ROUTING IN DELAY TOLERANT NETWORKS

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE OF

Bachelor of Technology

in

Computer Science and Engineering

By

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CERTIFICATE

This is to certify that the thesis entitled 'Routing in Delay Tolerant Networks' submitted by Md. Raiyan Alam and Bibekanand Minz, in the partial fulfillment of the requirements for the award of Bachelor of Technology Degree in Computer Science and Engineering at National Institute of Technology Rourkela is an authentic work carried out by them under my supervision and guidance. To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other university / institution for the award of any Degree or Diploma.

DATE: Dr. A. K. Turuk

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Last but not the least, we would like to dedicate this project to our families, for their love, patience and understanding.

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ABSTRACT

Delay-tolerant networks (DTNs) have the great potential to connecting devices and regions of the world that are presently under-served by current networks. A vital challenge for Delay Tolerant Networks is to determine the routes through the network without ever having an end to end, or knowing which "routers" will be connected at any given instant of time. The problem has an added constraint of limited size of buffers at each node. This situation limits the applicability of traditional routing techniques which categorize lack of path as failure of nodes and try to seek for existing end-to-end path. Approaches have been proposed which focus either on epidemic message replication or on previously known information about the connectivity schedule. The epidemic approach, which is basically a flooding technique, of replicating messages to all nodes has a very high overhead and does not perform well with increasing load. It can, however, operate without any prior information on the network configuration. On the other hand, the alternatives, i.e., having a prior knowledge about the connectivity, seems to be infeasible for a self-configuring network.

In this project we try to maximize the message delivery rate without compromising on the amount of message discarded. The amount of message discarded has a direct relation to the bandwidth used and the battery consumed. The more the message discarded more is the bandwidth used and battery consumed by every node in transmitting the message. At the same time, with the increase in the number of messages discarded, the cost for processing every message increases and this adversely affects the nodes. Therefore, we have proposed an algorithm where the messages are disseminated faster into the network with lesser number of replication of individual messages. The history of encounter of a node with other nodes gives noisy but valuable information about the network topology. Using this history, we try to route the packets from one node to another using an algorithm that depends on each node's present available neighbours'/contact and the nodes which it has encountered in the recent past. We have also focused on passing the messages to those nodes which are on the move away from the source/forwarder node, as the

nodes moving away have a greater probability of disseminating the messages throughout the network and hence increases chances of delivering the message to the destination.

ABBREVIATIONS

IEEE - Institute of Electrical and Electronics Engineers

DTN – Delay Tolerant Network

TTL - Time to Live

TTA- Time To Acknowledge

QoS – Quality of Service

TCP/IP – Transmission Control Protocol/Internetworking Protocol

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Chapter 1

INTRODUCTION

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INTRODUCTION

1.1 INTRODUCTION TO DTN

Today's Internet has been very successful at connecting communicating devices round the globe. It has been made possible by using a set of protocols, which is widely known as TCP/IP protocol suite. Every device on the innumerous sub-networks that comprise the Internet uses this protocol for transferring the data from source to destination with the minimal possible delay and high reliability. The underlying principle on which TCP/IP works is based on end-to-end data transfer using number of potentially dissimilar link-layer technologies. However, there are many regions where the assumptions of the internet cannot be upheld. If at any instant there is no path between the sources to destination, then TCP/IP fails to work properly or might even stop working completely. Because of such circumstances, a newer network has evolved which is independent end to end connectivity between nodes. This network is called as Delay Tolerant Networks (DTN).

Delay Tolerant Networking (DTN) is an approach to computer network architecture that aims to address the technical issues in heterogeneous networks that experience lack of continuous network connectivity. Delay Tolerant Networks (DTNs) enable data transfer when mobile nodes are only intermittently connected. Due to lack of consistent connectivity, DTN routing usually follows store-carry-and-forward; i.e., after receiving some packets, a node carries them around until it contacts another node and then forwards the packets. Since DTN routing relies on mobile nodes to forward packets for each other, the routing performance (e.g., the number of packets delivered to their destinations) depends on whether the nodes come in contact with each other or not.

1.2 NEED FOR DELAY TOLERANT NETWORKS

These networks are characterized by the following. It is because of these characteristics that Internet Protocols fail or is rendered useless.

1) Lack of Connectivity: If at any moment, there is no end-to-end path between source and destination (widely called *network partitioning), then* end-to-end communication cannot take place using the TCP/IP protocols suite. Here DTN comes very useful.
2) Irregular Delays**:** Long delays can cause the TCP/IP protocol suite to function improperly. Propagation delays between transmitting nodes compounded with queuing delay at each node can topple the protocols which rely largely on quick return of acknowledgement of a sent data. This can be overcome using DTNs.
3) Asymmetric Bidirectional Data Rates: Moderate asymmetries of bidirectional data rate can be tolerated to an extent in conventional protocols. But if asymmetries are large, they can be defeated easily.

Networks called as challenged networks violate the assumptions of the conventional Internet and hence TCP/IP protocols can't be used here. As described in [18] the examples of challenged networks can be Exotic Media Networks, Terrestrial Mobile Networks, Sensor-based Networks etc.

Chapter 2

LITERATURE REVIEW

Chapter 2

LITERATURE REVIEW

2.1 CONCEPT OF DTN

A Delay Tolerant Network can be considered as an overlay on the existing regional networks. This overlay is called as the bundle layer. This layer is intended to function above the existing protocol layers and provide the function of a gateway when two nodes come in contact with each other. The main advantage of this kind of protocol is flexibility. It can be easily linked with the already existing TCP/IP protocol networks or can be used to link two or more networks together. The position of the bundle layer can be seen in the following fig. 1.

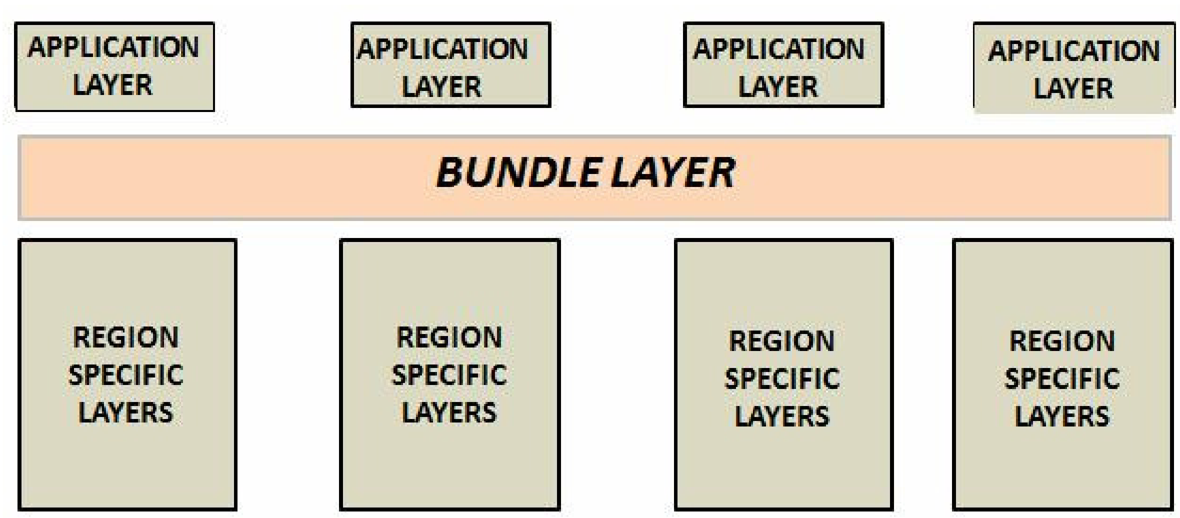

Fig 1: The position of the bundle layer.

Bundles are also called as messages. The transfer of data from one node to another can be made reliable by storing and forwarding entire bundles between nodes. The bundles comprise of three things, source node's user-data, control information (e.g., source node ID, destination node ID, TTL etc.), a bundle header. Besides Bundle transfer, custody transfer is also done. The custodian node for a bundle keeps the message until it is successfully transferred to the next node and it takes the custody for that message or until the TTL of the message expires.

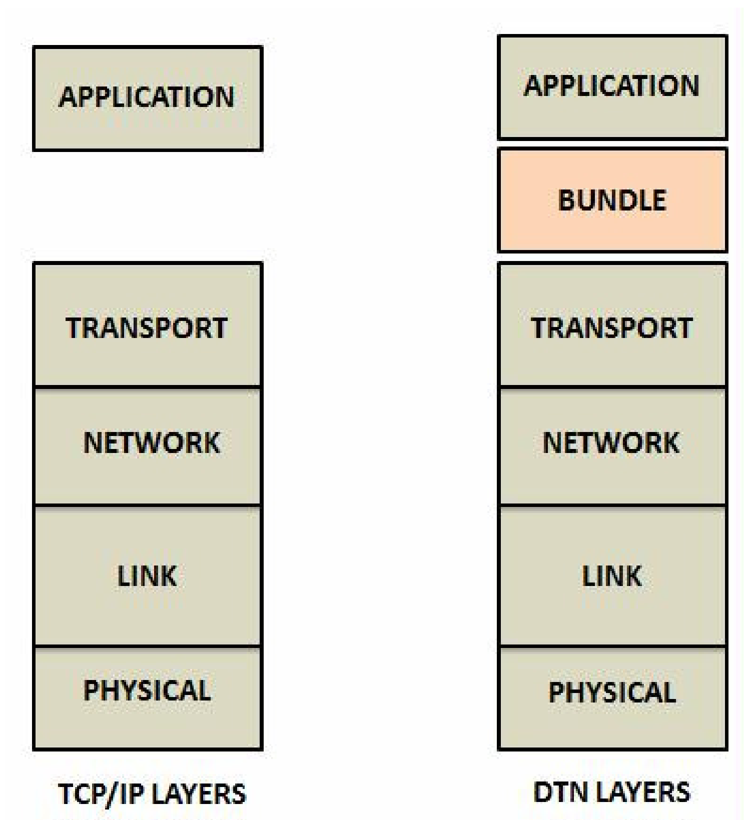

Fig 2: A comparison between TCP/IP layers and DTN layers

2.2 STORE AND FORWARD APPROACH

Delay Tolerant Networks have overcome the problems associated with the conventional protocols in terms of lack of connectivity, irregular delays, asymmetric bidirectional data rates etc. using the concept of store and forward. The method of store and forward is very analogous to the real life postal service. Every letter has to pass through a set of post offices, where it is processed and forwarded, before reaching the destination. Here the complete message or a chunk of it is transferred and stored in nodes successively until it reaches the destination. The following figure (fig. 3), gives a rough graphical representation of how a message is propagated through a network.

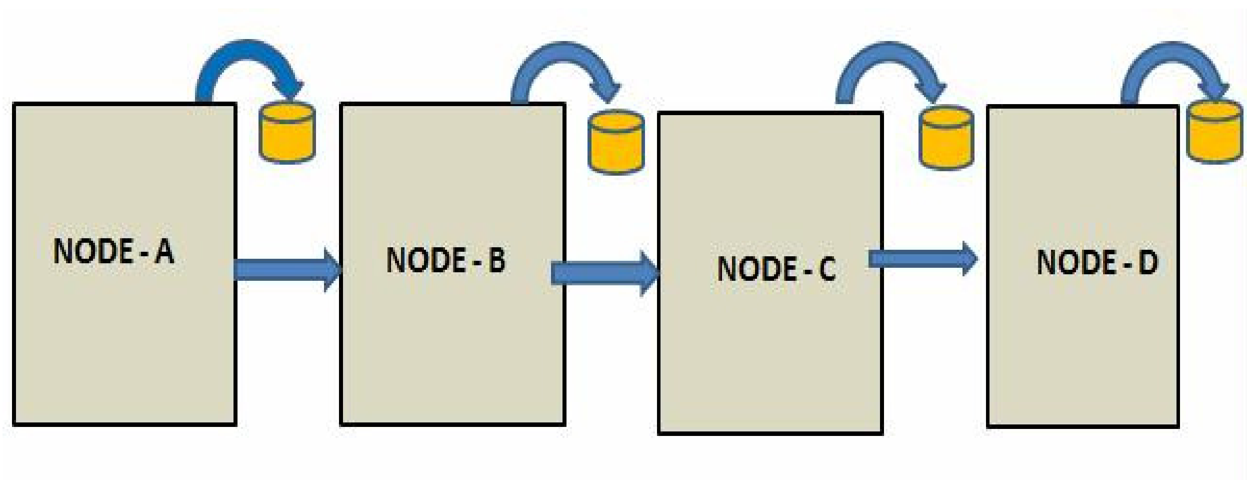

Fig 3: Store and forward approach in DTN layers

Each node is associated with a persistent storage device (like hard disk), where it can store the messages. It is called as persistent storage as it can store the message for indefinite amount of time unlike short-term memory devices. The persistent storage can be useful in situations when the next node is not available for a very long time, or when the rate of incoming messages is far higher than the rate of outgoing messages.

2.3 TYPES OF CONTACTS IN DTNs

There are broadly two kinds of contacts [18] that can occur in a DTN, Opportunistic and Scheduled. In opportunistic contacts the nodes do not have any kind of direct or indirect information regarding a contact in the future. All the contacts occur as a result of mere chance. Moving people, automobiles, airplanes etc. make an unscheduled contact and transfer messages if they are close enough and have sufficient energy to support the communication. On the other hand, scheduled contacts are those contacts whose occurrence is already known to the nodes. This information is directly given to the nodes or can be indirectly calculated by the nodes. This type of contacts generally happens when the nodes move along a specific pre-defined path. Scheduled contacts can be observed in inter-planetary communication or in communication involving the satellites moving around the earth. The main drawback here is that the time in every node has to be synchronized.

2.4 CUSTODY TRANSFER

The DTNs support error-checking of transferred messages. Retransmission of messages is done in- case of corrupted or lost data. This reliability is offered by using the bundle layer through the concept of custody transfers. When a source/forwarder node wants to send message to another node then it requests for a custody transfer and starts a Time-To-Acknowledge (TTA) timer. If the intended recipient acknowledges before the TTA timer expires then the custody is transferred along with the message. In case of no acknowledgement, retransmission of the message occurs. The threshold value for a TTA timer can be already preset into every node, or can varied according to the past experiences of a node. The node having the custody of a bundle, cannot delete the bundle unless another node takes the custody of the message or the TTL of the message expires.

2.5 ROUTING PROTOCOLS IN DTN

Many Approaches have been adopted to achieve a reliable communication between the source and the destination. The proposed approaches have focused on a number of problems like improving the delivery ratio, optimizing the usage of available resources like buffer space, battery etc., increasing the scalability.

Mobility of nodes was seen as an obstacle to routing, but some approaches have used this very mobility in order to face the problem of discontinuity. The most recent approach is in the area of exploiting the social interaction of humans, so as to improve the delivery rates of messages.

Routing in Delay Tolerant Networks can be broadly classified into 3 types,

- Dissemination based.
- History Based.
- Incentive based.

2.5.1 Dissemination based

In Dissemination based routing in Delay Tolerant Network, the main focus is laid on better way for dissemination of the message in the network. When the nodes which carry a particular message are not clumped into a small region but are spread throughout the network then there are higher chances that a node carrying the message will come in direct contact towards the destination. Some of the basic ways that proposed are that of Epidemic[1], Spray and wait[5]. In Epidemic approach, the protocol has absolutely no knowledge about the network and the movement of nodes. Epidemic protocol makes sure that a message reaches destination by spreading the message in Omni-directions, just like a virus spreading an epidemic disease. If a node encounters another node then both of them exchange messages which the other one does not have. By doing this, it is made sure that a message is under circulation and spreads throughout the network. But, the problem arises due to a large number of message transfers. Since in Delay Tolerant networks the nodes have a limited amount of buffer and energy (i.e. battery), epidemic protocol consumes a lot of battery for processing the messages and swapping them in and out of the buffer. This leads to a very high overhead cost as demonstrated in the paper [9]. So the epidemic protocol not that efficient. The other type of scheme used is Spray and Wait. This makes sure that the message distributed more in the direction of the destination node. The scheme comprises of two phases- Spray phase and Wait phase. In spray a node is allowed to inject replicas of a message into the network, while in the wait phase a node waits until it directly comes in contact with the destination node so as to deliver the carrying message. The main benefit of this scheme is that it bounds the maximum number (L) of copies that can be present in the network. It has two basic variants, vanilla and binary. In the vanilla version, only the source node continues to spray a single copy of message to first L-1 distinct nodes it encounters. The second version is Spray and Wait Binary. The source node starts with L number of copies with it. Every node transfers half the number of copies it possesses to the nodes which it encounters. Eventually all the nodes carrying the message will be left with just a single copy of message with them. Now these nodes wait until they directly come in contact to the destination node, so that they can transfer the intended message. The binary version is better than the corresponding vanilla, as the dissemination of message is very fast in the network.

In order to curb the high usage of bandwidth, single copy schemes have also been widely explored in [12, 13]. In these algorithms, only one copy of a particular message is present in the network at any instant of time. This drastically decreases the number of transmissions and hence saves energy and bandwidth. The applications of these single copy schemes are very limited and do not produce optimal results in most of the situations in terms of message delivery rate.

2.5.2 History based

History of encounters of a node with other nodes gives noisy but very valuable information about the location of an intended node in the near past. This history of encounters has been exploited in many works [7, 11]. The Zebranet project [10] was one of the foremost attempts to use the history of encounters for transfer of messages. Here each node maintains a history value for every other node that it has encountered. The recent the encounter the better is the history value. These history values hence carry the direct information about the relative node locations in a network. Therefore schemes have been designed where a node is made to forward a message copies to only those nodes which have a history value more than a particular threshold value H_{th} for the message's destination node. Such schemes hence have better performance than flooding related approaches [10, 11]. The decision making of these schemes is better than that of randomized routing [12]. But the main problem exists in the selection and varying of the history threshold value H_{th} . A low value of H_{th} is better initially when the source creates a new message and wants to spread it. In the later occasions, the value of H_{th} has to be gradually increased based on certain parameters. Nevertheless, history utility schemes can turn into flooding when the value of H_{th} is consistently low.

The scheme in [14] proposed a method called PROPHET (PRObabilistic Protocol using History of Encounters and Transitivity). Here, they have used the history of encounters in order to compute the delivery predictability of every node. Each node maintains a table for the delivery predictability of all the nodes for all the destinations. When any node comes in contact with another, then this information is interchanged. It also uses the transitive property of data to decide to the best node to forward the message to. A higher delivery ratio was observed by the author when compared with epidemic.

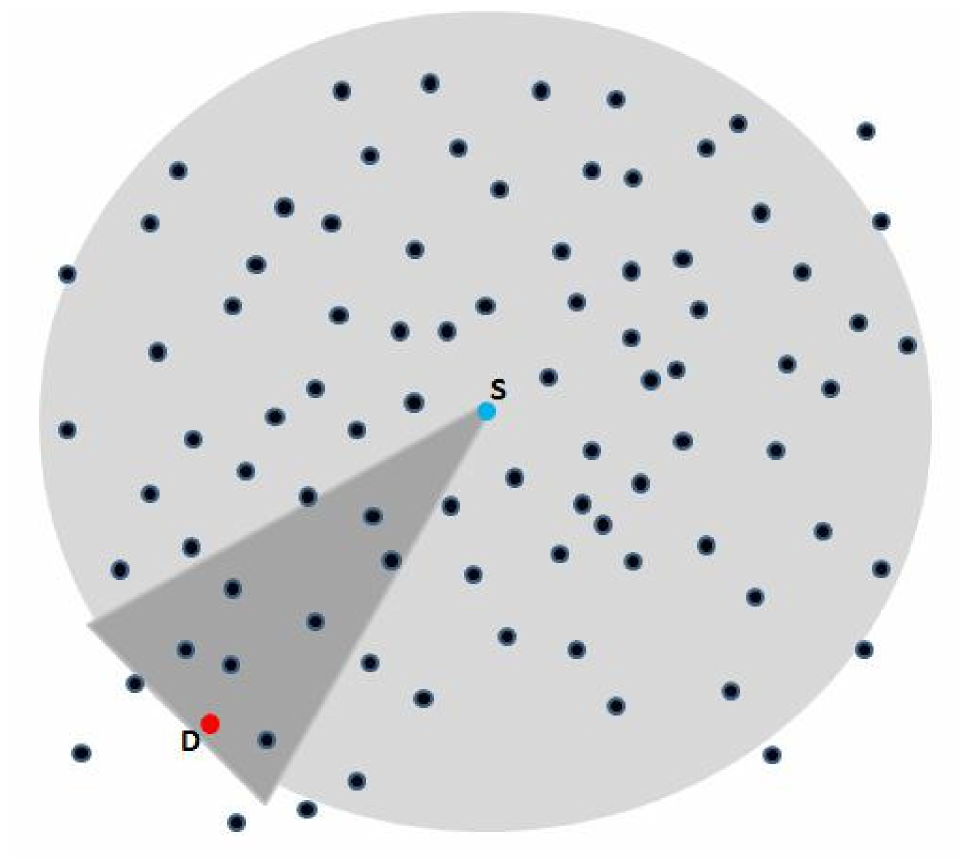

Fig 4: The light gray region roughly shows the nodes that will be receive message in an omni-directional flooding (e.g. Epidemic) . The dark gray region shows the nodes that will receive message in a 'steered' flooding (e.g. FRESH).

The scheme proposed in [7] was called as FRESH (Fresher Encounter SearcH). In this a node which wants to forward a message looks for a node which was in contact with the destination node for more number of times than itself. By this the authors expect that the forwarded node will have a greater probability of delivering the message to the destination. This process is followed repeatedly until the destination was reached.

2.5.3 Incentive based

These schemes take into consideration the fact that nodes in a DTN are controlled by rational entities like human, organizations etc. In such situations, it is obvious to assume that the nodes will behave selfishly in an attempt to conserve their resources and minimize the overheads. As for a message to travel from source to destination it requires the intermediate nodes to cooperate in forwarding the message, the delivery will be greatly hampered if the intermediate nodes are reluctant to cooperate. To manage message delivery under such conditions, incentive based routing was developed. In such schemes [3, 15, 16] every node is encouraged to pass a message for other nodes by giving an incentive. Incentive can be in form of a rating for a node. As the rating of a node increases, the messages sent by it will be preferred for forwarding by other nodes. Thus, resulting in higher chance of delivery of a message sent by the source. In [17] a scheme called pair-wise Tit-For-Tat (TFT) was used while forwarding messages. Here a node forwards as much traffic for a neighbor as the neighbor forwards for it. Hence every node tries to forward more, so that its messages are sent smoothly over the network.

Chapter 3

PROPOSED WORK

Chapter 3

PROPOSED WORK

3.1 ALGORITHM

This Algorithm focusses mainly on high delivery rate of messages in such a way that the average number of messages forwarded is the least. Here each node has to maintain a table which contains the details about the nodes which are currently in contact and the nodes which were in contact previously. The previously contact nodes should be associated with the time of last contact. The entries in the table are as follows, < node id, node availability, last contact time, list of nodes in contact with this node >.

For example the table maintained by node NOD001 is,

Nodes in Contact	Availability	Last Contact time	Nodes in Neighbor's Contact
NOD003	Y	99	NOD001, **NOD999**, NOD077, NOD055
NOD006	Y	99	NOD001, NOD098, NOD074, NOD545
NOD999	N	86	NOD022, NOD938, NOD001, NOD834
NOD675	N	74	NOD883, NOD001
. . .	. . .	. . .	. . .

Fig5: The table maintained by NOD001at time=99.

Algorithm:

Let the set of Nodes be N.

Let M_{ji} be the j^{th} message in the buffer of N_i .

For each Node $N_i \in N$ do

For each Message $M_{ji} \in Buffer(N_i)$

If $(Dest(M_{ji}) \in Available\_Contacts(N_i))$

- Forward Message to $Dest(M_{ji})$

Else if $(Dest(M_{ji}) \in Available\_Contacts(Available\_Contacts (N_i)))$

- Forward Message to N_f, where $Dest(M_{ji}) \in Available\_Contacts(N_f)$

Else

- Forward Message M_{ji} to a moving node N_m via N_f,

  where $N_f \in Available\_Contacts (N_i)$

  and $N_m \in Available\_Contacts (N_f)$

- $\forall$ (Available_Contacts (N_i) $\cup$ Available_Contacts (N_f))

  //Do_Not_Recieve(M_{ji})

- If(N_m does not exist)

  //Forward Message M_{ji} to a moving node N_{max}

  where N_{max} =

  Maximum_dissimiliar_contacts(N_i,N_{max})

- $\forall$ (Available_Contacts (N_i) $\cup$ Available_Contacts (N_{max}))

  //Do_Not_Recieve(M_{ji})

Explanation :

1) Let us take the fig 2 as a reference. First the forwarder/sender node checks if the destination is in contact with it. If yes then forward it. Else go to step 4.

2) Then check if the destination node is present in Nodes in Neighbor's Contact column. If yes then forward the message to the corresponding Node in contact. Else go to step 4.

3) If the forwarder/sender node (eg: NOD999) was available to the sender node (eg: NOD001) some time back, and this node (eg: NOD999) is now available to another node(eg: NOD003) in contact with the sender, then it infers that that particular node(eg: NOD999) is on the move, away from the sender. Thus the packet is forwarded to this node (eg: NOD999).

4) If a forwarder/sender node does not find any mobile nodes, then it should forward to those in-contact nodes which are farthest from it. The node which has the maximum number of dissimilar nodes in contact (comparing with that of sender) is the most distant.

5) A node is prohibited from sending the packet to the previous node or its contact nodes. This helps further in pushing the packets towards the destination. For Example, Node S sends the data via Node B to a moving Node X(Note the final destination is not Node X but Node D).Then the Node X is not allowed to forward the packet to,

   - Node S or Node S's current in-contact node.
   - Node b or Node B's current in-contact node.
   - Current in-contact nodes of (Common in-contact nodes of S and B).

6) Similarly, every node tries to forward the packet to a candidate set of nodes which are likely to be farthest from it or moving away from it. This way the packet reaches to the destination.

Chapter 4

SIMULATION AND RESULTS

Chapter 4
SIMULATION AND RESULTS

4.1 SIMULATION

The simulation for the proposed algorithm were done using,

- 15 Nodes in a region of 25 X 25 grid.
- 30 Nodes in a region of 50 X 50 grid.

In the grid the nodes were randomly deployed. Every node has a set of destinations to travel sequentially, but the path taken by the nodes to reach these destinations were again random. Messages were injected into the system randomly at any instant during the simulation.

Using MATLAB, the graphs plotted were for,

- Max. Hop Limit vs. No. of Message Delivered (out of 100).
- Max Hop Limit vs. Average No of Messages Discarded.

4.2 RESULTS

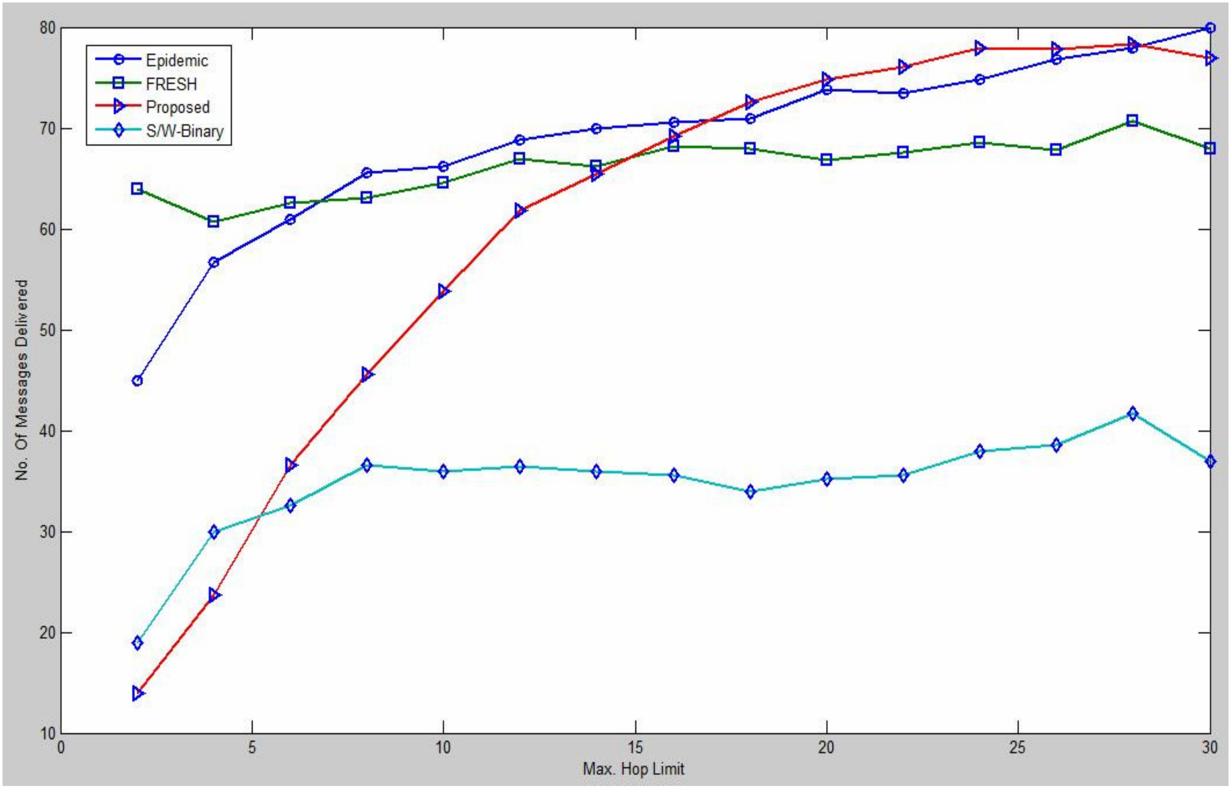

Fig 6 : Max Hop Limit Vs. No. of Messages Delivered in a 25X25 grid

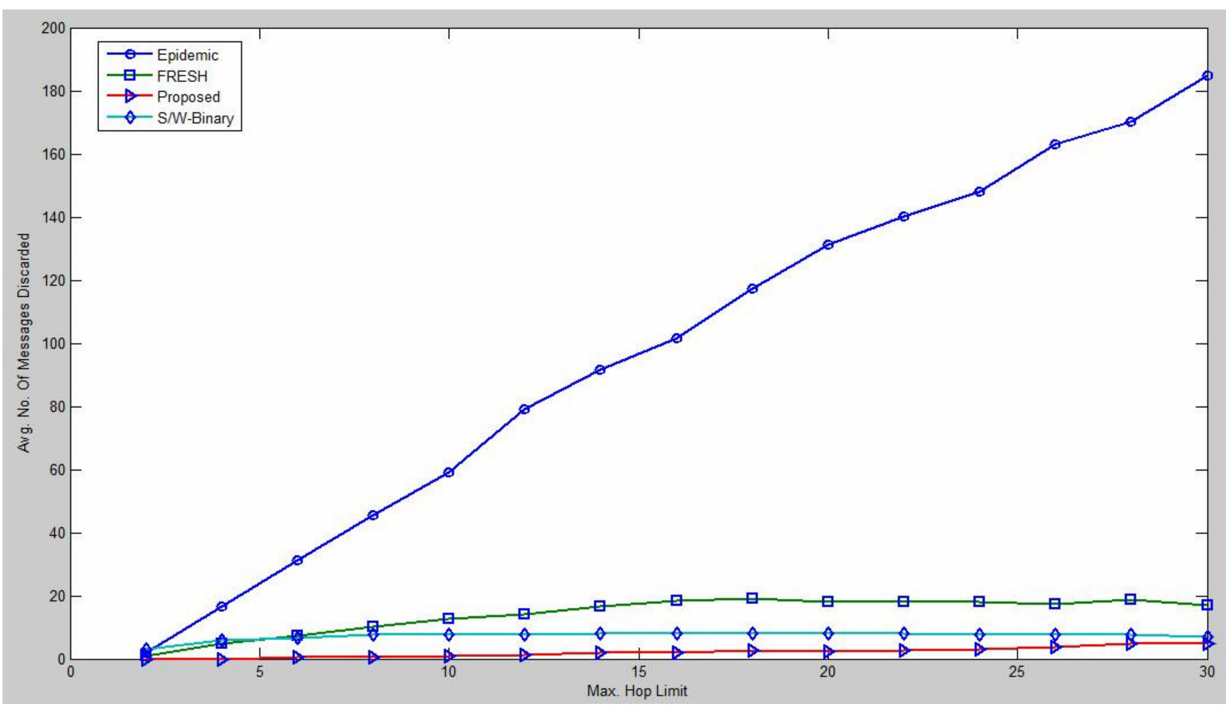

Fig 7: Max Hop Limit vs. Average No. Messages Discarded in a 25X25 grid

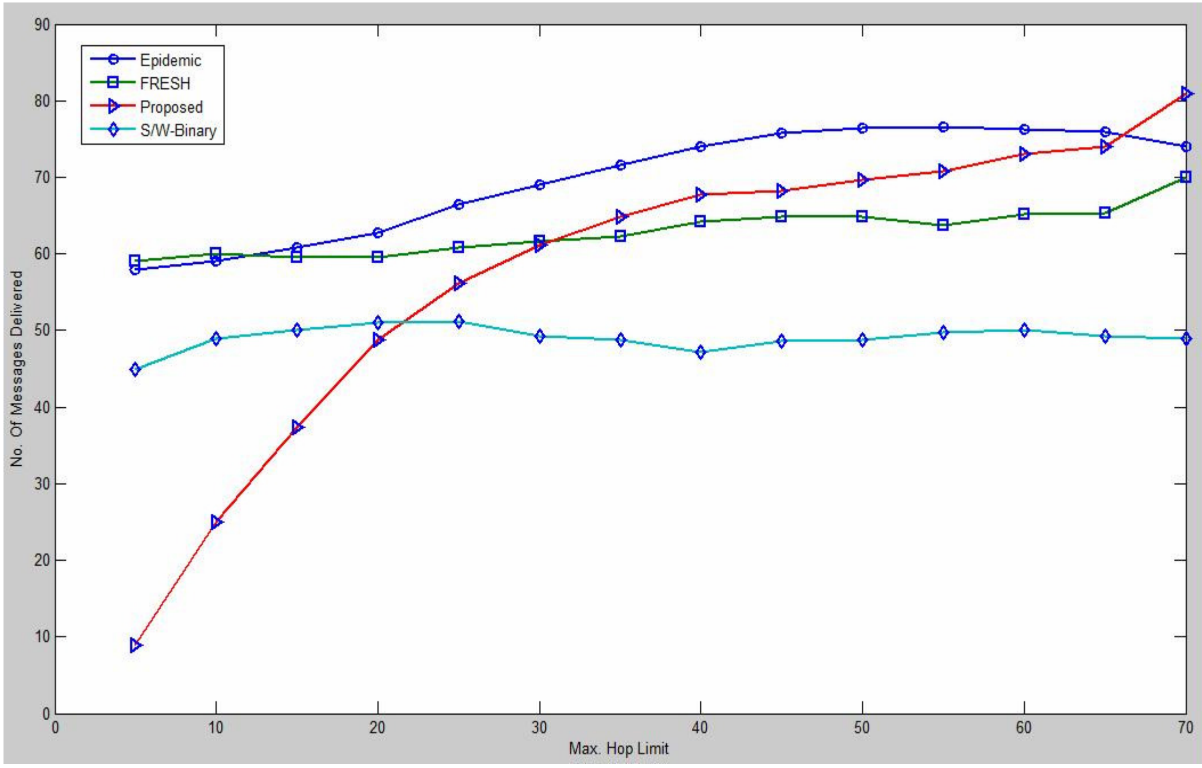

Fig 8: Max Hop Limit vs. No. of Messages Delivered in a 50X50 grid

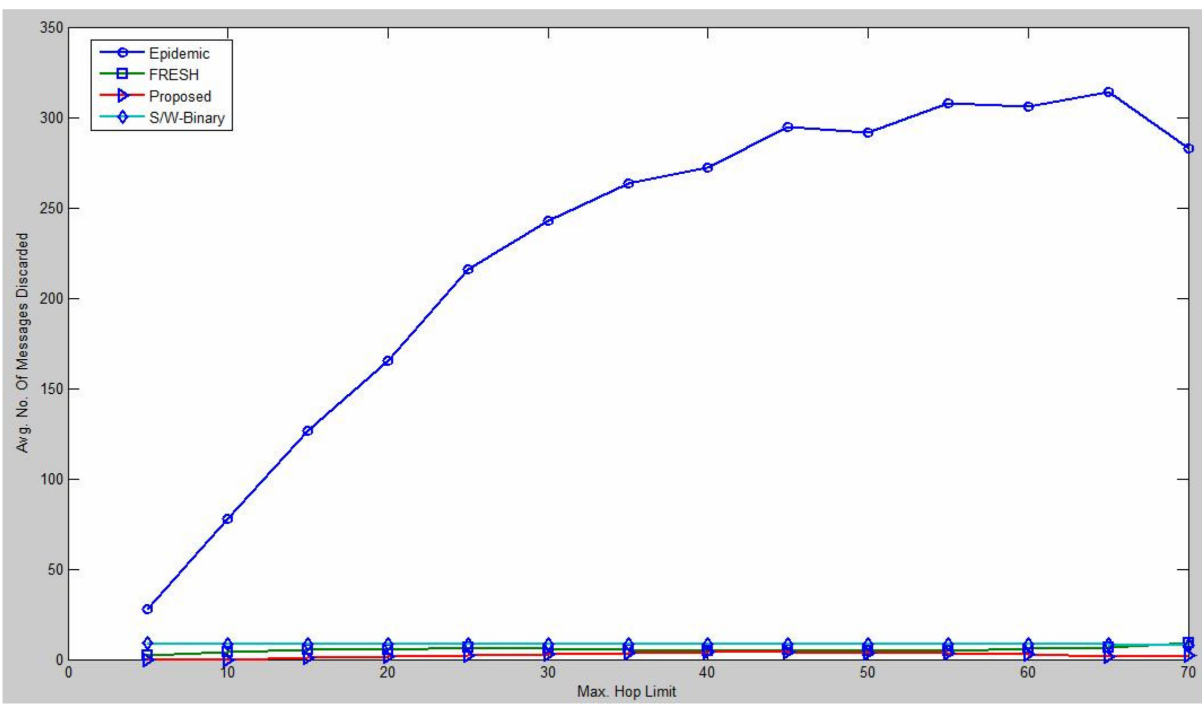

Fig 9: Max Hop Limit vs. Average No. Messages Discarded in a 50X50 grid

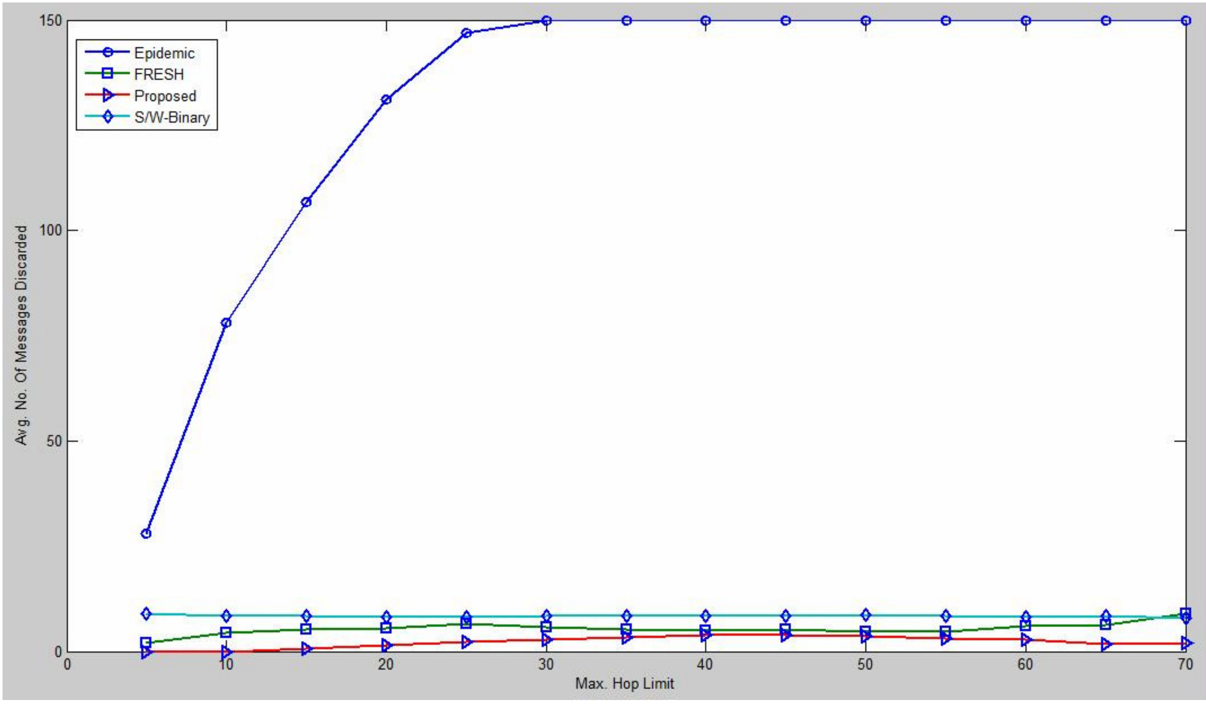

Fig 10: Max Hop Limit vs. Average No. Messages Discarded in a 50X50 grid (when the avg. no. of messages discarded in epidemic was floored to 150)

4.3 ANALYSIS

As it can be observed from the graphs, the no. of messages delivered in the proposed algorithm gradually increases with the increase in the Maximum Hop limit. At the same time, the average number of messages discarded from was the least in the proposed algorithm. This has a direct impact on conserving the energy (e.g. battery power) of the mobile nodes and saving the bandwidth. However if the maximum hop limit is kept low, then the proposed algorithm does not perform well in the sphere of delivering messages to the intended destination.

Chapter 5

CONCLUSION

Chapter 5

CONCLUSION

The history of encounters of a node with other nodes gives a vague but very important picture of the relative locations of the nodes in the network. In the proposed algorithm, we have tried to exploit this history along with the mobility pattern of the nodes. We have tried to strike a balance between high delivery of messages and low number of messages replication in the network. Since the nodes are generally held by rational entities like human beings, the social behavior of these nodes is also an important criterion and can play a pivotal role in improved delivery rates. In the future work, the social behavior of the nodes can be analyzed and included as a parameter in forwarding the message from one node to another.

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