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Study of Routing Protocols for Delay Tolerant Networks

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Abstract — ***Routing in DTNs is a key component in providing and maintaining high performance networking. The main performance metrics are delivery ratio, network overhead, and the average delay. Although many routing protocols have been proposed to provide high performance routing, they were captivated to reducing the delay at the expense of the other metrics. Each node has limited resource in terms of message buffering capability, battery power, as well as processing capacity. This paper analyses major routing protocols on the basis of delivery ratio and overhead ratio.***

Keywords — *DTN, Routing, ONE, Delay, Flooding, Forwarding, Delivery Ratio, Overhead Ratio.*

I INTRODUCTION

This paper Opportunistic networks or OppNets are designed for operation in environments (such as battlefields, underwater communications, and deep space exploration) characterized by lack of end-to-end connection, large delays, intermittent connectivity, and high error rates. Due to these characteristics, OppNets have present significant research challenges. With the proliferation of wireless mobile devices, OppNets are being used in a wide variety of areas including disaster recovery, military deployment, and wildlife. OppNets encompass different technologies, such as ad hoc networks, wireless sensor networks, peer-to-peer (P2P) systems, grid networks, and delay-tolerant networks (DTN).

II LITERATURE SURVEY

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

- Flooding based routing approaches
- Forwarding based routing approaches

A) Flooding Based Routing

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.

Direct Contact

In Direct Contact [1] 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.

Epidemic Routing

In Epidemic routing [2] 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 [3] epidemic.

Two-Hop Relay

In this approach [4], 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.

Tree Based Flooding

T. Small et al [5] 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.

Spray and Wait

The Spray and Wait [6] 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 relay nodes will store the message and performs direct transmission to the destination

B) Forwarding Based Routing

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.

Source Routing

The Source routing [7] 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.

Per-Hop Routing

In Per-Hop routing [8], 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, and 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 keeps going.

Per-Contact Routing

The most updated information is being used in Per-Contact Routing [9] 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 node for relaying the message and forward the message to the most appropriate node.

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 [10], 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.

III Performance Matrix used in DTN Routing Protocols

There are various performance parameters but we are here focusing on two primary parameters.

Delivery Ratio: The delivery ratio, or the number of messages that reach the destination divided by the total number of messages generated, is usually the primary measure of DTN routing protocol performance. After all, routing protocol exist to deliver messages to the destination. Furthermore, if the given message does not reach the destination, any resources consumed in routing that message are wasted and add to overhead. Delivery ratio is tracked in every comparison and evaluation of protocols.

$$Delivery\ Probability = \frac{No.of\ Messages\ Delivered}{No.of\ Messages\ Created}$$

Overhead Ratio: Overhead ratio is the total amount of data transmitted over the data used to transmit messages that reached their destination. It is used to measure the network congestion status and is calculated as the ratio of difference of total number of successfully relayed messages and the number of delivered messages to the number of delivered messages.

$$Overhead\ Ratio = \frac{No.of\ Relayed\ Messages - No.of\ Delivered\ Messages}{No.of\ Delivered\ Created}$$

IV Implementation of Major Routing Protocols

Two different types of cost metrics we have used for performance comparison under opportunistic network environment (ONE) simulator [11]. These are Delivery Probability and Overhead Ratio. There

are two well-known simulators used widely in DTN research, the Network Simulator 2 (NS-2) and The Opportunistic Network Environment simulator (ONE). NS-2 is an event driven simulator, developed through wide collaboration between several colleges and research firms, and models link layer through application layer network behavior. NS-2 is an open source project and includes a variety of user-developed extensions, protocols, and customizations. The ONE Simulator is also an event based simulator that was developed at the Helsinki University of Technology specifically for simulating DTN routing protocols. The detail of various simulation parameters is listed in table I given below.

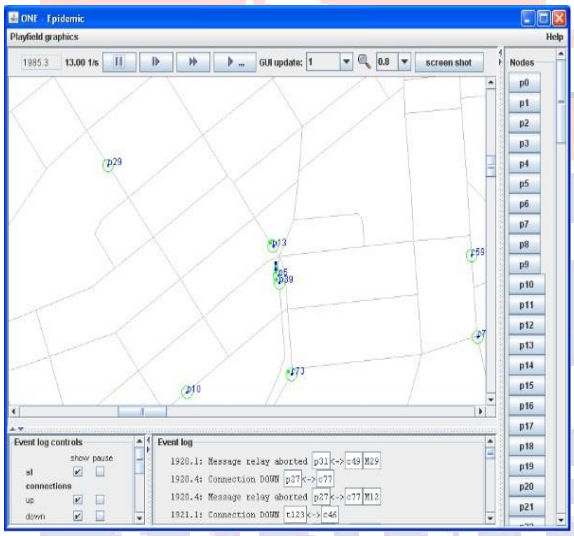

FIGURE 1. GUI OF ONE SIMULATOR

TABLE I
SIMULATION PARAMETERS

SIMULATION PARAMETERS	SIMULATION PARAMETER VALUES
Routing Approaches	Epidemic [12], PRoPHET [13], Spray and Wait [14], NDDR [15]
Map Size	4500m*3400m
No. of Nodes	50, 75, 100, 125, 150
Simulation Duration	14400 s
Message Creation Interval	10 s
Message Sizes	50 KB – 1 MB
Message TTL	Infinite
Node Buffer Size	50 MB
Node Speed	13 – 15 m/s
Node Transmission Range	150 m
Mobility Model	Shortest Path Map Based Movement

TABLE III
COMPARISON BASED ON DELIVERY RATIO BY VARYING NUMBER OF NODES

	Epidemic [12]	PRoPHET [13]	Spray and Wait [14]	NDDR [15]
50	0.2	0.38	0.5	0.75
75	0.18	0.34	0.6	0.85
100	0.15	0.29	0.699	0.96
125	0.12	0.25	0.75	0.97
150	0.1	0.2	0.82	0.97

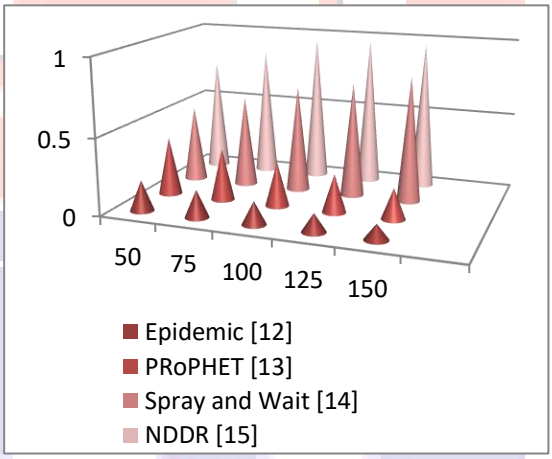

FIGURE 2. COMPARISON BASED ON DELIVERY RATIO BY VARYING NUMBER OF NODES

TABLE IIIII
COMPARISON BASED ON OVERHEAD RATIO BY VARYING NUMBER OF NODES

No. of Nodes	Epidemic [12]	PRoPHET [13]	Spray and Wait [14]	NDDR [15]
50	800	600	500	800
75	3500	2000	1800	3500
100	5000	2500	2350	5000
125	14000	7400	2400	14000
150	20000	11000	2500	20000

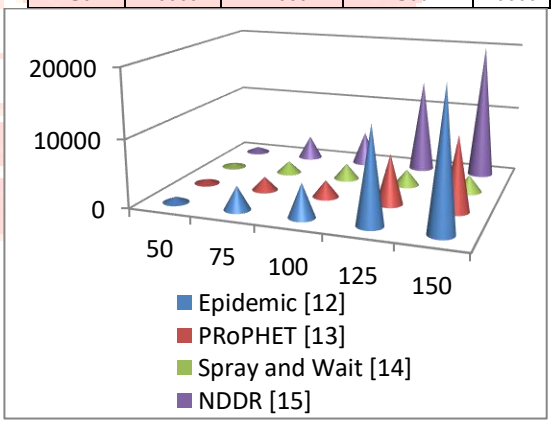

FIGURE 3. COMPARISON BASED ON OVERHEAD RATIO BY VARYING NUMBER OF NODES

V CONCLUSION

The proposed method is compared with the basic replication based routing protocol i.e. prophet, epidemic, spray and wait and NDDR protocol on the basis of delivery probability and overhead ratio. It is observed that the protocol performs better as compare to all the four protocols. The simulation is run for a maximum of 150 nodes and it is found that the delivery probability obtained by ISnW is better. Moreover, it also shows better results for overhead ratio.

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