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Performance Analysis of Triple Hop Cooperative Communication Networks

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Abstract: This paper mainly concentrates only on energy efficiency of triple hop multi-relay cooperative system. The performance of triple hop system is analyzed under imperfect channel estimate. Conclusion is derived based on the tradeoff between the system capacity and energy consumption. The capacity of system enhanced using multiple inputs and multiple outputs (MIMO) which in turn increases the power consumption of network. The power consumption must be minimized using optimized relay selection algorithm. Above process is complex due to the presence of triple hop.

Key words: System capacity · Energy consumption · Imperfect channel

INTRODUCTION

In the era of fifth generation, there is a terrific increase in the usage of wireless communication devices in terms of controlling the Internet Of Things (IOT), mobile phone communication, online transactions, internet, online applications. This made wireless communication to deal with mounting demand of high speed, security devices. In order to meet the high data traffic in the networks, the lifetime of wireless communication devices has to be increased [1-4]. This challenge made us motivated towards the cooperative communication.

Cooperative communication is full diversity with less synchronization and high spectral efficiency, the communication takes place indirect between source and destination due to presence of obstacle in cooperative manner [5]. In turn undergoes shadowing and fading, this can be minimized by regenerative relaying which has low path loss but requires complex operation and consumes more power.

The best way is move towards transparent relaying which reduces path loss and shadowing but not the fading completely. Fading is nothing but the distortion in signal magnitude due to the presence of atmospheric particles like humidity, dust particles, lightening and so on [6]. System performance increases with number of transmit antenna which is always not favorable hence we should make use of the available antennas.

In [7] and [13], MIMO has capacity to increase the capacity of wireless communication, hence we choose MIMO as relay. Perfect channel state information is an assumption made to derive the closed form expression for throughput, outage probability, error performance. The optimal or sub-optimal algorithms were developed for both perfect and imperfect channel estimates based on the SNR assumption [8-10]. As cited in [11], the closed form expressions were derived on effective SNR for both conventional and non-conventional opportunistic relaying. While channel state error urge to imperfect channel estimation owing to the noise and time varying nature of channel.

From the above literature survey, it is evident that conclusion were derived only for dual hop transmission not for triple hop. According to Bayes theorem, we consider the channel estimation occurs in training phase, MSE is priori based on which maximum SNR can be selected. In order to derive the upper and lower bound on the mutual information under imperfect channel estimate for relay selection. In [12], the capacity tightness on lower bound is close to capacity of the system; hence optimal total transmission can be allocated from source to destination. Based on literature survey, performance of the triple hop relay system is analyzed under imperfect channel and their corresponding outage probability derived aiming in minimizing the outage probability.

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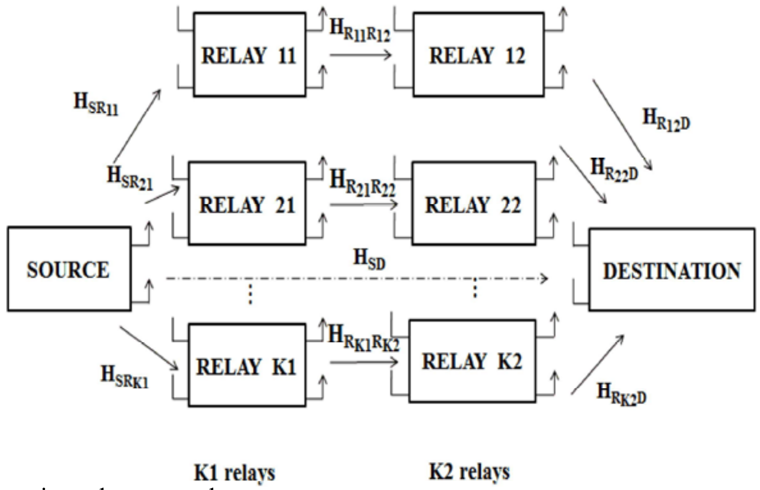

Fig. 1: Triple hop cooperative relay network.

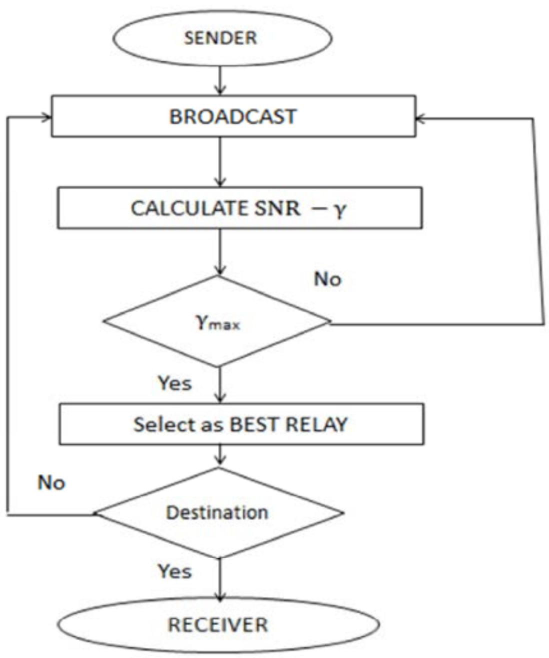

Fig. 2: Flow chart depicts the system model

System Model: In this section, triple hop cooperative system is modeled with MIMO relay. The information transmission takes places between source (S) and destination (D) through Ki and Li relay nodes indirectly as shown in the figure. We consider three scenario i) direct LOS ii) dual hop iii) triple hop. First scenario, there is direct transmission. Second scenario there is no existence of direct path; the signal undergoes fading effect in dual hop. Third scenario, based on the idea of increase the system capacity by increasing the relay, we can reduce the transmission power at source. As in Figure 1, source broadcasts the information at the initial stage. The channel with high SNR selected based on MSE, known as best relay. In subsequent step, the best relay broadcasts the information to nearby relay; again the step is done iteratively until reaches the destination, the flow is depicted in the Figure 2.

However, this is usual scenario occurrence, now we consider the channel with error that can be estimated.

The channel estimation error is illustrated [11, 12].

$$e_{h_{ij}} = h_{ij} - \hat{h}_{ij} \tag{1}$$

In the above equation, $\hat{h}_{ij}$ is the estimated channel, h_{ij} channel coefficient, we denote the fading channel coefficients using Gaussian distribution with zero mean and unit variance [5, 9-12], ($S \rightarrow R_{Ki}$) is represented as $h_{SR_{Ki}} \sim CN\left(0, \sigma^2_{SR_{Ki}}\right)$,

$(R_{Ki} \rightarrow R_{Li})$ as $h_{R_{Ki}R_{Li}} \sim CN(0, \sigma^2_{R_{Ki}R_{Li}})$

$(R_{Li} \rightarrow D)$ as $h_{R_{Li}D} \sim CN(0, \sigma^2_{R_{Li}D})$

Estimated error can be represented using MSE which is denoted by σ_{ij}, has already explained. P_S is the source power W is Johnson noise.

The signal received at relay Ki is represented as

$$y_{SR_{Ki}} = \hat{h}_{SR_{Ki}} \sqrt{P_S}\, x_S + W_{SR_{Ki}} \tag{2}$$

Signal at Li relay is characterized as

$$y_{R_{Ki}R_{Li}} = \hat{h}_{R_{Ki}R_{Li}} \sqrt{P_{R_{Ki}}} x_{R_{Ki}R_{Li}} + W_{R_{Ki}R_{Li}} \quad (3)$$

Signal at D is described as

$$y_{R_{Li}D} = \hat{h}_{R_{Li}D} \sqrt{P_{R_{Li}}} x_{R_{Li}D} + W_{R_{Li}D} \quad (4)$$

The signal received at destination from the sender is illustrated as

$$y_{SR_{Ki}R_{Li}D} = y_{SR_{Ki}} + \alpha_i y_{R_{Ki}R_{Li}} + \alpha_i y_{R_{Li}D} \quad (5)$$

where α_i is a amplification factor, (i.e. the signal from the sender is amplified at relay to boost the signal power in order to reach the destination) is given by

$$\alpha_i = \frac{1}{\sqrt{P_S \left| h_{SR_{Ki}} \right|^2 + P_{R_{Ki}} \left| h_{R_{Ki}R_{Li}} \right|^2 + P_{R_{Li}} \left| h_{R_{Li}D} \right|^2 + W_0}} \quad (6)$$

Path loss is the power loss in the signal due to the distortion since it travels in free space is formulated using Friss formula [15] is

$$\frac{P_R}{P_T} = G_T G_R \left(\frac{\lambda}{4\pi d} \right)^2 \quad (7)$$

where G_T is the transmitter gain, G_R is receiver gain, d is the distance and λ is wavelength.

Outage Probability: Outage probability (P_{out}) is a reasonable performance measure in evaluating the system capacity at the receiver side. The probability of mutual information ã$_{SD}$ below the transmission rate [14] is a major cause for packet drop. The packet drop can be calculated by taking complement of arrived packet. Initially the packet drop is unknown. Hence based on the arrived packets the outage probability can be calculated by taking complementary of the arrived packets.

The transmitter fixes the minimum SNR γ_{min} value encodes the data at the rate.

$$\zeta = Bw \log_2(1+\gamma_{ij}) \quad (8)$$

where Bw is bandwidth, ζ is the mutual information. The data recoded at the receiver when $\zeta \geq \gamma_{min}$.

The receiver bit over transmission burst can't be decoded with probability of

$$P_{out} = P(\zeta < \gamma_{min}) \quad (9)$$

Then the mean transmission rate received at the receiver is

$$C_{mean} = (1 - P_{out}) Bw \log_2(1+\gamma_{ij}) \quad (10)$$

Packet drop can be expressed from [14] as

$$P_{blackout} = \rho_{SD} \cdot \rho_{SR_{Ki}} \cdot \rho_{R_{Ki}R_{Li}} + (1 - \rho_{SR_{Ki}R_{Li}}) \rho_{SR_{Ki}R_{Li}D} \quad (11)$$

Numerical Results: The communication takes place between source and destination either direct or indirect. The information from source is broadcasted to the relay ki. The best relay is chosen, having high SNR. From the selected relay, the signal is amplified and forwarded to next stage. Since we considering triple hop again the process repeated in an iterative manner until it reaches the destination. Thus the transmission either take place in dual or triple hop, there is no possibility of LOS practically. As stated in [12], MIMO has capacity gain, it can be reduce, if CSI is not perfect.

Performance of triple hop system under imperfect channel is evaluated by bit error rate (BER) analysis.

Based on the Figure 3, two hops has low bit error rate than triple hop. This is due to the noise added in triple hop cooperative system. This has to be optimized.

Similarly we obtain for decode and forward only difference is the received is decoded, forwarded to the final terminal as illustrated in the Figure 4.

From Figure 5, on the performance analysis DF is better than AF but DF has more computational complexity and consumes more power due to the additional operation.

The power consumed during direct transmission, dual transmission and triple hop is depicted in the Figure 6. It is evident that the power consumed during triple hop is 0.12mW more than dual hop.

Figure 7 describes the probability of transmission is below the transmission rate under imperfect channel.

Figure 8 illustrates the comparison of outage probability under with and without imperfect channel. The encircle curve shows the outage probability under imperfect channel and plane curve under perfect channel.

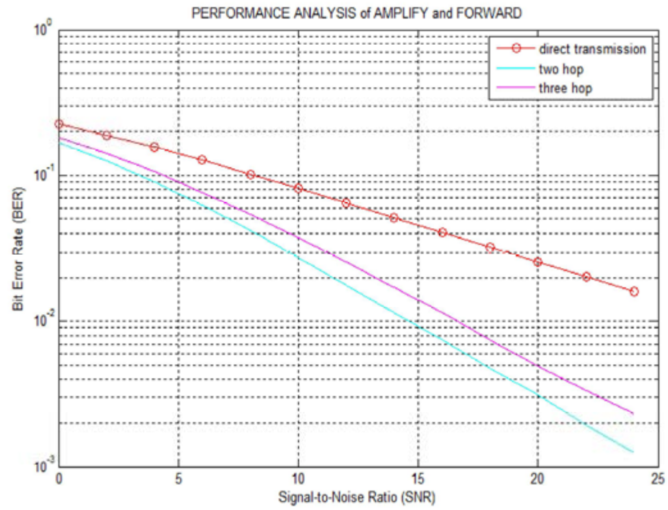

Fig. 3: Performance Analysis of Amplify and Forward

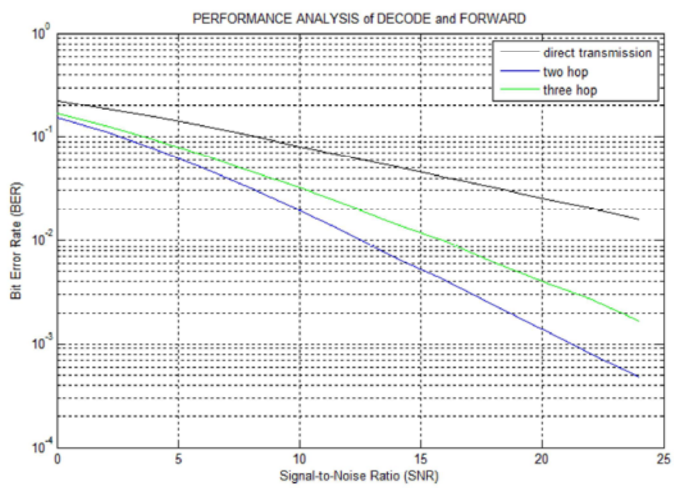

Fig. 4: Performance Analysis of Decode and Forward

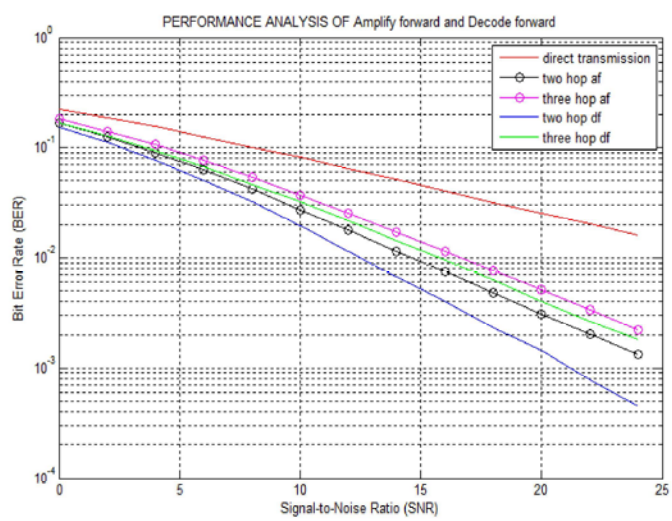

Fig. 5: Performance Analysis of AF and DF

(a)

(b)

(c)

Fig. 6: (a) direct transmission (b) dual hop (c) triple hop

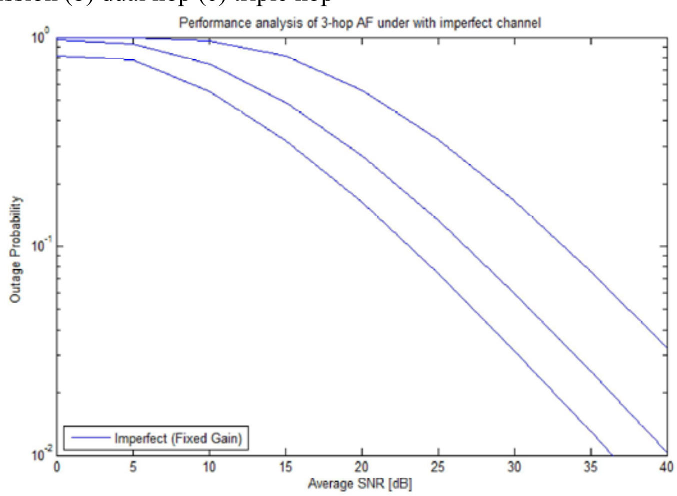

Fig. 7: Performance Analysis of 3-hop AF under imperfect channel

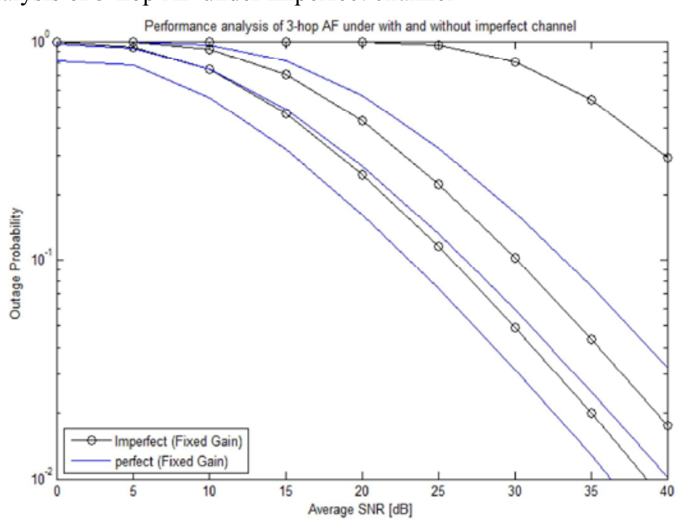

Fig. 8: Performance Analysis of 3-hop under with and without imperfect channel

CONCLUSION

In this paper, performance analysis of triple hop cooperative network is examined under AF and DF. Based on the results from the figure 5, we conclude that DF has better performance but has more entanglement and power consumption due to the additional steps. Since we concentrate in reducing the transmit power, we move on to AF. The power consumed during LOS and non LOS depicted in figure 6 and found to be 0.12mW more than dual hop communication. Then, the triple hop system capacity is evaluated using the outage probability under both imperfect and non-imperfect channel.

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