Comparative Performance Analysis of Mobile Ad Hoc Networking Protocols for different Mobility Models

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ABSTRACT

Mobile ad hoc network (MANET), or simply ad hoc network, comprises nodes that freely and dynamically self-organize into arbitrary and temporary network topology without any infrastructure support. Routing in a MANET is challenging because of the dynamic topology and the lack of an existing fixed infrastructure. In such a scenario a mobile host can act as both a host and a router forwarding packets for other mobile nodes in the network. Due to mobility, connections in the network can change dynamically and nodes can be added and removed at any time. In this paper, we evaluate the performance of reactive routing protocols, Ad hoc On demand Distance Vector (AODV) and Dynamic Source Routing (DSR) and proactive routing protocol Destination Sequenced Distance Vector (DSDV) using the Network Simulator-2 (NS-2) tool. The mobility models used for the comparison in this work are Random Waypoint, Manhattan Grid, Reference Point Group. The performance of the routing protocols in varied node density as well as loading conditions have been studied. The performance is analyzed with respect to Average End-to-End Delay, Normalized Routing Load (NRL), Packet Delivery Fraction (PDF) and Throughput. Simulation results verify that DSR gives better performance as compared to AODV and DSDV.

Keywords: MANET, AODV, DSR, DSDV, NS2.

1. INTRODUCTION

A mobile ad-hoc network is a collection of mobile nodes forming an ad-hoc network without the assistance of any centralized structures. These networks introduced a new art of network establishment and can be well suited for an environment where either the infrastructure is lost or where deploy an infrastructure is not very cost effective. Nodes in mobile ad-hoc network are free to move and organize themselves in an arbitrary fashion. Each user is free to roam about while communicating with others. In such environment, Neighbor nodes communicate directly with each other’s while communication between non-neighboring nodes performed via the intermediate nodes which act as routers. As the network topology changes frequently because of node mobility and power limitations, efficient routing protocols are necessary to organize and maintain communication between the nodes. MANETs have several salient characteristics: i) Dynamic topologies ii) Bandwidth constrained, variable capacity links, iii) Energy-constrained operation and limited physical security etc. This paper is structured as follows: In Section 2, we discuss some of the mobility models used in MANETs. Section 3 discusses simulation. Performance metrics for routing protocols, used in MANETs, are described in section 4. The Simulation set-up is given in section 5. The results are discussed in section 6. The last section presents the concluding remarks.

AD HOC ROUTING PROTOCOLS

All the routing protocols are categorized under three categories Table Driven, Source Initiated and Hybrid. Our key protocols for comparison are DSDV, AODV and DSR. DSDV is a table driven/proactive routing protocol. Ad hoc On Demand Distance Vector Routing (AODV) and the Dynamic Source Routing (DSR) are reactive routing protocols.

1.1 Destination-Sequenced Distance-Vector (DSDV)

Destination-Sequenced Distance Vector (DSDV) routing protocol is a pro-active, table-driven routing protocol for MANETs developed by Charles E. Perkins and Pravin. Bhagwat in 1994. It uses the hop count as metric in route selection. Here, every mobile node in the network maintains a routing table for all possible destinations within the network. Every node has a single entry in the routing table. The entry will have information about the node’s IP address, last known sequence number and the hop count to reach that node. Along with these details the table also
keeps track of the next hop neighbor to reach the destination node, the timestamp of the last update received for that node. The DSDV update message consists of three fields, Destination Address, Sequence Number and Hop Count.

1.2 Dynamic Source Routing (DSR)
The Dynamic Source Routing protocol (DSR) is a simple and efficient routing protocol designed specifically for use in multi-hop wireless ad hoc networks of mobile nodes. The protocol is composed of the two mechanisms of Route Discovery and Route Maintenance, which work together to allow nodes to discover and maintain source routes to arbitrary destinations in the ad hoc network. Route Discovery is the mechanism by which a node S wishing to send a packet to a destination node D obtains a source route to D. Route Discovery is used only when S attempts to send a packet to D and does not already know a route to D. Route Maintenance is the mechanism by which node S is able to detect, while using a source route to D, if the network topology has changed such that it can no longer use its route to D because a link along the route no longer works. When Route Maintenance indicates a source route is broken, S can attempt to use any other route it happens to know to D, or can invoke Route Discovery again to find a new route. Route Maintenance is used only when S is actually sending packets to D.

1.3 Ad hoc On-demand Distance Vector Routing (AODV)
Ad-Hoc On-demand Distance Vector Routing (AODV) is an improvement on the DSDV algorithm. To find a path to the destination, the source broadcasts a route request packet. The neighbors in turn broadcast the packet to their neighbors till it reaches an intermediate node that has recent route information about the destination or till it reaches the destination. When a node forwards a route request packet to its neighbors, it also records in its tables the node from which the first copy of the request came. This information is used to construct the reverse path for the route reply packet. As the route reply packet traverses back to the source, the nodes along the path enter the forward route into their tables. If the source moves then it can reinitiate route discovery to the destination. If one of the intermediate nodes move then they moved nodes neighbor realizes the link failure and sends a link failure notification to its upstream neighbors and so on till it reaches the source upon which the source can reinitiate route discovery if needed.

2. MOBILITY MODELS
A mobility model represents the movement of mobile users and how their location, velocity and acceleration change over time. Mobility model decide how mobile nodes move between the network. The mobility model that accurately represents the characteristics of the mobile nodes in MANET is the key to examine the whether the given protocol is useful in a particular type of mobile scenario.

2.1 Random Waypoint Mobility Model
A model includes pause times between changes in destination and speed. The current speed and direction of an MN is independent of its past speed and direction. A Mobile node begins by staying in one location for a certain period of time (i.e. pause). Once this time expires, the mobile node chooses a random destination in the simulation area and a speed that is uniformly distributed between \([\text{min-speed}, \text{max-speed}]\). The mobile node then travels toward the newly chosen destination at the selected speed. Upon arrival, the mobile node pauses for a specified period of time starting the process again.

2.2 Manhattan Mobility Model (MM)
The Manhattan mobility model uses a grid road topology. In the Manhattan model the movement pattern of mobile nodes on streets defined by maps, where the streets are in an organized manner. The Manhattan model employs a probabilistic approach in the selection of nodes movements, since, at each intersection, a vehicle chooses to keep moving in the same direction. The velocity of the mobile nodes at a time slot is dependent on the velocity at the previous time slot.

2.3 Reference Point Group Mobility Model (RPGM)
It represents the random motion of a group of MNs as well as the random motion of each individual MN within the group. The group movements are based upon the path traveled by a logical center of the group. Individual MNs randomly move about their own pre-defined reference points. The motion of the group center completely characterizes the movement of this corresponding group of mobile nodes including their direction and speed. RPGM can be used in military battlefield communication where commander and soldiers form a logical group.

3. SIMULATION
There are several simulators available like OMNET++, QualNet, OPNET and NS2. Here, NS2 is used for simulation experiments since it is preferred by the networking research community. NS2 is an object oriented simulator, written in C++ and OTcl (Object oriented Tool command language) as the frontend.
3.1 Traffic Generation

Two types of traffic can be generated for the purpose of simulation: constant bit rate (CBR) traffic or transmission control protocol (TCP) traffic. All simulations used CBR traffic type as the source of data traffic. CBR presents a more stringent demand on the mobile ad hoc network. CBR and TCP (in fact, it is a FTP application) traffic can be generated using pre-built in OTCL scripts (cbrgen.tcl) in the NS2 directory.

3.2 Scenario Generation

The scenario of the network is generated using BonnMotion software. BonnMotion is a Java software tool for the investigation of mobile ad hoc network characteristics. To use this software, you need to have a JDK or JRE installed.

4. PERFORMANCE METRICS

In this paper, we consider following four performance metrics to compare the three routing protocol.

Packet Delivery Ratio

This is the ratio of the number of data packets successfully delivered to the destinations to those generated by sources.

Packet Delivery Fraction = received packets/sent packets * 100

4.2 Average End to end Delay

It is defined as the average time taken by the data packets to propagate from source to destination across a MANET. This includes all possible delays caused by buffering during routing discovery latency, queuing at the interface queue, and retransmission delays at the MAC, propagation and transfer times.

4.3 Average Throughput

It is the rate of successfully transmitted data packets in a unit time in the network during the simulation

4.4 Normalized Routing Load (NRL)

The number of routing packets transmitted per data packet delivered at the destination.

5. SIMULATION SET UP

We simulate the AODV, DSR and AODV routing protocols for Random Waypoint, Manhattan, RPGM mobility models individually. The individual scenarios were generated with the following configurations:

<table>
<thead>
<tr>
<th>Table 1: General Simulation Parameters</th>
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<tbody>
<tr>
<td>Protocols</td>
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<tr>
<td>Simulation Time</td>
</tr>
<tr>
<td>No of Nodes</td>
</tr>
<tr>
<td>Map Size</td>
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<tr>
<td>Mobility model</td>
</tr>
<tr>
<td>Traffic Type</td>
</tr>
<tr>
<td>Packet Size</td>
</tr>
<tr>
<td>Connection rate</td>
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<tr>
<td>No of connection</td>
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</tbody>
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6. SIMULATION RESULTS AND ANALYSIS FOR SCENARIO

In this Section, we compare the capabilities of the three routing protocol studied in this paper. To evaluate more reliable performance of AODV, DSDV and DSR routing protocols in same simulation environment (25 to 100 mobile nodes). Simulations results are collected from a total of 36 scenarios of the three protocols. Performance metrics are calculated from trace file, with the help of AWK program. The simulation results are shown in the following section in the form of graphs. Graphs show comparison between the three protocols by varying different number of sources.

6.1 Random Waypoint model

6.1.1 Node Density - Result

In the first set of simulations, the node density of the simulation network was varied to ascertain the performance impact of the four routing protocols. The node density is increased from 25 to 100 nodes within the same map area as each simulation run is executed. The goal is to understand the impact of having more nodes within a fixed area of operation on the network’s packet delivery ratio and its delay as well as the overall routing overheads. Figure 1 shows the results of the simulation, which demonstrates the overall packet delivery ratio of the network using the routing protocols. In Figure 1, we have noticed a slight advantage to DSR when the number of nodes is increased in mobile networks. Overall, PDR of AODV and DSR is higher in a scenario than that of DSDV. Figure 2 represent the
Average end to end delay which shows delay of DSR is less than AODV. Normalized routing load (NRL) of AODV, DSDV and DSR protocols in different sources are presented in Figure 3. AODV and DSR demonstrate lower routing load. Figure 4 shows the throughput against node density. It shows DSR and AODV are better.
6.1.2 Network Loading
In second simulation, the connection load of each pair of communicating nodes was varied. The offered load is increased from 5 pkts/sec to 20 pkts/sec. The total number of nodes in this system remains at 25. The entire simulation run lasts for 100s. Figure 8,9,10,11 shows PDR, Network delay, Routing load and throughput against Network loading which is obtained from change of connection rate. The performance of DSR is better in variation connection rate as compared to AODV and DSDV.
6.1.3 Network Connection

In this third simulation of network load variation, the number of connections the simulated system will take was varied instead. The number of connections increases from five to 20 connections in each different set of simulation. The Figure 9 shows the PDR of AODV and DSR is better than DSDV. Figure 10 shows the average end to end delay of the network. Delay of the DSDV is less than DSR and AODV as it is table driven protocol. Delay of DSR is less than AODV. Figure 11 shows the Normalized Routing Load. For network low NRL is better. NRL of DSR is less than AODV and DSDV. Figure 12 shows Throughput for the varied network connection. Throughputs for all three protocols are same.

Figure 9 PDR with varied no of connection

Figure 10 Delay with varied no of connection

Figure 11 Routing Load with varied no of connection

Figure 12 Throughput with varied no of connection
6.2 Manhattan Mobility Model

6.2.1 Node Density

In this experiment on Manhattan Grid model, we investigate the performance aspect when the node density is varied within a fixed map area. The node density increases from 25 to 100 nodes within the same map area of 1000m x 1000m. The results shown in Figure 13 illustrate the packet delivery ratio against the node density and in Figure 15 demonstrate the routing overhead incurred in this variation. Also, Figure 14 is the overall network delay of the system as the node density varies. The DSR and AODV outperformed DSDV.

![PDR with varied node Density](image1)

![Delay with varied node Density](image2)

![Routing Load with varied node Density](image3)

![Throughput with varied node Density](image4)
6.2.2 Network Loading
In this simulation on Manhattan Grid model, we investigate the routing performance aspect when the offered load increases. We do so by increasing the average connection load offered by each connection, starting at 5 pkts/sec to 20 pkts/sec. AODV and DSR is better than DSDV.

Figure 17 PDR with varied Connection Rate

Figure 18 Delay with varied Connection Rate

Figure 19 Routing load with varied Connection Rate

Figure 20 Throughput with varied Connection Rate
6.2.3 Network Connection
In this third simulation of network load variation, the number of connections the simulated system will take was varied instead. The number of connections increases from five to 20 connections in each different set of simulation. AODV and DSR are better than DSDV.

![Figure 21 PDR with varied No of Connection](image1)

![Figure 22 Delay with varied No of Connection](image2)

![Figure 23 Routing Load with No of Connection](image3)

![Figure 24 Throughputs with No of Connection](image4)
6.3 RPGM
In the Reference Point Group Mobility model (RPGM), nodes cluster together and move as a group. All things being equal as in the Random Waypoint model, similar parameters for simulation are used.

6.3.1 Node Density
The results are shown in the series of graphs below. Figure 24 shows the packet delivery ratio of the network using the three different protocols in a RPGM model. Figure 25 represents the Average end to end delay of the network. Figure 26 shows Normalized Routing Load and figure 27 shows the Average Throughput with the variation of node density. AODV and DSR has same performance for the varied node density.

![PDR vs Node Density](image1)

**Figure 25** PDR with varied Node Density

![Avg E2E Delay vs Node Density](image2)

**Figure 26** Delay with varied Node Density

![Routing Load vs Node Density](image3)

**Figure 27** Routing Load with varied Node Density

![Avg Throughput vs Node Density](image4)

**Figure 28** Throughput with varied Node Density
6.3.2 Network Loading

In this simulation on RPGM model, we investigate the routing performance aspect when the offered load increases. We do so by increasing the average connection load offered by each connection, starting at 5 pkts/sec to 20 pkts/sec. All the three protocols AODV, DSR and DSDV are performed equal.

![Figure 29 PDR with varied Connection Rate](image1)

![Figure 30 Delay with varied Connection Rate](image2)

![Figure 31 Routing Load with Connection Rate](image3)

![Figure 32 Throughput with Connection Rate](image4)
6.3.3 Network Connection
In this third simulation of network load variation, the number of connections the simulated system will take was varied instead. The number of connections increases from five to 20 connections in each different set of simulation.

Figure 33 PDR with varied No of Connection

Figure 34 Delay with varied No of Connection

Figure 35 Load with varied No of Connection

Figure 36 Throughputs with No of Connection
7. CONCLUSION
This work uses ns2 simulator and evaluates the performance of three widely used Ad hoc on demand routing protocols under different mobility models and parameters such as Packet Delivery Ratio, Normalized Routing Overhead and End-to-end delay. A few conclusions can be drawn from the performance of the three protocols.

- The Result of simulation indicate that performance of AODV and DSR protocols are superior to DSDV
- For Random Waypoint mobility model DSR is best because it has high PDR ratio and less routing load.
- For RPGM mobility model, performance for AODV and DSR are nearly near to one another. There is no difference in the choice of routing protocols.
- For Manhattan mobility model DSR perform better as it has high PDR and less routing load.
- It is worthy of note to state that in terms of the chosen metrics, DSR performs best making it efficient in the utilization.

8. FUTURE WORK
In this work other network parameters such as simulation time, traffic type-CBR, etc. are kept constant. It would be interesting to observe the behavior of these three protocols by varying other network parameters and by using other performance metrics.

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