Chapter V

Performance of Ad Hoc Network with and Without Mobility Conditions.

Introduction

Mobile Wireless Ad Hoc Networks (MANET) is wireless network that work in a decentralized way without the need for a pre-determined infrastructure. This kind of network is based on a contention-based distributed MAC protocol such as IEEE 802.11 in a Distributed Coordination Function (DCF) operative mode or other no contention-based distributed MAC, based on TDMA schemes such as [1]. When a mobile node desires to communicate with some other node which is far away, it can use other mobile nodes on the fly that fall into its transmission range to make progress towards the destination node. For this reason, a multi-hop forwarding-based scheme routing is mandatory. The simulation of mobile network calls for a mobility model to generate the trajectories of the mobile users (or nodes). It has been shown that the mobility model has a major influence on the behavior of the system. Therefore, using a realistic mobility model is important if we want to increase the confidence that simulations of mobile systems are meaningful in realistic settings.

We have constructed detail simulation model which will compare the performance of Ad hoc network protocol with and without mobility conditions. Our simulation model is based on Opnet 14.5 simulator. Our model is measure effect of mobility by introducing different sets of nodes those are using different mobility model.
This chapter is organized as follows:
Section 5.1 introduction of mobility model, section 5.2 performance of Ad hoc network protocol without using mobility, section 5.3 detail reports of simulation model with using mobility and last section of this chapter introduces comparison of these two models.

5.1 The Mobility Model
A mobility model is a set of rules used to generate trajectories for mobile entities. Mobility models are used in network simulations to generate network topology changes due to node movement. A network simulator must know the position of a mobile node at any one time. Using the exact node position the simulator can compute signal fading from one node to another and take actions based on the current network topology (e.g., determine the set of nodes that will receive a certain packet). A mobility model uses an environment description to define the bounds of the simulated world. In addition to the bounds, the environment description can include obstacles or restrictions within the simulated environment (e.g., walls, streets). These restrictions directly influence the way nodes move: simulated humans must not walk through walls, simulated cars must stay on the streets, etc.

At a high level of abstraction, mobility has two components: a spatial component and a temporal component. The spatial component describes where the mobile entity is moving and the temporal component describes when an entity is moving and at which speed. Thus, when developing a mobility model, the two components of mobility must be clearly defined. The general set of parameters required by a mobility model to build the simulated world contains: the simulated population size $N$, the simulation time $t_{sim}$, the environment description, spatial mobility characteristics, and temporal mobility
characteristics. The mobility model produces node trajectories that can be fed into a network simulator.

The values of the mobility model parameters are obtained by processing a WLAN trace. The parameter values are used by the WLAN mobility model to generate different mobility scenarios. For a set of parameter values and different seeds, the mobility model generates different mobility scenarios. These mobility scenarios can be used by a network simulator to study the behavior of a mobile system. Our implementation of the WLAN mobility model generates mobility scenarios for the Opnet 14.5 simulator. The framework of the WLAN mobility model is depicted in Figure 5.1.

Figure 5.1 The framework of the WLAN mobility model

A mobility model for network simulations can be seen as the collaboration between two processes: a spatial process $PS$ and temporal process $PT$. The result of this collaboration is the generation of node trajectories in a described
environment. The environment is defined by the boundaries of the physical space in which mobile nodes can move, together with restrictions on the way nodes are allowed to move. The environment and its restrictions can be specified in multiple ways. For example, the Random Waypoint [5] model defines the rectangular area in which nodes are allowed to move and an empty set of restrictions (i.e., nodes are allowed to move to any point within the defined area).

The first process used by the mobility model is the spatial process ($PS$). It defines the spatial behavior of the mobile nodes. If we consider the simulated space as a volume of points, the spatial process defines the subset of points to be visited by a specific node during the life-time of a simulation. For example, the next destination of a node can be selected using a uniform random distribution, as implemented by the Random Waypoint model.

The temporal process ($PT$) defines the time component of the mobility model. Part of the temporal component of a model is, say, the time in which the node must reach the destination point (i.e., the speed of the node). The movement of the nodes is modeled as a series of movement sessions between different points in the environment. The next destination of a node is selected by an invocation of the spatial process $PS$, and the duration of the current session is generated by the temporal process $PT$. The environment restrictions are enforced by the spatial process. After both spatial and temporal components of the next movement are defined, the node moves to the next destination. This iterative session generation is repeated for the entire duration of the simulation.

### 5.1.1 Trajectories
A trajectory is a path specification for a mobile site's motion during a simulation. In OPNET Modeler, a trajectory can be defined as either *segment-based* or *vector-based*. 
1. Segment-Based Trajectories defines movement using a series of pre-defined points.

2. Vector-Based Trajectories defines movement in terms of a bearing, ground speed, and ascent rate.

5.1.1.1 Segment-Based Trajectories

A segment-based trajectory consists of one or more traversal-time values and a set of three-dimensional (x, y, and altitude) coordinates that define the mobile site's path. In addition, trajectories with variable-length segments have a set of angles (roll, pitch, and yaw) that defines the mobile site's orientation in space. Segment-based trajectories are stored in ASCII text files with a .trj extension and are assigned to a mobile node or subnet using the "trajectory" attribute.

During simulation, a mobile object follows its trajectory by moving in a great-circle path from one defined point to the next. An object's position at a given time is determined by interpolating between the trajectory points immediately before and after that time. A segment-based trajectory specifies a mobile object's location for a finite duration; if the simulation continues beyond the last specified time in the trajectory, the object remains at the trajectory's end point.

Segment-based trajectories come in two varieties: fixed-interval and variable-interval. In a fixed-interval trajectory, one value determines the traversal time for all segments; hence an object takes the same amount to time to traverse every segment, regardless of the segment's length. In addition, a single value generally determines the altitude for all points.

In a variable-interval trajectory, each point has its own specified altitude, wait time, traversal time (time from the previous point to the current point) and orientation. The wait time causes a mobile object to pause at each point before it begins traversing the next segment.
5.1.1.2 Vector-Based Trajectories
A vector-based trajectory consists of a direction and a velocity that can be changed at run time. You specify that a site will use a vector-based trajectory by setting the site's trajectory attribute to VECTOR. Vector-based trajectories rely on a great circle around the earth—specified by the bearing, ground speed, and ascent rate attributes—to define a site's path. This circular path is centered at the center of the earth and passes through a specific point, usually the mobile or satellite site that is following the path. During simulation, the site's latitude and longitude follow the circular trajectory. Contrary to statically defined trajectories, there is no time limit and the site's position changes as long as ground speed and ascent rate are not zero. Typically, a vector trajectory does not change during simulation. However, in OPNET Modeler the path of a site can change during simulation if the bearing of the site is changed. In this case, the current latitude/longitude coordinates of the site become the new origin and a new "great circle" route is recomputed based on the new bearing and origin.

5.2 Performance of Ad hoc Network without using mobility
Ad hoc network simulation model as shown in the figure 5.2 is developed using 100 mobile nodes. This model has two specific properties, one property is the model developed without the use of mobility and another property is for every node nine inter arrival probability distributions load are given and these distributions are selected randomly. Nodes of the model are configured in such a way that it will run on any MANET routing protocol. Performance of model is closely watched for four routing protocols i.e. AODV, DSR, OLSR and GRP.

5.2.1 Wireless LAN parameters
Wireless LAN parameters are already mentioned in chapter III, page no 60 and table 3.1.
5.2.2 MANET Traffic Generating Parameters

MANET traffic generating parameters are already mentioned in chapter IV, page no 113. Same parameters are used in this model.

![Ad hoc Wireless Network](image)

**Figure 5.2 Ad hoc Wireless Network**

5.2.3 Performance Analysis of Protocols.

Simulation models are developed using the parameters mentioned in table 3.1 for all protocols. Protocols’ performance analysis is based on the following matrices:

1. Throughput (bits/sec).
2. End to End Delay.
3. Retransmission Attempts (packets).
4. MANET traffic sent and received.
5. Total packets dropped.

5.2.3.1 Wireless Throughput (bits/sec)

![Wireless LAN Throughput (bits/sec) Graph]

Figure 5.3 Throughput (bits/sec)

AODV is the reactive protocol. It is maintaining route information in the table. Using route table information AODV will transfer the packets from one place to another. As shown in the figure 5.2, 57950.4 bits/sec average throughput was observed for AODV. DSR protocol is also a reactive protocol. It is using source routing because of that every sender knows complete hop by hop information up to the destination. Because of above property DSR has shown maximum average throughput i.e. 59288.1 bits/sec as compared to other protocols.

GRP always follows the shortest distance for reaching destination. Performance of GRP protocol was poor as compared to other protocols. On an average throughput 3983.31 bits/sec has shown throughout the simulation. OLSR
operates as a table driven, proactive protocol, i.e., it exchanges topology information with other nodes of the network regularly. OLSR protocol has shown slightly better performance than GRP protocol. On an average throughput was 12611.8 bits/sec throughout the simulation under OLSR protocol. As shown in the figure 5.3 OLSR and GRP’s performance was stable throughout the simulation, on the contrarily performance of AODV and DSR protocols was bit fluctuating.

5.2.3.2 End to End delay (sec)

As shown in the figure 5.4 DSR has shown maximum end to end delay in sec. Average end to end delay under DSR protocol was 0.0018 sec due to collisions throughout simulation time. DSR has shown maximum end to end delay then also it has maximum average throughput as compared to other protocols. At the start of simulation AODV has shown maximum
delay, as simulation progresses end to end delay was stable. Average delay was 0.00034 which is negligible.

OLSR and GRP performance was almost identical with reference to end to end delay throughout the simulation time. Average end to end delays of OLSR and GRP protocol were 0.00027 and 0.00028 respectively. OLSR and GRP protocol are proactive protocols. It collects the information of all nearby nodes and then it sent the information to the destination because of that minimum delay was observed under these protocols.

5.2.3.3 Retransmission Attempt

As shown in the figure 5.5, OLSR and GRP protocols attempted maximum retransmission attempts as compared to DSR and AODV protocol. OLSR and GRP are maintaining information of neighboring nodes by periodically sending hello messages. Due to that reason destination nodes are busy. So the source nodes have to send the data packets repeatedly.

AODV has shown one retransmission attempt and DSR has shown three retransmission attempts throughout the simulation time. AODV and DSR are reactive protocols. They are collecting information about source to destination when actually needed. Because of this property they need minimum retransmission attempts throughout the simulation.
5.2.3.4 Data Dropped

Maximum average data drop was observed under DSR protocol i.e. 12131.5 bits/sec as shown in the figure 5.6 throughout the simulation. AODV has shown minimum data drop throughout the simulation. On an average data drop under AODV was 256 bits/sec. Performance of AODV has shown minimum delay, minimum data drop with maximum throughput as compared to other protocols. OLSR and GRP protocols have shown 1682 and 174 bits/sec on an average data drop respectively. Simulation model under GRP protocol has shown lowest data drop throughout the simulation time.
5.2.3.5 Traffic Sent (bits/sec)

Till now we have considered wireless LAN matrices, now we will consider two performance matrices i.e. MANET Traffic received and sent. As shown in the figure 5.7 traffic sent under all protocols was identical throughout the simulation time. On an average traffic sent from source to destination was around 180000 bits/sec. As shown in the figure 5.7, it is observed that all nodes are participating in the network under all protocol.
5.2.3.6 Traffic Received (bits/sec)

As shown in the figure 5.8, performance of AODV and DSR was better in terms of MANET traffic received. Average MANET traffic received under AODV and DSR was 1219 and 1631 bits/sec respectively. If we compare MANET traffic sent and received, we observed that 80 percent of data loss during receiving process.

Performance of OLSR and GRP protocols was very poor in terms of MANET traffic received. Maximum MANET traffic received was 2916 bits/sec and 309 bits/sec under OLSR and GRP protocols respectively. 90 percent of data was lost under the OLSR and GRP protocols.
Chapter V   Performance of Ad hoc Network with and without mobility conditions

Figure 5.8 MANET Traffic Received (bits/sec)

5.3 Performance of Ad hoc Network with using mobility

As shown in the figure 5.9, Ad hoc wireless network model is developed using mobility models. In Ad hoc wireless network model 100 nodes are participating in the network. All nodes of the network are not following same mobility models, instead of that, 100 nodes are divided into 10 groups. Every group is following one trajectory; white lines indicated in the figure 5.9, shows moving direction of the nodes. Following are the trajectories which are followed by the wireless network nodes.

1. Clock Circle West.
2. Jammers Net
3. MANET Up Right
4. MANET Down left
5. Mobile IP Net
6. VECTOR
7. WLAN Roaming  
8. Xclock Circle south  
9. ZigBee Pan Demo  
10. Hand over Turns

Figure 5.9 Ad hoc Wireless Network Model with Mobility

Performance of network was analyzed when node movement of the network was not identical. Nodes of the network are moving on the basis of different trajectories which are mentioned above.
5.3.1 Performance Analysis of Protocols.

Simulation models are developed using the parameters mentioned in table 3.1 for all protocols. Protocols’ performance analysis is based on the following matrixes:

1. Throughput (bits/sec).
2. End to End Delay.
3. Retransmission Attempts (packets).
4. Total traffic sends and receives.
5. Total packets drop.

5.3.1.1 Wireless Throughput (bits/sec)

Performance of AODV with reference to throughput was best as compared to the other protocols as shown in the figure 5.10. Performance of OLSR and GRP was stable but poor throughout the simulation as compared to AODV and DSR. If we compare this model with network model without mobility, it will show that performance of model with mobility has improved.

The information of average throughput of model with mobility and without mobility has given in the following table 5.1.

<table>
<thead>
<tr>
<th>Name of Protocol</th>
<th>Average Throughput (bits/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model without Mobility</td>
</tr>
<tr>
<td>AODV</td>
<td>57950</td>
</tr>
<tr>
<td>DSR</td>
<td>59288</td>
</tr>
<tr>
<td>OLSR</td>
<td>12611.8</td>
</tr>
<tr>
<td>GRP</td>
<td>3983.3</td>
</tr>
</tbody>
</table>
Ad hoc wireless network models with mobility and without mobility conditions are implemented and performance of models is observed. As shown in table 5.1, it is observed that performance of model in terms of throughput is increased 10 to 20 times in model with mobility conditions. When we are putting restrictions on movements of nodes in terms of different trajectory, performance of model has increased tremendously.

In the Ad hoc network model without mobility conditions, DSR protocol has shown best performance as compared to other protocols. The performances of DSR and AODV are very much same of each other. On the contrarily, the performance of AODV was best for the model with mobility conditions as compared to other protocols. AODV performance is 15% better than DSR performance.
Chapter V  Performance of Ad hoc Network with and without mobility conditions

5.3.1.2 End to End delay (sec)

AODV and DSR at the starting of simulation have shown delay but as simulation progresses it becomes stable to the lowest value of delay. DSR has shown highest delay of 0.11 sec and AODV has shown 0.067 sec as shown in the figure 5.11. An average delay of OLSR was 0.00031 and GRP was 0.00033 respectively.

Delays of model with mobility conditions and without mobility conditions are shown in following table. As shown in the table 5.2, it is observed that model with mobility conditions has slightly more delay as compared to ad hoc network without mobility conditions. Ad hoc network model with mobility conditions has shown more delay as compared to model without conditions with better throughput.
Table 5.2 End to End Delay (sec)

<table>
<thead>
<tr>
<th>Name of Protocol</th>
<th>Average Delay(sec)</th>
<th>Model without Mobility</th>
<th>Model with Mobility</th>
</tr>
</thead>
<tbody>
<tr>
<td>AODV</td>
<td>0.00034</td>
<td>0.0014</td>
<td></td>
</tr>
<tr>
<td>DSR</td>
<td>0.0018</td>
<td>0.0019</td>
<td></td>
</tr>
<tr>
<td>OLSR</td>
<td>0.00027</td>
<td>0.00031</td>
<td></td>
</tr>
<tr>
<td>GRP</td>
<td>0.00028</td>
<td>0.00033</td>
<td></td>
</tr>
</tbody>
</table>

5.3.1.3 Retransmission Attempt

Initially, at the start of simulation AODV protocol has shown maximum number of retransmission attempts but as simulation progresses it settled on an average 0.00143621 packets. As shown in the figure 5.12 DSR has shown maximum number of retransmission attempts as compared to other protocols. At the start
of simulation DSR has also shown maximum retransmission attempts, and then it settled to average 0.01285 packets.

OLSR and GRP protocols have shown average retransmission attempts 0.000310 and 0.02843 packets respectively. GRP protocol has attempted more number of retransmission attempts as compared to OLSR protocol. Comparison between Ad hoc network model with mobility conditions and without mobility conditions are given in table 5.3

Table 5.3 Retransmission Attempts (bits/sec)

<table>
<thead>
<tr>
<th>Name of Protocol</th>
<th>Average Retransmission attempts (bits/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model without Mobility</td>
</tr>
<tr>
<td>AODV</td>
<td>0.7019</td>
</tr>
<tr>
<td>DSR</td>
<td>2.5900</td>
</tr>
<tr>
<td>OLSR</td>
<td>3.6867</td>
</tr>
<tr>
<td>GRP</td>
<td>2.5000</td>
</tr>
</tbody>
</table>

When in Ad hoc network model node movements are restricted then minimum number of retransmission attempts is required as shown in the table 5.3. As we employed movement restrictions in terms of trajectory, less than 2% bits are retransmitted as compared to model without the mobility conditions.

5.3.1.4 Data Dropped

As shown in the figure 5.13, data drop under all protocols is almost zero throughout the simulation except under the DSR protocol. At one moment of simulation DSR protocol has dropped data of 16 bits/sec because of congestion in the network. After the traffic was cleared no data drop was observed under DSR protocol.

Data drop under Ad hoc network with mobility conditions and without mobility conditions are given in the table 5.4. As shown in the table 5.4, data drop under
model with mobility conditions is almost zero under all protocol. As the movements of the nodes are restricted, the number of hops required to reach the destination is stable. Thus the minimum data was drop under all protocols.

![Figure 5.13 Data Dropped (bits/sec)](image)

**Table 5.4 Data Dropped (bits/sec)**

<table>
<thead>
<tr>
<th>Name of Protocol</th>
<th>Average Data Dropped (bits/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model without Mobility</td>
</tr>
<tr>
<td>AODV</td>
<td>256</td>
</tr>
<tr>
<td>DSR</td>
<td>12131.5</td>
</tr>
<tr>
<td>OLSR</td>
<td>1682</td>
</tr>
<tr>
<td>GRP</td>
<td>174</td>
</tr>
</tbody>
</table>
5.3.1.5 Traffic Sent (bits/sec)

As shown in the figure 5.14, MANET traffic sent under all protocols was identical throughout the simulation time. On an average 170000 bits/sec traffic was sent under all protocols throughout the simulation.

If we compare model with mobility conditions and model without mobility conditions, we may get slightly more MANET traffic sent bits/sec under network model without mobility conditions.

5.3.1.6 Traffic Received (bits/sec)

As shown in the figure 5.15, maximum traffic received under the OLSR protocol i.e. 6799 bits/sec. An average MANET traffic received under GRP protocol was 5821 bits/sec. Average MANET traffic received under AODV and DSR protocols were 1772 and 3753 bits/sec respectively.

The values of Ad hoc network model with mobility conditions and without mobility conditions are give in the table 5.5. When movements of nodes in the network are restricted then average MANET traffic received by the nodes gets
increased under all protocols. AODV performance with reference to MANET traffic received was increased by around 50%. In case of DSR protocol traffic received was more than 100% as compared to model without mobility conditions. OLSR and GRP performances were increased by 10 and 1000 times as compared the model without mobility conditions respectively.

![Figure 5.15 MANET Traffic Received (bits/sec)](image)

<table>
<thead>
<tr>
<th>Table 5.5 MANET Traffic Received (bits/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name of Protocol</td>
</tr>
<tr>
<td>------------------</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>AODV</td>
</tr>
<tr>
<td>DSR</td>
</tr>
<tr>
<td>OLSR</td>
</tr>
<tr>
<td>GRP</td>
</tr>
</tbody>
</table>
5.4 Conclusions:

A MANET simulation model was built-up using parameter which mention in table 3.1. Ad hoc wireless network models were developed with and without mobility conditions. Different statistical distributions load have given to the model and performance of simulation models were observed and discuss in above sections. Performance of routing protocols were considered and given in above sections. Overall performance of routing protocols is as follows:

1. Performance of all protocols has improved after putting mobility conditions except OLSR protocol with reference to throughput.
2. In terms end to end delay AODV has shown improvement as compared to other protocols.
3. Retransmission attempts have been considerably reduced in all protocols after putting mobility conditions.
4. The model without mobility conditions shown data drop but after putting mobility conditions data drop was observed almost zero in all protocols except DSR protocol.
5. MANET traffic sent by every protocols were almost identical for with and without mobility model.
References


[10] Mobility Generator (version 1.0) from the site, http://nile.usc.edu/important/software.htm, February 2004