Performance Evaluation of End-to-End Delay per Packet Over MANET Reactive Routing Protocols

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Abstract:

Mobile Ad-hoc Networks or MANETs are characterized by connectivity via a collection of wireless mobile nodes. MANETs are organized in situations where no base station is available. However, numerous routing protocols have been developed particularly for these circumstances during the last years, to discover and maintain optimized paths from a source to an intended destination in the network. In this paper, we evaluate and analyze the performance of most important reactive routing protocols i.e. DSR and AODV based on end-to-end delay per packet. This evaluation and comparison is very useful for researchers in understanding the conditions and challenges for reactive routing protocols in mobile ad hoc setting and structures the basis of designing and developing a novel routing protocol. Our simulation results based on simulations carried out utilizing Global Mobile Simulator (GloMoSim). Practically, the performance evaluation of AODV and DSR protocols has done in three simulation scenarios with respect to End-to-End Delay per data packet. Consequently, simulations show that DSR protocol out performance AODV routing protocol in most cases of node mobility, offered load and network size.

Key words : End-to-End Delay, MANETs, AODV, DSR, Simulation.

الملخص

تتميز شبكات الحاسوب المتنقلة الخاصة أو شبكات (MANET) بالاتصال عبر مجموعة من العقد المتنقلة اللاسلكية. يتم تنظيم الشبكات الخاصة المتنقلة في الظروف التي لا تتوفر فيها محطة أساسية ثابتة لتأمين الاتصال بين اجهزة الشبكة. ومع ذلك ، فقد تم تطوير العديد من بروتوكولات التوجيه خاصة بهذه الظروف خلال السنوات الماضية ، وذلك لاكتشاف المسارات المحسنة وصيانتها لتأمين الارسال من العقدة المصدر إلى العقدة الهدف في الشبكة. في هذه الورقة ، قمنا بتقييم وتحليل أداء أهم بروتوكولات التوجيه التفاعلي مثل DSR و AODV بناءً على التأخير في ايصال البيانات من الطرف المرسل إلى الطرف المستقبل لكل حزمة بيانات تم ارسالها بالشبكة. يعد هذا التقييم والمقارنة مفيدًا جدًا للباحثين في فهم الظروف والتحديات التي تواجه بروتوكولات التوجيه التفاعلي في الإعدادات المخصصة للشبكات الخاصة المتنقلة وكذلك الهيكلة الأساسية لتصميم وتطوير بروتوكول توجيه جديد لهذا النوع من الشبكات. تعتمد نتائج المحاكاة لدينا على عمليات المحاكاة التي تم إجراؤها باستخدام محاكي يسمى المحاكي المتنقل العام (GloMoSim) . أما من الناحية العملية ، حيث تم تقييم أداء البروتوكولات الاكثر شهره وهما AODV و DSR ، وجرى هذا التقييم بالاعتماد على ثلاثة سيناريوهات محاكاة فيما يتعلق بالتأخير من طرف إلى طرف لكل حزمة بيانات تم ارسالها بالشبكة. وبعد عرض نتائج الجانب العملي للمحاكي، تُظهر تجارب المحاكاة أن بروتوكول توجيه المصدر DSR يتفوق على بروتوكول التوجيه AODV في معظم التجارب التي اعتمدت على ثلاثة معايير وهي تنقل العقدة والحمل الاظافي وحجم الشبكة.

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1. INTRODUCTION

Nowadays, MANETs have become very famous and popular research topic in the field of wireless networks. Basically, MANETs are the stand of Mobile Ad-hoc NETworks (MANETs). Practically, MANETs are unlike the conventional wireless networks that necessitate expensive infrastructure equipments to support mobility (Sarkar et al., 2013). In MANET, portable nodes are connected to each other via wireless links. However, these portable nodes perform as routers, whereas they maintain to forwarding and receiving data with each other to accomplish the data transmission task in the network. Logically, because of the restricted transmission range of mobile nodes, more than one hop possibly will be necessitated to send and receive the required data packets. Besides, MANETs are designed for dealing with all topology problems during network reconfigurations. For this concern, numerous routing protocols have been created for maintaining connections in MANETs (Quy et al., 2019), for instance reactive, proactive and hybrid routing protocols (Mohammed and Al-Ghrairi, 2019). In this research we will focus specifically on reactive protocols (such as Ad-hoc On-demand Distance Vector routing protocol (AODV) (Perkins and Elizabeth, 1999), and the Dynamic Source Routing protocol (DSR) (Johnson et. al., 2001). Basically, reactive protocol may cause some delay per data packet due to initial or recall new route discovery method. Also, the node mobility, the number of sources and the total number of nodes inside the network are both other factors which may possibly influence the performance of MANET. Consequently, it is necessary to recognize, how much effect of node mobility and the offered load of sources are there on MANET performance as the number of sources in high mobility environment may cause numerous broken links which will require more data packet drops and extra delays in reinitialize of new routes.

In this research, we study and evaluate the impact of the node mobility, the offered load and the network size (number of nodes in MANET) on the most famous reactive routing protocols AODV and DSR in three different scenarios, and they are evaluated and analysed on major network performance metric specifically End-to-End delay per data packet. We have utilized Global Mobile Simulator (GloMoSim) for simulations.

The rest of this paper is constructed as: Part II: literature review is given. Part III present a methodology followed. Part IV illustrates a simulation and performance evaluation. Part V shows the simulation results and discussions.

2. ROUTING PROTOCOLS FOR MANETS

Generally, several routing protocols have been presented for MANETs (Mishra et al., 2019) (Quy et al.,2019) (Shantaf et al., 2020). As mentioned earlier in the previous section, MANET routing protocols could be divided into three categories: proactive, reactive, and hybrid routing protocols. Fig.1 shows a number of routing protocols for MANETs.

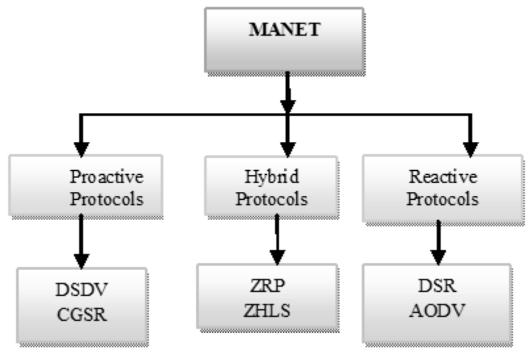

Fig. 1: Routing Protocols of MANETs

Reactive routing protocols - as well named "on-demand" routing protocols, which presented for MANETs. Basically, reactive routing protocols (for example Ad-hoc On-demand Distance Vector routing protocol (AODV) (Perkins and Elizabeth, 1999), and the Dynamic Source Routing protocol (DSR)) (Johnson et. al., 2001) are based on demand for dealing with data transmission processes in the network. Generally, reactive protocols can significantly decrease the routing overhead when the traffic is lightweight and the topology of MANET transforms less dramatically, since these protocols do not necessitate to periodically update route information and do not necessitate to discover and preserve the routes between nodes when there is no traffic in the network. However, the differences among this kind of protocols lie in the implementation of the route finding system and optimizations to it.

- *Proactive Routing Protocols* - as well named "table driven" routing protocols, which presented for MANETs. Basically, proactive routing protocols (for example Destination-Sequenced Distance Vector protocol (DSDV) (Perkins and Pravin, 1999), and the Wireless Routing Protocol (WRP) (Murthy and Garcia, 1996) desecrate limited bandwidth via constantly uphold the entire routing information relating to the whole MANET. However, proactive routing protocols react to topology changes all the time, even if there is no data traffic needed in the network. Moreover, reactive protocols in MANET environments differ in the number of routing tables maintained, since the routing information of each routing table includes the details of how they are updated.
- *Hybrid Routing Protocols*- the third kind of MANET routing protocols, since it merge both proactive and reactive strategies to discover the required routes in the network. However, Zone-Based Hierarchical Link State Routing (ZHLS) (Joa-Ng and Lu, 2006) is the popular one of hybrid routing protocols. In ZHLS, the entire network is separated into non-overlapping zones. Fundamentally, ZHLS is working as proactive if the traffic destination node is inside the same zone of the source node, while it is working as reactive because a location search is required to discover the zone of the intended destination node in the network.

3. RELATED WORK

Since routing protocols for MANETs demonstrate significant design challenges, several research attempts have been directed to developing and comparing well-known routing protocols of MANETs, some of which are significance discussing.

Work by (Hakak et al., 2014) presented and analysed the effect of three key factors specifically Routing Protocol, Packet Size and Node Mobility Pause time, since these factors was evaluated on couple MANET performance parameters explicitly Average

Delay and Average Jitter, as these performance parameters are essential for MANET performance along with directly influences the buffering conditions for all video devices and downstream network. In addition overload cost of Delay and Jitter can launch several issues ranging from lip-synchronization problem to the failure of data packets because of buffer overflow or underflow.

Work by (Zafar et al., 2016) analyzed and compared three important routing protocols from both reactive and proactive protocols in terms of throughput, end-to-end delay and packet delivery ratio. Their simulation results were based on number of simulations approved out utilizing Network Simulator (NS2). Simulation results proved that DSR protocol offers superlative performance as compared to DSDV (Destination Sequenced Distance Vector) and AODV routing protocols when Network Size is large and Node Mobility is high.

(Das et al., 2019) studied the impact of propagation models on distance vector routing protocols specifically AODV and DSDV for MANET, since their performance is evaluated utilizing end-to-end delay, packet delivery fraction (PDF), and energy consumption. Both routing protocols (AODV and DSDV) are estimated with different node densities in two scenarios (static and mobile mode). Moreover, the models used in MANET are two-ray ground, free-space and shadowing. The simulation results of this work demonstrates that, in term of packet delivery fraction, as the number of nodes reduces, whereas the Shadowing model is not as severe as the two-ray ground model. On the other hand, with a raised number of nodes in MANET, the Two-ray ground outperforms the shadowing model. As well, as mobile nodes move in high mobility speed and the number of mobile nodes raises, the PDF reduces slowly, whereas in terms of end-to-end delay, as the number of nodes raises the delay as well raises. This work considers that dissimilar propagation models possibly will influence AODV and DSDV routing protocols in regards to end-to-end delay, packet delivery fraction and energy consumption.

Study by (Chavana, 2016) have analyzed two protocols for MANETs, Ad hoc on demand distance Vector Routing (AODV) as reactive routing protocol), and Destination Sequenced Distance Vector (DSDV) as a proactive routing protocol in terms of average of end-to-end delay, packet delivery fraction, throughput and routing overhead. The performance result of this study shows that AODV is better than DSDV in terms of throughput, packet delivery fraction and routing overhead.

Work by (AL-Dhief et. al., 2018) has presented the performance comparison between three routing protocols for MANETs, DSR and AODV as reactive routing protocols, and DSDV as a proactive routing protocol to specifically determine which routing protocol of MANETs is more efficient. Since the performance of these protocols have been simulated and evaluated using Network Simulator (NS2) in terms of the packet delivery ratio (PDR), throughput, end-to-end delay, and packet loss ratio (PLR)with respect to network size (the variable number of nodes) in the network. The simulation results have shown that DSDV is superior to DSR and AODV protocols in terms of PDR and PLR, whereas AODV protocol is superior to DSDV and DSR protocols in terms of throughput. DSR protocol is superior to other protocols in end-to-end delay. However, this research concluded that DSDV protocol is the best routing protocol as compared to AODV and DSR protocols.

4. REACTIVE ROUTING PROTOCOLS

4.1. AODV: Ad-hoc On-demand Distance Vector Protocol

Ad hoc On-demand Distance Vector protocol, also called AODV. It is a universally accepted reactive routing protocol in MANET society. AODV was designed by C. E. Perkins and and Elizabeth in1999. In the main, AODV is a blend of two routing protocols i.e. DSR and DSDV (Shantaf et. al., 2020). However, the AODV protocol generates a path to an intended destination node only in on-demand mode. In MANET, AODV protocol remains silent until a connection is necessitated. Once a source node requires a connection to a destination node, it begins propagates a route request (R.REQ) message to the required destination node in the MANET (Mishra et al., 2019). As well, other neighboured nodes (except the destination node) broadcast the received R.REQ message; in addition each node has to record the node that they received it from. Whereas an intermediate node receives a R.REQ and already has a route in its routing table to the required destination node, it starts to send a route reply (R.REP) message towards the back to the main source node. In contrast, when the source receives more than one R.REP message, it picks the R.REP message that has the fewest number of hops (Prakash et al., 2013). In case of link failures, a route error (R.ERR) message transmits back to the source of R.REQ message. When the main source node received the R.ERR message, it reruns a new route discovery procedure again in the network.

4.2. DSR: Dynamic Source Routing Protocol

Principally, DSR is a reactive (or on-demand) routing protocol. DSR protocol was designed for MANET by D. B. Johnson, Maltz and Broch in 2001. Basically, when a source node desire to send data to an intended destination node which is not appear in its route cache, the main source node directly buffer its data and start to propagate a R.REQ message to its neighbour nodes in the network, and then the neighbour nodes propagate the R.REQ message again for the intended destination in the network (Mishra et al., 2019). In contrast, when the destination node receives R.REQ message; immediately it start to send a Route Reply (R.REP) message on the reverse route back to the main source node of R.REQ message. On the other hand, if the sent R.REP is not received by the main source after a permanent number of attempts and within the NTT (Net _Traversal _Time), immediately the intermediate nodes will erase the data packets from their routing buffer, whereas if more data packets are still waited at the buffer of the main source node these data packets, a new path discovery procedure will be rerun to send the remaining data packets. Moreover, whereas the main source node receives a R.REP, it stores the received route in its route cache, and then it starts to sends its data to the intended destination node. In case of failure route a route maintenance procedure will started, since the intermediate nodes send back Route Error (R.ER) message to the main source node of data, flowed by rerun a new route discovery in the network (Mohammed and Al-Ghrairi, 2019).

5. END-TO-END DELAY OF REACTIVE PROTOCOLS

Basically, the typical of end-to-end delay of reactive routing protocols (such as AODV and DSR) is all the expected delays that are caused as a consequence of buffering at the time of path discovery queuing, transfer, retransmission delays, latency and broadcast times (Sugandhi et. al., 2016). In other words, the end-to-end delay means that the entire time taken via the file to arrive from the source node to the intended destination node, and include of all the different delays experienced by the data packets through their passage from sender to receiver. However, End-to-end delay is a very significant performance routing metric in MANETs essentially in real-time applications, since it indicates to the overall time experienced by a single data packet transmitting from source node to destination node in a MANET (Adam and Hassan, 2013). Generally, the raise of end-to-end delay time may cause by congestion and/or collision, in addition other operators like the length of the path. However, it is important for MANETs to avoid network end-to-end delay, in order to improve MANETs' performance in general. Mainly, the delay of MANET has several types (Perkins et. al., 2001) (Bisnik et. al., 2006) (Zafar et. al., 2016) the most important of which are the following:

- Transmission delay: it is the time taken by the sender to transfer bits in a packet on the link.
- Propagation delay: it is the time taken by the packets to reach from one end of the link to the other end.
- Queuing delay: it is the delay experienced by packets during waiting in router buffer before being served or transmitted.
- Processing delay: it is the delay experienced by the packet during its processing at the router that is when routing consults its routing tables to determine where to forward the packet.
- Transmission delay: it is affected by the link bandwidth.
- Propagation delay: it is the time to broadcasting the control packets in the network, and it depends on link speed.
- Queuing delay: it is flexible and varies significantly from one packet to the other, thus measured as average queuing delay.
- Processing delay: it depends on router processing capability and router load. It also includes the retransmission delay between intermediate nodes.

Basically, for typical end-to-end delays every delay is added for successively data packet and then will divided by the total number of successively received data packets. Fundamentally, a minor value of end-to-end delay in a routing protocol performs effective routing protocol for MANETs, since the end-to-end delays are very important for applications that utilize voice and video data transmissions in MANT environments (Mishra et. al., 2019), the formula for end-to-end delay is in this manner:

$$End-to-end\ delay = \frac{1}{N}\sum_{n=1}^{N}(R_n - S_n)$$

Where
S_n = Time at which *nth* data packet is sent
R_n = Time at which *nth* data packet is received
N = Number of data packets received

6. IMPLEMENTATION

- In this section, based on the effect of the network size, the offered load and node mobility on the end-to-end delay per packet an evaluation between the simulation results of the typical AODV and DSR protocols will be presented, as well as present a discussion of these simulation results.

6.1 Simulation Environment

- In order to build fair evaluations between the recommended reactive routing protocols specifically AODV and DSR, it is essential to challenge the particular routing protocols with the same loads and environmental conditions. In the methodology of this research, three different scenarios are described in this research. We have prepared scenario for each experiment. In the first scenario (in Section 7.1), we show some of the impact of node mobility (varying of pause time) on the performance of the two reactive protocols (i.e. AODV and DSR) for MANETs. The second scenario (in Section 7.2) explains the impact of utilizing different network sizes (varying of mobile nodes) on the performance of same protocols AODV and DSR. The third scenario (in Section 7.3) describes the impact of utilizing different number of source nodes on the performance of these reactive protocols.
- Practically, we simulated a number of mobile nodes shaping a MANET, movable in a simulation area (2200m x 600m) flat space, and simulation time was 900 sec. Nodes in the simulation area move compatible with the random waypoint model, whereas the speed of mobile nodes between 0 m/sec and some maximum speed, and the period of the simulation (900 seconds). However, the communication model that utilized in these simulations is constant bit rate (CBR) traffic, while the size of each packet of data is 512 bytes. Each data point symbolizes an average of 5 runs of the simulator with the same traffic models, excluding different randomly produced mobility scenarios. The three scenarios of experiments employ the simulation parameters presented in Tables (1, 2, and 3).
- 6.2. Simulation Results and Discussions
- This section reports on three scenarios of experiments manifesting the impact of: Node Mobility, Offered Load, and Network Size with respect to End-to-End delay per data packet in the MANET. The simulation results bring out numerous significant characteristic differences in the recommended reactive routing protocols (DSR and AODV). However, we discuss these presented scenarios in the following subsections.

6.1. Scenario 1: Effect of Node Mobility on End-to-End delay

Basically, this set of experiments varies the node mobility (the pause time of node) to show the impact of mobility on the performance of AODV, and DSR with respect to End-to-End delay per data packet. However, this scenario simulates a 50 mobile node in MANET network. Basically, the mobility (varying pause time of nodes) is changing between 0, 300, 600 and 900 seconds. Specifically, varying the pause time changes the frequency of node movement, while the mobile node speed is selected: 0 m/sec as low speed and 10 m/sec as high speed of mobile node in the MANET. In addition, the MANET consists of 10 CBR/UDP traffic source nodes sending 512 byte data packets to the selected destination nodes at the rate of 4 packets/sec, since the entire simulation time is 900 sec. Table 1 explains the major simulation parameters in this scenario.

Table 1: Simulation Parameters for Scenario 1

Parameter	Value
Routing Protocol	AODV / DSR
Simulation Duration	900 sec
Number of Mobile Nodes	50 nodes
Pause Time of Mobile Node	0, 300, 600 or 900 sec
Speed of Mobile Nodes	0-10 m/sec
Number of Source Nodes	10 sources
Terrain-Dimensions	2200m x 600m
Mobility Model	Random Way-point Model
Bandwidth (in bits per second)	2Mbps
Mac-Protocol	802.11
Promiscuous-Mode	Yes
Network-Protocol	TCP - UDP
Data traffic – CBR	4 UDP packets a second
Packet Size	512 bytes

As result of scenario (1), Figure 2 illustrates the Average End-to-End Delay for AODV and DSR in different Node Mobility cases (by varying of Pause Time 0, 300, 600 or 900 sec) environments. The figure clearly shows that AODV demonstrates significantly the highest end-to-end delay is higher for all mobility environments (excepting when mobility is very high), this is due to the policy of route discovery process of AODV, since it periodically flooding route request messages in the network instead of using cache route to keep the previous discovered routes for future use, which is the main reason of the high end-to-end delay in AODV. On the hand, DSR presents the lowest end-to-end delay in most node mobility cases (when pause time is 300, 600 and 900 sec), which indicate that DSR presents the lowest end-to-end delay per packet in medium and low mobility networks. Whereas DSR gives the highest end-to-end delay in case of the mobility is very high (Pause Time=0), which mean nodes always move and will stop the mobility in the network. The major reason is that DSR uses cached route, which usually become broken routes due to the high speed of nodes in the network.

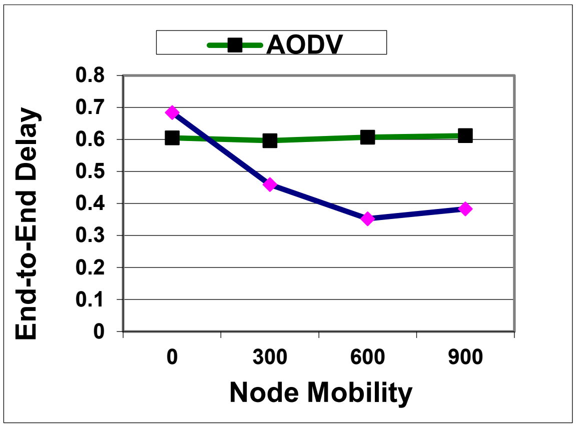

Fig. 2: End-To-End Delay by Node Mobility

6.2. Scenario 2: Effect of Offered Load on End-to-End delay

This set of experiments varies the number of source nodes to show the impact of number of sources on the performance of AODV and DSR. The simulations are performed for 5, 8, 10 and 12 source nodes. However, Table 2 shows the simulation parameters that utilized in Scenario 2.

Table 2: Simulation Parameters for Scenario 2

Parameter	Value
Number of Source Nodes	5, 8, 10 or 12 sources
Number of Mobile Nodes	50 nodes
Pause Time of Mobile Node	300 sec
Routing Protocol	AODV / DSR
Simulation Duration	900 sec
Speed of Mobile Nodes	0-10 m/sec
Terrain-Dimensions	2200m x 600m
Mobility Model	Random Way-point Model
Bandwidth (in bits per second)	2Mbps
Mac-Protocol	802.11
Promiscuous-Mode	Yes
Network-Protocol	TCP - UDP

Data traffic – CBR	4 UDP packets a second
Packet Size	512 bytes

As result of scenario (2), Fig. 3 shows the End-to-End Delay for variations of the number source nodes (5, 8, 10 or 12 sources) in the network for AODV and DSR protocols. The figure illustrates that AODV demonstrates significantly the highest End-to-End Delay for most cases of the number source nodes. As we mentioned in the previous scenario, AODV suffers from its policy of periodically route discovering process due to the number of control packets being propagated in the network, in addition to increase the number of source nodes, which also increasing the number of route discovering process in the network. On the other hand, DSR gives the lowest End-to-End Delay in the network (excepting when number of sources in the network is very high (12 sources)). The main causes for the low End-to-End Delays in DSR are the organized technique of route caching, which offers the required route to intended destination instead of calling a new route discovery, in addition to its packet salvaging process which repair the selected route and selvage its transmitted data packets, since all of this reduce the repeatedly route discovery processes in the network.

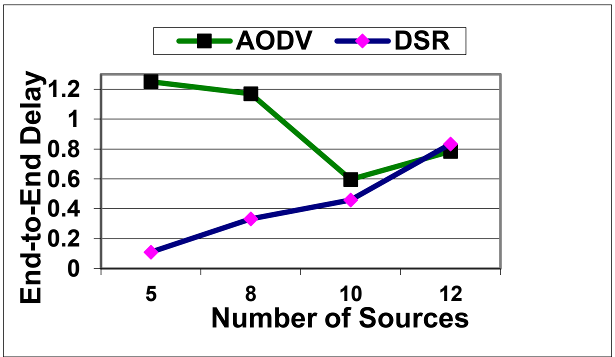

Fig. 3: End-to-End Delay by varying Number of Sources

6.3. Scenario 3: Network Size vs. End-to-End delay

Basically, this set of experiments varies the number of nodes (30, 40, 50 or 60 nodes) in the MANET to explain the impact of network size on the performance of AODV, and DSR. The simulations are performed for 30, 40, 50 and 60 nodes. However, we assume that the size of network has four cases (high density size networks=60 nodes, density size networks=40 nodes, medium size networks=40 nodes, and small size networks=30 nodes). Whereas the pause time is used: 300 seconds correspond to a dynamic network. The simulation results are collected at highest speed of 10 m/s. Table 3 shows the simulation parameters that used in Scenario 3.

Table 3: Simulation Parameters for Scenario 3

Parameter	Value
Number of Mobile Nodes	30,40,50 or 60 nodes
Number of Source Nodes	10 sources
Pause Time of Mobile Node	300 sec
Routing Protocol	AODV / DSR
Simulation Duration	900 sec
Speed of Mobile Nodes	0-10 m/sec
Terrain-Dimensions	2200m x 600m
Mobility Model	Random Way-point Model
Bandwidth (in bits per second)	2Mbps
Mac-Protocol	802.11
Promiscuous-Mode	Yes
Network-Protocol	TCP - UDP
Data traffic – CBR	4 UDP packets a second
Packet Size	512 bytes

As result of scenario (3), Fig. 4 explains the End-to-End Delay per data packets for variations of the size of the network for AODV and DSR. The Figure obviously illustrates that AODV gives significantly the highest End-to-End Delay is higher for density and high density size networks follows by DSR. This is due to the frequently route discovery process of ADOV, which push the total End-to-End Delay per data packets to get higher with increasing of the size of network, since the excessive number of control packets being propagated in the network. These End-to-End Delays result in data packets waiting in the queues being removed. On the other hand, DSR provides slightly higher End-to-End Delay per data packets in case of small and medium size networks. The main causes for the large End-to-End Delays in DSR are the lack of a technique to get rid of expired and stale routes from its route caches, together with the excessive employ of route caching instead of run a new route discovery process.

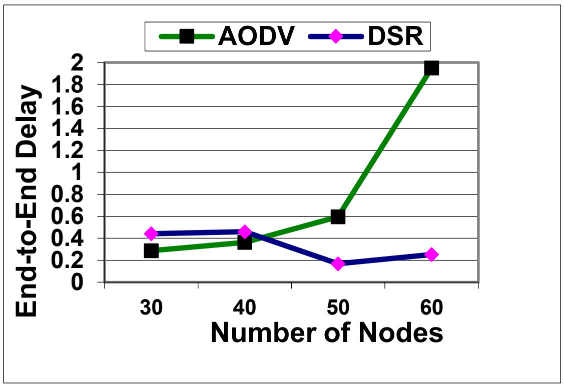

Fig. 4: End-To-End Delay by varying Number of Nodes

7. CONCLUSION AND FUTURE WORK

The high-level contribution of this article is a simulation-based performance evaluation of two reactive different MANET protocols: Ad-hoc on demand vector (AODV) protocol and Dynamic Source Routing (DSR) protocol utilizing GloMoSim simulator. The simulations have been conducted via three different scenarios (node mobility, network size and offered load) in the simulated network. Practically, the performance is evaluated with respect to End-to-End Delay per data packet in MANET. However, it can be observed that while deploying these scenarios on AODV and DSR in MANET. As we observed for DSR protocol, the most important factor to keep the average of end-to-end delay at optimum level is to give priority to Node Mobility followed by Offered Load as both of these factors has important impact on the network performance metrics. On the other hand, as we observed for AODV protocol, the most important factor to keep the average of end-to-end delay at optimum level is to give priority to less cases of the selected factors, such as Node Mobility in high speed mode only, followed by Network Size in case of medium and low number of nodes, while AODV has worst level in case of Offered Load factor. Consequently, the simulations and investigations prove that DSR protocol achieved better performance than AODV in term of end-to-end delay per packet in the network.

Future work can be featured by estimating the effect of these factors on other important metrics of MANET performance such as: Routing Overhead, Packet Delivery Ratio and Throughput.

REFERENCES

1. Adam SM, Hassan R. Delay aware reactive routing protocols for QoS in MANETs: A review. Journal of applied research and technology. 2013;11(6):844-50.
2. AL-Dhief, Fahad Taha, Naseer Sabri, M. S. Salim, S. Fouad, and S. A. Aljunid. "MANET routing protocols evaluation: AODV, DSR and DSDV perspective." In *MATEC web of conferences*, vol. 150, p. 06024. EDP Sciences, 2018.
3. Bisnik, Nabhendra, and Aihussein A. Abouzeid. "Queuing delay and achievable throughput in random access wireless ad hoc networks." In 2006 3rd Annual IEEE Communications Society on Sensor and Ad Hoc Communications and Networks, vol. 3, pp. 874-880. IEEE, 2006.
4. Chavana, P. D. (2016). Performance Analysis of AODV and DSDV Routing Protocol in MANET and Modifications in AODV against Black Hole Attack. 7th International Conference on Communication, Computing and Virtualization, 835-844.
5. Das A. and S. Mohapatra, "Impact of propagation models on distance vector routing protocols in MANET," *VLSI Signal Processing and Trends in Telecommunication*, pp. 56 – 60, 2019.
6. Hakak S., F. Anwar, S. A. Latif, G. Gilkar and M. K. Alam, "Impact of Packet Size and Node Mobility Pause Time on Average End to End Delay and Jitter in MANET's," *2014 International Conference on Computer and Communication Engineering*, Kuala Lumpur, Malaysia, 2014, pp. 56-59, doi: 10.1109/ICCCE.2014.28.
7. Joa-Ng, M. and Lu, I. T. "A peer-to-peer zone-based two-level link state routing for mobile ad hoc networks." IEEE Journal on Selected Areas in Communications 17.8 (2006): 1415-1425.
8. Johnson, D. B., Maltz, D. A., and Broch, J., "DSR: The dynamic source routing protocol for multi-hop wireless ad hoc networks". Ad hoc networking, 5 (2001): 139-172.
9. Mishra, A., Singh, S. and Tripathi, A.K.," Comparison of MANET routing protocols.", International Journal of Computer Science and Mobile Computing, IJCSMC, Vol. 8, Issue. 2, pg.67 – 74, 2019.
10. Mohammed, Ali Abdul Wahhab, and Assad H. Thary Al-Ghrairi. "Differences between Ad Hoc Networks and Mobile Ad Hoc Networks: A Survey." Journal of Southwest Jiaotong University 54.4, 2019.
11. Murthy and J. J. Garcia-Luna-Aceves, "An Efficient Routing Protocol for Wireless Networks," "ACM Mobile Networks and App. J., Special Issue on Routing in Mobile Communication Networks", Oct. 1996, pp. 183–97.
12. Perkins, Charles E., and Elizabeth M. Royer. "Ad-hoc on-demand distance vector routing." Proceedings WMCSA'99. Second IEEE Workshop on Mobile Computing Systems and Applications. IEEE, 1999.
13. Prakash, S., Saini, J. P., and Gupta, S. C. "A Comparative Analysis of Reactive and Proactive Routing Protocols in Mobile Ad-hoc Networks". IJAIR, 2.4(2013):315-321.
14. Quy, V. K., Ban, N. T., Nam, V. H., Tuan, D. M., & Han, N. D. " Survey of recent routing metrics and protocols for mobile Ad-hoc networks", Journal of Communications, 14(2), 110-120, 2019.
15. Sarkar, S. K., Basavaraju, T. G., and Puttamadappa, C. Ad Hoc Mobile Wireless Networks: Principles, Protocols, and Applications. 2nd Edition, CRC Press, FL, USA, 2013.
16. Shantaf, Ahmed Muhi, Sefer Kurnaz, and Alaa Hamid Mohammed. "Performance Evaluation of Three Mobile Ad-hoc Network Routing Protocols in Different Environments." 2020 International Congress on Human-Computer Interaction, Optimization and Robotic Applications (HORA). IEEE, 2020.
17. Sugandhi, Pooja, and Chhaya Nayak. "A review of performance evaluation and enhancement of proactive and reactive routing protocols of MANET." Int. J. Rapid Res. Eng. Technol. Appl. Sci 2 (2016): 1-6. (Sugandhi et. al., 2016).
18. Zafar S, Tariq H, Manzoor K. Throughput and delay analysis of AODV, DSDV and DSR routing protocols in mobile ad hoc networks. International Journal of Computer Networks and Applications (IJCNA). 2016 Mar;3(2):1-7.