CHAPTER 6

REGION BASED SPRAYING FOR CONTROLLED REPLICAION

Region is a place where people stay for a period of time. People may reside in different regions at different times based on their work nature. The research work presented in this chapter predicts this mobility behaviour and finds the popular regions of a node and then forwards the messages to that region. This chapter provides the prediction of the popular region of each node and the propagating of that information through the network of nodes. The routing is done with the information of a destination's popular region. The results are compared with the existing works for performance validation.

6.1 INTRODUCTION

In order to increase the performance of routing protocols in IC-MANETs, it is necessary to select good intermediate nodes for forwarding. Selection of intermediate nodes is done by recording the previous encounters of each node with the destination. Direct encounter alone does not ensure that the nodes again meet soon. Usually, the people or animals visit any locality, reside there for a period of time, and then travel back and forth. The encounter history is useful in predicting the next encounter in a given locality. However, when users change their locality, the encounter information obtained at previous locations may no longer be correct and may be of no assistance for obtaining new locations.
In a scenario where students who attend classes in the same building, they are expected to frequently encounter each other at study time. But after the class, they may go to different areas. It is difficult to guess the students who will again encounter with each other in new places based only on encounter history in one building, because two students who attend the same class do not necessarily live in the same locality. Although on small time scales or within small distances the node encounter may still be useful, it is necessary to take the macro level information in a real scenario. From a social context, both locations of stay and people’s encounters have a strong association with affiliation and lifestyle. In contrast with encounter history based protocols, the region-based model offers a different way of solving the routing problem in IC-MANETs (Wen et al 2011).

The research work called FIRE considered the connectivity whenever possible among the source and the destination. It is seen to find the destination within a particular area of the network. If destination is not found within that then it switches to multi-copy routing. The issue that is still to be solved is in deciding the area for finding the destination.

The next research work addresses both the issues discussed above. It focuses on studying Region Based Find and Search (RBFS) strategy in realistic network environments with limited resources like bandwidth and buffer. In this, the network environment is divided into number of regions. The regions are an example of populated localities in reality as like residential areas, industrial area, institutions, bus stand etc., or it can be combined, and the movement history of nodes among the regions is tracked for routing. Due to mobility and other reasons the source and destination may be connected if they are within the region or may get disconnected some other time. Therefore, this work makes use of the connections whenever possible. It tries to establish a connection from source to destination first within a region. If
the destination is not available for a specified delay then the source switches to controlled replications of the messages using intermediate nodes. As a result, the average number of copies replicated is reduced based on the destination availability.

6.2 REGION BASED FIND AND SPRAY

The mobility models commonly used in ad hoc networks are the simplistic random IID models that do not reflect actual mobility characteristics of real life. In all existing models, all mobile nodes act statistically identical to everyone, and their activities do not change with respect to time. But in mobility-assisted routing schemes, it is important to consider the real life mobility for performance analysis. There is an increasing need for realistic mobility characteristics and hence the community based mobility model is introduced (Musolesi and Mascolo 2006). This mobility model exactly forecast the intermittent connectivity in nature and the delay of message delivery is coupled strongly with the properties of mobility of a node.

This work makes use of the community based mobility where every node tracks its own community or region within a unit time and creates its own trace, based on its affiliation and everyday life. Therefore each node has the information of the community or popular region it belongs to. Based on this information good utility based intermediate nodes are found and then the messages are sprayed with the intermediates. The intermediates then take the messages to regions where the destination is popularly found. Inside that region, the destination is searched and messages are sent if it is found.

The network area is divided into number of regions and named like 1, 2, 3... etc. All the nodes move by recording the tracking history of different regions that the nodes encounter. A node then calculates the following,
i) Residing Time

It gives the average of continuous staying time of a node in the same region.

\[
R_{t_{ij}} = \begin{cases} 
\frac{(1+\rho)}{\rho_i D} & \text{Update } R_{t_{ij}} \text{ after every } t \text{ seconds if } \\
\rho_i D e & \text{it is in the same region} \\
(1-\rho_{ij}) \rho_i D e & \text{Decrease } R_{t_{ij}} \text{ after every } t \text{ seconds if } \\
\rho_{ij} D e & \text{it is in the next region} 
\end{cases}
\]

where \( \rho_{ij} \) - Number of times a node encountered a region

\( D \) - Number of different regions encountered so far.

\( i, j \) - \( i \) gives the node id and \( j \) gives the region id.

Update of \( R_{t_{ij}} \) is done whenever a node stays in the same region. If a node moves from one region to another region then the \( R_{t_{ij}} \) is decreased as given in the above equation. The exponential values are chosen to increase the residing time whenever a node stays in the same region and to decrease proportionately whenever it moves to different region.

Considering the sample tracking history of node 1 which is 2-2-2-2-2-3-3-5-5-5-5-5 then the last values of \( R_{t_{12}}= 150.65, R_{t_{13}}=0, R_{t_{15}}=24 \). Normally for the home region the value of residing time update is very high.

ii) Encounter History

This is the normalized number of hitting times of a node that arrives to region \( j \).
where \( t_2 - t_1 \) indicates the time difference between the last update and current update time.

\( \varphi \) gives the preference to the previous history or the time differences of the updates.

\( H_{i_j-1} \) is the previous encounter history value for the encountered region.

For the same set of tracking history and the time differences as 5s the value of \( H_{t_2} = 1.6 \). Similarly for region 3 and 5 can be calculated by the node 1.

iii) Selection of Intermediate Node

If the destination belongs to the same community of the intermediate node then the message is forwarded to that intermediate node. While choosing the intermediate node, the best intermediate node is chosen based on the utility value given in the following.

\[
U_{t_{ij}} = \left( \frac{\alpha R_t \ H_{ij}^m + \beta H_t \ H_{ij}^n}{\alpha R_t \ H_{ij}^m \cdot \beta H_t \ H_{ij}^n} \right)
\]  \hspace{1cm} (6.4)

where \( \alpha, \beta \) are constants. Normally \( \alpha, \beta > 1 \) and \( \alpha < \beta \). \( m, n \) are also constants \( m > n, 0 < m < 1, 0 < n < 1 \).
For the above set of tracking history while leaving region 2 the node 1 has the value of $U_{t/2}$ which is 3.39 for $\alpha = 1$, $\beta = 2$, $m = 0.2$, and $n = 0.1$.

iv) Community Update

If two nodes 1 & 2 meet in a region, and if node 1 has the same mobility pattern as node 2 or at least, one region frequently visited by node 1 is visited by node 2, then node 1 updates the Community Update table for node 2. The nodes also exchange the community update for other nodes it met already. This makes popular region information of a node to propagate into the network. An example for the community update is given as in Table 1. It shows the utility update for node 1. It had initially only node 4’s and its own utility values. After meeting with node 2, it is updated with node 2’s utility since it belongs to the same community of node 1. Also it has been updated with node 5 since node 2 has already met node 5 and it has its utility value in its table. The blank indicates no visit to the region. The same process is repeated for node 2 also.

Table 6.1 Community Update Table

<table>
<thead>
<tr>
<th>Region</th>
<th>Node</th>
<th>Utility Value</th>
<th>Update Time(s)</th>
<th>Utility Value</th>
<th>Update Time(s)</th>
<th>Utility Value</th>
<th>Update Time(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>2</td>
<td>5</td>
<td>7</td>
<td>2</td>
<td>3.39</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>3.1</td>
<td>10</td>
<td>1.25</td>
<td>10</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>5.5</td>
<td>21</td>
<td>4.5</td>
<td>21</td>
<td>5.1</td>
<td>21</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>10.1</td>
<td>6</td>
<td>-</td>
<td>-</td>
<td>6.1</td>
<td>6</td>
</tr>
</tbody>
</table>
6.2.1 Message Dissemination in Spray and Search Strategy

When a node likes to send a message to any destination, it first checks the community update table for checking the destination lies in the same community of its own. If so, it first searches for the destination in that region. If the destination is found then it sends the message directly to that destination. The destination is searched by broadcasting a route request message for the destination. The route request messages are sent with the source address, destination address, sequence number, hop count and time to live and region id of the source’s current region.

The nodes that receive the route request message inside the same region processes those requests again. If the destination is reached within that region then the destination replies with the route reply message. Then the source forwards one copy of the message to that destination. Sometimes, the destination may not be available and it may be roaming in other popular regions or the source node does not have any information of the destinations popular community regions in its community table. The source then sprays some limited number of copies of the message to other intermediate nodes. These nodes carry the messages and transfer the messages to destination if met; else it forwards it to the other best intermediate node which has the high utility to reach the destination’s popular region.

If the source node has the information of community regions of the destination, it transfers the messages to the intermediate nodes which belong to the same community of the message destination. Then the messages are buffered in all the intermediate nodes until it moves to the destination’s community or to the other intermediate node which has high utility for reaching the destination region.
6.2.2 Handling Route Request Packets

The route request packets are broadcast from the source if one of the destination popular regions belongs to the current region of the source. The route request has the source address and also the current region information of the source. While broadcasting the route request message, the nodes increase their transmission power double the time and then sent them. Since the ICMN is disconnected in nature, the nodes inside the region also get disconnected. Increasing the power does not have much impact on energy consumption since it is only inside the region. But, the destination may be reached soon. Nodes do the following after receiving the route request,

(i) Nodes inside the region

Receives the request and checks for the region id of the request message. If the region id is the current region of the node and it is not the destination then it again forwards it via the nearby nodes. If the node is the destination then it accept the request and send a route reply for the source.

(ii) Nodes outside the region

When a route request is received outside the current region then it is discarded because of the destination unavailability.

6.2.3 Message Dissemination by Intermediate Nodes

The source node sprays fixed number of copies to the intermediate nodes when destination is not available within the region. Then the intermediate nodes transfer the copy when it meets the destination or else there are two possible cases,
(i) If inside the destination’s popular region

It increases its transmission power and searches for the destination inside that region with the route request broadcast. If the destination is found then the message is forwarded to that destination after receiving the route reply.

(ii) If not found in the destination’s popular region

If the intermediate node is not inside the destinations popular region then it forwards it copies only when it meets the destination or otherwise if it finds the intermediate node which has high utility to reach the destinations popular region. The utility value is calculated as said in (6.4). It is given as follows.

\[
U_{ij} = \left( \frac{\alpha R_t}{H_t} \right)^m + \left( \frac{\beta H_t}{R_t} \right)^n
\]

The utility for a best intermediate node is chosen when it spends more time in that region and it hits the region a number of times during its mobility. Based on these two values, the utility value is calculated and the best intermediate node is the one which has the high utility parameter.

6.2.4 Handling Acknowledgement

Whenever a destination node receives the message it sends the acknowledgement to the intermediate node which has carried the message. Then that message is dropped and also the acknowledgement is flooded into
the popular region of the source node while the intermediate node is moving into that region. If it finds other intermediate node which belongs to the same community of the source with high utility to reach the sources’ region then the acknowledgement is also copied. Even though the acknowledgement messages are flooded, due to the flooding being only inside the region they do not waste much of the resources like data messages.

6.3 RESULTS AND DISCUSSIONS

The same discrete event-driven simulator called QualNet is used to evaluate the performance of different routing protocols under a large range of connectivity levels and for different mobility and different traffic. Although the intermittently connected or delay tolerant networks of interest are disconnected in general, they may range from extremely sparse to almost connected networks. The RBFS is implemented and simulation results are compared with the Epidemic Routing, Spray and Focus and RENA. The pseudo code for the RENA routing scheme is given in Appendix 4.

The kind of disconnected environment is implemented by forming some disconnected clusters. Clusters are nothing but the region of nodes which are separated from the geographical area. Nodes inside the cluster may later go around and get connected to other nodes in the cluster. Here, the community based mobility model is introduced by attaching file based mobility. These nodes initially stays in a region called home region and then they have periodic movements among the regions and again return back to the home region like university employees and students, working people in industries etc. Among all the nodes, many of the nodes are attached for community based mobility. Other than that, some of the nodes are assigned with random way point mobility and the remaining are static nodes. Random way point mobility is assigned for the nodes to predict the realistic behaviour of nodes which do not have community based mobility like door-to-door
salespersons and sales executives in real time since they do not make regular visits to same places.

In the scenarios there are maximum of 100 nodes moving inside a 2500m × 2500m network. A region is set as 500m × 500m and nodes are distributed inside that region. Also, 20 nodes are chosen randomly to move among the regions and 50 messages are sent for a pair per a second throughout a run. Each node has a buffer space of 150 messages. The other parameters for the simulation analysis are given in Table 6.2.

**Table 6.2 Simulation Parameters for RBFS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Default Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Network Size</td>
<td>2500m × 2500m</td>
</tr>
<tr>
<td>Number of Nodes</td>
<td>20 to 100</td>
</tr>
<tr>
<td>Transmission Power</td>
<td>10 dbm/25 dbm</td>
</tr>
<tr>
<td>Battery Model</td>
<td>Linear</td>
</tr>
<tr>
<td>Speed of Mobile nodes</td>
<td>50 mps to 75 mps</td>
</tr>
<tr>
<td>Mobility model</td>
<td>Community based mobility</td>
</tr>
<tr>
<td>Pause time</td>
<td>30 seconds</td>
</tr>
<tr>
<td>Maximum Buffer Size</td>
<td>150 Messages/Node</td>
</tr>
<tr>
<td>Message Size</td>
<td>512 Bytes</td>
</tr>
<tr>
<td>Simulation Time</td>
<td>1000s</td>
</tr>
<tr>
<td>Physical Layer</td>
<td>802.11b Radio</td>
</tr>
<tr>
<td>MAC Layer</td>
<td>802.11(Ad hoc)</td>
</tr>
<tr>
<td>Channel Frequency</td>
<td>2.4GHz</td>
</tr>
</tbody>
</table>
The throughput, delay and number of messages duplicated parameters are checked for different scenarios and with different connectivity too. Connectivity is directly related to the number and quality of forwarding opportunities presented to the message custodian or to the intermediate node. Therefore, connectivity is expected to have an important effect on the performance. Connectivity is the measure of how many new nodes are encountered by a given region within some time interval, and is important in situations where mobility is exploited to deliver traffic from source to destination.

Figure 6.1 shows the delivery ratio of different routing protocols for different numbers of nodes in the scenario. It is common in IC-MANET that when the number of nodes is raised then the delivery ratio is increased due to increase in number of intermediates. All the protocols show improvement in message delivery. Initially all the protocols are delivering messages to a minimum level due to sparsely connected network. Epidemic Protocol has very low delivery ratio compared to others even when there is an

![Figure 6.1 Delivery Ratio Analysis of RBFS over Existing Schemes](image-url)
increase in the number of nodes. This is due to the uncontrolled replications with each of the messages. The nodes running with Epidemic protocol transfer all their messages to nearby nodes that don’t have a copy of it already. Therefore, soon the nodes buffer gets occupied and the network becomes congested. At last, there are a number of messages dropped before reaching the destination.

The nodes equipped with some moderate mobility and periodic movements of the Community Based Model use the spraying method to have a superior performance. Since Spraying methods distribute some fixed number of copies of each message, the messages are replicated to certain number of nodes in the Spray phase. Owing to mobility, these copies get distributed by the source and may reach the destination during Focus phase. Spray and Focus finds for a best intermediate node in focus phase for further forwarding. The utility value is calculated based on the timers when two node encounters. The intermediate node is chosen based on the high utility value of the nodes. Therefore, the message is forwarded to the best intermediate nodes that have recent encounter timers with the destination. The results in Figure 6.1 show the differences of the Epidemic and Spray and Focus methods during community based mobility.

In RENA protocol, the geographical area is divided into a number of regions. Each node calculates it’s hitting time, staying time and updates its transition probability matrix. Each node periodically advertises its presence in any of the regions. This advertisement is disseminated like flooding. Therefore, the source node has the information of the region where actually the destination is roaming. With that the source finds the best intermediate nodes which have low routing delay to reach the destinations region.

When the intermediate node reaches the destinations region it sprays the messages of some fixed number of copies to search for the
destination. The RENA works better than others when the number of nodes increases. The RBFS outperforms both flooding based and spraying based routing protocols because the RBFS tries to capture the destination’s availability before the actual replications begin. Here, the simulation traffics are included with the combination of both destination availability and unavailability inside the region. Therefore, other protocols go for multiple replications all the time. But the RBFS looks into the availability and make use of it whenever possible. Therefore the buffer of each node is saved and on the average the number of messages that might reach the destination is higher. Unlike Spray and Focus, it does not need to have the last encounter of destination with the intermediate node. The RBFS sprays the messages to the nearby nodes initially. But, in the second phase the intermediate nodes search for the best intermediate nodes that have high utility to reach the destination region. Hence, the Spray and Focus have to wait for an intermediate node which has encountered the destination. But the RBFS does source spraying initially and then those nodes distribute the copies to the best utility intermediates. Compared with RENA also, RBFS works better due to the initial source spraying and then multiple intermediates towards the destination regions.

Figure 6.2 shows the effect of number of nodes increasing in average end-end delay of the messages. It is also known that whenever there is a increase in number of nodes then delay in reaching the destination is reduced. But the average end-end delay may vary based on the routing protocols. The delay measurement shown in Figure 6.2 is different from that of the throughput results. Here, the delay of the RENA method is very high comparatively than that of the others. The RENA fails to route messages when the source doesn’t have the information of the current region of the destination.
The region information of the destination may not reach the source due to intermittent connectivity. The other reason is that the source may not have the chance to meet the best intermediates initially. Epidemic always has a high delay because of improper management of buffer and not finding the best intermediate nodes to transfer the messages. Therefore, even when the number of the nodes is increased the delay is reduced only to a certain amount. Spray and Focus and RBFS have much reduced delays when there is an increase in the nodes, since they can find many intermediates to reach the destination. The delay of RBFS is much reduced due to the search of the destination by increasing the transmission power inside the popular region of the destination instead of spray and search as like in RENA. The different intermediates for each popular region of the destination and the finding of destination inside the region makes the delay of RBFS to improve nearly 50% compared to others.
Figure 6.3 displays the number of messages duplicated for different numbers of nodes in the scenario. Certainly, it is very huge for Epidemic since it makes uncontrolled replication when buffer space is available. Looking at spraying method, they are seen to greatly reduce the number of copies. In terms of number of copies, Spray and Focus, RENA and RBFS have only slight variations.

![Comparison Analysis of Duplicated Messages Generated for RBFS over Existing Schemes](image)

**Figure 6.3  Comparison Analysis of Duplicated Messages Generated for RBFS over Existing Schemes**

Spray and Focus may have some few copies extra than that of RENA. But, RENA limits the copies still to a greater extent by spraying the copies only if it finds the best intermediate. If the message reaches the destination region, then copies are made for spray and search inside that region. Spray and Focus have some increased number of copies compared with RENA and RBFS. Since it has to spread the messages throughout the network of nodes, the fixed numbers of copies to be sprayed are increased.
while increasing the number of nodes. RBFS also results in some increased number of copies than that of RENA. If the destination is available in the searching region or the source and destination are of the same community then only one copy of each message is forwarded to that destination. But if the source and destination are of different community then the source spraying inside the region is necessary and these intermediates again find better utility based intermediates to forward to. Even though the message replications are somewhat high in RBFS compared to RENA, it is actually needed to achieve the reduced delay and delivery ratio in case of intermittent connectivity. The overhead involved in flooding the region matrix of each node in RENA is not considered here.

The buffer sizes of nodes have a great impact on the performance of intermittently connected networks. The flooding based protocols work better if they have infinite buffer space. If buffer space is restricted then there are a high number of packets dropped. This is depicted in Figure 6.4. Here, the results are shown for the buffer size of each node increased from 50 to 250 messages.

The buffer size is increased for each node and the performance is checked. When the buffer size is low then message drops are really high in Epidemic hence the delivery ratio is very low. But there are sudden increases in flooding based schemes when there is an increase in buffer space of nodes. Since, they try to duplicate almost all the copies of the messages intermediated. Spray and Focus again needs the buffer size comparatively less than Epidemic but greater than RENA and RBFS. It uses fixed copies which are more than those two. Therefore, it also reacts faster for buffer size increase. The RENA and RBFS have moderate throughput even if the buffer size is small since they are in need of replication only inside the region of
nodes and that too some fixed number of copies which are very less compared to others.

![Graph](image)

**Figure 6.4 Impact of Buffer Size in Delivering the Messages for RBFS**

Since these protocols have smaller number of message drops. Therefore, unnecessary flooding and more number of copies to be spread are avoided. Therefore, the buffer of many number of nodes are kept free for useful traffic.

Figure 6.5 shows the transmission range of nodes and their effect on the delivery delay of all the messages. When there is increase in the transmission range then delay is reduced since connectivity among the nodes increases. But the Epidemic protocol shows that the delay is reduced initially and then starts increasing. This is due to the connectivity increase making the
number of replications high but which fail to make useful transmissions in intermediate nodes. The remaining protocols show consistent performance while the transmission power is increased since they do not replicate much even when they are able to reach many number of nodes.

![Figure 6.5 Impact of Transmission Power in RBFS over Existing Schemes](chart)

**Figure 6.5 Impact of Transmission Power in RBFS over Existing Schemes**

Among the remaining three, the RBFS has very low delay when the transmission power gets increased. In RBFS, the transmission power is increased to reach the destination inside their popular region. Due to this, the messages would get transferred to the destination nodes within a short period, when they reach their popular region.
6.4 SUMMARY

In this chapter, single-copy routing is proposed whenever possible in IC-MANETs. This work presented a region based routing to decrease unnecessary transmissions and to reach the destinations sooner. The realistic mobility models are established and the performances are measured. The nodes are found easily in their popular regions and then they are connected easily with a single copy itself. From the results, it is found that carefully designed region based schemes could often will be a feasible substitute for more general multi-copy strategies, without the overhead of using unnecessary replications. Thus, the RBFS makes use of the nodes for frequent visits and connectivity whenever possible and the results show that delay is reduced increasing in turn the delivery ratio. Also, unnecessary replications and message drops are greatly reduced compared to the other controlled replication schemes.