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The Performance Improvement of Inter-Relay Cooperative Wireless Communication using Three Time Slots TDMA based Protocol over Rician Fading

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Abstract*— Time Division Multiple Access (TDMA) amplify and forward based protocols have been investigated previously by various researchers. However, the gap is still there to investigate the performance of these protocols using inter-relay communication in order to improve the diversity order at destination over Rician fading channel. Therefore, the aim of this paper is to propose TDMA based amplify and forward three time slot protocol with inter-relay communication over Rican fading channel. The proposed protocol is also investigated for various relay locations in order to optimize the best relay locations in terms of less bit error rate (BER). It is concluded that the proposed amplify and forward three time slot protocol (PAFP) perform better in terms of low BER values as compared to previously proposed amplify and forward (PPAF) two time slots and three time slots protocols. Moreover, PAFP shows better results as compared to PPAF three time slots protocol in terms of less BER values when the inter-relay distance is minimum

***Index Terms*— Cooperative inter-relay wireless communication, AF Protocol, TDMA, BER.**

I. INTRODUCTION

The mobile radio channel suffers due to fading effects during transmission of data from source to destination and undergoes through several signal variations at destination. In order to mitigate fading, diversity communication is used to send the same data over independent fading paths (diversity branches). There are some common techniques such as micro diversity, macro diversity, space diversity, frequency diversity and time diversity, which are used at the transmitter and receiver to achieve diversity communication [1]. The diversity achieved by the above methods tends to increase the size, complexity and total power of the wireless network devices. To solve this problem cooperative diversity communication has been introduced recently.

In cooperative diversity communication, diversity is achieved due to cooperation among users or relays, for example, in case of two users or relays and one destination, each user or relay is not only responsible for transmitting their own information data, but the information of their partner user or relay as well to the destination, virtually seeking the advantages of MIMO spatial diversity [2-5].

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Each user in cooperative diversity acts as a relay for another user using either amplify and forward (AF) or decode and forward protocol (DF) in order to transmit the information to destination. In DF the relay decodes the received signal from the source and forwards to destination, while, in AF the relay amplifies the received signal from source and forwards to destination [3],[6]. Cooperative communication solves the issues of size, cost, and hardware limitations of multiple antennas [7]. Moreover, cooperative communication also helps to reduce the effects of multi-path fading and increase capacity of wireless channel as well as achieves high data rates [8-9].

Different multiple access techniques such as time-division multiple access (TDMA), frequency division multiple access (FDMA), and code division multiple access (CDMA) have been proposed by various researchers to achieve high diversity order at destination [10-12].

In [13], the authors proposed three different two time slots TDMA based transmission protocols. The protocols implement varying degree of broadcasting and receive collision at destination. In each protocol the relay either amplifies and forward or decode and forward the received signal from source. In [14]a novel scheme of cooperative network using three time slots is analyzed. The cooperative network is based on data exchange between relays in the third time slot in order to enhance the link performance between relays and destination. In [15], the authors proposed hybrid TDMAFDMA based three time slots protocol with inter-relay communication over Nakagami-m fading channel. In [16], the authors proposed TDMA based three time slot protocol with inter-relay communication over Nakagami-m and Rician fading channels. In the first time slot the source broadcasts to both the relays and destination. in the second time slot the relays exchange their data as well broadcasts to destination. In the 3rd time the relays broadcasts the previously exchange data in the 2nd time slot to destination. The source remains silent in the 2nd and 3rd time slots and does not broadcasts to destination in these slots.

In our work, a three time slot TDMA based protocol with inter-relay communication is proposed. The proposed protocol shows high degree of broadcasting and diversity order. The BER analysis results for the proposed protocol are compared with the results obtained from previously proposed protocols in [13],[16] and [17]. It is shown that the proposed protocol performs better in terms of less BER as compared to two times slot protocol proposed in [13] and three times slot protocols proposed in [16] and [17].

II. SYSTEM MODEL

A cooperative wireless network with inter-relay communication is considered as shown in Fig. 1. The system model consists of source, two relays and destination. The source (S), relay 1 (R1), relay2 (R2) and destination (D) all are equipped with single antenna. The hSR1, hSR2, hR1D, hR2D, hR1R2 and hR2R1 are the path gains of S to R1, S to R2, R1 to D, R2 to D, R1 to R2 and R2 to R1 channels respectively. Orthogonal amplify and forward (AF) communication is used by the relays. Maximum ratio combining (MRC) is used at destination in order to obtain BER at destination.

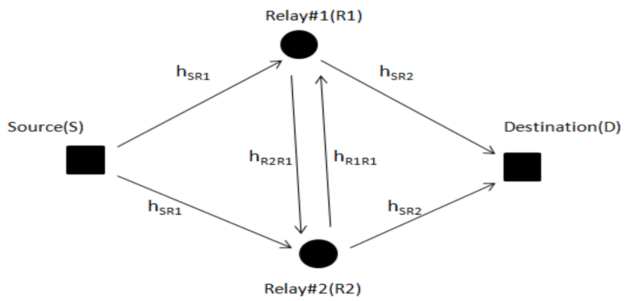

Fig. 1: Inter-relay communication using three time slot protocol

III. INPUT-OUTPUT RELATIONS

The input-output relation for the system model as shown in Fig. 1 can be derived using single-input-single-output (SISO) model.Moreover, SNR can also be obtained using SISO model. The following three cases are considered

Case-1: Single-relay wireless cooperative network with orthogonol channels

Case-2: Dual-relay wireless cooperative network with orthogonol channels

Case-1: Dual-relay wireless cooperative network using inter-relay commnunication with orthogonol channels

A. Single-relay network with orthogonol channels

Consider the system model shown in Fig. 2. The x1 and x2 are the signals transmitted by the source during 1st and 2nd time slots [13], [18].

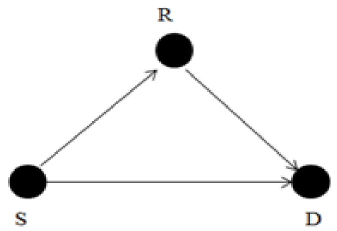

Fig. 2: Single-relay network using two time slot protocol

The signal transmitted by the source druing 1st time slot

$$y_1 = \sqrt{E_{SD}}\, h_{SD} x_1 + n_1 \qquad (1)$$

Where E_{SD} is average signal energy over one symbol periodreceived at destination terminal, n_1 is the Additive whit Gaussian Noise (AWGN) with 0 mean and variance N_0 added through the $S \rightarrow D$ channel during first time slot and h_{SD} is random complex channel gain between $S \rightarrow D$ channel. The signal received at the relay terminal during 1st time slot is given by

$$y_{R1} = \sqrt{E_{SR}}\, h_{SR}\, x_1 + n_{SR} \qquad (2)$$

Where E_{SR} is average signal energy over one symbol period received at relay terminal, n_{SR} is the Additive whit Gaussian Noise (AWGN) with 0 mean and variance N_0 added through the $S \rightarrow D$ channel during first time slot and h_{SD} is random complex channel gain between $S \rightarrow D$ channel.

The relay terminal normalizes the received signal by a factor of $\sqrt{E\{|y_{R,1}|^2\}}$ and retransmits the signal during second time slot. The destination terminal receives the superposition of the relay transmission and the source transmission during 2nd time slot according to

$$y_2 = \sqrt{E_{SD}}\, h_{SD}\, x_2 + \sqrt{E_{RD}}\, h_{RD} \cdot \frac{y_{R,1}}{\sqrt{E\{|y_{R,1}|^2\}}} + n_2 \qquad (3)$$

Where n_2 is the Additive whit Gaussian Noise (AWGN) with 0 mean and variance N_0 added through the $S \rightarrow D$ channel during 2nd time slot. Using $E\{|y_{R,1}|^2\} = E_{SR} + N_0$, we can write (3) as

$$y_{D,2} = \sqrt{E_{SD}}\, h_{SD} x_2 + \sqrt{\frac{E_{SR}E_{RD}}{E_{SR} + N_0}}\, h_{SR} h_{RD} x_1 + \tilde{n} \qquad (4)$$

In the second time slot, destination D receives the combined signal from relay R and source S. The total effective noise $(\tilde{n})$ at destination D is $\tilde{n} = \sqrt{E_{RD}/(E_{SR}+N_0)}\, h_{RD} n_{RD} + \tilde{n}_2$. The $\tilde{n}$ can be modeled as with 0 mean and variance N_0', where $N_0' = \left[\sqrt{E_{RD}/(E_{SR}+N_0)}\, |h_{RD}|^2 + 1\right] N_0$ and the normalization factor w can be modeled as $w^2 = E_{RD}/(E_{SR}+N_0)|h_{RD}|^2 + 1$. The $\tilde{n}_2$ is the AWGN component received through $S \rightarrow D$ path.

Finally, using the normalization factor w, the received signal at destination D can then be expressed as

$$y_2 = \frac{1}{w}\sqrt{\frac{E_{RD}}{E_{SR} + N_0}}\, h_{SR} h_{RD} x_1 + \frac{1}{w}\sqrt{E_{SD}}\, h_{SD} x_2 + n_2 \qquad (5)$$

Where $n_2 | h_{RD}$ can be modeled as with 0 mean and variance N_0

Let $A = \sqrt{E_{SD}}\, h_{SD}$, $B = 1/w\sqrt{E_{RD}/(E_{SR}+N_0)}\, h_{SR} h_{RD}$ and $C = 1/w\sqrt{E_{SD}}\, h_{SD}$, the input-output relations can be written as

$$Y = HX + N \qquad (6)$$

$$Y^T = \begin{bmatrix} y_1 & y_2 \end{bmatrix}_{1\times 2}$$

$$N^T = \begin{bmatrix} n_1 & n_2 \end{bmatrix}_{1\times 2}$$

$$X^T = [x_1 \quad x_2]_{1\times 2}$$

$$H^T = \begin{bmatrix} A & 0 \\ B & C \end{bmatrix}$$

B. Dual-relay wireless cooperative network with orthogonol channels

Consider the system model as shown in Fig. 3. The *S* transmits to *R1* and *R1* as well as *D* in the first time slot. The *R1* and *R2* normalize the received signals and retransmit to destination in the second time slot. The *S* also broadcast to *D* in the second time slot

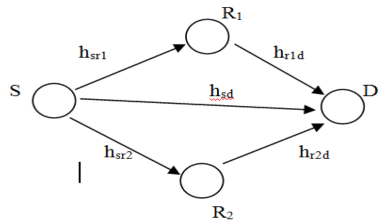

Fig.3 System model using two time slot protocol.

The x1 and x2 are the signals transmitted by the source during 1st and 2nd time slots. The signals transmitted by the source druing 1st time slot from [13], [18] can be expressed as

$$y_{R1} = \sqrt{E_{SR1}}\, h_{SR1}\, x_1 + n_{SR1} \qquad (7)$$

$$y_{R2} = \sqrt{E_{SR2}}\, h_{SR2}\, x_1 + n_{SR2} \qquad (8)$$

$$y_1 = \sqrt{E_{SD}}\, h_{SD}\, x_1 + n_1 \qquad (9)$$

Where E_{SR1} and E_{SR2} are the average signal energies over one symbol period received at R1 and R2 terminals respectively. The n_{SR1} and n_{SR2} are the Additive whit Gaussian Noises (AWGN) added through $S \rightarrow R1$ and $S \rightarrow R2$ channels respectively during first time slot. Both the noises can be modeled as with 0 mean and variance N_0. The h_{SR1} h_{SR2} and h_{SD} are random complex channel gains between $S \rightarrow R1$, $S \rightarrow R2$ and $S \rightarrow D$ channels respectively.

From [13] and [18], the normalization factors ω_1 and ω_2 for two relay wireless cooperative networks can be expressed by the by expressions $\omega_1 = \sqrt{E_{R1D}/(E_{SR1}+N_0)|h_{R1D}|^2+1}$ $\omega_2 = \sqrt{E_{R2D}/(E_{SR2}+N_0)|h_{R2D}|^2+1}$. It is supposed that $\omega_1 \cong \omega_2 \cong \omega$ then the received signal at destination D in the second time slot from the two relays as well as source at destination is given by

$$y_2 = \left(\frac{1}{\omega}\left(\sqrt{\frac{E_{SR1}E_{R1D}}{E_{SR1}+N_0}}\, h_{SR1}\, h_{R1D} + \sqrt{\frac{E_{SR2}E_{R2D}}{E_{SR2}+N_0}}\, h_{SR2} h_{R2D}\right)\right) x_1$$

$$+ \frac{1}{\omega}\sqrt{E_{SD}}\, h_{SD}\, x_2 + n_2 \qquad (10)$$

Where, $n_2 = n_{R1D} + n_{R2D}$. The $n_{R1D}|h_{R1D}$ and $n_{R2D}|h_{R2D}$ both can be modeled as with 0 mean and variance N_0 for the 2nd time slot.

Let $A = \sqrt{E_{SD}}.h_{SD}$, $B = 1/\omega\left(\sqrt{E_{SR1}E_{R1D}/(E_{SR1}+N_0)}h_{SRi}h_{R1D}\right)$ $+\sqrt{E_{SR2}E_{R2D}/(E_{SR2}+N_0)}h_{SR2}h_{R2D}$ and $C = 1/\omega\sqrt{E_{SD}}\, h_{SD}$.

The derived input-output relations can then be expressed as

$$Y = HX + N \qquad (11)$$

$$H^T = \begin{bmatrix} A & 0 \\ B & C \end{bmatrix}$$

$$Y^T = [y_1 \quad y_2]_{1\times 2}$$

$$X^T = [x_1 \quad x_2]_{1\times 2}$$

$$N^T = [n_1 \quad n_2]_{1\times 2}$$

C. Dual-relay wireless cooperative network using inter-relay commnunication with orthogonol channels

Consider the system model as shown in Fig. 1, the received signals at R1 and R2 and destination during 1nd time slot are given as

$$y_{R1} = \sqrt{E_{SR1}} h_{SR1} x_1 + n_{SR1} \qquad (12)$$

$$y_{R2} = \sqrt{E_{SR2}} h_{SR2} x_1 + n_{SR2} \qquad (13)$$

$$y_1 = \sqrt{E_{SD}} h_{SD} x_1 + n_1 \qquad (14)$$

First, if we take the $S \rightarrow R_2 \rightarrow R_1$ links, then the received signal at R_1 from source during 3rd time slot is

$$y_{R1} = \sqrt{\frac{E_{SR2}E_{R2R1}}{E_{SR2}+N_0}}\, h_{SR2}\, h_{R2R1}\, x_1 + \tilde{n}_2 \qquad (15)$$

From [13], [18], the total effective noise at R1 $\tilde{n}_2 = \sqrt{E_{R2R1}/(E_{SR2}+N_0)} h_{R2R1} n_{R2} + n_{R1}$ is modeled as with0meanandvariance N_0' .Where, $N_0' = \left(E_{R2R1}/(E_{R2R1}+N_0)|h_{R2R1}|^2+1\right)N_0$

Second if we take the $S \rightarrow R_2 \rightarrow R_1 \rightarrow D$ links, then the received signal at destination during 3rd time slot is

$$y_3 = \sqrt{\frac{E_{SR2}\, E_{R2R1}\, E_{R1D}}{(E_{SR2}+N_0)(E_{R2R1}+N_0')}}\, h_{SR2}\, h_{R2R1}\, h_{R1D}\, x_1 + \tilde{n}_1 \qquad (16)$$

The total effective noise at D during third time slot is modeled as $\tilde{n}_1 = \sqrt{E_{R1D}/((E_{SR2}+N_0)(E_{R2R1}+N_0'))}\, h_{R1D}\, n_{R1} + n_D$. The $\tilde{n}_1$ can be modeled as with 0 mean and variance N_0''. Where,

$N''_0 = \left(E_{R1D} / \left((E_{SR2} + N_0)(E_{R2R1} + N'_0)\right)\left|h_{R2R1}\right|^2 + 1\right) N_0$.

The normalization factor $\beta_1^{\,2}$ is modeled as $\beta_1^{\,2} = \left((E_{R1D} / (E_{SR2} + N_0)(E_{R2R1} + N'_0))\left|h_{R2R1}\right|^2 + 1\right)$. Similarly, for the $S \to R_1 \to R_2 \to D$ links the normalization factor $\beta_2^{\,2}$ is modeled as $\beta_2^{\,2} = \left(E_{R2D} / ((E_{SR1} + N_0)(E_{R1R2} + N'_0))\left|h_{R1R2}\right|^2 + 1\right)$.It is supposed that $\beta_1^{\,2} \cong \beta_2^{\,2} \cong \beta^{\,2}$, the received signal at destination D in the 3rd time slot from the two relays as well as source at destination is given by

$$y_3 = \frac{1}{\beta}\sqrt{E_{SD}}h_{SD}x_2 + n_1$$
$$+ \left(\frac{1}{\beta}\sqrt{\frac{E_{SR2}E_{R2R1}E_{R1D}}{(E_{SR2} + N_0)(E_{R2R1} + N'_0)}}\, h_{SR2}\, h_{R2R1}h_{R1D}\right.$$
$$\left. + \frac{1}{\beta}\sqrt{\frac{E_{SR1}E_{R1R2}E_{R2D}}{(E_{SR1} + N_0)(E_{R1R2} + N'_0)}}\, h_{SR1}h_{R1R2}h_{R2D}\right) + n_2 \qquad (17)$$

Where, $n_2 = n_{R1D} + n_{R2D}$.The $n_{R1D}\left|h_{R1D}\right.$ and $n_{R2D}\left|h_{R2D}\right.$ both are modeled as with 0 mean and variance N_0 for the 3rd time slot.

Let $A = \sqrt{E_{SD}}\, h_{SD}$

$$B = 1/\omega\left(\sqrt{E_{SR1}E_{R1D} / (E_{SR1} + N_0)}\, h_{SR1}h_{R1D}\right)$$
$$+ \sqrt{E_{SR2}E_{R2D} / (E_{SR2} + N_0)}\, h_{SR2}h_{R2D},\quad C = 1/\omega\sqrt{E_{SD}}h_{SD}.$$
$$D = 1/\beta\left(\sqrt{E_{SR2}E_{R2R1}E_{R1D} / ((E_{SR2} + N_0)(E_{R2R1} + N'_0))}\right.$$
$$h_{SR2}h_{R2R1}h_{R1D} + \sqrt{E_{SR1}E_{R1R2}E_{R2D} / ((E_{SR1} + N_0)(E_{R1R2} + N'_0))}.$$
$$\left. h_{SR1}h_{R1R2}h_{R2D}\right) \text{ and } E = 1/\beta\sqrt{E_{SD}}\, h_{SD}$$

The derived input-output relations can then be expressed as

$$Y = HX + N \qquad (18)$$

$$H^T = \begin{bmatrix} A & 0 \\ B & C \\ D & E \end{bmatrix}$$

$$Y^T = \begin{bmatrix} y_1 & y_2 & y_3 \end{bmatrix}_{1\times 3}$$

$$X^T = \begin{bmatrix} x_1 & x_2 \end{bmatrix}_{1\times 2}$$

$$N^T = \begin{bmatrix} n_1 & n_2 \end{bmatrix}_{1\times 2}$$

IV. RELAY DISPALCEMENT OPTIMIZATION

This section describes the optimal relay locations for the system model as shown in Fig .1 in order to enhance the system performance in terms of less BER. Fig. 4 shows the a system model in which dSR1, dR1D, dSR2, dR1D, dR1R2 and dR2R1 are distances between S to R1, R1 to D, S to R2, R2 to D, R1 to R2 and R2 to R1 respectively. The distance between source and destination is d. The purpose of relays movement is to find the best relay locations in terms of less BER. The proposed AF three times protocol with inter-relay communication is used for the system model as shown in Fig. 4.

Consider the system model as shown in Fig. 1. From eq. (12), (13) and (14) the received signals at R1 and R2 and destination during 1st time slot are given as

$$y_{R1} = (d)^{-\alpha}\sqrt{E_{SR1}}h_{SR1}x_1 + n_{SR1} \qquad (19)$$
$$y_{R2} = (d)^{-\alpha}\sqrt{E_{SR2}}\, h_{SR2}x_1 + n_{SR2} \qquad (20)$$
$$y_1 = (d)^{-\alpha}\sqrt{E_{SD}}\, h_{SD}\, x_1 + n_{D,1} \qquad (21)$$

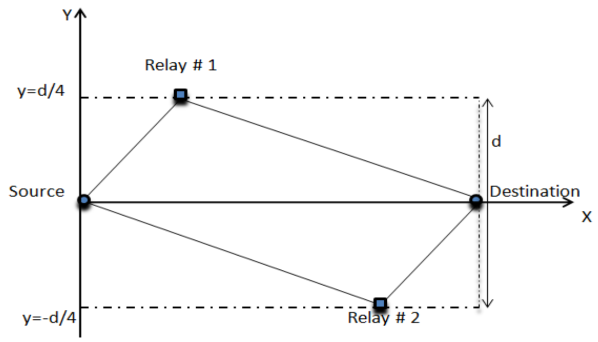

Fig. 4 Relays displacement optimization

From eq. (10), the received signal at destination during 2nd time slot is

$$y_2 = \left(\frac{1}{\omega}\left((d_{SR1})^{-\alpha}(d_{R1D})^{-\alpha}\sqrt{\frac{E_{SR1}E_{R1D}}{E_{SR1} + N_0}}h_{SR1}h_{R1D}\right)\right)x_1$$
$$(23)$$
$$+ \left((d_{SR2})^{-\alpha}(d_{R2D})^{-\alpha}\sqrt{\frac{E_{SR2}E_{R2D}}{E_{SR2} + N_0}}h_{SR2}h_{R2D}\right)x_1$$
$$+ (d_{SD})^{-\alpha}\frac{1}{\omega}\sqrt{E_{SD}}\, h_{SD}x_2 + n_2 \qquad (22)$$

For the $S \to R_2 \to R_1$ links, the received signal at R_1 from source during 3rd time slot from eq. (15) is

$$y_{R1} = (d_{SR2})^{-\alpha}(d_{R2R1})^{-\alpha}\sqrt{\frac{E_{SR2}E_{R2R1}}{E_{SR2} + N_0}}\, h_{SR2}\, h_{R2R1}x_1 + \tilde{n}_2 \qquad (23)$$

Similarly, for the $S \to R_2 \to R_1 \to D$ links, the received signal at destination during 3rd time slot from equation (17) is

$$y_3 = ((d_{SR2})^{-\alpha}(d_{R2R1})^{-\alpha}(d_{R1D})^{-\alpha}\sqrt{\frac{E_{SR2}\, E_{R2R1}\, E_{R1D}}{(E_{SR2} + N_0)(E_{R2R1} + N'_0)}}$$
$$h_{SR2}\, h_{R2R1}\, h_{R1D}\, x_1 + \tilde{n}_1) \qquad (24)$$

Finally, for the $S \to R_2 \to R_1 \to D$ and $S \to R_1 \to R_2 \to D$ links, the received signal at destination during 3rd time slot is given from equation (18) as

$$y_3 = ((d_{SR2})^{-\alpha}(d_{R2R1})^{-\alpha}(d_{R1D})^{-\alpha}(\frac{1}{\beta}\sqrt{\frac{E_{SR2}E_{R2R1}E_{R1D}}{(E_{SR2}+N_0)(E_{R2R1}+N_0')}}$$

$$h_{SR2}h_{R2R1}h_{R1D} + (d_{SR1})^{-\alpha}(d_{R1R2})^{-\alpha}(d_{R2D})^{-\alpha}\frac{1}{\beta}\sqrt{\frac{E_{SR1}E_{R1R2}E_{R2D}}{(E_{SR1}+N_0)(E_{R1R2}+N_0')}}$$

$$h_{SR1}h_{R1R2}h_{R2D}) + n_2 + (d_{SD})^{-\alpha}\frac{1}{\beta}\sqrt{E_{SD}}h_{SD}x_2) \qquad (25)$$

Where, $n_2 = n_{R1D} + n_{R2D}$. The $n_{R1D}|h_{R1D}$ and $n_{R2D}|h_{R2D}$ both are modeled as with 0 mean and variance N_0 for the 3rd time slot.

Let $A = \sqrt{E_{SD}}h_{SD}$,

$$B = 1/\omega((\sqrt{E_{SR1}E_{R1D}/(E_{SR1}+N_0)}h_{SR1}h_{R1D}) + (\sqrt{E_{SR2}E_{R2D}/(E_{SR2}+N_0)}h_{SR2}h_{R2D}))$$

$$C = (d_{SD})^{-\alpha}\frac{1}{\omega}\sqrt{E_{SD}}h_{SD}$$

$$D = 1/\beta((d_{SR2})^{-\alpha}(d_{R2R1})^{-\alpha}(d_{R1D})^{-\alpha}\sqrt{E_{SR2}E_{R2R1}E_{R1D}/((E_{SR2}+N_0)(E_{R2R1}+N_0'))}$$

$$h_{SR2}h_{R2R1}h_{R1D} + (d_{SR1})^{-\alpha}(d_{R1R2})^{-\alpha}(d_{R2D})^{-\alpha}$$

$$\sqrt{E_{SR1}E_{R1R2}E_{R2D}/((E_{SR1}+N_0)(E_{R1R2}+N_0'))}h_{SR1}h_{R1R2}h_{R2D})$$

$$E = (d_{SD})^{-\alpha}\frac{1}{\beta}\sqrt{E_{SD}}h_{SD}$$

The derived input-output relations can then be expressed as

$$Y = HX + N \qquad (26)$$

$$H^T = \begin{bmatrix} A & 0 \\ B & C \\ D & E \end{bmatrix}$$

$$Y^T = [y_1 \quad y_2 \quad y_3]_{1\times 3}$$

$$X^T = [x_1 \quad x_2]_{1\times 2}$$

$$N^T = [n_1 \quad n_2]_{1\times 2}$$

V. SIMULATION AND RESULTS DISCUSSIONS

In this section we evaluated the performance of proposed Inter-relay protocol with comparison of three approaches presented in [13], [16] and [17]. The approach in [13] uses two time slots protocol. In the first time slot the source broadcast to relays and in the second time slot the relays amplify and forward the signal received from the source in the first time slot and broadcast to destination. The approach in [16] proposed three time slot protocol. In the first time slot the source broadcasts to relays and in the second time slot the relays amplify the signals received from source and broadcast to destination. The relays also exchange their data in the second time slot. In the 3rd time slot, both the relays amplify (normalize) the exchange data and broadcast to destination. The approach in [17] also proposed three time slot protocol. However, the degree of broadcasting and diversity order are higher than the proposed protocol in [16]. Moreover, BER was used as performance metric at destination. Maximum ratio combining was used at destination in order to combine the signals received in different time slots from relays and extract information.

We use BER as a performance metric in simulation and calculate BER at destination for proposed inter-relay three time slot cooperative protocol. MRC is used at destination to combine the signals received in different time slot. Bipolar Phase shift keying (BPSK) modulation is used to modulate the signal. Additive White Gaussian Noise with zero mean and variance along with the Rayleigh and Rician fading is used to make the channel noisy and multipath respectively. In order to plot the BER Vs signal to noise ratio 10^5 number of symbols are used.

Fig. 4 shows the BER for proposed amplify and forward protocol (PAFP) at different K values. It is expressed that as the values of K increases (i.e., decrease in fading) the PAFP performs better in terms of less BER. It is also indicated that the PAFP using Rayleigh fading (i.e., at K=0 and severe fading) indicated highest BER as compared to Rician fading (i.e., at K=1, 2, 4 and lower fading).

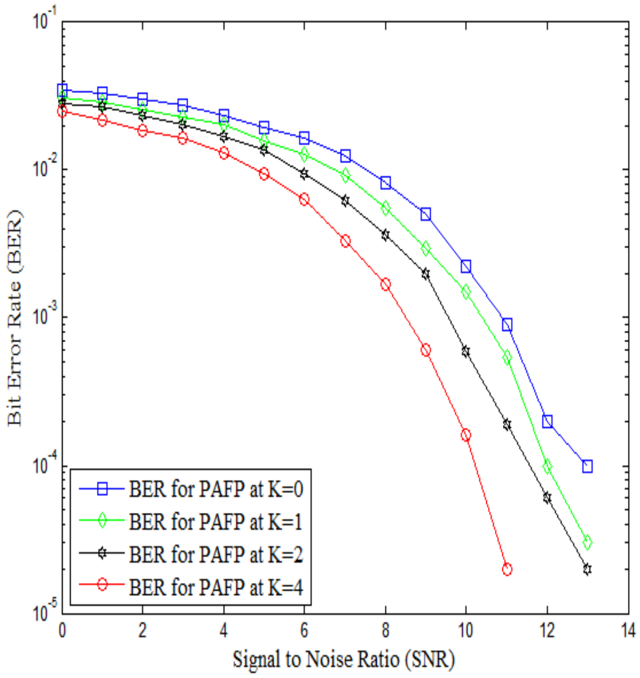

Fig. 4 BER for PAFP using different K values

Fig 5 shows the comparison of proposed amplify and forward (PAF) three time slot protocol and the previous proposed protocols in [13], [16] and [17] for BPSK over Rician fading channel. The PPAF protocol in [16] performs better in terms of less BER as compared to PPAF protocol in [13]. It is because of the inter-relay communication. Similarly, the PPAF protocol in [17] shows less BER performance as compared to PPAF protocol in [16]. It is due to the fact that the PPAF in [17] has high diversity order at destination and high degree of broadcasting at source. The PAF protocol shows better performance in terms of less BER as compared to PPAF two time slots and three times slots protocols. Owing to that fact that PAF has inter-relay communication as compared to PPAF protocol in [13]. Moreover, it has high diversity order and degree of broadcasting as compared to PPAF protocol in [16].

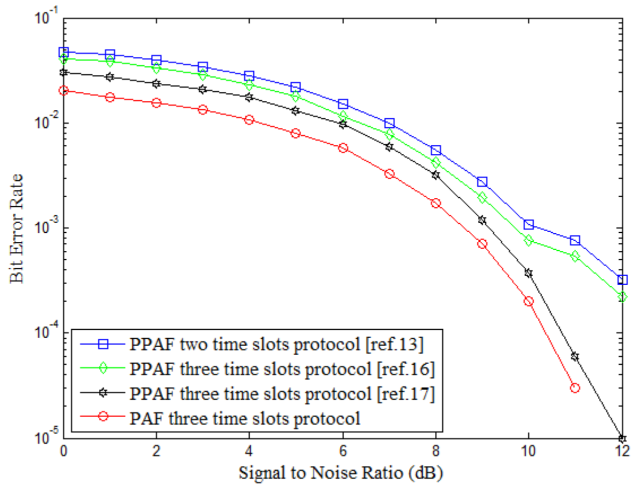

Fig. 5 Comparison of PAF and three previous proposed protocols

The PAF protocol has a similar diversity order and degree of broadcasting as compared to PPAF protocol in [17]. However, the derived normalization factor β for PAF protocol makes this protocol superior as compared to PPAF protocol in [17].

In [17], we evaluated the performance of proposed protocol in terms of BER using step1, step2 and step3. In step 1 and step2 either R1 or R2 is closed to the source while in step 3 neither relays are close to the source. It was indicated that in [17] the proposed protocol using step3 (i.e., minimum inter-relay distance) performs better in terms of less BER as compared to using step1 and step2. We further evaluated the PAF protocol in this work to the previous proposed protocol in [17] using step3 as shown in Fig. 6. It is expressed that the PAFP shows less BER as compared to the previous proposed protocol in [17] using step3 (i.e., both relays R1 and R2 are using inter-relay communication and neither relay is closed to the source). It is because of derived normalization factor (β) for the PAF protocol.

Figure 7 shows BER with R1 and R2 projections for PAFP with inter-relay using step3 over Rician fading channel. It is indicated that PAFP shows minimum BER when inter relay distance is minimum (i.e., when both the relays are at central values). However, when the inter-relay distance increases the BER rate increases accordingly.

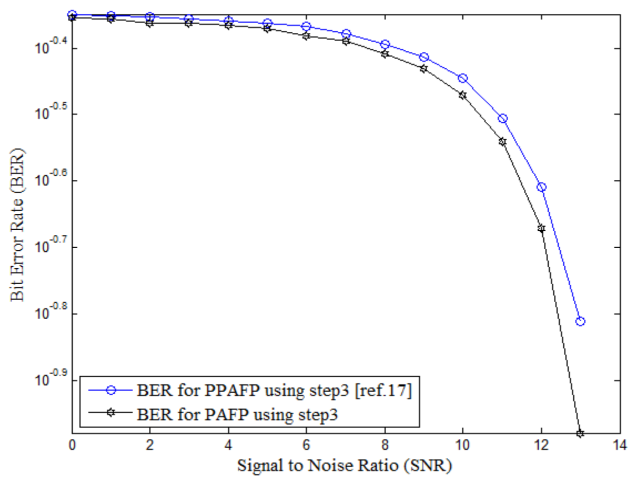

Fig. 6 Comparison of PAF and PPAF protocols using step3 [ref.17]

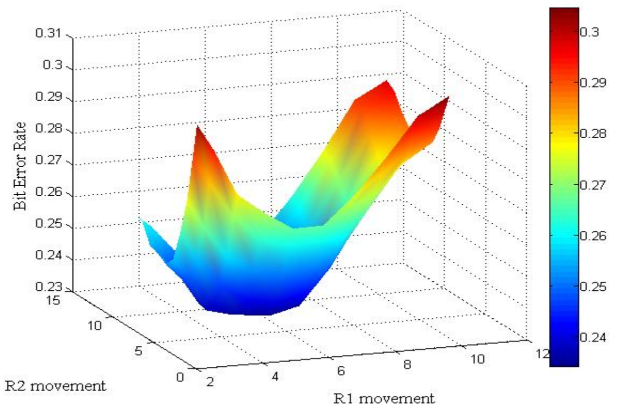

Fig.7: BER with R1 and R2 projections for PAFP with inter-relay

VI. CONCLUSIONS

A three time slot TDMA based protocol with inter-relay communication has been investigated. It is concluded that the proposed amplify and forward three time slot protocol (PAFP) perform better in terms of low BER values as compared to previously proposed amplify and forward (PPAF) two time slot and three time slots protocols.

The proposed protocol has also been investigated for BER at various relay locations and inter-relay distances. It is concluded that the PAFP shows better results in terms of less BER values as compared to previous three times slots protocols when the inter-relay distance is minimum.

The signal to noise ratio derivation using SISO model as well as BER using the derived signal to noise ratios over fading models is left for future work. Moreover, the performance of the network can be further improved by considering multiple-relays.

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