CHAPTER 4 PERFORMANCE ANALYSIS OF SELECTED ROUTING PROTOCOLS

4.1 INTRODUCTION

It has become widespread fact among the MANET community that because of the high cost involved and lack of flexibility, experimentation in the MANET research area is done through simulations. There exist numerous simulation tools such as the Glomosim, Qualnet, NS2 and Opnet etc. The simulation tools are used for evaluating the ability of the chosen routing protocols i.e. DSDV, DSR and AODV and should be adaptable to different scenarios and modification. The tool should be extensible i.e. we should be able to extend or add a functionality. The tool should provide implementation of the selected routing protocols, also should have the scope to modify them. The presence of the desired features is not merely the criterion to choose a tool; but its results should be highly trusted among the community. We used NS2 simulation tool which is developed at the University of California at Berkeley. The monarch research group at CMU extended the ns-2 to include wireless scenarios for MANET. The MAC layer is defined by IEEE 802.22 standard for mobile nodes. We have used random way point mobility model, two ray ground reflection model and IEEE802.11 standard for our work.

4.1.1 Network Simulator 2

NS-2 is the discrete event simulator used for simulating any kind of internet communication. It provides implementation for TCP, UDP and variety of routing protocols and support QoS etc. The simulator is written in C++ and TCL, and uses tcl interpreter for the user i.e. user writes the TCL script for the network to be simulated and then it is used by ns for simulation. The result of the simulation is the trace file containing various attributes concerning the protocol used. The trace file can be parsed with the scripts like perl and awk for determining the metrics such as the throughput and the delay etc. The simulation can be visualized with the help of network animator comes with the package. The use of C+ and TCL increases the complexity of simulator.
However, being open source, its design is complex and makes any extension difficult. There have been the efforts going on to improve the structure and design of NS-2. However, the obtained results are most trusted by the research community.

4.1.2 Two Ray Ground Propagation Model

In wireless networks, the path loss is defined as the ratio of the transmitted power to the received power of the same signal on the path. The estimation of path loss is important for designing the wireless networks. It is dependent on many factors such as the radio frequency and the terrain. Since the terrain cannot be the same everywhere, so a single model cannot be sufficient. Therefore several models have been proposed in the literature for designing the wireless networks. The free space model is the simplest and most referred path loss model. In this model atmospheric attenuation is not assumed and a direct path signal exists between the sender and the receiver. In this model the relationship between the received power and transmitted power is given by Eqn. (4.1).

\[ P_r = P_t G_t G_r \left( \frac{\lambda}{4\pi d} \right)^2 \] (4.1)

Where \( G_t \) and \( G_r \) are the gains of transmitter and receiver antennas, in the direction from transmitter to the receiver, \( d \) is the distance between transmitter and receiver, and \( \lambda \) is the wavelength of the signal.

Realistic path loss model considering propagation effects of the specific environment can be obtained by Maxwell’s equation but it a complex process. Hence, simpler models have been proposed. The free space model assumes only single path from transmitter to receiver while in reality the signal is received through multiple paths. The two ray propagation model tries to capture real environment phenomenon and assumes that signal is received through two paths, one is the direct path and the other is via reflection or refraction. According to the two ray ground reflection model received power is given by Eqn. (4.2).
\[ P_r = P_t G_t G_r \left( \frac{h_t h_r}{4\pi d} \right)^2 \]  \hspace{1cm} (4.2)

Where \( P_t, G_t, G_r \) and \( d \) are the same as in Eqn. (4.1) and \( h_t, h_r \) are heights of the transmitter and receiver antennas respectively.

### 4.2 ENERGY CONSUMPTION MODEL

The energy consumption model used in the present work is of Carlos et. al. [48,49]. The energy consumption varies from 230mA to 330mA. The 230mA is used in receive mode and 330mA is used in transmit mode. We have assumed the energy supply of 5 V. The values used corresponds to 2,400 MHz WaveLAN implementation of IEEE802.11.

The networks interface of the node decrements the energy according to the following parameters:

a) the NIC characteristics  
b) the size of the packet  
c) the used bandwidth

Eqn. (4.3) and (4.4) gives the energy in Joule to transmit and receive a packet.

\[ \text{Energy}_{\text{Tx}} = \frac{(330 \times 5 \times \text{Packet\_Size})}{2 \times 10^6} \]  \hspace{1cm} (4.3)

\[ \text{Energy}_{\text{Rx}} = \frac{(230 \times 5 \times \text{Packet\_Size})}{2 \times 10^6} \]  \hspace{1cm} (4.4)

We have assumed RF (radio frequency values) 281.8mW which is equivalent to the energy required to model a radio range of 250 meters.

### 4.3 SIMULATION TOOLS AND PARAMETERS

The performance evaluation of the selected routing protocols is done using the event driven ns2.34 simulator. The simulations are implemented using the random way point mobility models. The setup consists of 25 nodes in 500m X 500 m rectangular area. The initial energy of every node is 1000 J and the range is 250 m. We have used two ray ground reflection models being the realistic and the simulation time is 500 sec.

The traffic is generated using constant bit rate (CBR). The TCP sources are not
being chosen because it adapts to the load of the network [50]. For the same data traffic and movement scenario, the time of sending the packet of a node will be different in case of TCP, hence will become difficult to compare the performance of different protocols. The packet size is 512 bytes and the sending rate is 4.0 packets/second. The energy consumption analysis is done to find the behavior of selected routing protocols i.e. how the energy is consumed by different types of packets i.e. by the data packets, routing packets and MAC packets, by varying the various parameters such as the number of nodes, pause time, speed of nodes, sending rate of packets, number of sources and the area. The performance evaluation metrics used [51] are packet delivery fraction, energy consumed per successful data delivery, network lifetime and number of link breaks, and have been selected to determine the performance of chosen routing protocols. Some of these metrics might have been used in earlier simulation works also. Based on the performance of routing protocols we will choose the protocol to be modified for inclusion of our proposed technique. The number of link breaks is most significant and important metric from our present work point of view so we will analyze the modified routing protocol performance preferably based on this metric but the other metrics will also be analyzed.

<table>
<thead>
<tr>
<th>Table 4.1: Simulation Parameters</th>
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<tbody>
<tr>
<td>Parameter</td>
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<tr>
<td>Channel type</td>
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<tr>
<td>Radio- propagation model</td>
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<tr>
<td>Antenna type</td>
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<tr>
<td>Interface queue type</td>
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<tr>
<td>Maximum packets in queue</td>
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<tr>
<td>Network interface type</td>
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<tr>
<td>MAC type</td>
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<tr>
<td>Topological area</td>
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<tr>
<td>txPower</td>
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<tr>
<td>rxPower</td>
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<tr>
<td>idlePower</td>
</tr>
<tr>
<td>sleepPowe</td>
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<tr>
<td>initial energy of a node</td>
</tr>
<tr>
<td>Routing protocols</td>
</tr>
<tr>
<td>Number of mobile nodes</td>
</tr>
<tr>
<td>Maximum speed</td>
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<tr>
<td>Rate</td>
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</tbody>
</table>
Pause time | Simulation time
---|---
5, 10, 15, 20, 25 sec. | 500 sec.

4.4 ENERGY CONSUMPTION ANALYSIS

Fig. 4.1 to 4.6 depicts the energy consumption of the network against the sources, pause time, number of nodes, area, rate and the mobility of the nodes respectively.

![Total Energy Consumption Chart]

**Fig. 4.1: Total Energy Consumption Vs Sources**

The energy consumption is maximum for AODV and minimum for DSDV while varying the number of sources (Fig. 4.1). The increase in energy consumption due to the number of sources is consistent. If the nodes are static or are moving with the constant speed, then DSDV have shown minimum energy consumption because once it has established the routes to destination, further no more computation is required. While the reactive routing protocols have shown more energy consumption since establishes the route on demand.
The DSR has shown less energy consumption in contrast to AODV in all the cases, and this might be due to the fact that the multiple paths are stored in the route caches of the nodes in the MANET using the DSR routing protocol, and which helps in future transmissions and reduces the route discovery overhead. The routing overhead for DSR is negligible compared to AODV (Fig. 4.7 (a), 4.7 (b), 4.8 (a) and 4.8 (b)).
The energy consumption against paused time has shown variable behavior. So accurate prediction is not possible but the routing overhead is minimal for DSR among all three protocols in this case.
We have varied all the parameters for sufficient range of values to evaluate the energy consumption of the selected protocols. But overall in most of the cases DSDV consumed minimum energy, and among reactive protocols DSR outperformed AODV. Based on the energy consumption behavior of routing protocols in all the cases, the performance analysis against the considered metrics (mentioned in section 4.3) was done by varying two parameters i.e. mobility and the number of nodes and these are the important and significant parameters from present study point of view.

Fig. 4.7(a): Energy Consumption of AODV

Fig. 4.7, 4.8 and 4.9 shows the energy consumption of the selected routing
protocols (AODV, DSR and DSV) by different types of packets (mac, routing and data packets). The routing energy consumption increases with the increase of either the nodes or the speed and it is minimum for DSR and maximum for DSDV. The mac layer energy consumption has shown decreasing behavior and it is minimum for DSDV. The DSR consumed less energy as compared to AODV because DSR uses cache mechanism for route maintenance whereas AODV starts a new route discovery for every link breakage.

Fig. 4.7(b): Energy Consumption of AODV

Fig. 4.8(a): Energy Consumption of DSR
Fig. 4.8(b): Energy Consumption of DSR

Fig. 4.9(a): Energy Consumption of DSDV
4.5 PERFORMANCE ANALYSIS BASED ON CHOSEN METRICS

Fig. 4.10 shows the packet delivery fraction (PDF) of DSDV, DSR and AODV routing protocols at different speed and nodes. The DSR and AODV outperformed DSDV. Their PDF is constant irrespective of the speed or the number of nodes. The performance of DSDV decreases with the increase of mobility (Fig. 4.10 (b)) because of the presence of stale routing table entries, thereby packets are sent or forwarded over broken links (happens due to stale routing table entries) and this behavior worsen at higher speeds. The throughput of DSR is better than AODV, because DSR has access to a significantly greater amount of routing information than AODV in a single cycle of route discovery. The DSR, being the source routing protocol, can learn routes to each intermediate node on the route to the destination in a single request-reply cycle. However, AODV uses too many routing packets to build the necessary routing tables.
Fig. 4.10 (a): Packet Delivery Fraction Vs Nodes

Fig. 4.10 (b): Packet Delivery Fraction Vs Speed

Fig. 4.11 depicts that the energy consumption of reactive protocols is considerably constant against the speed of nodes though it increases with the number of nodes. However, both the reactive protocols (AODV, DSR) have outperformed DSDV. The Energy Consumption per Successful Data Delivery (ECPSDD) of DSDV increases against the speed because the probability of link breakage also increases with the speed. Therefore, an additional amount (is variable depends on many factors such the distance of the node from the source, the maintenance policy adopted etc.) of energy is consumed in
constructing new routes. The ECPSDD of DSR is less than AODV because DSR uses less number of routing overheads than AODV.

Fig. 4.11 (a): Energy Consumption per Successful Data Delivery Vs Nodes

Fig. 4.11 (b): Energy Consumption per Successful Data Delivery Vs Speed

Fig. 4.12 shows the network life time of the chosen routing protocols. The DSDV protocol keeps the network energetic longer than the AODV and DSR. Fig. 4.13 shows that the energy variance of residual battery energy (EVRB) of the nodes of DSR is not distributed properly as compared to AODV and
DSDV. The DSDV prolonged the network lifetime although consumed more energy per packet than DSR and AODV, since the energy consumption for routing overhead is distributed among all the nodes of the network and results in minimizing the exploitation of specific nodes energy repeatedly and also fairly utilizes the nodes energy. In spite of being unfair utilization of nodes (exploitation) by DSR (Fig. 4.13), its network life time is more (Fig. 4.12), since the energy consumption per packet of DSR is less than AODV. However, the AODV have shown (Fig. 4.13) better load balancing than DSR. The network lifetime of AODV is shorter than DSR (Fig. 4.12), because high mobility causes link breakages and AODV is aggressive to maintain broken links incur energy cost.

![Fig. 4.12 (a): Network Lifetime Vs Nodes](image-url)
Fig. 4.12 (b): Network Lifetime Vs Speed

Fig. 4.13 (a): Energy Variance Vs Nodes
Fig. 4.14 shows the number of link breaks detected by the routing protocols. The AODV have shown the minimum number of link breaks. The DSDV detects the maximum number of link breaks, since it is not able to adapt to the dynamic environment and the performance deteriorates further with the increase of mobility. The DSR link breaks are also increasing with the speed but AODV is able to adapt itself with the mobility and keeping the link breaks to minimum. We know Short Retry Limit of RTS (07) and Long Retry Limit of Data packet (04) is checked [52] before triggering a link failure in IEEE 802.11 MAC. And as per the considered Energy model, energy consumed in transmitting and receiving the packets, depends on the size of the packet sent/received. Therefore, a link failure may cause at least 15.5 Joule (3.37 x 4 Joule for data packets and 2.02 Joule for RTS packets). Hence, the protocols reporting more link failures will consume larger amount of energy of the network.
4.6 PROTOCOL SELECTION TO REDUCE ENERGY CONSUMPTION INCURRED IN LINK BREAKS

The existing routing protocols of MANET have been designed to offer best efforts service with less delay and maximum throughput. They were not designed with the objective of energy efficiency so have shown significant differences in energy consumption. A single routing protocol does not qualify all the metrics of energy efficient routing. The throughput of DSDV decreases
with the increase of either of the considered parameters i.e. nodes or speed whereas that of reactive protocols remain constant. Since, it is the most important measure from the network design efficient point of view. DSR outperforms others by consuming minimum energy per successful data delivery. DSDV makes network lifetime longer than others. However, taking into account the throughput performance of DSDV and it also consumes maximum energy among others for successful delivery of data packets, thus it will not be a wise choice. The AODV outperformed in some special scenarios. But throughput and the energy consumption per successful data delivery from our problem domain are the two main metrics which helps to determine the performance of the networks. DSR performed well for both the metrics. We know that a single cycle of DSR route discovery may return multiple paths thereby reducing the energy incurred in discovering multiple paths since the simultaneous multiple paths reduces the communication overhead exponentially [34]. The energy consumption in routing overhead for DSR is minimum. The ns2 implementation of DSR lacks of local recovery mechanism, reported more number of link breaks. In view of all these facts and reasons, the DSR was selected for the inclusion of our presented technique.

4.7 SUMMARY

In this chapter we have presented the concepts required to understand the simulation work. Section 2, give the energy consumption behavior of DSDV, AODV and DSR protocols considering various parameters such as the pause time, number of nodes, mobility, area and rate etc. The behavior of the protocols remained same against all the chosen parameters. Based on energy consumption analysis, only two parameters were considered for performance evaluation. The performance evaluation was done considering the metrics given in section 4.2. Finally section 4.6, concludes with the selection of a routing protocols favoring the present work.