Performance Comparisons Using Routing Protocols with OPNET Simulator in Mobile Ad Hoc Networks

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***Abstract*— *In this paper performance comparisons of mobile ad hoc network's protocol with its quality of service factors has been measured. It is seen that mobile ad hoc networks will be an integral part of next generation networks because of its flexibility, infrastructure less nature, ease of maintenance, auto configuration, self administration capabilities, and costs effectiveness. This research paper shows comparison within mobile ad hoc networks' routing protocols from reactive, proactive and hybrid categories. We comprehensively analyzed the results of simulation for mobile ad hoc routing protocols over the performance metrics of packet delivery ratio, end to end delay, media access delay and throughput for optimized link state routing, temporary ordered routing algorithm and ad hoc on demand distance vector protocol. In mobile ad hoc networks, mobile nodes must collaborate with each other in order to interconnect, organize the dynamic topology as mobility cause route change and establish communication over wireless links. Our simulation results show the lead of proactive over reactive and hybrid protocols in routing traffic for dynamic changing topology. Proactive protocol optimized link state routing, a protocol for building link tables for ad-hoc networks, can transmit traffic more rapidly though involve less processing speed in packet forwarding.*

Keywords: *MANET, Mobility, Routing Protocol, Wireless.*

I. INTRODUCTION

Mobile ad hoc networks (MANETs) are rapidly evolving as an important area of mobile mobility. MANETs are infrastructure less and wireless in which there are several routers which are free to move arbitrarily and can manage themselves in same manners. MANETs as shown in fig (1) have characteristics that network topology changes very rapidly and unpredictably in which many mobile nodes moves to and from a wireless network without any fixed access point where routers and hosts move, so topology is dynamic. It has to support multi hop paths for mobile nodes to communicate with each other and can have multiple hop

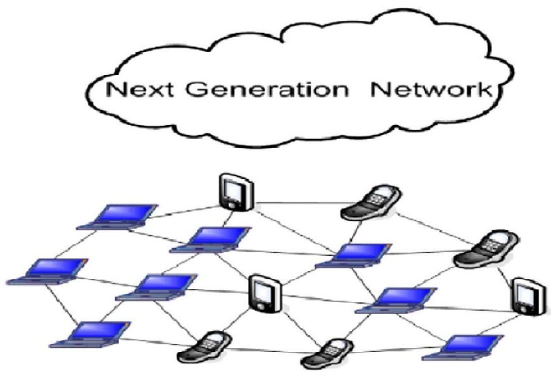


Fig 1: *Mobile Ad Hoc Networks-MANETs*

over wireless links, also connection point to the internet may also change. If mobile nodes are within the communication range of each other than source node can send message to the destination node otherwise it can send through intermediate node. Now-a-days mobile ad hoc networks have robust and efficient operation in mobile wireless networks as it can include routing functionality into mobile nodes which is more than just mobile hosts and reduces the routing overhead and saves energy for other nodes. Hence, MANETs are very useful when infrastructure is not available [5], impractical, or expensive because it can be rapidly deployable, without prior planning or any existing infrastructure. Mostly mobile ad hoc networks are used in military communication by soldiers, planes, tanks etc, operations, automated battlefields, emergency management teams to rescue [5], search, fire fighters or by police and replacement of a fixed infrastructure in case of earthquake, floods, fire etc, quicker access to patient data about record, status, diagnosis from the hospital database, remote sensors for weather, personal area network, taxi cab network, sports stadiums, mobile offices, yachts, small aircraft, electronic payments from anywhere, voting systems [6], vehicular computing, education systems with set-up of virtual classrooms, conference rooms, meetings, peer to peer file sharing systems [6], collaborative games with multi users.

Major challenges in mobile ad hoc networks are routing of packets with frequently mobile nodes movement, there are resource issues like power and storage and there are also wireless communication issues. As mobile ad hoc network consists of wireless hosts that may move often. Movement of hosts results in a change in routes. In this paper we have used routing protocols from reactive, proactive and hybrid categories to make comparison.

II. MOBILE AD HOC NETWORKS ROUTING PROTOCOLS

MANETs routing protocols are characteristically subdivided into three main categories. These are proactive routing protocols, reactive on-demand routing protocols and hybrid routing protocols as shown in fig (2).

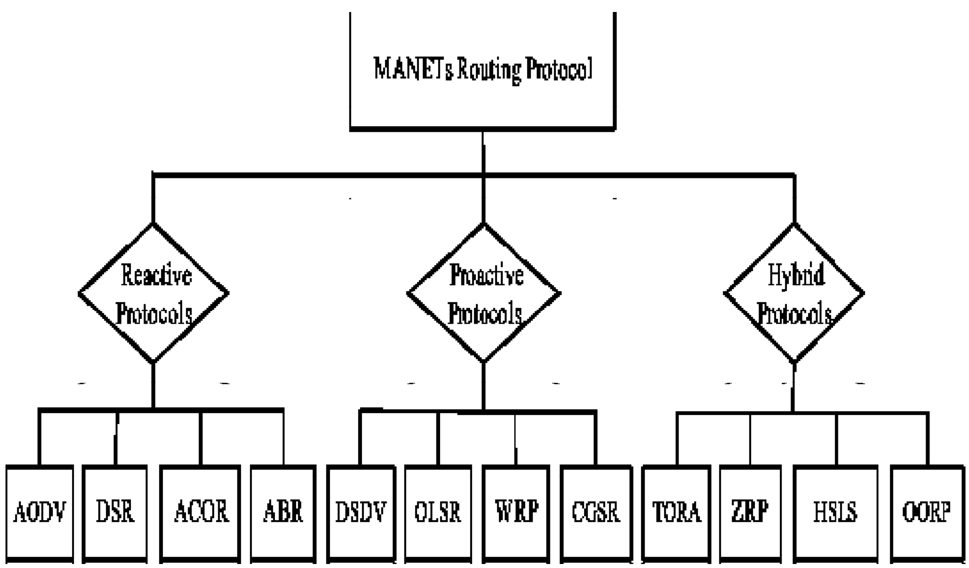


Fig 2: *Categories of routing protocols in Mobile Ad Hoc Networks.*

Proactive routing protocols maintain regular and up to date routing information about each node in the network by propagating route updation at fixed time intervals throughout the network, when there is a change in network topology. As the routing information is usually maintained in tables, so these protocols are also called *table-driven* protocols i.e. ad hoc on demand distance vector protocol (AODV), dynamic source routing (DSR), admission control enabled on-demand routing (ACOR) and associatively based routing (ABR). **Reactive routing protocols** establish the route to a destination only when there is a demand for it, so these protocols are also called *on demand* protocols i.e., destination sequenced distance vector (DSDV), optimized link state routing (OLSR), wireless routing protocol (WRP) and cluster head gateway switch routing (CGSR). When a source wants to send to a destination, it uses the route discovery mechanisms to find the path to the destinations by to initiating route request. When a route has been established, then route remains valid till the destination is reachable or when the route is expired. **Hybrid routing protocols** is the combination of both proactive and reactive routing protocols i.e. temporary ordered routing algorithm (TORA), zone routing protocol (ZRP), hazy sighted link state (HSLS) and orderone routing protocol (OOPR). Proactive and reactive algorithms are used to route packets. The route is established with proactive routes and uses reactive flooding for new mobile nodes. In this paper we have compared MANETs routing protocols from reactive, proactive and hybrid categories, as we have used randomly one protocol from each categories as from reactive AODV, proactive OLSR, hybrid TORA.

III. SIMULATION SETUP

We have conducted extensive simulation study to evaluate the performance of different mobile ad hoc networks routing protocols reactive AODV, proactive OLSR, hybrid TORA. We used OPNET 14.0 simulator to carry out simulation study [7], which is used for network modeling and simulation results as it has fastest event simulation engine.

A. Mobility Model: Mobile nodes in the simulation area move according to random waypoint model [5].

B. *Radio Network Interfaces:* The physical radio characteristics of each mobile node's network interface, such as the antenna gain, transmit power, and receiver sensitivity, were chosen to approximate the direct sequence spread spectrum radio [6].

C. *Media Access Control:* The distribution coordination function (DCF) of IEEE 802.1 1b was used for underlying MAC layer [6]. Default values are used for MAC layer parameters.

D. *Network Traffic:* In order to compare simulation results for performance of each routing protocol, communication model used for network traffic sources is FTP.

E. *Traffic Configuration:* For traffic configuration, all experiments have one data flow between a source node to a sink node consisting of TCP file transfer session and TCP transmits with the highest achievable rate. TCP is used to study the effect of congestion control and reliable delivery [3].

IV. SIMULATION ENVIRONMENT

It consists of 50 wireless nodes which were placed uniformly and forming an ad hoc network, moving about over a 1000 X 1000 meters area for 900 seconds of simulated time [2]. All mobile nodes in the network are configured to run AODV or TORA or OLSR and multiple FTP sessions. In our simulation studies we set different values for seed of the pseudo random number generator *(PRNG)* properly, so that each simulation will produce independent results, in order to affirm the independent replication method for analysis. We collected AODV, TORA, OLSR related statistics and analyze them as the network dynamics changes. Data points represented in the graphs were averaged over 10 simulation runs, each with a different seed. All protocols used Karn's algorithm for accurately estimating the round trip time for messages when using TCP. It is incorporated with transmission timeouts with timer backoff strategy which computes an initial timeout. If the timer expires and causes a retransmission, TCP increases the timeout generally by a factor of 2 as *new_timeout = 2* timeout.*

Beacon Periods	3 sec
Max Beacon Timer	9 sec
Max Tries	3 Attempts

Table 1: *Constants of IMEP used in the TORA simulation.*

Route Discovery Parameter	Gratuitous Reply
Active Route Timeout	30 Seconds
Hello Interval	uniform (1 0,10.1)
Allowed Hello Loss	10
TTL Parameter	2

Table 2: *Constants used in the AODV simulation.*

Hello Interval	2 sec
TC Interval	5sec
Neighbor Hold Time	6 seconds
Entries in topology table expire	15 seconds

Table 3: *Constants used in the OLSR simulation.*

The AODV simulation parameters used are the same as in [1] except the active route timeout which was set to 3 seconds [8], the TORA parameters we used are similar to those in [2]; moreover, the OLSR parameters we used are similar to those in [2], OLSR's Hello interval and TC interval were set to 2 and 5 seconds respectively, its neighbor hold time was 6 seconds, and entries in topology table expire after 15 seconds. When we run AODV simulation then speed and results are improved by active route timeout, Hello interval and allowed Hello loss values. These reduced FTP download and upload response times. As now the routes expire only after 30 seconds rather than 3 seconds. Also gratuitous reply and increased time to live (TTL) start values reduce route discovery frequency. Less routing traffic

is generated because of increased Hello time interval for periodic Hello broadcasts and results in less congestion in wireless network. In OLSR scenario the mobile nodes in the network are grouped in clusters and each cluster of mobile nodes has MPR. The transmission range is 300 meters so that one hop is required for communication for the MN at other ends of the network. Mobile node in centre cluster can be accessed easily than nodes near boundary clusters. The willingness parameters for MPR are chosen to reduce the number of MPRs. If the willingness attribute are already set for some specific MNs then those nodes can guaranteed to be selected as MPR. The MPRs that are selected in each cluster are the MNs which have high willingness parameter. In that case all mobile nodes in wireless network have part of information about network topology and chosen MPR. When mobile nodes receive new topology information then MPRs are selected again and finally move towards stable state. We have five clusters each having its own five MPRs that move towards stable state. MPR mobile nodes in the network send topology control messages periodically. The numbers of MPR in network are directly proportional to the number of TC traffic sent. Each MN sends periodically Hello messages in the network that consists of list of neighbors and node movement's changes. When the number of neighbors for each mobile node decreases then the nodes in centre cluster moves away as a result the size of each hello message reduces [7].

V. METRICS

In our simulation study, performance comparisons are made using following parameters:

A. *Throughput* is the total number of packets received by the destination.

B. *End to End Delay* is the average end to end delay of packets from senders to receivers

C. *Media Access Delay* is the media transfer delay for multimedia and real time traffics' data packets from senders to receivers.

D. *Packet delivery ratio* (PDR) is ratio between the number of packets received by the TCP sink at the final destination and number of packets generated by the traffic sources. Moreover, it is the ratio of the number of data packets received by the destination node to the number of data packets sent by the source mobile node [4].

VI. SIMULATION RESULTS

When the mobile ad hoc network simulations were run than result shows that all mobile nodes were in range of each other, no data packets experience collisions in presence of ftp traffic load and all mobile nodes were capable of sending packets. Hence, it shows that carrier sense and back off mechanisms of the 802.1 1b were working precisely. All results were obtained by averaging over 10 random mobility scenarios of mobile ad hoc networks.

Protocols	Average Number of Events Simulated	Average Speed
AODV	229,537	398,557 events/sec
TORA	199,354,5	544,829 events/sec
OLSR	143,571,00	232,943 events/sec

Table 4: *Simulation results over simulation time of 900 seconds.*

The most of events were simulated by OLSR which are 143, 571, 00.Consequently, average number of events simulated by TORA and AODV are 199, 354, 5 and 229,537 respectively. On the other hand, high simulation speed for most of events simulated per seconds was observed in TORA routing protocol simulation runs that was 544,829 events per second, than it was in AODV and OLSR for about 398,557 and 232, 943 events per seconds. These statistics shows that proactive protocol can simulate millions of more event than reactive and hybrid protocols.

A. Throughput Details

Throughput which is the number of routing packets received successfully by each routing protocol was shown in fig (a). When comparing the routing throughput packets received by each of the protocols, OLSR has the high throughput. Throughput is a measure of effectiveness of a routing protocol. OLSR receives about 1,950,000 routing packets at start of simulation time, then fluctuates for 60 seconds and gradually becomes stable around 1,600,200 data packets received. In fig (b) AODV and TORA are plotted on the different scales to best show the effects of varying throughput. TORA's throughput increases IMEP's neighbor discovery mechanism, which requires each node to transmit at least 1 Hello packet per BEACON period (3 second). For 900 second simulations with 50 mobile nodes, this results in a maximum throughput of 1, 4500 packets. In reactive protocol AODV as the number of sources nodes increases than the number of routing packets receive increases to 8,000 packets as it maintains cache of routes in routing table to destination and unicast reply by reversing route generated by source node or re broadcast route request. Delivery of broadcast packets are not reliable at receiver as there cannot be reservation for the wireless medium at the receivers before transmitting a broadcast packet by exchange of RTS/CTS packets.

The source nodes generate packets and broadcast packets which are received by many mobile nodes, so number of packets received is much higher than the number of packets sent. This difference does not exist in wired networks and shows fundamental limitation of wireless networks. Overall, proactive routing protocol has highest throughput in MANETs.

B. End to End Delays Details

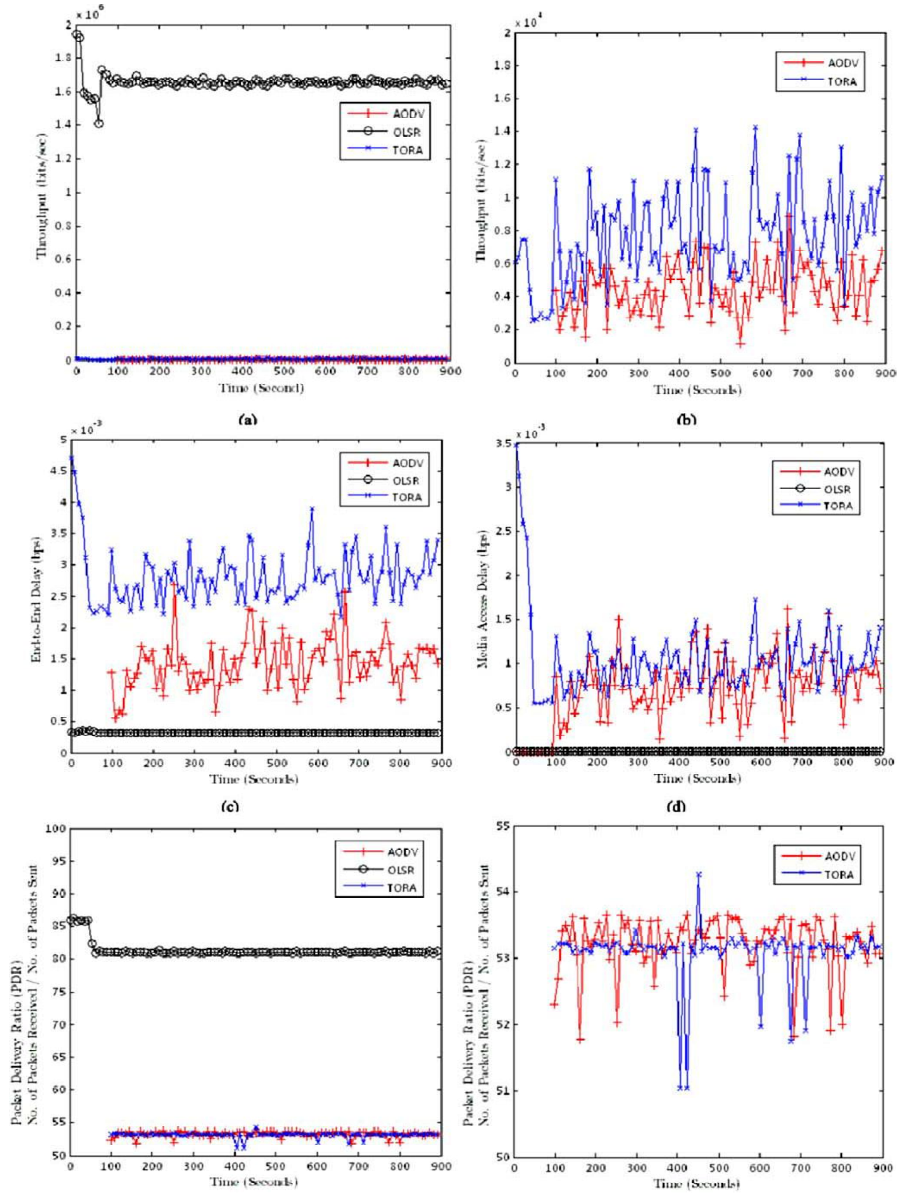
Figure (c) shows that OLSR has lowest steady end to end delays which are about 0.0004 seconds. Further on, the end to end delay start to rise and fall abruptly in AODV and TORA therefore ends up in less end to end delays in AODV as compare to TORA that is around on average 0.0015 second and 0.0032 respectively. TORA had higher delays because of network congestion. As created loop where the number of routing packets sent caused MAC layer collisions, and data, Hello and ACK packets were lost that resulted in assuming that links to neighbors was broken by IMEP. Therefore, TORA reacted to these link failures by sending more UPDATEs, in turn that created more congestion as failure to receive an ACK from retransmitted UPDATEs was considered as link failure indication.

C. Media Access Delay Details

In fig (d) we plotted media access delay which is very important for multimedia and real time traffic; furthermore it is vital for any application where data is processed online. Media access delay was low for OLSR that is around 0.0001 second. However, the media access delay for AODV and TORA fluctuates more frequently but AODV fluctuates more frequently above and below its mean while TORA mainly around its mean, thus in both case fluctuation is higher and more frequent as compared to OLSR that remains steady over 900 seconds of simulation time.

D. Packet Delivery Ratio Details

The fraction of the originated application data packets each protocol was able to deliver at varying time as shown in fig (e). As packet delivery ratio shows both the completeness and correctness of the routing protocol and also measure of efficiency. We used packet delivery rate as the ratio of number of data packets received at the sink node to the number of data packets transmitted by source nodes having a route in its routing table after a successful route discovery. For all protocols packet delivery ratio is independent of offered traffic load, where



(e) **(f)**

Fig 3: *Comparison between the MANETs routing protocol's simulation results (a) Throughput, (b) Throughput for TORA and AODV, (c) End to End Delay, (d) Media Access Delay, (e) Packet Delivery Ratio, (f) Packet Delivery Ratio for AODV and TORA.*

Routing protocols OLSR, AODV, TORA delivering about 81, 53.6 and 53.1 % of the packets in all cases. OLSR provides better packet delivery rate than all other routing protocols, on the other hand TORA has higher delivery ratio as compared to AODV. As packet delivery ratio indicates the loss rate that can be seen by the transport protocols that effects the maximum throughput that the network can handle. OLSR have MRPs for each cluster which maintains routes for group of destination, packets that the MAC layer is unable to deliver are dropped since there are no alternate routes. In fig (f) we have used different scales of axes to show results of packet delivery ratio visibly for reactive and hybrid protocol. TORA in 50 MN wireless networks delivered around fifty three percentages of data packets over simulation time, TORA fall short to converge because of increased congestion. In TORA mainly data packets were dropped because of short lived routing loops, which are part of its link reversal process. In that when MN X has some routing packets for sending to Z by intermediate node Y. While in link reversal process, if mobile node's Y link to Z breaks down then Y can reverse its link to X and transmit routing updation message to its neighbors, by the time X receives the routing updation message, data packets to Z can loop between X and Y. After receiving route updation message, it starts sending routing packets from Z to X. When the packet of next hop and previous hop are same then more data packets were dropped because the packets were looped until time to live expires or when loop exited; moreover, data packets which were in loops interfered by broadcast UPDATE packet from neighbor mobile nodes which in turn can resolve routing loop. It was observed that packet delivery ratio was less in TORA than AODV. Moreover, routing protocols have differed in how much protocols can deliver packets to destination mobile node.

VII. CONCLUSION

The mobile nodes' mobility management is key area since mobility causes route change and frequent changes in network topology, therefore effective routing has to be performed immediately. This paper makes contributions in two areas. Firstly, this paper compared the performance of reactive ad hoc on demand distance vector protocol; proactive optimized link state routing protocol and hybrid temporary ordered routing algorithm protocol in mobile ad hoc networks under ftp traffic. Secondly, we have presented the comprehensive results of packet delivery ratio, throughput, media access delay, and end to end delay over mobile ad hoc networks of fifty mobile nodes moving about and communicating with each other. The simulation results were presented for a range of node mobility at varying time. OLSR performs quite predictably, delivering virtually most data packets at node mobility. In [2] also shows that OLSR shows the best performance in terms of data delivery ratio and end-to-end delay. TORA, although did not perform adequate in our simulation runs in terms of routing packet delivery ratio, delivered over fifty three percentage of the packets. Since the network was unable to handle all of the traffic generated by the routing protocol and a significant fraction of data packets were dropped. As well as in [9] shows that the relative performance of TORA was decisively dependent on the network size, and average rate of topological changes; TORA can perform well in small network size but TORA's performance decreases when network size increases to 50 nodes. On the other hand, AODV performed better than TORA in most performance metrics with response to frequent topology changes. Finally, the overall performance of OLSR was very good when mobile nodes movement was changing over varying time. We have analyzed that all routing protocol successfully delivers data when subjected to different network stresses and topology change. Moreover, mathematical analysis and simulation results both show that optimized link state routing protocol, from proactive protocol category, is a very effective, efficient route discovery protocol for MANETs.

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