Performance Comparison of Routing Protocols in Mobile Ad hoc Networks using ftp Traffic

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***Abstract*— Mobile Ad Hoc Networks (MANETs) are receiving a significant interest and are becoming very popular in the world of wireless networks and telecommunication. MANETs consist of mobile nodes which can communicate with each other without any infrastructure or centralized administration. In MANETs, the movement of nodes is unpredictable and complex; thus making the routing of the packets challenging. As a result, routing protocols play an important role in managing the formation, configuration, and maintenance of the topology of the network. A lot of routing protocols have been proposed as well as compared in the literature. However, most of the work done on the performance evaluation of routing protocols is done using the Constant Bit Rate (CBR) traffic. This paper involves the evaluation of MANETs routing protocols such as Ad hoc on Demand Distance Vector (AODV), Dynamic Source Routing (DSR), Temporary Ordered Routing Algorithm (TORA), and Optimized Link State Routing (OLSR) using file transfer protocol (ftp) traffic. The performance metrics used for the evaluation of these routing protocols are delay and throughput as a function of the load; that is under light load and heavy load. The overall results show that the proactive routing protocol (OLSR) performs better in terms of delay and throughput than the reactive routing protocols AODV, DSR and TORA for medium size MANETs.**

***Index Terms*—mobile ad hoc network, routing protocols, ftp traffic.**

I. INTRODUCTION

Mobile Ad Hoc Networks (MANETs) are becoming very popular in the world of wireless networks. MANETs are ad hoc networks consisting of mobile nodes which can communicate with each other without any infrastructure. In MANETs, there is no need for infrastructure or central administration since the temporary network formed by the mobile nodes are self-configuring, self-routing and self-organizing.

Every node in a MANET acts as a router or as a relay station [1]; each node participates in routing packets [2]. That is, the sender node can either forward the packet directly to the destination when it is close enough or through intermediate nodes when the destination node is out of reach [3]. MANET nodes can form the network at anytime and anywhere thus making the network topology highly dynamic and the routing of packets complex. Hence there is a need for MANETs to have routing protocols which can adapt to the mobility and dynamically changing topology of the network.

A number of routing protocols have been proposed, evaluated and implemented. Some researchers have classified routing protocols into two categories: link-state protocols and distance-vector protocols [4], whereas others [5] classified them into four categories: proactive protocols, reactive protocols, hybrid protocols and cluster-based protocols.

In MANETs, the movement of the nodes is unpredictable; so reliable routing protocols should be able to adapt to the unpredictable and dynamic topology of the network caused by the random displacement of mobile nodes within a specific area [3]. As stated earlier, many routing protocols have been proposed and implemented by researchers; however most of them use Constant Bit Rate (CBR) traffic [2], [3], [5], [6], [7] , [8] and [9] because CBR traffic preserves constant bandwidth and minimizes the packets loss during transmission. However, with the increased use of file transfer applications recently, there is a need to analyze routing protocols using file transfer protocol (ftp) traffic.

This paper evaluates the performance of MANETôs routing protocols e.g., Ad Hoc on Demand Distance Vector (AODV), Dynamic Source Routing (DSR), Temporally Ordered Routing Algorithm (TORA) and Optimized Link State Routing (OLSR) protocols in terms of delay and throughput as a function of the load for a common and simple application such as ftp.

II. ROUTING PROTOCOLS OVERVIEW

The challenges and flexibility of MANETs have generated a lot of research in routing protocols for such networks. The network research community has been working intensively on modeling, designing and implementing new routing protocols for MANETs. De Rango et al. [5] classify MANET routing protocols into four categories: proactive protocols, reactive protocols, hybrid protocols and cluster-based protocols. Three popular reactive routing protocols, DSR, AODV and TORA and a popular proactive routing protocol, OLSR, will be briefly discussed in the next section.

A. Ad hoc On Demand Distance Vector (AODV)

AODV routing protocol is a reactive routing protocol which was first proposed by an IETF Internet draft in 1997. According to Belding-Royer and Perkins [4], AODV was proposed to meet the following goals:

- Minimal control overhead.
- Minimal processing overhead.
- Multi-hop path routing capability.
- Dynamic topology maintenance.
- Loop prevention.

The operation of AODV is done using the following two mechanisms: route discovery and route maintenance [4], [8].

Route discovery: This is a mechanism by which a source node wishing to send a packet to a destination node obtains dynamically a source route when it does not have a route in its routing table.

Route maintenance: Once a route has been established, the source node will maintain the route for as long as it needs it. The movement of nodes not lying along the active route does not affect the routing to that path's destination.

B. Dynamic Source Routing (DSR).

DSR is a reactive routing protocol developed at Carnegie Mellon University, Pittsburgh USA, for the use of multi-hop wireless MANETs. DSR allows the network to be completely self-organizing and self-configuring [6]. The operation of DSR is done using the following two mechanisms: route discovery and route maintenance [5].

Route discovery: This is a mechanism by which a source node wishing to send a packet to a destination node dynamically obtains a path to the destination. Route discovery is used only when the source node does not know a route to the destination.

Route maintenance: This is performed when there is an error with an active route. When a node of the network that is part of some route notices that it cannot send packets to the next hop, it will create a message containing the addresses of the node that sent the packet and of the next hop that is unreachable; and send that to the source node.

C. Temporally-Ordered Routing Algorithm (TORA).

TORA is an efficient, highly adaptive, and scalable routing protocol based on the link reversal algorithm [10]. TORA provides multiple routes to transmit data packets between source and destination nodes of the MANET.

According to [6], the TORA protocol consists of three basic functions: creating routes, maintaining routes, and erasing routes. Creating routes corresponds to the selection of heights to form a directed sequence of links leading to the destination in a previously undirected network or portion of the network. Maintaining routes refers to adapting the routing structure in response to network topological changes. During this erasing routes process, routers set their heights to null and their adjacent links become undirected.

D. Optimized Link State Routing (OLSR).

OLSR is an MANET proactive routing protocol that uses the concept of Multi Point Relays (MPRs). MPR is an optimized þooding control protocol used by OLSR to construct and maintain routing tables by diffusing partial link state information to all nodes in the network [5].

The functioning of OLSR can be divided into the following three mechanisms:

- Neighbor/Link sensing.
- Efficient control þooding using MPR.
- Optimal route calculation using the shortest route algorithm.

III. RELATED WORK

Many researchers have studied MANETs routing protocols especially in terms of performance analysis. The next section presents some of the related work done on MANETs routing protocols.

A study by Gupta et al. [6] analyzed the performance of AODV, TORA and DSR using simulation. The simulator used for evaluation was Network Simulator version 2 (NS-2). The simulation was done in a rectangular field of 500m x 500m with 50 nodes. The traffic source used was CBR traffic and the simulation time was 2000s. The performance metrics used were Packet Delivery Fraction (PDF) and average end-to-end delay. From the results generated, it was concluded that the AODV protocol has the best overall performance. The result also demonstrated that the DSR protocol is suitable for networks with moderate mobility rate and since it has a low overhead that makes it suitable for low bandwidth and low power networks. The results also proved that TORA protocol is suitable for operation in large mobile networks having a dense population of nodes.

Layuan et al. [11] carried out the simulation analysis of three reactive protocols AODV, DSR, and TORA and a table-driven protocol Destination-Sequenced Distance-Vector (DSDV). The simulator used was NS-2 and the traffic source used was CBR traffic. The simulation models the network size with 10, 20, 40, 50, and 100 mobile nodes placed randomly within a 1000 m × 1000 m area. The packet size used was 512 bytes and the simulation time for each scenario was 300 seconds. The performance metrics used were: end-to-end data throughput, average end-to-end data delay, jitter, packet loss ratio, and normalized routing load. Additional metrics such as scalability and connectivity were also used. The results showed that TORA has a lowest routing load and a good scalability. The results also showed that DSR has a less loss ratio, a large throughput and a long delay. In all the scenarios, AODV displays the smallest delay and loss ratio, and the greatest throughput.

De Rango et al. [5] presented a comparative analysis of DSR and OLSR from an energy point of view in MANETs. The objective of their study was to evaluate how DSR and OLSR affect the energy use of mobile nodes. The performance evaluation was through simulation and the simulator used was NS-2. The packet size was set to 512 bytes and the metrics used were: control overhead, data packets received, average end-to-end delay, throughput, connection expiration time, number of live nodes and energy consumption. The traffic used was CBR, fixed connection pattern and variable connection pattern. The results illustrated that the DSR protocol takes advantage of its routing policy, but the OLSR protocol can perform well with high traffic load and a variable traffic pattern. In the same work, De Rango et al. also stated that the route cache reply mechanisms activated on DSR can increase the data packet delivery and the protocol control overhead. However, the drawback of this approach is the increasing end-to-end data packet delay. The presented results also show that for the OLSR protocol, the link failure notiýcation at the data link layer permits the delivered data packets to be considerably increased and the data throughout to be increased without expending more energy.

Kulla et al. [12] compared the performance of AODV and OLSR for different source and destination moving scenarios. They implemented a MANET testbed which provides the environment to make different measurements for indoor and outdoor communications. AODV and OLSR were implemented using four scenarios: Static Scenario, Source Moving Scenario, Destination Moving Scenario and Source-Destination Moving Scenario. The researchers performed the experiments in an indoor environment with the size nearly 70 m × 25 m. The packet size was ýxed to 512 kilobytes and they used CBR over UDP to create the traffic. The performance metrics used were bit rate, delay, and packet loss. The results indicated that OLSR performs better than AODV in all the scenarios when both source nodes and destination nodes are moving during the communication.

A study by Naumov and Gross [2] analyzed the impact of the network size (up to 550 nodes), nodes mobility, nodes density and suggested data traffic on AODV and DSR performance. NS-2 was used since it supports the popular WaveLAN cards to study the performance of AODV and DSR in the areas of 2121 m × 425 m, 3000 m × 600 m, 3675 m × 735 m, 4250 m × 850 m, and 5000 m × 1000 m populated by 100, 200, 300, 400, and 550 mobile nodes, respectively. CBR was used for traffic sources. The performance metrics used were PDF, routing overhead and average end-to-end delay. The results indicated that in stationary scenarios with a low number of traffic sources, both protocols demonstrate good scalability with respect to the number and density of nodes. But as the mobility rate increases, the routing overhead of DSR prevent this protocol from delivering data packets effectively.

IV. METHODOLOGY

Routing algorithms are usually difficult to be formalized into mathematics [6]; they are instead tested using extensive simulation. Besides the difficulty to formalize these routing protocols into mathematics, there are two other great challenges: the cost and the difficulty of managing these routing protocols on large scale networks. From the related work done earlier, it appears that most of the research done in wireless networks today is done using simulators. This section presents the conceptual model used for modeling and simulation. It also presents the performance metrics in the methodology of this paper and the simulation setup of the MANET designed.

A. Conceptual Model.

The conceptual model of the MANET to be modeled consists of 30 nodes (in this paper, laptops were used) and a Wireless Local Area Network (WLAN) server. The nodes have applications running over TCP/IP and UDP/IP. They support wireless communication at rates of up to 11Mbps. The WLAN server has applications running over TCP. Depending on the scenarios, the WLAN server should be able to support http applications. Figure 1 shows the conceptual model of the MANET designed and modeled in this paper.

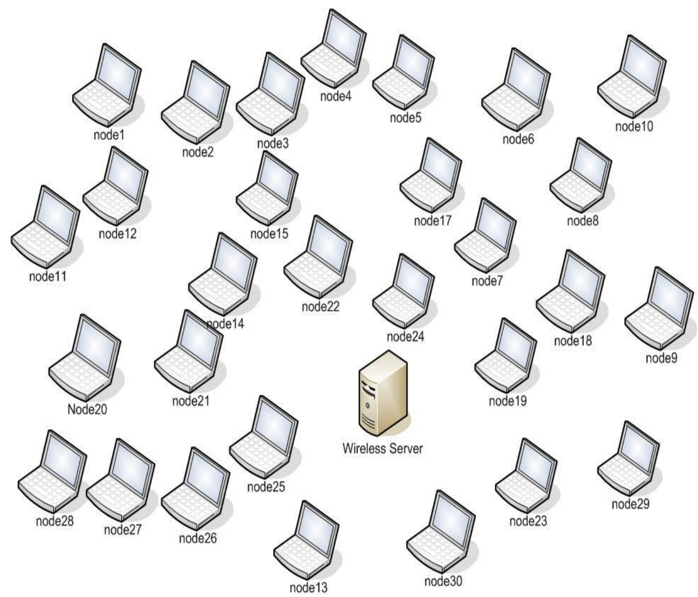

Figure 1: Conceptual Model for the MANET

B. Performance Metrics.

The performance metrics evaluated in this paper are:

Å Throughput: This is the sum of data packets generated by every source in the network. It is expressed in bits per second. So high throughput is desirable in wireless networks. The throughput reflects the completeness and accuracy of the routing protocol [6].

Å Delay: This is the time it takes for a packet to be transmitted from the source node to the destination nodes. It is expressed in seconds. Short delay is desirable.

The throughput and the delay metrics are the most important performance metrics for traffic modeling [13].

C. *Simulation Setup.*

The performance evaluation of the routing protocols mentioned earlier was done using the discrete even simulator OPNET (Optimized Network Engineering Tools) version 14.0 [14].The simulation models in this paper were run with 30 nodes randomly distributed in an area of 1000 m × 1000 m. The nodes moved following the random waypoint mobility model with a speed of 10 meters per second and a pause time of 100 seconds. The protocols that were studied in the simulation are: DSR, AODV, OLSR and TORA.

In this paper, two profiles were modeled:

- ftp light: that is, under light load conditions. Under light load, the download and upload is done at a rate of one file per hour (1file/hour) with a file size of 10 000 bytes.[15]
- ftp heavy: that is, under heavy load conditions. Under heavy load, the download and upload is done at a rate of 10 files per hour (10files/hr) with a file size of 100,000 bytes. [15]

The nodes in the MANET modeled supported a data rate transmission of 11Mbps with a power of 0.005 Watts. The packet size used for modeling was 1024 bytes. The MAC protocol used was the IEEE 802.11b and the transmission range was set to 250 meters. Each profile created was applied to each of the protocols during the simulation. Figure 2 shows the simulation arrangement used in this paper.

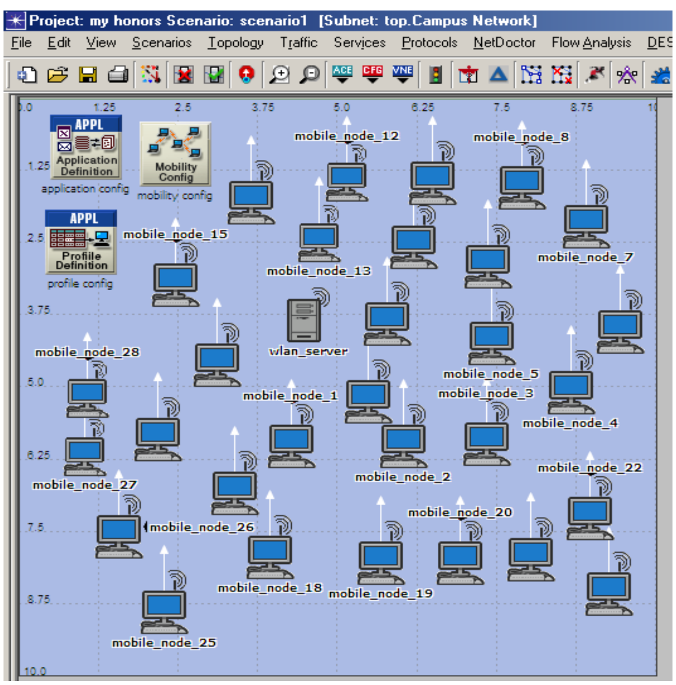

Figure 2: Simulation setup used in this study

V. RESULTS AND DISCUSSION

In this section, the experiments results are presented and discussed. The performance analysis of the routing protocols AODV, DSR, OLSR and TORA are done according to the performance metrics cited earlier; that is based on the delay and the throughput. In terms of delay, TORA experiences oscillations due to the slow route reconstruction after a connection has been lost between nodes. Also in terms of delay, all the reactive routing protocols start to generate traffic only after a certain amount of time (simulation time); that is due to the route discovery mechanisms of reactive protocols in MANETs.

A. *Delay Comparison under Light Load and Heavy Load*

The performance in terms of delay of AODV, DSR, OLSR and TORA routing protocols over light load ftp traffic and heavy load ftp traffic is respectively shown Figure 3 and Figure 4.

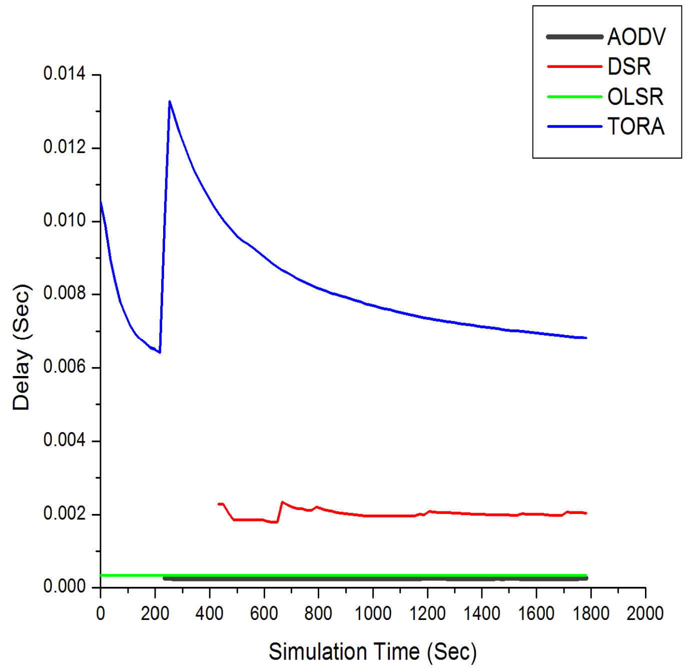

Figure 3: Delay of all the chosen routing protocols under light load

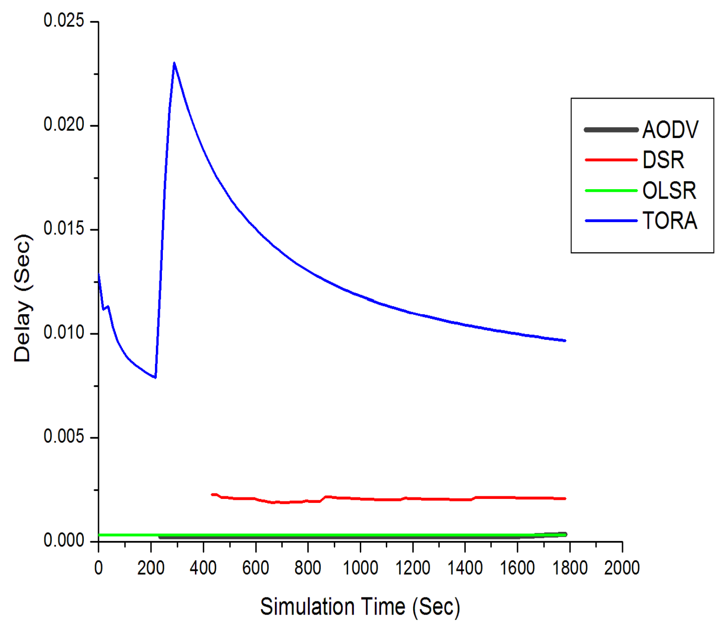

Figure 4: Delay of all the chosen routing protocols under heavy load

Figure 3 and Figure 4 indicate that under light and heavy ftp loads, the OLSR and AODV protocols are competing for the shortest delay. The poor performance of TORA in terms of delay under light ftp load and heavy ftp load is due to fact that route rebuilding after a connection is lost may not occur as fast as in other reactive routing protocols[6] . This is due to the potential oscillations that may occur during this period. This is the basis behind the probable long delays encountered while waiting to determine the new routes. The DSR protocol has the second longer delay behind TORA; the potential long delay experienced by DSR may be the result of wrong updates that could occur if its cache does not have the exact route to the destination node.

B. Throughput Comparison under Light Load and Heavy Load.

The performance in terms of throughput of the MANETs routing protocols AODV, DSR, OLSR and TORA over light load ftp traffic and heavy load ftp traffic is respectively shown in Figure 5 and Figure 6.

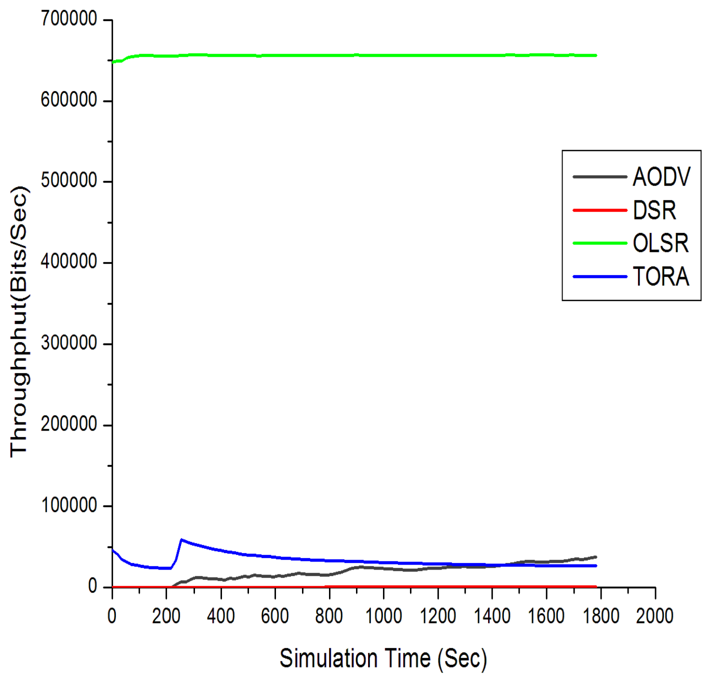

Figure 5: Throughput for all the chosen routing protocols under light load.

Figure 5 and Figure 6 show that the routing protocol OLSR outperforms the routing protocols AODV, DSR and TORA respectively under light load ftp and heavy load ftp traffics. This is due to the fact that OLSR does not need to find routes to the destination since all the paths are already available. Thus the source nodes are able to transmit more data packets when the OLSR routing algorithm is applied on the nodes. Under light load ftp traffic, DSR throughput generated is constant but under heavy load, it slightly increases but still remains very low. Figure 6 shows that under heavy ftp load traffic, TORA performs better than the other reactive routing protocols DSR and AODV.

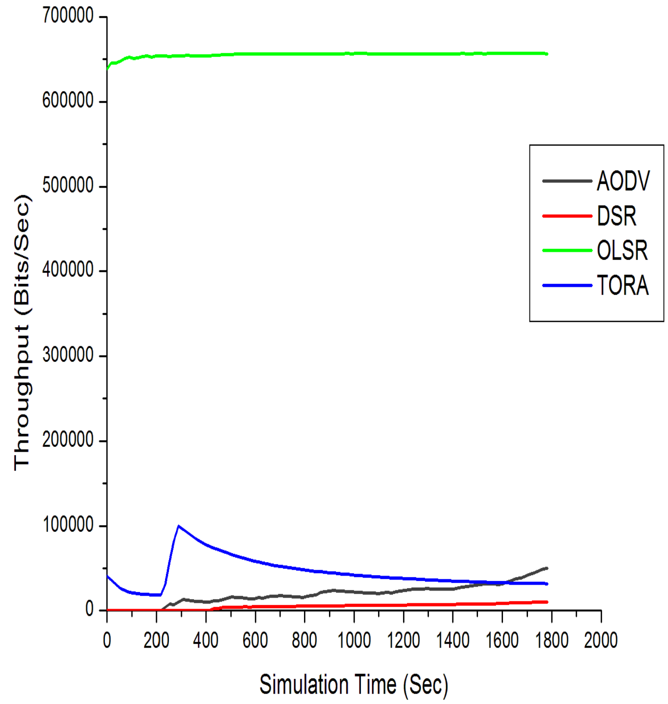

Figure 6: Throughput for all the chosen routing protocols under heavy load.

VI. CONCLUSIONS

From the results generated above, it can be concluded that:

- In terms of delay, OLSR competed with AODV for the shorter delay. DSR had the second longest delay behind TORA which had an extremely long delay. Still in terms of delay, it was observed that TORA oscillates and that was due to the time that TORA takes to rebuild the route after a link failure.
- In terms of throughput, OLSR outperformed AODV, DSR and TORA in all the scenarios. DSR had the lowest throughput. This is due to its route discovery process.

The overall results showed that the proactive routing protocol OLSR performed better than the reactive routing protocols AODV, DSR and TORA for medium size MANETs. One of the main reasons of the good performance of OLSR is that proactive routing protocols transmit control messages to all the nodes and update their routing information even if there is no actual routing request, hence the routes are always up to date. OLSR is therefore a routing protocol suitable for medium size MANETs.

VII. FUTURE WORK

The MANET modeled and designed in this paper uses the Random Waypoint as a mobility model. Further study could be done by modeling the Reference Group Point mobility model and using it as a mobility model under the same conditions as the ones used in this paper. Further study could also look at voice over IP traffic for the evaluation of

MANETs under the same conditions as the ones used in this paper.

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