Performance Analysis of Ad hoc Routing Protocols AODV, DSR and OLSR under Certain Conditions as Speed, Network Density and Packet Size

Zahraa E. Mohamed [a], Mahmoud Atef [b]

[a]*Faculty of Science, Mathematics Department, Zagazig University*, Zagazig, Egypt.
[b]*High Institute for Engineering & Technology – Al-Obour, Cairo, Egypt.*

Abstract

MANET is a collection of mobile nodes which are independent, self-organization and self-configuration where each node communicates with others by a multi-hops manner and can move arbitrarily without any infrastructure or central control. This paper aims to analysis and compare the performance of three ad hoc routing protocols namely: AODV, DSR and OLSR vs. three different variables parameters using OPNET 17.5 simulations. Furthermore, this study focuses on comparing the main features of these protocols and evaluated the performance of these protocols. We studied the effect of nodes density, mobility speed and data packet size on the performance of these protocols based on the rate of file transfer protocol (FTP) with medium load traffic. The results in all simulations decided that the performance of OLSR protocol is better than both of them AODV and DSR in terms of end to end delay and data dropped, Whereas the performance AODV protocol is the best in terms of throughput and also DSR protocol has the lowest network load. As, we concluded that each protocol has different effect with respect to the environment conditions and considered metrics, including the average throughput, network load, end-to-end average delay, and data dropped. The results are shown that OLSR protocol can be more suitable choice in a large density networks compared to AODV and DSR.

Keywords:
MANET, Routing Protocols, FTP, AODV, DSR, OLSR, OPNET.

1. Introduction

Mobile ad hoc network (MANET) is considered the oldest multi-hop network pattern and is comprised of a mobile nodes that can communicate with each other’s via wireless links without using an existing network infrastructure or centralized administration. The other multi-hop patterns like Wireless Mesh Networks [1], Wireless Sensor Networks [2], and Vehicular Ad-Hoc Networks [3] can be considered as special cases of MANETs with some individual characteristics, application areas, and design requirements. Nodes in a MANET are autonomous, self-configuring and are free to move randomly and organize themselves arbitrarily; thus, the network’s wireless may experience rapid and unpredictable topology changes. Some scenarios where an ad hoc network can be used and also plays an important role are business associates sharing information during a meeting, emergency disaster relief personnel coordinating efforts after a natural disaster such as a hurricane, earthquake, or flooding, and military personnel relaying tactical and other types of information in a battlefield [4].

In general, ad hoc routing protocols in MANETs can be divided into two main categories namely reactive and proactive routing protocols depending on how the route is discovered. Moreover, the main purpose of Ad hoc routing protocols is to discovering an efficient and reliable route and maintaining the connection between communicating nodes. In order to choose the most suitable protocols for real world applications like virtual classrooms or conference rooms, disaster recovery – earthquake, hurricane, sensor networks, road or accident guidance , military communications and operations and etc., these protocols needs to be tested under realistic conditions.

The main objective of this paper is to analysis and evaluate the performance of three most popular MANETs routing protocols namely Optimized Link State Routing (OLSR) [5], Ad Hoc On-Demand Distance Vector Routing (AODV) [6] and Dynamic Source Routing (DSR) [7] which have been selected from the two categories proactive and reactive routing protocols. the performance of this ad hoc routing protocols were analyzed according to the following stages: (1) varying the number of nodes, (2) varying the speed of nodes, (3) and varying the data packet size based on the rate of file transfer protocol (FTP) with a medium load traffic and implemented the random waypoint (RWP) model in all scenarios with different network parameters; throughput, network load, end-to-end delay and data dropped. For this simulations study, OPNET 17.5 [8] simulator was chosen due to its accuracy and it is used to generate mobility models. OPNET is used widely by researchers, engineers, university students, and the US military due to its powerful characteristic such as comprehensive graphical user interface and animation, also it contains hundreds of protocols with giant flexibility for examination and analysis [9].

The remainder of this paper is structured as follows: Section 2 discusses the related work in the networks topology-based routing protocols and the performance evaluations. In section 3, we present the routing protocols category in MANET and describe the characteristics of the above protocols while in section 4 we show environment conditions and some the metrics for evaluation the protocols in the experiment. Section 5 discusses the scenario features, the simulation results and comparison among the protocols in this study. Finally, Section 6 presents the conclusion of this study and proposes some points in the future.

2. Related Works

In recent years, there are many routing protocols have been proposed and implemented in MANETs in order to enhance bandwidth utilization, and to get minimum routing overhead, higher throughputs, lesser overheads per packet, minimum end to end delay, packet delivery ratio and others. The work done by the researchers on the performance comparison between most of the existing routing protocols in MANETs Routing Protocols is shown on Table 1. In contrast, this paper focuses on the comprehensive analysis of these well-known routing protocols named by AODV, DSR and OLSR in terms of data dropped, end to end delay, throughput and network load by using OPNET simulator version 17.5 to reach the best protocol to be deployed in some real-time applications.

Table 1 Related Works

Author name and reference	Protocols and simulator used	Variables parameters	Performance metric
J. Kumar et al. [10]	AODV, DSR, OLSR, ZRP using Qualnet 5.0.2	Fixed all parameters	Jitter, Throughput, Delay, PDR
A. A. Chavan et al. [11]	DSDV, AODV using NS-2	Number of nodes	Routing overhead, PDR, Throughput, Delay
Z. E. Mohamed and M. Atef [12]	AODV, DSR, OLSR using OPNET 17.5	Number of nodes	Data dropped, Delay, Routing overhead, Throughput
S. Singh et al. [13]	DSR, AODV using Matlab	Mobility, Number of nodes	PDR, PMR, Throughput, Delay, Routing overhead
A. Al baseer et al. [14]	DSR, AODV, DSDV, OLSR using OMNET++	Number of nodes	End to end delay, collision, PDR
D. Bandral and R. Aggarwal [15]	AODV,DSDV, ZRP	-	Throughput, delay, routing overhead
S. Mohapatra and P.Kanungo. [16]	AODV, DSR, DSDV, OLSR using NS-2	Number of nodes, mobility, network area	Delay, throughput, control overhead, PDR
Y. Maleh and D. A. Ezzati [17]	DSDV, DSR, AODV using NS-2	Number of nodes	Throughput, PDR, Delay
Z. Ishrat et al. [18]	DSR, DSDV, ZRP and NS-2	Pause time , number of nodes	Throughput, packet delivery fraction ratio
A. K. Maurya and D. Singh.[19]	AODV, FSR, ZRP using Qualnet 5.0	Pause time, number of nods	Delay, PDR, throughput, average jitter
S. R. Raju et al.[20]	AODV, DSR, ZRP using Qualnet 4.5.1	Number of nodes	Average jitter, Delay, PDR, total bytes received, throughput

3. Routing Protocols in Mobile Ad Hoc Network

An ad hoc routing protocol is a convention or standard which organizes the relations between nodes and controls that decide how nodes choose the path to send data packet between the devices with each other from source to destination node in a MANET system [21, 22].The main target of an ad-hoc network routing protocol is the correct and efficient route establishment between a pair of nodes so that messages may be delivered reliably and in a timely manner. There are a several types of routing protocols for MANETs which are divided into two main categories namely Reactive and Proactive, in addition to The ad hoc routing protocols which have a properties of both reactive and proactive, is known as hybrid routing protocols [23].

Reactive (on demand) routing protocols determine routes when the node has a data packet to send only and this node referred to a source. When any nodes (source) has a data to send and the route to destination unknown, firstly they sends this data and then starts searching a route to destination by route discovery process[24]. The advantage of such a scheme is that there is no periodic routing overhead. For examples, in this paper AODV and DSR routing protocols are considered based on reactive routing protocols and etc. like LAR, TORA, CBRP and ARA.

In contrast, in Proactive (table driven) routing protocols, before it is needed, each node in the network knows the route to every other node in the same network and always maintain routes at all times by using a periodic route update process. the protocols in this category, sends a broadcast message to gather update information and all possible connectivity through the network [25], and each node require to maintain more than one table to store routing information regardless of the need for such route information [26]. For examples in this paper OLSR routing protocol is considered based on proactive routing protocols and etc. like FSR, STAR, GSR, DSDV and WRP.

In general, the integration of the characteristics of proactive and reactive protocols are called a hybrid routing protocol. The hybrid routing protocol take advantages of reactive and proactive protocols and as a result it can work very well for any particular network. For examples, ZRP, DST, ZRP, DDR and ZHLS.

4. Simulation Environment and Methodology

In this section, we state the main features comparison among the three routing protocols are AODV, DSR and OLSR and assign the specific environment conditions and some the metrics for evaluation the performance of these protocols.

4.1 Performance Metrics

For the performance evaluation of the selected routing protocols against three proposed scenario model under specific conditions, the following metrics have been chosen for this purpose:

4.1.1 *Data dropped (bits/sec):*

Data dropped is the total size of data packets dropped in the network due to the size of the higher layer packet, which is greater than the maximum allowed data size and shows that how many packets are successfully sent and received across the whole network [12].

4.1.2 *End To End Delay (sec):*

It is the time of generation of a packet by the source up to the destination reception. So this is the time that a packet takes to go across the network and generally, the end-to-end-delay is measured as per the equation 1 [27].

$$Delay = N\left[D_{transmission} + D_{propagation} + D_{processing} \right] \quad (1)$$

Where N is a scalar number

4.1.3 *Throughput (bits/sec):*

The average rate at which the data packet is delivered successfully from one node to another over a communication network is known as throughput and the average rate of successful messages delivery over a channel during a communication [12]. Throughput can be represented mathematically by equation 2.

$$Avg.throughput = \frac{packets\ no.* packet\ size * 8}{total\ duration\ of\ simulation} \quad (2)$$

4.1.4 *Network Load (bits/sec):*

It represents the total load (in bits/sec) submitted to WLAN MAC layer by all higher layers in all WLAN nodes of the network and is the total packet sent and received across the whole network at a particular time. The network load occurs when there is more traffic coming on the network, and it is difficult for the network to handle all this traffic. The efficient network can easily cope with large traffic coming in. [28].

4.2 Comparative Study of AODV, OLSR and OLSR

Table 2 [29][30] compares the main characteristics of the three routing protocols considered in this study, namely AODV, DSR and OLSR which have been selected from reactive and proactive category.

Table 2 Comparison Of Three MANET Routing Protocol: AODV, DSR, AND OLSR

Parameter	AODV	DSR	OLSR
Routing Architecture	Flat	Flat	Flat
Protocol Type	Distance vector	Source routing	Link state scheme
Routing Category	Reactive or on demand	Reactive or on demand	Proactive or table driven
Routing Architecture	Flat	Flat	Flat
Routes Maintained In	Routing table	cache	Routing table
Multicast capability	Yes	No	No
Route Discovery Required	Yes (entirely)	Yes (aggressive)	No
Sequence Numbers	Yes	No	No
Routing Metric	Hops/date	None	Hops
Routing types	Hope by Hope routing	Source routing	Hope by Hope routing
Routing method	Broadcast or flooding	Broadcast	Flooding
Critical Nodes	No	No	Yes
Periodical Update Required	No	No	Yes
Routing information update	As needed	As needed	Periodically
Update information & Route maintenance	Route error	Route error	Neighbour's link state
Update To	No update	No update	Only MPRs
"HELLO" Messages uses	Yes (only for active neighbors)	No	yes
Route Is Within Packet Header	No	Yes	No
Use Timers For Routes	Yes	No	No
Multiple Routes Available	No	Yes	No
Control messages	Only hello messages used for neighbor detect	No beacon or hello message	Hello, TC, and MID message
Beacons	Yes, hello message	No	Yes
Advantages	Much more efficient to dynamic topology	Does not flood the network with routing updates	Trim down the number of broadcasts
Disadvantages	large delay, Scalability problem, hello message	Failed routes are not repaired locally.	The MPR sets could be overlapped

5. Result and Comparative Analysis

The simulations in this study using OPNET17.5 [8] have been done to analyze the performance of AODV, DSR and OLSR protocols under file transfer protocol (FTP) application. In this work, the results have been divided into a three different scenarios namely, network density load, speed of the nodes, and data packet size in terms of data dropped, end to end delay, throughput, and network load. In the following Sections 5.1, 5.2 and 5.3, we comparative study the impact of network nodes density, speed of the nodes, and data packet size on the behavior of the three routing protocol that have been selected and installed in the OPNET-17.5.

5.1 Performance Analysis by Varying Network density

5.1.1 Experiment settings

In this experiment, the scalability of the networks is measured by varying the number of nodes from 25 to 100 with a different increment. The mobility speed of nodes was set to 5 m/s, while the pause time was set to 0 m/s and the simulation duration of 900 second. In table 3, other network settings have been described.

Table 3: simulation parameters of a network load

Parameter	values
Network Load	
Nodes number	25, 35, 50, 75, 85, 100
Network size (m^2)	1000 x1000
Speed (m/sec)	5
Pause time (sec)	0
Simulation duration (sec)	900 (15 min.)
Traffic	
Traffic type	Constant bit rate (CBR)
Packet rate (packet/sec)	4
File size (bytes)	512
Data Packet size (bits)	512 (64 bytes)
Data Rate of Each Node	24 mbps
Application definition	
Application name	FTP
Description	FTP with medium load
Routing protocol	
Protocols	AODV, OLSR, DSR
Mobility	
Mobility models	Random waypoint (RWP)

5.1.2 Result

Figures 1, 2, 3 and 4 show the performance parameters of the routing protocols AODV, DSR and OLSR against network nodes density in terms of data dropped, delay, throughput and network load.
Figures 1 and 2 show that OLSR outperform AODV and DSR in terms of data dropped and delay in all nodes densities, and it is due to their proactive characteristics. The data dropped and delay of AODV and DSR increases as the number of nodes increases, but in OLSR increase slightly when the nodes increases. In a low density network nodes, it's observed that AODV and DSR are the same performance in terms of data dropped and delay, but in a high density network nodes, AODV has a maximum data dropped and delay due to broadcasting the routing request by source nodes for the whole network, logical link repair (LLR) and also multicast routing.
Figures 3 and 4 show that the network load and throughput of AODV, DSR and OLSR increases as the number of nodes increases. Figure 3 indicates that AODV achieves the highest network load, and OLSR makes average network load due to its MPR advantage in enabling forwarding of the control messages to other nodes, whereas the DSR protocol has the lowest network load because the packet delivery uses only one route. Figure 4 shows that AODV has the highest throughput compared to other protocols, OLSR has a medium, whereas DSR has a low throughput in a low density network, but OLSR perform well in terms of throughput especially in high density network.

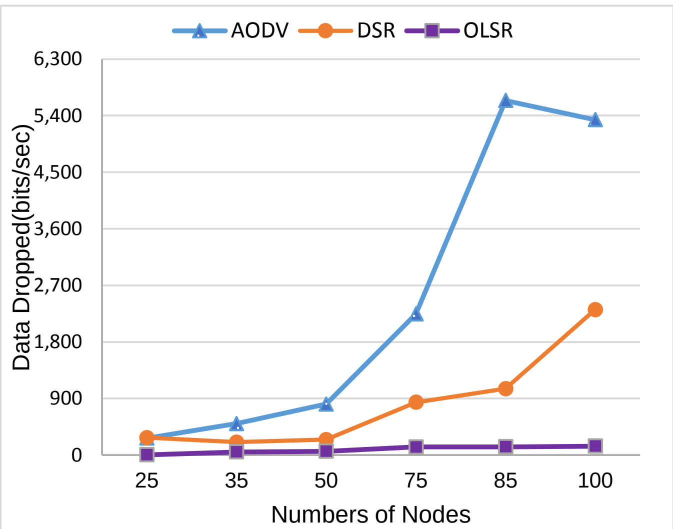

Figure 1: data dropped vs. number of nodes

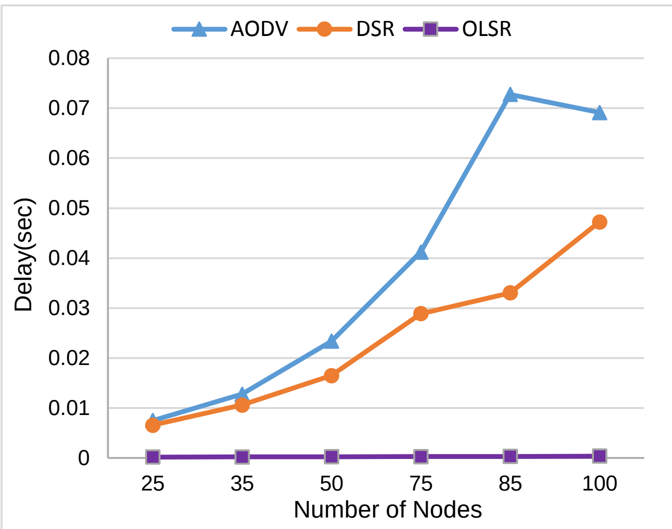

Figure 2: delay vs. number of nodes

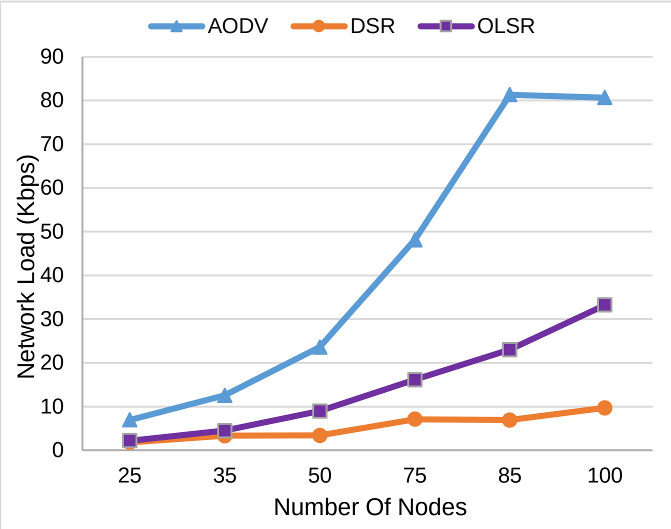

Figure 3: network load vs. number of nodes

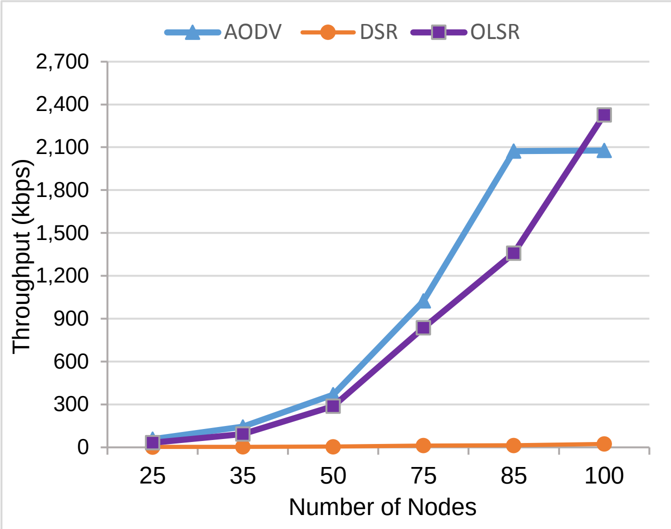

Figure 4: throughput vs. number of nodes

5.2 Performance Analysis by Varying Speed

5.2.1 Experiment settings

In this experiment simulation, the number of nodes in the network was kept constant at 25, the pause time was set to 0 sec, the connection speed was set at 24 Mbps and the speed of the nodes was varied from 1 m/s to 3, 5,10,15,20 and 50 m/s where the minimum speed 1 m/s (3.6 km/hr.) corresponds to walking at a slow speed and the maximum speed 50 m/s corresponds to the speed of a very fast vehicle. The remaining parameters that have been used in this scenario shown in table 4.

Table 4: simulation parameters speed of nodes

Parameter	values
Speed of nodes	
Nodes number	25
Network size (m^2)	1000 x1000
Speed (m/sec)	1, 3, 5, 10, 15, 20, 50
Pause time (sec)	0
Simulation duration (sec)	900 (15 min.)
Traffic	
Traffic type	Constant bit rate (CBR)
Packet rate (packet/sec)	4
File size (bytes)	512
Data Packet size (bits)	512 (64 bytes)
Data Rate of Each Node	24 mbps
Application definition	
Application name	FTP app.
Description	FTP with medium load
Routing protocol	
Protocols	AODV, OLSR, DSR
Mobility	
Mobility models	Random waypoint (RWP)

5.2.2 Result

Figures 5, 6, 7 and 8 show that data packet, end to end delay, average network load and average throughput for varying node speeds in a low sized MANET.
Figures 5 and 6 show that OLSR outperform AODV and DSR in terms of data dropped and delay in a low, moderate and high mobility, however OLSR low performance in a low speed (1 m/s) compared to the other speeds. The AODV protocol has better performance than DSR protocol with a low speed (1 m/s, 2 m/s), whereas the DSR protocol has better performance than AODV protocol with a moderate speed (10 m/s, 15 m/s). Therefore, it's observed that OLSR protocol is more suitable with the speed increases because of OLSR can detect a link failure and also figure 6 shows that the OLSR protocol has the lowest and most stable in terms of delay due to its proactive characteristics that shown in table 2.
From figure 7 it's observed that the network load in AODV and OLSR protocols increase as the speed increase, but the network load in the DSR protocol decreases, so the DSR protocol has the best performance in terms of network load compared to AODV and OLSR protocols except when using the low speed (1 m/s), the OLSR protocol is the best. Moreover, according to figure 7 the OLSR protocol showed better network load performance as compared to AODV protocol Because of the reasons mentioned in the previous scenario.
From figure 8 it's observed that the increasing speed nodes resulted increasing in throughput in the AODV and OLSR protocols and decreasing in the DSR protocol. Moreover, according to figure 8 the AODV protocol has the highest throughput followed by OLSR protocol in a low size network of nodes, whereas the DSR protocol has the lowest throughput.

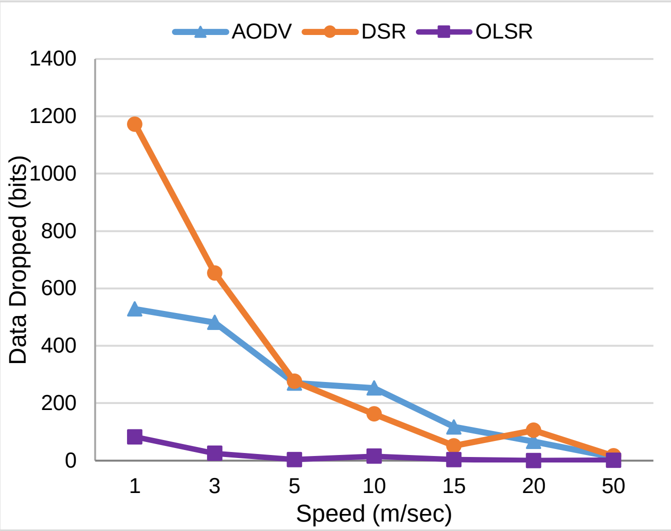

Figure 5: data dropped vs. speed of nodes

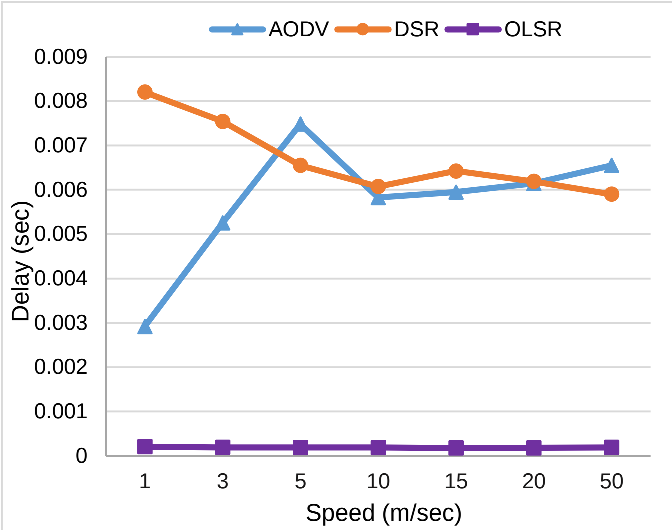

Figure 6: end to end delay vs. speed of nodes

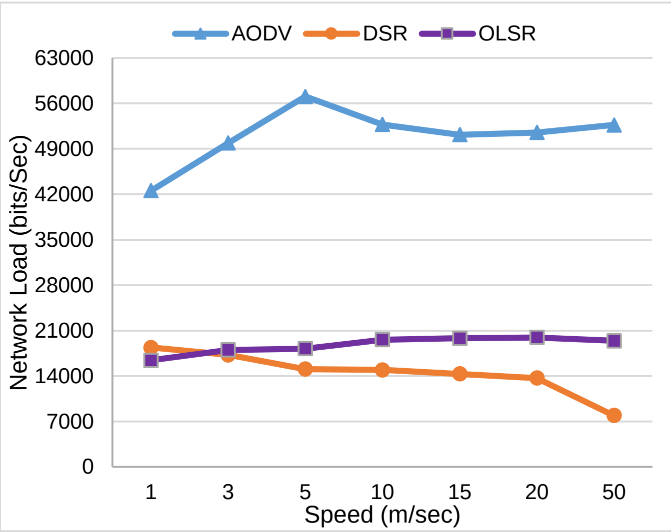

Figure 7: network load vs. speed of nodes

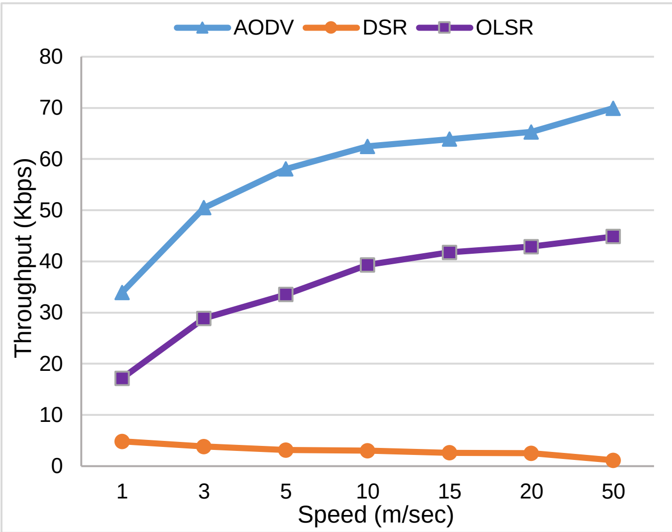

Figure 8: throughput vs. speed of nodes

5.3 Performance Analysis by Varying Data Packet Size

5.3.1 Experiment settings

In this experiment simulation, the number of nodes in the network was fixed to 25, the pause time was set to 0 sec, the mobility speed of nodes was set to 5 m/s and the packet size was varied from 512 to 8192 bits with an increment of 512 bits. Furthermore, this scenario study the impact of data packet size on the three routing protocols AODV, DSR, and OLSR. Table 5 shows all the simulation parameters that have been used in this scenario.

Table 5: simulation parameters of a data packet size

Parameter	values
Speed of nodes	
Nodes number	25
Network size (m^2)	1000 x1000
Speed (m/sec)	5
Pause time (sec)	0
Simulation duration	900 sec (15 min.)
Traffic	
Traffic type	Constant bit rate (CBR)
Packet rate (packet/sec)	4
File size (bytes)	512
Data Packet size (bits)	512, 1024, 2048, 4096, 8192
Data Rate of Each Node	24 mbps
Application definition	
Application name	FTP app.
Description	FTP with medium load
Routing protocol	
Protocols	AODV, OLSR, DSR
Mobility	
Mobility models	Random waypoint (RWP)

5.3.2 Result

Figures 9, 10, 11 and 12 show that data dropped, end to end delay, average network load and average throughput for varying data packet size in a low sized MANET.
From figure 9, it's observed that once the data packet size increases the data dropped increases for all the three protocols and for all packet size OLSR protocol achieved the best performance as compared to AODV and DSR protocols. Furthermore, DSR performs well than AODV for packet size 512 bits, but for the remaining packet sizes AODV has performance better than DSR.
Figure 10 shows that OLSR outperform AODV and DSR in terms of end to end delay and for all data packet size OLSR maintain the lowest delay, whereas AODV perform better than DSR. According to figures 9 and 10, it's obvious that for OLSR routing protocol have very
From figure 11, it's observed that once the data packet size increases the network load increases for all the three protocols and for all packet size AODV protocol achieved the lowest performance as compared to OLSR and DSR where AODV has the maximum network load. Moreover, DSR perform better than OLSR for packet size 512 and 1024 bits, but OLSR perform better than DSR for packet sizes 2048, 4096 and 8192 bits.
Similarly, from Figure 12, its notice that the average throughput of AODV, OLSR and DSR protocols increases while increasing the data packet size. Moreover, according to figure 12 the DSR protocol has the lowest throughput and OLSR protocol has the medium throughput in low size network of nodes, whereas the AODV protocol has the highest throughput.

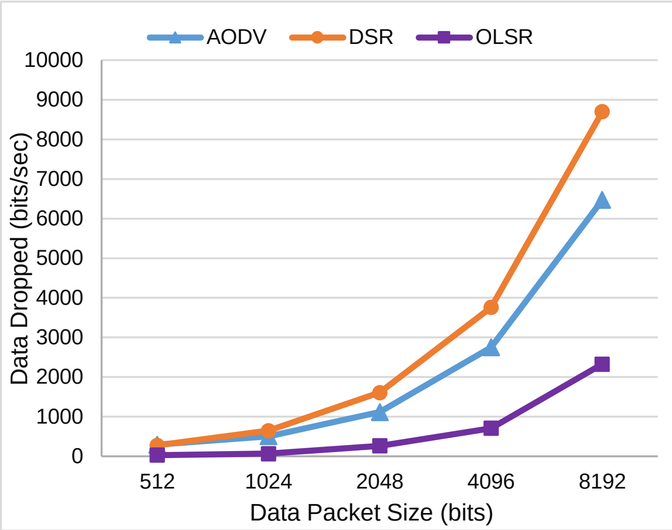

Figure 9: data dropped vs. data packet size

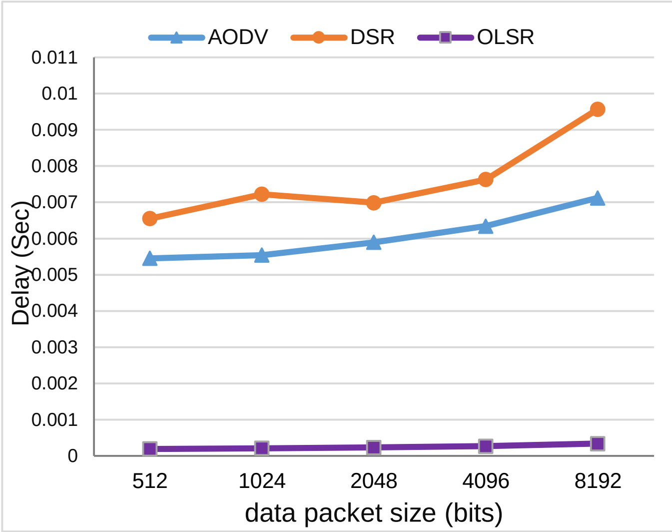

Figure 10: end to end delay vs. data packet size

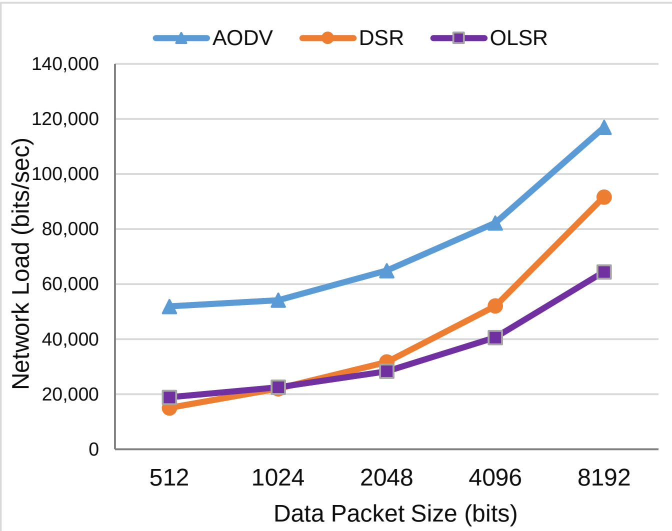

Figure 11: network load vs. data packet size

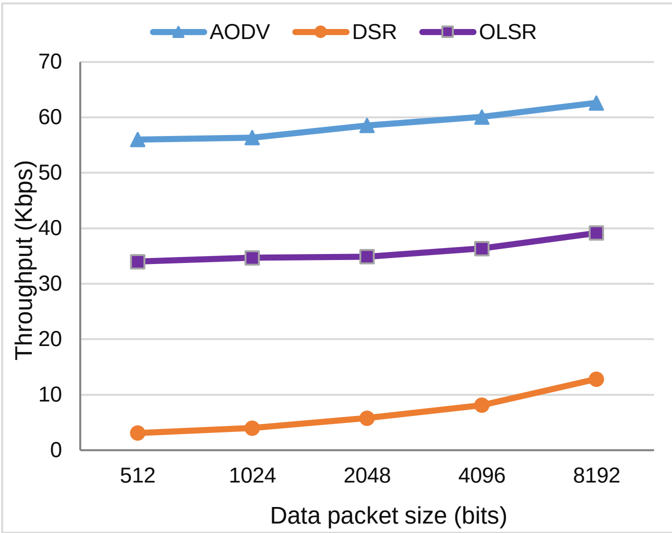

Figure 12: Throughput vs. data packet size

5.4 Results Summary

All simulation results can be summarized in the following tables 6, 7, 8, 9, 10 and 11.

Table 6 Routing Performance result In Low Network density

Low Network nodes density				
Protocol	Data Dropped (bits/Sec)	Delay (Sec)	Network Load (bits/Sec)	Throughput (bits/Sec)
AODV	Average 270	Average 0.007482	High 57,063	High 475,820
OLSR	Low 3	Low 0.000187	Low 18,210	Average 274,722
DSR	Average 276	Average 0.006549	Low 15,060	Low 25,493

Table 7 Routing Performance result In High Network density

High Network node density				
Protocol	Data Dropped (bits/sec)	Delay (sec)	Network Load (bits/sec)	Throughput (Kbps)
AODV	Average 270	Average 0.007482	High 660,901	Average 2,078
OLSR	Low 3	Low 0.000187	Average 272,343	High 2,327
DSR	Average 276	Average 0.006549	Low 79,543	Low 25

Table 8 Routing Performance Summary In Low speed of Nodes

Low Nodes speed				
Protocol	Data Dropped (bits/Sec)	Delay (Sec)	Network Load (bits/Sec)	Throughput (Kbps)
AODV	Average 528	Average 0.0029	High 42,563	High 33.94
OLSR	Low 83	Low 0.0002	Low 16,429	Average 17.16
DSR	High 1173	High 0.0082	Low 18,400	Low 4.80

Table 9 Routing Performance Summary In High speed of Nodes

High Nodes speed				
Protocol	Data Dropped (bits/Sec)	Delay (Sec)	Network Load (bits/Sec)	Throughput (Kbps)
AODV	High 10.99	High 0.0066	High 52,671	High 69.93
OLSR	Low 0.75	Low 0.00019	Average 19,437	Average 44.85
DSR	High 16.28	High 0.0059	Low 7,923	Low 1.14

Table 10 Routing Performance Summary In Low data packet Size

Low data packet Size				
Protocol	Data Dropped (bits/sec)	Delay (sec)	Network Load (bits/sec)	Throughput (bits/sec)
AODV	High 291.42	High 0.00545	High 51,919	High 458,765
OLSR	Low 28.04	Low 0.00019	Low 18,847	Average 278,472
DSR	High 275.95	High 0.00654	Low 15,060	Low 25,493

Table 11 Routing Performance Summary In High data packet Size

High data packet size				
Protocol	Data Dropped (bits/Sec)	Delay (Sec)	Network Load (bits/Sec)	Throughput (bits/Sec)
AODV	Average 6,471.18	High 0.00712	High 116,948	High 512,754
OLSR	Low 2,326.35	Low 0.00034	Low 64,444	Average 320,706
DSR	High 8,703.71	High 0.00957	Average 91,677	Low 104,958

6. Conclusion

In this paper, we study the comparison of performance analysis of Ad Hoc Routing Protocols AODV, DSR and OLSR in MANETs by varying the number of nodes, speed of nodes and data packet size. The performances were analyzed based on the rate of file transfer protocol (FTP) with a medium load traffic and implemented by a random waypoint model in all scenarios on the basis parameters; throughput, network load, end-to-end delay, and data dropped. By evaluating the results, we assured that there is no protocol that outperforms others with respect to all considered criteria in all scenarios. In general, AODV protocol perform better in the network density, node speed and packet size of the ad hoc network, in case of average throughput as compared to OLSR and DSR protocols, whereas OLSR shows the better throughput than AODV in a high density networks. The OLSR protocol also achieved the lowest value of data dropped and minimum end-to-end Delay in all scenarios; mobility, scalability and packet size when compared to AODV and DSR, this is due to their proactive characteristics. DSR protocol might perform well according to previous works, but was only in small scale networks and when the time duration is minimum in any application in environment and here DSR has lowest network load as it use only route for the packet delivery. Therefore, its performance has not been comparable to the other ad-hoc routing protocols AODV and OLSR in this work.

Finally, results simulations established that OLSR protocol is maybe a good suitable in all scenarios of mobility, scalability and packet size for minimal delay and lowest of data dropped and is much more choice compared to AODV and DSR in highly dense networks, whereas DSR protocol has proved to be a better reacting protocol in loaded networks and AODV is a good choice in any network for a higher throughput without considering any other environmental conditions.

References

[1] I. F. Akyildiz, W .Su, Y .Sankarasubramaniam and E. Cayirci. “Wireless sensor networks: a survey”. *Computer networks, Volume 38, Issue 4, 15 March 2002, Pages 393-422, Published by Elsevier.*

[2] I. F. Akyildiz, X. Wangb and W. Wang, “Wireless mesh networks: a survey”, *Computer Networks, Volume 43, Issue 9, Sept. 2005, pages 445–487, Published by Elsevier.*

[3] G. Karagiannis, O. Altintas, E. Ekici, G. Heijenk, B. Jarupan, K. Lin and T. Weil. “Vehicular networking: A survey and tutorial on requirements, architectures, challenges, standards and solutions”, *IEEE Communications Surveys & Tutorials, Volume: 13, Issue: 4, July 2011, pages 584 – 616.*

[4] Anuradha and I. S. Gill “Performance Evaluation of AODV and OLSR for Different Mobility Patterns By Varying Source Nodes in MANET”, *IJIREEICE, Volume 3, Issue 10, October 2015.*

[5] P. Jacquet, P. Muhlethaler, T. Clausen, A. Laouiti, A. Qayyum and L. Viennot. “Optimized link state routing protocol for ad hoc networks”. *Multi Topic Conference 2001, IEEE International, august 2002, pages 1-7.*

[6] C. E. Perkins and E. M. Royer. “Ad-hoc on demand distance vector routing” *In Proceedings of 2nd IEEE workshop on mobile computing systems and applications, February 1999, pages 90–100.*

[7] D. B. Johnson and D. A. Maltz. “Dynamic Source Routing in Ad Hoc Wireless Networks”. *mobile computing, The Kluwer International Series in Engineering and Computer Science, vol. 353, Boston, MA, 1995, Published by Springer.*

[8] OPNET, [Online]. Available: http://www.opnet.com/.

[9] X. Xian, W. Shi and H. Huang. “Comparison of OMNET++ and other simulator for WSN simulation”. *IEEE Conference on Industrial Electronics and Applications (ICIEA) 2008, pages 1439 –1443.*

[10] J. Kumar A. Singh, M. K. Panda, H. S. Bhadauria. “Study and Performance Analysis of Routing Protocol Based on CBR”. *Procedia Computer Science 85 (2016), pages 23 – 30, published by Elsevier.*

[11] A. A. Chavan, D. S. KuruleProf and P. U. DereProf. “Performance Analysis of AODV and DSDV Routing Protocol in MANET and Modifications in AODV against Black Hole Attack", *Procedia Computer Science 79 (2016), pages 835 – 844, published by Elsevier.*

[12] Z. E. Mohamed and M. Atef. “Performance Evaluation of AODV, DSR and OLSR in MANET using Opnet Simulator”. *International Journal of Computer Applications, Volume 163 – No 11, April 2017, pages 0975 – 8887.*

[13] S. Singh, B. Dhaliwal and R. Malhotra. "Performance Analysis of Hybrid Routing Protocol in Mobile Ad hoc Networks". *International Journal of Computer Science and Mobile Computing, Vol.5 Issue.6, June- 2016, pages 434-441.*

[14] A. Albaseer, G. B. Talib and A. Bawazir."Multi-hop Wireless Network: A Comparative Study for Routing Protocols Using OMNET++ Simulator", *Journal of Ubiquitous Systems & Pervasive Networks, Volume 7, No. 1 (2016), pages 29-34.*

[15] D. Bandral and R. Aggarwal. "Comparative Analysis of Proactive, Reactive and Hybrid Routing Protocols for Improving Quality of Service in Mobile Ad-Hoc Networks". *International Journal of Engineering Trends and Technology (IJETT) – Volume 30 Number 4 - December 2015, pages 192-196.*

[16] *S. Mohapatra and P.Kanungo*. "Performance analysis of AODV, DSR, OLSR and DSDV Routing Protocols using NS2 Simulator", *Procedia Engineering, 30 (2012), pages 69 –* 76, *Published by Elsevier.*

[17] Y. Maleh and D. A. Ezzati. "Comparative Analysis of Routing Protocols AODV DSDV and DSR in MANET". International Journal of Computer Science and Mobile Computing, Vol.3 Issue.3, March- 2014, pages 379-385.

[18] Z. Ishrat, P. Singh and R. Ahmad. "Performance Evaluation of DSDV, DSR AND ZRP Protocol in MANET", International Journal of Computer Applications Technology and Research, Volume 2– Issue 3, 2013, pages 345 – 349.

[19] A. K. Maurya and D. Singh. "Simulation based Performance Comparison of AODV, FSR and ZRP Routing Protocols in MANET". *International Journal of Computer Applications (0975 – 8887), Volume 12– No.2, November 2010, pages 23-28.*

[20] S. R. Raju, K. Runkana and J. Mungara. "ZRP versus AODV and DSR: A Comprehensive Study on ZRP Performance". *International Journal of Computer Applications (0975 – 8887), Volume 1 – No. 12, 2010, pages 35-40.*

[21] G. R. Vijayavani, and G. Prema. "Performance comparison of MANET routing protocols with mobility model derived based on realistic mobility pattern of mobile nodes." *Advanced Communication Control and Computing Technologies (ICACCCT), 2012 IEEE International Conference on. IEEE, 2012.*

[22] S. Tayal, and M. R. Tripathy. "VANET-challenges in selection of vehicular mobility model." *Advanced Computing & Communication Technologies (ACCT), 2012 Second International Conference on. IEEE, 2012*.

[23] E. M. Royer and C. K. Toh, "A Review of Current Routing Protocols for Ad hoc Mobile Wireless Networks", *IEEE Journal of Personal Communication, vol. 6, no. 2, 1999, pages 46-55.*

[24] W. Abushiba and P. Johnson. "Performance comparison of reactive routing protocols for Ad Hoc network", *e-Technologies and Networks for Development (ICeND), 2015 Forth International Conference on*. *IEEE 23 Sep. 2015.*

[25] D. B. Johnson, D. A. Maltz and j. Broch. "The Dynamic Source Routing Protocol for Multi-Hop Wireless Ad Hoc Networks". *International Journal on Ad Hoc Networking, vol. 4, no. 1, 2001, pages 139-172*.

[26] S. H. Amer and J. A. Hamilton. "Performance evaluation: running DSR and TORA routing protocols concurrently", *presented at the 2007 summer computer simulation conference, 2007, pages1-5.*

[27] M. Gulati and K. Kumar, "Performance Comparison of Mobile Ad Hoc Network Routing Protocols." International Journal of Computer Networks & Communications (IJCNC), Volume 6, No.2, March 2014.

[28] S. B. Abdlatif, M. A. Rashid and F. Alam. "Profiling Delay and Throughput Characteristics of Interactive Multimedia Traffic over WLANs Using OPNET", *Computer and Information Science, IEEE/ACIS International Conference on, july2007.*

[29] A. Boukerche. "Performance evaluation of routing protocols for ad hoc wireless networks," *Mobile Networks and Applications, vol. 9, no. 4, pp. 333-342, 2004, published by springer*.

[30] S. R. Das, C. E. Perkins and E. M. Royer. "Performance Comparison of two on-demand routing protocols for ad-hoc networks", *IEEE International Conference on Computer Communications (INFOCOM) 2000.*