Towards an OPNET Modeler Based Performance Comparison of Routing Protocols in Mobile Ad-Hoc Networks Using Voice over IP Traffic

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***Abstract*—** With the increasing use of mobile devices and advances in wireless technologies, Mobile Ad-hoc Network (MANET) has drawn great attention for being part of ubiquitous networks. MANET is an autonomous collection of mobile and/or fixed nodes that can communicate together over relatively bandwidth constrained wireless links, and the network topology may change rapidly and unpredictably over time. Unlike the conventional network, MANET is decentralized radio wireless network that can be established in situations where no infrastructure exists or where deployment of infrastructure is expensive or inconvenient**.** As a result, routing protocols play a crucial role in managing the formation, configuration, and maintenance of the topology of the network. There has been an extensive research on performance analysis of routing protocols in MANETs. However, most of the work done on the performance evaluation of routing protocols is done using the Constant Bit Rate (CBR) traffic. This paper presents the performance analysis 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 Voice over Internet Protocol (VoIP) traffic. The performance metrics used for the analysis of these routing protocols are delay and throughput. 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.

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1. INTRODUCTION

With the increasing use of mobile devices and advances in wireless technologies, MANET has drawn great attention for being part of ubiquitous networks. MANET is an autonomous collection of mobile and/or fixed nodes that can communicate together over relatively bandwidth constrained wireless links, and the network topology may change rapidly and unpredictably over time. Unlike the conventional network, MANET is decentralized radio wireless network that can be established in situations where no infrastructure exists or where deployment of infrastructure is expensive or inconvenient. MANET has many applications in military operations, rescue operations, vehicle to vehicle networks, sensor networks, etc.

Every node in a MANET operates 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 form the network at anytime and anywhere thus the network topology highly dynamic and the routing packets difficult. Hence there is a need for MANETs have routing protocols which can adjust to the movement of nodes and dynamically changing topology of the network.

A lot of routing protocols have been proposed, evaluated and implemented and tested. 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 nodes move randomly so consistent 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 [2-9] because CBR traffic attempt to preserve constant bandwidth and minimizes the packets loss during transmission. However, with the increased use of Voice over IP application (VoIP), the study of routing protocols using VoIP traffic is highly needed. This paper evaluates the performance of MANET's routing protocols e.g., Ad Hoc on Demand Distance Vector (AODV), Dynamic Source Routing (DSR) and Optimized Link State Routing (OLSR) protocols in terms of routing load and throughput for a common and simple application such as VoIP.

2. 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.

2.1 Ad hoc On Demand Distance Vector (AODV)

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.

2.2 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.

2.3 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.

2.4 Optimized Link State Routing (OLSR).

OLSR is an MANET proactive routing protocol that uses Multi Point Relays (MPRs). MPR is an optimized flooding 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 flooding using MPR.
- Optimal route calculation using the shortest route algorithm.

3. 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 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.

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 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 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 notification at the data link layer permits the delivered data packets to be considerably increased the data throughout to be increased without expending more energy

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.

Ahmed and Alam (2005) [11] evaluated the effect of the load on the performance of TORA, DSR and AODV through simulation and the tool used for the simulation was OPNET modeler 10.5. For all the scenarios, the same movement models were used, and the MANET load was successively increased from 40, 60, 80 to 100 nodes. A square of 10 meters was used to define the area of the node's mobility. The simulation characteristics used in this research, were the control traffic received and sent, data traffic received, throughput, retransmission attempts, utilization, average power, route discovery time, and ULP traffic received. The results show that TORA shows a good performance for the control traffic received, control traffic sent, and data traffic sent. However, AODV shows better performance for data traffic received and throughput. DSR and AODV show poor performance compared to TORA for the control traffic sent and throughput. However, TORA and AODV show an average level of performance for the data traffic received and data traffic sent, respectively. The result also showed that for DSR, the number of packets in routing traffic received and sent, as well as the number of packets in total traffic received and sent, increase with increasing load.

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 fixed 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.

4. METHODOLOGY

Routing algorithms are usually complex 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 seems that most of the work done on routing protocols is done using simulators. This section presents the performance metrics used in this paper and the simulation setup of the MANET designed.

4.1 Performance Metrics.

The performance metrics evaluated in this paper are:

- 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].
- Normalized routing load: This represents the ratio of all routing packets sent to the successfully received data packets It is expressed in bits per second. Layuan et al. [13] stated that:" *The routing load evaluates the *internal* efficiency of a protocol*."

Both the throughput and the routing load indicate the efficiency and scalability of a protocol [13]

4.2 Simulation Setup.

The MANETs to be modeled consists of 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. The WLAN server has applications running over TCP. Depending on the scenarios, the WLAN server should be able to support VoIP applications. The performance evaluation of the routing protocols mentioned earlier was done using the discrete even simulator OPNET (Optimized Network Engineering Tools) version 14.0 .

The simulation models in this paper were run with nodes randomly distributed in an area of 2000 m × 2000 m. The nodes moved following the random waypoint mobility model with a speed of 10 meters per second and a pause time of 200 seconds. The protocols that were evaluated during the simulation are: DSR, AODV, OLSR and TORA.

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 scenario created was applied to each of the protocols during the simulation. The traffic transmitted and used During the simulation was a Voice over IP under medium load traffic with moderate sender and receiver

The simulation setup of the MANETs modeled in this paper is shown in Figure 1.

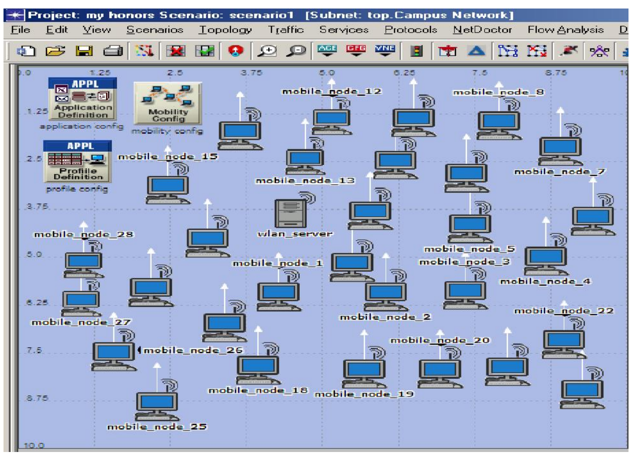

Figure 1: Simulation setup used in this paper

5. Results and discussions

In this section, the experiments results are presented and discussed. The performance analysis of the routing protocols AODV, DSR and OLSR are done according to the performance metrics cited earlier; that is based on the normalized routing load and the throughput.

5.1 Routing load comparison under VoIP

The performance in term of normalized routing load of AODV, DSR and OLSR routing protocols over VoIP traffic is shown in Figure 2. The x-axis of Figure 2 shows the simulation times in minutes while the y-axis shows the normalized routing load in bits per seconds. Figure 2 shows that AODV and DSR only generates traffic after a certain amount of time; that is due to their route discovery mechanism. From the fourth minutes, OLSR competes with AODV for the highest routing load. However, OLSR has a slightly greater routing load that AODV. DSR has the lowest routing load; the DSR routing protocol required nodes to maintain route caches that can contain multiple source routes to any destination. Entries in the route cache are continually updated as new routes are learned.

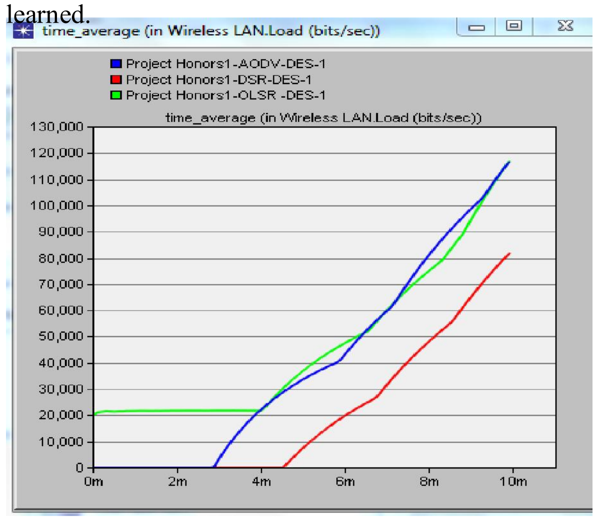

Figure 2: Normalized routing load of all the chosen routing protocols under VoIP

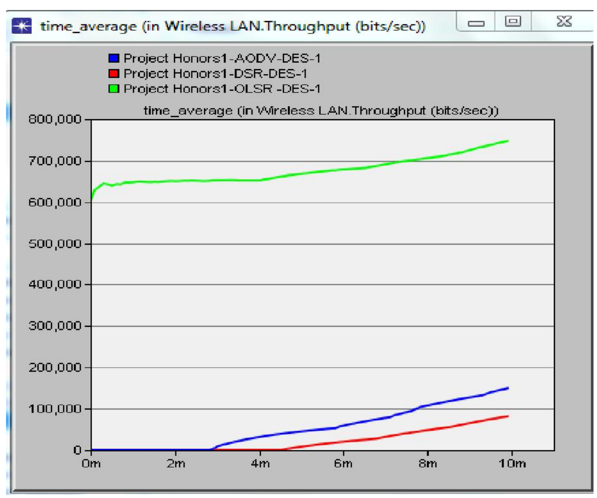

Figure 3: Throughput for all the chosen routing protocols under VoIP traffic

5.2 Throughput comparison under VoIP

The performance in term of throughput of the MANETs routing protocols AODV, DSR and OLSR over VoIP is shown in Figure 3. The x-axis for Figure 3 represents the simulation times in minutes while the y-axis represent the throughput in bits per second.

Figure 3 shows that routing protocol OLSR outperforms the routing protocols AODV and DSR under VoIP. 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. Figure 3 also shows that, DSR has the worst throughput; that is due to the fact that DSR destination node sends replies to all of the RREQs whereas AODV replies only for the first one hence improving AODV throughput. AODV could be performing better than the other reactive DSR due to the hop-to-hop initiation process by AODV protocol on nodes.

6. CONCLUSIONS

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

- In terms of Normalized routing load, OLSR competed with AODV for the highest routing load. DSR had the lowest routing load.
- In term of throughput, OLSR outperformed AODV and DSR. DSR had the lowest throughput. This is due to its route discovery process.

The overall results showed that the proactive routing protocol OLSR has a very good performance in term of throughput than the reactive routing protocols AODV and DSR for medium size MANETs. One of the main reason 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. However, the same cannot be said in term of routing load because OLSR competes with AODV for the highest routing load.

7. 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 remote logging traffic for the evaluation of MANETs under the same conditions as the ones used in this paper

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