INVESTIGATION ON MULTILINK MULTIHOP WIRELESS RELAY NETWORK WITH COOPERATIVE DF PROTOCOL

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Abstract

Performance analysis is studied in this paper by deriving the end to end symbol error probability for flat Rayleigh fading multihop multilink wireless relay network with decode and forward protocol. We have investigated the performance of the network by two models. 1: Model of two hop, three hop and four hop relay network. 2: Model of multihop multilink relaying with symbol error detection. Probability density function and cumulative density function are derived for expressing SNR at the destination. M-ary Phase Shift Keying modulation is used for the theoretical analysis of Symbol error probability. The relay links are assumed to be identically and independent distributed with partial CSI. Analytical and computer simulated results are verified by Monte Carlo simulator.

Keywords: *symbol error probability (SEP), M-ary Phase Shift Keying (MPSK), Multihop, Multilink, decode and forward protocol*

1. Introduction

In the recent year the demand of data is increasing in mobile communication. Further mobile communication is in need of high data rate requirement. Further communication can serve massive access nodes wireless services. The installation of new base station is limited and one base station can fulfill all requirements for the future generation of communication.

Many researchers in last decade have been attracted by cooperative communication ever single antenna can separated virtually [1-3]. The performance can be improves by adding the benefits of cooperative in relay node. In cooperative communication, the relay nodes are able to receive the information and transmit the information to neighbor node by their broadcasting nature. Cooperative communication holds number of advantages over direct link transmission in terms of channel capacity, power and connectivity. The direct transmission is not practically feasible due to the power constraints and path loss [4]. This cooperative relaying can be applied to mobile network, ADHOC network, WLAN and hybrid networks.

In cooperative communication, the relay node receives the information from the source and forward to the destination. The forwarding of the information by relay nodes is manipulated by three main protocols. Amplify and forward: the received information from the source is amplified and the amplified version of information is forward to the destination. In this protocol, while amplifying the information noise present in the received information is also amplified lead to a poor SNR. Compress and forward: the information are compress with the own intelligence of the relay and forward to the destination. Intelligence adapted the relay is unknown to the destination. Decode and forward: the relay node regenerates the information from the source and forward to the destination. This protocol holds the advantage power constraint throughout the link [5, 6]. Multiple replica of the same information from the source at the destination is allowed to select the best signal by opportunistic technique. By selecting the best copy of the information guarantee the diversity gain without reducing the spectral efficiency of the system.

In [7–9] performance analysis for the dual hope network has been considered in the case of the single relay and single user at the destination with the presence of interference. Opportunistic multi destination users with a single relay has been investigated in [4] without considering interference. In [10], the authors considered multiple antennas at the relay as well as multiple destination users again without considering interference. Authors in [6] studied opportunistic multiple users with single relay in the presence of interference.

In this work we investigate the performance analysis of the opportunistic multihop multilink relay cooperative network without presence of co-channel interference. Specifically, for multihop multilink relay cooperative communication using Decode and forward protocol at the relay, in section 2 we derive the received symbol signal for two hop, three hop and four hop relay network with DF protocol. Symbol error probability for multilink multihop relay network is derived in section 3. The results of numerical and computer simulation are compared followed by conclusion in section 5.

2. System model

2.1 Two hop network model

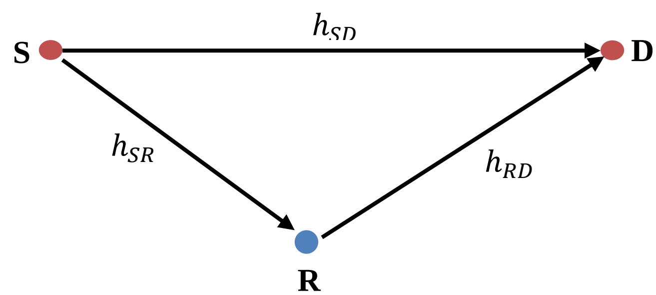

Figure 1: Two hop relay network

This network model consists of a source node S, destination node D and a relay node R between source and destination as shown in the figure 1. The relay node is consider to be a cooperative diversity node with decode and forward protocol.

Transmission of information from source to destination in the network consists of two phases. MPSK symbol S_K is transmitted from source to relay node and destination during phase 1. The transmitting MPSK symbol S_K as the energy of $2E_S$ which belong to the one of the M-complex constellation symbol $S_k = \{S_1, S_2, \dots S_N\}$, the symbol S_K is expressed as

$$S_K = \sqrt{2E_s}\exp\left(\frac{\mathrm{j}2\pi(\mathrm{n}-1)}{\mathrm{N}}\right), \mathrm{n} = 1, 2, 3, \dots \mathrm{N} \tag{1}$$

The complex baseband signal received at destination and intermediate relay during phase 1 are given by

$$r_{SD} = h_{SD}S_k + n_{SD}, r_{SR} = h_{SR}S_k + n_{SR} \tag{2}$$

During the phase 2, the relay node decodes the received symbol S_K as $\widehat{S_K}$ and forwards to the destination. The baseband complex signal received at the destination is expressed in equation 3

$$r_{RD} = h_{RD}\widehat{S_k} + n_{RD} \tag{3}$$

h_{SD} is the channel weight response between the source and destination, h_{SR} is the channel weight response between source and the relay and h_{RD} is the channel weight response between relay and destination. The noise function are modeled as mean zero complex Gaussian function with variance $2N_0$ that is $CN(0, 2N_0)$. Further n_{SD} , n_{SR} , and n_{RD} are the complex symmetric cyclic Gaussian noise of zero mean and with variance Ω_{SD}, Ω_{SR}, and Ω_{RD} respectively.

The instantaneous SNR of the links are given by

$$\gamma_{SD} = \frac{E_s}{N_O}|h_{SD}|^2, \quad \gamma_{SR} = \frac{E_s}{N_O}|h_{SR}|^2, \quad \gamma_{RD} = \frac{E_s}{N_O}|h_{RD}|^2 \tag{4}$$

and the average SNR for corresponding above links are given by

$$\Gamma_{SD} = \mathrm{E}[\gamma SD] = \frac{E_s\Omega_{SD}}{N_O}, \quad \Gamma_{\mathrm{SR}} = \mathrm{E}[\gamma SR] = \frac{\mathrm{E_s}\Omega_{\mathrm{SR}}}{N_O}, \quad \Gamma_{\mathrm{RD}} = \mathrm{E}[\gamma \mathrm{RD}] = \frac{\mathrm{E_s}\Omega_{\mathrm{RD}}}{N_O} \tag{5}$$

The decoding of the symbol in the intermediate relay node is based on the following equation

$$\widehat{S_K} = \arg\left\{\max_{s\epsilon S_K} Re(S_K{}^* h_{SR}^* r_{SR})\right\} \tag{6}$$

Where (.)* denotes the complex conjugate. At the destination two symbols will be combined by the proposed selection combining from the decision rule as given below.

$$\widehat{\widehat{S_K}} = \begin{Bmatrix} arg\left\{\max_{s\epsilon S_K} Re(s^* h_{SD}^* r_{SD})\right\} \; if \; \gamma SD > \min(\gamma RD) \\ arg\left\{\max_{s\epsilon S_K} Re(s^* h_{RD}^* r_{RD})\right\} \; if \; \gamma SD < \max(\gamma RD) \end{Bmatrix} \tag{7}$$

2.2 Three hop network model

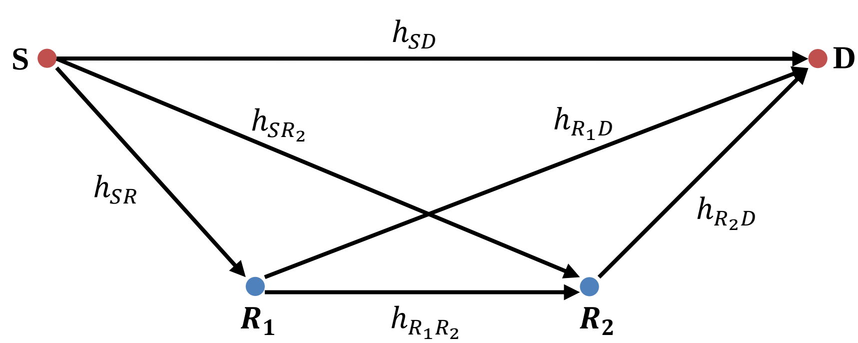

Figure 2: Three hop relay network

In this network model, two cooperative relay with DF protocol are consider between the source and destination. The spatial diversity allows the source to transmit the MPSK symbol over four paths to the destination as shown in figure 2. At the destination the received symbol are selected and combine by the proposed SC scheme. The transmission of the symbol occurs in three phases. In phase 1, the source broadcast the complex MPSK symbol S_k with signal energy $2E_S$ to the destination node, relay node R_1

and relay node R_2. The received symbol signal is given by

$$r_{SD} = h_{SD} S_k + n_{SD}, r_{SR_1} = h_{SR_1} S_k + n_{SR_1}, r_{SR_2} = h_{SR_2} S_k + n_{SR_2} \quad (8)$$

During the phase 2, the received symbol S_k at the relay node R_1 and R_2 is decoded as $\widehat{S_k}$ by the equation (6) and both relay node forward the symbol to the destination. Meanwhile relay node R_1 also forward the symbol to the relay node R_2. The received signals at the destination and the relay node R_2 is given by

$$r_{R_1D} = h_{R_1D}\widehat{S_k} + n_{R_1D}, r_{R_2D} = h_{R_2D}\widehat{S_k} + n_{R_2D}, r_{R_1R_2} = h_{R_1R_2}\widehat{S_k} + n_{R_1R_2} \quad (9)$$

In phase 3, the received symbol $\widehat{S_k}$ at the relay node R_2 is decoded as $\widehat{S_k}$ which is belong to the M complex constellation $S_k \in \{S_1, S_2, \dots S_N\}$ and forward the symbol to the destination. At the destination, the received baseband signal is given by

$$r_{R_2D} = h_{R_2D}\widehat{S_k} \quad (10)$$

All the received signals are then combined at the destination by the proposed decision rule as discussed in the equation (7).

2.3 Four hop network

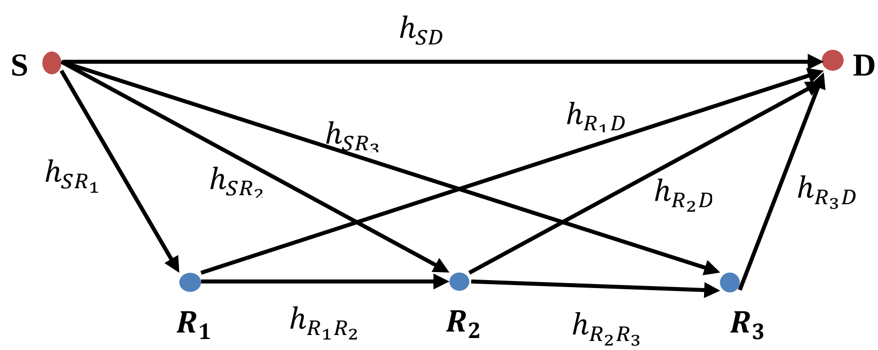

Figure 3: Four hop relay network

By adding one more relay between the source and the destination in the previous model, the transmission paths between the source and destination increase to seven possible paths by spatial diversity with three hops in figure 3. Transmission of symbol takes places by four phases. Phase 1, the source broadcast the complex MPSK symbol S_k with signal energy $2E_S$ to the destination node, relay node R_1 , relay node R_2 and relay node R_3. The received signal during this phase is given by

$$r_{SD} = h_{SD} S_k + n_{SD}, r_{SR_1} = h_{SR_1} S_k + n_{SR_1}, r_{SR_2} = h_{SR_2} S_k + n_{SR_2}, r_{SR_3} = h_{SR_3} S_k + n_{SR_3} \quad (11)$$

In phase 2, the intermediate relay nodes decode the received signal and forward to nearby relays and to the destination along with the complex symmetric cyclic Gaussian noise. The received signal by the relay nodes and the destination in phase 2 is given by

$$r_{R_1D} = h_{R_1D}\widehat{S_k} + n_{R_1D}\ , \qquad r_{R_2D} = h_{R_2D}\widehat{S_k} + n_{R_2D}\ , \qquad r_{R_1R_2} = h_{R_1R_2}\widehat{S_k} + n_{R_1R_2}$$
$$r_{R_3D} = h_{R_3D}\widehat{S_k} + n_{R_3D}\ ,\ r_{R_2R_3} = h_{R_2R_3}\widehat{S_k} + n_{R_2R_3} \qquad (12)$$

In phase 3, the received signal are decoded by the relay node and forward to the near relay node and the destination by

$$r_{R_2D} = h_{R_2D}\widehat{S_k} + n_{R_2D}\ , r_{R_3D} = h_{R_3D}\widehat{S_k} + n_{R_3D}\ , r_{R_2R_3} = h_{R_2R_3}\widehat{S_k} + n_{R_2R_3} \qquad (13)$$

by phase 4, the destination receive seven symbol signal propagated through relays and received signal at this phase is given by

$$r_{R_3D} = h_{R_3D}\widehat{S_k} + n_{R_3D} \qquad (14)$$

The received seven symbol signals are selected and combine by the modified rules of equation (7)

$$\widehat{\widehat{S_K}} = \begin{Bmatrix} arg\left\{\begin{matrix} max \\ s\epsilon S_K \end{matrix} Re(s^* h_{SD}^* r_{SD})\right\}\ if\ \gamma SD > \min(\gamma R_1 D, \gamma R_2 D, \gamma R_3 D) \\ arg\left\{\begin{matrix} max \\ s\epsilon S_K \end{matrix} Re(s^* h_{RD}^* r_{RD})\right\}\ if\ \gamma SD < \max(\gamma R_1 D, \gamma R_2 D, \gamma R_3 D) \end{Bmatrix} \qquad (15)$$

3. Multihop multilink DF relay model

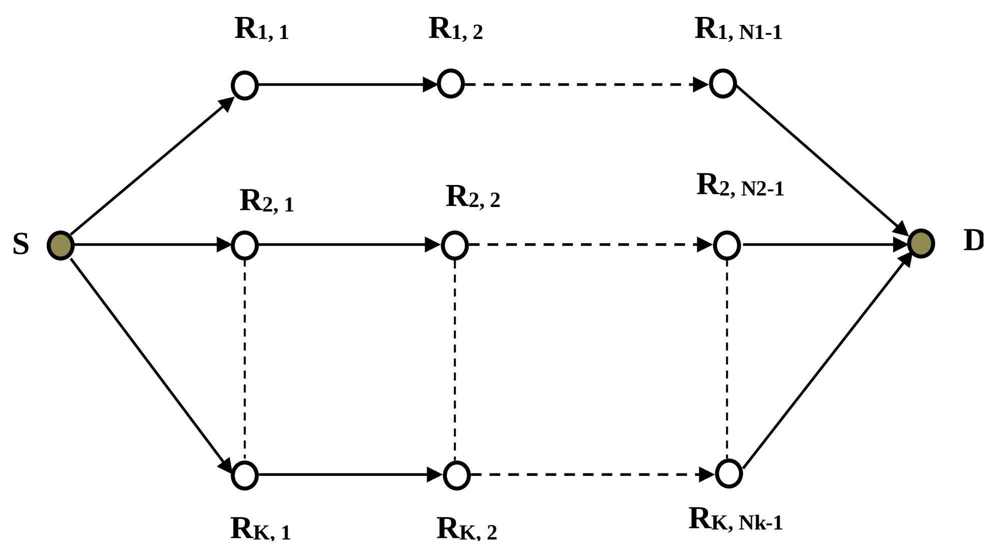

Figure 4: multihop multilink cooperative relay network

The network model consists of a source, destination and N number of relay disturbed in K multiple links and N_k hops as shown in the figure 4. The destination receives the signal from the source through K multiple links; the intermediate relay nodes are considered to have cooperative decode and forward protocol. MPSK complex symbol S_K is broadcast from the source to the relay node in each link. The multiple relay in each link carry the symbol to the destination independent of other. With the partial CSI of the neighboring relay node, the symbol is decoded and forward through relay node to the destination. At the destination the received symbols from $R_{k,N_{k-1}}$ of K multiple links are selected on the correctness of the symbol otherwise discarded.

The correctness the symbol is consider from the outcome events of the source symbol S_k and the decoded error symbol S_M by the nodes from the tree diagram as shown in figure 5

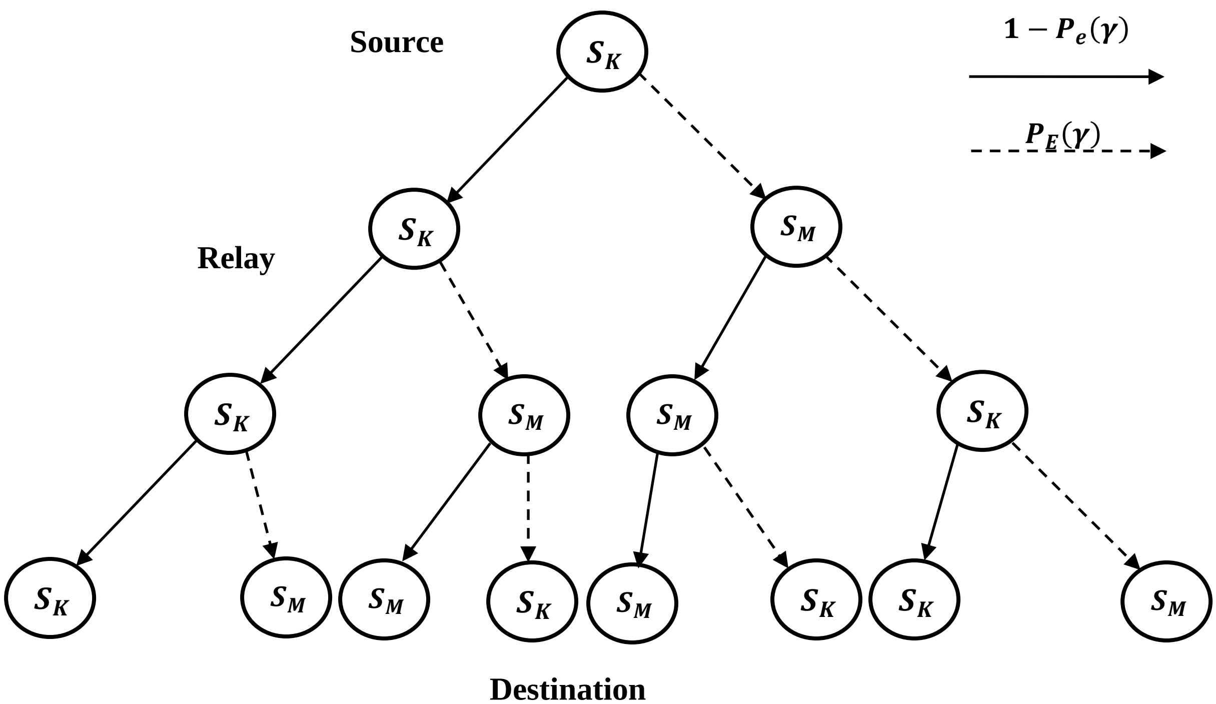

Figure 5: Tree diagram- outcomes of events when the source transmits symbol S_K

The correctness of the decision during the symbol transmission from source to destination and its conditional probability is given by

$$P_{S_K} = \sum_{n=0}^{N} \left(P_e(\gamma)\right)^n \left(1 - P_e(\gamma)\right)^{N-n} \tag{16}$$

Where N= Number of Hops and $n = 0,2,4,6,8 \ldots .even$

$$P_{S_K} = \sum_{n=0}^{N} \left(P_e(\gamma)\right)^n \left(1 - P_e(\gamma)\right)^n \tag{17}$$

Where N= Number of Hops and $n = 1,3,5 \ldots odd$

3.1 Symbol error probability of the model

The conditional error probability of MPSK modulation over a random variable γ, is given by

$$P_e(\gamma) = \frac{1}{\pi} \int_0^{\frac{\pi(M-1)}{M}} exp\left(-\frac{\gamma sin^2\left(\frac{\pi}{M}\right)}{sin^2\phi}\right) d\phi \tag{18}$$

and the equation (19) and (20) represent the probability density function and cumulative density function of the exponential distributed random variable γ

$$f(x) = \left(\frac{1}{\Gamma_{XY}}\right)\exp\left(-\frac{x}{\Gamma_{XY}}\right) \tag{19}$$

$$F(x) = 1 - exp\left(-\frac{x}{\Gamma_{XY}}\right) \tag{20}$$

Based on the correctness of the symbol, take the average of the equation (18) over the exponential statistics of the relay links. The average symbol error probability is given by

$$P_{eD} = \int_0^{\infty} P_e(x)\, F_{V_i}(x) f_{SD}(x) dx \tag{21}$$

Let us define another random variable V_i

$$V_i = \min\left(\gamma R_{1,2}, \gamma R_{2,3}, \gamma R_{3,4}, \ldots\ldots \gamma R_{N-1,D}\right) \tag{22}$$

The overall CDF (F_{V_i}) of the SD link with above random variable for K multiple links is given by,

$$F_{V_i}(u) = \prod_{n=1}^{N}\left(1 - exp\left(\frac{u}{\Gamma_{XY}}\right)\right)^n \tag{23}$$

Substitute the value of equation (18), (19) and (23) in equation (21)

$$P_{eD} = \frac{1}{\pi}\int_0^{\infty}\int_0^{\frac{\pi(M-1)}{M}} exp\left(-\frac{x sin^2\left(\frac{\pi}{M}\right)}{sin^2\phi}\right).\prod_{n=1}^{N}\left(1 - exp\left(\frac{u}{\Gamma_{XY}}\right)\right)^n.\left(\frac{1}{\Gamma_{XY}}\right) exp\left(-\frac{x}{\Gamma_{XY}}\right) d\phi dx \tag{24}$$

Where $\Gamma_{XY} = \Gamma_{R_{n.n+1}}$

Integrate the equation (24) with respect to x, we get

$$P_{eD} = \prod_{n=1}^{N}\binom{N-n}{n}\frac{(-1)^n}{\pi\Gamma_{R_{n,n+1}}}\int_0^{\frac{\pi(M-1)}{M}}\left(\frac{1}{\frac{sin^2\left(\frac{\pi}{M}\right)}{sin^2\phi}+\frac{N+n+1}{\Gamma_{R_{n,n+1}}}}\right) d\phi \tag{25}$$

4. Numerical and simulated results

In this section, we present the various performance evaluation results derived by numerical and simulations with a M-ary phase shift keying modulation scheme. We also verify the gap between the derived theoretical results and the numerical simulations. The performance of the network model is evaluated using Monte Carlo. The DF relay network model is consider as identically and independent distributed ($\text{i.e.}\Gamma_{SR} = \Gamma_{RR} = \Gamma_{RD} = \Gamma_{XY}$). In the analysis of both the models, the energy is considered to be equally distributed from source to destination through relays.

Figure 6 plots the outage probability versus SNR at the destination with increasing relay ($m = 1, 2, 3$) nodes between source and destination. Thus it is concluded that the analytic results and the simulated results are same. The outage probability can be decreased by increasing the relay so better the system performance.

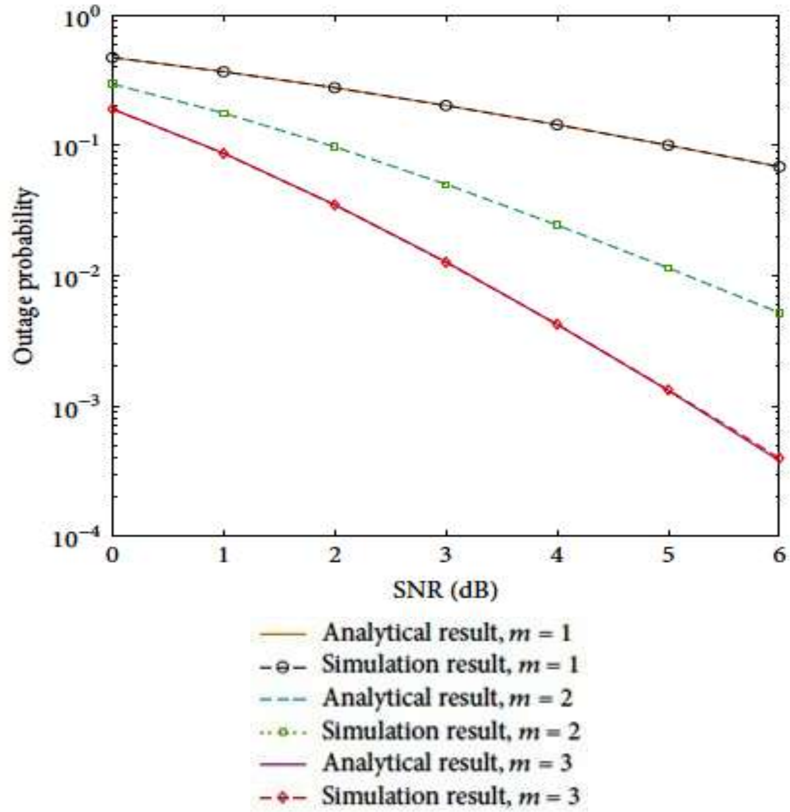

Figure 6: outage probability vs SNR by increasing relay nodes $(m = 1, 2, 3)$

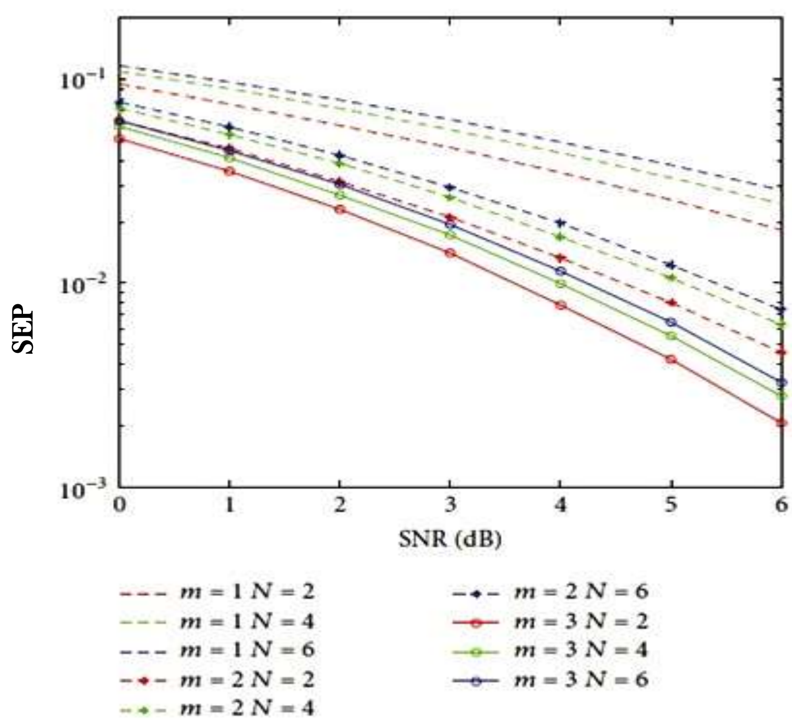

Figure 7: SEP vs SNR varying multiple links $(m = 1, 2, 3)$ and hops $(N = 2, 4, 6)$.

The symbol error probability versus SNR is plot in the figure 7 for varying multiple links $(m = 1, 2, 3)$ between source and destination with even hops $(N = 2, 4, 6)$. Performance is more superior for the multihop multilink network.

5. Conculsion

In this paper, the received signal equation for two, three and four hop network is derived. The closed form of end to end symbol error probability is derived for multihop multilink relay network using partial CSI. M-ary phase shift keying modulation scheme is consider over a flat Rayleigh fading channel. Symbol error rate decrease with the increasing relay nodes between the source and the destination.

Reference:

[1] *J.N.Laneman, D.N.Tse, and G.W.Wornell,"Cooperative diversity in wireless networks: Efficient protocols and outage behavior," IEEE Translation Information Theory, vol. 50, no. 12, pp. 3062–3080, 2004.*

[2] *D.Benevides da Costa and S.Aissa,"Performance of cooperative diversity networks: Analysis of amplify and forward relaying under equal gain and maximal ratio combining," in Porc. IEEE ICC, June 2009, pp. 1–5.*

[3] *Baofeng Ji, Bingbing Xing, Kang Song, Chunguo Li," Performance Analysis of Multihop Relaying Caching for Internet of Things under Nakagami Channels," Hindawi-Wireless Communications and Mobile Computing, April 2018.*

[4] *A.Forghani, S.Ikki, and S.Aissa,"On the performance and power optimization of multihop multibranch relaying networks with cochannel interferers," IEEE Trans. Veh. Technol., vol. 62, no. 7, pp. 3437–3443, Sept 2013.*

[5] *N.Yang, M.Elkashlan, and J.Yuan,"Impact of opportunistic scheduling on cooperative dual hop relay networks," IEEE Trans. Commun., vol. 59, no. 3, pp. 689– 694, March 2011.*

[6] *Q.Chen, Q.Zhang, and Z.Niu, "Qos aware cooperative and opportunistic scheduling exploiting multiuser diversity for rate adaptive adhoc networks," IEEE Trans. Veh. Technol., vol. 57, no. 2, pp. 1113–1125, 2008.*

[7] *K.Hemachandra and N.Beaulieu, "Outage analysis of opportunistic scheduling in dual hop multiuser relay networks in the presence of interference," IEEE Trans. Commun., vol. 61, no. 5, pp. 1786–1796, May 2013.*

[8] *C.Zhong, S.Jin, and K.K.Wong,"Dual hop systems with noisy relay and interference limited destination," IEEE Trans. Commun., vol. 58, no. 3, pp. 764–768, March 2010.*

[9] *H.Suraweera, H.Garg, and A.Nallanathan,"Performance analysis of two hop amplify and forward systems with interference at the relay," IEEE Commun. Lett., vol. 14, no. 8, pp. 692–694, August 2010.*

[10] *S. Ikki and S. Aissa, "Performance analysis of dual hop relaying systems in the presence of co-channel interference," in 2010 IEEE Global Telecommunications Conference., Dec 2010, pp. 1–5.*

[11] *N.Yang, M.Elkashlan, and J.Yuan,"Outage probability of multiuser relay networks in nakagami fading channels," IEEE Trans. Veh. Technol., vol. 59, no. 5, pp. 2120–2132, Jun 2010.*