Analyzing the Effects of Shadowing and Fading On the Performance of Ad Hoc Routing Protocols in MANET

Sachin Poria, Rohit Sangwan, Dr. Manoj Duhan, Kusum Dalal
Department of Electronics & Communication,
Deenbandhu Chhotu Ram University of Science and Technology,
Murthal, Sonepat, Haryana (India) – 131039

ABSTRACT

Two-ray ground reflection model and FRIIS free-space model have been widely used as the propagation model to investigate the performance of ad hoc networks. But two-ray model is too simple to represent a real world network, that is, it neglects the obstacles of a propagation environment. The radio wave propagation model has a strong impact on the results of the simulation run. The more realistic models namely shadowing and fading propagation models have been used in this investigation. This paper shows the impact of shadowing and fading on the performance of several ad hoc routing protocols by utilizing a realistic shadow fading channel in MANET environment. The performance of ad hoc routing protocols namely; LAR, RIP and LANMAR is analyzed and compared on the basis of different metrics of application layer like Average End to End Delay, Average Jitter, Throughput and Packet Delivery Ratio; and metrics of Physical Layer such as Power Consumed in Transmit Mode, Power Consumed in Receive and Idle Modes, Battery consumed. The simulation analysis is performed over well known network simulator QualNet 6.1.

Keywords **-** mobile ad hoc network, fading, interference, shadowing, Qual Net 6.1.

I. INTRODUCTION

The Mobile ad hoc network is one of the emerging trends in wireless communication. In conventional wireless communication [1] there is need of base station for communication between two nodes. Such base station leads to more infrastructure and more cost to communication network. Mobile ad hoc network facilitates communication between nodes without the support of any infrastructure. In general, MANETs are formed dynamically by an autonomous system of mobile nodes that are connected via wireless links without using any centralized administration. Mobile nodes that are within each other's radio range communicate directly via wireless links, while those are far apart rely on the other nodes to relay messages as routers. The nodes mobility in mobile ad hoc networks causes frequent changes of the network topology. The scopes of the ad hoc network [2] are also associated with dynamic topology changes, bandwidth and energy constrained operation, broadcast nature of the wireless medium, limited wireless transmission range, mobility induced packet losses and a variety of routing protocols. Initially MANET was developed to provide networking support for the military applications, where infrastructure based network is almost impossible to setup and maintain. But now-a-days, the applications of MANET have been extended to crisis management, personal communication, virtual navigation, process control, education and security. Although these applications looks very appealing yet there are still some unsolved performance issues too. These issues[2], [3] include, but not limited to (a)energy conservation, (b) average end-to-end delay, (c) jitter, (d) node mobility, (e) designing as efficient Medium Access Control (MAC) schemes and (f) shadowing, fading and inter-channel interference effects [4]. These issues have been widely investigated since the inception of ad hoc networks except the last one. The mobile radio channel places a fundamental limitation on the performance of a MANET. The transmission path between a transmitter and a receiver can vary from simple line-of-sight to one that is severely obstructed by buildings, trees, road signs, mountains, and other objects. Hence mobile radio channel is extremely random unlike its wired counterpart. Different propagation models have been proposed in the literatures to predict the signal attenuation that occurs between two mobile nodes separated by a distance. The ground reflection model or two-ray propagation model is widely used in the test bed and also in the simulation model [4]. Two ray propagation model assumes that there is a line-of-sight path and a ground reflected propagation path between a transmitter and a receiver. This model has been found to be reasonably accurate for predicting the large-scale signal strength over distances of several kilometers for mobile radio system. This model characterizes signal propagation in an isolated area with few reflectors such as rural road or highways. It is not typically a good channel model for a real world mobile communication system especially when the system is deployed in an urban area. Because this model does not consider the fact that the surrounding environment of a network is always changing. In a real world situation, the surrounding environmental cluster is always changing. This leads to a signal level that can vary vastly across a given distance. The short-term variations in the signal strength of 10-20 dB due to multipath fading are typical and it can cause a link to experience unstable behavior. Most of the ad hoc network routing protocols proposed in the literature rely on the consistent and stable performance of individual links. Therefore irregular links can result in high packet loss rates [2], [5]. Hence shadowing and fading models are considered more attentions now-a-days compared to other simple models like two-ray ground reflection model and FRIIS free-space model. Further when the transmitting node and receiving nodes work on different channels, different channel indexes, different frequencies, or different bandwidths, and there is frequency overlap between the channels then Inter-channel interference occurs.

This paper investigates the performance of LAR, RIP and LANMAR routing protocols for MANETs, based on different metrics of application layer like Average End to End Delay, Average Jitter, Throughput and Packet Delivery Ratio and different metrics of Physical Layer such as Power Consumed in Transmit Mode, Power Consumed in Receive and Idle Modes and battery consumed, based on the simulation analysis on simulation tool QualNet 6.1.The paper is organized as follows. Sections 2 briefly describes the classification of Ad hoc Routing Protocols. Section 3 discusses the different shadowing and fading models. Section 4 gives the details of simulation setup and simulator QualNet 6.1. The simulation results are shown in section 5 and finally sections 6 conclusions are drawn.

II. AD HOC ROUTING PROTOCOLS

Routing is the process of finding a path from a source to some arbitrary destination on the network. The broadcasting [2], [3] is inevitable and a common phenomenon in ad-hoc networks. It consists of diffusing a message from a source node to all the nodes with in the network. The broadcasting can be used to diffuse information to the whole network. Broadcasting is also used for route discovery protocols in ad-hoc networks. The various protocols under consideration are given below :

A) Location-Aided Routing (LAR) Protocol

Location-Aided Routing (LAR) [6] is an on-demand routing protocol that exploits location information. It is similar to DSR, but with the additional requirement of GPS information.

- The destination location known to the source
- The time instant when the destination was located at that position
- The average moving speed of the destination. In LAR scheme 1 (which is implemented here) [7], the source defines a circular area in which the destination may be located and determined by the following information:

The smallest rectangular area that includes this circle and the source is the request zone. This information is attached to a ROUTE REQUEST by the source and only nodes inside the request zone propagate the packet. If no ROUTE REPLY is received within the timeout period, the source retransmits a ROUTE REQUEST via pure flooding.

B) Routing Information Protocol (RIP)

It is an Interior Gateway Protocol used to exchange routing information within a domain or autonomous system. It is based on the Bellman-Ford or the distance-vector algorithm. This means RIP makes routing decisions based on the hop count between a router and a destination. RIP does not alter IP packets; it routes them based on destination address only. A router in the network needs to be able to look at a packet’s destination address and then determine which output port is the best choice to get the packet to that address. The router makes this decision by consulting a forwarding table [8].

C) LANMAR Routing Protocol

LANMAR [9] is an efficient routing protocol in a “flat” ad-hoc wireless network. It assumes that the large scale ad-hoc network is grouped into logical subnets in which the numbers have a commonality of interests and are likely to move as a “group”. LANMAR uses the notion of landmarks to keep track of such logical subnets. It uses an approach similar to the landmark hierarchical routing proposed for wired network. Each logical group has one node serving as landmark. The route to a landmark is propagated throughout the network using a distance vector mechanism. The routing update exchange of LANMAR routing can be explained as follows [10]: Each node periodically exchanges topology information with its immediate neighborhoods. In each update, the node sends entries within its Fisheye scope. Updates from each source are sequentially numbered. To the update, the source also piggybacks a distance vector of all landmarks. Through this exchange process, the table entries with larger sequence numbers replace the ones with smaller sequence numbers. As a result, each node has detailed topology information about nodes within its Fisheye scope and has a distance and routing vector to all landmarks.

III. SHADOWING AND FADING MODELS

Radio channels are much more complicated to analyze than wired channels. Their characteristics may change rapidly and randomly. There are large differences between simple paths with line of sight (LOS) and those which have obstacles like buildings or elevations between the sender and the receiver (Non Line of Sight (NLOS)). To implement a channel model generally two cases are considered: large-scale and small-scale propagation models. Large scale propagation models account for the fact that a radio wave has to cover a growing area when the distance to the sender is increasing. Small scale models (fading models) calculate the signal strength depending on small movements or small time frames. Due to multipath propagation of radio waves, small movements of the receiver can have large effects on the received signal strength. In the following, the frequently used models for the QualNet 6.1 network simulator are described in more detail.

A. Constant Shadowing Model

A shadowing model [11] is used to represent the signal attenuation caused by obstructions along the propagation path. The constant shadowing model is suitable for the scenarios without mobility where the obstructions along the propagation paths remain unchanged.

B. Lognormal Shadowing Model

The Lognormal Shadowing model [11] is suitable for a scenario with mobility and obstructions within the propagation environment. In this model, the shadowing value follows a log-normal distribution with a user-specified standard deviation. In general, this shadowing value should be in the range of 4 to 12 dB depending on the density of obstructions within the propagation environment.

C. Rayleigh Fading Model

Rayleigh fading model [11],[12] is a statistical model to represent the fast variation of signal amplitude at the receiver. In wireless propagation, Rayleigh fading occurs when there is no line of sight between the transmitter and receiver. The fading speed is affected by how fast the receiver and/or transmitter, or the surrounding objects, are moving. QualNet's Rayleigh fading model uses pre-computed time series data sequence with different sample intervals to represent the different fading speeds or coherence times of the propagation channel.

D. Fast Rayleigh Fading Model

The Fast Rayleigh fading model[11],[12] is a statistical model to represent the fast variation of signal amplitude at the receiver due to the motion of the transmitter/receiver pair. In wireless propagation, the motion of the transmitter/receiver or the surrounding objects causes Doppler frequency shift in the received signal components, which causes the fast variation of the received signal amplitude. The variation in the received signal amplitude is affected by the speeds and relative directions of the receiver and transmitter.

QualNet's Fast Rayleigh fading model uses the instantaneous relative speed between the transmitter and receiver and a pre-computed time series data sequence to represent the fast variation of the received signal amplitude.

E. Ricean Fading Model

Ricean fading model [11],[12] is a statistical model to represent the fast variation of signal amplitude at the receiver. In wireless propagation, Ricean fading occurs when there is line of sight between the transmitter and receiver, and the line of sight signal is the dominant signal seen at the receiver.

QualNet's Ricean fading model uses pre-computed time series data sequence with different sample intervals to represent the different fading speeds or coherence times of the propagation channel.

IV. SIMULATION TOOL AND SET UP

A) QUALNET 6.1

The simulator used in our paper is QualNet 6.1 [13], [14] which is developed by Scalable Network Technologies, USA. The simulation is running based on discrete event scheduler i.e the simulation is not performed in a constant time flow. QualNet is implemented using a TCP/IP network model which is similar to layered architecture. QualNet is a high-fidelity modeling tool that can be used for wired and wireless networks of tens of thousands of nodes. The application layer takes place of traffic generation and application level routing. Numerous traffic generator models and application level routing protocols have been implemented in QualNet. It supports different Traffic generators like HTTP, MCBR, CBR, FTP, VoIP, VBR TELNET etc. FTP (File Transfer Protocol) is generally used to simulate transferring files between server and client while CBR (Constant Bit Rate) is used for simulating fixed-rate uncompressed multimedia traffic.

B) DESIGNING OF SIMULATION SCENARIO

The network simulator used for network simulation is QualNet 6.1 and the simulation scenario is shown in fig. 1. It consists of total number of nodes as 100, the Terrain area chosen is 1500 m *1500 m, the Constant Bit Rate of packet size is 512 and the mobility is Random way point, most. It shows the performance of LAR, RIP and LANMAR routing protocols with respect to application layer model. The nodes are connected via CBR connections. The various parameters considered for simulation scenario setup are listed in table 1. CBR is chosen over TCP because the protocol is much simpler which makes the results easier to analyze. Furthermore, it seems to be best practice to use CBR for ad hoc simulations. The traffic scenarios are generated randomly. The objective of these simulations is to compare the standards of LAR, RIP and LANMAR protocols.

Table 1. Parameters considered for simulation set up

S.No.	Parameter	Value
1.	Simulator	QualNet Version 6.1
2.	Terrain Size	1500 x 1500 m^2
3.	Antenna model	Omni-directional
4.	No of nodes	100
5.	Radio Type	802.11b
6.	Data size	512 bytes
7.	Data Rate	2Mbps
8.	Mobility Model	Random Way Point
9.	Channel	2.4 GHz
10.	Traffic Source	Constant Bit Rate
11.	Pause time	30s
12.	Nodes speed	Min.=2m/s,
13.	Position	1.0
14.	Battery model	Residual life Estimator
15.	Routing	LAR, RIP and
16.	Battery models	Duracell AA(MX-
17.	Shadowing	Constant, Log Normal
18.	Fading Models	Rayleigh, Ricean, Fast Rayleigh
19.	Inter-channel Interference	Enabled/Disabled
20.	Performance metrics in Application layer	PDR, Average Jitter, Average End to End Delay, Throughput
21.	Performance metrics in Physical layer	Energy consumed in Transmit mode, Energy consumed in Received mode, Energy Consumed in Idle mode, Battery Consumed

C) SNAPSHOT OF RUNNING SCENARIO

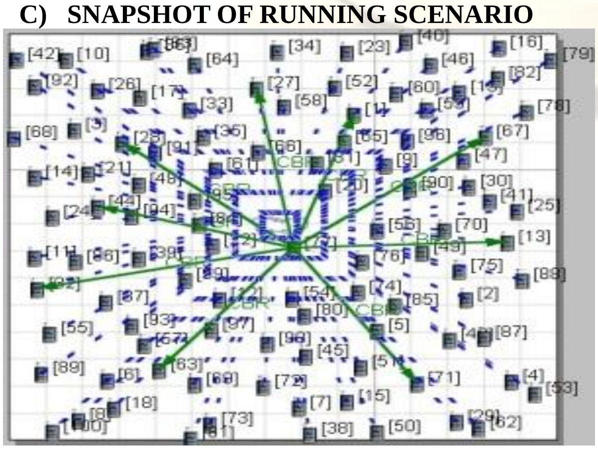

Figure 1. Snapshot of simulation scenario applying CBR between various nodes.

V. SIMULATION PARAMETERS AND RESULTS

There are several different metrics [15] that can be applied to measure the performance of ad hoc routing protocols. The following metrics are used for the performance evaluations of different ad hoc routing protocols for mobile ad hoc networks :

(a) SIMULATION RESULTS (SHADOWING)

Average End to End Delay :

From fig. 2. it is clear that whether the shadowing is constant or log normal, the LANMAR protocol has almost constant average end to end delay and has least value among three protocols. For constant shadowing, LAR protocol has nearly double Average end to end delay. For log normal shadowing, the average end to end delay increases for LAR, while decreases for RIP and LANMAR protocol. For the Log Normal shadowing model, the LAR protocol has very high value average end to end delay. So it can be concluded that LAR protocol is not suited for the applications where end to end delay is of critical importance.

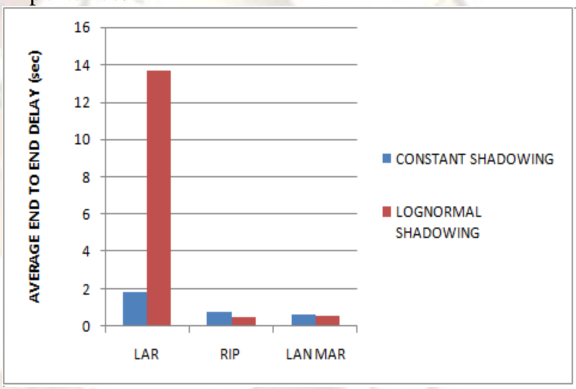

Figure 2. Impact of Shadowing on Average End to End Delay

Average Jitter :

As shown in fig. 3, the RIP protocol has lowest average jitter while the LAR protocol has the highest for both the constant and lognormal shadowing. LANMAR protocol has intermediate value of average jitter as compared to other two protocols for both types of shadowing. LAR protocol has specially very high value of average jitter for Log Normal Shadowing.

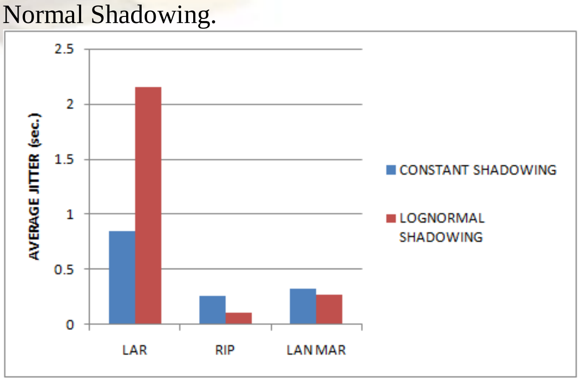

Figure 3. Impact of Shadowing on Average Jitter

Packet Delivery Ratio :

From fig. 4, it can be observed that Packet Delivery Ratio is highest for LAR protocol followed by the RIP protocol for constant shadowing model and having the least value for LANMAR protocol. For Log Normal Shadowing the PDR decreases for RIP protocol and increases for LANAMR. Further for LAR Packet delivery ratio remains almost constant for Constant and Log Normal Shadowing. Hence it can be concluded that LAR protocol shows best performance as far as PDR is considered.

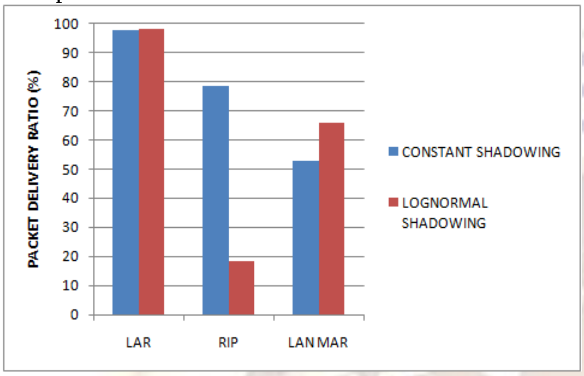

Figure 4. Impact of Shadowing on Packet Delivery Ratio

Throughput

For Constant shadowing model, the throughput is highest for the LAR protocol followed by RIP and LANMAR as shown in fig. 5, but the difference in their throughput values is very small. For Log Normal shadowing model, the throughput drastically increases and for RIP protocol decreases, while for LANMAR protocol there is slight decrease in throughput. So as far as throughput is concerned, LAR protocol is better as compared to other two protocols for both type of shadowing environments.

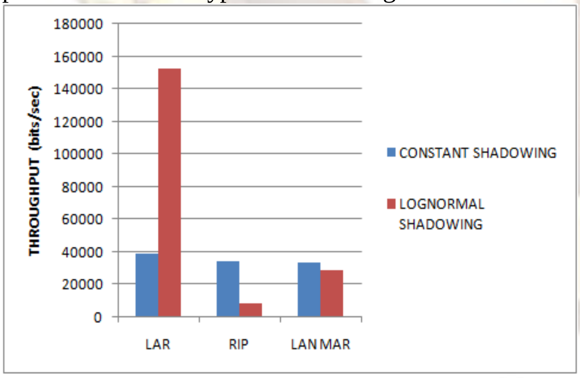

Figure 5. Impact of Shadowing on Throughput

Energy Consumed in Transmit Mode :

As shown in figure 6, the energy consumed in transmit mode is highest for LANMAR protocol as expected, while least for LAR protocol for constant shadowing. Under the effect of Log Normal shadowing the energy consumed in transmit mode increases to a high value for LANMAR protocol while slightly decreases for RIP protocol and remains almost same for LAR protocol. That is, LAR protocol is least affected by shadowing effects.

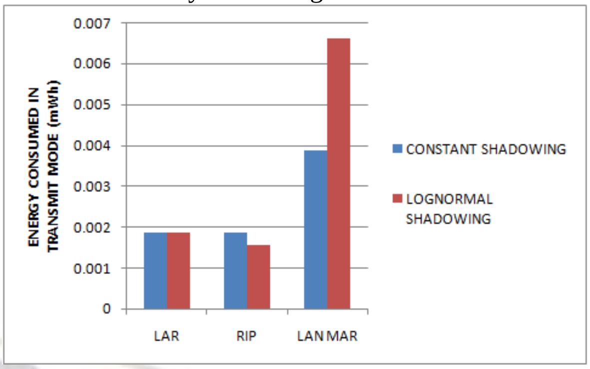

Figure 6. Impact of Shadowing on Energy Consumed in Transmit Mode in Physical Layer

Energy Consumed in Receive Mode :

From fig. 7, it is clear that energy consumed in receive mode is highest for LANMAR protocol and almost equal energy is consumed by RIP and LAR protocols in receive mode. Same is the case for Log Normal Shadowing.

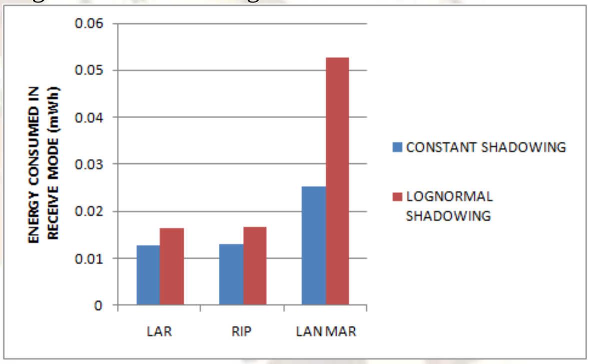

Figure 7. Impact of Shadowing on Energy Consumed in Receive Mode in Physical Layer

Energy Consumed in Idle Mode :

In Idle mode the LAR and RIP protocols consumes more energy as compared to LANMAR protocol, which is opposite in nature as compared to energy consumption behavior in transmit and receive mode for both the shadowing models. The energy consumption in Idle mode decreases for LANMAR when the Log Normal type of shadowing effects are considered as shown in fig. 8.

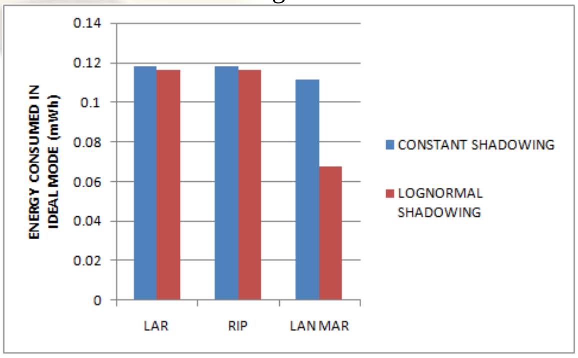

Figure 8. Impact of Shadowing on Energy Consumed in Idle Mode in Physical Layer

Battery Consumed :

The battery consumed measured in mAh for the same set of parameters is highest for LANMAR protocol and hence proves to be least energy efficient protocol for both types of shadowing as shown in fig. 9. The LAR and RIP protocols same battery consumption behavior for Constant and Log Normal Shadowing.

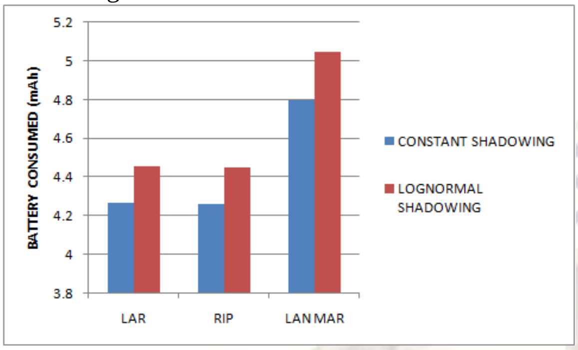

Figure 9. Impact of Shadowing on Battery Consumed

(b) SIMULATION RESULTS (FADING)

Average End to End Delay :

From fig. 10, it can be observed that due to Ricean type of fading the protocols suffers from greater average end to end delay as compared to Rayleigh and Fast Rayleigh fading. Further overall we can conclude that LAR protocol has highest average end to end delay whether the fading is Rayleigh, Ricean or Fast Rayleigh and RIP having the least.

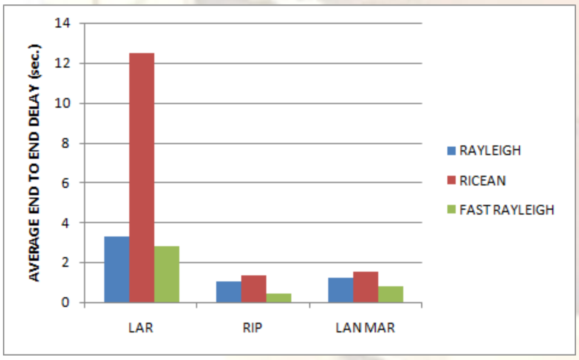

Figure 10. Impact of Fading on Average End to End Delay

Average Jitter :

RIP protocol has least average jitter and LAR protocol has highest average jitter value for all fading environments. For Ricean fading, the average jitter increase for all the protocols, with very high increase for LAR protocol. So RIP protocol proves to be the best for the applications which requires low standard deviation of packet delays. Further for Fast Rayleigh fading environment the jitter is smaller for protocols as compared to other types of fading as shown in fig. 11.

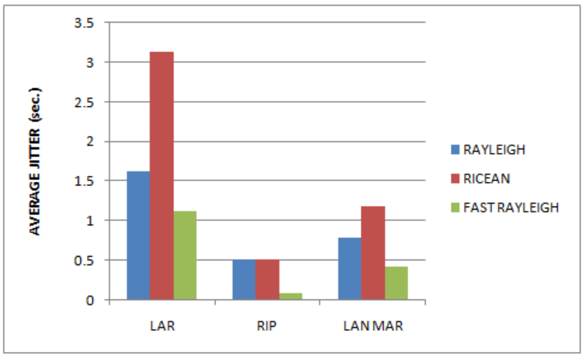

Figure 11. Impact of Fading on Average Jitter

Packet Delivery Ratio :

The LAR protocol has highest packet delivery ratio and RIP protocol has the lowest as shown in fig. 12. RIP protocol has the least effect of several types of fading on PDR but has the lower value. The LANMAR protocol has equivalent performance in case of PDR to RIP protocol, but it shows superior performance in Fast Rayleigh Fading Environment.

LAR protocol is best as far as higher packet delivery ratio is required.

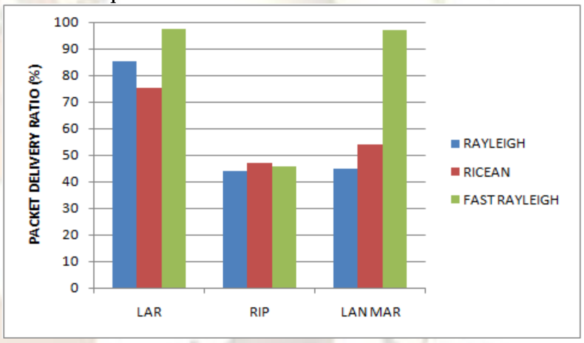

Figure 12. Impact of Fading on Packet Delivery Ratio

Throughput :

RIP protocol has least value of throughput while LAR protocol having the highest. In Rayleigh fading environment the throughput of LAR and LANMAR protocol is lesser as compared to other fading environments as shown in fig. 13.

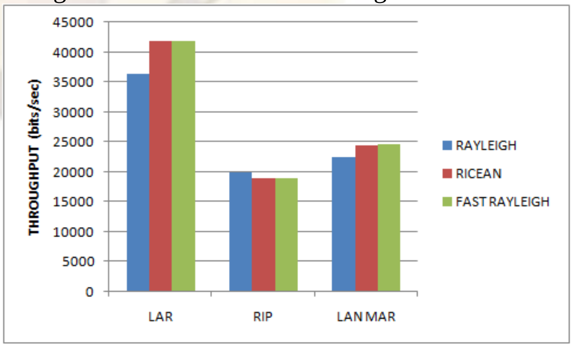

Figure 13. Impact of Fading on Throughput

Energy Consumed in Transmit Mode :

The LANMAR protocols suffers from more energy loses during transmit mode as compared to other two protocols for all type of fading environments and hence has highest energy consumption in transmit mode. RIP protocol has the least effect of fading losses in transmit mode and least value of energy consumed in transmit mode as shown in fig.14.

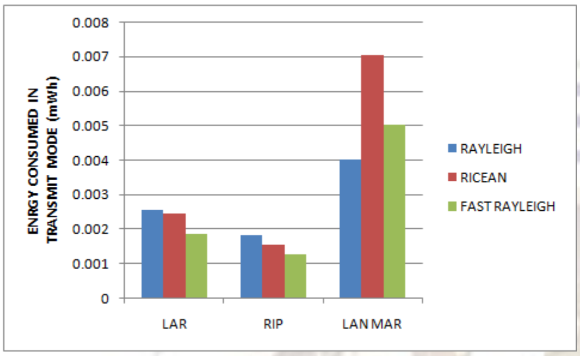

Figure 14. Impact of Fading on Energy Consumed in Transmit Mode in Physical layer

Energy Consumed in Receive Mode :

As shown in fig. 15, RIP protocol has least energy consumption in receive mode while LANMAR protocol has the highest. The Ricean fading environment has the most bad effect on the performance of routing protocols in fading environment. Overall we can say that RIP protocol is best suited for fading environments as far as energy consumed in receive mode is considered.

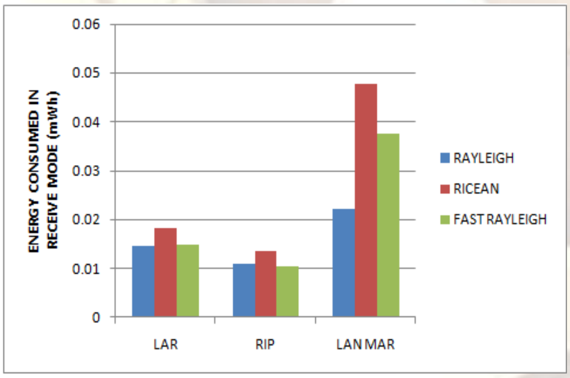

Figure 15. Impact of Fading on Energy Consumed in Receive Mode in Physical Layer

Energy Consumed in Idle Mode :

The behavior of RIP protocol is opposite to that in transmit and receive mode, that is, the RIP protocol has the highest energy consumption in Idle mode for all fading environments. The LANMAR protocol has lowest energy consumption in idle mode among the three protocols as shown in fig. 16.

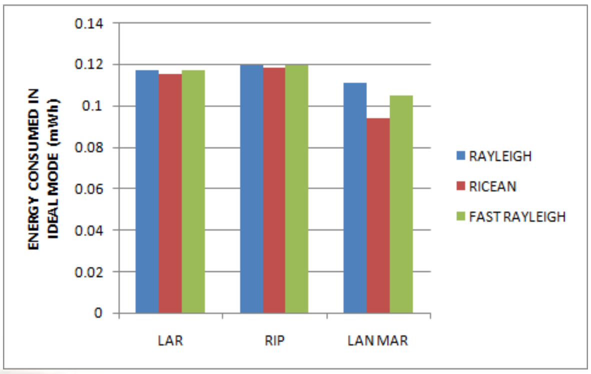

Figure 16. Impact of Fading on Energy Consumed in Idle Mode in Physical Layer

Battery Consumed :

From fig. 17, it can be concluded that the overall battery consumption measured in mAh is highest for LANMAR protocol for all fading environments. RIP protocol has highest battery consumption in Fast Rayleigh fading while for Rayleigh and Ricean Fading it is almost equal. For Ricean Fading the battery consumption in LAR protocol is higher as compared to other fading environments.

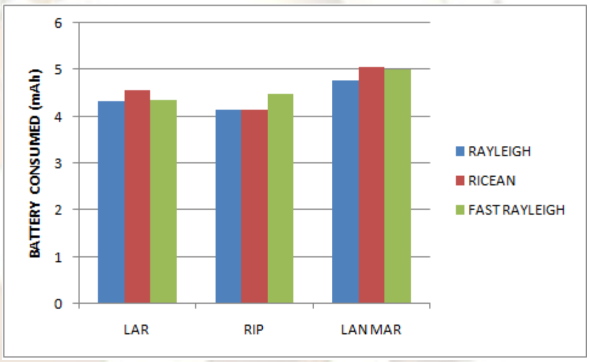

Figure 17. Impact of Fading on Battery Consumed

VI. CONCLUSIONS

In this paper the effect of shadowing and fading on the performance of ad hoc routing protocols in MANET environment has been investigated. Although two-ray model and FRIIS free space model are widely used as a propagation model in ad hoc network simulation, but these models does not represent a real world network scenario because the surrounding environment of a network is always changing. Through simulations on QualNet 6.1, it is concluded that the performance of a network deteriorates if the shadowing and fading effects are taken into account. The main reasons for this degradation in performance is due to the fact that there is large variation of the received signal level for a given link distance. Hence a packet (routing packet or MAC packet) may not be received successfully by a mobile node due to poor signal level. This may cause problem to the normal operations of a routing protocol as well as the MAC protocol. In this work, we evaluated the performance of ad hoc routing protocols i.e. LAR, RIP and LANMAR on the basis of different shadowing and fading models for the mobile nodes & the parameters of application layer such as Throughput, PDR, Average Jitter and Average Delay and metrics of physical layer like Power Consumed in Transmit Mode, Power Consumed in Receive and Idle Modes and total battery consumption are analyzed. The trio of routing protocols is simulated for two of the shadowing models i.e. Constant and Log Normal model, three fading models i.e. Rayleigh, Ricean and Fast Rayleigh. In general it is concluded that the performance of ad hoc routing protocols degrades when the effects of the shadowing and fading are taken into account. But it is necessary to take into consideration these effects while analyzing the performance of routing protocols otherwise the results will not be true in the real world scenario. So now the future work involves the investigation of these effects more deeply and propose a model which takes into consideration both the effects of shadowing and fading more precisely.

REFERENCES

[1] C. Siva Ram Murthy and B. S. Manoj, *Ad Hoc Wireless Networks Architectures and Protocols*, (Pearson Education Inc., 642-643).

[2] J. Goldsmith and S. B. Wicker, Design challenges for energy constrained ad hoc wireless networks, *IEEE Wireless Communications Magazine, 9(4)*, 2002, 8–27.

[3] Ahmed S. and Alam M. S., Performance Evaluation of Important Ad Hoc Network Protocols, *EURASIP Journal on Wireless Com. and Networking*, 2006(2), 1-11.

[4] B. Kasiri, Jun Cai, Effects of Correlated Shadowing on Soft Decision Fusion in Cooperative Spectrum Sensing, *INFOCOM IEEE Conference on Computer Communications Workshops*, 2010, 1-6.

[5] Subir Kumar Sarkar, T. G. Basavaraju and C. Puttamadappa, *Ad Hoc Mobile Wireless Networks: Principles, Protocols and Applications* (Auerbach Publications, US, 2008).

[6] Nen-Chung Wang & Si-Ming Wang, An Efficient Location-Aided Routing Protocol for Mobile Ad Hoc Networks, *11th International Conference on Parallel and Distributed Systems (ICPADS'05)*, Vol. 1, 2005, 335-341.

[7] Dahai Du & Huagang Xiong, A Location aided Energy-Efficient Routing Protocol for Ad hoc Networks, *19th Annual Wireless and Optical Communications Conference (WOCC)*,2010, 1-5.

[8] G. Pei, M. Gerla and X. Hong, LANMAR: Landmark Routing for Large Scale Wireless Ad-Hoc Networks with Group Mobility, *Proceedings of IEEE/ACM MobiHOC 2000*, 2000, 11-18.

[9] KaixinXu, Xiaoyan Hong, and Mario Gerla, Landmark Routing in Ad Hoc Networks with Mobile Backbones, *Journal of Parallel and Distributed Computing (JPDC)*, Special Issues on Ad Hoc Networks, 2002.

[10] Theodore S. Rappaport, *Wireless Communications Principles and Practise*, 2nd Edition, (Pearson Education Inc., 2002).

[11] Arne Schmitz, Martin Wenig , The Effect of the Radio Wave Propagation Model in Mobile Ad Hoc Networks, *MSWiM'06*, 2006.

[12] QualNet documentation, QualNet 6.1 Model Library:Wireless, http://www.scalablenetworks.com.

[13] QualNet 6.1 details : www.scalable-networks.com

[14] A. Nasipuri, K. Li and U. R. Sappidi, Power Consumption and Throughput in Mobile Ad Hoc Networks using Directional Antennas, *IEEE International Conference on Computer, Communication and Networking*, 2003.