Performance Evaluation of Routing Protocols in MANETs using Varying Number of Nodes and Different Metrics

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ABSTRACT

This work evaluates the performance of three well-known routing protocols in mobile ad-hoc networks, namely Ad-hoc On demand Distance Vector Protocol (AODV), Dynamic Source Routing (DSR) and Temporally Ordered Routing Algorithm (TORA). Two scenarios were created using OPNET and extensive simulations were made on each scenario to evaluate the performance of the three protocols. Results were presented as a function of three performance metrics namely: throughput, delay and network load. In most simulations and overall, DSR and AODV performed better than TORA while DSR shows a better performance compare to AODV. In terms of throughput, DSR is better than any of the other two protocols for both scenarios while AODV shows a better result in delay than DSR and TORA. The lowest value of network load is generated in both scenarios when TORA is used than when any of DSR and AODV is used. Thus, DSR because of its highest value of throughput outperformed others, followed by AODV and then TORA.

Keywords: AODV, DSR, MANETs, performance analysis, performance

I. INTRODUCTION

“Mobile Ad hoc Networks (MANETs) are fundamental element of pervasive networks, where user can communicate anywhere, any time and on-the-fly. MANETs introduce a new communication paradigm, which does not require a fixed infrastructure – they rely on wireless terminals for routing and transport services” [11]. A mobile ad hoc network is a self-configuring network of mobile devices or nodes connected by wireless links. It is a collection of mobile nodes that communicate together without any stationary infrastructure or predetermined topology of wireless links[1]. Every nodes in a mobile ad-hoc network can move freely in any direction and can change links to other nodes independently [2]. Each nodes dynamically discover other nodes such that, they can communicate together directly.

However, not all nodes can communicate directly to each other due to some signal transmission problems. Thus, each node function as a router and forward unrelated traffic to its own to others. The major challenge in MANET is maintaining the information needed to properly route traffic. Hence, mobile nodes are needed to forward packets on behalf of other nodes and deliver data through the network. An important characteristic of mobile ad hoc networks is changes in connectivity and link caused by node mobility and power requirement [1].

An ad hoc network is built around technology such as radio frequency (RF), global positioning system (GPS), Infrared (IR), Bluetooth and others. All the mobile devices or nodes in MANETs posses transmitters and receivers for communicating with one another [1]. MANET is suitable for many applications because of its flexibility and many other features such as easy set up and establishment of temporary communication in a disaster area without any pre-installed infrastructure [16].

2. RELATED WORK

Much work has been done in the area of routing protocols in MANETs. Different protocols had been evaluated using different kind of simulators most especially ns2. Some of these works are described next. Golan et al [3] worked on simulation-based comparative study of two On Demand Routing Protocols (DSR and TORA) using quantitative performance metrics such as data dropped, delay, throughput and media access delay for the analysis. The simulation result indicated that DSR performed better because of its less overhead control packets, and yielded more throughput than TORA. The usefulness of [3] is that, it help to know some of the metrics needed in evaluating the routing protocols. [4] worked on the design of scenario-based experiment and analyzed the performance of SEAD, which is a secure table driven routing protocol that is based on DSDV. [5] studied DSR, AODV, DSDV, CBRP and PAODV.
Their performance using different scenarios and workload were compared. His results show that CBRP has a higher overhead compared to DSR due to its periodic hello messages while AODV has the shortest end-to-end packet delay. DSR is once again a better consideration for this work.

In [6], three routing protocols AODV, DSR and DSDV were analyzed through three realistic scenarios. By using average traffic load, it was shown that DSR performed better than AODV when tested with the mobility values. This helps to know different scenarios that can be created to evaluate the performance of routing protocols.

In [7], several routing protocols were evaluated using packet-level simulations. The authors concluded that the on-demand routing protocols use lower routing load as compared to the traditional distance vectors and link state protocols. [8] Described the study of the performance evaluation of mobility speed on MANET. DSR, AODV and DSDV were compared using ns-2. Packet routing overhead, packet delivery ratio and normalized routing load were used as their performance metric. It was concluded in [8] that no winner emerge among the protocols used because different mobility patterns give different performance.

Although [9] tried to compare TORA, LDR and ZRP using OPNET, it could not compare TORA along the most common reactive protocols. Different scenarios were simulated in [10] using AODV and DSR as protocols as well as throughput, delay and receiving traffic as the performance metrics. OPNET 12 was used for this design with Campus of “Graphic Era University” as the realistic scenario. Also used is standard application (FTP) situated at the centre of Graphic Era University, 20 nodes with the two protocols enabled. The authors reported that in Wireless LAN throughput, AODV is slightly better than DSR. In the Wireless delay, it was reported that AODV is better.

Having done so much study on the previous related work, it was discovered that much have not been done in evaluating the performance of AODV, DSR and TORA together. Research effort have not focused much in evaluating their performance under a variable number of nodes. Moreover, most of the works described above used ns2 as a simulator whereas this work will be done in OPNET Modeler environment.

3. ROUTING PROTOCOLS

Routing in mobile ad hoc networks is quite different from conventional routing in wired networks. A dynamic routing protocol is needed for mobile ad hoc network to function properly in a rapidly changing network topology. Thus, routing here is really challenging because a node acts as both node and a router (or server). The Internet Engineering Task Force (IETF) through a MANET working group has published many of these protocols.

The purpose of this group is to standardize IP routing protocol that is suitable for wireless routing application within static and dynamic topologies [9]. Ad hoc routing protocols are grouped based on the network structure as flat routing, hierarchical routing and geographic assisted routing as shown below.

In flat routing, nodes communicate directly with each other and there is no clustering. It can be further classify into proactive, reactive and hybrid. Proactive protocols follow the strategies which are mostly followed by conventional routing protocols [9]. In proactive, routes are calculated before one is needed and up-to-date routing information is kept by all nodes every time. In reactive protocols, a route is only calculated when it is needed and does not keep routing information to all node every time. Also, a proactive scheme require a small delay in determining the route while in reactive scheme, a significant amount of delay is needed for creating a route. Hybrid protocols incorporate both properties of proactive and reactive protocols. Hierarchical routing protocols are used in a larger network where flat routings protocols are struggling with constraints [9]. They build and extend clusters and manage the communication inside a cluster. In Geographic position routing, no routing table is required, information can be send in any way in the direction of the destination. Also, no overhead is required to find or update routes, however position is required.

A. Ad Hoc On-Demand Distance Vector Protocol (AODV)

AODV is a reactive unicast routing protocol based on the distance vector algorithm. It allows mobile nodes to communicate, to form ad-hoc networks in a timely and self-configuring manner. It offers routes quickly and on demand and nodes do not need to maintain routes to destination nodes that are not communicating [6]. AODV also allows mobile nodes to adjust to network changes such as link outages. Although it is a distance vector protocol, based on the Bellman Ford Algorithm, it avoids the counting to infinity problem associated with distance vector protocols and ensures a loop-free routing.
Routing information in AODV is maintained at the active paths and routing tables at nodes. Each node here contains the routing information of the next hop. The routing table will expire if it is not used or reactivated for a specified time or period and the route will be broken. To discover a route, a route discovery operation is initiated and then send packets from a source node to a destination node. This route discovery operation consists of broadcasts route request (PREQ) packets, the broadcast ID, destination sequence number as well as the sequence number of the source node. A node in MANET sends hello messages to notify its existence to its neighbors or to discover its neighbors and monitor the links status to the next hop in active route. When a link disconnection occurs, a broadcast route error (RERR) packet is sent by a node to its neighbors, which then propagates the PERR packet towards other nodes that may be affected by the link [12]. A route discovery operation will now be reinitiated if the route is still needed.

B. Dynamic Source Routing Protocol (DSR)

DSR is a reactive routing protocol that uses source routing algorithm to pass data across the network. Each data packet header carries the sequence of nodes from which the packet must pass. This means that the intermediate nodes need only to keep track of their immediate neighbours to forward data packets while the source nodes need to know the entire hop sequence to the destination.

In DSR, the route acquisition procedure requests a route by flooding a Route Request packet similar to AODV. When a node receives a Route Request packet, it searches for all known routes to the requested destination in its route cache. When no route is found, it adds its own address to the hop sequence in the Route Request packet and forwards the packet further on. The Route Request packet then propagates through the network until it reaches a node with the route to the destination or the actual destination [5]. A Route Reply packet with the proper hop sequence for reaching the destination is then unicasted back to the source after finding the route. It should be noted that DSR does not rely on the bi-directional links since the Route Reply packet is sent to the source node through a route already stored in the route cached of the replying node, or by being piggybacked on a Route Request packet to the source node [5]. However, the reverse path in the Route Request can be used by the Route Reply message [5].

The advantage of DSR protocol is that, routes can be learnt from the source routes in the received packets. For example, a node ‘A’ can find a route to node ‘C’ through node ‘B’. In this way ‘A’ will learn route to ‘B’ and ‘C’ will also learn route to ‘A’ and so on [13]. This however leads to increase in flooding of the network with Route Request messages. To avoid this, the route acquisition procedure first queries the neighbouring nodes to see if they have a route to the intending destination. This can be done by sending a first Route Request message with zero hop-limit which will not be forwarded by neighbours. If there is no response from this initial request, then a new Route Request message will be flooded through the entire network.

DSR uses the MAC layer to tell nodes about link failures. When there is a link failure, a Route Error packet will be send back to the source node, which will then removes the broken link from its route cache as well as truncating all routes to the broken link. Moreover, an intermediate node that forwarded the Route Error will update its route cache in a similar way. Generally, DSR operates in two ways viz: Route discovery and Route maintenance. Both are on demand and does not require a periodic hello messages or link state advertisement between neighbours. DSR also supports multiple routes (thus large amount of overhead) to destinations because nodes use a caching property to maintain multiple routes. The routes can be learned during a route discovery or from other control packets they overheard (overhearing property). Multiple route support means that if one route fails, node using DSR can quickly pick another route from its cache. Caching also reduces overhead require in performing a new route discovery every time a route fails.

C. Temporally-Ordered Routing Algorithm (TORA)

“"The Temporally Ordered Routing Algorithm (TORA) is a highly adaptive, efficient and scalable distributed routing algorithm that is based on the concept of link reversal” [14]. TORA can be used for highly dynamic mobile and multi-hop networks. It is a source-initiated on-demand routing protocol that finds multiple routes from a source node to a destination node. Its main feature is that the control messages are typically localized to a very small set of nodes near the occurrence of a topological change [13][14]. To do this, routing information about adjacent or nearby node is maintained.

The network topology in TORA is regarded as a directed graph. A Directed Acyclic Graph (DAG) can be accomplished for this network by giving each node i a height hi [15]. A directional link from i to j means that hi is greater than hj (hi > hj). The height of the node defined as a quintuple includes the logical time of a link failure, a reflection indicator bit, propagation ordering parameter as well as a unique ID of the node. Packet moves from upstream downward according to the difference in height between nodes. DAG gives TORA the ability that many nodes can send packets to a given destination as well as guarantees that all routes are loop-free. TORA can be separated into three main functions: route creation, route erasure and route maintenance. The route creation begins by setting the height of the destination to ‘0’ and heights of the remaining nodes to NULL (i.e. not defined). The source then broadcasts a QRY packet containing ID of the destination and a node with a not defined height responds by broadcasting a UPD packet containing the height of its own [15]. When a node receives a UPD packet, it sets its height to be greater than that of the UPD generator. A node with higher height is then considered as upstream and the node with a lower height as downstream. Hence, a DAG is constructed from the source to the destination and thus exist multiple paths route.
The DAG in TORA may be disconnected due to the node mobility. Route maintenance operation is therefore necessary in TORA. It has a unique characteristic that control messages are localized into a small set of nodes near the occurrence of topology changes. After losing its last downstream link, a node generates a new reference level which is broadcasted to its neighbors. Hence, links are reversed to reflect topology changes and adapt it to the new reference level. The route erasure operation in TORA floods CLR packets into the network and erase all invalid routes. The three protocols can be compared as follows:

### Table 1: Comparing the three Routing Protocols

<table>
<thead>
<tr>
<th>Parameters</th>
<th>AODV</th>
<th>DSR</th>
<th>TORA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source Routing</td>
<td>No</td>
<td>Yes</td>
<td>NO</td>
</tr>
<tr>
<td>Topology</td>
<td>Full</td>
<td>Full</td>
<td>Reduced</td>
</tr>
<tr>
<td>Broadcast</td>
<td>Full</td>
<td>Full</td>
<td>Local</td>
</tr>
<tr>
<td>Update Information</td>
<td>Route error</td>
<td>Route error</td>
<td>Node's height</td>
</tr>
<tr>
<td>Update destination</td>
<td>Source</td>
<td>Source</td>
<td>Neighbours</td>
</tr>
<tr>
<td>Method</td>
<td>Unicast</td>
<td>Unicast</td>
<td>Broadcast</td>
</tr>
</tbody>
</table>

#### 4. EXPERIMENTAL SETUP

In this work, two scenarios have been created and analyzed for varying the number of nodes. The first scenario consists of 20 mobile nodes and it called Conference scenario. It has a low mobility compare to other one as only few of the people or nodes are moving at any point in time. Due to low mobility and low node density, the congestion here are low. The second scenario which made up of 40 mobile nodes is called Event scenario. This scenario models a group of 40 mobile people which are changing position more frequently than conference scenario. Thus they have high mobility, high node density and more congested. The purpose of these scenarios is to model a set of usage in a more realistic manner. The three performance metric used are discussed below.

#### A. Delay

Delay is refers to as the time it takes a packet to go from the source to the destination. It is expressed in seconds and thus called packet end-to-end delay. It is also refers to as latency. Because some applications are very sensitive to delay, they are often called delay sensitive applications.

#### B. Throughput

Throughput can be defined as the ratio of the total data that reaches a receiver from the sender. It is expressed as bytes or bits per second. Throughput can be affected by many factors such as limited bandwidth, network topology changes, and unreliable communication between nodes.

#### C. Network load

This is overall load of the network in bit per second submitted to wireless LAN lower layers by all higher layers in all nodes of the network. For a network to be efficient, it should be able to cope with large amount of traffic coming in. MANET routing packets are affected by high network loads; these increase the collisions of the control packet and eventually slow down the packet delivery in the channel.

#### D. Simulation Setup

One WLAN server was configured with FTP application in each scenario and three other important configurations for standard application were made. The size of the ftp file was set to 10000000 bytes and inters request time of 3600 seconds was used. The simulation environment size of 1000x1000 meters was also used. The configuration parameters used for mobility, ftp application, and profile are shown in table 2, 3 and 4 below.

### Table 2: Mobility configuration

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>x_min (meters)</td>
<td>0.0</td>
</tr>
<tr>
<td>y_min (meters)</td>
<td>0.0</td>
</tr>
<tr>
<td>x_max (meters)</td>
<td>500</td>
</tr>
<tr>
<td>y_max (meters)</td>
<td>500</td>
</tr>
<tr>
<td>Speed (meters/seconds)</td>
<td>constant (20)</td>
</tr>
<tr>
<td>Pause Time (seconds)</td>
<td>constant (5)</td>
</tr>
<tr>
<td>Start Time (seconds)</td>
<td>constant (10)</td>
</tr>
</tbody>
</table>

### Table 3: Application configuration (ftp)
5. RESULT ANALYSIS AND OBSERVATIONS

The results of the simulations of the two scenarios and the observation made from the graph are discussed below. Appropriate conclusion on which protocol has a better performance in each scenario using the three metrics was made.

A. Analysis of AODV using the three metrics

The figure 2 shows how AODV can be compared in the two scenarios using delay as the metric. It can be noted that the delay in the conference scenario is lower than in the event scenario although the difference is not that significant. Since more nodes were involved in the event scenario, one can say that more hello messages will be sent to discover neighbour and more delay would be experienced. Hence for this work, AODV performs better in terms of delay in a network with fewer nodes (conference scenario) than in network with more nodes (event scenario). In general, AODV shows a high performance in network with fewer nodes than the network with more nodes.

Figure 2: AODV Delay Graph

This means that AODV perform well in terms of network load generated when more nodes are used than for fewer nodes. Also in figure 4, AODV performs very well in terms of throughput which means better performance for fewer nodes i.e. conference scenario than in event scenario with more nodes. In general, AODV shows a high performance in network with fewer nodes than the network with more nodes.

Figure 3: AODV Network Load Graph
B. Analysis of DSR using the three metrics

Figure 5, 6 and 7 show how DSR can be compared using the two scenarios discussed in this work. In figure 5, the delay in conference scenario i.e. fewer nodes network is low compared to the event scenario with more nodes because the number of source packets or information forward to the next nodes is high in the event scenario and thus experience more delay. The network load generated in the conference scenario is almost the same as the one generated in the event scenario as shown in figure 6 except a little difference. In figure 7, throughput is higher in conference scenario with fewer nodes than in the event scenario with more nodes because in event scenario, more multiple routes are needed to be supported thereby increasing the overhead and subsequently deteriorating the network performance (i.e. reducing the throughput). Thus, for this work, DSR performs better generally in network with fewer nodes i.e. conference scenario than in the network with more nodes i.e. event scenario.

C. Analysis of TORA using the three metrics

Figure 8, 9, and 10 show how TORA is compared in the two scenarios using the three performance metrics considered in this work. The delay in figure 7 is very high for event scenario with more number of nodes than in conference scenario with less nodes. More time are needed to maintain multiple routes to destination in event scenario with more nodes than in conference scenario. Hence the delay graph is high. In figure 9, conference scenario with fewer nodes generated a high value of network load compared with the event scenario with more nodes. And in Figure 10, the throughput is higher in the conference scenario than in the event scenario because in the event scenario more control packets are transmitted to update the routing information immediately after a change in topology occur in event scenario than in conference scenario. This therefore lowers the throughput of the network with more nodes. Again, DSR performs generally better in a network of smaller nodes than the network with a higher number of nodes.
6. CONCLUSION

The aim of this study to evaluate the performance of three routing protocols under a variety of conditions has been successful with an appropriate conclusion drawn from the results and observations. Summary of the main points from the study are:

AODV and DSR outperform TORA in all scenarios. In both scenarios, DSR perform better than AODV and TORA in terms of throughput, with AODV showing a moderate result. AODV outperforms DSR and TORA by having the lowest value of delay in both scenarios, with DSR showing a moderate result. TORA perform well than both AODV and DSR in terms of network load generated in both scenarios. DSR shows a good performance than AODV in 20 nodes network i.e. conference scenario but cannot display the same good performance compared to AODV when the number of nodes is 40 i.e. in the event scenario. DSR begins to degrade in performance in terms of network load generated (this is due to source routes carried in every packet header) as the node density is increase in the network and according to the theoretical study of the DSR.

Since a high throughput is desirable of every network, and with DSR showing a higher throughput for these two scenarios under consideration, one can therefore concludes that DSR performs better than AODV and TORA while AODV performs better than TORA. However, the performance of these protocols may vary by varying the network and the parameters.
7. RECOMMENDATION
A more complex or realistic scenario could be carried out on the three protocols to be able to evaluate their performance better using a very large number of nodes especially to know the behaviour of DSR when nodes are more than 200. Since OPNET was used in this study, another simulator can be used to see how the three protocols are compared under the same performance metric and same number of nodes. Others can vary the parameters, scenarios and general model implementation. Performance metrics such as data drop, Packet Delivery Fraction (PDF) and Normalized Routing Load (NRL) can be used to further determine the best protocol.

The study of the performance of protocols could also be achieved using a real life Ad hoc network. This will be of utmost interest in the academic environment.

REFERENCES


[18] [19]...