THE IMPACT OF TCP CONGESTION WINDOW SIZE ON THE PERFORMANCE EVALUATION OF MOBILE AD HOC (MANET) ROUTING PROTOCOLS

Nihad I. Abbas[1], Emre Ozen[2] and Mustafa Ilkan[3]

[1]Department of Computer Engineering, Eastern Mediterranean University, Famagusta, N.Cyprus
[2]School of Computing and Technology, Eastern Mediterranean University, Famagusta, N.Cyprus
[3]School of Computing and Technology, Eastern Mediterranean University, Famagusta, N.Cyprus

ABSTRACT

A mobile ad hoc network (MANET) is a temporary collection of mobile nodes randomly moved within a limited terrain area. The nodes are connected to form a wireless network without use any communication infrastructure. Because of the limiting resources of MANET nodes, multiple hops scheme is proposed for data exchange across the network. Varieties of mobile ad hoc routing protocols have been developed to support the multi-hop scheme of ad hoc networks. A popular Transmission Control Protocol (TCP) provides a reliable connection in a computer network environment; it sets its congestion window size in response to the behavior of the network to achieve the best performance. This work aims to investigate and compare the MANET protocol performance, such as DSDV, AODV and DSR in terms of network throughput, average routing load, the packet delivery ratio (PDR), and average end-to-end delay by varying the maximum congestion window size. Our simulation has been implemented using a well-known NS-2.35 network simulator. The simulated results show that the demonstrates of the concepts of MANET routing protocols with respect to TCP congestion window size in MANET environment.

KEYWORDS

MANET, Routing Protocols, DSR, DSDV, AODV, Window size, NS 2.

1. INTRODUCTION

Mobile ad hoc Network (MANET) has received considerable attention over the past few years' decades. The rapid deployment of wireless mobile networks in many emergency cases, such as disaster areas, search and rescue operations, and battlefield operations make these types of networks more attractive, where there is a little or no time available to build a service communication infrastructure. MANET is an infrastructure less wireless communication network with different mobile types. The nodes in MANET can connect and interact with each other via wireless multi-hop scheme to preserve node's energy and prolong the network lifetime [1]. The nodes in a mobile ad hoc network may act as a router, which forwards the data information to the neighbors in the network. Unfortunately, route failures in MANET are frequently occurring in

DOI : 10.5121/ijwmn.2015.7203

many cases due to the node's mobility, free movement of nodes in any speed and direction within the network. For that reason, therefore, an efficient routing protocol is needed to reconnect the broken routes. A number of protocols have been proposed for MANET networks such as: DSDV (Destination-Sequenced Distance Vector), DSR (Dynamic Source Routing), and AODV (Ad-Hoc On Demand Distance Vector).

Transport Control Protocol (TCP) is the most predominant protocol utilized in the Transport Layer of wired and wireless network environments. It is widely used to achieve a reliable transmission over the internet world. There have been several attempts to improve TCP performance since its introducing in 1981. Congestion control and avoidance techniques are the two important concepts proposed by Jacobson. In order to control the amount of packets sends by a sender, the sender changes its TCP congestion window size according to the network environments. TCP congestion window size (cwnd) increases exponentially up to the receiver's maximum window size. The TCP window size of the sender's node remains at a constant size and equals the maximum size unless the receiver's advertised window, reaches to a constant size during the transmission period [2]. In this study, we simulate and observe the effect of the maximum window size changes in the popular wireless routing protocol performance.

Comparing the evaluation results to estimate the optimum value of maximum window size that could be used for specific environment for each protocol simulated in this study. The organized of the rest of this paper would be as follows: Section 2, explain the overview of MANET Routing Protocols. Section 3, provides the transport control protocol (TCP). Section 4, summarize the related research works. The simulation environment, the simulation results and the conclusions drawn from this work are presented in sections 5, 6 and 7 respectively.

2.OVERVIEW OF MANET ROUTING PROTOCOLS

The routing protocol consists of the procedural steps that need to be obeyed by the MANET nodes to successfully transfer source information packets to the destination node. The routing protocol should be able to automatically establish the route with a limited period of time and without any intervention. The nodes in MANET are self-organizing in distributed form behavior. The route establishment is essential to perform the routing process properly. MANET routing protocols can be categorized into [3, 4]:

- Table driven routing protocols (proactive protocols).
- On-demand routing protocols (Reactive protocols).
- Hybrid routing protocols.

Some of popular routing protocols adopted by MANET networks are described below:

2.1. Destination - Sequenced Distance Vector (DSDV) Protocol

The DSDV routing protocol is one of a proactive protocols based on the Routing Information Protocol (RIP). The MANET nodes store a table of the number of hops to each destination and all routes valid to the destinations in the network. DSDV uses bi-directional links and provides just one route for source-destination pairs; it also updates periodically the broadcast routing table. Each node keeps a listing of route table indicating the next hop to a pre-determined destination. DSDV protocol generates a unique sequence number tag with each route in the MANET and uses the most favorable one with the lowest metric. All nodes in the network, advertise, monotonically incrementing their sequence number. When an established route between nodes (S) to node (D) in the network has broken anytime, it advertises an infinite metric to the route to (D) by increasing the sequence number by one. So that if the node (A) forwarded data through node (B) incorporates an infinite-metric route into its routing table until the node (A) recovers a route to node (D) with a higher sequence number. Each table entry in DSDV protocol has a sequence number that is incremented upon each updated packet sending. In addition, the routing tables in DSDV are periodically updated each time the network topology is changed. The updated tables are broadcast throughout the network to retain consistent updated information. MANET nodes keep one routing table for forwarding the data packet, and another table for advertising incremental routing packets. The information of routing sent periodically includes: destination address, new sequence number, hop count to destination, and the destination sequence number. Any node in network that detects network topology changes will send an updated packet to all neighboring nodes [5].

2.2.Ad-hoc On Demand Distance Vector (AODV) Protocol

AODV is one of the most popular reactive MANET routing protocols in the research environment. The AODV routing protocol supports multicast besides a unicast routing. It uses an on-demand scheme to discover the best route valid to the destination. Moreover, the protocol uses a sequence number to recognize the most updated path to guarantee the freshness routes to the destination. Also, AODV is one of the reactive protocols that exploits minimum control traffic overhead signals in detecting new routes. It periodically broadcasts a (HELLO) packet to inform the neighbors in the network that the link is still active. Whenever a source node in MANET wishes to transmit data to another node, the source broadcasts a Route Request (RREQ) packet throughout the network. The source node waits a predefined period of time for an acknowledged a reply to its route requested packet. If a Route Reply (RREP) packet does not received, then the source retransmits a new RREQ. After a neighbor node receives a (RREQ) packet, it generates a (RREP) packet to notify the source node that the node is the destination or it has a route to the destination else it rebroadcasts the (RREQ) packet. The route validity is approved by comparing the sequence number of the intermediate node with the destination sequence number of the Route Request packet. Once the source receives a (RREP) packet, it stores the information on this route and starts sending data information to the destination. However, if the source receives multiple (RREP) packets, the shortest hop count route will be selected. In cases of network link failure occurs any time, a packet of Route Error (RERR) is created and returned back to the originator node that will initiate a route discovery process again if more data available to send and the route is still needed [6].

2.3. Dynamic Source Routing (DSR) Protocol

DSR uses a source routing algorithm. In this algorithm, all header packets routed in the network carry the complete list of nodes addresses through which the packets must pass. The intermediate nodes in the network do not need to retain updated routing information to forward data packets, because the packets themselves previously include all information of routing decisions to the destinations. For that reason, the DSR protocol avoids the needing of a repeating route advertisement. DSR protocol applies two operation phases in its routing process scheme:

1- Route Discovery phase
2- Route Maintenance phase.

The initiation of a Route Discovery process phase is occurring when the source node has a data packet to send, then it will try to send its packets to a destination node in the network. At the beginning, the source node broadcasts a ROUTE REQUEST (RREQ) packet through the network, and then it waits the reply that will be either by the destination node or by the intermediate node which has a route to the destination. In order to minimize the Route Discovery cost, each node in the network keeps a cache table of source routes it has collected previously and it uses to limit the number of RREQs packet propagation repeatedly. The Route Maintenance process starts when the source node detects any changes occurring or which have occurred in the MANET network topology. When a route breakage is discovered by the source node, and which is informed by a ROUTE ERROR packet. The source will attempt to use any already exist route stored in its cache or it explore a new route by recalling the Route Discovery process again to find a new route [7].

3.TRANSPORT CONTROL PROTOCOL (TCP)

TCP [8, 9], is the traditional internet transport protocol, uses a congestion window size (cwnd) for controlling the data packets flow according to the network congestion. Congestion window size can be defined as the maximum number of packets that the source can transmit without receipt of any acknowledgment (ACK) from the destination node. In TCP protocol, congestion control mechanism is achieved by the receiver to prevent the sender to send more data packets through the network. The sender in TCP protocol regulates its window size (cwnd) according to the window size of the receiver advertised in order to avoid extra packets transmitted and as a result, minimizing the probability of network congestion occurring. The TCP sender utilizes slow start mechanisms by setting its window size (cwnd) to one segment. As the first ACK packet receipts by the sender, its congestion window size incremented by one. Thus, in the first round trip time (RTT), there is one data packet is transmitted by the sender. In second RTT, there is two data packets are sent, in third RTT, there is four data packets are sent, and so on. This incrementing of data packet transmission will continue as an exponential function behavior. The slow start mechanism sometimes called as an exponential growth phase. The slow start process increments cwnd by the number of packets acknowledgments received and the process will stop in one of the following conditions: 1) the receiver's window size equal to the sender's cwnd. 2) An acknowledgment lost for some transmitted packets. 3) Reaching to the slow start threshold value [10]. The cwnd size increases by the value calculated by the formula [(segment size x segment size) / (congestion window)] each time an ACK is received. In MANETs, because of the network topology frequent changes during the TCP connection lifetime, the relation becomes too loose between tolerable data rate and the cwnd. In [11], the authors explain the reasons of degrading the TCP performance when the cwnd value is incremented larger than an upper bound value. Also, the authors in [12] determined the optimal cwnd size for specific flow pattern and network topology that TCP shows the best throughput. Usually, TCP operates at a mean value of window size which is larger than the calculated cwnd; this, unfortunately, leads to increasing of packet loss due to the wireless channel contention.

4. LITERATURE REVIEW

Mobile Ad Hoc (MANET) routing protocol's performance has been an important research field. The focus of these routing studies concerns the investigation of the effects of changing routing protocol parameters on their performances in different environments. The performance metrics determine which protocol is suitable for a specific application for each environment case. Also, different simulators are used for this purpose. Rusdi et al [13] proposed a new approach to enhance the TCP performance over mobile ad hoc network environments by using a dynamic path for TCP congestion estimation. They are succeeded in decreasing the amount of the packet loss. Their simulation results show that the TCP performance improved over different scenarios of mobile ad hoc network. S. j. Kohakade and S. A Jain in [14] explains the effects of congestion window size on the improving of TCP performance and also discusses the problems of the medium channel contention on the MANET networks. They propose a dynamic adjustment of the congestion window size to improve the TCP performance by reducing the overshooting problems of congestion window. A. Deshpande [15] discusses the reasons of TCP performance degrading due to mobile ad hoc network environment. In his work, the author suggests different optimization techniques to enhance TCP performance by using contemporary WAN optimization techniques to avoid the challenges of TCP performance degradation. Nilesh et al [16] examine AODV and DSR routing protocols using an NS2 simulator. In their simulation study, a 50 node density is simulated with varying MANET sizes in an ad hoc environment. A channel access control using IEEE 802.11 performance study is summarized by Zhenghua et al in [17] they investigate the existence of an optimal size of the congesting window at which TCP protocol performs best throughput by maximum spatial reuse of multihop wireless shared channels. Dimitrios et al [18] tested a TCP performance of 32 nodes deployed in a realistic environment mesh network. In their studies, they recommended the use of a maximum window size in order to gain maximum throughput in the some simulated cases when disabling the RTS/CTS control signals. Ankur Patel. et. al [3] modelled Proactive and Reactive routing protocols with different mobility patterns. In their simulation research focuses on the performance evaluation of the same numbers of node groups using an NS2 simulator. B. Nithya et al [19] proved from the simulated results that the degradation in TCP performance of an ad-hoc wireless network was due to an incorrect reaction to the congestion window size which affects the overall mobile ad hoc network performance. The shorter delay in packet transferring through the network is achieved by adjusting and modifying the TCP congestion window size compared to traditional TCP protocol.

Jekishan et al in [20] investigates the behavior of the AODV routing protocol using two different simulators: NS2 and OMNET++. The analysis of the performance results shows the effects of the simulator architecture on the results obtained. Abdul Hadi et al [5] studied the performance behavior of ad-hoc on-demand protocols using the NS2 simulator. In their work, different scenarios of MANET networks with various numbers of nodes and different pause times were tested.

5. SIMULATION ENVIRONMENT

5.1. Simulation Model

Performance evaluations of wireless ad-hoc routing protocol have been done using a discrete event simulator NS2 version NS-2.35 [21]. The NS2 simulator supports simulations of various wired and wireless routing protocols such as TORA, AODV, DSDV, and DSR. The core programming language used in writing NS2 simulation package is C++ and the interactive user interface language is Tool Command Language (TCL). TCL makes the network simulation environment parameters change easily without the need to recompile NS2 software each time modifying the network attributes parameters.

5.2. Simulation Parameters

Our simulation study considers a network area size of 500 m x 500 m with 50 wireless mobile nodes randomly distributed across the simulated area with a maximum speed of 20m/s and constant pause time. The parameter values of the performance simulation are listed in table 1.

Table 1. Parameter values of simulation scenario

Parameters	Values
Network Simulator	NS-2.35
Routing protocols	AODV, DSR and DSDV
Wireless Mac Layer protocol	IEEE 802.11
Number of nodes	50
Simulation area	500m x 500m
Wireless transmission range	250m
Mobility model	Random waypoint model
Pause time	5 Sec
Simulation time	100 Sec
Mobility maximum speed	20 m/Sec
Interface queue size	50
Packet size	512 bytes/packet
Application Layer	FTP

5.3. Performance Metrics

Routing protocols of MANET's performance can be evaluated using many quantitative metrics. We have used a popular performance evaluation metrics in our wireless ad- hoc routing protocol simulation.

5.3.1. Average Network Throughput:

It is defined as the number of data packets successfully received per unit of simulation time.

$$Throughput = \frac{\sum_1^n Packet\ Rec.}{Simulation\ time}$$

5.3.2. Packet Delivery Ratio (PDR):

It can be defined as the ratio of the packets successfully receipted by the destination nodes to the packets sent by the source nodes.

$$Packet\ Delivery\ Ratio\ (PDR)\% = \frac{\sum_1^n Packet\ Rec.}{\sum_1^n Packet\ sent} \times 100$$

5.3.3. Average Routing Overhead Load:

It can be defined as the total number of all routing control overhead packets sent by all nodes in the network over simulation time.

$$Average\ Routing\ Load = \frac{\sum_1^n RTR\ Packet}{Simulation\ time}$$

5.3.4. Average End to End Delay:

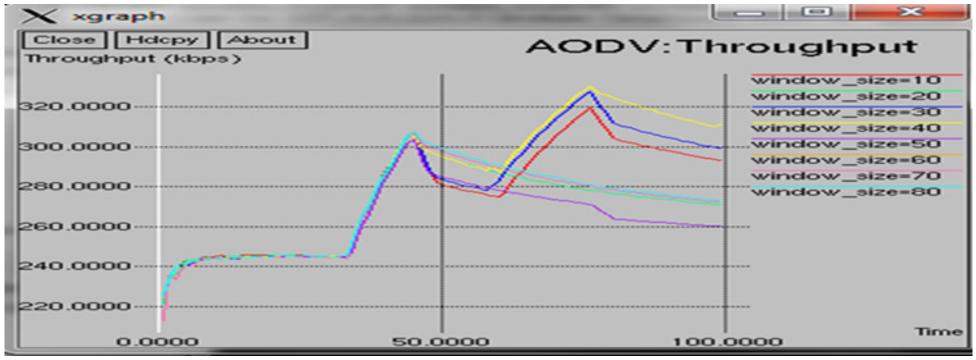
It can be defined as the average time has elapsed by data packets for transferring from source nodes to destination nodes with considering all delays caused by queuing, buffering, and propagation delays.

$$Avg.End\ to\ End\ Delay = \frac{\sum_1^n (Packet\ Rec._{time} - Packet\ Sent_{time})}{\sum_1^n Packet\ Rec.}$$

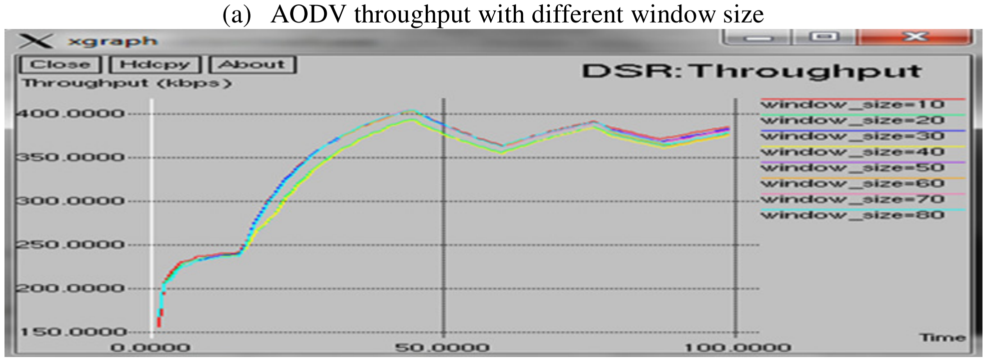
6. SIMULATION RESULTS

Simulations have been done with varying maximum congestion window size to examine the protocols in different performance metrics. Comparisons have been evaluated on a proactive protocol (DSDV) and two reactive protocols: DSR and AODV. The results obtained are discussed below.

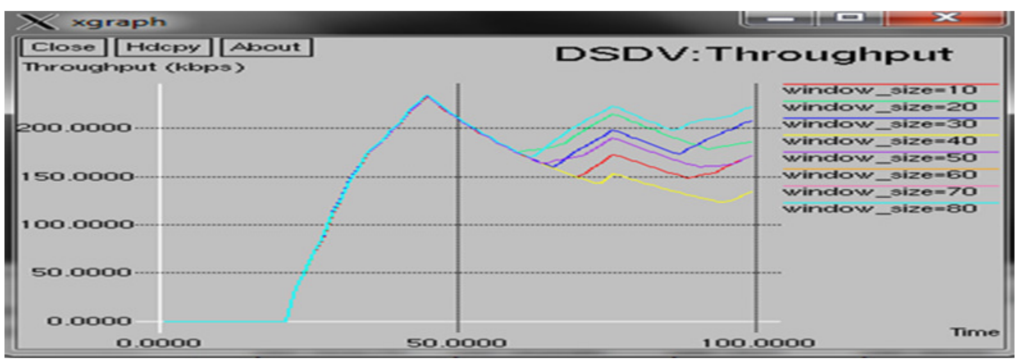
The main task of a routing algorithm is to set a route to connect a source node to destination one in MANET. Thus, one metric of routing protocol success is the throughput of data packets received successfully by destinations over a specific period of time.



(a) AODV throughput with different window size



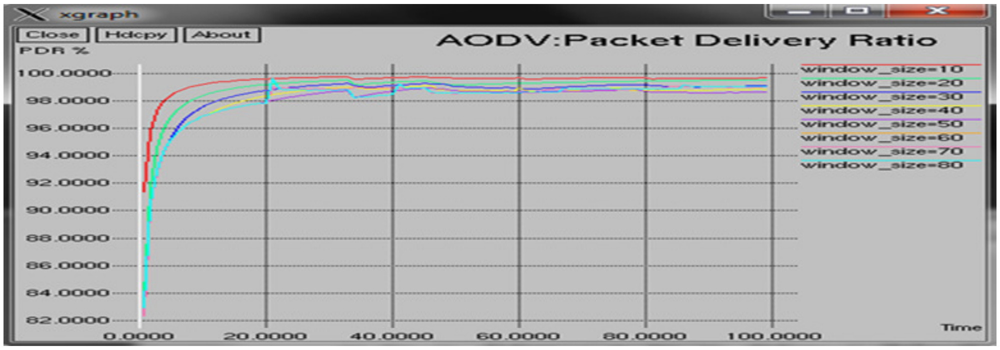
(b) DSR Throughput with different window size



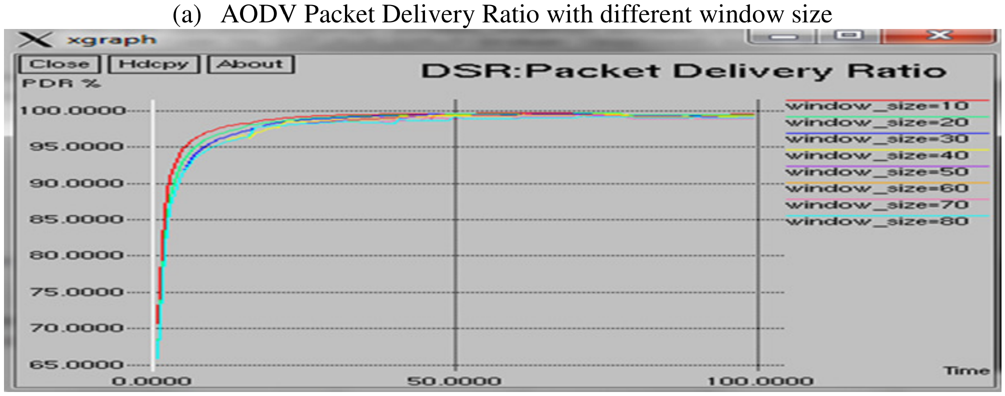
(c) DSDV Throughput with different window size

Figure 1. Throughput for AODV, DSR and DSDV with different window size

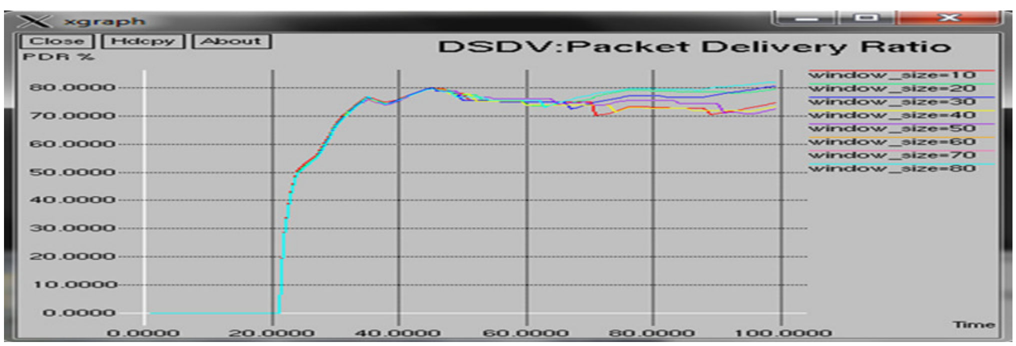
Figure 1 presents the throughput of AODV, DSR and DSDV protocols with increasing of congestion window size. It is observed that DSR has insensitive behaviors to the window size variation compared to AODV and DSDV protocols. Throughput values of AODV and DSR protocols are slightly larger than the throughput of DSDV. When we increase the congestion window size in MANET network, more data packets are lost due to collision.



(a) AODV Packet Delivery Ratio with different window size



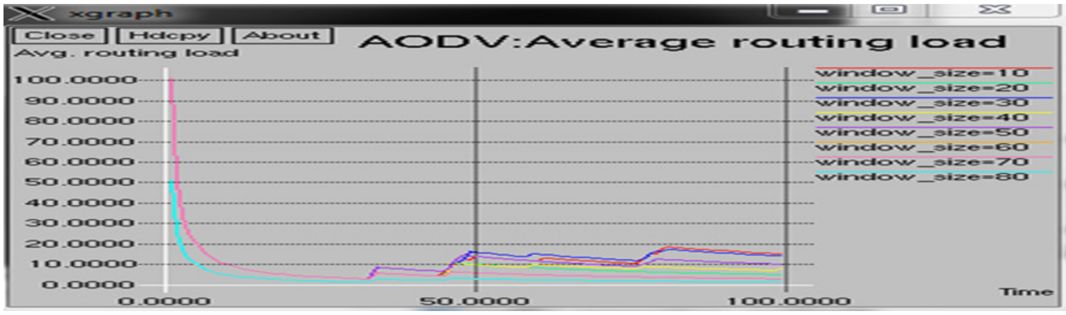
(b) DSR Packet Delivery Ratio with different window size



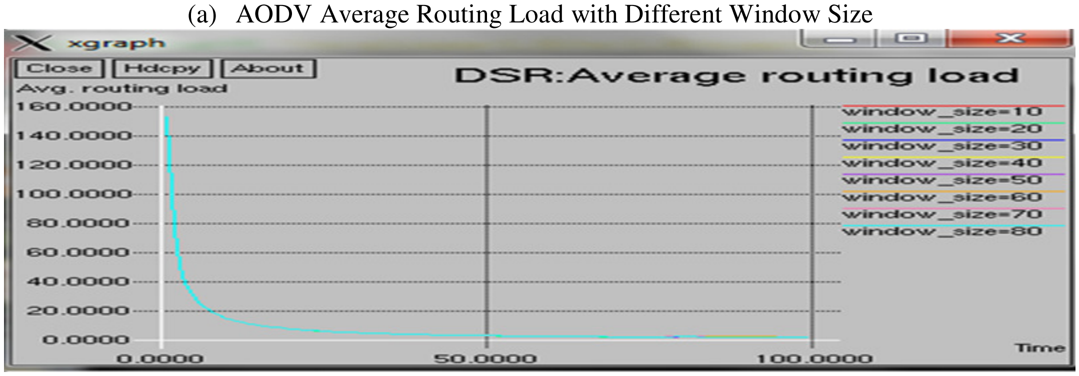
(c) DSDV Packet Delivery Ratio with different window size

Figure 2. Packet Delivery Ratio of AODV, DSR and DSDV with different window size

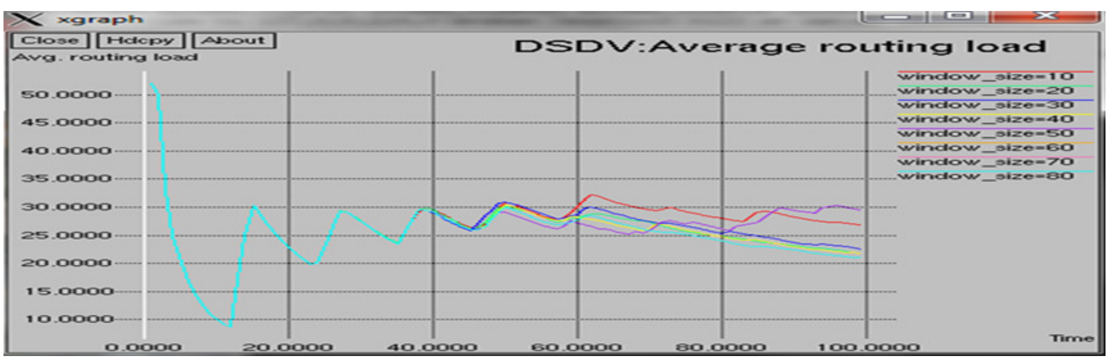
Figure 2 shows that the two reactive routing protocols DSR and AODV perform roughly equivalent and deliver the same amount of packets at the simulation time in the network. We notice the effects of packets' buffering in the reactive protocols, in case of a route is not available, the performance of the packet delivery ratio of DSR and AODV is slightly higher than that of DSDV protocol. In addition, it noticed that the window size variations have no significant effect on the packet delivery ratio metric of these routing protocols in general.



(a) AODV Average Routing Load with Different Window Size



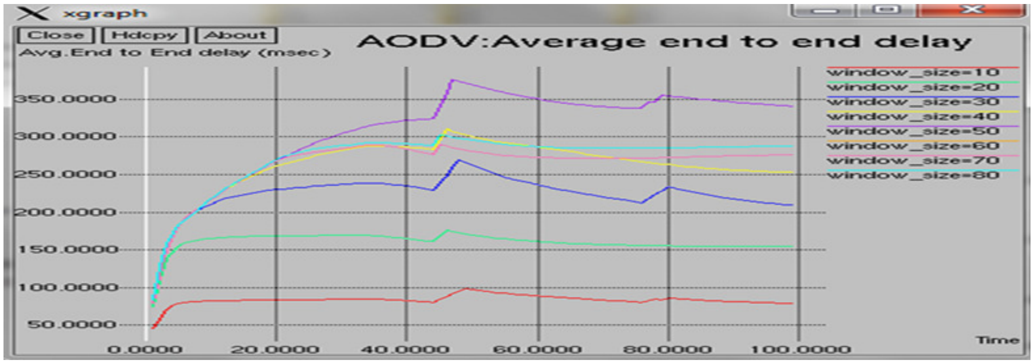
(b) DSR Average Routing Load with Different Window Size



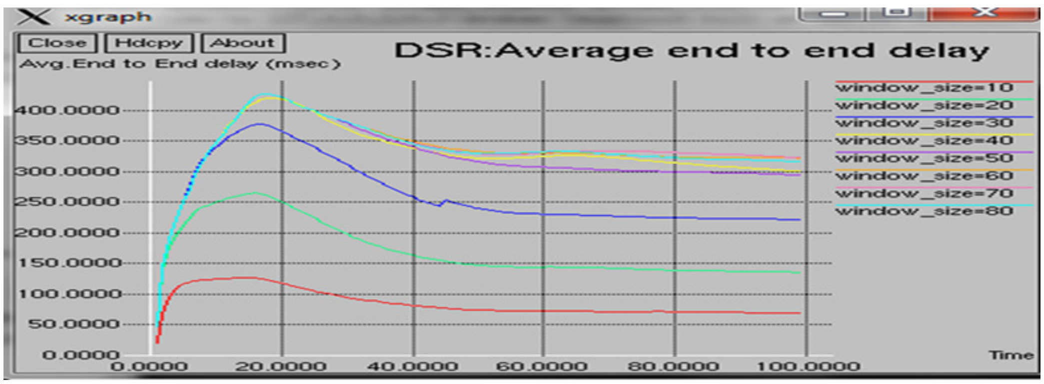
(c) DSDV Average Routing Load with Different Window Size

Figure 3. Average routing load of AODV, DSR and DSDV with different window size

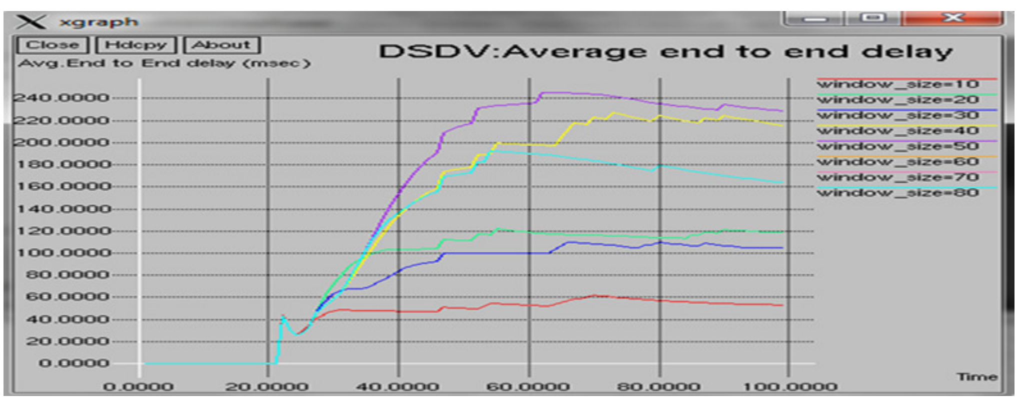
Figure 3 shows average routing loads of AODV, DSR and DSDV MANET routing protocols under various congestion window size. It is observed that DSR exhibits excellent behavior with minimum routing overhead control load over simulation time. There is no influence of window size variations in the average routing load of DSR protocol. DSR generates lower routing overhead than AODV while DSDV generates greater overhead control packets than reactive routing protocols. Also, the DSDV proactive routing protocol shows worst performance and almost fluctuated around a mean value as shown in Fig. 3 (c) for different window size and that is due to nature of proactive DSDV routing protocol algorithm.



(a) AODV Average end to end Delay with Different Window Size



(b) DSR Average end to end Delay with Different Window Size

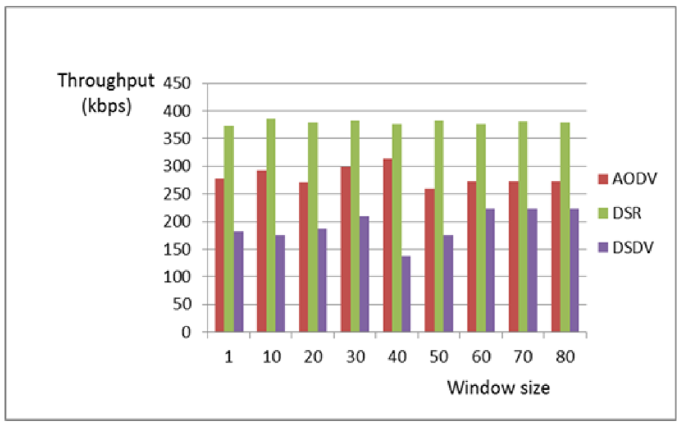


(c) DSDV Average end to end Delay with Different Window Size

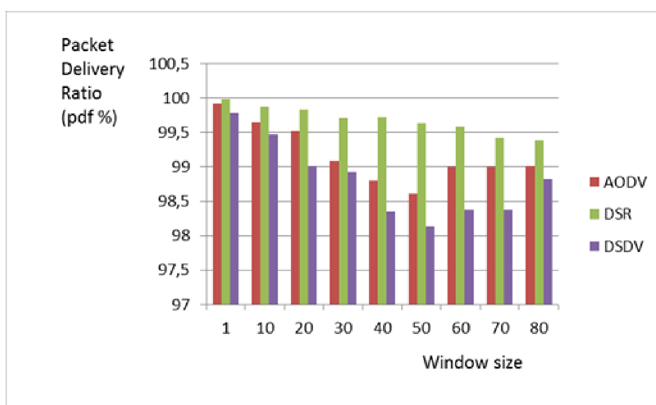
Figure 4. Average end to end delay of AODV, DSR and DSDV with different window size

The congestion window size has considerable effects on the average packets end to end delay performance for all studied MANET routing protocols. Generally, from figure 4, we observe that the average end to end delay values is inversely proportional to the TCP congestion window size used for each scenario performed. However it also can observe that DSDV presents a lower average delay compared with the two reactive protocols. This is due to the fact that DSDV is a proactive protocol, when a node receives a packet, it immediately forward the packet to the predetermined next hop node. In reactive protocols, the data packets are temporarily stored in the nodes buffer if there is no valid route. This may cause a longer delay which increases the average delays of DSR and AODV protocol performance.

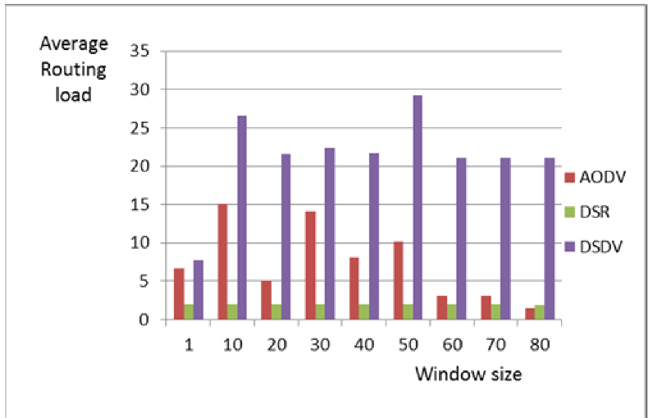
We can display and summarize the simulation results as shown in figure 5.



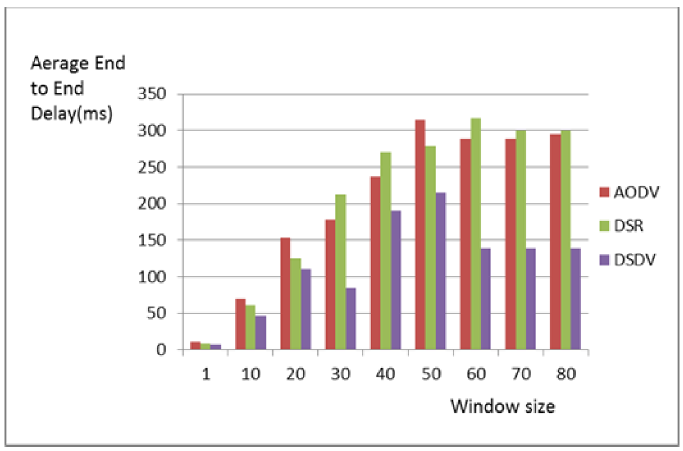
(a)



(b)



(c)



(d)

Figure 5. Performance metrics of AODV, DSR and DSDV with different window size

Figure 5 (a) and (b) shows that the throughput and packet delivery ratio performance metrics. It is observed that DSR protocol performs better than AODV and DSDV. There is a slight effect of window size variations on the throughput and PDR performance of the DSR protocol comparing with AODV and DSDV protocols. When looking at figure 5 (c), the average routing load, it can easily be observed that, DSDV protocol performs much worse than DSR and AODV. The high route control packet exchanges between MANET nodes in proactive protocol, as DSDV, to track updates of the routing tables of any changed occurred in network topology. Also DSR performs much better compared to AODV in terms of average routing load and it maintains a constant value along with window size increasing.

Figure 5 (d) demonstrates average end-to-end delay of DSDV, DSR, and AODV. It shows clearly the effect of the window size on the average end to end delay performance. The rate of end to end delay gradually increases for all protocols used. However, the values of end to end delay reaches to approximate insignificant changes when the window size equals to or larger than the Interface

Queue size value (IFQ=50) used in the simulation scenarios as shown in figure 5 (d), DSDV exhibits the lowest average end-to-end delay among the three routing protocols scenarios.

7 CONCLOSION

In this work, the routing protocols: DSR, AODV, and DSDV are simulated for the performance metrics of throughput, average routing load, average end to end delay and packet delivery ratio by increasing the maximum congestion window size up to 80 with steps of 10. As the window sizes are increasing, DSR protocol performance well in terms of throughput, average route load, and packet delivery ratio with increasing the congestion window size that is due to its reactive characteristics in discovering fresh routes to destinations. Proactive protocol DSDV exhibit lower end to end delay as compared with AODV and DSR. The average delay of MANET protocols increases as the window size increased, that is due to limited node's buffer size used in the network. Finally, our simulation results indicate to impact of congestion window size on the overall routing protocol performance, DSR performs well with varying window size compared with the AODV routing protocol. While DSDV proactive protocol is attractive for minimum packet delay applications.

REFERENCES

[1] Franck Legendre, Theus Hossmann, Felix Sutton, Bernhard Plattner," 30 Years of Wireless Ad Hoc Networking Research: What about Humanitarian and Disaster Relief Solutions? What are we still missing?" ACWR '11, Dec 18-21 2011, Amritapuri, Kollam, Kerala, India, 2011 ACM.

[2] H. ElAarag, M. Bassiouni, "Performance Evaluation of TCP Connection in Ideal and non-ideal Network Environments." Elsevier. Computer Communication 24 (2001).

[3] A. Patel, S. Dubey, A. Verma, S. P. Patel, "Group Mobility Model Based Proactive and Reactive Routing Protocol in MANET." International Journal of Electronics and Computer Science Engineering IJECSE, Volume1, Number 4, V1N4-2377-2386.

[4] N. Kaur, S. Umrao, R. K. Gujral, "Simulation based Analysis of TCP Variants over MANET Routing Protocols using NS2." International Journal of Computer Applications (0975 – 8887) Volume 99– No.16, August 2014.

[5] A. Abd Rahman, Z. A. Zukarnian, "Performance Comparison of AODV, DSDV and I-DSDV Routing Protocols in Mobile Ad Hoc Networks." European Journal of Scientific Research, ISSN 1450-216X Vol.31 No.4 (2009), pp.566-576.

[6] H. Nishat, V. Krishna, D. S. Rao and S. Ahmed, "Performance Evaluation of On Demand Routing Protocols AODV and Modified AODV (R-AODV) in MANETS." International Journal of Distributed and Parallel Systems (IJDPS) Vol.2, No.1, January 2011.

[7] D. B. Jagannadha Rao, K. Sreenu, P. Kalpana, "A Study on Dynamic Source Routing Protocol for Wireless Ad Hoc Networks." International Journal of Advanced Research in Computer and Communication Engineering ,Vol. 1, Issue 8, October 2012.

[8] V. Jacobson, "Congestion avoidance and control", ACM Sigcomm, Aug. 1988

[9] M. Allman, V. Paxson, and W. Stevens, "TCP congestion control," RFC 2581, Apr. 1999.

[10] Senthamilselvi M., Muruganandam A., "Performance Evaluation of Routing Protocols by TCP Variants in Mobile Ad-hoc Networks", International Journal of Computer Science and Mobile Computing, Vol.4 Issue.2, February- 2015, pg. 346-358.

[11] K. Chen, Y. Xue, and K. Nahrstedt, "On setting TCP's congestion window limit in mobile Ad Hoc networks", in Proc. of IEEE ICC, Anchorage, Alaska, USA, May 2003.

[12] Z. Fu, P. Zerfos, H. Luo, S. Lu, L. Zhang, and M. Gerla, "The impact of multihop wireless channel on TCP throughput and loss", in Proc. of IEEE INFOCOM, San Francisco, USA, Apr. 2003

[13] R. A. Hamamreh and M. J. Bawatna, “Protocol for Dynamic Avoiding End-to-End Congestion in MANETs” Journal of Wireless Networking and Communications 2014, 4(3): 67-75.
[14] S. J. Kohakade and S. A. Jain, “Improving TCP performance by congestion window adaptation MANET”, Multidisciplinary Journal of Research in Engineering and Technology, Volume 1, Issue 2, Pg.251-258.
[15] A. Deshpande, “Role of WAN Optimization Solutions in overcoming limitations of TCP performance in Ad-Hoc Networks”, International Journal of Computer Networks and Communications Security, VOL. 2, NO. 11, NOVEMBER 2014, 386–391.
[16] N. P. Bobade and N. N. Mhala,” Performance Evaluation of AODV and DSR ON-Demand Routing Protocol with Varying MANET Size” International Journal of Wireless & Mobile Networks (IJWMN) Vol. 4, No. 1, February 2012.
[17] Z. Fu, H. Luoy, P. Zerfos, S. Lu, L. Zhang and M. Gerla,” The Impact of Multihop Wireless Channel on TCP Performance “IEEE Transactions on Mobile Computing, 2005
[18] D. Koutsonikolas, J. Dyaberi, P. Garimella, S. Fahmy, and Y. Charlie Hu, “On TCP Throughput and Window Size in a Multihop Wireless Network Testbed”, WiNTECH’07, September 10, 2007, Montréal, Québec, Canada
[19] B .Nithya, C.Mala and V. Kumar B,” Impact of Contention Window on Gonestion Control Algorithms For Wireless Ad hoc Network.” pp. 159–170, 2012. © CS & IT-CSCP 2012.
[20] J. K. Jekishan, K. Parmar and M. Mehta,” Performance Evaluation of NS2 And OMNET++ Simulators For AODV Protocol in MANET” International Journal of Research in Engineering and Technology. Volume 03 sssue 2 Feb. 2014
[21] Network Simulator, NS-2, http://www.isi.edu/nsnam/-ns/.

AUTHORS

Nihad I. Abbas received Bachelor of Electronic Engineering degree in Electrical Department from University of Technology, Baghdad, Iraq. And Master degree from University of Technology, Bagdad, Iraq. He has twenty years of teaching experience in engineering colleges. His research interest includes image processing, Mobile ad hoc network, and Electromagnetic computation

Assist. Prof. Emre Ozen received a PhD of Engineering degree in Computer Engineering from Computer Engineering Department, Eastern Mediterranean University, Famagusta, N. Cyprus. His research interest includes Mobile Ad-hoc network, artificial Intelligence Algorithms and computer programming web Technologies.

Assoc. Prof. Mustafa Ilkan received a PhD of Engineering degree in Electrical Engineering from Electrical Engineering Department, Eastern Mediterranean University, Famagusta, N. Cyprus. He has around thirty years of teaching experience in engineering colleges. His research interest includes Renewable Energy Systems-Solar Energy/Photovo, He has more than 30 of international and local published papers on international and local journals.