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Performance Evaluation of Routing Protocols in Mobile Ad Hoc Networks Using Http Traffic

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Abstract. Mobile Ad Hoc Networks (MANETs) are receiving 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. 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 modeling and simulation of Mobile Ad hoc Networks (MANETs). The performance analysis of the MANET 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) of MANET routing protocols are evaluated under different scenarios using hypertext transfer protocol (http) traffic. The performance metrics used for the evaluation of these routing protocols are delay and throughput as function of the load; that is under light browsing and heavy browsing. 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 a medium size MANETs

Keywords: MANET, Routing protocols, Reactive Routing, Proactive Routing, CBR Traffic, Http Traffic

1. 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 networks 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], while 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], [9] because CBR traffic attempt to preserve constant bandwidth and minimizes packet loss during transmission. However, with the increased use of Internet services recently, there is a need to analyze routing protocols using hypertext transfer protocol (http) traffic.

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This paper evaluates the performance of MANET's 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 support application such as http.

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)

AODV routing protocol is a reactive routing protocol which was first proposed by an IETF Internet draft in1997. According to [4], AODV was proposed to meet the following goals: *Minimal control overhead; Minimal processing overhead; Multi-hop path routing capability; Dynamic topology maintenance and Loop prevention*. The operation of AODV is done using the following two mechanisms namely route discovery and route maintenance [4], [8]. Route discovery is a mechanism by which a source node wishing to send a packet to destination node obtains dynamically a source route when it does not have a route in its routing table. In Route maintenance mechanism is whereby route has to establish first and 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 use of multi-hop wireless MANET. DSR allows the network to be completely self-organizing and self-configuring [6]. The operation of DSR is also done using the route discovery and route maintenance mechanism [5]. Here Route maintenance 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 link reversal algorithm [10]. TORA provides multiple routes to transmit data packet 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 the concept of 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. A study by [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 sources used were CBR traffic and the simulation time was 200s. The performance metrics used were Packet Delivery Fraction (PDF) and average end-to-end delay. The traffic generated indicated 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.

Researchers such as those in [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 sources used were 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 or each scenario was 300 seconds. The results showed that TORA has a lowest routing load and a good scalability. The results also indicated that DSR has a less loss ratio, a low throughput and a long delay. In all the scenarios, AODV displays the shortest delay and loss ratio, and the greatest throughput.

A research from [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 traffics used were 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.

A study by [12] compared the performance of AODV and OLSR for different source and destination moving scenarios. They implemented a MANET test-bed 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 kilobyte 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 [2] analyzed the impact of the network size (up to 550 nodes), nodes mobility, nodes density and suggested data traffics on AODV and DSR performance. NS-2 was used since it supports the popular Wave LAN 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.

4. Methodology

This section presents the simulation setup as well as the performance metrics used in this paper.

4.1. 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 [13]. The simulation models in this paper were run with 30 nodes and a Wireless Local Area Network (WLAN) server randomly distributed in a square area of 1000 m × 1000 m. The nodes moved following the random waypoint mobility model with a speed of 2 meters per second and a pause time of 100 seconds. The MAC protocol used was the IEEE 802.11b and the transmission range was set to 150 meters. The nodes have applications running over TCP/IP and UDP/IP. They support wireless communication at rate of up to 11Mbps. The WLAN server has applications running over TCP. Depending on the scenarios, WLAN server supports http and ftp support applications.

The nodes in the MANET modeled supported a data rate transmission of 3Mbps with a power of 0.005 Watts. The packet size used for modeling was 1024 bytes. Figure 1 show the simulation arrangement used in this paper. In this paper, two profiles were modeled:

- **http light**: that is, under light browsing conditions. **http light** load is characterized by the following parameters [14]: *Page Rate (Pages/hour): 5; Page Size (Objects/page): 10 & Average Object Size (bytes/object): 12 000.*
- **http heavy**: that is, under heavy browsing conditions. **http heavy** load is characterized by the following parameters [14]: *Page Rate (Pages/hour): 60; Page Size (Objects/page): 10 & Average Object Size (bytes/object): 12,000.*

4.2. Performance Metrics

The performance metrics used in this paper are:

- **Throughput**

This is the sum of data packets transmitted and successfully received by every source in the network. It is expressed in bit per second. In wireless networks, so high throughput is desirable. The throughput reflects the completeness and correctness of the routing protocol [6].

- **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 [15].

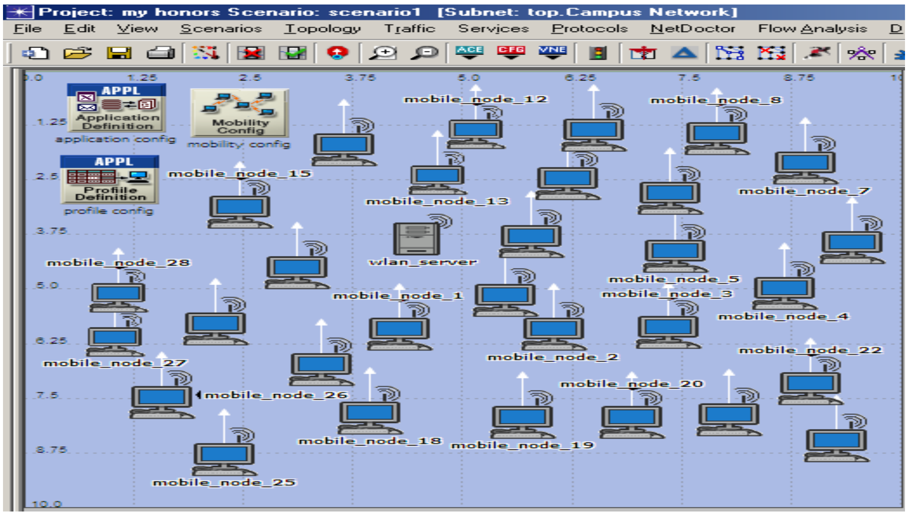

Figure 1: Simulation setup used in this paper

5. Results and Discussion

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.

5.1. Delay Comparison under Low and Heavy Browsing Traffic.

The performance in term of delay of AODV, DSR, OLSR and TORA routing protocols over http light browsing and http heavy browsing is respectively shown Figure 2 and Figure 3. Under light browsing, Figure

2 shows that TORA experience the longest delay; this is due the fact that TORA route construction does not occur quickly, leading to potential long delays while waiting for discovery of new routes. Figure 3 indicates that the DSR has the second longest delay; this is due to it's the route discovery mechanism. This is also due to probable collisions that could occur between route request messages transmitted by neighboring nodes.

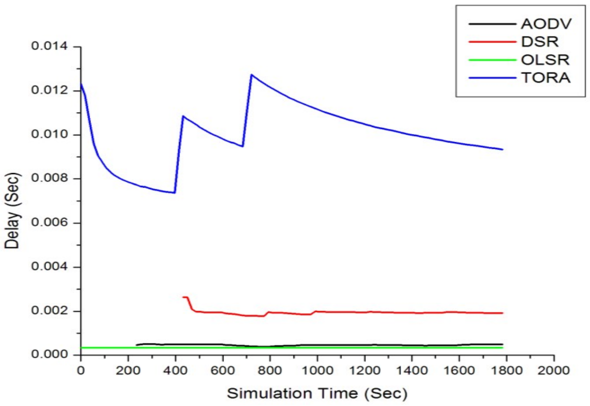

Figure 2: Delay of routing protocols under light browsing conditions

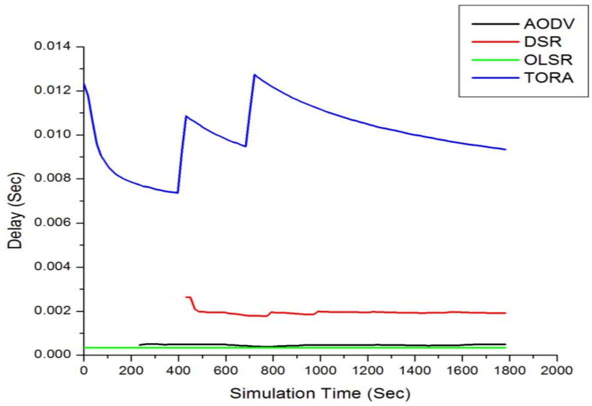

Figure 3: Delay of routing protocols under heavy browsing conditions

Figure 2 also indicates that under light and heavy browsing, AODV competes with OLSR in terms of shorter delay. The absence of high latency induced by the route discovery processes in OLSR explains its relatively low delay under light and heavy browsing conditions [6]. The AODV has a shorter delay as compare to other reactive protocols DSR and TORA; this is due to the hop-to-hop initiation process by AODV protocol on nodes.

5.2. Throughput Comparison under Low and Heavy Browsing Traffic

The performance in term of throughput of the MANETs routing protocols AODV, DSR, OLSR and TORA over http light browsing and http heavy browsing is respectively shown in Figure 4 and Figure 5.

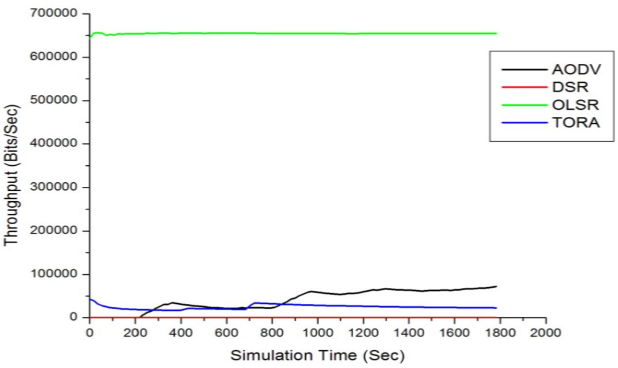

Figure 4: Throughput of routing protocols under light browsing traffic

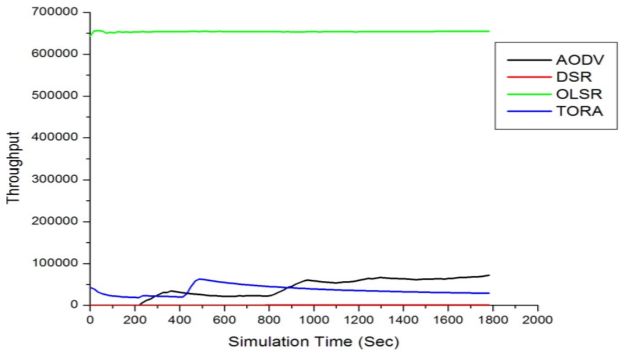

Figure 5: Throughput of routing protocols under heavy browsing traffic

Figure 4 and Figure 5 show that routing protocol OLSR outperforms the routing protocols AODV, DSR and TORA respectively under low http browsing and heavy http browsing. 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 is applied on the nodes. Figure 5 also indicates that under heavy browsing, TORA has the lowest throughput (close to zero). This is due to the fact that as the load increases, TORA becomes more sensitive to the packets drop, hence leading to a decrease in throughput [6].

6. Conclusions and Future Work

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 under heavy browsing (http heavy) causing the delay graph to be out of scale. Still in terms of delay, it was noticed that TORA oscillates and that was due to the time TORA take 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. Under heavy browsing, the throughput of TORA is very low; however under heavy ftp load, TORA routing protocols had a better throughput than the others reactive routing protocols.

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 sizes MANET. 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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