Multicasting in Delay Tolerant Networks

A *Thesis Submitted*

in Partial Fulfilment of the Requirements

for the Degree of

MASTER OF TECHNOLOGY

by

SHIVI SHUKLA (ABMTI-13039)

Under Guidance of

Dr. Yatindra Nath Singh (Professor, IIT Kanpur)

to the

AIM & ACT DEPARTMENT

BANASTHALI VIDYAPITH

MAY, 2015

CERTIFICATE

It is certified that the work contained in the thesis entitled " **MULTICASTING IN DELAY TOLERANT NETWORKS"** being submitted by **SHIVI SHUKLA** has been carried out under my supervision. In my opinion, the thesis has reached the standard fulfilling the requirement of regulation of the M.Tech degree. The results embodied in this thesis have not been submitted elsewhere for the award of any degree or diploma.

Dr. Yatindra Nath Singh

Professor

Department of Electrical Engineering

Indian Institute of Technology-Kanpur

May, 2015

Dedicated to

My Guruji

&

My Parents

Mrs. Kiran Shukla & Mr. Hari Om Shukla

Acknowledgements

I feel immense pleasure in expressing my profound sense of gratitude to my thesis guide Dr. Y. N. Singh under whose supervision and inspiring guidance, I would privilege me to carry out my research work. I am indebted to him for his constant and ungrudging encouragement, valuable suggestions and ingenious ideas. I also express my heartiest thanks to Amit Munjal for giving me the continuous support and guidance through my research and He showed me different ways to approach a research problem and the need to be persistent to accomplish any goal.

I wish to express my deep gratitude to my teachers Dr. C K Jha, Vikas Pareek, Chandani Joshi, and Divya Bhattacharya whose consistent help and encouragement to boost my moral and confidence. I immensely express my heartiest thanks to my friends Shruti Tyagi , Mayuri Shikarwar for their support and help. I want to express my special thanks to Ajit Vasudevan and Sahil Gupta for their support.

Though it is beyond the scope of any acknowledgement for all that I have received from my parents. May God guide me to the wishes of my parents so i can make them feel proud on me.

(Shivi Shukla)

Contents

List of Figures

List of Tables

Chapter 1

Introduction

In today's scenario, each user wants to remain connected so that the transfer of information and data can be done quickly. We can share our thoughts, data and other information from one country to another within seconds. It became very easy to share our data with others by means of connection to internet. We do not need to move physically anywhere to transfer our data, but for this (for using internet) all devices need to be connected by some medium and with servers as well.

With the help of internet we are connected worldwide but while establishing internet some medium like central servers, communication media or wireless medium are used. In remote areas, where there is no server or medium is available to provide connectivity we can not depend upon the internet to transfer the data because the internet connectivity could not be provided there.

The internet has well established medium for communication. It has pre established routers, gateways, wired or wireless communication system. There are servers which manage the whole network. In internet, there are many servers located at different places according to the connectivity area and range. But here a question remained

unanswered i.e. how to transfer data or establish communication in remote area or crisis environment where there is no network established. The answer of this question could be the **Delay Tolerant Networks (DTN)** [1]. There may be some situations where the communicating device is in home location and getting served with the traditional wireless networks but in some cases when you have to move out of your home network to the location where no end to end path is available then here also the delay tolerant networks can be used.

1.1 Introduction to DTN

The Delay Tolerant Network is totally different approach than regularly connected wired or wireless networks. In DTN, there is no end to end path available at any point of time for transferring data between a pair of sender and destination node. The communication in DTN is done by exploiting the characteristic of nodes i.e. mobility, available connections, and provided buffer space etc..

The Delay Tolerant Networks play the main role in the scenario where the routes between any pair of nodes could never be achieved. In sparse network scenario where there are no end to end routes available, like in military battlefields, DTN provides the means to communicate. It does not require any prior knowledge of networks to forward the bundles from one node to another. It is based upon the store-carry-forward approach. In internet where routing means to choose the best optimal path whereas in DTN routing means to ensure the delivery of bundles to destination with minimum delay incurred. The idea of Delay Tolerant Network (DTN) [2] was taken from InterPlanetary Networks (IPN) [3], this was started in 1970s. The IPN was invented to communicate between earth and mars. The DTN is a type of wireless ad-hoc network which tolerates

the intermittent connectivity. The intermittent connectivity can be defined as the sudden change of state (up/down) of any communication link between the nodes. The DTN can also be defined as intermittently connected wireless ad-hoc network [4] that can tolerate longer delays, intermittent connectivity and prevent data from being lost by using store-carry-forward approach. The Store-carry-forward approach enables the nodes to take the message, store it in the buffer provided at each node and forward the same whenever new node comes in its communication range.

Note: In delay tolerant networks the data packets are called bundles and the bundles could be of variable sizes.

1.2 Multicasting in DTN

In general, multicasting refers to forwarding messages to a group of nodes with established path towards every other node through some intermediate nodes. In DTN, the paths are not already established. Message for even a single destination may travel through multiple relay nodes to assure the delivery at earliest. Multicasting [5] [6] in DTN is done in the way that source node generate the message and start replicating it to other nodes coming in contact, the nodes receiving the message also further replicate it to other nodes to make it reach the set of destinations. The message does not contain destination as group of nodes but the address of nodes particularly because nodes keep changing their positions and so their corresponding groups.

1.3 Salient Features

The DTN has some salient features [7] [8] which make it different than available wireless networks.

- **Tolerates high latency** : DTN supports the communication even when the delay incurred in availability of next contact could be very high. The nodes are provided with buffer memory, so till the next node will come in contact, the messages are held in the buffer of the sending node.

- **Tolerates asymmetric data rates** : DTN allows the transferring of data even when the rate of incoming and outgoing transfer of messages are different.

- **Prevent data loss** : In DTN, every node is provided with some amount of buffer memory in which node stores the message and the node removes the message only when the custody of message has been transferred to other node.

- **Tolerates intermittent connectivity** : Intermittent connectivity can be defined as the sudden change of state (Up/Down) of any communication link. DTN tolerates the intermittent connectivity because it supports the buffer and custody transfer concept.

- **Store-Carry-Forward approach** : The main principal of DTN is the Store-Carry-Forward approach, which make use of the Bundle Protocol. Store-Carry-Forward approach enables the DTN nodes to receive the message, store it, carry it to the relay/destination node and forward it, if the relay node is currently not available, then save it in buffer.

- **Supports heterogeneous environment** : DTN allows communication between different types of networks such as MANET, WLAN, cellular, cordless phones etc.

- **Tolerates long queuing delays** : The nodes communicate with each other one at a time, so a list of connections is generated at each node. Nodes check the list and start communicating from the very first node of the list to the last node, if the link remain available.

1.4 Need for DTN

When the things come upon the natural hazard affected application areas or the areas where connectivity could not be achieved, and then here comes the need to use the DTN because the MANET [9] cannot work properly in these type of application scenario where end to end path cannot achieved. Some times DTN is confused with MANET [10]. Here are some points by which it is easier to get a clear difference between DTN and MANET.

- In MANET, the forwarding of message is done when the path between end points are already created. It means in MANET, the paths are created to and from the end nodes then after the forwarding is done from source to destination. Whereas in DTN,no paths are previously created for forwarding. The messages are routed by relaying the messages to available appropriate nodes.

- MANET does not use any store and forward approach which means if the next relay node is not available in MANET at any time then the message will be dropped and lost. In DTN, when any node receives a message to forward then it stores that message in its buffer and wait for other good relay node to come and

then forward the message to the relay node. The selection of relay nodes depends upon the applied routing algorithm in DTN network.

1.5 Application Scenario

The application areas [11] of DTN are the challenged environments, when the things come upon the natural hazard affected application areas or the areas where connectivity could not be achieved then here comes the need to use the DTN where the scenario for communication can not be established, like military battlefields, deep under water communication, natural hazard affected areas. The DTN can also be used for social networking in remote areas where connectivity is not available.

1.6 Research Objective

The objective of our research is to design an routing algorithm which can be used for multicasting in DTN, which better utilizes the network resources and assures the delivery of message with minimum possible delay incurred.

1.7 Organization of Thesis

In this chapter, we have introduced you with DTN, its salient features and the different application scenarios and we have also given some points to make it understand that how it is different from other traditional networks. In chapter 2, we have presented the study of literature we have done to find out the problem statement and to better understand the Delay Tolerant Network concepts and the routing algorithms. In chapter

3, we have stated the problem scenario, the approach we have chosen to solve the presented problem and then proposed a new algorithm for multicasting in DTN. Chapter 4 presents the simulation technique and the result analysis of the performance of our proposed algorithm. At the end, chapter 5 presents the conclusion.

Chapter 2

Delay Tolerant Networks: A Study

In this chapter, we are presenting the literature survey that we have done. The chapter includes the concept of DTN, how the routing takes place in DTN and the classification of the routing algorithms. We have categorized [9] [12] the routing protocols in DTN into two broad categories. Some of the routing algorithms which falls under these two broad categories are briefly defined. Some other routing algorithms are also defined which are used in DTN.

2.1 Concept of DTN

The Delay Tolerant Network (DTN) is an intermittently connected wireless ad-hoc network in which nodes have minimal or none of the knowledge about the network scenario. The DTN allows the communication between the wireless nodes in the scenario where end to end connectivity could never be achievable or when the delay associated in relaying data could be very high. The DTN uses the concept of Store-carry-forward, which distinguishes it from other traditional routing approaches. The Store-carry-forward approach enable the nodes to take the message, store it in buffer

and forward the same whenever new node comes in its communication range. The Store-carry forward approach and the tolerance of intermittent connectivity is achieved by the Bundle Protocol positioned above the TCP protocol in the protocol architecture stack of DTN. The application areas of DTNs are challenged environments like military battlefields, deep under water communication, natural hazard affected areas or remote area social networking etc. The advantage of DTN over other wireless networks is that DTN tolerates the Intermittent Connectivity and assures the data delivery with very limited knowledge of network nodes and scenario. In other traditional networks if the communication link goes down at any point of time of communication then the data loss is assured but in DTN, if the communication is in process and the link goes down then the data get stored in the sender nodes buffer rather being lost. In DTN the message forwarding is done by replicating the message to other nodes.

2.1.1 Concept of Bundle

In DTN, Self-Delimiting Numeric Value (SDNV) [13] scheme is used which provides the extensibility and scalability in encoding the messages. These extensible messages are given a specific name in DTN called bundles. The format of bundle block contains the Primary Bundle Block and Bundle Payload Block. All the fields in the bundle block are of variable size.

2.1.2 Concept of Replica

In DTN, we need to generate multiple copies of the same message (known as replicas) to forward it to the available relay nodes. The number of replicas [14] created for a message is directly counted as the cost incurred in the delivery of a particular message.

The need and distribution of replica can be understood as at a single point of time a node can communicate to all the available active nodes so it would create copies of the message for those particular nodes. Because in DTN, if the relay links are not available then the message get stored in the buffer of sender node so the nodes only generate the replica when the relay nodes are available. So nodes check at the moment that how many relay links are up at the moment and generate the same number of copies. When again a node need to send a copy to other nodes it will again create the replicas. The replicas can be created at once i.e. on the Source node or can be created distributive i.e. on relay nodes.

2.1.3 Concept of Custody

Custody Transfer is done by the sender and Custody acceptance is done by the relay nodes and it is the assurance of holding the bundle by the receiving node until it finds any other good relay node or destination to forward it. The node which takes the custody of the bundle is called Custodian. Many custodians can be present in the network for a particular bundle at a particular time.

2.2 Protocol Architecture of DTN

The operation of DTN makes use of Bundle Protocol (BP) [15], positioned above the application protocol in the protocol architecture stack of DTN. The main functions a Bundle Protocol can provide are given below:

- **Retransmission** can be done any time as because the transfer of data is done by transferring the custody of the message to other node.

- Tolerate the **intermittent connection** by providing buffer at each node.
- Make use of **any type of connectivity** like scheduled, predicted, and opportunistic. Most of the time the opportunistic connectivity is exploited in DTN for data transfer.
- Bundle Protocol provides support to **late binding** so that it can support the heterogeneous environments. Different Networks may use different addressing scheme [16] so while communicating with one type of network to another type of network, addressing scheme do not stop communication.

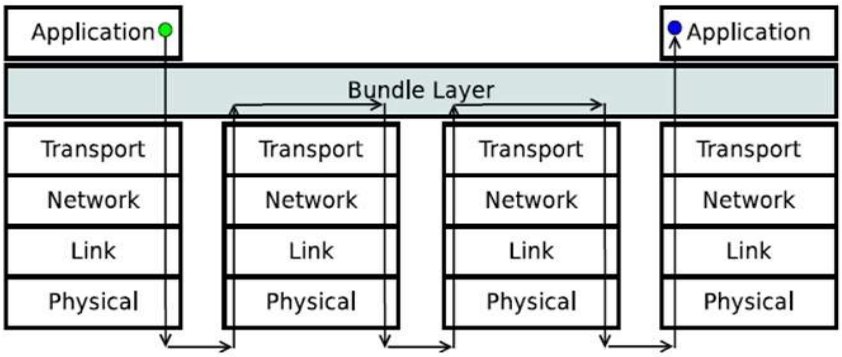

Figure 2.1: Position of Bundle Protocol in protocol architecture of DTN

2.3 Introduction to Routing in DTN

In traditional networks [17], the routing of packets between a pair of nodes aims to select the optimal path with minimum cost incurred. In these networks an optimal route needs to be established before the actual transmission of message. As in DTN the end to end route can never be achieved so the routing [18] [19] [20] of packets in DTN is done hop by hop, in which the selection of next hop is done dynamically as per the application scenario as well as the algorithm used. In general, when a node receives

any bundle (or message) then as per the algorithm, that node will search the good relay node to which it can forward the bundle. The transmission of message in DTN can either be done by replicating the message or forwarding it, that depends on the type of algorithm used.

2.4 Routing algorithms classification

In the literature of DTN, the routing protocols are categorized into two broad categories :

- Flooding based routing approaches
- Forwarding based routing approaches

In the literature, there exists a variety of routing algorithms for DTN. Here we have discussed some of them.

2.4.1 Flooding based routing approach

This type of routing strategy can be opted even when the nodes have no knowledge about the nodes in the network. In such case, epidemic routing algorithm is chosen in which the sender node replicates the message to each node it met so far. Replication based routing can comparatively give better results but it consumes more network resources because for a single message to be delivered the whole network could be holding so many copies of that message. The Flooding based routing is further classified into two types:

- Replication Based: Replication based routing allows the network nodes to create the replicas of the received message. The maximum number of replicas generated within a network for a particular message could be n-1, where n denotes the number of nodes in the network.
- Quota Based: In Quota based routing each message is assigned with fixed quota i.e. the number of replicas for a particular message is limited.

2.4.1.1 Direct Contact

In Direct Contact [21] routing algorithm, the source node will directly forward the bundle to the destination node. The source node first creates the bundle and then waits for the destination node. As the algorithm does not require any information about the network so it falls in the category of flooding based routing. The amount of delay incurred in delivery of bundle is very high and the cost involved in routing the bundle is very low.

2.4.1.2 Epidemic Routing

In Epidemic routing [22] each node replicates the message to every other node it met if the other node is not having the message copy. The message replication is done after checking the summary vector. The summary vector is maintained at each node that stores the information about all the messages that are passed by that node or currently stored in its buffer. In the literature, different enhancements were proposed to the original Epidemic routing algorithm such as prioritized epidemic and immunity based [23] epidemic.

2.4.1.3 Two-Hop Relay

In this approach [19], the source node replicates the message to a large number of relay nodes. In this approach a message will be delivered to the destination within two hops only i.e. either the source node directly delivers the message to destination or the relay node. Relay nodes will not further replicate it to any other node except the destination node i.e. after one hop transmission of message, the direct contact delivery approach is used and the relay node wait for the destination to come in contact.

2.4.1.4 Tree Based Flooding

T. Small et al [24] have given the concept of binary tree based algorithm. The algorithm works upon the concept that the source node must be limit with the number of replicas to control the width and depth of the tree i.e. when the nodes are limit with number of copies then they can go in depth up to a certain level. Each node can have max of two child nodes so the replicas are equally distributed in between them. After this receiving phase, the nodes start offloading the message to collection stations so to reach the destination.

2.4.1.5 Spray and Wait

The Spray and Wait [25] algorithm is the advanced version of the epidemic routing. In this algorithm the nodes are not distributing the replicas to each and every node but an optimal number of nodes (say m) are selected to which the source node will relay the message. There are two phases in this approach: Spray and Wait. In Spray phase, the source node replicates the message to the m nodes and these m nodes will further relay the message to m relay nodes. If the destination is not found in spray phase then the

Protocol	Number of Messages generated	Message delivery ratio	Average delay	Resource consumption
Direct contact	Single	Low	High	Less
Epidemic	N-1	High	Low	High
Two-hop	K	Medium	Medium	Less
Tree-based	1+log(N/2)	Medium	High	Medium
Spray and Wait	>=K	Medium	Medium	Medium

Table 2.1: Comparison of flooding based routing algorithms

relay nodes will store the message and performs direct transmission to the destination.

2.4.2 Forwarding based routing approach

This type of routing takes place when nodes have some relevant knowledge about the other nodes in the network. In this type of routing no node will generate replicates of the messages. Each node will search for the best suitable relay nodes and forwards the message to them. This approach reduces the extra resource consumption as replication of messages is not permitted. This type of routing is used when the network resources are limited such as buffer size at each node, battery life, etc..

2.4.2.1 NECTAR

The NECTAR [26] algorithm has given the concept of neighborhood index table that is maintained at each of the node. This table stores the information about the meeting frequency of the node with every other node in the network. The node with higher meeting frequency will be assigned a higher index value. When a node needs to forward the message to a particular destination, then it will select one of the relay nodes that

have highest index value for the respective destination.

2.4.2.2 Source Routing

The Source routing [27] consist of two phases i.e. route discovery phase and route maintenance phase. Initially a route is discovered by sending control packets towards a destination node. Each of the intermediate nodes will append its address in the packet. Each node also maintains a cache for the routes that the node has learnt over time. When the packet reaches at the destination the entire route is appended in the packet only. In route maintenance phase if a link failure is detected then a route error message is broadcasted by the source node.

2.4.2.3 Per-Hop Routing

In Per-Hop routing [28], each intermediate node will decide the next node to which the packet is to be forwarded for a particular destination. This approach has better performance than Source routing because the more updated information is used than Source Routing. The source node sends the message to all the connected nodes, then these nodes search for the closeness of the destination node and the node have the destination node as closest will further broadcast it. This process goes on and thus the refinement of routes keep going.

2.4.2.4 Per-Contact Routing

The most updated information is being used in Per-Contact Routing [29] because when any intermediate node receives any message for a particular destination then it will update its routing table and will check the current up contacts and select the appropriate

Protocol	Information maintenance	Message delivery ratio	Average delay	Resource consumption
NECTAR	Medium	High	Normal	Medium
Per-hop	Medium	Medium	Medium	Low
Per-contact	Medium	High	low	Medium
Source	Normal	Low	High	Low
CRHC	High	High	Normal	Medium

Table 2.2: Comparison of forwarding based routing algorithms

node for relaying the message and forward the message to the most appropriate node.

2.4.2.5 Hierarchical Forwarding and Cluster Control Routing

This approach introduces the concept of clustering (i.e. grouping) of nodes on the basis of link property and communication characteristics. After formation of clusters, a cluster head is selected depending upon some criteria. In [30], the cluster head node is selected based on the higher stability or the higher quality among all nodes within the cluster. The routing decisions are then taken by the selected cluster head.

2.5 Delegation Forwarding

In Delegation Forwarding, the referenced papers [15] and [31] has given a concept to calculate a quality value of node. As per their algorithm every node has a quality value and a threshold value for each message. Initially the value of the threshold is equal to the value of the quality of the node generating the message. When this source node met with other node, it will compare its threshold value with the quality value of other node, and if found greater quality value, the node will update its threshold value equal to the quality value of the node and will forward the message to this available node if

it is already not holding the message. Later on,Xiao et al has proposed the enhanced version of delegation forwarding [32].

Chapter 3

Proposed Routing Algorithm for DTN

3.1 Problem Scenario

Consider a scenario in which numbers of nodes are randomly deployed over a certain region of interest. The nodes communicate with their neighbors by exchanging messages whenever they come in proximity with them. All the nodes make use of Bluetooth interface for communication with their neighbors. Here we are considering uniform range of transmission i.e. some group of nodes are taken, and the buffer size, speed of movement of nodes and the range of transmission each node from a particular group are same. These nodes communicates with similar power level and thus covering uniform area. Initially none of the node is aware of the geographical location of itself as well as of other nodes.

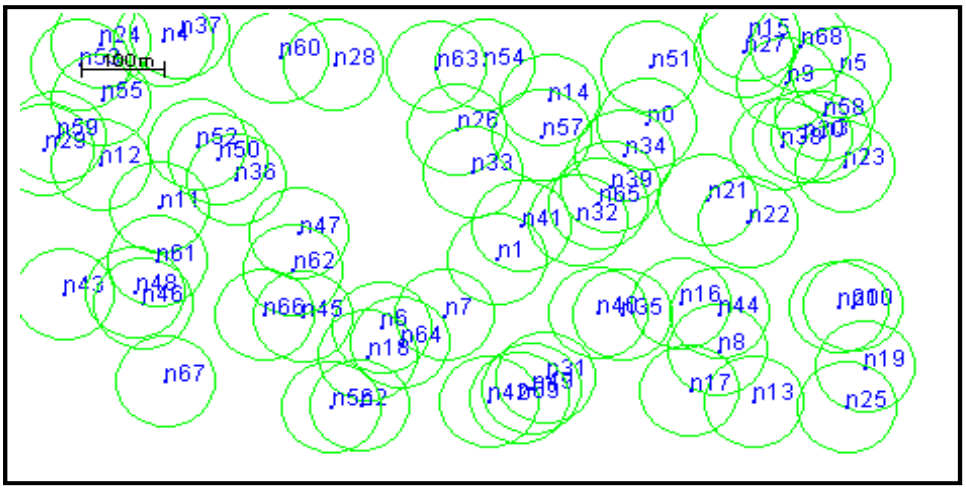

Figure 3.1: Randomly distributed nodes over a region

3.2 Approach

In DTN, if n nodes will store the information about all the n nodes in the network then overhead will be increased as to distribute this knowledge to all the nodes will consume the network resources. So it is better to group the nodes on some basis and then store the network information on only k nodes in n node network where k¡n and all the nodes can be updated with the information when it will be needed.

3.3 Proposed Algorithm

In our protocol we have used following nomenclature.

- Cluster: The cluster is a group of closely situated nodes.
- Cluster nodes: The member nodes of a cluster.
- Cluster-Head: The node having the highest Nodal degree among all the cluster member nodes.

Node-Id

- Gateway node: A node associated with two or more than two cluster-head.

In our approach, we create clusters on the basis of node's Nodal Degree. Nodal Degree can be defined as the number of other nodes a node can hear at a particular time. The cluster is being created by the highest degree node which announces for becoming Cluster Head(CH) and all the nodes which can hear the this highest degree node(CH) would get themselves associated with this CH and create a cluster. The lower degree nodes will always accept the broadcast of higher degree nodes of being CH. There are three phases in this algorithm:

1. Neighbor identification and cluster formation
2. Information sharing
3. Message forwarding

3.3.1 Neighbor identification and Cluster formation

1. Initially at the time of start up, every node will broadcast a Hello packet with its Id because the degree of node will be zero and then start maintaining a Neighbor degree table. This broadcasting is done to identify the neighbors.
2. As per the table created, nodes will calculate their degree and broadcast this updated degree to form a cluster. Subsequently nodes will keep updating their degree after a time span.

Node-Id	Nodal Degree	neighbor nodes	Associated CH-Id

Table 3.1: Neighbor identification

Node-Id	Nodal Degree	neighbor nodes	Associated CH-Id
A1	3	A2,A5,B2	B2
Own	-	-	-

Table 3.2: Neighbor information maintenance

3. After broadcasting , nodes will listen and maintain a Neighbor Information table of adjacent nodes and their nodal degree

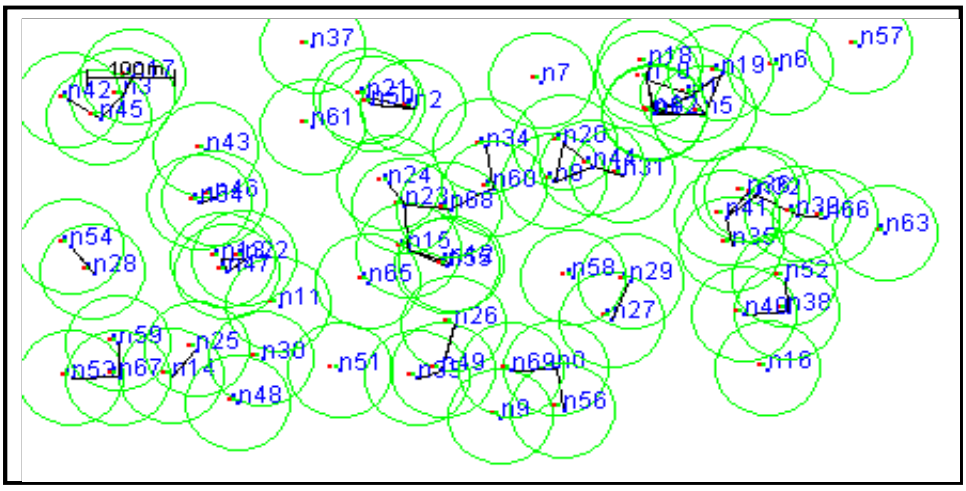

Figure 3.2: Cluster formation

4. Every node will look up its degree table and compare its degree with other nodes. For any node i, Ni is the node Id, NDi is the node degree and NDmax(i) is the highest degree in the table of Ni. Based upon this comparison there will be three cases:

   - Case 1: $ND_i > ND_{max(i)}$ i.e. Node itself has the highest degree compared to any other node in its table
     - Node will announce for being Cluster-Head.

- Case 2: $ND_i < ND_{max(i)}$ i.e. Node has other higher degree nodes , in the table, than its own
  - Node will wait for other node to broadcast and will get associated with every node which has broadcasted for being Cluster-Head
  - Node may have two or more equal higher degree nodes in it's table and thus waiting for broadcast from those higher degree nodes but these higher degree node belongs to some other CH then this node will become leaf node.
- Case 3: $ND_i = ND_{max(i)}$ i.e. Node has other nodes with the degree equal to its own
  - Every equal degree node will broadcast for being cluster head and will get associated with other equal degree cluster head.

3.3.2 Information Sharing

- After the clusters have been created, every CH will maintain a Neighbor Information table .

- Every node will maintain two tables
  - Neighbor Information table
  - History table

3.3.3 Forwarding Part

- Any node (S) which wants to send any message to a set of destinations , will send the message (M) to its CH with the destination EID.

Node	Meeting Frequency
-	-

Table 3.3: Meeting history

Destination Id	Meeting Frequency
-	-

Table 3.4: Destination look up

- CH will check if the destinations are within the cluster or out of its cluster nodes.

- If the destinations are within the same CH, then the CH will directly forward the message to the destinations.

- Otherwise CHs will broadcast a message to know about which cluster node has met with the destinations with what frequency. CH will maintain this history update of its Cluster nodes and forward the replicas to the nodes having the highest meeting frequency with destinations.

- Then the CH will check the Nieghbor Information table and find out which nodes belong to other CH, then CH will forward the replicas to these nodes so that the message get quickly distributed over the network region.

3.4 Motivation

DTN is a sparse network and it faces frequent disconnections, but to reduce the number of replicas for delivering a particular message is also important because the number of replicas present in the network is directly count as the cost of delivery for

that particular message. In DTN, if n nodes will store the information about all the n nodes in the network then overhead will be increased as to distribute this knowledge to all the nodes will consume the network resources. So it is better to group the nodes on some basis and then store the network information on only k nodes in n node network where $k < n$ and all the nodes can be updated with the information when it will be needed.

Chapter 4

Simulation and Analysis

There are different simulation tools available for simulating the algorithms of mobile ad-hoc networks, and these tools are user friendly, means easy to work upon. In case of DTN algorithm implementation, these tool cannot work properly because of the frequent disconnection environment of nodes in DTN. We have used The ONE simulator [33] for implementing our proposed DTN algorithm.

4.1 Introduction to the simulator: The ONE

ONE stands for Opportunistic Network Environment, and it is a java based simulator used for DTN specific environment. In this simulator, the source code of some famous DTN algorithms such as PRoPHET, Spray and Wait etc. are given and different types of movements models are also embedded. There are some .txt files are provided with ONE [34] in which two files are of main concern. One is README.txt and other is default_settings.txt. Every time when the simulation runs it reads the default_settings.txt file to get the values of the variables defined in the java files of the classes used from routing and movement packages. The README.txt file introduces the user with the

working of ONE and how to use it.

By default, the epidemic router is used with the ShortestPathMapBased movement model. So after running the default settings we get this result, for the 43200 seconds simulation time it gives the average of 0.2522 delivery probability with a total of 126 nodes. In the following figure 4.1, we are showing the run window of the ONE simulator.

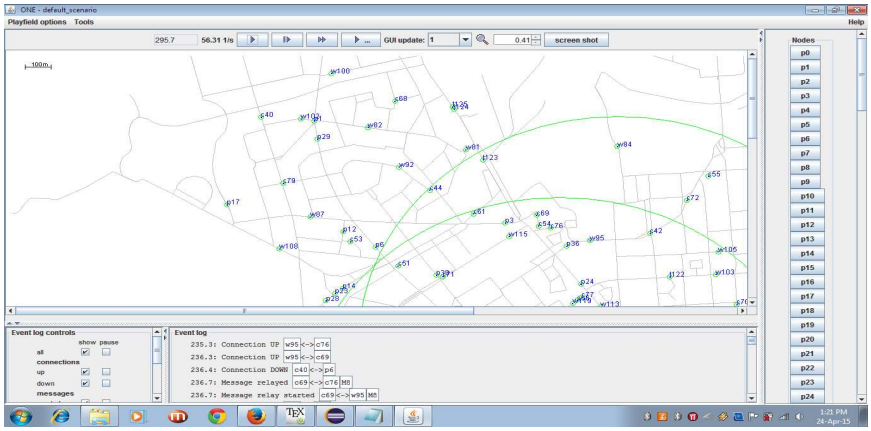

Figure 4.1: Run window of ONE simulator

In the figure 4.2, the nodes are deployed in the region given by the helsinki_ underlay map in which the nodes are shown at their intended paths defined for different group of nodes in the default_settings file.

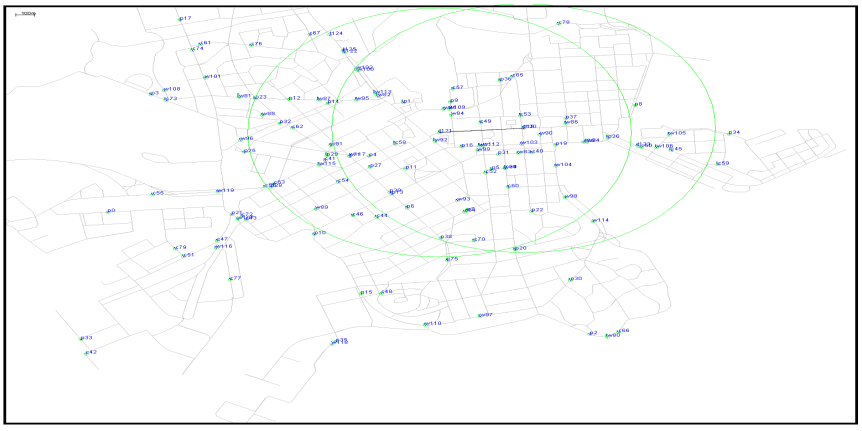

Figure 4.2: The position of nodes in the helsinki_ underlay map

4.2 A test scenario

In this section, we are considering a scenario with 5 nodes in a region 400, 300 meters size of height and width. In the figure 4.3, the green circle around the nodes are showing

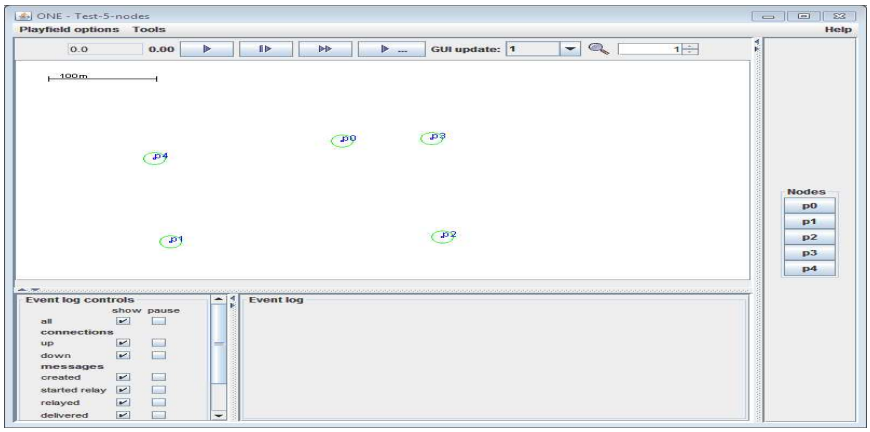

Figure 4.3: Test scenario with 6 nodes

the range of the node. When we click on the play button(provided on the top of the window), nodes start the movement and generation of messages. When two or more nodes come in communication range of each other, exchange messages. The exchange the messages depend upon the message destined for which node and if the available node is good relay node for that destination.

In the above figure 4.4, the event log window (at bottom) showing the events happened during the simulation run such as, at which point of time the connection goes up, the message get relayed, the connection goes down and when the message get aborted.

In the node window(at right side of the window), one may click on any particular node to view its information about how many messages it received and how many messages it forwarded.

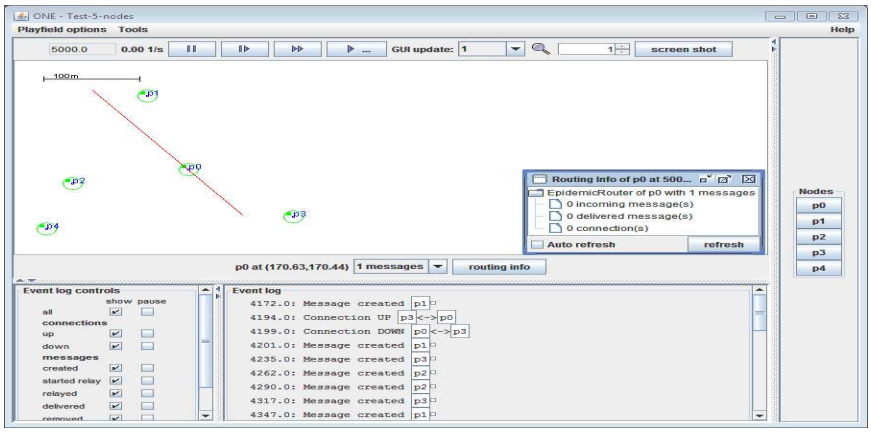

Figure 4.4: The node movement and message transfer

4.3 Algorithm simulation

The simulation of our proposed algorithms needs to be implemented in the ONE simulator. In ONE, for any algorithm implementation, it needs two minimum settings: First is to setup a simulation environment and second is the Router logic. The Router logic we have already explained in the proposed algorithm section. Here we are presenting the code flow of our logic of router. We are presenting the code flow of our algorithm in figure 4.5 in which, the first phase is to form the cluster of nodes and the rest of the steps are defined sequentially.

4.4 Performance metrics and analysis

The performance parameters which we use for analyzing our algorithm are:

- **Simulation time**: The total time a simulation run. The default value of simulation time is 43200 seconds = 12 hours.

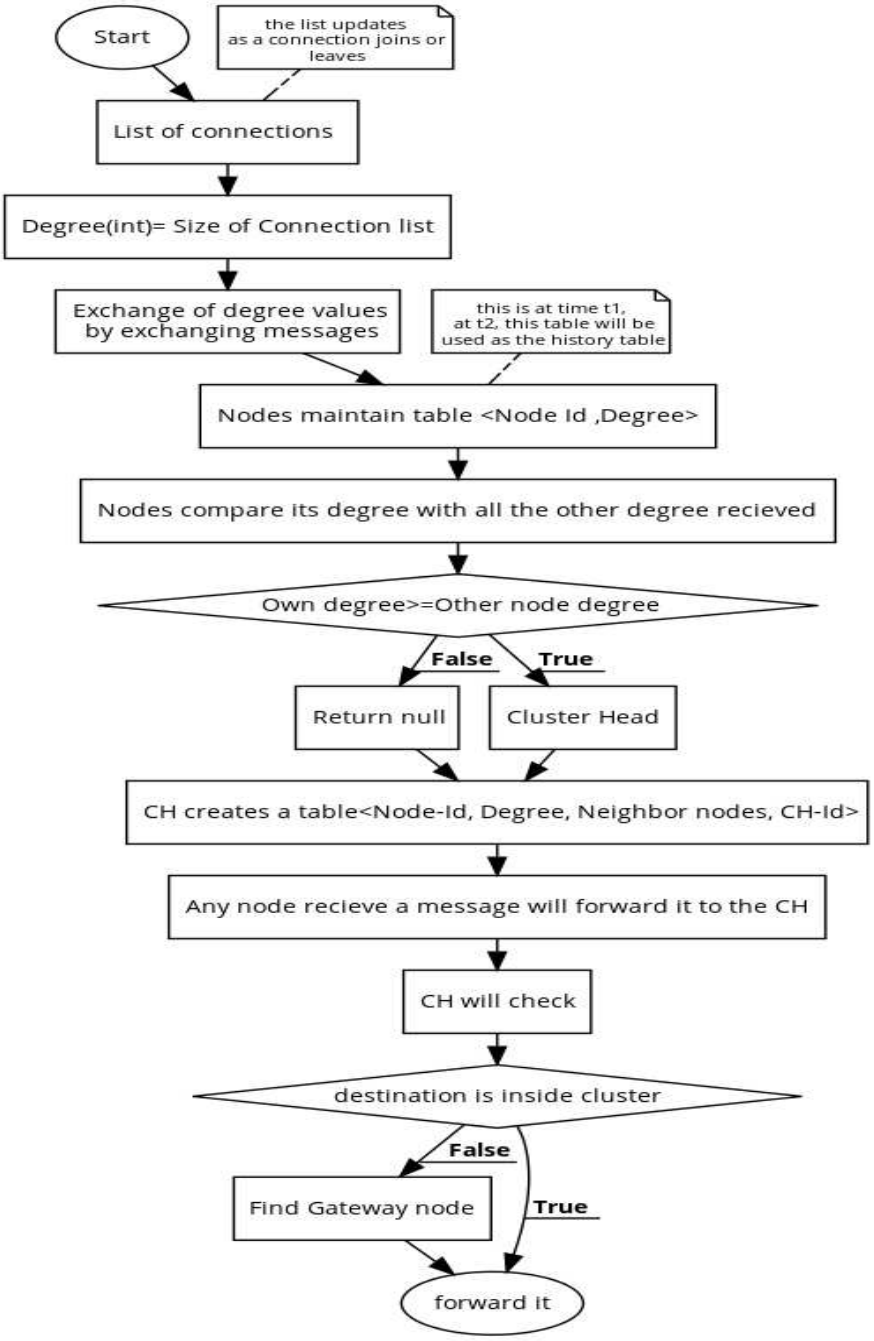

Figure 4.5: Code Flow of Proposed algorithm

- **Message created** : The total number of messages which are created during the simulation time.

- **Message started** : The total number of messages created plus the total number of replicas generated for the original message.
- **Message relayed** : The total number of messages which get connections to get relayed.
- **Message aborted** : The number of messages which get aborted before the successful transmission. It could be because of buffer full or message TTL finished or the message is already delivered.
- **Message delivered** : The total number of messages received at their intended destination nodes.
- **Delivery-Probability** : The total number of messages delivered divided by the total number of messages created.
- **Overhead ratio** : The total number of messages relayed divided by the total number of messages delivered.

Our proposed algorithm is suitable for the college campus or office type environment where nodes come in contact and remain in contact for an adequate time period. We have also calculated the time period which a nodes need to form the cluster, in the following para. $Transmission - time = \frac{Bundlesize}{Bitrate}$

If we consider the size of a control messages be 50 k and transmission speed 250 kbps, so maximum Transmission time of one message would be .2 sec with overhead included. Considering a scenario of 50 nodes in which 5 nodes come in contact for cluster formation, so the minimum time for which these nodes must be in contact for effective data transfer would be 1 seconds for cluster formation and information maintenance.

After this, the effective data transfer can takes place and the time would then depend upon the size of the data message.

So in analysis of performance of proposed algorithm, we can say that it is feasible to use this cluster approach because the cluster formation and information maintenance is not taking much time and the data is effectively being transferred between nodes with less resource consumption.

Chapter 5

Conclusion

In the proposed algorithm, we are using the current availability of nodes as well as the meeting frequency. This algorithm is suitable for the environment where the nodes have a limited mobility speed or the nodes come in contact with a each other for a while. The cluster based approach has a main advantage that it is better to store the n node information at k nodes only. Where n is the total number of nodes in the network and k is the number of cluster-Head nodes in the network. So this algorithm proposes the idea to consume less network resources in the form of buffer storage.

Bibliography

[1] Cerf, Vinton, et al. Delay-tolerant networking architecture. RFC 4838, April, 2007. online available at http://www.hjp.at/doc/rfc/rfc4838.html

[2] Warthman, Forrest. "Delay-and Disruption-Tolerant Networks (DTNs)." A Tutorial. V.. 0, Interplanetary Internet Special Interest Group (2012).

[3] Burleigh, Scott, et al. "Delay-tolerant networking: an approach to interplanetary internet." Communications Magazine, IEEE 41.6 (2003): 128-136.

[4] Mobile Ad-Hoc and DTN Networks at IPCAS Lab, online available: http://www.ece.gatech.edu/research/labs/WCCL/DTN2.html

[5] Santiago, Jos, Augusto Casaca, and Paulo Rogrio Pereira. "Multicast in Delay Tolerant Networks Using Probabilities and Mobility Information." Ad Hoc & Sensor Wireless Networks 7.1-2 (2009): 51-68.

[6] Zhao, Wenrui, Mostafa Ammar, and Ellen Zegura. "Multicasting in delay tolerant networks: semantic models and routing algorithms." Proceedings of the 2005 ACM SIGCOMM workshop on Delay-tolerant networking. ACM, 2005.

[7] Karimzadeh, Morteza, et al. "Information deliveryin delay tolerant networks." online available at http://www.cs.tut.fi/ moltchan/pubs/dtn2011.pdf

[8] 'Introduction To Delay Tolerant Networks', presentation. online available at: cherry.cs.nccu.edu.tw/ ttsai/course/inv_cs/intro_dtn.ppt

[9] Ott, Jrg, Dirk Kutscher, and Christoph Dwertmann. "Integrating DTN and MANET routing." Proceedings of the 2006 SIGCOMM workshop on Challenged networks.(pp. 221-228). ACM, 2006.

[10] Daly, Elizabeth M., and Mads Haahr. "Social network analysis for routing in disconnected delay-tolerant manets." Proceedings of the 8th ACM international symposium on Mobile ad hoc networking and computing. ACM, 2007.

[11] Presentation by Dukhyun Chang on "DTN Architecture and Protocols" online available at http://mmlab.snu.ac.kr/courses/2007 _ advanced_ internet/handout/20071008_ dhchang.pdf

[12] Ip, Yin-Ki, Wing-Cheong Lau, and On-Ching Yue. "Forwarding and replication strategies for dtn with resource constraints." Vehicular Technology Conference, 2007. VTC2007-Spring. IEEE 65th. IEEE, 2007.

[13] Scott, Keith L., and Scott Burleigh. "Bundle protocol specification." RFC 5050 (2007) online [available]: http://tools.ietf.org/html/rfc5050

[14] Bindra, Harminder Singh, and A. L. Sangal. "Need of Removing Delivered Message Replica from Delay Tolerant Network-A Problem Definition." International Journal of Computer Network and Information Security (IJCNIS) 4.12 (2012): 59.

[15] Erramilli, Vijay, et al. "Delegation forwarding." Proceedings of the 9th ACM international symposium on Mobile ad hoc networking and computing. ACM, 2008.

[16] Clare, Loren, Scott Burleigh, and Keith Scott. "Endpoint naming for space delay/disruption tolerant networking." Aerospace Conference, IEEE, 2010.

[17] Das, Priyanka. "An Analysis of Routing Strategies in MIA-DTN." American Journal Of Advanced Computing 1.2 (2014).

[18] Dubois Ferriere, Henri, Matthias Grossglauser, and Martin Vetterli."Age matters efficient routing mobile adhoc networks using encounter ages" Proceedings of the 4th ACM international symposium on mobile ad hoc networking & computing,2003.

[19] Jones, Evan PC, and Paul AS Ward. "Routing strategies for delay-tolerant networks." Submitted to ACM Computer Communication Review (CCR) (2006).

[20] Anthru, Shermina V., and T. P. Jayakumar. "Opportunistic Routing Protocols In Human Working Day Model Delay Tolerant Networks." International Journal Of Engineering And Computer Science 3.5 (2014): 5960-5965.

[21] Spyropoulos, Thrasyvoulos, Konstantinos Psounis, and Cauligi S. Raghavendra. "Single-copy routing in intermittently connected mobile networks." Sensor and Ad Hoc Communications and Networks, 2004. IEEE SECON 2004. 2004 First Annual IEEE Communications Society Conference on. IEEE, 2004.

[22] Vahdat, Amin, and David Becker. Epidemic routing for partially connected ad hoc networks. Technical Report CS-200006, Duke University, 2000.

[23] Mundur, Padma, Matthew Seligman, and Ginnah Lee. "Epidemic routing with immunity in delay tolerant networks." Military Communications Conference, MILCOM, IEEE, 2008.

[24] Small, Tara, and Zygmunt J. Haas. "Resource and performance tradeoffs in delay-tolerant wireless networks." Proceedings of the 2005 ACM SIGCOMM workshop on Delay-tolerant networking. ACM, 2005.

[25] Spyropoulos, Thrasyvoulos, Konstantinos Psounis, and Cauligi S. Raghavendra. "Efficient routing in intermittently connected mobile networks: the multiple-copy case." Networking, IEEE/ACM Transactions on 16.1 (2008): 77-90.

[26] de Oliveira, Etienne CR, and Clio VN de Albuquerque. "NECTAR: a DTN routing protocol based on neighborhood contact history." Proceedings of the 2009 ACM symposium on Applied Computing. ACM, 2009.

[27] Wang, Lei, et al. "Multipath source routing in wireless ad hoc networks." Electrical and Computer Engineering, 2000 Canadian Conference on. Vol. 1. IEEE, 2000.

[28] Biswas, Sanjit, and Robert Morris. "ExOR: opportunistic multi-hop routing for wireless networks." ACM SIGCOMM Computer Communication Review. Vol. 35. No. 4. ACM, 2005.

[29] Jones, Evan PC, et al. "Practical routing in delay-tolerant networks." Mobile Computing, IEEE Transactions on 6.8 (2007): 943-959.

[30] Hua, Daowen, et al. "A dtn routing protocol based on hierarchy forwarding and cluster control." Computational Intelligence and Security, 2009. CIS'09. International Conference on. Vol. 2. IEEE, 2009.

[31] Mongiovi, Misael, et al. "Efficient multicasting for delay tolerant networks using graph indexing." INFOCOM, 2012 Proceedings IEEE. IEEE, 2012.

[32] Chen, Xiao, Jian Shen, and Jie Wu. "Enhanced delegation forwarding in delay tolerant networks." International Journal of Parallel, Emergent and Distributed Systems 26.5 (2011): 331-345.

[33] Kernen, Ari, Jrg Ott, and Teemu Krkkinen. "The ONE simulator for DTN protocol evaluation." Proceedings of the 2nd international conference on simulation tools

and techniques. ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), 2009.

[34] Technical guide of ONE by Sahil Gupta, "Developer Documentation On ONE Simulator" online available at https://docs.google.com/viewer?a=v&pid=sites&srcid=ZGVmYXVsdGRvbWFpbnxzYWhpbGd1cHRhMjIxMjMxfGd4OjU0ZTJiNWZhNDM5NGNkNmM

List of Publications

Conferences:

1. **Shivi Shukla** , Amit Munjal and Y. N. Singh, "Study of Routing Strategies in Delay Tolerant Networks," *ICEIT Conference on Advances in Mobile Communications,Networking and Computing* ,pp. 91–95, Apr 16-17 2015.