at destination.

III. RESULTS AND DISCUSSIONS

A. *BER Analysis*

This section provides results for protocol A and B discussed in previous section. BER is the performance metric and is calculated for the above system models for Nakagami-m and Rician fading channel. Better performance has been observed for inter-relay communication i.e. three time slot protocol. Binary phase shift keying (BPSK) is used to modulate the signal; the AWGN samples are complex Gaussian variables with zero mean and one variance. The performance curves are plotted in terms of BER versus Signal to Noise Ratio (SNR). 10^5numbers of symbols have been simulated for plotting the BER curves.

Figure 3 shows the comparison of protocol A and protocol B for BPSK over Nakagami-m fading channels with m=1 (Rayleigh fading), m=2 and m=3. Protocol A is for cooperation without inter-relay communication while in protocol B inter-relay communication is used.

The curves of inter-relay communication with the third extra time slot show higher diversity order then the two time slot transmission protocol. The results clearly showed that inter-relay communication shows better performance for Nakagami-m fading channel.

It is also observed that as we increased the value of m from 1 to 3 higher diversity order has been achieved. Fig.4. Shows the comparison of both the system models discussed above for Rician fading channel where k=0, 2 and 5.

As shown from the simulation that for inter-relay communication we have achieved better performance of BER. It is also clear that for higher values of k, an increased performance of BER has been observed.

From the above discussion of both the comparison with Nakagami-m and Rician fading it is justified by the simulations that using third time slot for inter-relay communication results in the better performance of BER using BPSK modulation scheme.

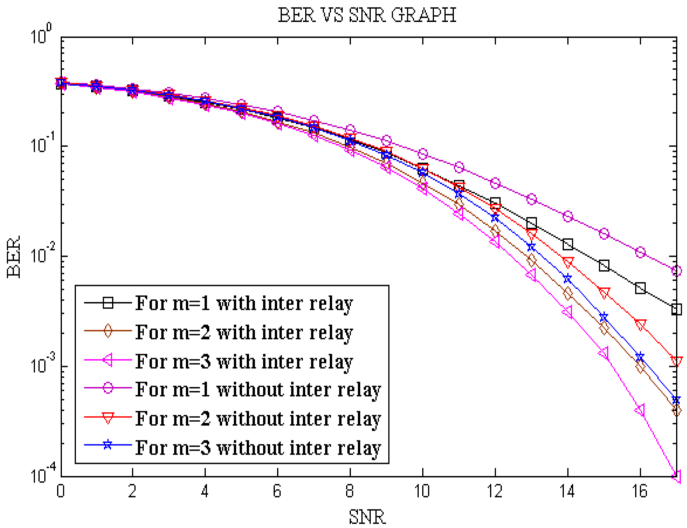

Fig. 3. Comparison of two time slot transmission protocol and three time slot TDMA based protocol with inter-relay communication for Nakagami- m fading where m=1,2and 3.

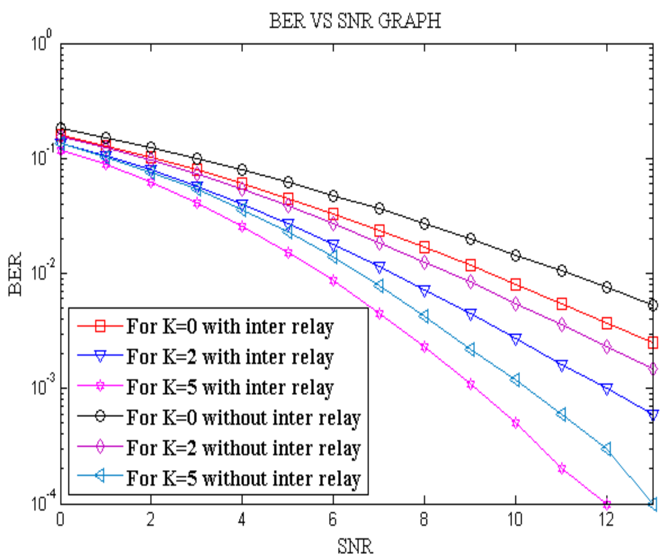

Fig. 4. Comparison of two time slot transmission protocol and three time slot TDMA based protocol with inter-relay communication for Rician fading where k=0,1and 5.

B. Optimal Relay Location

Protocol A is been simulated for analyzing the best relays location.Assuming different locations of both the relays we have considered three cases for our simulation where the location of both the relays will be varied and we get different simulation results of BER. BPSK modulation scheme is used in this simulation for Nakagami-mfading where value of m is kept 1 (Rayleigh fading) for simplicity.

a) *Case 1*

When R1 is at 0.25 and R2 is at 0.75, the result is shown in Fig, 5(a) for Nakagami-m fading when m=1.And it can be observed that the performance increases as SNR is increased.

b) Case 2:

For R1 at 0.4 and R2 at 0.6 we get best performance of BER. Asthe distance between two relays is decreased an increased performance BER is observed as inter-relay communication becomes prominent in this case.

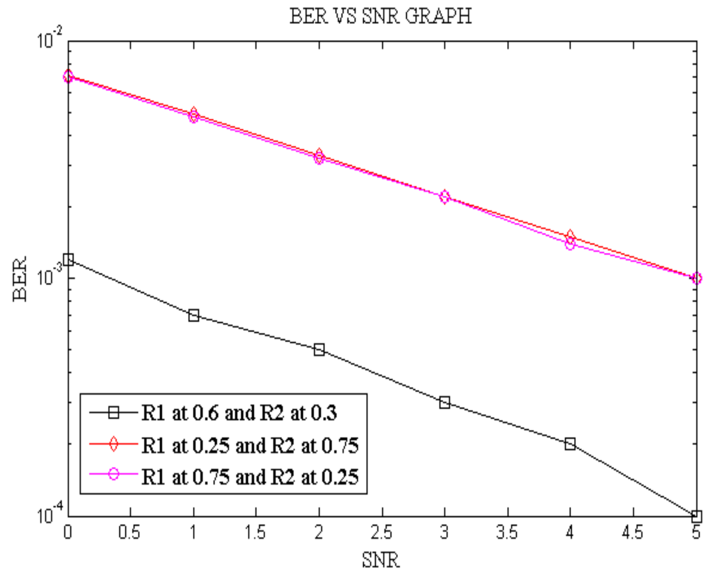

Fig. 5 (b) Optimal Relay location for Rician Fading when k=1

c) Case 3:

As R1 is at 0.75 and R2 at 0.25 the result of this case is much similar to the case one where R1 was at 0.25 and R2 at 0.75

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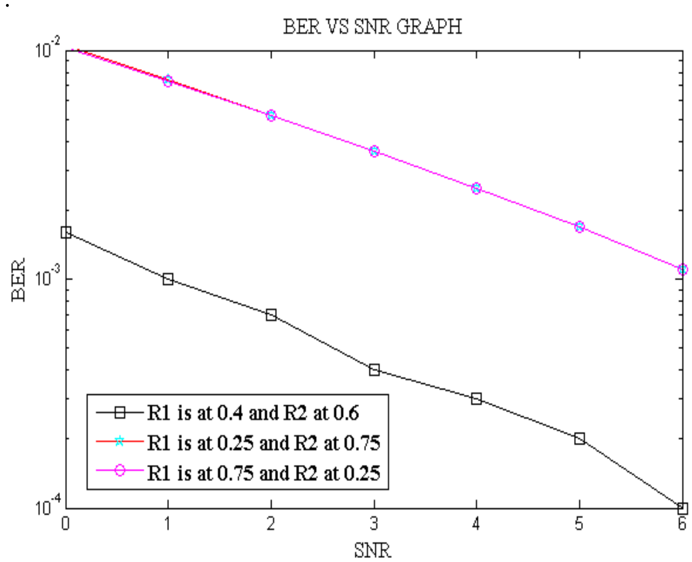

Fig. 5 (a) Optimal Relay Location for Nakagami fading channel when m=1

Fig. 5(b) shows the results of the simulations of Rician fading when k=1 and is similar to Nakagami-m fading case.

Fig. 6 and Fig. 7 show the simulation model for BER analysis with relay optimization. The system model is simulated for Nakagami-m and Rician fading channels. The distance between source and destination is assumed asd_t, this is further normalized as 1 for simplicity. We have placed the both the relays on number of possible locations and analyzed the BER performance at SNR=8 db.

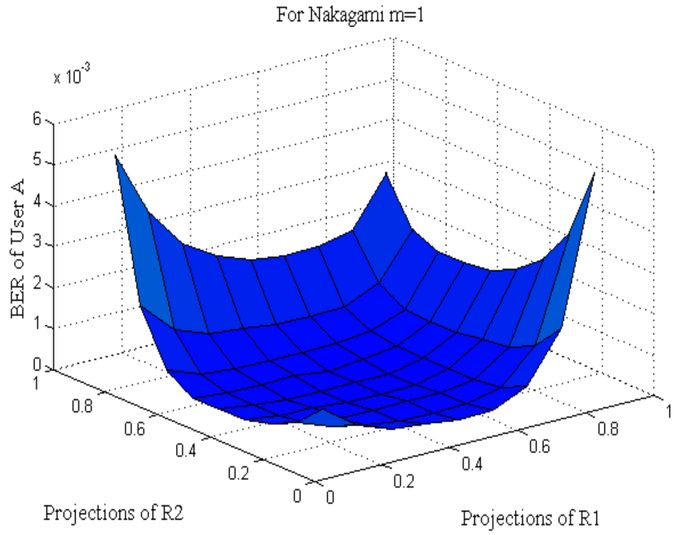

Fig. 6. BER Analysis with relay optimization for Nakagami-m fading channel (m=1)

First of all we assumed that R1 is at $0.1d_t$while we kept on moving R2 from $0.1d_t$ to $0.9d_t$. Then in the second step we fixed the distance of R2 to $0.2d_t$ and moved R1 along the axis from $0.1d_t$ to $0.9d_t$. Fig. 6 shows the 3d graph for this simulation model for Nakagami-m fading where m=1.

Fig. 7 shows the BER analysis of with relay optimization for Rician fading channel where k=1.The result shows higher values of BER at end and better performance at the centre for both the fading channels.

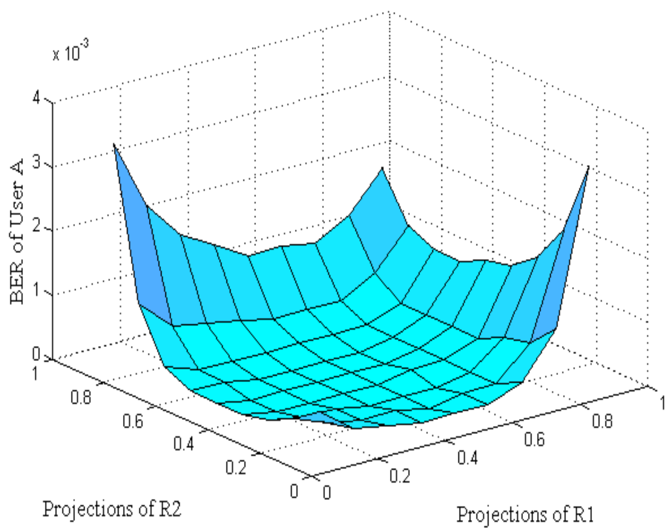

Fig. 7 BER Analysis with Relay Optimization for Rician Fading (k=1)

When both the relays are at central values then we get best performance as shown by the graph.

C. *Cooperation Gain*

Cooperation gain has been evaluated and simulated for the simulation model shown in Fig. 8 and 9.

Cooperation gain can be evaluated by the following relation

Gain= BER_{nc}/BER_c

Where BER_{nc} and BER_c are the bit error rate with no cooperation and bit error rate with cooperation.

Fig. 8 and Fig. 9 show the gain analysis of the simulation model for Nakagami-m and Rician fading channel respectively. Different locations of relays have been taken into account and gain is calculated at these locations.

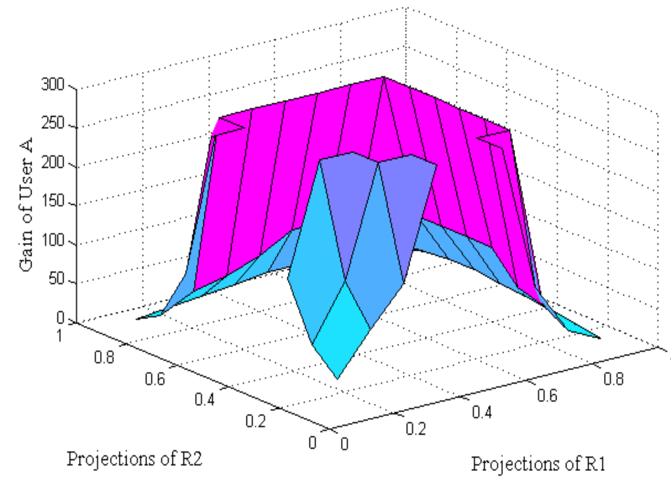

Fig. 8. Cooperation gain for Rician Fading channel with relay optimization

The value of m for Nakagami fading is kept as one similarly for Rician k=1.

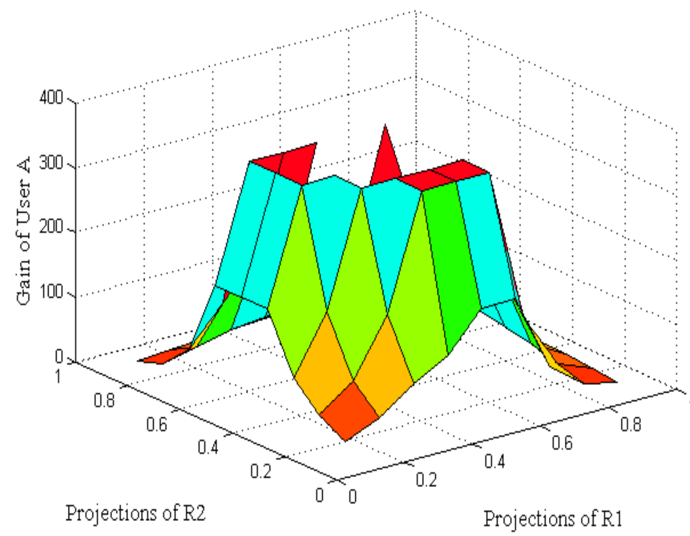

Fig. 9. Cooperation Gain for Nakagami-1 fading channel with relay optimization

The advantage of cooperation is shown by this gain analysis in terms of BER.

This section can be concluded by discussing the overall results achieved in our analysis and contribution to the field.

Different TDMA based transmission protocols were suggested however were not analyzed and were needed to be addressed and compared for Nakagami-m and Rician fading channels. The prominence of our work can be estimated by the fact that a profound analysis of three time slot transmission protocol is presented and the results substantiated that an extra time slot for inter-relay communication demonstrated better performance of BER than two time slot transmission protocol. Our work will be supportive in solving the challenges of the system capacity, coverage area and improving diversity in Next Generation Wireless Networks.

IV. CONCLUSION

A three time slot TDMA based transmission protocol has been investigated and simulated with an extra time slot for inter-relay cooperation. The comparative analysis of three time slot transmission protocol with two time slot transmission protocol shows the better performance of three time slot transmission protocol. Results show a clear increased performance of the investigated protocol for different fading channels. Furthermore BER and Gain cooperation for relay optimization have been analyzed for various locations of the relays.

Future work is desired to perform the mathematical modeling of this system. For simplicity we have considered just two relays though in real-world scenarios multiple relays are used and the performance will be dissimilar. BER performance can be further enhanced by removing the assumptions made in our work.

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