Ad Hoc On-demand Multipath Distance Vector Based Routing in Ad-Hoc Networks

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***Abstract*—**In this paper, AOMDV (Ad hoc on-demand distance vector) routing protocol has been analysed based on different performance parameters in different network scenarios. Performance parameters like normalized routing load (NRL), throughput, dropped packets, receiving packets, average delay. At different values of network connections, pause times, simulation times, and speed rates, we compared performance of AOMDV with AODV(Ad hoc on-demand distance vector), DSDV(Destination-Sequenced Distance Vector), and DSR(Dynamic Source Routing) routing protocols. For simulation work, network-simulator 2.35 has been used.

***Index Terms*—**E2E delay, throughput, dropped packets, network connections, pause time

I. Introduction

Mobile ad-hoc networks (MANETs) are the popular networks that are frequently used ad-hoc networks because of ease of installation and low cost [1]. Routing in such types of networks is a big challenge. Because of nodes changes their position frequently. Also performance of various routing protocols during connection establishment is a big task. To reduce the packet loss and end-to-delay, several routing protocols like AODV have been enhanced. Similar type of modified extended version of AODV is AOMDV routing protocol which is a multi-route, disjoint path, and loop free protocol [2]. AODV, DSR [3], and DSDV [4] are three main routing protocols that are used in Mobile ad-hoc networks [5]. All these have some features that vary depends on network conditions. Extended versions of these routing protocols have been proposed by several researchers. AOMDV [6] is the extended version of AODV. AODV is single path routing protocol while AOMDV is multi path routing protocol. Performance of AOMDV is evaluated in different network scenarios with several performance parameters [7]. Some researcher analysed AOMDV with network size and speeds while others evaluated with various traffic rates and pause times. AOMDV routing protocol is loop free and disjoint path based protocol in mobile ad-hoc networks. Basic working principal of AOMDV is same as AODV. There are some rules for AOMDV which have to follow while taking decision for connection establishment.

We can classified routing protocols in MANET based on routing information update. First reactive routing protocols like AODV, AOMDV, and DSR. These are on demand routing protocols. They do not main topology. Other category is proactive routing protocols like DSDV. They are table driven routing based protocols. They update network topology information in routing table.

- AODV and AOMDV routing protocols both are reactive routing protocols.
- Routing table in AODV and AOMDV are same, the main difference is that instead hop count, in AOMDV use advertisement hop count.
- During route discovery phase in AOMDV, it maintains multiple paths from source to destination.
- In AODV, when destination receives same copy of two route request protocols(RREQ) from source to destination, only first route request(RREQ) will be entrainment, while other coming after will be dropped.
- AOMDV having two components:
    - ✓ Maintaining multiple loop free paths for source to destination.
    - ✓ Maintaining multiple link disjoint paths,
- Link disjoint path: from source S to destination D, it might be possible multiple paths. Multiple paths which have not any path common
- In this paper AOMDV routing protocol is evaluated with some performance parameters like throughput, end-to-end delay, normalized routing load, dropped packets etc. at the same time AOMDV is compared with existing AODV routing protocol [8]. Some best features and drawbacks identified during simulation work. Simulation results were carried out using network simulator (NS-2.35) [9]. This paper is partitioned in five sections. In section II, related work is described. Research methodology is discussed in section III. Section IV elaborates about the simulation results and discussions based on these results. Conclusion part is discussed in section V.

II. Related Work

Fan Zi Fu *et al*. proposed an optimized AOMDV routing protocol. In this work, standby route invalidation problem in wireless sensor networks is solved [10]. For this, AOMDV is enhanced in the form of ANS-AOMDV (Adaptive Node Speed-AOMDV). Here, route reconstruction times are improved under high speed network scenarios. Comparative analysis of ANS-AOMDV, AOMDV, and MP-AOMDV is carried out.

Manuscript received January 20, 2019; revised July 8, 2019.
doi:10.12720/jcm.14.8.706-714

Route consumption time and route reconstruction time were considered as performance parameters. Updating of standby routes is completed using SFM (Speed Field Message) and SFMR (Speed Field Message Reply) messages. It is observed form simulation results that ANS-AOMDV performs best better as compared to AOMDV and MP-AOMDV routing protocols at high speed network environment.

Manveen Singh Chadha et al. compared the AODV, DSR and AOMDV routing protocol in mobile ad-hoc networks based on different network parameters like end-to-end delay, throughput, number of connections, packet delivery fraction [11]. Route discovery, route maintenance of AODV, DSR and AOMDV is also elaborated in detail. For simulation results, network simulator NS-2.34 was used. CBR and TCP type of traffic was applied with maximum 50 network connections. Packet delivery ratio and throughput for AOMDV was declared as best. DSR performs better with respect to end-to-end delay as compared to AODV and AOMDV routing protocols.

In [12] Vinod Kumar et al. proposed a load-balancing scheme in wireless ad-hoc networks. Here, the AOMDV routing protocol is enhanced with minor changes. Routes are decided on the basis of hop count and queue length. Route requests may be rejected depends on the length of queue. Proposed enhanced protocol AOMDV-LB (AOMDV-Load Balancing) is evaluated and compared with AOMDV using three performance metrics (packet loss rate, end-to-end delay, load distribution). For each route request, threshold value is calculated. AOMDV-LB performs better with high traffic loads. End-to-end delay for AOMDV-LB is also less as compared to AOMDV. Using NS-2, a simulation environment was created for 25 nodes.

Vivek B. Kute *et al*. [13] analysed AOMDV routing protocol for CBR and TCP traffic at various data packet generation rates. Several issues and challenges are also discussed with respect the quality of services. Using network simulator (NS-2.34), network environment was produced for TCP and CBR traffics. AOMDV was compared with AODV at various packet generation rates with respect to average delay, route discovery frequency, routing overhead, throughput.

It was concluded that AOMDV is consistent with TCP traffic at various data packet generation rates. But, its performance degrades for CBR traffic at various data packet rates.

To ensure loop free and disjoint paths in AODV, AOMDV routing protocol proposed by Mahesh K. Marina and Samir R. Das in [14]. It is extension of AODV routing protocol having multipath routing capability. AODV was discussed with its features and drawbacks. After that enhancement of AODV referred as AOMDV is discussed with its routing algorithmic steps. Route discovery, route maintenance for AOMDV was elaborated in detail. Performance evaluation and comparison work was carried out with several metrics like packet loss, route discovery latency, average delay, mean node speed. It was concluded that AOMDV having better performance at higher mobility environment.

To reduce the drawback and to enhance the performance of AOMDV, NS-AOMDV (Node State based AOMDV) routing protocol is proposed by Jieying Zhou et *al*. in [15], on the basis of node state, routing paths are decided. Node state factor is calculated on the basis of residual energy rate, idle rate of buffer queue, and node weight. On The basis of path weight (PW) value, routes are decided for forwarding the packets.

NS-AOMDV is simulated in network simulator (NS-2.35) by considering the performance parameters like throughput, normalized routing overhead, and average end to end delay. By varying the mobility and pause times, performance of AN-AOMDV was evaluated. It was concluded on the basis of simulation results that AN-AOMDV produces best results in higher mobility and pause times network scenarios.

In [16], Poonam and Preeti Deskhmukh suggested AOMDV routing protocol for wireless sensor networks to reduce the energy consumption and packet loss. Calculation of disjoint paths, routing tables, route discovery, and route maintenance are elaborated in details. Drawbacks and advantages of AOMDV over AODV, DSR are highlighted. This paper concluded that AOMDV produces better results as compared to DSR and AODV routing protocols. Authors suggested for using clustering approach with AOMDV routing protocol.

A comparison of AODV and AOMDV is carried out by Pankaj Oli and Vivek Kumar Gupta in [17]. Several parameters like throughput, packet delivery ratio, packet dropped, normalized routing load, end-to-end delay were used for performance evaluation. Simulation work was performed on the platform of network simulator (NS-2.34). This paper concluded that at higher pause times, throughput of AOMDV is higher than AODV routing protocol. Packet dropped rate for AODV is higher at higher pause times. End-to-end delay for AOMDV is less at all levels of pause times. Authors concluded that AOMDV outperform than AODV routing protocol at different network scenarios.

A. Marcy Rani *et al*. [18] used square and triangle based technologies to evaluate the AOMDV routing protocol in wireless mesh network. In this paper, varying the pause time and transmission rates, AOMDV has been analysed using different metrics like end-to-end delay and dropped packets. It is concluded that AOMDV outperforms at 20 pause time, but routing overhead is high for the same pause time (i.e. pause times20). When transmission rate is low, end-to-end delay is high for AOMDV.

In [19], a modified AOMDV routing protocol named DRE-AOMDV (Delay Renaming Energy AOMDV) is proposed. In this protocol, handoff occurs through link availability estimations. The end-to-end delay for modified AOMDV is less as compared to AOMDV routing protocol. Routing controlled overhead for proposed AOMDV is higher than AOMDV. This paper concluded that proposed AOMDV reduces PDR (Packet Delivery Ratio) than AOMDV.

A comparison work of AODV and AOMDV routing protocols has been carried out by S.R. Biradar *et al*. in [20]. Packet delivery ratio and routing overhead were considered as performance parameters. Varying the CBR connections and pause times, simulation results were carried out at the platform of network simulator (NS-2.34). This paper concluded that AOMDV works well at heavy traffic loads than AODV routing protocol. Overall routing overhead for multipath routing protocol (AOMDV) declared as low as compared to AODV.

In [21] , a modified multipath routing protocol referred as RB-AOMDV (Receiver-based AOMDV) is proposed by Abdulaziz *et al*. the proposed protocol takes less time in discovery phase during establishing the connections. Through simulation results, it was claimed that delay and delivery ratio performance metrics were better in proposed protocol. Also single path (AODV) and multipath (AOMDV, RB-AOMDV) routing protocols were compared at various number of nodes and traffic loads. Performance parameters like normalized routing load, end-to-end delay, packet delivery ratio were used to get the simulation results using network simulator (NS-2.35).

III. Methodology

For Simulation purpose, network-2(NS-2.35) was used at Linux platform (Ubuntu 16.5). We conducted simulations for AODV, AOMDV, DSDV, and DSR routing protocols in different network conditions like speed, connection, simulation time, and pause time.

We conducted simulation work for six different network scenarios. Performance parameters were considered as: Normalized Routing Load (NRL), throughput, E2E delay (End-to-End delay), speed, network connection, pause time, received packets, dropped packets, average delay, and simulation time.

TABLE I: DIFFERENT NETWORK SCENARIOS WITH PERFORMANCE PARAMETERS

Network parameters	Scenario-III	Scenario-IV
Layer Type	Link layer	Link layer
MAC Type	802.11	802.11
Connections	20	20
Nodes	31	31
Protocols	AODV, AOMDV, DSR, DSDV	AODV, AOMDV, DSR, DSDV
Network size	971×591	971×591
Simulation time	10,20,40,60,80 ,100	100s
Antenna Type	Omni Antenna	Omni Antenna
Pause time	0	0
Max speed	20	10,30,40.60,80,85,90,100,120,150,200,250,280
Sent rate	.25	.25
Seed	1	1
Packet size	512	512
Interval	.25	.25
Traffic type	CBR	CBR
Connection type	UDP	UDP
Network model	Two Ray Ground	Two Ray Ground
CBR rate	4.0 Mb	4.0 Mb
Channel type	Wireless Channel	Wireless Channel

TABLE II: PARAMETERS FOR SCENARIO-I AND SCENARIO-II

Network parameters	Scenario-I	Scenario-II
Layer Type	Link layer	Link layer
MAC Type	802.11	802.11
Connections	5,10,12,15,18,20,25,30	10
Nodes	31	31
Protocols	AODV, AOMDV, DSR, DSDV	AODV, AOMDV, DSR, DSDV
Network size	971×591	971×591
Simulation time	100s	100s
Antenna Type	Omni Antenna	Omni Antenna
Pause time	30	0,10,30,40,60,80,90
Max speed	30	30
Sent rate	.25	.25
Seed	1	1
Packet size	512	512
Interval	.25	.25
Traffic type	CBR	CBR
Connection type	UDP	UDP
Network model	Two Ray Ground	Two Ray Ground
CBR rate	4.0 Mb	4.0 Mb
Channel type	Wireless Channel	Wireless Channel

TABLE III: TEST-I

Parameter	Description
Pause times	0,10,30,40,60,80,90
Protocols	AODV,AOMDV,DSDV,DSR
Network size	x=971, y=591
Simulation time-	100s
Nodes	31
Antenna	Omni Antenna
Model	Two Ray Ground
Max seed	30 m/s
Max Connections	10
Packet size	512
Connection type	UDP
Traffic type	CBR
Rate	4.0 Mb

TABLE IV: TEST-II

Parameter	Description
Speed	30,40,60,80,85,90,100, 120,150,200, 250,280
Protocol	AODV,AOMDV,DSDV,DSR
Simulation time	100s
Nodes	31
Pause time	0

Max speed	30 m/s
No. of connections	10
Connection type	UDP
Packet size-512	512
Traffic type	CBR
Rate	4.0 Mb

In **scenario-I: At** different network connections (5, 10, 12, 15, 18, 20, 25, 30), we conducted simulation work case with respect to E2E delay, average delay, NRL, and throughput.

In **scenario-II:** At different pause times (0, 10, 30, 40, 60, 80, 90), simulation tests conducted with respect to all performance parameters as taken in scenario-I.

In **scenario-III:** At different simulation times (10, 20, 40, 60, 80, 100), test were performed with respect to throughput, E2E delay, normalized routing load.

In scenario-IV: At different speed levels (10, 30, 40, 60, 80, 85, 90, 100, 120, 150, 200, 250, 280), but keeping other network parameters same, tests were conducted. (Table I and Table II)

In scenario-V: Here we implement as per the parameters as given in Table III.

In scenario-VI: Here, we have conducted the simulation as per the Table IV.

IV. Results and Discussion

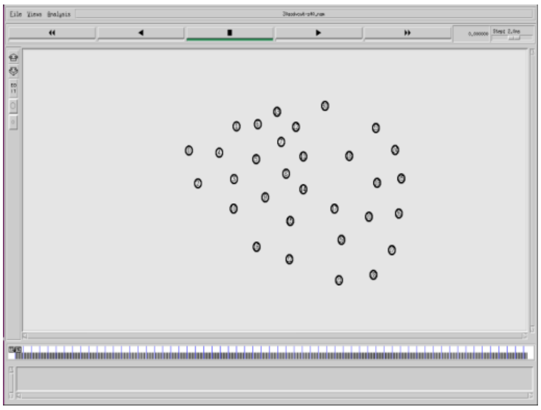

Fig. 1. NAM window with 31 nodes

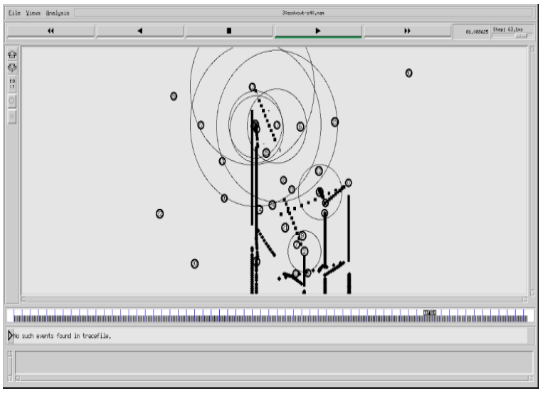

Fig. 2. Nam window during simulation at NS 2.35

Scenario-I: Varying connections

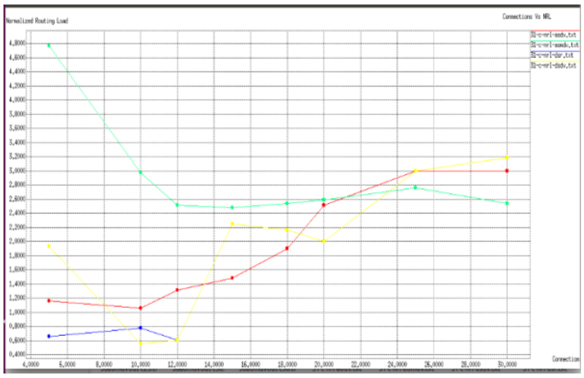

Fig. 3. Connection Vs NRL

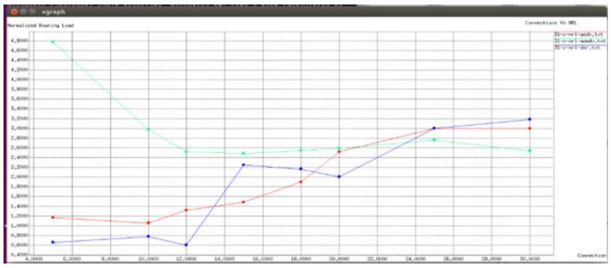

Fig. 4. Connections Vs NRL

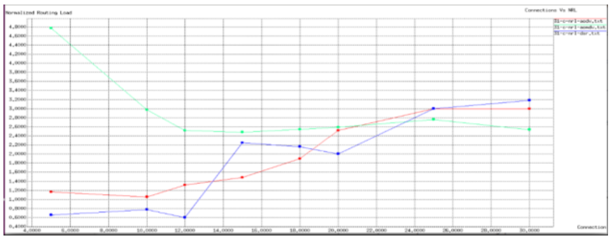

Fig. 5. Connections Vs NRL

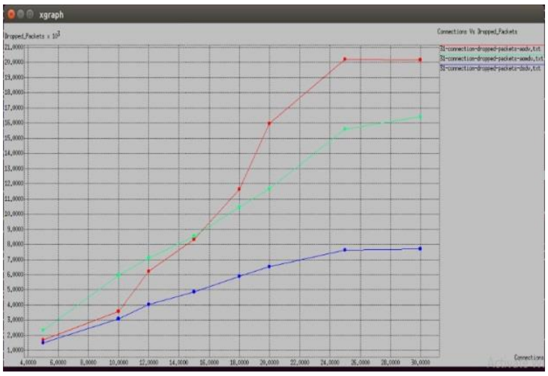

Fig. 6. Connections Vs dropped packets

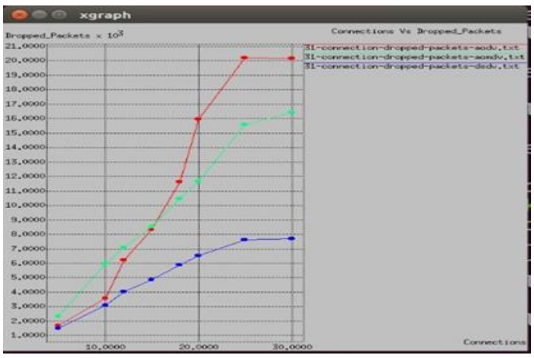

Fig. 7. Connections Vs dropped packets

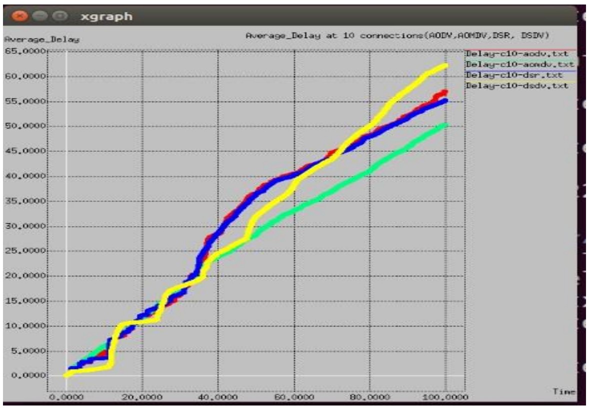

Fig. 8. Average delay at 10 connections

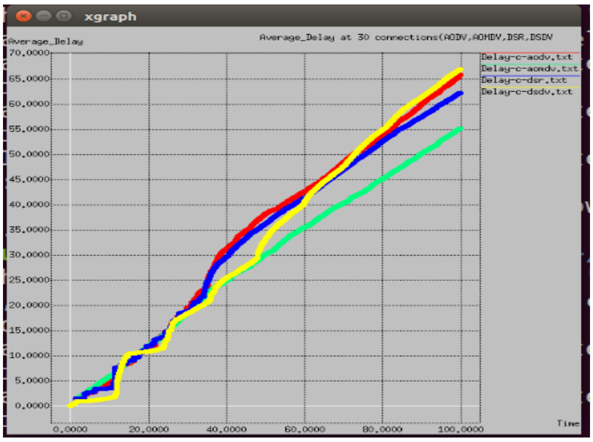

Fig. 9. Average delay at 30 connections

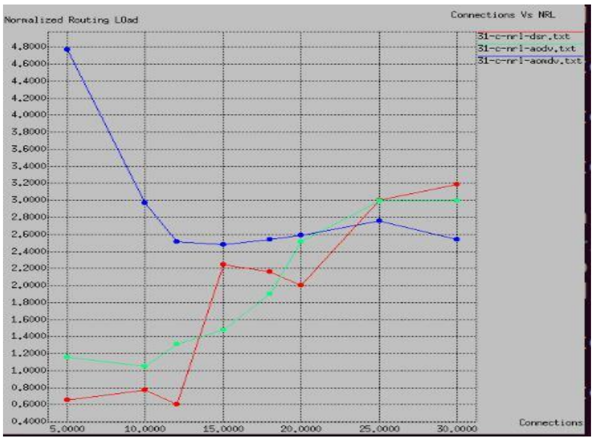

Fig. 10. No. of connections Vs NRL

All parameters are kept same, varying different number of connections 5, 10,12,15,18,20,25,30. We calculate different parameters (performance) at different number of connections (Figures 1-11).

We compared AODV, AOMDV, and DSR at various connections vs NRL. As shown in figure, increasing the number of connections, normalized routing load goes down for AOMDV as compared to DSR and AODV , DSR having low NRL at less number of network connections. As connections are increased, AOMDV performs best in respect of NRL.

In next step, we compared AODV, AOMDV, and DSDV using network parameters number of connections vs dropped packets. Numbers of dropped packets for AOMDV are less as compared to AODV. But numbers of dropped packets are less for DSDV. But at less connection, number of dropped packets for DSDV and AODV are less.

We compared AODV, AOMDV, DSR, and DSDV with parameters average delay vs connections (10 connections and 30 connections). At 10 connections, average delay for AOMDV is less as compared to all other three protocols. But delay is approximately same at low connections.

For DSDV, average delay is higher when we simulate for 30 connections, for AODV, AOMDV, DSDV, and DSR. Average delay for DSDV is high at higher simulation time. Average delay for AOMDV is less at 30 connections.

- At low connections, AOMDV having high NRL and for AODV, DSR and DSDV, NRL is low. But at higher number of connections, NRL for AODV, DSR, and DSDV is approximately same, but it is for AOMDV is low.

Scenario-II: Varying pause times

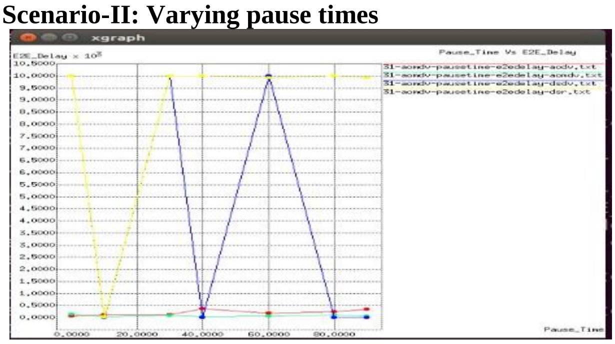

Fig. 11. Pause time Vs E2E delay

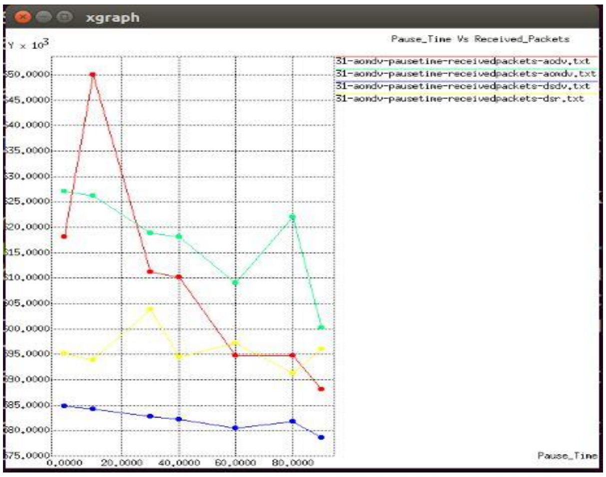

Fig. 12. Pause time Vs received packets

All parameters are same, but at various pause times (0, 20, 40, 60, 80), the E2E delay for AOMDV is less as compared to AODV, DSDV, and DSR routing protocols. For DSR, E2E delay is more. For DSDV E2E delay various up and down. At pause time 0, E2E delay is approximately same for AOMDV, and AODV.

Received packets for AOMDV is less. But more at low pause times as compared to AODV.

- As shown in Fig. 11, at low pause times, end-to-end delay for AODV, AOMDV is same while it is variable for DSDV and DSR. But at higher pause times, AOMDV outperforms the AODV.
- At low pause times, received packets for AODV is best, while it is low for DSR, DSDV and AOMDV as compared to AODV. But at higher pause times, AOMDV outperforms and DSDV having lowest received packets at the same values of pause times (as shown in Fig. 12).
- Varying the pause times, jitter for AODV vary for various values and it is lowest at higher pause times.
- At lowest pause times, NRL is higher for AODV, while it fluctuates for both AODV and AOMDV.
- PDF at initially stage of pause time, it is high for AODV while higher at higher pause times for AOMDV. PDF also fluctuates while the pause times are changed.
- Packet delivery ratio mostly is same for AODV and AOMDV at medium level of pause times. But AOMDV outperforms AODV at higher pause times.
- For all values of pause times, number of received packets for AOMDV is higher than AODV. A value of received packets fluctuates for various values of pause time.

Scenario-III: Varying simulation time

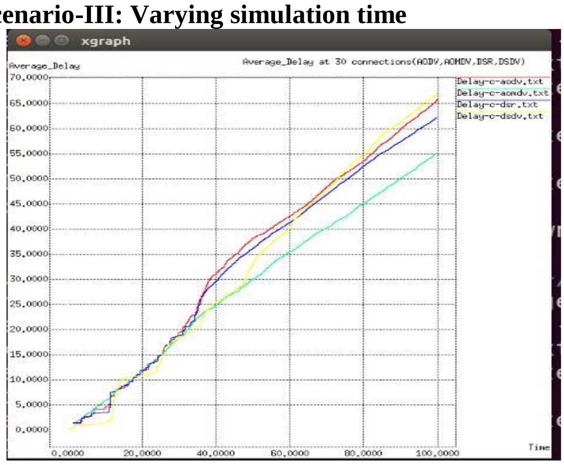

Fig. 13. Average delay Vs Simulation time at 30 connections

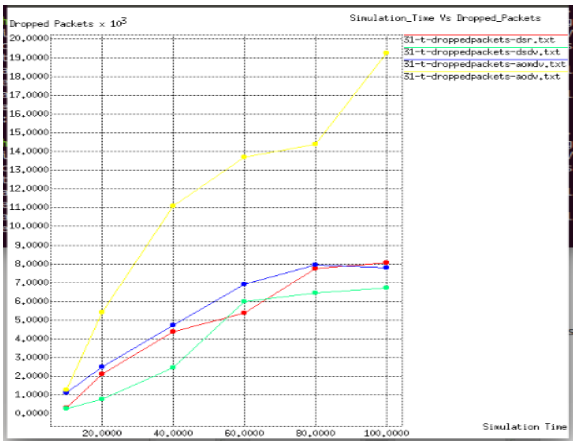

Fig. 14. Simulation time Vs Dropped packets

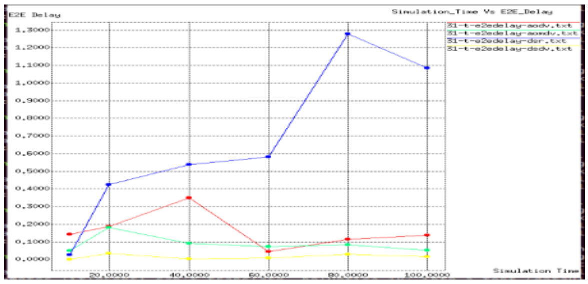

Fig. 15. Simulation time Vs E2E delay

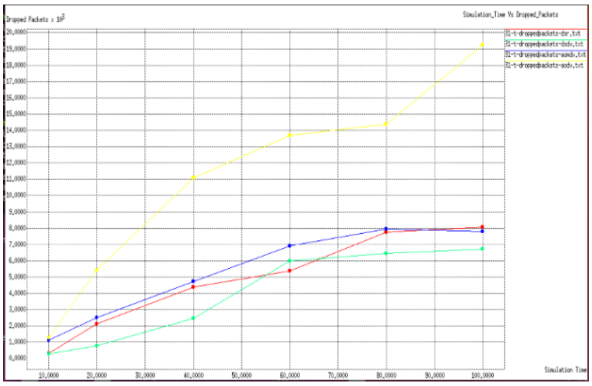

Fig. 16. Simulation time Vs dropped packets

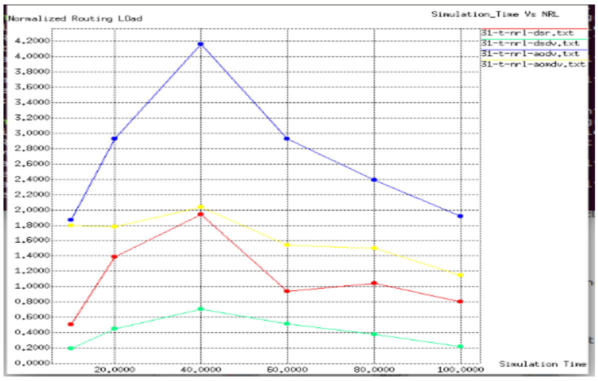

Fig. 17. Simulation time Vs normalized routing load

All parameters kept same, but at different simulation times (20, 40, 60, 80, 100s) dropped packets for AOMDV are less as compared to AODV and DSR. But for DSD, dropped packets are less as compared to AOMDV.

E2E delay for AOMDV is less as compared to AODV and DSR, but high as compared to DSDV at all levels of simulation times.

Normalized routing load (NRL) is less for DSDV at various simulation times as compared to DSR, AODV, and AOMDV.

NRL is less for AOMDV as compared to AODV at various levels of simulation time. But it is same at lowest simulation time. As simulation time increased, NRL for AODV increased. NRL decreased, when simulation times are increased. We can summarize the tests from Fig. 13-Fig. 17 as below:

- As illustrated in figure 13, at 30 connections, from low to medium values of simulation times, average delay is approximately same for AODV, AOMDV, DSR and DSDV. But as graph grows, it will vary and AOMDV having lowest average delay.

- From low to medium simulation times, numbers of dropped packets are highest for AODV while it is low for DSDV. DSDV outperforms at highest simulation times. AODV have poor performance from low to higher values of simulation times.
- At average simulation times, E2E delay for DSR is highest while it is lowest for DSDV. But when simulation time is at peak stage, AOMDV outperforms the AODV. E2E delay for DSDV is approximately same at all values of simulation times.
- At lowest values of simulation times, both protocols AODV and AOMDV having same quantity of dropped packets. But as time values increases, number of dropped packets for AODV are higher than AOMDV (i.e. AOMDV outperforms AODV at this stage).
- E2E delay varies as the simulation value is increased. But, it is lowest for AOMDV at highest values of simulation time as compared to AODV.
- Jitter for AODV is higher than AOMDV at peak value of simulation times.
- NRL is same for AODV and AOMDV at lowest value of simulation time. But, it will go down for AOMDV as time values are increased.
- Numbers of dropped packets are always high for all stages of simulation times. At medium and higher levels of simulation times, it is approximately same for DSR and AOMDV. DSDV having maximum number of dropped packets at higher values of simulation times.
- As simulation times increases, NRL for all routing protocols (AODV, AOMDV, DSR, and DSDV) is decreased and DSDV outperforms. AOMDV have lower NRL as compared to AODV routing protocol.

Scenario-IV: Varying the speed

All parameters are kept as it is, speed will vary at different levels (0,50, 100, 150, 200, 250) dropped packets for AOMDV is very less at higher speed as compared to AODV, DSR, and DSDV. But lower speeds, AODV performs best. But as speed increased, performs of AODV degrades. As speed of nodes will increase, performance of AOMDV improves. Dropped packet rate is highest as speed is increased. E2E delay for DSR is highest at all levels of speed. DSDV performs best for all speeds as compared to AODV, AOMDV, and DSR. E2E delay for AOMDV is less than E2E delay of AODV. E2E delay also decreased even though as speed is increased. But E2E for AODV increased. Normalized routing load for DSDV is lowest at different speed levels. It is mostly same for all time. DSR have highest NRL at all speed rates. Initially NRL for AODV and AOMDV is same. But as speed increased, it increased for AODV and decreased for AOMDV. AOMDV performs best at higher speeds as compared to AODV and DSR.

Received packets for DSR are lowest as speed levels are improved. But at highest level of speed, received packets are more for AOMDV as compared to AODV, DSDV, and DSR. As speed varies from low to highest levels, the quantity of received packets varies. But highest level of speed, AOMDV performs best.

Throughput for DSR is lowest at highest level of speed. But it is best for AOMDV as speed is increased. AODV performs best as compared to DSDV and DSR, but having low throughput as compared to AOMDV at higher speed rates.

- As illustrated in Fig. 18, number of dropped packet varies as the speed is increased for AODV, AOMDV, DSR, and DSDV routing protocols. Numbers of dropped packets are approximately same for AODV and DSR at medium speed values. But as it is increased, dropped packets quantity is increased for DSDV. At higher level of speed values, numbers of dropped protocols are lowest.
- As shown in Fig. 19, as speed is increased, E2E delay is also vary for different values for all protocols. But, for all stages of speeds, DSR having highest values of E2E delay while it is lowest for DSDV. Here, in this network scenario, E2E delay for AOMDV is lower than AODV at all values of speed.
- NRL is approximately same at all values of speed. But, it varies for all other protocols (AODV, AOMDV, and DSR). NRL is highest for DSR at different levels of speed. From initial to medium speed values, NRL is same for AODV and AOMDV, but as speed is increased, NRL for AOMDV is lower than AODV (as shown in Fig. 20).
- As illustrated in Fig. 21, DSR outperforms for all stages of speeds (i.e. number of received packets are higher for DSR). From lowest to medium level of speed values, number of received packets varies. But, it is highest for AOMDV at peak value of speed. Here, AOMDV outperforms the AODV routing protocol.
- As shown in Fig. 22, throughput is very low for DSR at various stages of speed values. Throughput is also varying up to medium level of speeds, but at highest speed, AOMDV outperforms the AODV, DSDV, and DSR routing protocols.
- Delay and jitter for AOMDV is lower than AODV for all values of speed.

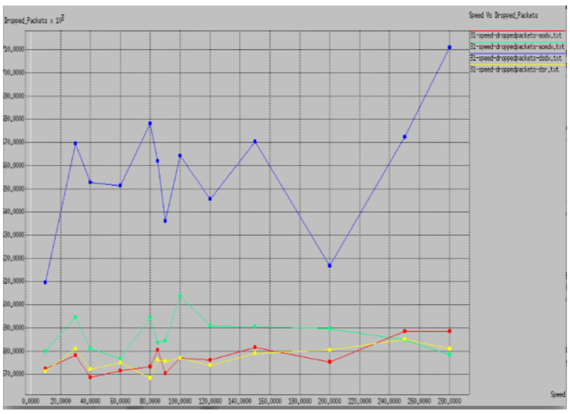

Fig. 18. Speed Vs dropped packets

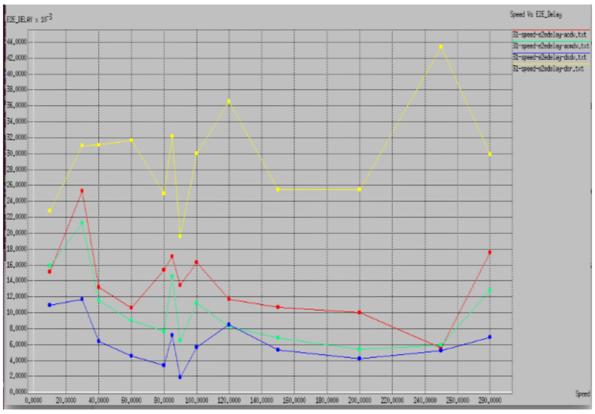

Fig. 19. Speed Vs E2E delay

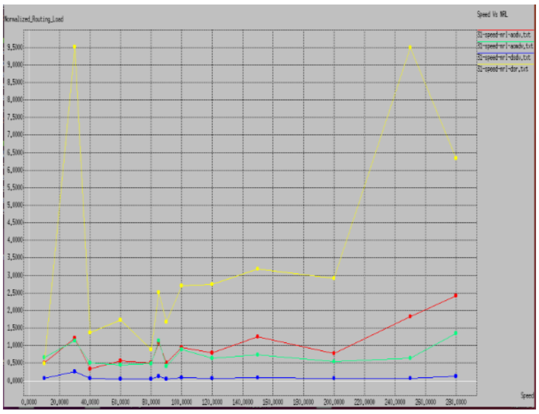

Fig. 20. Speed Vs normalized routing load

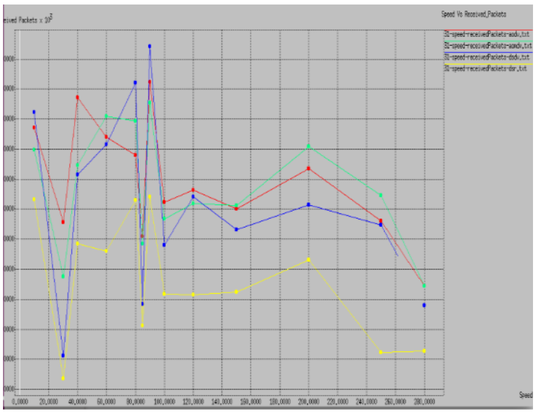

Fig. 21. Speed Vs received packets

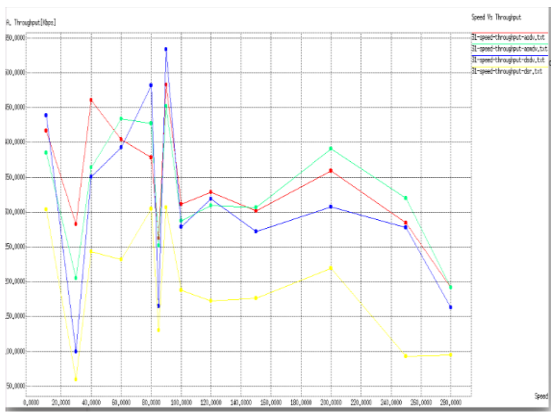

Fig. 22. Speed Vs throughput

V. CONCLUSION

We analysed AOMDV routing protocol within different network conditions and different performance parameters. We compared AOMDV with other routing protocols like AODV, DSR, and DSDV. AOMDV performs best at higher speed rates as compared to AODV. As numbers of connections are increased, E2E delay for AOMDV is less than AODV. Average throughput for AOMDV is best at higher values of simulation times. Normalized routing load for AOMDV is less at higher speed rates. On the basis of all simulations, AOMDV performs best as compared AODV. But, AODV also best suitable when speed of network nodes is low. Packet dropping rates for AOMDV is less at higher speed rates of network nodes. At last, AOMDV is best recommended in a network, when speed of nodes is high and also network connections are more.

REFERENCES

[1] D. P. I. I. Ismail and M. H. F. Ja'afar, "Mobile ad hoc network overview," in *Proc. Asia-Pacific Conference on Applied Electromagnetics*, 4-6 Dec. 2007, pp. 324-330.

[2] P. Sarao, S. Suresh, and A. Kabde, "Performance analysis of reactive routing protocols in MANET," *International Journal of Innovations & Advancement in Computer Science (IJIACS)*, vol. 7, no. 5, pp. 219-224, May 2018.

[3] T. R. Devi, R. Biswal, V. Kumar, and A. Jena, "Implementation of dynamic source routing (DSR) in mobile ad hoc network (MANET)," *International Journal of Research in Engineering and Technology*, vol. 2, no. 11, pp. 339-345, Nov. 2013.

[4] H. Narra, Y. Cheng, E. K. Çetinkaya, J. P. Rohrer, and J. P. G. Sterbenz, "Destination-sequenced distance vector (DSDV) routing protocol implementation in ns-3," in *Proc. 4th International ICST Conference on Simulation Tools and Techniques*, March 21, 2011, pp. 439-446.

[5] E. M. Royer and C. K. T. Georgia, "A review of current routing protocols for ad hoc mobile wireless networks," *IEEE Personal Communications*, pp. 1-20, April 1999.

[6] G. S. Brindha and M. Rajeswari, "AOMDV- Multipath routing protocol in mobile networks to enhance network security," *International Journal of Science and Research*, vol. 3, no. 12, pp. 62-66, December 2014.

[7] S. Dubey, A. Nema, and A. Verma, "AODV and AOMDV routing protocol with 801.11p in VANET," *International Journal of Advanced Research in Computer Science and Software Engineering*, vol. 6, no. 6, pp. 136-140, June 2016.

[8] V. Bondre and S. Dorle, "Design and performance evaluation of AOMDV routing protocol for VANET," in *Proc. International Conference on Computer, Communication and Control (IC4)*, Sept. 2015, pp. 389-392.

[9] The Network Simulator - ns-2. [Online]. Available: https://www.isi.edu/nsnam/ns/

[10] F. Z. Fu, Z. Ling, and W. X. Yu, *International Workshop on Information and Electronics Engineering (IWIEE*

2012), ELESEVIER, Procedia Engineering 29, 2012, pp. 33-37.

[11] M. S. Chadha, R. Joon, and Sandeep, "Simulation and comparison of AODV, DSR and AOMDV routing protocols in MANETs," *International Journal of Soft Computing and Engineering*, vol. 2, no. 3, pp. 375-381, July 2012.

[12] R. V. Kumar and R. S. D. W. Banu, "Load-balancing approach for AOMDV in ad-hoc networks," *IJCA Special Issue on 'Mobile Ad-hoc Networks' MANETs*, pp. 200-205, 2010.

[13] V. B. Kute and M. U. Kharat, "Analysis of quality of service for the AOMDV routing protocol," *ETASR-Engineering, Technology, & Applied Science Research*, vol. 3, no. 1, pp. 359-362, 2013.

[14] M. K. Marina and S. R. Das, "Ad hoc on-demand multipath distance vector routing," *Wireless Communication and Mobile Computing*, pp. 969-988, 2006.

[15] J. Zhou, H. Xu, Z. Qin, Y. Peng, and C. Lei, "Ad-hoc on-demand multipath distance vector routing protocol based on node state," *Communications and Network*, vol. 5, pp. 408-413, September 2013.

[16] P. Meghare and P. Deskmukh, "Packet forwarding using AOMDV Algorithm in WSN," *International Journal of Application or Innovation in Engineering of Management (IJAIEM)*, vol. 3, no. 5, pp. 456-459, May 2014.

[17] P. Oli and V. K. Gupta, "Simulation and comparison of AODV and AOMDV routing protocols in MANET," *International Journal of Engineering Research & Technology*, vol. 3, no. 9, pp. 745-749, September 2014.

[18] A. M. Rani and K. Priyadharshini, "Analysis of AODV routing protocol in square and triangle based topologies of wireless mesh network," *International Journal of Engineering Technology and Advanced Engineering*, vol. 7, no. 7, pp. 252-257, July 2017.

[19] R. Prabha and N. Ramaraj, "Link availability estimation for modified AOMDV protocol," *International Journal of Computer and Information Engineering*, vol. 9, no. 3, pp. 854-859, 2015.

[20] S. R. Birdar, S. K. Singh, and S. K. Sarkar, "Performance comparison of AODV and AOMDV routing protcols," in *Proc. First International Conference on Advanced Computational and Communication Paradigm*, September 2015, pp. 1-7.

[21] A. Al-Nahari and M. M. Mohamad, "Receiver-Based ad-hoc on demand multipath routing protocol for mobile ad-hoc networks," *PLoSONE*, vol. 1, no. 6, pp. 1-18, June 3, 2016.

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