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Effects of Shadowing, Fading & Inter-channel Interference on the Performance of Ad hoc Routing Protocols in MANET

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Abstract— The simple two-ray model and FRIIS free-space model have been widely used in the literatures as the propagation models for the performance analysis of Mobile Ad hoc Network (MANET). These models are too simple to represent a real world network. In the real world scenarios, the environmental clutter varies widely for a given distance between two mobile nodes and has a strong impact on the performance of the routing protocols. This paper shows the impact of different shadowing, fading and inter-channel interference effects on the performance of three categories of routing protocols i.e. proactive, reactive and hybrid, in MANET environment. The performances of ad hoc network have been investigated for different metrics of application layer like Average End to End Delay, Average Jitter, Throughput and Packet Delivery Ratio based on the simulation analysis. The simulation analysis is performed over well known network simulator QualNet 6.1.

Keywords— mobile ad hoc network, fading, interference, shadowing, QualNet 6.1.

I. INTRODUCTION

A mobile ad hoc network (MANET) [1] is a highly appealing means of providing temporary network support to a group of people without the aid of any existing infrastructure, access point or central administration. The necessary controls and networking functions are performed by using a distributed control algorithm. In MANETs, mobile nodes moves randomly and forward packets for other mobile nodes in addition to transmitting their own packets in a multi-hop fashion. The mobile nodes are free to move at any time in any direction in an unpredictable manner, so this kind of topological changes can result in high route 'breakages' in the network and it imposes significant challenges for the researchers in MANET. 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 include, but not limited to (a) energy conservation, (b) overhead control packets, (c) packet loss rate, (d) end-to-end delay, (e) node mobility, (f) designing as efficient Medium Access Control (MAC) schemes, and (g) shadowing, fading and inter-channel interference effects. These issues have been widely investigated since the inception of ad hoc networks except the last one. The shadowing is the effect that causes the received signal power fluctuate due to objects obstructing the propagation path between a transmitter and a receiver. The shadowing effects represent a real world propagation model because the wireless propagation channel contains different types of objects that randomly scatter the transmitted signal energy. These scattered signals introduce a variety of channel impairments including fading and multipath delay spread, Doppler spread, attenuation, and the inherent background noise as well. The constructive and destructive summing of multipath signal components of differing phases result in large fluctuations of signal strength. 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 behaviour. 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]. 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 different categories of ad hoc routing protocols in MANETs [3] i.e. reactive protocols like AODV, DSR and DYMO, proactive protocols like OLSR and FSR and hybrid protocols like ZRP, based on different metrics of application layer like Average End to End Delay, Average Jitter, Throughput and Packet Delivery Ratio 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, fading and inter-channel interference 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

A routing protocol governs the way through which two communication entities exchange information; it includes the procedure of establishing a route, decision in forwarding information and action in maintaining the route and/or recovering from the routing failure. In MANETs, the routing protocols can be divided into three categories [1], [3] :

A. Proactive Routing Protocols

Proactive protocols are also called as Table-driven routing protocols in which the nodes keep the up-to-date routes to all the destinations in the network by exchanging topological information. Each node maintains routing tables to store such information. These tables are updated periodically in order to maintain latest view of the network. The advantage of proactive protocols is that there is a minimal time delay for applications. However, it requires additional messaging overhead in order to maintain a consistent and up-to-date routing table, which consumes bandwidth and power and decreases throughput. The various Proactive protocols are: Fisheye State Routing protocol (FSR)[4], Optimized Link State Routing protocol (OLSR)[5].

B. Reactive Routing Protocols

Reactive Routing Protocols, known as On-demand routing protocols are based on some kind of query-reply dialog approach. They do not maintain or constantly update their routing tables with the latest route topology. Whenever a source node has a packet to send to a destination node, then it initiates a route discovery to find the path to the destination node. After a route has been established, the route maintenance procedure is initiated to maintain this route. Since these protocols do not need periodic transmission of topological information of the network, so overhead messaging is reduced. The drawback of reactive protocols include high latency time in route finding and excessive flooding may lead to network clogging. e.g. Ad-hoc On Demand Distance Vector (AODV)[6], Dynamic Source Routing (DSR)[7], Dynamic Manet On Demand (DYMO)[8].

C. Hybrid Routing Protocols

The hybrid routing protocols for MANETs exploit hierarchical network architectures i.e. hybrid routing protocols are zone based, in which the network is partitioned or seen as a number of zones by each node where proactive maintains route within a zone and reactive maintains route in between zones through reactive flooding. The drawback of hybrid protocols is that success depends on amount of nodes participating and reaction to traffic depends on gradient of traffic volume. Example of hybrid protocol is : Zone Routing Protocol (ZRP)[1],[9].

III. DIFFERENT SHADOWING, FADING AND INTER-CHANNEL INTERFERENCE MODELS

Radio channels are much more complicated to analyse 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 [10] 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 [10] 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 [10],[11] 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[10],[11] 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 [10],[11] 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.

F. Inter-channel Interference Model

The Inter-channel Interference model [10],[11] accounts for both co-channel and inter-channel interference. (If the Inter-channel Interference model is not enabled only co-channel interference is taken into account.)

Co-channel interference occurs when the transmitting node and receiving nodes work on the same channel, the same channel index, the same frequency, and the same bandwidth. Inter-channel interference occurs 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. The Inter-channel Interference model estimates the effect of wide band jamming, narrow band jamming, frequency hopping jamming, frequency hopping spectrum spreading, frequency planning, spectrum analysis and spectrum management, etc. In the case of inter-channel interference, the model estimates the overlap bandwidth for the desired signal according to the frequencies and bandwidths for the desired and interference signals. The inter-channel interference power is estimated based on the overlap bandwidth, node's properties such as transmitter power and antenna gain, etc. and system parameters such as frequency, pathloss model, and distance etc.

IV. SIMULATION SETUP

A. QualNet 6.1

QualNet [12] is a comprehensive suite of tools for modelling large wireless and wired networks. It uses simulation and emulation process to predict the behaviour and performance of networks to improve their design, operation & management. It enables users to design new protocols, optimize new and existing protocols, designing of large wired and wireless networks using preconfigured or user-designed models, analysing the performance of networks and perform what-if analysis to optimize the results. QualNet is a commercial product that grew out of GloMoSim simulator [13] and it is distributed by Scalable Network Technologies. QualNet simulator is C++ language based tool. All the protocols are implemented in a series of C++ files and are called by the simulation kernel. QualNet simulator comes with java based graphical user interface (GUI). The QualNet Simulator has a scalable network library and provides accurate and efficient execution.

B. Designing Of Scenario

We have chosen QualNet version 6.1 over Windows platform for our simulation studies. QualNet is a discrete event simulator. It is equally capable of simulating various wired or wireless scenarios from simple to complex conditions. In our simulation model, there are 100 nodes and all of these are connected to one wireless station. The terrain condition we have set as 1500m × 1500m as flat area. The entire area is further divided into 100 square shaped cells as shown in fig. 1. The type of wireless propagation model is Two Ray ground propagation. The entire connection set up has been done randomly. The battery model considered in our simulation is Panasonic AAA. The simulation is performed with CBR (Constant bit rate) traffic flow. The various parameters considered in simulation experiment are listed in table 1.

C. Simulation Scenario Snapshot

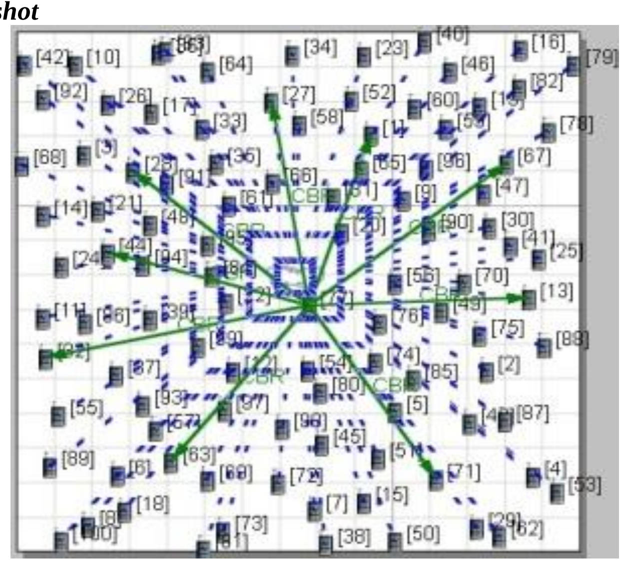

Fig. 1. Snapshot of simulation scenario applying CBR between various nodes

Table 3. Parameters considered for simulation

S.No.	Parameter	Value
1.	Simulator	QualNet Version 6.1
2.	Terrain Size	1500 x 1500 m^2
3.	Antenna model	Omnidirectional
4.	No of nodes	100
5.	Radio Type	802.11b
6.	Data size	512 bytes
7.	Data Rate	2 Mbps
8.	Mobility Model	Random Way Point
9.	Propagation model	Two Ray Ground
10.	Channel Frequency	2.4 GHz
11.	Traffic Source	CBR
12.	Nodes speed	Min.=1m/s , Max.=10m/s
13.	Position granularity	1.0
14.	Pause time	30s
15.	Battery model type	Residual life Estimator
16.	Routing Protocols	Proactive : AODV, DSR, DYMO Reactive : FISHEYE, OLSR Hybrid : ZRP
17.	Battery model	Panasonic AAA
18.	Shadowing Models	Constant, Log Normal
19.	Fading Models	Rayleigh, Ricean, Fast Rayleigh
20.	Inter-channel Interference	Enabled/Disabled
18.	Performance metrics in Application layer	PDR, Average Jitter, Average End to End Delay, Throughput

V. SIMULATION RESULTS

There are several different metrics [1], [9] 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)

A. Average End to End Delay

From figure 2. it is clear that whether the shadowing is constant, log normal or no shadowing is considered the AODV and DSR protocol has almost constant average end to end delay. For constant shadowing, AODV and DSR has smallest Average end to end delay, while the FSR and OLSR having the highest. For log normal shadowing, the average end to end delay increases for ZRP, DYMO and FSR as compared to Constant shadowing model. When no shadowing is considered, the end to end delay decreases for OLSR and ZRP, but shadowing effects always act on the radio signals and affects the performance of the routing protocols. Hence not considering the shadowing effects will make the performance analysis of routing protocols less accurate.

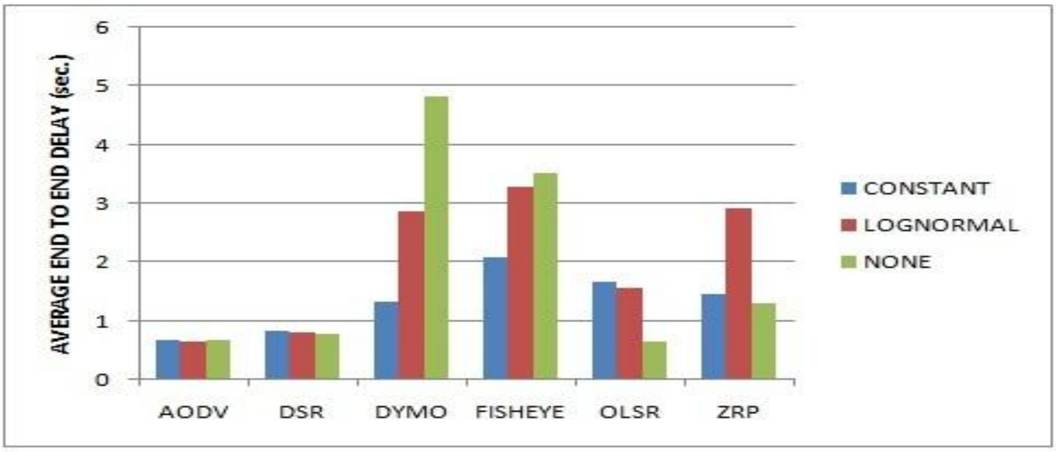

Figure 2. Impact of Shadowing on Average End to End Delay for different protocols

B. Average Jitter

As shown in figure 3, the AODV and DSR protocol has lowest average jitter for both the constant and lognormal shadowing. For constant shadowing model, the FSR and DYMO protocol has highest average jitter values. For Log Normal Shadowing, FSR and ZRP has high average jitter and AODV and DSR has the lowest average jitter values. For OLSR protocol, when shadowing effects are considered, the average jitter increases.

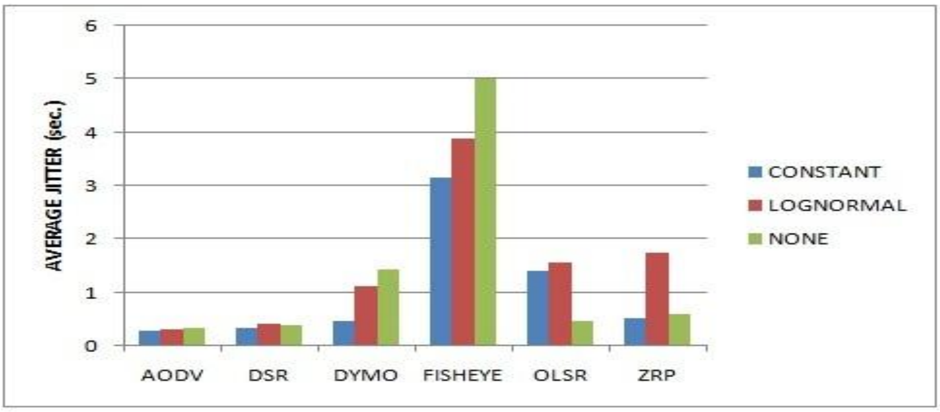

Figure 3. Impact of Shadowing on Average Jitter for different protocols

C. Throughput

For Constant shadowing model, the throughput is highest for the DYMO and DSR protocol followed by AODV as shown in figure 4. Similar is the case for Log Normal shadowing model. For OLSR protocol, the throughput is higher when Log Normal shadowing is considered as compared to Constant Shadowing. The opposite is the case for FSR and ZRP protocols i.e. the throughput is lower when Log Normal shadowing is considered as compared to Constant Shadowing.

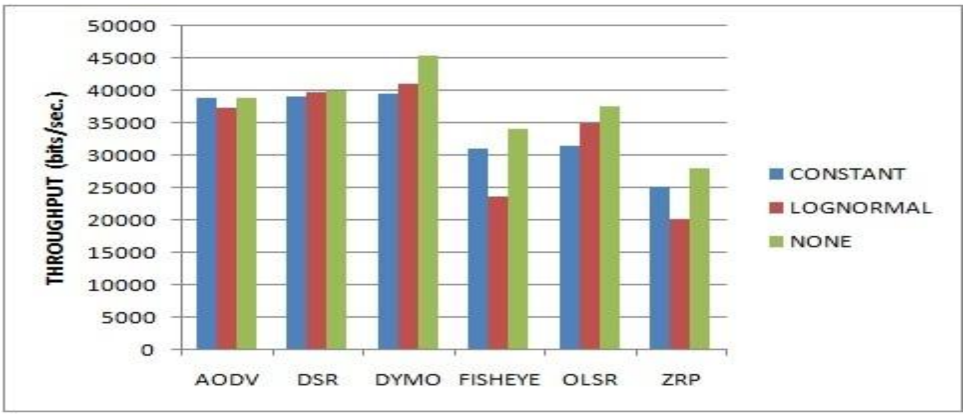

Figure 4. Impact of Shadowing on Throughput for different protocols

D. Packet Delivery Ratio

From figure 5, it can be observed that PDR is highest for DSR and AODV protocol followed by the DYMO protocol for constant shadowing model and having the least value for OLSR and ZRP. For Log Normal Shadowing the PDR decreases for AODV, DSR, DYMO, FSR and increases for FSR and OLSR. Further for AODV and DSR, the PDR remains almost constant for Constant and Log Normal Shadowing model or when no shadowing is considered.

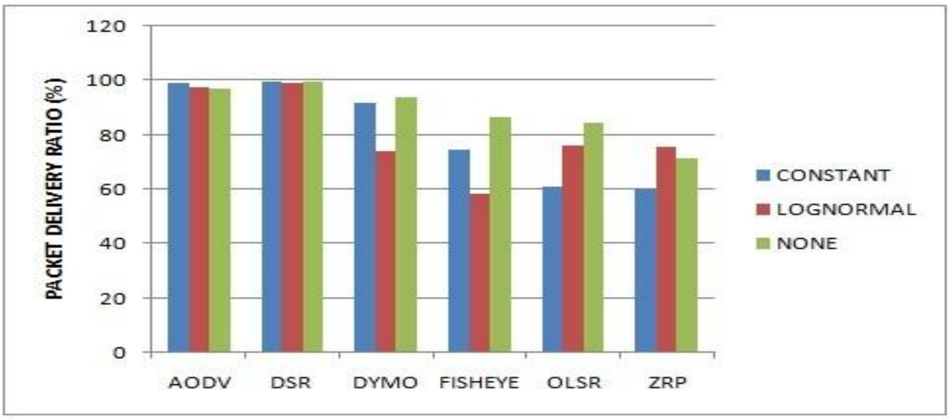

Figure 5. Impact of Shadowing on Packet Delivery Ratio for different protocols

(b) SIMULATION RESULTS (FADING)

A. Average End to End Delay

From figure 6, it is clear that for Rayleigh Fading the ZRP and FSR protocols has highest average end to end delay and AODV and DSR has the lowest. For Ricean Fading the average end to end delay decreases for all the six protocols as compared to Rayleigh Fading. In case of Fast Rayleigh fading, the DYMO and FSR protocols has the highest average end to end delay while ZRP and AODV having the lowest. Overall we can say that the fading effects more severely affects the performance of FSR and DYMO protocols and ZRP is also badly affected by Rayleigh fading.

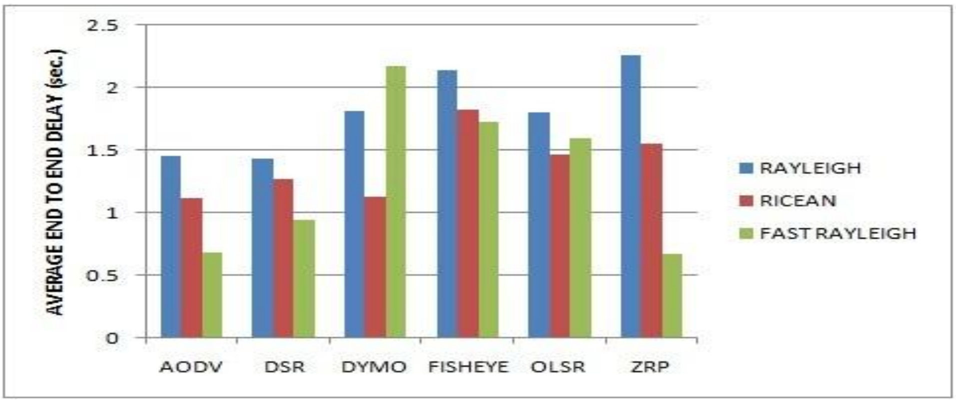

Figure 6. Impact of Fading on Average End to End Delay for different protocols

B. Average Jitter

For Rayleigh type Fading, the DSR and AODV protocols has lowest jitter values while FSR and DYMO having the highest as shown in figure 7. For Ricean fading the average jitter decreases for all of the protocols as compared to Rayleigh fading. For fast Rayleigh fading, the average jitter further decreases for AODV, DSR, DYMO and ZRP protocols and increases for OLSR and FSR. The FSR protocol has the worst performance in terms of average jitter in between all the six routing protocols for all the fading models.

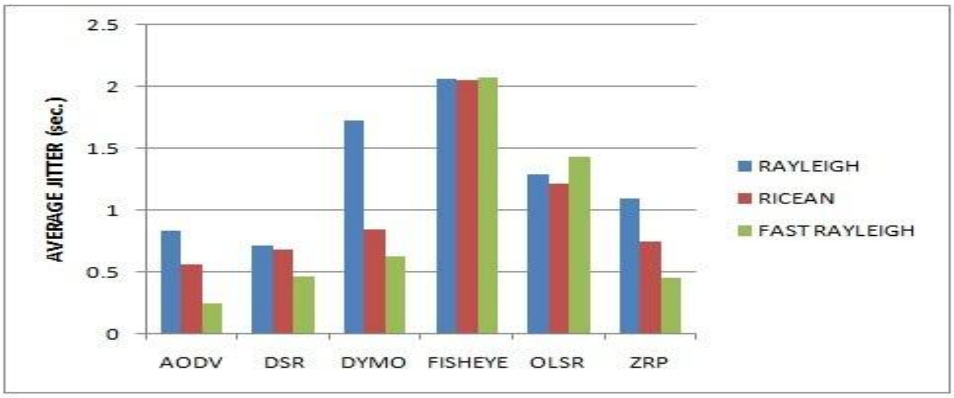

Figure 7. Impact of Fading on Average Jitter for different protocols

C. Throughput

For Rayleigh fading , the DSR and AODV has highest throughput followed by DYMO protocol while ZRP and FSR has the lowest as shown in figure 8. For Ricean Fading, the DSR and DYMO performs well while ZRP and FSR has sill poor throughput. In case of Fast Rayleigh Fading, DSR and AODV still performs good while ZRP protocol proves to be the worst.

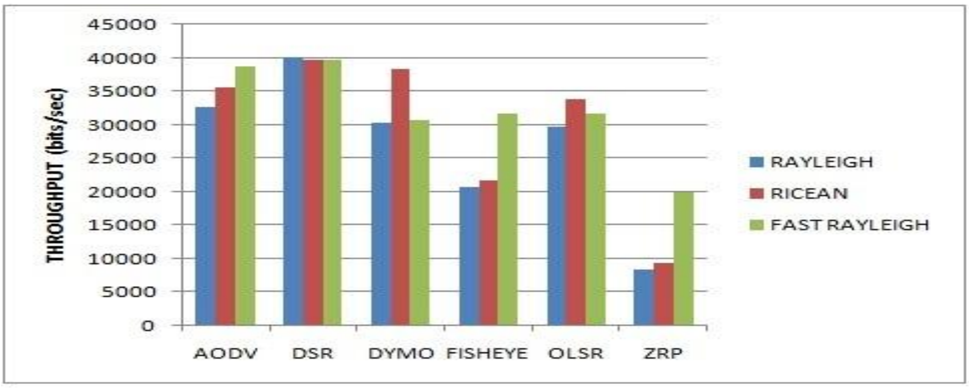

Figure 8. Impact of Fading on Throughput for different protocols

D. Packet Delivery Ratio

Whether the fading is Rayleigh, Ricean or Fast Rayleigh, the DSR and AODV protocols has highest PDR while ZRP and FSR has the lowest PDR as shown in figure 9. The ZRP protocol has worst packet delivery ratio for all the fading models.

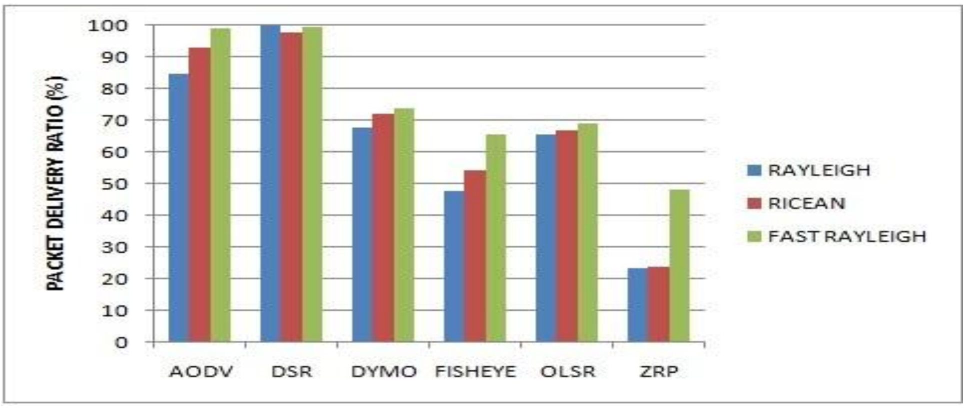

Figure 9. Impact of Fading on Packet Delivery Ratio for different protocols

(c) SIMULATION RESULTS (INTER-CHANNEL INTERFERENCE)

A. Average End to End Delay

As shown in figure 10, when the inter-channel interference effects are considered on the protocols, the average end to end delay increases. The inter-channel interference most badly affects the DYMO and FSR protocols in terms of average end to end delay i.e. the DYMO and FSR protocols has highest average end to end delay.

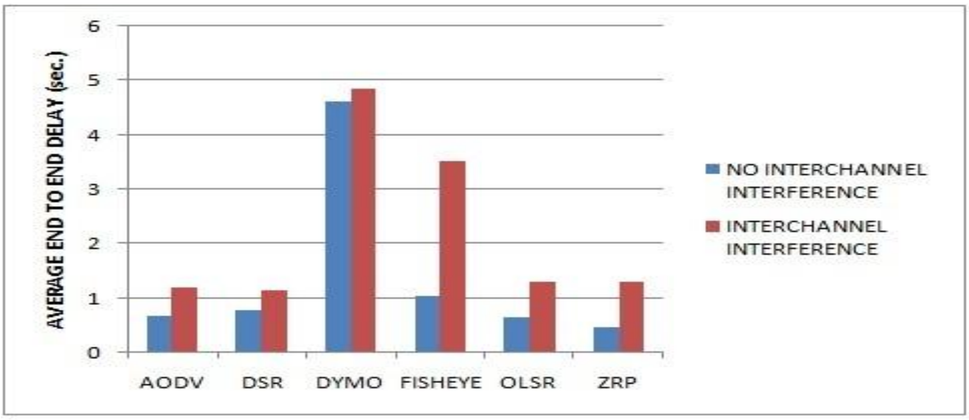

Figure 10. Impact of Inter-Channel Interference on Average End to End Delay for different protocols

B. Average Jitter

Figure 11. shows that FSR and DYMO protocols has the highest average jitter values when the inter-channel interference is considered i.e. shows the worst performance among six protocols. The DSR and ZRP has although some increase in average jitter value for the inter-channel interference but overall increased value of jitter is lower as compared to FSR and DYMO.

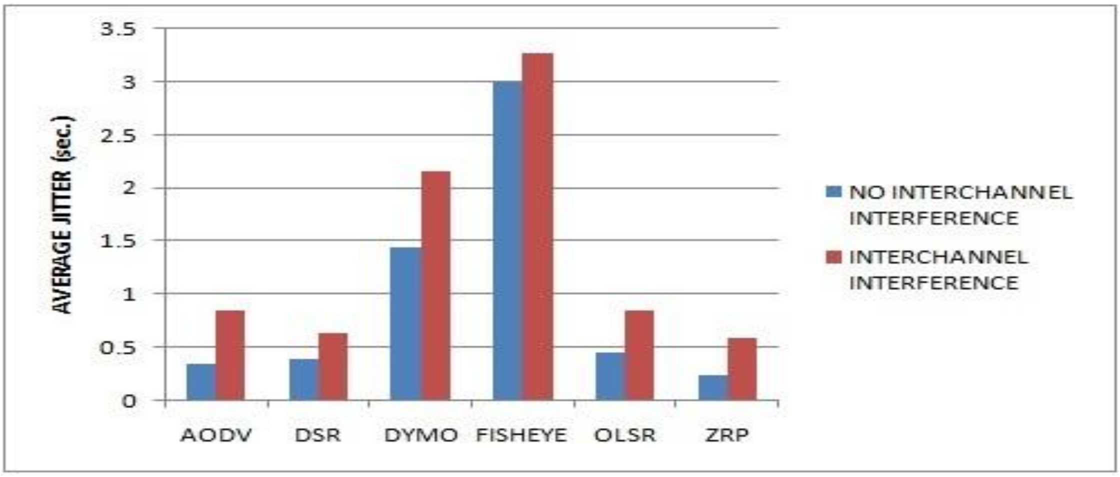

Figure 11. Impact of Inter-Channel Interference on Average Jitter for different protocols

C. Throughput

In general. the throughput of the routing protocols decreases when the inter-channel interference is considered as shown in figure 12. DSR and AODV protocol has the highest throughput while FSR and ZRP having the lowest. The FSR protocol is most badly affected by the inter-channel interference and hence has the lowest throughput.

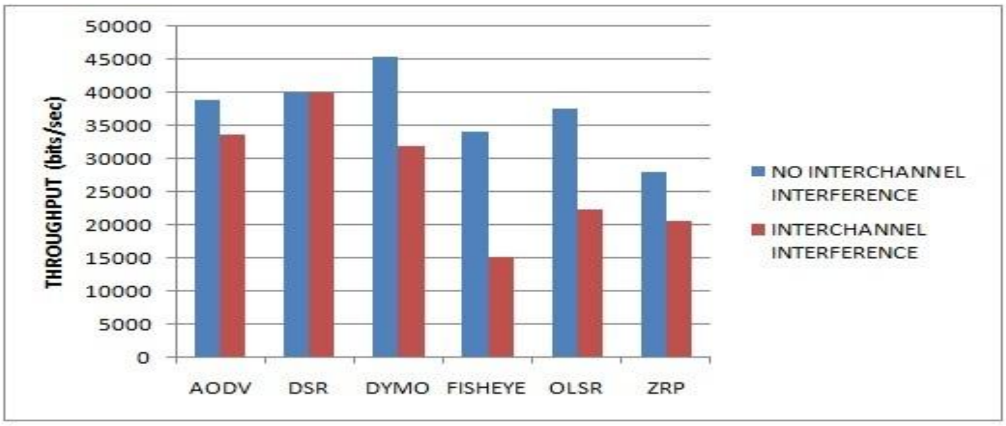

Figure 12. Impact of Inter-Channel Interference on Throughput for different protocols

D. Packet Delivery Ratio

The PDR of the routing protocols decreases when the inter-channel interference is considered as shown in figure 13. DSR and AODV protocol has the highest PDR while FSR having the lowest. The FSR protocol is most badly affected by the inter-channel interference i.e. the decrease in throughput for FSR protocol is highest as compared to PDR when no inter-channel interference is considered.

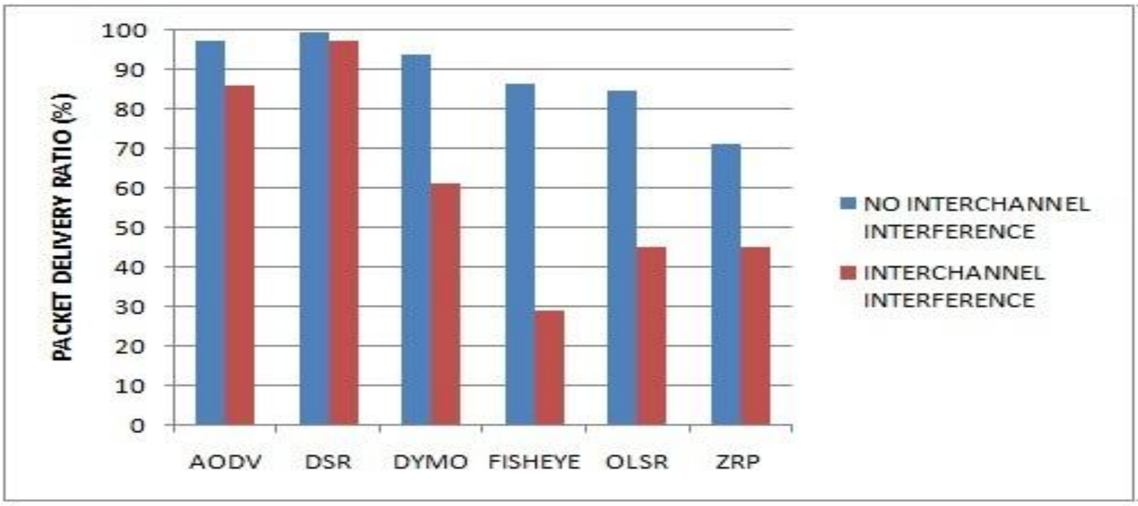

Figure 13. Impact of Inter-Channel Interference on Packet Delivery Ratio for different protocols

VI. CONCLUSION

In this simulation work the shadowing, fading and inter-channel interference effects on ad hoc network has been investigated. Although two-ray model is widely used as a propagation model in ad hoc network simulation, but this model does not represent a real world network propagation model because the surrounding environment of a network is always changing. It is shown that the performance of a network deteriorate very quickly if the shadowing effects are taken into account. The main reasons for this degraded performance resulted from the fact that there will be a 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 causes problem to the normal operations of a routing protocol as well as the MAC protocol.

In this work, we evaluated the performance of various ad hoc routing protocols on the basis of different shadowing models, fading models and inter-channel interference models for the mobile nodes & the parameters such as Throughput, PDR, Average Jitter and Average Delay 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, fading and inter-channel interference are taken into consideration. Specially the proactive protocols are badly affected by these affects. But it is necessary to take into consideration these effects while analysing 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 on more protocols and suggest some measures to improve their performance.

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