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Performance Evaluation of MANET Routing Protocols under Different Traffic Loads for Varying Maximum Congestion Window Size

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

[1] Department of Computer Engineering, Eastern Mediterranean University, North Cyprus

[2] Asst. Prof., School of Computing and Technology, Eastern Mediterranean University, North Cyprus

[3] Assoc. Prof., School of Computing and Technology, Eastern Mediterranean University, North Cyprus

E-mail: [1]nehadiabbas@yahoo.com, 2 emre.ozen@emu.edu.tr, 3mustafa.ilkan@emu.edu.tr

ABSTRACT

A Mobile ad hoc network is a collection of wireless mobile nodes connected to form a temporary wireless network without using any communication infrastructure. Due to limited network resources and in order to exchange data packets within the network, wireless multiple hops route scheme adopted for mobile node's connection. Researchers, with the increasing importance of applications in nonmilitary areas proposed several routing protocols for mobile ad hoc networks. This work investigates and compares the performance of MANET routing protocols, namely AODV, DSR and DSDV under different traffic loads with different maximum TCP congestion window size. The Metrics used to compare routing protocol performance are addressed as a packet delivery ratio, the average end-to-end delay, average routing load, and average network throughput.

Keywords: *MANET, Routing Protocols, DSR, AODV, DSDV, Congestion Window Size, NS2.*

1 INTRODUCTION

A mobile ad hoc network (MANETs) consists of a group of mobile nodes connected with each other through wireless links without using any central administrations. Each node in MANET can act as a host or as a router by forwarding data packets to neighbors in the network. The nodes are free to move in any direction and speed so that the network topology could unpredictably change within a short period of time. Nevertheless, studies efforts concern to develop a routing protocol that meet these challenges by showing an efficient communi-cation route between data packet sources and destinations with minimum control overhead packets and less bandwidth resource consumption [1]. A number of routing protocols for wireless ad hoc networks have been developed and evaluated. These routing protocols can be generally classified into two categories: Table-driven (proactive) routing protocol and On-demand (reactive) routing protocols. In the Proactive routing protocol, path topology information of nodes updated continuously and stored in the routing table at each node. While, the reactive routing protocols, route from source to the destination is created when it's needed. The popular multi-hop wireless ad hoc routing protocols that support a range of design choices are: On-Demand Distance Vector Routing (AODV) [2], Dynamic Source Routing (DSR) [3] and Destination-Sequenced Distance-Vector (DSDV) [4]. AODV and DSR protocols are fall under the reactive routing protocols; DSDV represents a table-driven routing protocol category.

For several decades, Transport Control Protocol (TCP) has been proposed to establish a reliable connection in computer wired networks over the Internet (IP) protocol. In case of a MANET, TCP is also preferred as a transport layer protocol. Due to the dynamic topology of MANET, the packet losses occur as a result of a failure path inherent in ad hoc wireless link connections. However, TCP protocol assumes that, the packet loss is due to congestion of the network route at the source rather than the route failure. TCP reacts to packet losses by dropping its transmission congestion window size (cwnd) before retransmitting packets. Hence, the TCP protocol invoked congestion control mechanisms to minimize the effects of the network congestion on the performance of mobile ad hoc routing protocol [5]. Increasing number of source-destination pairs does increase traffic load that leads to increase the number of network wireless packet collisions which decreases the availability of bandwidth resources, it may also be important to study how the optimum congestion window size varies with different traffic loads. Because of different routing protocols have different route characteristics, the results obtained in this case can be generalized to most reactive protocols as: Ad-Hoc on Demand Routing (AODV) and Dynamic Source Routing (DSR) and make a comparison against Destination-Sequenced Distance Vector (DSDV) proactive routing protocol. This paper investigates how the traffic load upon the MANET network and the maximum TCP congestion window size impacts on the overall performance of the network. The rest of the paper is organized as follows: the overview of MANET Routing Protocols is explained in section 2. The transport control protocol TCP congestion window size impacts on MANET provided in section 3. The literature review is summarized in section 4. The simulation environment, simulation results and conclusion of this work is presented in sections 5, 6 and 7 respectively.

2 OVERVIEW OF MANET ROUTING PROTOCOLS

Routing protocols for mobile ad hoc network MANET are depending on the cooperation of MANET nodes in the network. Without this cooperation, no packet can be transferred and no route can be established. The routing protocol consists of the procedural steps that need to be obeyed by the MANET nodes to forward packets across the network and should be automatically able to establish a route in a limited predefined time without human intervention. The nodes in MANET are self-organizing in distributed form behavior and route establishment is essential to perform the routing process properly. MANET routing protocols can be categorized into [6, 7]:

- Table driven protocols (Proactive protocols)
- On-demand protocols (Reactive protocols)
- Hybrid routing protocols

Some popular Ad hoc routing protocols proposed for MANET are described below:

2.1 Destination-Sequenced Distance-Vector (DSDV)

The Destination-Sequenced Distance-Vector (DSDV) Routing protocol is a proactive table-driven algorithm based on the Bellman-Ford routing mechanism involving free from loops in routing tables [4]. Each node in the network stores a routing table of all possible destinations and a recording of the number of hops to each destination available. In order to avoid of routing loops, a sequence number assigned to each entry marked by the destination node. It used to distinguish between the old-fashioned routes from new ones. Routing table updates are transmitted periodically throughout the network to keep table consistency. This mechanism of routing updates will generate a large amount of unnecessary overhead traffic loads that's lead to minimize the network's resources such as channel bandwidth and node energy. The route updates employ full dump packet, which transmited infrequently, carries all routing information available. In order to decrease the amount of traffic generated, DSDV uses a smaller incremental packet to carry only the information which has changed since the last full dump. Every node uses DSDV proactive protocol in MANET maintains a route table includes Destination-address, Metric, and Sequence-number for every possible destination.

2.2 On-demand Distance Vector Routing (AODV)

The AODV routing protocol is an improvement on Destination-Sequenced Distance-Vector (DSDV). AODV decreases the number of broadcasting overhead routing packets to create routes on a reactive basis. AODV protocol doesn't need to keep a list of routes in its route table as in the DSDV algorithm. The routing protocol (AODV) categorized as a style of a pure on demand routing protocol, since the nodes that were not in the specified path does not keep routing information or to participate in the routing table exchanges. When a source node has a data packet to send to a destination, it starts a path discovery process to locate the destination node by flooding a route request (RREQ) packet to neighbor nodes which they are in node wireless transmission range. The node which receives the RREQ packet will forward the request to their neighbors, and so on, until the node is the destination or it has a freshness route to the destination is located. Once the RREQ packet received by an intermediate node or the destination, they reply to this Route Request packet by sending a Route Reply (RREP) packet back to the node from which it received the RREQ. This RREP packet is then transmitted to the source through all nodes in the reverse route path. Hence, every node participates in discovering this route will update their routing tables accordingly. Once the source node receives a (RREP) packet, it stores the information on this route and starts sending data to the destination node. However, in cases where the source node receives multiple (RREP) packets, the shortest hop count route will be selected. In cases where a link failure occurs, a Route Error (RERR) packet is created and returned back to the originator node that will initiate a route discovery process again if the route is still needed [2].

2.3 Dynamic Source Routing (DSR)

The Dynamic Source Routing (DSR) is an on demand source routing based protocol. Mobile nodes are required to keep route caches that include the source routes, of which the mobile is aware. Entries in the route cache are continually updated as new routes are discovered. DSR protocol applies two major mechanism processes: route discovery process and route maintenance process. When the mobile node has a data packet to send to some destination, it examines its route cache to find if there's a route already records in the cache or not. If it finds an unexpired route to the destination, it will send the packet using this route. Otherwise, it initiates a route discovery process by broadcasting a route request packet across the network containing the source node's address, the address of the destination, and a unique identification number. Each node receives the route request packet will check if it has a route to the destination or does not. So, the receiving node records its own address to the route table of the packet and then forwards the packet along its outgoing path. When the route request packet arrives to the destination node itself, or an intermediate node which includes an unexpired route to destination, they generate a RREP packet back to the originator. The advantage of DSR protocol that is no routing tables must be saved to route a given packet, because the entire route is carried in the packet header. The one of the disadvantages of DSR is that it is difficult to scale the DSR protocol networks, and it needs more processing resources than most other protocols [3].

3 TCP CONGESTION WINDOW SIZE IMPACT ON MANET

Todays, Transport control protocol (TCP) plays a significant role in internet world communication because of increasing the internet users and the amount of information exchanges across the network. Therefore, network congestion, is a big challenge faces software engineer's designer for minimizing the effects of the network congestion on overall network performance. Congestion can be defined as the network case when there is no sufficient bandwidth resource to support the network traffic. TCP affected in wireless ad hoc networks considerably due to the nature of the wireless environment issues like mobility, frequent route broken, and energy constrains [8]. Because of the reliability features of TCP protocol, it exhibits some undesirable behavior on MANET protocol performance in the context of efficient energy consumption [9]. For example, wireless transmission packet delay in a MANET network, causing the timer expire of TCP packets that's will impose TCP protocol to retransmit unnecessarily expired packets. So, the MANET nodes will consume more energy and time delay, resulting in network performance degrading.

In mobile ad hoc network environment, when a route to the destination is broken, the originator node starts to find a new route to the destination. The discovering new route process may take longer interval than the TCP retransmission timeout interval (RTO) at the originator node. Thus, the TCP starts a congestion control algorithm to reduce the probability of losing more transmitted packets and reduce the network load traffic. This will reduce the amount of data receipt by destinations in consequently degrade the network throughput performance. TCP increases its congestion window size using the slow start scheme, but this will be undesirable behavior because the TCP connection will be inefficient and the packet transmission rate may not reach to the maximum advertised TCP congestion window size. TCP congestion window size (cwnd) represents the maximum number of packets that the source node can transmit without receipt of any acknowledgment (ACK) from the destination. The aim of slow-start and congestion avoidance algorithm is to maintain the TCP congestion window size around an optimal size. Slow-start scheme increases the window size exponentially to reach a maximum packet transfer rate (SSThresold). On the other hand, a congestion avoidance scheme increases the (cwnd) slowly to avoid packet losses as long as possible. If a source transmitted packet is not received an acknowledgment packet from the destination after a predetermined timeout, Retransmission Time Out (RTO), it will be regarded as a lost packet and is retransmitted again after a predefined period of time. In the case of the Fast Retransmit algorithm, the lost packets retransmitted without waiting for the RTO. This will speed up the lost packet retransmission [10, 11].

4 LITRETURE REVIW

In the last years, several researchers have investigated the performance of TCP protocol over MANET networks. Most of them are pointing to the TCP behavior that displays poor performance in MANET networks [12]. Typically, some of these papers suggested enhancing the standard TCP protocol to improve its performance [13, 14, 15]. Some reliable transport protocols optimized for the MANET network environment have been proposed in [16, 17]. Many papers have studied the effects of MANET node mobility in degrading of the TCP performance [18, 19]. TCP performance in static MANET networks is pointed out by other papers; where the maximum throughput achieved in the static environment is limited because of the interaction, packet exchanges occur just between neighboring nodes within the transmission range of wireless communication [20]. In [21] the authors investigated the optimal value of TCP congestion window size at which TCP throughput performance is maximized for a specific network topology and traffic load pattern. Unlike wired networks, in wireless ad hoc networks, packet losses due to link-layer and communication channel contention are largely dominant. In [20] suggested, based on a spatial reuse consideration to set the TCP maximum window size (CWND) to h/4, where h is the number of hops in the chain network topology. [22, 23] defined abounded setting of the maximum congestion window is depending on the bandwidth-delay product. The authors proposed an adaptive algorithm to set the maximum congestion window size according to the number of hops between the originator node and the destination node of the TCP connection. Most of the studies on TCP performance under static conditions, do not consider any specific mobile routing protocol. In contrast, the effects of various mobile routing

C++ and the interactive user interface programming language is a Tool Command Language (TCL). Figure 1 shows a snapshot of the simulated network.

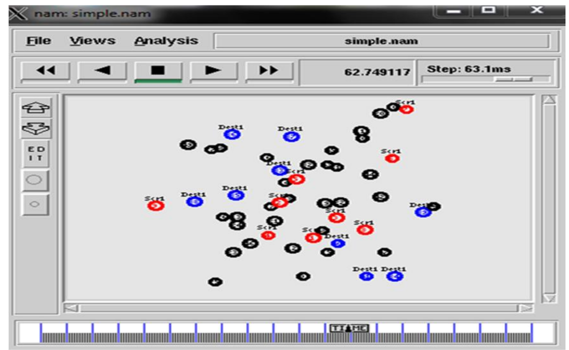


Fig. 1. Snapshot of network topology

5.2 Simulation Parameters

In this work, we have studied the effects of TCP maximum congestion window size on the MANET routing protocol performance by considering two reactive protocols (AODV and DSR) and one proactive routing protocol (DSDV). In addition, we examine the network under different traffic loads, via NS2 network simulator. All the simulated scenarios include 50 mobile nodes distributed randomly across a terrain area of 500 m X 500 m. The nodes move in random waypoint model generated with a maximum speed of 20m/s and different simulation runs with a different traffic loads. In this simulation, the performance evaluation metrics examines for the protocols are (i) Average network throughput, (ii) packet delivery ratio (PDR), (iii) average end to end delay and (iv) average route load. Parameter values of the network simulated are listed in table 1.

protocols have been examined in [24, 25] for different MANET routing protocols are considered.

5 SIMULATION ENVIRONMENT

5.1 Simulation Model

Performance evaluations of MANET routing protocols have been done using a discrete event simulator NS2 version NS-2.35 [26]. The NS2 simulator supports simulations of various wired and wireless routing protocols such as DSR, DSDV, TORA, and AODV. The core programming language used in writing NS2 simulation package is

Table 1: Parameter values of simulation scenario

Parameter	Value
Simulator	NS-2.35
MANET Protocols	AODV, DSR and DSDV
Simulation time	100 Sec
Number of nodes	50
Terrain area	500m x 500m
Wireless transmission range	250m
Mobility model	Random waypoint model
Pause time	5 Sec
Mac Layer Protocol	IEEE 802.11
Interface queue size (IFQ)	50
Packet size	512 bytes/packet

Maximum speed	20 m/Sec
Maximum CWND	10, 30, 50, 70
Application Layer	FTP

5.3 Metrics for Network Performance Evaluation

Routing protocols of mobile ad-hoc network performance can be analyzed and evaluated using many of quantitative metrics. We have been using the following four metrics for evaluating the performance of our wireless ad- hoc routing protocol simulation [27].

- Average throughput is the amount of data packets successfully transferred over a period of time expresses in kbps.
- Packet Delivery Ratio (PDR) is the ratio of total number of packets successfully received by the destination nodes to the number of packets sent by the source nodes throughout the simulation period.
- Average routing load is defined as the number of all routing packets transmitted by all nodes in the network over the simulation time.
- Average end to end delay is the average time elapsed due to data packets for transferring from source nodes to a destination, including all delays caused by buffering, queuing and propagation delays.

6 SIMULATION RESULTS

In this section, we describe the results obtained from our simulation in different scenarios. The first set of simulation considered AODV, DSR and DSDV as routing protocol used, and assumed that there is a different number of source-destination pairs to generate different traffic loads. The purpose was to investigate the impact of TCP maximum congestion window size on network throughput performance. Then, we repeated the above simulation scenario analysis with the rest of the performance metrics.

6.1 Average Network Throughput

Figure 2 shows average network throughput versus congestion window size (cwnd) for AODV, DSR and DSDV MANET routing protocols under a different number of source – destination pairs. It is observed that average throughput of DSDV has performed slightly better compared to a reactive protocols AODV and DSR under different traffic load. AODV throughput is poor at various traffic loads compared with the DSR routing protocol, more packets are dropped in the network due to the collision. In general, variation of TCP maximum window size has a little effect on the packet transferring across the network of routing protocol, especially on DSDV protocol.

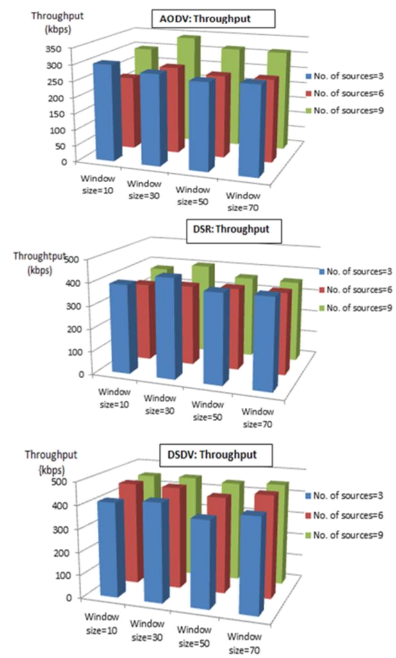
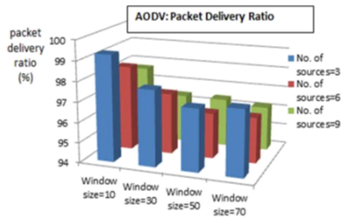


Fig. 2. Throughput for AODV, DSR and DSDV with different window sizes and different traffic load

6.2 Packet Delivery Ratio (PDR)

Figure 3 shows the packet delivery ratio versus congestion window size (cwnd) for AODV, DSR and DSDV MANET routing protocols under a different number of source – destination pairs. It is observed that the packet delivery ratio values of AODV, DSR, and DSDV protocols decrease along with increasing of window size and traffic load values. While TCP window size increments, more data packets are transmitted across the network. The increasing of source-destination pairs, add extra traffic packets to the network as well, that leads to the competition for the wireless transmission channel and increasing the number of collisions as a result, more packets lose and drop occurs.



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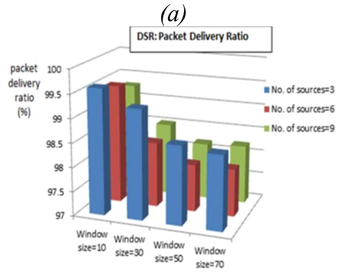

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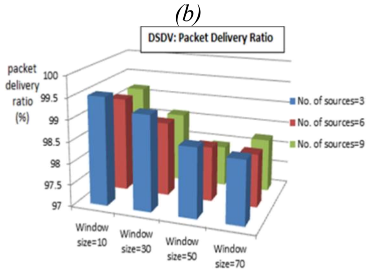
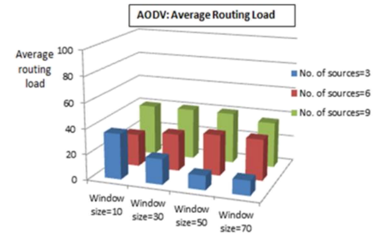


(c)

Fig. 3. Packet Delivery Ratio for AODV, DSR and DSDV with different window sizes and different traffic load

6.3 Average routing load

One of the disadvantages inherent to the routing protocols is the amount of unnecessary overhead control traffic generated by all nodes in MANET, related to the route installation process. Figure 4 shows the average routing load versus congestion window size for AODV, DSR and DSDV MANET routing protocols under different source – destination pairs. It is confirmed that the DSDV routing protocol has a minimum average routing load, whereas AODV and DSR have worse performance. The amount of control traffic generated by DSDV slightly increases with increasing the congestion window size and the number of sources in the network, that is due to the proactive nature of DSDV routing. DSR has lower average routing loads compared with AODV in all cases of increasing network traffic load or increasing window size. As a number of source–destination pairs increases, more nodes contributed in transmitting more overhead packets for route discovery process as in reactive protocols. However, DSDV performance works better than DSR and AODV reactive protocols in both of increasing window size or more network traffic load as shown in figure 4.



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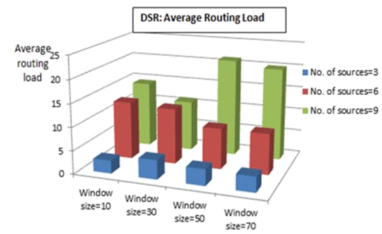

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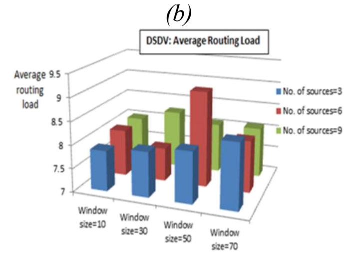
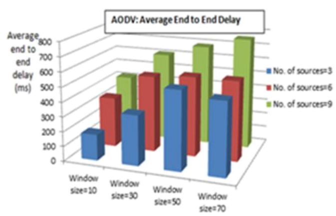


(c)

Fig. 4. Average routing load for AODV, DSR and DSDV with different window sizes and different traffic load.

6.4 Average end to end delay

The packet delay in a network is affected by the high rate of the packets transfer within the network as well, the limited buffer size that full much quicker. The transmitted packets are stored temporarily in the nodes buffer have to wait much longer intervals before they are sent again to the destination. This can be investigated in fig. 5. The number of packet transfers within the network increases as a result of increasing both of window size and traffic load. So, the network packet delay increase too. We observed that DSDV protocol presents the lowest delay compared to reactive protocols AODV and DSR. This can be understood because of the proactive routing process algorithm nature, when a packet received by a node, it may immediately forward to the next neighbor node without waiting to find a route to the destination and it doesn't need discovery process as in reactive protocol. On the other hand, in reactive protocols, packets will be stored in the nodes buffer while the route discovery process is accomplished. This will add extra time delay to the average end to end performance of reactive protocols as seen in fig 5. The average end to end delay of DSR with minimum traffic load (source-destination=3) slightly increases along with the increasing of congestion window size as compared with the AODV average delay, which its value increases rapidly. In contrast, the average delay values of AODV protocol are less than the delay values of the DSR protocol for a number of sources more than 3 along the increasing window size as shown in fig 5.



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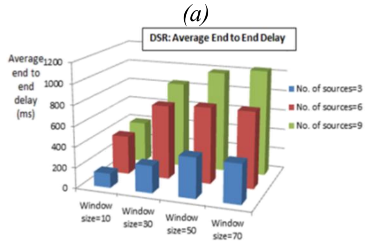

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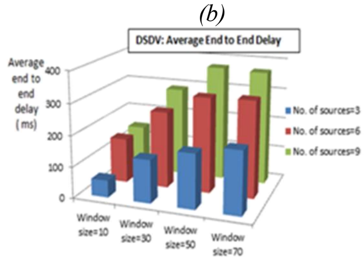

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Fig. 5. Average end to end delay for AODV, DSR and DSDV with different window sizes and different traffic load

7 CONCLUSION

The purpose of MANET routing protocol simulations is to specify which the individual protocols have their weakness or strengths, rather than to propose one protocol is better than the others via using multiple scenarios, randomly generated, with different sets of network's parameters. MANET performance over different modeling environments have been studied and analyzed in many researches. In this work, we describe three of routing protocols adopted by MANET networks; AODV, DSR, and DSDV and they were classified according to the routing mechanisms techniques used (reactive and proactive protocol). The observation results that the protocols simulated in this study shows that the best performance is achieved under lower traffic load (i.e. Source-destination pairs=3) and with minimum value of the TCP congestion window size (i.e. cwnd=10), that is clear in terms of the average end to end delay, average throughput and packet delivery ratio. The increasing of traffic load (increase the congestion window size and/or increase the number of data packet sources) consequently leads to more drop of data packets in the network, also the interface queue buffer overflow quickly. Proactive protocol (DSDV) performs almost well compared to reactive protocols DSR and AODV. DSR performs well than AODV protocol in the amount of overhead control packets send to set up a route to destinations. As far as the dropped packets ratio and average packet delay are considered, DSDV performs better than AODV and DSR with minimum number of traffic sources. Also DSR is preferred over AODV on demand routing in most simulated cases, while DSDV's performance evaluation is superior than DSR and AODV routing protocols.

9 REFERENCES

[1] Franck Legendre, Theus Hossmann, Felix Sutton, and 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] S.R. Das, C.E. Perkins, and E.M. Royer.," Performance comparison of two on-demand routing protocols for ad hoc networks.", In Proceedings of the IEEE Infocom, March 2000, pp. 3-12.

[3] T. Clausen, P. Jacquet, and L. Viennot,." Comparative study of routing protocols for mobile ad hoc networks.", In MED-hoc Net, Sardaigne, France, September 2002.

[4] J. Broch, D.A. Maltz, David B. Johnson, Y. Hu, and J. Jetcheva.," A performance comparison of multihop wireless ad hoc networking protocols." ,In Proceedings of the Fourth Annual ACM/IEEE Internation Conference on Mobile Networking (Mobi-Com'98, , October 1998, pp 25-30.

[5] M.Berger, S. Lima, Manoussakis, A. Manoussakis J. Pulgarin and B. Sanchez, "A performance comparison of TCP protocols over mobile wireless ad hoc networks, "IEEE Electronics, Robotics and Automotive Mechanics Conference, 2006, pp. 88-94,.

[6] 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, ISSN 2277-1956/V1N4-2377-2386.

[7] N. Kaur, S. Umrao, and 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.

[8] V. Ramarathinam and M. A. Labrador,"Performance Analysis of TCP over Static Wireless ad hoc network", In ISCA 15th International Conference on Parallel and Distributed Computing Systems, PDCS'02, Sep. 2002

[9] V. Tsaoussidis, A. Lahanas and C. Zhang,"The Wave and Probe Communication mechanism", The Journal of Supercomputing Kluwer Academic Publishers, Vol. 20, No 2, Sep. 2001.

[10] M. Allman, V. Paxon, W. Stevens, «TCP Congestion Control», RFC 2581, IETF, Apr. 1999.

[11] V. Jacobson., «Congestion avoidance and control», In ACMSIGCOMM'88 symposium on communications architectures and protocols, Vol. 18, No. 4, Aug. 1988.

[12] G. Bhatia1 and V. Kumar "A CROSS-LAYER INFORMATION BASED TCP FOR MANET" International Journal of Ad hoc, Sensor & Ubiquitous Computing (IJASUC) CTCP, Vol.5, No.1, February 2014.

[13] G. Anastasi, E. Ancillotti, M. Contia and A. Passarella,"Experimental Analysis of TCP Performance in Static Multi-hop Ad Hoc Networks" , Pervasive Computing & Networking Lab. (Per Lab).

[14] I. Huh, J. Yong Lee, and B. C. Kim, "Decision of Maximum Congestion Window Size for TCP Performance Improvement by Bandwidth, and RTT Measurement in Wireless Multi-Hop Networks" International Journal of Information Processing Systems, Vol.2, No.1, March 2006.

[15] S. Hamrioui," TCP Performance in Mobile Ad hoc Networks", Network Protocols and Algorithms. Microthink institute, Vol. 5, No. 4, 2013.

[16] K. Sundaresan, V. Anantharaman, H. Y. Hsieh, and R. Sivakumar, "ATP: A Reliable Transport Protocol for Ad hoc Networks", Proc. ACM Symposium on Mobile Ad Hoc Network and Computing (MobiHoc 2003), Annapolis (Maryland), June 2003.

[17] G. Anastasi, E. Ancillotti, M. Conti, and A. Passarella, "TPA: A Transport Protocol for Ad hoc Networks", Proceedings of the IEEE Symposium on Computers and Communications (ISCC 2005), Cartagena (Spain), June 27-30, 2005.

[18] K. Chandran, S. Raghunathan, S. Venkatesan, R. Prakash, "A Feedback Based Scheme for Improving TCP Performance in Ad Hoc Wireless Networks", IEEE Personal Communication Magazine, Special Issue on Ad Hoc Networks, Vol. 8, N. 1, February 2001, pp. 34-39.

[19] T.D. Dyer and R.V. Boppana "A Comparison of TCP Performance over Three Routing Protocols for Mobile Ad Hoc Networks", Proceedings of the ACM Symposium on Mobile Ad Hoc Networking & Computing (MobiHoc), October 2001.

[20] J. Li, C. Blake, D. De Couto, H. Lee,and R. Morris, "Capacity of Ad Hoc Wireless Networks", Proc. ACM/IEEE International Conference in Mobile Computing and Networking , Rome, Italy, July 2001.

[21] Z. Fu, P. Zerfos, H. Luo, S. Lu, L. Zhang and M. Gerla, "The Impact of Multihop Wireless Channel on TCP Throughput and Loss", Proceedings of IEEE INFOCOM 2003, San Francisco (California), March 30.April 3, 2003.

[22] Z. Fu, P. Zerfos, H. Luo, S. Lu, L. Zhang and M. Gerla, "The Impact of Multihop Wireless Channel on TCP Throughput and Loss", Proceedings of IEEE INFOCOM 2003, San Francisco (California), March 30.April 3, 2003.

[23] S.Karthik et,al "An Investigation about Performance Comparison of Multi-Hop Wireless Ad-Hoc Network Routing Protocols in MANET" IJCSI International Journal of Computer Science Issues, Vol. 7, Issue 3, No 6, May 2010.

[24] S.Karthik et,al "An Investigation about Performance Comparison of Multi-Hop Wireless Ad-Hoc Network Routing Protocols in MANET" IJCSI International Journal of Computer Science Issues, Vol. 7, Issue 3, No 6, May 2010

[25] S.Tamilarasan, "A Performance Analysis of Multi-Hop Wireless Ad-Hoc Network Routing Protocols in MANET", (IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 2 (5) , 2011, 2141-2146.

[26] Network Simulator, NS-2, http://www.isi.edu/nsnam/-ns/.

[27] L. Layuan, Y. Peiyan, and L. Chunlin,"Performance evaluation and simulations of routing protocols in Ad hoc networks," Computer Communications, vol. 30, 2007.Technologies, Vol. 2 (5), 2011, pp. 1890-1998.