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Large Scale Cooperative Wireless Networks: Relay Selection and Performance Analysis

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ABSTRACT

This paper presents a proficient relay selection criterion for large-scale cooperative wireless networks (LSCWN) under Rayleigh fading, where each node in the network employs an Amplify and Forward (AF) relay protocol. We obtain analytic expression for Probability Density Function (pdf) and Cumulative Density Function (CDF) of end-to-end instantaneous signal-to-noise ratio and obtained minimized expression for the Moment Generating Function (MGF). The performance of the proposed relay selection criteria is analyzed and simulated. Simulation results shows an improvement in outage probability and symbol error rate by 63.88% and 84.89%, respectively, when the number of hops are increased from 1 to 3.

Key words : Large scale cooperative wireless network, relay selection, moment generating function, PDF, CDF.

1. INTRODUCTION

Wireless network performance degraded by fading and its affect can be mitigate by providing the redundancy at the receiver called diversity technique. Cooperative communication is the technique provides the spatial diversity by forming Virtual Multiple Input Multiple Output (VMIMO) without having multiple radio terminals at both the transmitter and receiver. Cooperative communication is the promising technique for the latest wireless communication because of its ability to improve coverage area with reduced node transmission power, capacity and spectral efficiency [1-7].

There are several cooperative relay protocols based on their operation at relays. Some of the most commonly used protocols are DF and AF. In AF relaying protocol, relay node forwards the amplified version of the source message to the destination (also called non-regenerative relaying protocol). Whereas in DF relaying protocol, the re-encoded form of the message is forwarded to the destination (also called regenerative relaying protocol). [2-7].

Routing is the key factor of large cooperative wireless networks which has high impact on the performance of the network. In recent years, several routing algorithms have been proposed based on the way of establishing the path. They are based on: protocol operation, network structure, initiation of communication, path establishment or next op selection [8].

Next hop selection based routing algorithms are classified into 3 categories namely: Proactive, reactive and hybrid routing algorithms. In proactive routing algorithms, route for every node is calculated and maintained by routing table well before it is needed. This route table is updated periodically by route update process [9-10].

In reactive routing algorithms, route is established only when it is needed. Therefore these routing algorithms do not need to maintain any routing information (route table) globally. Modified versions of routing protocols were presented for MANETs and VANETs [11-13].

Energy Efficiency or energy conservation and network life time are the key parameters for the cooperative routing algorithms. Several routing algorithms have been proposed recently to enhance the energy efficiency and lifetime of the cooperative wireless networks [14-16]. Authors in [17] have been adopted bio-inspired algorithms to obtain optimal cooperative routing path.

The authors in [18] have been derived the minimal form expression for the harmonic mean of two random exponential random variables over Rayleigh fading channels. The study of cooperative network with parallel relay has been presented in [19-20] over Rayleigh fading channels. In [21-22] the authors have been studied the total performance of non-regenerative cooperative wireless network, to do this they developed the analytic expression for average SER and outage probability for different modulation schemes. But all the fore mention authors considered the network with dual hop for their analysis.

The study of outage probability for Multiple-Input-Multiple-Output multi hop network based on radio terminal selection criteria over Rayleigh fading have been presented in [23]. In [24], the authors have been obtained the expression for outage probability over Rayleigh fading channel for non-regenerative multi hop networks based on power allocation. Asymptotic expression for the P_0 and $\overline{P}_e$ of non-regenerative cooperative network with multiple hops over generalized–k fading and Rayleigh fading channels are presented in [25-26] respectively. Study of cooperative network with multiple hops over Nakagami-m fading is presented in [27], in this, authors have been considered incremental relay selection scheme where the existence of relay paths depends on the direct link SNR.

In multi hop network, if one of the channels is weak the performance of the network may degrade, since the received SNR is the minimum SNR of all the individual links in the path. To prevent the received SNR hop selection scheme for AF cooperative multi hop network is presented in [28]. To simplify the analysis, the authors considered the spectral efficiency of dual hop network and multi hop network are equal. In [28], the number of hops are dynamic and are decided by a control relay node based on the SNR at the destination. In this paper, we proposed a proficient relay selection criteria for LSCWN and analyzed its performance using P_0 and $\overline{P}_e$.

The rest of the paper is organized as: In section 2, we describe the system model and relay selection criteria, Performance Evaluation is presented in section 3. In section 4, we present simulation results of the proposed approach. Finally, we concluded the paper in section 5.

2. SYSTEM MODEL

For the analysis, we consider an Large Scale Cooperative Wireless Network (LSCWN) with '*M*' Nodes over Rayleigh fading channel and every node in the employs Amplify – and – Forward (AF) relay protocol and each node having fixed transmission power (*P*). Let Source (r_0) broadcasts information '*x*' to a destination node (*d*) in multiple hops (*N*) as shown in figure 1. By using relay selection algorithm, source node selects one node (from its transmission region) as relay node, which acts as the source node for the next hop.

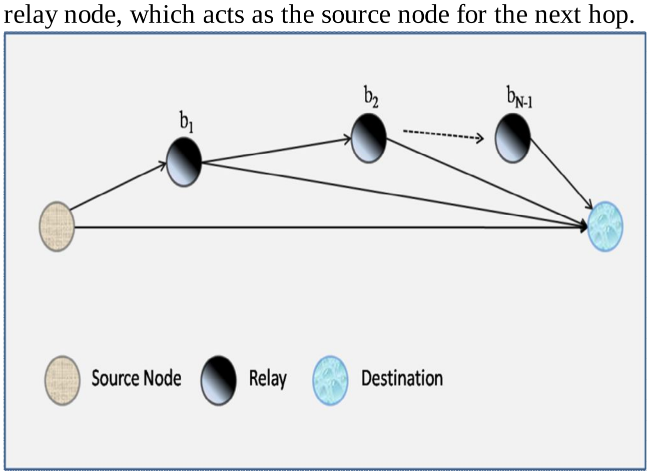

Figure 1: Schematic Model for N-Hop Large Scale Cooperative Wireless Network

Let r_i^k be the set of nodes in the transmission coverage area of $(k\text{-}1)^{th}$ relay node. Source broadcasts the information '*x*' to the destination and relay (r_i^1), where i=1,2,3,……. The information at the destination and relay (r_i^1) can be given by [29-30],

$$y_{r_0 d} = \sqrt{P} h_{r_0 d} x + \eta_{r_0 d}$$

$$y_{r_0 r_i^1} = \sqrt{P} h_{r_0 r_i^1} x + \eta_{r_0 r_i^1} \tag{1}$$

Where P is the transmit power; $\eta_{r_0 d}$, $\eta_{r_0 r_i^1}$ are the additive white Gaussian noises for the links $r_0 \to d$ and $r_0 \to r_i^1$. $h_{r_0 d}$ and $h_{r_0 r_i^1}$ are the channel coefficients between the links $r_0 \to d$ and $r_0 \to r_i^1$ respectively, which are modeled as $\left|h_{ij}\right|^2 = \sigma_{ij}^2 d_{ij}^{-n}$, where σ_{ij}^2 is the variance of the link $i \to j$ and n is the path loss exponent.

2.1 Relay Selection:

Let R_c be the transmission coverage area of each node in the network. Source node (r_0) select one of the nodes (r_i^1) as relay (b_1) as follows:

1. The instant SNR for the selected relay in first hop is given by

$$\gamma_{b_i^1} = \min\left(\gamma_{r_0 r_i^1}, \gamma_{r_0 d}\right)$$

2. Forms a set of nodes which has the relative difference less than the pre-defined threshold τ_1

$$Z = \left\{ p \mid \max_{i \in R}\left\{\gamma_{b_i^1}\right\} - \gamma_{b_i^1} < \tau_1 ; p \in r_i^1 \right\} \tag{2}$$

where R={1,2,…..} be the set of nodes in R_c and γ_i be the instantaneous SNR i^{th} hop relay.

3. Selects one node from set Z as relay node b_1 which is closer to line of sight i.e.,

$$b_1 = \min\left(dis\left(l_{i,LOS}\right)\right) \mid l_{i \in Z}$$

The instant SNR for the selected relay in first hop is given by

$$\gamma_{b_1} = \min\left(\gamma_{r_0 b_1}, \gamma_{b_1 d}\right) \tag{3}$$

the selected relay node (b_1) becomes the intermediate source node for the next hop. The instant SNR for the k^{th} hop relay is given by

$$\gamma_{b_k} = \left\{\min\left(\gamma_{r_0 b_1}, \gamma_{b_1 b_2}, \ldots\ldots\ldots\ldots, \gamma_{b_k d}\right)\right\} \tag{4}$$

Therefore the upper bound of the total SNR (γ_t) is given by

$$\gamma_t \le \gamma_{r_0 d} + \sum_{l=1}^{N-1} \gamma_{b_l} \tag{5}$$

The entire network shown in figure 1 is assumed with Rayleigh fading. Therefore the pdf and CDF of the instantaneous SNR of a link can be written as:

$$f_{r_m}(\gamma) = \frac{1}{\overline{\gamma}_m} e^{-\gamma/\overline{\gamma}_m} \tag{6}$$

$$F_{\gamma_m}(\gamma) = 1 - e^{-\gamma/\bar{\gamma}_m} \tag{7}$$

Where '*m*' denotes link index.

3. PERFORMANCE ANALYSIS

An analytic expression of MGF for end – to – end SNR (γ_t) is evaluated first and then the PDF and CDF for the γ_t are obtained in this section.

3.1 MGF

The MGF for γ_t can be written with the assumption that the instantaneous SNRs of all the links are independent as

$$\mathrm{M}_{\gamma_t}(s) = \mathrm{M}_{\gamma_{r_0d}}(s)\prod_{i=1}^{N-1}\mathrm{M}_{\gamma_{b_i}}(s) \tag{8}$$

$\mathrm{M}_{\gamma_{r_0d}}$ and $\mathrm{M}_{\gamma_{b_i}}$ are the MGF of instantaneous SNR for the link (*source* $\rightarrow$ *destination*) and i^{th} hop relay (given by equ (4)) respectively. MGF for the SNR γ given by

$$\mathrm{M}_{\gamma}(s) = \mathrm{E}\left\{e^{-s\gamma}\right\} = \int_0^\infty e^{-s\gamma} f_\gamma(\gamma)d\gamma \tag{9}$$

MGF for the link source to destination is given by (after the simplification)

$$\mathrm{M}_{\gamma_0 d}(s) = \frac{1}{\left(1+\bar{\gamma}_{r_0d}s\right)} \tag{10}$$

MGF for the k^{th} hop relay link is given by

$$\mathrm{M}_{\gamma_{b_k}}(s) = \int_0^\infty e^{-s\gamma} f_{\gamma_{b_k}}(\gamma)d\gamma \tag{11}$$

To evaluate the PDF of SNR γ_{b_k}, CDF for same SNR will be evaluated first. The CDF of γ_{b_k} can be expressed as follows for the independent link SNR's (i.e., $\gamma_{r_0r_i^1}, \gamma_{r_i^1r_i^2}, \ldots\ldots\ldots, \gamma_{r_i^kd}$ are independents).

$$\begin{aligned} F_{\gamma_{b_k}} &= 1-\Pr\left(\gamma_{r_0r_i^1} > \gamma\right)\Pr\left(\gamma_{r_i^1r_i^2} > \gamma\right)\ldots\ldots\ldots\Pr\left(\gamma_{r_i^kd} > \gamma\right) \\ &= 1-\left[1-\Pr\left(\gamma_{r_0r_i^1} \le \gamma\right)\right]\left[1-\Pr\left(\gamma_{r_i^1r_i^2} \le \gamma\right)\right]\ldots\ldots\ldots\left[1-\Pr\left(\gamma_{r_i^kd} \le \gamma\right)\right] \\ &= 1-\left[1-F_{\gamma_{r_0r_i^1}}(\gamma)\right]\left[1-F_{\gamma_{r_i^1r_i^2}}(\gamma)\right]\ldots\ldots\ldots\left[1-F_{\gamma_{r_i^kd}}(\gamma)\right] \end{aligned} \tag{12}$$

After substituting the CDF of the SNR for the respective links, equation (12) can be re-written as

$$F_{\gamma_{b_k}}(\gamma) = 1 - e^{-\gamma/\bar{\gamma}_{G^k}} \tag{13}$$

Where $\bar{\gamma}_{G^k} = \frac{1}{\bar{\gamma}_{r_0r_i^1}} + \frac{1}{\bar{\gamma}_{r_i^1r_i^2}} + \ldots\ldots\ldots + \frac{1}{\bar{\gamma}_{r_i^kd}}$

PDF for the SNR γ_{b_k} can be obtained by performing the differentiation w.r.t to γ.

$$f_{\gamma_{b_k}}(\gamma) = \frac{1}{\bar{\gamma}_{G^k}} e^{-\gamma/\bar{\gamma}_{G^k}} \tag{14}$$

Therefore equation (11) can be written as

$$\mathrm{M}_{\gamma_{b_k}}(s) = \frac{1}{\left(1+\bar{\gamma}_{G^k}s\right)} \tag{15}$$

Finally the MGF of the total SNR is given by

$$\mathrm{M}_{\gamma_t}(s) = \mathrm{M}_{\gamma_{r_0d}}(s).\mathrm{M}_{\gamma_{b_1}}(s).\mathrm{M}_{\gamma_{b2}}(s)\ldots\ldots\ldots\mathrm{M}_{\gamma_{bN}}(s)$$

$$\mathrm{M}_{\gamma_t}(s) = \prod_{i=0}^{N-1}\frac{1}{1+\bar{\gamma}_{G^i}s} \tag{16}$$

Where $\bar{\gamma}_{G^0} = \bar{\gamma}_{r_0d}$

3.2 Outage Probability

It is one of the performance criteria over fading channels, which gives the probability to fall the total SNR below a pre-defined threshold value τ [31].

$$P_0 = \int_0^\tau f_{\gamma_t}(\gamma)d\gamma = F_{\gamma_t}(\tau) \tag{17}$$

The PDF of γ_t can be obtained from MGF as

$$f_{\gamma_t}(\gamma) = \mathrm{L}^{-1}\left(\mathrm{M}_{\gamma_t}(s)\right) = \int_0^\infty \mathrm{M}_{\gamma_t}(s)e^{s\gamma}ds \tag{18}$$

Where $\mathrm{L}^{-1}(\bullet)$ denotes the inverse Laplace transform. Substitute the obtained MGF expression $\mathrm{M}_{\gamma_t}(s)$ in the equation (18). After the simplification the PDF of the total SNR γ_t can be written as

$$f_{\gamma_t}(\gamma) = \sum_{i=0}^{N-1}\frac{\left(\bar{\gamma}_{G^i}\right)^{N-2} e^{-\gamma/\bar{\gamma}_{G^i}}}{\prod\limits_{\substack{j=0,\\ i\neq j}}^{N}\left(\bar{\gamma}_{G^i}-\bar{\gamma}_{G^j}\right)} \tag{19}$$

The CDF can be obtained by integrating PDF w.r.t. γ, after the simplification it can be written as

$$F_{\gamma_t}(\gamma) = \sum_{i=0}^{N-1}\frac{(-1)^N\left(\bar{\gamma}_{G^i}\right)^{N-1} e^{-\gamma/\bar{\gamma}_{G^i}}}{\prod\limits_{\substack{j=0,\\ i\neq j}}^{N}\left(\bar{\gamma}_{G^i}-\bar{\gamma}_{G^j}\right)} \tag{20}$$

Substituting CDF equation into MGF yields

$$P_0 = \sum_{i=0}^{N-1}\frac{(-1)^N\left(\bar{\gamma}_{G^i}\right)^{N-1} e^{-\tau/\bar{\gamma}_{G^i}}}{\prod\limits_{\substack{j=0,\\ i\neq j}}^{N}\left(\bar{\gamma}_{G^j}-\bar{\gamma}_{G^i}\right)} \tag{21}$$

3.3 Average Symbol Error Rate:

Based on Movement Generating Function, $\bar{P}_e$ for M -ary QAM modulation scheme can be evaluated as [21]

$$\begin{aligned} \bar{P}_e &= \frac{4}{\pi}\left(1-\frac{1}{\sqrt{\mathrm{M}}}\right)\int_0^{\pi/2}\mathrm{M}_{\gamma_t}\left(\frac{g_{QAM}}{\sin^2\theta}\right)d\theta \\ &\quad -\frac{4}{\pi}\left(1-\frac{1}{\sqrt{\mathrm{M}}}\right)^2\int_0^{\pi/2}\mathrm{M}_{\gamma_t}\left(\frac{g_{QAM}}{\sin^2\theta}\right)d\theta \end{aligned} \tag{22}$$

4. SIMULATION RESULTS

Simulation results of our proposed algorithm and analysis is presented in this section. We evaluated performance of our proposed algorithms using MATLAB with the simulation parameters listed in Table 1.

Table 1: Simulation Parameters

Parameter	Value
Transmit Power (P)	1W
SNR Threshold	2dB
Noise Variance	10^{-10}
Modulation	M -QAM
Path loss exponent (n)	4
Combining Strategy	MRC

Figure 2 depicts the simulated symbol error rate (SER) for 4-QAM over SNR for the number of hops N=1, 2 and 3. From the figure, it can be observed that the SER performance was enhanced with N. The simulation value of SER for N=1 and SNR=20dB is 0.03027, at the same SNR for N=3 the SER is 0.004572. The percentage of SER improvement is observed as 84.89% by escalating the N from 1 to 3.

Figure 3 shows the $\overline{P}_e$ of the network over Rayleigh fading channel w.r.t SNR for N=1, 2 and 3. The simulation value of outage probability at N=1 and SNR=20dB is $3.223*10^{-2}$, at the same SNR and N=3 the outage probability is $1.164*10^{-2}$. The percentage improvement of outage probability is observed as $\left(\frac{0.03223-001164}{0.03223}\times 100\right)$ 63.88% when increased the number of hops from 1 to 3. The SER and outage probabilities for different SNR values are given in Tables II and III, respectively.

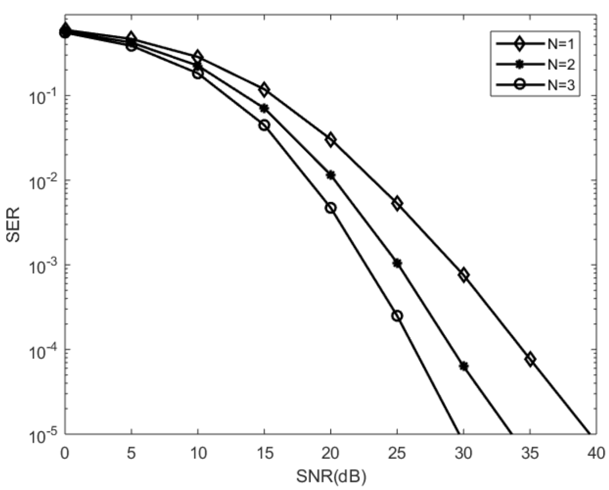

Figure 2: Average SER Performance of LSCWN

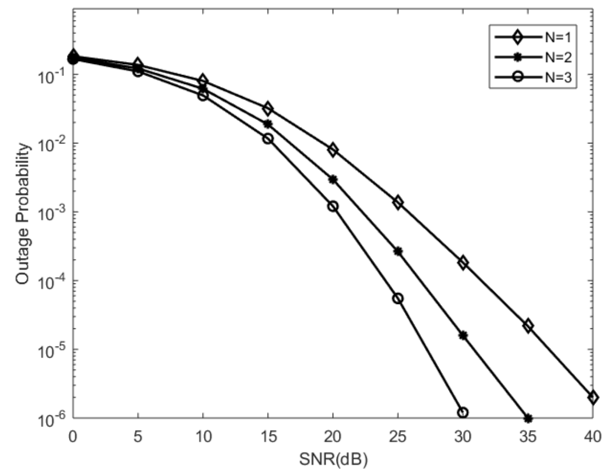

Figure 3: Outage Performance of LSCWN

Figure 4 shows the variation of SER w.r.t to number of hops at different SNR values (SNR=20dB, 25dB 30dB). From the figure it is clearly observed that the SER is improved by increasing the hops.

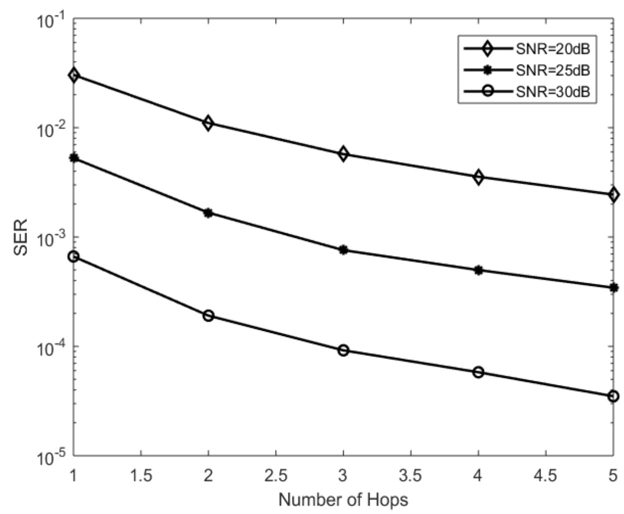

Figure 4: SER Performance of LSCWN

Table-2: Symbol Error Rate for different SNR values

SNR	**SER**		
	N=1	**N=2**	**N=3**
20	0.03027	0.01113	0.004572
25	0.005259	0.001072	0.000213
30	0.00069	7e-5	1e-5

Table-3: Symbol Error Rate for different SNR values

SNR	$\overline{P}_e$		
	N=1	**N=2**	**N=3**
20	0.008097	0.002922	0.001185
25	0.001371	0.0002559	5.92e-5
30	0.0001858	1.52e-5	1.4e-6

5. CONCLUSION

Performance analysis of large scale cooperative wireless network over i.i.d Rayleigh fading channel with Amplify and Forward (AF) relays was presented in this paper. For this network, a simplified form expression of MGF of end – to – end SNR (γ_t) is derived first and then the PDF and CDF for the γ_t are calculated. Based on PDF and CDF, we analyzed the P_0 and $\overline{P}_e$ metrics for QAM modulation scheme. From the simulation results, we conclude that the presented approach prevents the performance degradation of multi-hop network by considering a separate link from each relay node to destination.

REFERENCES

1. A. Sendonaris, E. Erkip, and B. Aazhang, **User Cooperation Diversity — Part I: System Description**, *IEEE Trans. Commun.*, vol. 51, pp. 1927–38, Nov. 2003.
2. J. Laneman, D. Tse, and G. Wornell, **Cooperative Diversity in Wireless Networks: Efficient Protocols and Outage Behavior**, *IEEE Trans. Info. Theory*, vol. 50, no. 12, pp. 3062–80, Dec. 2004. https://doi.org/10.1109/TIT.2004.838089
3. T. Wang *et al*., **High-Performance Cooperative Demodulation with Decode-and-Forward Relays**, *IEEE Trans. Commun*., vol. 55, no. 7, pp. 1427–38, July 2007.
4. A. S. Ibrahim, A. K. Sadek, W. F. Su, and K. J. R. Liu, **Cooperative communications with relay-selection: when to cooperate and whom to cooperate with?**, *IEEE Transactions on Wireless Communications*, vol.7, no. 7, pp. 2817-2827, July 2008.
5. P. Li, S. Guo, and Z. X. Cheng, **Max-min lifetime optimization for cooperative communications in multi-channel wireless networks**, *IEEE Transactions on Parallel and Distributed Systems*, vol. 25, no. 6, pp. 1533-1542, June 2014.
6. J.N. LanemanandG.W.Wornell, **Distributed space-time coded protocols for exploiting cooperative diversity in wireless networks**, *IEEE Transactions on Information Theory*, vol. 49, no. 10, pp. 2415-2425, Oct. 2003.
7. Yonghui Li, University of Sydney, **Distributed Coding for Cooperative Wireless Networks: An Overview and Recent Advances**, **IEEE Communications Magazine**, vol. 47, no. 8, pp: 71-77, August 2009. https://doi.org/10.1109/MCOM.2009.5181895
8. Srikanth Reddy P., Saleem Akram P., Adarsh Sharma M., Aditya Sai Ram P., Pruthvi Raj R. (2019), **Study and analysis of routing protocols**, *International Journal of Emerging Trends in Engineering Research*, 7(11), PP.434-440.
9. Rajendra Prasad C., Bojja P. **A survey on routing protocols in wireless body area networks for medical applications** *Journal of Advanced Research in Dynamical and Control Systems*, 10 (10 Special Issue),PP. 92- 97
10. Cynthia C., Saguturu P.K., Bandi K., Magulluri S., Anusha T. **A survey on MANET protocols in wireless sensor networks** *International Journal of Engineering and Technology(UAE)*, 7 (2),PP. 1- 3.
11. Shafi S., Venkata Ratnam D. **A Cross Layer Cluster Based Routing Approach for Efficient Multimedia Data Dissemination with Improved Reliability in VANETs** *Wireless Personal Communications*, 107(4), PP.2173-2190.
12. Sadakale R., Patil R.A., Ramesh N.V.K. **An efficient AODV routing protocol for vehicular Ad hoc network** *International Journal of Innovative Technology and Exploring Engineering*, 8(4), PP.1-4.
13. Shaik S., Venkata Ratnam D., Bhandari B.N. **An Efficient Cross Layer Routing Protocol for Safety Message Dissemination in VANETS with Reduced Routing Cost and Delay Using IEEE 802.11p** *Wireless Personal Communications*, 100 (4),PP. 1765- 1774
14. Suseela R.S.U., Murthy K.S.N., Valiveti H.B. **Performance analysis of cross-layer efficient selfishness prevention routing protocol for the dynamic CR networks** *International Journal of Innovative Technology and Exploring Engineering*, 8(0), PP.377-381. https://doi.org/10.35940/ijitee.I3069.0789S319
15. Srikanth N., Prasad M.S.G. **Family based efficient routing protocol (FERP) for lifetime improvement in heterogeneous wireless sensor networks** *Journal of Advanced Research in Dynamical and Control Systems*, 11(0), PP.131-140.
16. Ayushree, Balaji G.N. **Comparative analysis of coherent routing using machine learning approach in MANET**, *Smart Innovation, Systems and Technologies*, 77 (),PP. 731- 741
17. Rajendra Prasad C., Bojja P. **A review on bio-inspired algorithms for routing and localization of wireless sensor networks** *Journal of Advanced Research in Dynamical and Control Systems*, 9 (Special Issue 18), pp.1366-1374.
18. Mazen O. Hasna, and Mohamed-Slim Alouini, **End-to-End Performance of Transmission Systems With Relays Over Rayleigh-Fading Channels**, *IEEE Transactions on Wireless Communications*, vol. 2, no. 6, pp: 1126-1131, November 2003. 8
19. Paul A. Anghel and Mostafa Kaveh, "**Exact Symbol Error Probability of a Cooperative Network in a Rayleigh-Fading Environment**, *IEEE Transactions on Wireless Communications*, vol. 3, no. 5, pp: 1416-1421, September 2004. 9
20. Kefeng Guo, and Jin Chen, **Outage analysis of cooperative cellular network with hardware impairments**," *International Conference on Information Science, Electronics and Electrical Engineering*, April 2014, pp-26-28. 10

21. Mohammad Torabi, WessamAjib and David Haccoun, **Performance Analysis of Amplify-and-Forward Cooperative Networks with Relay Selection over Rayleigh Fading Channels**, *IEEE 69th Vehicular Technology Conference*, 26-29 April 2009. 11
https://doi.org/10.1109/VETECS.2009.5073774
22. Salama S. IkkiandMohamed H. Ahmed, **Performance of Multiple-Relay Cooperative Diversity Systems with Best Relay Selection over Rayleigh Fading Channels**, *EURASIP Journal on Advances in Signal Processing*, Vol. 2008, Article ID 580368. 12
23. In-Ho Lee and Dongwoo Kim, **Outage Probability of Multi-Hop MIMO Relaying with Transmit Antenna Selection and Ideal Relay Gain over Rayleigh Fading Channels**, *IEEE Transactions on Communications*, vol. 57, no. 2, pp: 357-360, February 2009. 13
24. Golnaz Farhadi and Norman C. Beaulieu, **Power-Optimized Amplify-and-Forward Multi-Hop Relaying Systems**, *IEEE Transactions on Wireless Communications*, vol. 8, no. 9, pp: 4634-4343 September 2009. 14
25. Hafiz Yasar Lateef, Mounir Ghogho, and Des. McLernon, **On the Performance Analysis of Multi-Hop Cooperative Relay Networks over Generalized-*K* Fading Channels**, *IEEE Communications Letters*, vol. 15, no. 9, pp:960-970, September 2011. 15
26. Hafiz Yasar Lateef, Des McLernon, and Mounir Ghogho, **Performance Analysis of Multi-User, Multi-Hop Cooperative Relay Networks over Nakagami-m Fading Channels**, *IEEE Communications Letters*, vol. 15, no. 7, pp: 776-778, July 2011. 16
27. Bumsoo Lee and Chungyong Lee, **Performance Analysis of Incremental Hop Selection Scheme With Adaptive Modulation for Cooperative Multi-Hop Networks**, *IEEE Transactions on Wireless Communications*, vol. 14, no. 1, pp: 435-445, January 2015. 17
https://doi.org/10.1109/TWC.2014.2349984
28. Bumsoo Lee and Chungyong Lee, **Performance Analysis of Cooperative Multi-Hop Networks with Hop Selection in Nakagami-m Fading Channels**, *IEEE Transactions on Wireless Communications*, vol. 12, no. 8, pp:3851-3859, August 2013. 18
29. Zhixin Liu, Huanhuan Yuan, Hongxiang Li, Xinping Guan, and Hongjiu Yang, **Robust Power Control for Amplify-and-Forward Relaying Scheme**, *IEEE Communications Letters*, vol. 19, no. 2, Feb. 2015. 19
30. D. Praveen Kumar, M. SushanthBabu, and M.S.G. Prasad, **Suboptimal Comparison of AF and DF Relaying For Fixed Target Error Probability**, *IEEE International Conference on Computer Communication and Informatics*, Jan. 07 – 09, 2016. 20
31. M.-S. Alouini and Simon, M.K **An MGF-based performance analysis of generalized selection combining over Rayleigh fading channels**, *IEEE Trans. Commun.*, vol. 48, no. 3, pp. 401-415, March 2000. 21
https://doi.org/10.1109/26.837044