AN EFFICIENT TDMA-BASED PROTOCOL USING INTER-RELAY DISPLACEMENT ANALYSIS

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ABSTRACT *— The low diversity order reduces the performance of TDMA-based Amplify-and-Forward (AF) two and three time slots protocols and has several limitations. Moreover, the two time slots protocols exhibit low performance when the relay is placed far from the source. Therefore, in this work an efficient Enhanced Amplify-and-Forward (EAF) three time slots TDMA based protocol with inter-relay communication has been proposed. The relay displacement analysis using the EAF protocol with respect to different relays location is also carried out and the optimal relays location has been identified. The normalization factor β has been derived, for the 3rd time slot to further enhance the performance of the proposed protocol. According to results, the EAF protocol showed low Bit Error Rate (BER) and high BER-Gain values, as compared to previous AF two and three time slots TDMA based protocols, with the increase in signal to noise ratio values. The EAF three time slots protocol also demonstrated improvement using the optimal relays location, in terms of low BER and high BER-Gain values in contrast to previous AF two time slots and three time slots protocols. The accuracy of the EAF protocol has been identified using the Global Percentage Error Decrease and Local-Percentage-Error methods.*

Index Terms— Three Time Slots Protocol, Normalization factor Beta, BER, BER-Gain, GPED, LPED

I. INTRODUCTION

The mobile radio signal experiences several signal variations and weakens due to multipath fading effects during transmission of data from source to destination. To mitigate the multipath fading and to send the same data over independent fading paths, diversity communication has been used. To achieve diversity communication, several communication techniques, for instance, micro diversity, macro diversity, space diversity, frequency diversity and time diversity have been used [1]. However, these methods tend to increase the size, complexity and the total power of the wireless network devices [2-3]. In order to solve these issues, cooperative diversity communication has been introduced recently.

In cooperative diversity communication, cooperation among users or relays ensures the diversity at destination. Each user or relay transmits their own information data as well as along with the information of their partner, to the destination, virtually seeking the advantages of MIMO spatial diversity [4-7].

Each user in cooperative diversity uses either Amplify-and-Forward (AF) or Decode-and-Forward (DF) protocol to transmit the information data to destination [8]. In DF mode, the relay decodes the received signal from the source and forwards to destination [9-10]. However, in AF mode the relay amplifies the received signal from source and forwards to destination [5],[11-18]. Cooperative communication solves the issues of size, cost, and hardware limitations of multiple antennas [19]. 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[20-21]. 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 [22-24].

Three different TDMA based two time slots protocols have been proposed [25]. Using protocol I, the source broadcasts to relay and destination during first time slot. In the second time slot, the source broadcasts to relay and destination. This protocol has maximum degree broadcasting at source and maximum diversity order, at destination. Using protocol II, the source broadcasts to destination and relay, over the first time slot. In the 2nd time slot, the relay only transmits to destination. This protocol has maximum degree of broadcasting at source and low diversity order, as compared to protocol I. Using protocol III the source communicates to relay only, in the 1st time slot. In the 2nd time slot, the source as well as relay communicates to destination. This protocol exhibits no broadcasting but realizes maximum degree of diversity order. The performance analysis of the two time slots TDMA-based protocols over Nakagami-m fading channel has been analyzed [26]. The closed form MGF of the total SNR has been derived and used to obtain the diversity order and SER at destination. A novel scheme of cooperative network using three time slots has been analyzed [27]. Data exchange between relays is used over the third time slot, in order to improve the link performance between relays and destination. Hybrid TDMA-FDMA based three time slots protocol with inter-relay communication over Nakagami-m fading channel has been proposed [28]. The BER, outage probability and Gain have been used as performance metrics. Three time slots TDMA based protocol is proposed [28-30]. In this protocol, the source broadcasts to relays and destination over the 1st time slot. In the second time slot, the relays broadcast to destination. Similarly, the relays also exchange their data in the 2nd time slot. In the 3rd time slot, the relay broadcasts the data to destination which was previously exchanged by the relays, in the 2nd time slot. The performance analysis of single relay and multiple relay cooperative network over Nakagam-m fading channels has been carried out [31]. The closed form expression of MGF for the total SNR is derived. Moreover, the expressions of symbol error rate, outage capacity, and outage probability have been obtained using the derived MGF.

The low diversity order at the destination and low broadcasting degree at the source reduces the performance of AF two time slots and three times slots TDMA based protocols and has several limitations. Moreover, the previous two time slots protocols exhibits low BER when relay is placed closed to the source. However, high BER values have been observed when relay is placed away from the source. Furthermore, the source of the previous three time slots protocol remains silent during the 2nd and 3rd time slots, which also affect the performance of these protocols, in terms of low diversity order at destination with high BER and low BER-Gain values.

In this paper, an efficient Enhanced Amplify-and-Forward (EAF) three time slots TDMA based protocol with inter-relay communication has been proposed, and analyzed the performance of the EAF protocol with respect to the relay displacement from the source as well as destination. The main contribution of this work is that the source has been activated over the 2nd and 3rd time slots, and diversity order has been improved at the destination, in order to get low BER and high BER-Gain values. Moreover, the normalization factor β is derived, to further enhance the performance of EAF three time slots protocol. Furthermore, the optimal relay locations have been identified, in terms of low BER and high BER-Gain values. Simulation results indicated that the proposed EAF protocol demonstrated low BER and high BER-Gain values as compared to Previous Proposed Amplify-and-Forward (PPAF) two time slots protocol [25] and PPAF three time slots protocol [29]. Besides, the EAF indicated low BER values at optimal relay location, in contrast to previous two time and three time slots protocols.

II. THE ENHANCED AF THREE TIME SLOTS TDMA BASED PROTOCOL WITH INTER-RELAY COMMUNICATION

In the EAF three time slots protocol, the source broadcasts to destination, relay1 and relay2 over the 1st time slot. In the second time slot, both the relays transmit to destination and also exchange their data. In the third time slot, the relays transmit the data which was previously exchanged in the 2nd time slot, to destination. Moreover, the source does not remain silent during the 2nd and 3rd time slots and continuously broadcasts to destination. Due to this, the proposed protocol achieves high degree of broadcasting at the source and high diversity order at the destination and low BER values and high BER-Gain values at destination have been observed.

The summary of the proposed protocol is shown in Table I.

TABLE I: THE EAF THREE TIME SLOTS TDMA BASED TRANSMISSION PROTOCOL

Time Slot 1	Time Slot 2	Time Slot 3
$S \to R_1, S \to R_2$ $S \to D$	$R_1 \to D, R_2 \to D$ $R_1 \to R_2, R_2 \to R_1$ $S \to D$	$R_1 \to D, R_2 \to D$ $S \to D$

A. *System model for the EAF three time slots TDMA based protocol*

The system model for the proposed protocol is shown in Fig. 1. It consists of wireless cooperative network with source, two relays and destination. The source (S), relay 1 (R1), relay 2 (R2) and destination (D) all are equipped with single antenna.

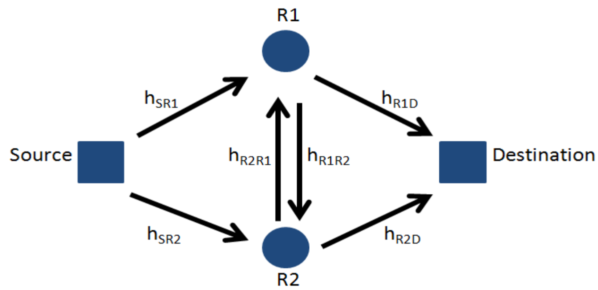

Fig. 1. Inter relay wireless cooperative network

The parameters h_{SR1}, h_{SR2}, h_{R1D}, h_{R2D}, h_{R1R2} and h_{R2R1} are the Rician fading channels from source to relay1, source to relay2, relay1 to destination, relay2 to destination, relay1 to relay2 and relay2 to relay1 links respectively.

B. *System model for the EAF three time slots TDMA based protocol using inter-relay displacement*

The system model for the relay displacement analysis is shown in figure 2. The purpose of relay displacement analysis was to find out an appropriate relay location, in terms of low BER and high BER-Gain values. The system model used for the relay displacement is shown in Figure 2. The parameters d_{SR1}, d_{R1D}, d_{SR2}, d_{R1D}, d_{R1R2} and d_{R2R1} are the distances between source to relay1, relay1 to destination, source to relay2, relay2 to destination, relay1 to relay2 and relay2 to relay1 links, respectively. The distance between source and destination is taken d_{SD}. The distances between source to relay1 and source to relay2 are taken initially $d_{SD}/4$ and $-d_{SD}/4$ respectively. However, these distances are dependent upon the relays movement with respect to the source and destination. Similarly, the distances between relay1 to destination and relay2 to destination also reliant upon the relays displacement with respect the source and destination.

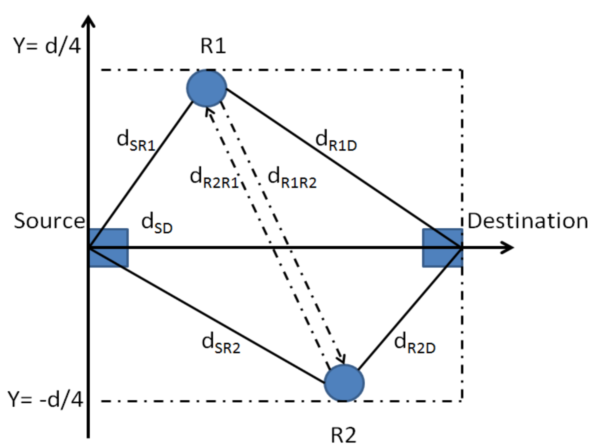

Fig. 2. Inter relay wireless cooperative network using inter-relay displacement with respect to different locations

C. Signal models for the EAF three time slots TDMA based protocol

The received signals at relay1, relay2 and destination, over the 1st time slot are given as:

$$y_{R1} = (d_{SR1})^{-\alpha}\sqrt{E_{SR1}}\, h_{SR1} x_1 + n_{SR1} \qquad (1)$$

$$y_{R2} = (d_{SR2})^{-\alpha}\sqrt{E_{SR2}}\, h_{SR2} x_1 + n_{SR2} \qquad (2)$$

$$y_1 = (d_{SD})^{-\alpha}\sqrt{E_{SD}}\, h_{SD} x_1 + n_1 \qquad (3)$$

Where E_{SR1} and E_{SR2} are the average signal energies over one symbol period received at relay1 and relay2 terminals respectively. The parameters n_{SR1} and n_{SR2} are the AWGN's added to $S \rightarrow R1$ and $S \rightarrow R2$ channels, over the first time slot respectively. 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 multipath Rician fading channel of $S \rightarrow R1$, $S \rightarrow R2$ and $S \rightarrow D$ links respectively.

The normalization factors ω_1 and ω_2 for two relay wireless cooperative networks can be expressed by the following expressions as [25-26]:

$$\omega_1 = \sqrt{E_{R1D}/(E_{SR1}+N_0)\left|h_{R1D}\right|^2 + 1} \qquad (4)$$

$$\omega_2 = \sqrt{E_{R2D}/(E_{SR2}+N_0)\left|h_{R2D}\right|^2 + 1} \qquad (5)$$

It is supposed that $\omega_1 \cong \omega_1 \cong \omega$, the received signal at destination, over the second time slot from the two relays as well as source, at destination can be determined as [25-26]:

$$y_2 = \frac{1}{\omega}[(d_{SR1})^{-\alpha}(d_{R1D})^{-\alpha}\sqrt{(E_{SR1}E_{R1D}/E_{SR1}+N_0)}\; h_{SR1}h_{R1D}$$

$$+(d_{SR2})^{-\alpha}(d_{R2D})^{-\alpha}\sqrt{(E_{SR2}E_{R2D}/E_{SR2}+N_0)}\; h_{SR2}h_{R2D}]x_1$$

$$+(d_{SD})^{-\alpha}\frac{1}{\omega}\sqrt{E_{SD}}h_{SD}x_2 + n_2$$

For the 3rd time slot, the source signal is first normalized by relay1 and then relay2. Therefore, first we take the $S \rightarrow R_2 \rightarrow R_1$ link and then $S \rightarrow R_2 \rightarrow R_1 \rightarrow D$ link, in order to derive the normalization factor β and to get the signal at destination, for the 3rd time slot. Hence, for $S \rightarrow R_2 \rightarrow R_1$ links, the received signal at relay1 from source, over the 3rd time slot is given as:

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

(7)

The total effective noise at relay1 is $\tilde{n}_2 = \sqrt{E_{R2R1}/(E_{SR2}+N_0)}h_{R2R1}n_{R2} + n_{R1}$, which is modeled as with 0 mean and variance (N_0'). Where $N_0' = \left(E_{R2R1}/(E_{R2R1}+N_0)\left|h_{R2R1}\right|^2 + 1\right)N_0$. Similarly, for $S \rightarrow R_2 \rightarrow R_1 \rightarrow D$ links, the received signal at destination, over the 3rd time slot can be expressed as:

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

$$h_{SR2}h_{R2R1}h_{R1D}x_1 + \tilde{n}_1 \qquad (8)$$

The total effective noise at destination, over the 3rd time slot can be expressed as:

$$\tilde{n}_1 = \sqrt{\frac{E_{R1D}}{(E_{SR2}+N_0)(E_{R2R1}+N_0')}}\, h_{R1D}n_{R1} + n_D \qquad (9)$$

The parameter $\tilde{n}_1$ is modeled as with 0 mean and variance N_0''. Where the parameter N_0'' can be determined as:

$$N_0'' = \left(\frac{E_{R1D}\left|h_{R1D}\right|^2 + 1}{(E_{SR2}+N_0)(E_{R2R1}+N_0')}\right)N_0 \qquad (10)$$

Moreover, the normalization factor β_1 for the $S \rightarrow R_2 \rightarrow R_1 \rightarrow D$ links can be modeled as:

$$\beta_1 = \sqrt{\frac{E_{R1D}}{(E_{SR2}+N_0)(E_{R2R1}+N_0')}\left|h_{R1D}\right|^2 + 1} \qquad (11)$$

.

Similarly, for the $S \rightarrow R_1 \rightarrow R_2 \rightarrow D$ links, the normalization factor β_2 can be modeled as:

$$\beta_2 = \sqrt{\frac{E_{R2D}}{(E_{SR1}+N_0)(E_{R1R2}+N_0')}\left|h_{R2D}\right|^2 + 1} \qquad (12)$$

Suppose that $\beta_1 \cong \beta_2 \cong \beta$, the received signal at destination, over the 3rd time slot from the two relays as well as from source at destination, using the derived normalization factor β, is given as:

$$y_3 = (d_{SD})^{-\alpha}\frac{1}{\beta}\sqrt{E_{SD}}\, h_{SD}x_2 + n_1 + ((d_{SR2})^{-\alpha}(d_{R2R1})^{-\alpha}(d_{R1D})^{-\alpha}$$

$$\times\frac{1}{\beta}\sqrt{\frac{E_{SR2}E_{R2R1}E_{R1D}}{(E_{SR2}+N_0)(E_{R2R1}+N_0')}} \times h_{SR2}h_{R2R1}h_{R1D} +$$

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

$$\times h_{SR1}h_{R1R2}h_{R2D}) + n_2 \qquad (13)$$

Where $n_2 = n_{R1D} + n_{R2D}$. The parameters $n_{R1D}|h_{R1D}$ and $n_{R2D}|h_{R2D}$ both are modeled as with 0 mean and variance (N_0) for the 3rd time slot. It is supposed that

$$A = (d_{SD})^{-\alpha}\sqrt{E_{SD}}\, h_{SD}$$

$$B = 1/\omega((d_{SR1})^{-\alpha}(d_{R1D})^{-\alpha}\sqrt{\frac{E_{SR1}E_{R1D}}{(E_{SR1}+N_0)}}\, h_{SR1}h_{R1D} +$$

$$(d_{SR1})^{-\alpha}(d_{R1D})^{-\alpha}\sqrt{\frac{E_{SR2}E_{R2D}}{(E_{SR2}+N_0)}}\, h_{SR2}h_{R2D})$$

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

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

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

$$\times h_{SR1}h_{R1R2}h_{R2D})$$

and $E = 1/\beta(d_{SD})^{-\alpha}\sqrt{E_{SD}}h_{SD}$, then the input-output signal relations can be expressed as:

$$Y = HX + N \qquad (14)$$

$$Y = [y_1 \quad y_2 \quad y_3]_{1\times 3}$$
$$X = [x_1 \quad x_2]_{1\times 2}$$
$$N = [n_1 \quad n_2]_{1\times 2}$$
$$H = \begin{bmatrix} A & 0 \\ B & C \\ D & E \end{bmatrix}$$

III. SIMULATION RESULS AND DISCUSSION

The simulation model used for the EAF three time slots protocol is shown in Figure 3.

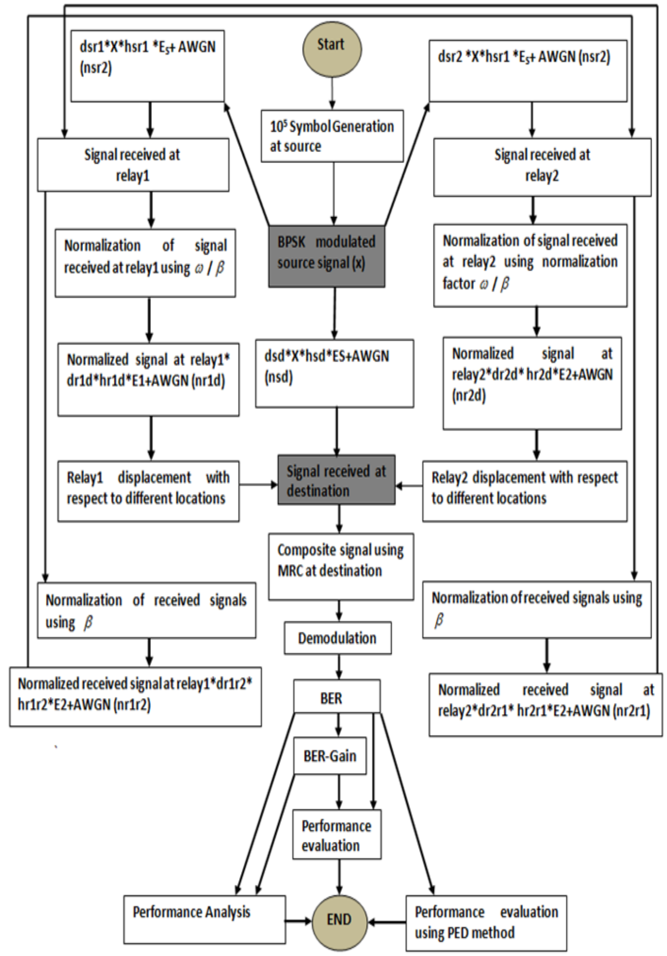

Fig. 3. Simulation model for the EAF three time slots protocol with respect to relay displacement optimization

The 10^5 symbols are generated at source. In order to modulate the source signal, BPSK modulation technique is used. The distance between source and destination is taken d_{SD}, which is assumed 10m in this model. The distances between source to relays and relays to destination as well as between relays are calculated using eq. (15-20) as:

$$d_{SR1} = \sqrt{(0.1\times i\times d_{SD})^2 + (d_{SD}/4)^2} \qquad (15)$$

$$d_{SR2} = \sqrt{(0.1\times i\times d_{SD})^2 + (-d_{SD}/4)^2} \qquad (16)$$

$$d_{R1D} = \sqrt{((d_{SD}-i)/(10\times d_{SD}))^2 + (d_{SD}/4)^2} \qquad (17)$$

$$d_{R2D} = \sqrt{((d-i)/(10\times d_{SD}))^2 + (-d_{SD}/4)^2} \qquad (18)$$

$$d_{R1R2} = \sqrt{(d_{SD}/2)^2 + (0.1\times i\times d_{SD})^2} \qquad (19)$$

$$d_{R2R1} = \sqrt{(-d_{SD}/2)^2 + (0.1\times i\times d_{SD})^2} \qquad (20)$$

Where the variable i indicates the scaling parameter which is used to find the links distances with respect to different relay locations from the source and destination.

Moreover, the relay1 is first kept close to destination and relay2 is moved from source to destination along x-axis. Similarly, the relay2 is kept close to destination and relay1 is moved along from source to destination along x-axis. The purpose of relays movement was to demonstrate BER and BER-Gain with respect to different distances from the source.

The Rician multipath channels h_{sr1} h_{sr2} and h_{sd} are created, for the source to relay1, source to relay2 and source to destination links respectively. The distances obtained from equations 15 and 16 are included to h_{sr1} and h_{sr2}, to make the channels (i.e. h_{sr1} and h_{sr2}) distance dependent. Moreover, the 10m assumed distance is included to h_{sd}. The BPSK modulated signal along with average energy per symbol is passed through each of the Rician multipath channel. The AWGN's are included to each Rician multipath channel, in order to make the distance dependent Rician multipath noisy signals. The noisy signals along with multipath effects are received at relay1, relay2 and destination, over the 1st time slot. The received signals at relay1, relay2 are then normalized by pre-existing normalization factor ω, in order to transmit for the 2nd time slots. The Rician multipath channels h_{r1d}, h_{r2d}, h_{r1r2} and $h_{r2r1}$are created for the relay1 to destination, relay2 to destination, relay1 to relay2 and relay2 to relay1 links respectively. Moreover, the distances from equations 17, 18, 19 and 20 are included to Rician multipath channels h_{r1d}, h_{r2d}, h_{r1r2} and h_{r2r1} respectively. The normalized signals along with average energy per symbol are passed across each Rician multipath channel. Moreover, the AWGN's are included to each Rician multipath channel, in order to make the distance dependent Rician multipath noisy signals. The noisy distance dependent signals are received by destination, over the 2nd time slot. Moreover, the relay1 receives the Rician multipath noisy signal from relay2 and relay2 receives the Rician multipath noisy signal from relay1, over the 2nd time slot. The relay 1 and relay2 again normalize the received signals using the derived normalization factor β, in order to transmit for the 3rd time slot. The Rician multipath channel h_{r1d} and h_{r2d} are created and the distances obtained from 17 and 18 are included to each Rician multipath channels respectively. The normalized signals along with average energy per symbol are passed across each Rician multipath channel h_{r1d} and h_{r2d}, in order to make distance dependent noisy signals, for the 3rd time slot. Moreover, the AWGN's are included to each of the multipath channel, to make the signal distance dependent as well as noisy, for the 3rd time slot. The destination receives these noisy signals from relay1 and relay2, over the 3rd time slot. In addition, the destination also receives the noisy Rician multipath noisy signal from the source directly, over the 3rd time slot. The MRC is used to get the composite signal at destination, and demodulation is used to get BER and BER-Gain at destination. Finally, the performance analysis, performance evaluation and performance evaluation using PED method, with the comparison of PPAF two time slots and three time slots have been carried out.

In order to measure the performance of EAF three time slots protocols two performance metrics i.e. BER and BER-Gain are used at destination. The BER and BER-Gain values are calculated for different low K values and using signal to noise ratio e.g. 0dB to 10 dB, as shown in figures 4 and 5 respectively. The purpose of taking low fading parameter K values and SNR i.e. 0dB to 10dB was to analyze the performance of EAF protocol at severe fading conditions and low SNR values.

The EAF three time slots protocol performed better over PPAF two time slots protocol, in terms of low BER values and high BER-Gain values with the increase in SNR values, while, using constant K values, as shown in Figure 3 and 4 respectively. It is due to the fact that the EAF protocol has high degree of broadcasting and high diversity order at destination, as compared to PPAF two time slots protocol. Moreover, the use of derived normalization factor β also enhances the performance EAF protocol as compared to PPAF two time slots protocol.

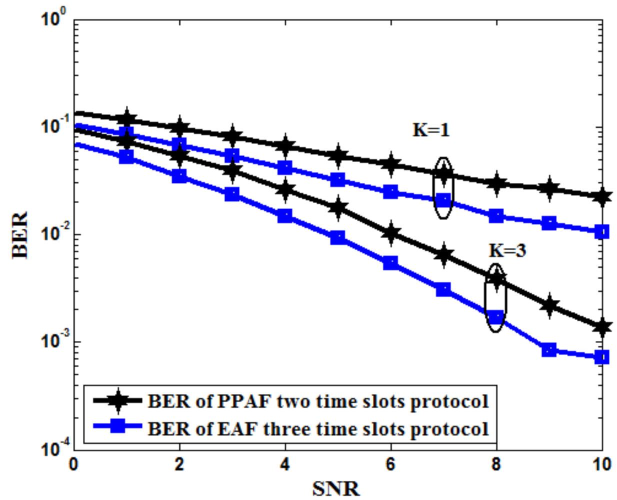

Fig. 4. BER comparison of EAF three time slots with PPAF two time slots protocol

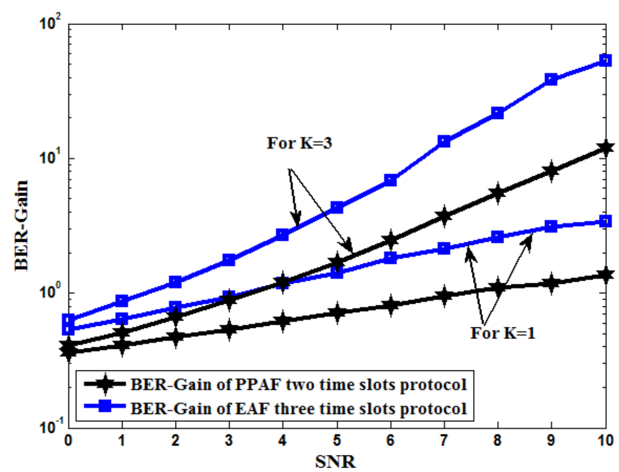

Fig. 5. BER-Gain comparison of EAF three time slots with PPAF two time slots protocol

The EAF three time slots protocol is also assessed with the comparison of PPAF three time slots protocol [29]. The EAF three time slots protocol showed low BER and high BER-Gain values, as compared to PPAF three time slots protocol, with the increase in SNR values (e.g. from 0dB-10dB), while, keeping constant K values (e.g. at K= 1 and 3), as shown in figures 6 and 7 respectively. It is because of the fact that the use of derived normalization factor β for the 3rd time slot, and the high diversity order at destination makes the EAF three time slots protocol superior, as compared to PPAF three time slots protocol.

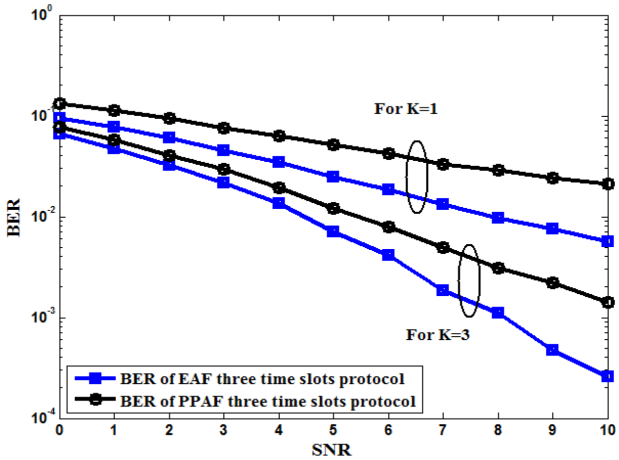

Fig. 6. BER comparison EAF three time slots protocol with PPAF three time slots protocol

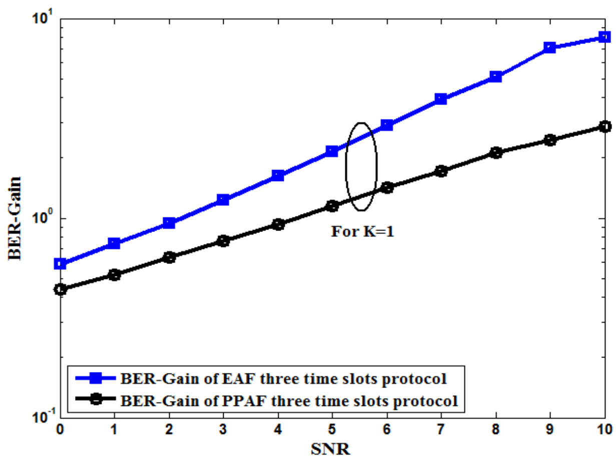

Fig. 7. BER-Gain comparison of EAF three time slots protocol with PPAF three time slots protocols

The performance analysis of the EAF protocol using relay displacement has been also carried out. The BER and BER-Gain values have been demonstrated using the relays displacement with respect to the source and destination, as shown in figures 8 and 9. The relay1 is moved along x-axis from source to destination, while, relay2 is kept close to destination. Similarly, the relay2 is moved along the x-axis from source to destination, while, relay1 is kept close to destination. The EAF protocol indicated high BER and BER-Gain values when both the relays are close to destination, as shown in figures 8 and 9. It is because the source to relay1 and source to relay2 distances are high, as compared to relays to destination distances. Similarly, the proposed protocol showed high BER and BER-Gain values when both the relays are close to the source. Owing to the fact that the relays to destination distances are high, as compared to source to relays distances. Moreover, the EAF three time slots protocol demonstrated high BER and BER-Gain values when relay1 is close to the source and relay2 is close to destination or when relay1 is close to destination and relay2 is closed to source. It is due to the fact that in the first case the relay1 to destination as well source to relay2 distances are high, while, in the 2nd case the source to relay1 and relay2 to destination distances are high. Moreover, the inter-relay distances are also high in both the cases.

Furthermore, it is shown from the results that the proposed protocol illustrated optimal results, with respect to the optimal relays (i.e. relay1 and relay2) location, in terms of low BER and high BER-Gain. The optimal relays location is obtained using the optimum minimum inter-relay distances as well as optimum source to relays and relays to destination distances. The source to relays and relays to destination links as well as inter-relay links distances, which shows the optimal relays location are d_{SR1}=6.2101m, d_{R1D}=6.2101m, d_{SR2}=6.2101m, d_{R2D}=6.2101m, d_{R1R2}=7.7717m and d_{R2R1}=7.7717m.

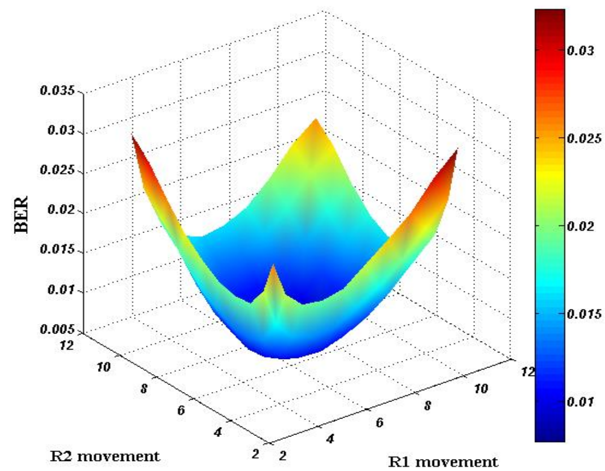

Fig. 8. BER of EAF three time slots protocol with respect to the relay1 and relay2 movement

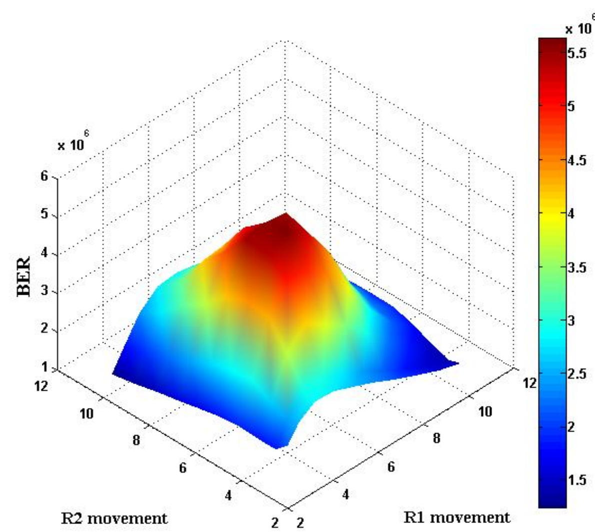

Fig. 9. BER-Gain of EAF three time slots protocol with respect to the relay1 and relay2 movement

It is indicated from results that using the optimal relays location with optimal links distances (i.e.d_{SR1}=6.2101m, d_{R1D}=6.2101m, d_{SR2}=6.2101m, d_{R2D}=6.2101m, d_{R1R2}=7.7717m and d_{R2R1}=7.7717m), the EAF three time slots protocol showed low BER and high BER-Gain values. Therefore, the EAF protocol is further evaluated using the optimal relays location, with the comparison of PPAF two time slots [25] and PPAF three time slots protocols [29]. The SNR values from 0dB to 12 dB have been used for evaluation. The purpose of taking SNR values from 0dB to 12dB was to evaluate the performance of EAF protocol at low to medium SNR values.

The EAF protocol showed improvement over PPAF two time slots protocol using the optimal relays location, in terms of low BER values and high BER-Gain with respect to the increase in SNR values, as shown in figures 10 and 11 respectively.

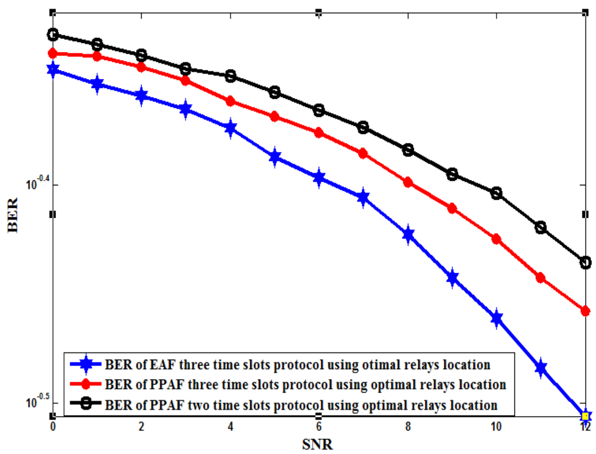

Fig. 10. BER comparison of EAF three time slots protocol using optimal relays location

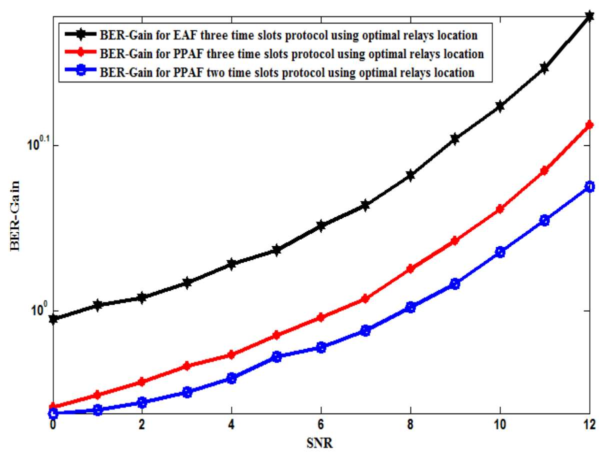

Fig. 11. BER-Gain comparison of EAF three time slots protocol using optimal relays location

Owing to the fact that the EAF three time slots protocol has one extra time slot, due to which it receives two extra copies of input signal at destination. Hence, the high diversity order is achieved by the EAF protocol at destination, which results in low BER and high BER-Gain values as compared to PPAF two time slots protocol. The EAF three time slots protocol also demonstrated improvement over PPAF three time slots protocol with respect to the increase in SNR values, in terms of low BER and high BER-Gain values, as shown in figures 10 and 11 respectively. It is due to the fact that the source of EAF three time slots protocol does not remain silent over 2nd and 3rd time slots and continuously broadcasts along with the relays, while, the source PPAF three time slots protocol does not broadcast over the 2nd and 3rd time slots and remain silent.

The accuracy of the EAF three time slots protocol has been evaluated statistically by using Global Percentage-Error-Decrease (GPED) and Local Percentage-Error-Decrease (LPED) methods [32-33]. The high LPED and GPED in BER mean better performance of the EAF three time slots protocol, in terms of low BER values over PPAF two time slots and three time slots protocols. These statistical methods are defined by the following eq. [21-22] as:

$$LPED = \left| \frac{\overline{E}_0 - \overline{E}_1}{\overline{E}_0} \right| \times 100 \qquad (21)$$

$$GPED = \frac{\sum \left| \frac{\overline{E}_0 - \overline{E}_1}{\overline{E}_0} \right| \times 100}{N} \qquad (22)$$

Where $\overline{E}_0$ is the average BER of the EAF three time slot protocol and $\overline{E}_1$ is the average BER of PPAF two time slots and three time slots protocols and N is the total number of SNR values taken.

The EAF protocol is evaluated using the optimal relays location with optimal link distances i.e. d_{SR1}=6.2101m, d_{R1D}=6.2101m, d_{SR2}=6.2101m, d_{R2D}=6.2101m, d_{R1R2}=7.7717m and d_{R2R1}=7.7717m. Moreover, the performance evaluation is carried out at severe fading condition e.g. at K=1 and at SNR values e.g. 0dB to 15dB. The purpose of taking SNR values from 0dB to 15dB was to evaluate the performance of the proposed protocol at low to medium SNR values. Furthermore, the performance evaluation is accomplished with the comparison of PPAF two time slots protocol [25] and three time slots protocol [29].

Using the optimal relays location, the EAF three time slots protocol showed improvement over two time slots protocol, in terms of 60.22% GPED in BER at SNR values from 0dB to 15dB, as shown in figure 12.

Moreover, the proposed protocol showed improvement in LPED in BER, in contrast to previous two time slots protocol, with the increase in SNR values. For 0dB SNR, the proposed EAF protocol showed LPED in BER of 38.10%. With respect to the 15dB SNR, the proposed EAF protocol demonstrated LPED in BER of 75.10%.

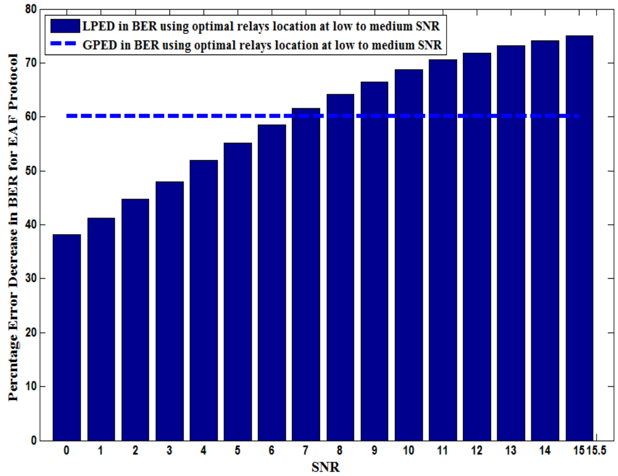

Fig. 12. GPED and LPED of EAF three time slot protocol as compared to PPAF two time slots protocol

From the performance evaluation with PPAF three time slots protocol, it is indicated that the EAF three times lots protocol showed GPED in BER of 41.50% at SNR 0dB to 15dB, as shown in figure 13. Moreover, the performance of the EAF protocol is further improved over three time slots protocol, in terms of increase in LPED values with respect to the increase in SNR values. The proposed protocol indicated LPED in BER of 23.60% at SNR=0dB. However, the LPED in BER of 55% has been demonstrated at SNR=15dB, in contrast to PPAF three time slots protocol.

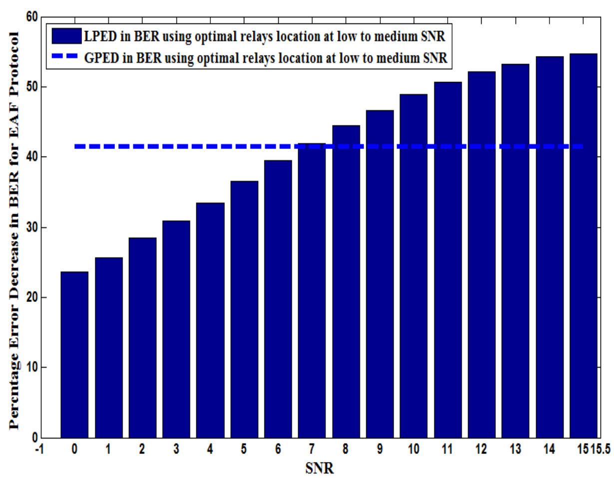

Fig. 13. GPED and LPED of EAF three time slot protocol as compared to PPAF three time slots protocol

IV. CONCLUSIONS AND FUTURE WORK

The EAF three time slots TDMA based protocol has been proposed, and the optimal relays location has been identified using the relay displacement analysis. Moreover, the normalization factor β is derived for the 3^{rd} time slots, which further enhances the performance of the EAF protocol, in terms of low BER and high BER-Gain. The simulation results indicated that the EAF showed low BER and high BER-Gain values, in contrast to previous two and three time slots protocols, with the increase in SNR values. Moreover, the optimal relays location with optimal link distances has been found, in terms of low BER and high BER-Gain values with the increase in SNR values. Using the optimal relays location, the EAF protocol demonstrated improvement over previous two and three time slots protocols, in terms of low BER and high BER-Gain values. The GPED and LPED results indicated the accuracy of the EAF protocol at optimal relay location, with GPED in BER of 60.22% and 41.50%, as compared to previous two time slots and three time slots protocols respectively. Moreover, the EAF protocols showed improved LPED in BER, in contrast to previous two time slots and three time slots protocols, with the increase in SNR values. At 0dB SNR, the EAF protocol showed LPED in BER of 38.10% and 23.60%, in contrast to previous two time slots and three time slots protocols respectively. While at 15dB SNR, the LPED in BER of 75.10% and 55% is demonstrated, in contrast to previous two time slots and three time slots respectively.

In this work, only two relays in the system model has been used for simplicity. However, multiple relays can used to further demonstrate the performance of the EAF protocol. Moreover, the performance of the proposed protocol could be further analyzed using parameters like delay, throughput and outage probability.

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