Analysis of the Impact of Selfish Nodes on the Lifetime of a MANET

6.1. Introduction

An ad-hoc network nodes are typically portable and are equipped with radios, memory, and processors, all powered by a battery. These nodes come together and spontaneously form a network. It is imperative that the protocols be energy-efficient, which, not only increases the operational lifetime of the network, but also contributes to better network performance. Hence, designing energy-efficient routing algorithms is of paramount importance in MANETs. Since each node in a MANET works as a terminal node and a routing node as well, a node cannot participate in the network if its battery power runs out. Such nodes are declared as dead nodes. The increase of such dead nodes generates many network partitions and consequently, normal communication as a MANET will fail. Sometimes the nodes in the MANETs tend to become selfish by not forwarding packets belonging to other nodes, thereby stylizing their battery power for their self transmission and reception. In this chapter we have focused on the study of impact of selfish node concentration on the performance of the MANET, especially on its lifetime.

6.1.1. Selfish nodes

The conventional protocols in MANETs such as WRP, DSDV, AODV and DSR assume that all the nodes are cooperative and, whenever a node receives a request to relay traffic, it always does so truthfully. Occasionally, there is a tendency in MANET nodes to become selfish. The selfish nodes are reluctant to spend their resources such as CPU time, memory and battery power for others.

A part of this chapter is published in the
These nodes use the network and its services but they do not cooperate with other nodes. Such selfish nodes do not consume their resources such as CPU power, battery and also bandwidth for retransmitting the data of other nodes and they reserve them only for themselves. The problem is especially critical, when the nodes have little residual power and want to conserve it for their own purpose. Thus, in a MANET environment, there is a strong motivation for a node to become selfish. [Marti et al., 2000] have defined the characteristics of selfish nodes as follows:

- Do not participate in routing process: A selfish node drops routing messages or it may modify the Route Request and Reply packets by changing TTL value to smallest possible value.
- Do not reply or send hello messages: A selfish node may not respond to hello messages. Hence, other nodes may not be able to detect its presence when they need it.
- Intentionally delay the RREQ packet: A selfish node may delay the RREQ packet up to the maximum upper limit time. It will certainly avoid itself from routing paths.
- Dropping of data packet: A selfish node may participate in routing messages but may not relay data packets.

The limited energy resources coupled with the multi-hop nature of MANETs causes a new vulnerability that does not exist in traditional networks. To preserve its own battery, a node may behave selfishly. The major reason for such a behavior is low residual battery power of a node. A selfish node is not malicious and doesn’t intend to involve itself in the network damaging activities such as content alteration, spoofing, etc. It normally restrains itself from the activities of the other nodes, which do not bring any benefit to it. One immediate effect of node misbehaviors and failures in MANET is the node isolation problem due to the fact that communications between nodes are completely dependent on routing and forwarding of packets. In turn, the presence of selfish node is a direct cause for node isolation and network partitioning, which further affects network survivability. Traditionally, node isolation refers to the phenomenon in which nodes have no active neighbors. The selfish nodes do not participate correctly
in routing function by not advertising available routes or by not forwarding route request packets. Consequently, such selfish nodes will not appear on packet forwarding path. As far as the effect of selfish nodes on the power consumption in MANET is concerned, it is observed that, as the number of selfish nodes increase, they save more energy as compared to the good nodes. It is true for both static and dynamic topologies. The selfish behavior in the MAC layer can have devastating side effects on the performance of wireless networks, similar to the effect of Denial of Service (DoS) attacks.

**Dealing with selfish nodes**

There are basically two techniques available to detect selfish nodes in the MANET. They are reputation based technique and credit based technique [Dipali Koshti et al., 2011]. In reputation based scheme, network nodes collectively detect and declare the misbehavior of a suspicious node. Such a declaration is then propagated throughout the network. Credit based schemes provide incentives for nodes to faithfully perform networking functions. In order to achieve this goal, virtual (electronic) currency or similar payment system may be set up. Nodes get paid for providing services to other nodes.

### 6.1.2. Impact of selfish nodes on QoS parameters

As the number of selfish nodes increases, there is a definite impact on the performance of the network. The following QoS parameters are normally taken into consideration to measure the performance of a MANET [Shailender Gupta et al., 2011]:

- **Throughput**: Percentage of packets received by the destination to the number of packets sent by the source.
- **Hop count**: Defined as the number of intermediate hops from source to destination.
- **Packet dropped**: Measure of the number of packets dropped by the routers due to various reasons.
- **Probability of Reachability**: Fraction of possible reachable routes to the all possible routes between all different sources to all different destinations.
There will be no significant decrease in average throughput when the number of selfish nodes are up to 10% of the total number of nodes. There is a generic trend of decrease in average throughput with the increase in concentration of selfish nodes. The average throughput doesn’t fall to zero even if all the nodes are selfish. The reason for this is that even at 100% selfish behavior the communication between two immediate neighbors, as source and destination, still survives.

There will be an increase in the average hop count as the concentration of selfish nodes increases. The average hop count is almost same when the selfish nodes are up to 10% of the total number of nodes. The average hop count increases to 2.5 times when the selfish nodes are nearly 100%.

There is no remarkable change in the percentage packet dropped when the selfish node concentration is up to 10%. It reaches to a maximum value of nearly 60% when the selfish node concentration is nearly 90%.

As expected the probability of reachability is nearly 100% when no node is selfish. As the number of selfish nodes increases the probability of reachability decreases but never reaches zero because even at 100% selfish behavior the communication between two immediate neighbors, as source and destination, still survives.

6.2. Proposed method

The proposed methodology comprises, the basic AODV protocol in the presence of selfish nodes. Some of arbitrarily chosen nodes of MANET are designated as selfish nodes. In addition, to achieve energy awareness, adaptive fuzzy threshold energy protocol is employed. The proposed method is described below.

The impact of the selfish nodes on the lifetime of the MANET for various node densities (ranging from 50 to 300 in steps of 50) and also for various concentration of selfish nodes (ranging from 10% to 50% of total number of nodes in steps of 10). That is, out of the total number of nodes in the MANET, 10% of the nodes are
randomly chosen to be selfish and the percentage of selfish nodes is increased in steps of 10. The basic routing algorithm used is AODV. The Adaptive Fuzzy Threshold Energy (AFTE) routing algorithm is applied to the MANET with selfish nodes in order to analyze the impact of the presence of selfish nodes on the energy efficiency.

The lifetime of the MANET achievable by the proposed algorithm, in the presence of selfish nodes, is compared with that available in the following cases:

i. AODV without selfish nodes (AODV self)

ii. AODV with application of AFTE protocol

iii. AODV with selfish nodes

iv. AODV with selfish nodes with application of AFTE protocol.

6.3. Results and discussions

The simulation experiment is carried out using NS2 simulator for different simulation times (50, ..., 600), in steps of 50. In the experiment various node densities ranging from 50 to 300 in steps of 50 and various levels of selfish nodes ranging from 10% to 50% of total number of nodes in steps of 10% are used. The other simulation parameters are given in the Table 6.1. The results are shown in the graphical form in the Figure 6.1. To keep the graph simple, the results corresponding to only 20% and 50% of selfish nodes are presented.

Table 6.1 Simulation parameters for AODV and AFTE

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simulation Time</td>
<td>50,...500 sec.</td>
</tr>
<tr>
<td>Terrain Area</td>
<td>500 X 500 sq. mts</td>
</tr>
<tr>
<td>Number of Nodes</td>
<td>50,...300</td>
</tr>
<tr>
<td>Node placement</td>
<td>Random</td>
</tr>
<tr>
<td>Propagation Model</td>
<td>RWP</td>
</tr>
<tr>
<td>Channel Frequency</td>
<td>2.4 G.Hz.</td>
</tr>
<tr>
<td>Routing Protocol</td>
<td>AODV,AFTE</td>
</tr>
<tr>
<td>Transmission Range</td>
<td>250 mts</td>
</tr>
<tr>
<td>Initial Energy for each node</td>
<td>100 Joules</td>
</tr>
</tbody>
</table>
In the simulation experiment carried out, the following three cases are considered [Marco Fotino et al., 2011]

a. Time when the first node fails.

b. Time when 50% of the nodes fail.

c. Time when all the nodes fail.

The results for the four protocols, namely, AODV, AFTE, AODV with selfish nodes and AFTE with selfish nodes are given in the Table 6.1. From the Fig. 6.1, it is clear that as the simulation progresses; more and more nodes lose their energy and hence become dead. It shows that AFTE based routing protocols provide 15 to 50% more network lifetime as compared to AODV and other protocols. Thus, it is able to achieve higher network lifetime as compared to the other three protocols considered therein. Further, as the number of selfish nodes increases, there is a gradual reduction in the network lifetime. This reduction in the network lifetime is due to the fact that, as more and more nodes become selfish, the routing load on the good nodes increases. The good nodes keep losing their energy and hence become dead earlier. On an average, with 30% increase in the selfish nodes, the network lifetime reduces by 25%.

From the Figure 6.1, it can be seen that for a network with smaller node density, the impact of selfish nodes on the network lifetime is more. As the node density increases, this impact also keeps on reducing. This is because, with the increase in the node density, more nodes are available for sharing the routing load, excluding the selfish ones. An improvement in the network lifetime with the application of AFTE protocol can be seen from the Table 6.1. Considering only the first node failure, there is an improvement in network lifetime from 2 to 41%. Considering 50% node failure, there is an improvement in network lifetime from 2 to 16%. Considering 100% node failure, there is an improvement up to 14% in network lifetime.
Figure 6.1 The % of dead nodes vs. simulation time for (a) 50 nodes, (b) 100 nodes, (c) 150 nodes, (d) 200 nodes, (e) 250 nodes, and (f) 300 nodes. In the legend, A & B correspond to AODV & AFTE without selfish nodes, C & E to AODV & AFTE with 20% selfish nodes, D & F to AODV & AFTE with 50% selfish nodes, respectively.
TABLE 6.1. The time when 1st node fails, 50% nodes fail and 100% nodes fail in case of AODV & AFTE protocols without and with the presence of selfish nodes.

<table>
<thead>
<tr>
<th>No. of Nodes</th>
<th>Time when first node's residual energy becomes zero</th>
<th>Time when 50% of nodes' residual energy becomes zero</th>
<th>Time when 100% of nodes' residual energy becomes zero</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A  B  C  D  E  F</td>
<td>A  B  C  D  E  F</td>
<td>A  B  C  D  E  F</td>
</tr>
<tr>
<td>50</td>
<td>221  354 162 112 204 158</td>
<td>232 426 212 192 240 205</td>
<td>350 500 350 300 400 300</td>
</tr>
<tr>
<td>100</td>
<td>215  364 165 115 162 116</td>
<td>230 476 185 178 220 206</td>
<td>350 600 300 300 350 300</td>
</tr>
<tr>
<td>150</td>
<td>217  364 154 132 154 112</td>
<td>236 482 188 220 223 204</td>
<td>300 600 300 300 350 300</td>
</tr>
<tr>
<td>250</td>
<td>211  405 204 161 212 215</td>
<td>235 476 220 225 260 262</td>
<td>300 550 300 300 350 350</td>
</tr>
<tr>
<td>300</td>
<td>215  308 208 204 220 222</td>
<td>242 422 225 222 254 240</td>
<td>300 500 300 300 350 350</td>
</tr>
</tbody>
</table>

6.4. CONCLUSION

The nodes in a MANET become selfish in order to conserve their energy for a longer period. But, as more and more nodes become selfish, the routing load on the remaining good nodes increases. This leads to the usage of the same nodes again for packet routing, which ultimately leads to network partitioning. In this chapter, a MANET is simulated with different node densities and different concentration of selfish nodes using adaptive fuzzy threshold energy based protocol and AODV protocol. It is found that as the number of selfish nodes increases, there is reduction in the network lifetime. The network lifetime can be enhanced 14 to 41% by the application of AFTE routing protocol in comparison with AODV protocol.