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Simulation and Performance Analysis of AODV, TORA & OLSR Routing Protocols

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Abstract: An ad hoc network is a collection of wireless mobile nodes dynamically forming a temporary network without the use of any pre-existing network infrastructure. A number of ad hoc routing protocols have been developed during the time, but none of these is able to produce efficient routing of packets in large number of nodes due to their own limitations. Therefore, scalability is an open issue in all routing protocols. In this paper, we presented our observations regarding the scalability comparison of the three MANET routing protocols, Ad hoc On Demand Distance Vector (AODV), Temporally Ordered Routing Protocols (TORA) and Optimized Link State Routing (OLSR) by varying the number of nodes. The simulation is done by using OPNET Modeler 14.5 simulator by taking throughput and network delay as performance metrics. In case of delay AODV and OLSR perform in a similar manner as the number of nodes increases. However, in throughput OLSR outperforms AODV and TORA.

Index terms: AODV, MANET, OLSR, Scalability, TORA

I. INTRODUCTION

In last three decades, wireless network has grown enormously. Although, wireless network has eased the information sharing and communication but we have to setup static links before we can start the communication between two systems. This form of network is known as infrastructured network. These networks can only work in the environment where a fixed infrastructure exists. This motivates the need of infrastructureless networks which are known as *ad hoc* networks. Ad-hoc means “for one specific purpose only” [1]. Hence, these networks are formed when needed. All available nodes are aware of all other nodes within range. The entire collection of nodes is interconnected in many different ways. The topology of such networks changes very rapidly because the nodes in ad hoc network are mobile and independent of each other. This makes the routing very difficult. The widespread adaptation of ad hoc networks has produced the challenge of scalability. The scalability performance of the network depends on the routing protocol used in the network. A routing protocol is responsible for delivering the packet from source to destination. In this paper, we have analysed and compared three widely used routing protocols namely AODV, TORA and OLSR based on the scalability. Network delay and throughput are chosen as the performance metrics.

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The rest of the paper is organized as follows: Section II presents the definition of MANET, Routing and protocol classification. Overview of three protocols used in the study is presented in Section III.
Section IV describes the simulation environment and performance metrics and then the results are presented in Section V. Finally, Section VI concludes the paper.

II. MOBILE AD-HOC NETWORK (MANET)

Mobile Ad-hoc NET work (MANET) [1] is a collection of wireless mobile nodes forming a temporary/short-lived network without any fixed infrastructure where all nodes are free to move arbitrarily and where all the nodes configure themselves. The entire collection of nodes is interconnected in many different ways. There are more than one path from one node to another. The nodes in a MANET can be of varying capabilities. Mobile phones, laptop computers and Personal Digital Assistants (PDAs) are some examples of nodes in ad-hoc networks.

2.1 Routing In MANETs

To facilitate communication within the network a routing protocol is used to discover routes between nodes. The goal of the routing protocol is to have an efficient route establishment between a pair of nodes, so that messages can be delivered in a timely manner.

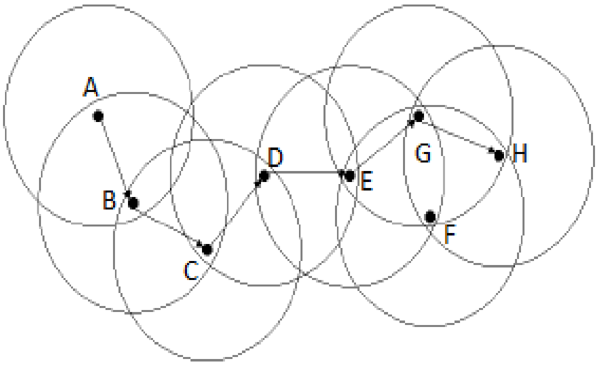

Figure 1. Routing in MANETs

As shown in Fig. 1, route is created between nodes A and H using a number of intermediate nodes. This is called multi-hop routing. Bandwidth and power constraints are the important factors to be considered in current wireless network because multi-hop ad-hoc wireless relies on each node in the network to act as a router and packet forwarder. This dependency places bandwidth, power computation demands on mobile host to be considered while choosing the protocol for the nodes. Routing protocols used in wired network cannot be used for mobile ad hoc networks because of node mobility [2].

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2.2 Classification of Routing Protocols

Many protocols have been proposed for MANETs. These protocols can be mainly divided into two categories [3].

- Reactive/On-demand Routing Protocols
- Proactive/Table-driven Routing Protocols

A. Reactive/On-demand Routing Protocols

In reactive or On-demand protocols, the routing information is maintained only for active routes. That is, the routes are determined and maintained by a node only when it wants to send data to a particular destination. A route search is needed for every unknown destination. Therefore, the communication overhead is reduced at expense of delay due to route research. Some reactive protocols are Ad hoc On-Demand Distance Vector (AODV), Temporally Ordered Routing Algorithm (TORA) and Dynamic Source Routing (DSR). But here we’ll discuss only AODV and TORA as we have simulated these two protocols from reactive category[2].

B. Proactive/Table-driven Routing Protocols

In proactive or table-driven routing protocols, the routing tables are used. Each node maintains up-to-date routing information to every other node in the network in the routing tables. Routing information is periodically transmitted throughout the network in order to maintain routing table consistency. However, for highly dynamic network topology, the proactive schemes require a significant amount of resources to keep routing information up-to-date and reliable. Some highly used proactive routing protocols are Optimized Link State Routing (OLSR), Destination Sequenced Distance Vector (DSDV) and Wireless Routing Protocol (WRP) [2].

III. DESCRIPTION OF AODV, TORA AND OLSR

A. Ad hoc On-Demand Distance Vector (AODV)

The AODV joins the mechanism of DSDV and DSR. The hop-by-hop routing and sequence number of DSDV and the on-demand mechanism of route discovery and route maintenance from DSR are combined in AODV [4].

Route Discovery: In this part when the route is present in cache, route discovery is not used. Otherwise the RREQ which contains the last known sequence number, is flooded in network. The intermediate nodes store the reverse route to source. When destination gets the RREQ, it sends back RREP that contains number of hops to it and most recent sequence number. All intermediate nodes that forward the RREP backward build a forward path. Because of the hop-by-hop nature of AODV the nodes store only the next hop instead of entire route. Route Maintenance: To maintain routes, the nodes check link status of their next hop neighbor in active routes. The node, detecting a link break sends a route error (RERR) message to each of its upstream neighbor to invalidate this route and the neighbors forward it further. Consequently, these nodes propagate the RERR to their predecessor nodes. This process continues until the source node is reached. When RERR is received by the source node, it can either stop sending the data or reinitiate the route discovery mechanism by sending a new RREQ message if the route is still required. A routing table entry is removed if not used recently [7] .

B. Temporally Ordered Routing Algorithm (TORA)

The TORA [5] is a distributed routing protocol. This is based on the link reversal algorithm. TORA is designed to minimize the reaction to topological changes. The key concept is that control messages are typically localized to very small set of nodes. TORA can be separated into three separated functions:

- Creating Routes
- Maintaining Routes
- Erasing Routes

The creation of routes basically assigns directions to the undirected network forming a Directed Acyclic Graph (DAG) rooted at the destination node. When a link between the source and the destination fails, the nodes reverse the direction of the links and update the previous nodes in the path. Additionally, each node maintains multiple paths to a given destination and is capable of detecting any partitions in the network.

In TORA, a value “height“ is associated with each node at all times. The Data flow occurs from a node with a higher value of height to a node with a lower value. When a node cannot detect the height value of one of its neighbors, it does not forward data packets to that node. Routes are discovered using query (QRY) and update (UPD) packets. When a node with no downstream links needs a route to destination, it will broadcast QRY packet. This QRY packet will propagate through the network until it reaches a node that has route or a destination itself. Such a node will then send a UPD packet that contains the node height. Every node receiving this UPS packet will sets its own height to larger height than specified in the UPD message. The nodes will then broadcast their own UPD packets. This will result in a number of directed links from the originator of QRY packet to destination. This process can result in multiple routes. Maintaining routes refers to reacting to topological changes in the network in a manner such that routes to destination are re-established within finite time, meaning that its directed portion return to destination oriented graph within finite time. Upon detection of network partition, all the links in portioned part are marked as undirected to erase invalid routes by using clear (CLR) message. TORA disseminates control messages in a small local area [10], not in the entire network, thus preserving bandwidth and minimizing processing time in the nodes. When a link failure occurs, there is no need for a large-scaled dissemination of control packets, as they can be limited to the small region where the link failure occurs. TORA requires bidirectional links between the nodes in the network.

C. Optimized Link State Routing (OLSR)

The Optimized Link State Routing protocol (OLSR) [6] is an optimization of a pure link state protocol (complete link information is flooded though network) as it compacts the size of information sent in each message, and reduces the number of retransmissions to flood these messages in the entire network. The protocol uses a multipoint relaying technique to flood its control messages in an efficient and economic way.

The idea of multipoint relays is to minimize the flooding of broadcast packets in the network by reducing retransmissions in the same region. Each node selects a set of 1-hop neighbors, which retransmits its packets. These neighbors are called the multipoint relays (MPRs) of that node. For the retransmission, each of the nodes maintains a set of neighbors called MPR Selectors. The node is assumed to retransmit every broadcast message coming from one of these MPR Selectors. The multipoint relay set is chosen among a node's one-hop neighbors in such a manner that it is the minimum set that covers (radio range) all the nodes that are two hops away. The multipoint relay set of N, MPR(N), satisfies the following condition: every node in the two hop neighborhood of N must have a bi-directional link towards other nodes in MPR(N). These bi-directional links are determined by periodically broadcasting HELLO messages, containing the information about neighbors and their link status [3]. OLSR protocol depends on the selection of multipoint relays and determines routes through these nodes. The MPR nodes are selected as intermediate nodes in the path. To use this scheme every node periodically broadcasts its one-hop neighbors, which have selected it as multipoint relay. Each node uses this information to calculate and update each known destination. A route is a sequence of hops through the multipoint relays from source to destination.

IV. SIMULATION SETUP

4.1 Simulator

The simulation is performed using the OPNET (Optimized Network Engineering Tool) Modeler 14.5 simulator. OPNET is a discrete event network simulator that provides virtual network communication environment. OPNET Modeler 14.5 is chosen because it is one of the leading environments for network modelling and simulation. It offers easy graphical interface. This tools is highly reliable, robust and efficient. It supports large number of built-in industry standard network protocols, devices, and applications [9].

4.2 Simulation Parameters

This simulation study focuses on the performance of routing protocols with increase in the number of nodes. Therefore, nine simulation scenarios consisting of different number of nodes i.e. 25, 50 and 75 are considered for three routing protocols AODV, TORA & OLSR. HTTP traffic is generated using the Application and Profile Configuration. Table 1 shows the simulation parameters used in this study. The speed of the nodes is set to 5 meters/sec. We have chosen random waypoint mobility model as this assures that mobile nodes are configured with mobility. Buffer size is set to 1024000 bits as heavy browsing is used for traffic generation.

Table 1. Simulation Parameters

Attribute	Value
Maximum Simulation Time	300 sec
Interface Type	Wireless(ad-hoc)
Network Area	500*500 meters 700*700 meters 900*900 meters
Mobility Model	Random Way Point
Data Rate(bps)	11Mbps
Transmit Power(W)	0.020
Buffer Size(bits)	1024000
No. of Nodes	25, 50, 75
Protocols	TORA, AODV, OLSR
Traffic Generation Application	HTTP

4.3 Performance Metrics

The metrics have been chosen in order to evaluate the routing protocols for scalability. The metrics which capture the most basic overall performance of Routing protocols studied in the research work are as follows:

(a) Throughput (messages/second): Total number of delivered data packets per second of simulation time. We analyze the throughput of the protocol in terms of number of messages delivered per second.

Throughput= (number of delivered packets * packet size)/ total duration of simulation.

(b) Average End-to-End Delay: Average End-to-End delay (seconds) is the average time it takes a data packet to reach the destination. This includes all possible delays.

Delay= (Total Delay for all successful data packet delivery)/ Number of received data packets.

V. RESULTS AND DISCUSSIONS

The performance comparison is made between three routing protocols AODV, TORA and OLSR by varying the number of nodes from 25 to 75.

A. Average End-to-End Delay

The first performance metric, Average End-to-End Delay is calculated for all three routing protocols for 25, 50 and 75 number of nodes.

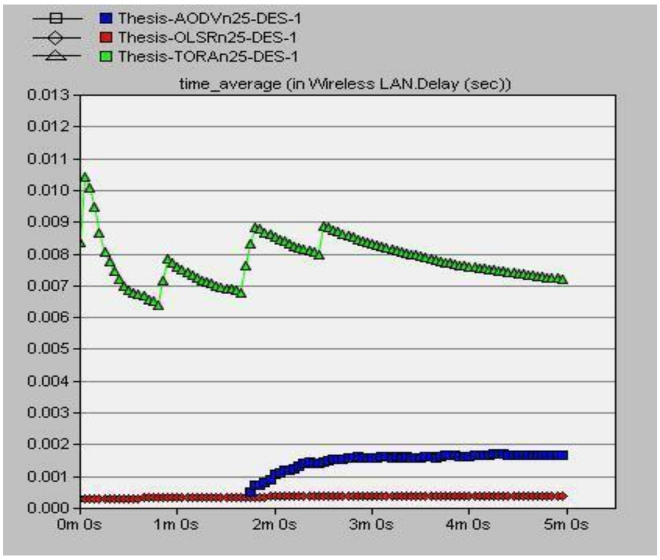

Figure 2. Network Delay for 25 nodes (TORA, AODV and OLSR)

The Fig. 2 , 3 and 4 show the network delay in all three protocols for 25, 50 and 75 nodes respectively. In all three cases TORA has maximum delay as compared to AODV and OLSR as the number of nodes increased.

Therefore, TORA performance is worst among these three protocols for scalability. The main reason behind failure of TORA to react quickly is that it finds multiple routes from source to destination so, it takes more time for searching the routes. AODV shows lower delays but slightly higher than the OLSR.

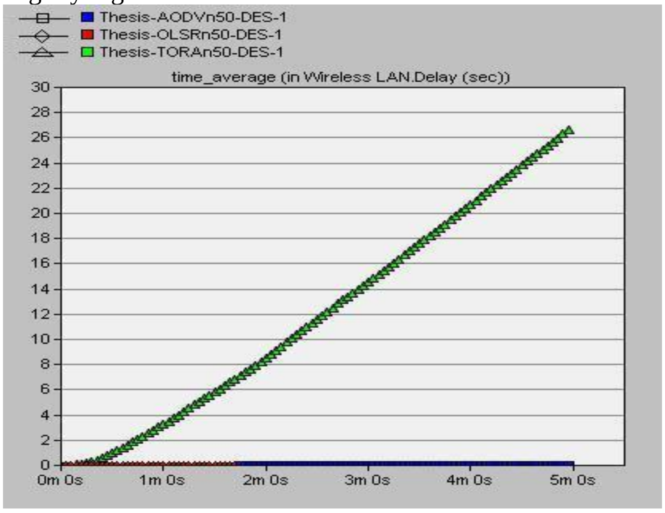

Figure 3. Network Delay for 50 nodes (TORA, AODV and OLSR)

OLSR protocol performed better as compared to AODV and TORA in case of network delay. This is due to the proactive nature of the protocol. Based on the performance of protocols in delay metric, we can say that OLSR is scalable with respect to the number of nodes.

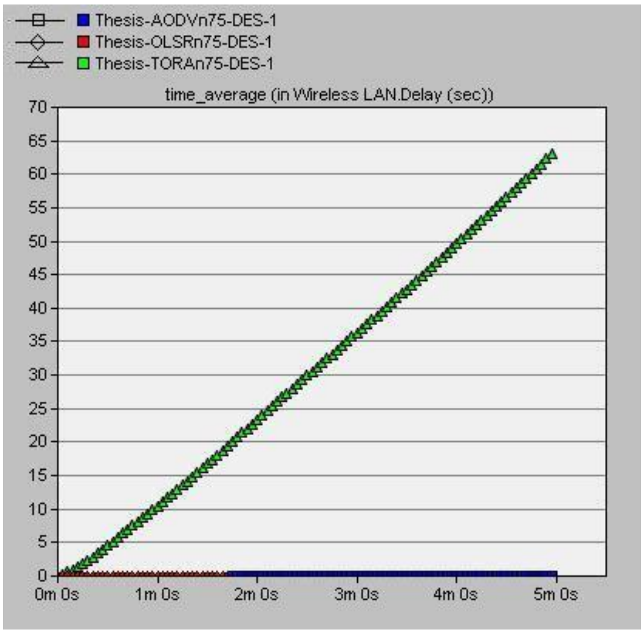

Figure 4. Network Delay for 75 nodes (TORA, AODV and OLSR)

B. Throughput

Network Throughput is taken as main performance metric for the comparative analysis of the protocols. As in case of delay, throughput is also calculated for all three protocols AODV, TORA and OLSR by varying number of nodes.

Figure 5, 6 and 7 show the network throughput in all three protocols for 25, 50 and 75 number of nodes.

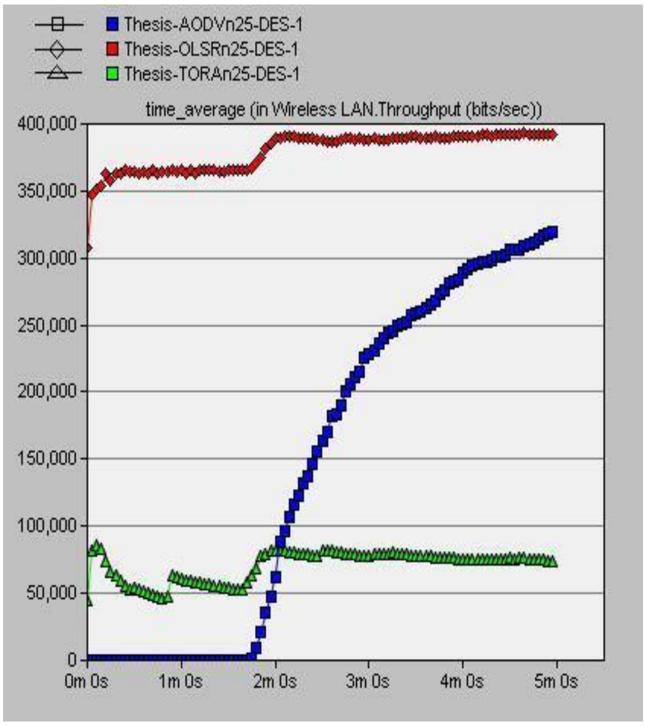

Figure 5. Throughput for 25 nodes (TORA, AODV and OLSR)

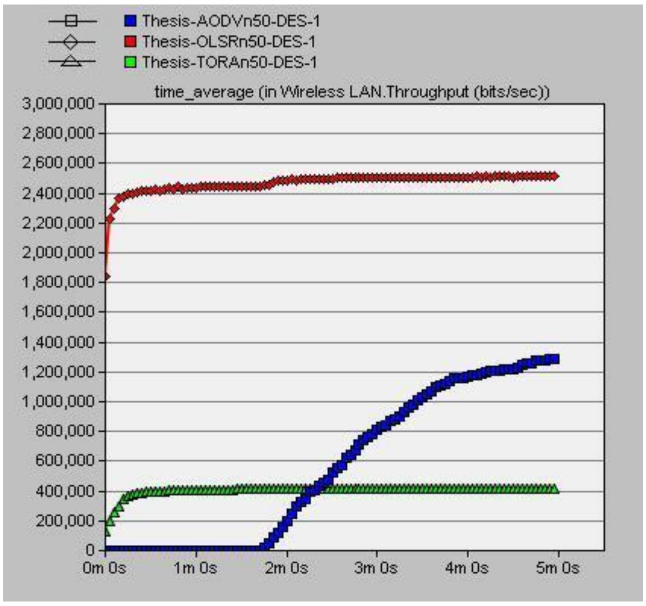

Figure 6. Throughput for 50 nodes (TORA, AODV and OLSR)

Comparing all three protocols, TORA performed worst in case of throughput too. Throughput of TORA is very less than that of AODV and OLSR. This is due to the large network overhead generated by TORA. Other reason for lower throughput by TORA is, it deletes its routes when they are not in use. AODV performed decently in terms of throughput when increased the number of nodes. AODV discovers multiple routes from source to destination so there are always the chances of finding an optimal route.

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AODV tends to reduce the control traffic overhead at the cost of increased latency in finding new routes. The Hello messages, which are responsible for the route maintenance, are also limited so that they do not create unnecessary overhead in the network.

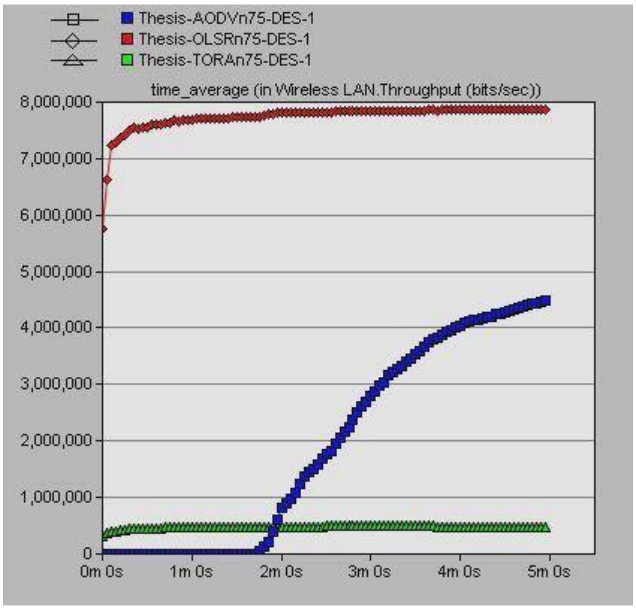

Figure 7. Throughput for 75 nodes (TORA, AODV and OLSR)

OLSR performed better than TORA and OLSR in case of throughput too. This is due to the proactive nature of OLSR. OLSR reduce the control overhead forcing the MPR to propagate the updates of the link state. But the drawback of this is that it must maintain the routing table for all the possible routes, so there is no difference in small networks, but when the number of the mobile hosts increase, then the overhead from the control messages also increases. This constrains the scalability of the OLSR protocol to some extent. The OLSR protocol work most efficiently in the dense networks.

VI. CONCLUSION

In this research study, we have performed simulations of three MANET routing protocols AODV, TORA and OLSR to evaluate their scalability and then compared them. Simulation is done using the OPNET Modeler 14.5. In the research work, Average end to end delay and throughput are considered as the performance evaluation parameters. HTTP heavy browsing is used for traffic generation. The simulation results conclude that on increasing the number of nodes there is performance degradation in all protocols, but it varies from protocol to protocol. As the number of nodes increased the network average end to end delay also increased for all three routing protocols. However, OLSR protocol outperformed the AODV and TORA protocols and has least network latency. TORA performed worst even it uses the localization feature [3]. In case of network throughput too, it is observed that on varying the number of nodes performance of TORA protocol was very poor. Whereas, the performance of the OLSR protocol was far better than the AODV and TORA in terms of throughput. AODV performance was average during the simulation however; it reduces the routing overhead to great extent and reacts quickly during its operation. Hence, this paper concludes that the OLSR protocol in highly scalable with reference to varying network size, however the AODV protocol is almost equally scalable but less than OLSR. This comparative analysis is done to identify the suitable protocols according to the network size, so that the routing could be more efficient and cost effective.

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