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PERFORMANCE ANALYSIS OF ROUTING PROTOCOLS FOR DELAY TOLERANT NETWORKS

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ABSTRACT

Delay Tolerant Networks (DTNs) enable communication in challenged environments where end to end connectivity may not exist at some intervals. DTNs use store, carry and forward paradigm for delivering the message from one node to other node. Routing in DTNs is considered a challenging task because of the frequent disconnections and short contact durations. In present paper we evaluate the performance of some popular routing protocols used in DTNs based on characteristics like delivery probability, delivery latency and overhead ratio. Evaluating the performance of routing protocol requires suitable simulation tool so that the parameters used in simulation may be varied widely and the evaluated performance gives the result closer to the real world scenario. We used ONE (Opportunistic Network Environment) simulator for our simulation for providing a comparative analysis of performance of routing protocols.

Keywords: delay tolerant networks, routing protocols, opportunistic network environment.

1. INTRODUCTION

Cellular phones and other personal communication devices can communicate globally with the help of infrastructure networks. Ad-hoc networks can be used to achieve local connectivity among the devices. Due to frequent change in topology and network disruption, classic TCP/IP based communication which requires end to end connectivity all the time fails where infrastructure is not available or is distroyed due to some natural disaster. In the scenarios similar to this, DTN concept is introduced, which works on the principle of store, carry and forward. In DTNs, a message received at a node is stored if no connectivity is found, necessary for forwarding the message. The message is forwarded to the next node when connectivity for other node towards the destination is available. In other words messages are forwarded from one node to other node when oppurunity occurs [1].

DTNs can be applied in many fields and many applications which can tolerate delays, may be deployed in challenged environments comparatively at very low cost. Application area of DTN includes telemedicine in remote areas, advertisement etc. It can be help in improving the possibility for doctors to give correct diagnose and prescribe treatment from remote location. Another application may be monitoring of wild life and communicating in the situation of natural disaster etc.

DTN operations can be assumed in three stages. In first stage nodes are required to discover their neighour as they are not aware about next opportunity to meet the neighour. In second stage the node stores the packet that it originates or receives from other nodes. In the third stagetha data is transferred other node. At this point they do not have any idea about the span of opportunity. Performance of such opportunistic networks is highly variable and depends on the movement of mobile nodes, density of node population and some other factors like the distance between source and destination node. Delivery of message may vary from a few minutes to hours or days, and it is possible that a large portion of data may not be delivered. Routing and forwarding algorithms play very important role in the performance of networks and it is very challenging task to design a routing strategy which performs well in the environment where regular internet routing algorithms do not work.

In section II we discuss the various routing algorithms used in DTNs. Section III describes the experimental setup and scenarios in which protocols will be evaluated. In section IV we discuss the performance analysis based on simulation results. Section V concludes the paper.

2. ROUTING IN DELAY TOLERANT NETWORKS

Many researchers have proposed routing algorithms for DTNs scenarios. Some of them use replication and no information is used, on the other hand some algorithms use no replication and forwarding is based on the available information. In some cases information with some replication is used to forward the message. In this section we discuss some of the popular routing algorithms available in literature.

In First Contact routing algorithm a node when comes in the contact with first N number of nodes forwards the messages to them. This approach is helpful in increasing the delivery probability but at the same time it also increases the bandwith and storage consumption [2]. Direct Delivery routing algorithm delivers the message when source node comes in the contact with destination node. In this strategy a source node has to wait until it comes in the proximity of destination node. However the probability that a source comes in the contact with destination may be very low even zero [3]. Epidemic routing forwards the message arbitrarily to any node without any knowledge about the network topology. Each node is required to maintain a buffer for the messages it originates and for the messages it receives from other nodes to forward. So each node sets a maximum buffer size for the distribution of buffers. Older messages needs to be dropped for making rooms for new coming messages and some policy is required for selecting a victim for dropping [4]. In Spray and Wait routing protocol a fixed number of copies of message are sprayed to equal number of nodes in the network and then wait till any node meets the destination. In first phase of the algorithm namely spray phase, source nodes sprays L copies of a message to L neighours. If destination is found in the spray phase algorithm stops otherwise it enters in the second phase of algorithm namely wait phase. All the nodes who have received the copies of message in spray phase wait until they come in the contact of destination. They forward the message only when they meet to the destination. This algorithm saves the energy, bandwidth and storage [5]. This protocol also has a binary version in which L/2 copies are transferred to a node when it comes in contact. When a node contains only one copy of the message then it forwards the message only when it meets the destination. Maxprop protocol works on the principle of order of transmission of packet and deletion of packets. It uses various mechanisms to give order of packet transmission and deletion to increase the delivery rate. This protocol prepares a rank list of all the stored packets in the nodes which is based on the cost assigned to destination. This cost indicates the delivery likelyhood estimated for the each destination [6]. The Probabilistic Routing Protocol using History of Encounters and Transitivity (PRoPHET) uses the mobility pattern of nodes in the network to enable the communication among two nodes which are interminently connected. PRoPHET uses an algorithm which estimates the expected duration between the encounter among nodes [8].

3. EXPERIMENTAL SET UP

For simulation we used ONE (Opportunistic Network Environment) simulator. The ONE, a JAVA based simulator is used for the routing protocols implementation and tests. Since the ONE is specially designed for DTN like environment it is our natural choice [7].ONE provides an excellent support for evaluating many routing protocols as well as new protocols developed for the opportunistic environment. Default map in the ONE is map of Helsinki city (Figure-1) on which nodes move according to the movement model set in the scenario. Movement models available for the simulation purpose in ONE are Random Walk, Random Direction, Map Based Movement model, Shortest Path Map Based Mobility Model and Working Day Movement model. These models try to imitate the real world movements of nodes in various environments. Random walk mobility model is based on the argument that entities naturally move around in unpredictable ways. In this model, every node moves towards a new randomly chosen location. RWP includes a random pause time after finishing each movement segments in the random walk.

Figure-1. Simulation scenario of Helsinki city.

The simple random Map-Based Mobility model (MBM) is a derivative of the Random Walk model. In this model, nodes move to randomly determined directions on the map following the roads as defined by the map data. The improved version of MBM is the Shortest Path-Based Map Mobility Model. This model also initially places the nodes in random places of map area. Table-1 shows the a screen shot of parameters used in a particular scenario.

4. PERFORMANCE ANALYSIS

Application in DTN need to tolerate delays resulting from the challenged environments and the primary requirement of protocols of DTN is reliable message delivery. Hence, performance metrics for evaluating the performance of DTN protocols are delivery probability and delivery latency. Overhead in transmission of the messages results in additional energy consumption. As the mobile nodes in DTNs are energy constrained, the overhead is considered as another important metric. In this study, the performances of various DTN protocols are evaluated based on the metrics like delivery probability, average delivery latency and overhead ratio under different scenarios. Delivery probability is defined as ratio of the number of messages actually delivered to the destination and the number of messages sent by the sender. Delivery Latency is defined as the time taken by messages to reach from source to destination. Overhead Ratio is defined as the ratio of difference between the total number of relayed messages and the total number of delivered messages to the total number of delivered messages.

Effects of simulation time

The performance of various DTN routing protocols are compared by varying the simulation time. Average of many simulations of same duration is used for computing the delivery probability, delivery latency and overhead ratio. Results are shown in Figures 2 to 4 respectively.

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Table-1. An example of parameter sets used in simulation.

Simulation time (hours)	48
Update Interval (seconds)	1
Warm-up Time (seconds)	900
Bundle Time-to-Live (hours)	5
Buffer Size (Mbytes)	100 MB
Number of Interfaces	1
Transmission Range (meters)	10
Transmission Speed (kBps)	100
Number of Nodes	400
Number of Copies of message in SnW (Binary)	10
Seconds in time out (Prophet)	30
Node Movement	[RW; RWP; MBM; SPMBM;]
Routing Protocol	[Epidemic; Prophet; Spray and Wait]
Node Speed (m/s)	0.5~5
Wait Time (seconds)	0~8
Message creation interval(sec)	15~20
Message Size (Kbytes)	500~1000
Movement Random Seed	8372
Map Size (meters)	10000 x 8000
Map File (for Map Based Movement)	Helsinki City (data/HelsinkiMedium/roads.wkt)

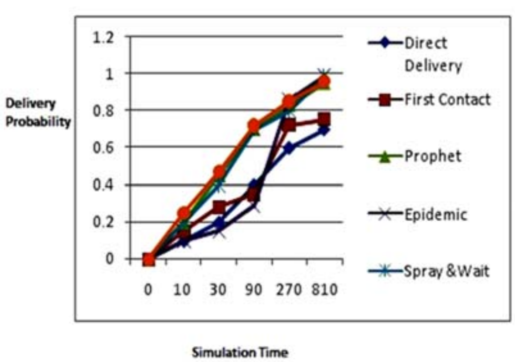

Figure-2. Delivery probability vs. simulation time.

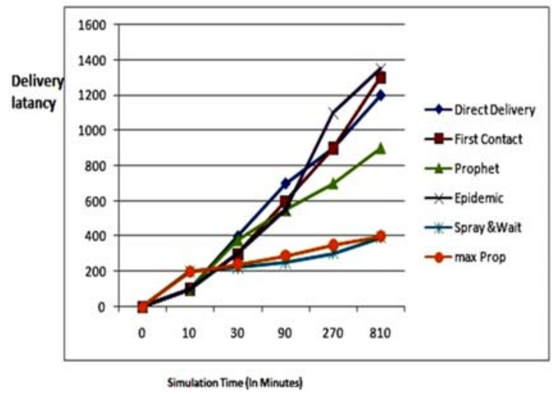

Figure-3. Average delivery latency vs. simulation time.

Figure-2 show the relation between simulation time and delivery probability. If more time is there delivery probability of most of the routing protocols increases. It is observed that if a certain amount of time is available then for certain protocols like spray and wait perform very well and gives delivery probability of more than 0.9. Delivery Probability of First contact routing is found low if the duration given for the delivery is low and it increases when duration of simulation is increases. Since fisrt contact routing delivers the packet to the node which comes in contact without any criteria, delivery of the message to the destination takes mor time. It is also clear that when simulation time is increased Delivery Probability increases significantly. Same behavior is observed in the case of Direct Delievery. Epidemic protocols show some better performance as it achieves higher delivery probability in less time.

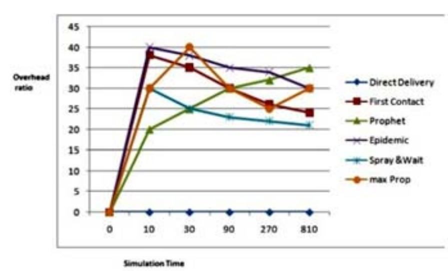

Figure-4. Overhead ratio vs. simulation time.

Delivery latency is calculated by measuring the time elapsed between the creation of message and delivery of message to the destination. Maxprop and S&W algorithms maintain the average delivery latency low even when simulation time is increased.A significant increase in delivery latency is observed in other routing protocols (Figure-5). However it can be noted that in these protocols when simulation time is less delivery probability is also low.

Overhead ratio represents the cost of transmission in the netwok. Since Direct Delivery routing protocol forwards the message to the destination only when it gets

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the opportunity to meet the destination node, overhead in this routing protocol is almost negligible. Spray and Wait routing protocols has controlled replication policy so the graph in Figure-4 shows that it maintains the overhead of the network low.

Effects of transmission range

Transmission range has a very important role in sending messages in wirelss communication. In our case routing protocols for DTNs have been evaluated by varying transmission range of nodes. In each iteration simulation range for all the nodes were taken equal for the sake of simplicity. Transmission speed of the nodes were assumed constant and same for all nodes.

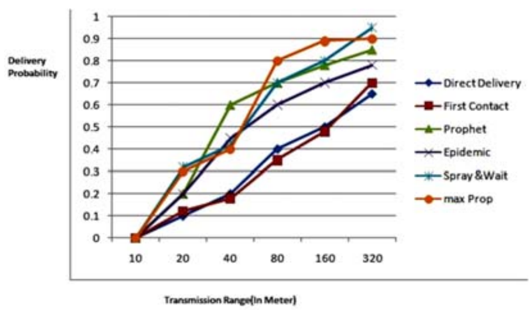

Figure-5. Delivery probability vs. transmission range.

Behaviour of routing protocols for different transmission range is depicted in figure 5. It reveals that Maxprop and Spray and Wait routing protocols gives delivery probability more than 0.8 after a certain transmission range(160 m).They gives a good delivery probability even in the transmission range near 80 m.Other routing protocols also perform well but only when the transmission range croses 160 m. First contact and direct delivery protocols gives delivery probability in the range of 0.6 to 0.7 when transmission range is more than 200m.
Increasing transmission range reduces delivery latancy in most of the procols (Figure-6). The reason behind this is getting more opportunity by a node to deliver the message to other nodes. Also since the increased transmission range of nodes makes it possible to transfer the message in less number of contacts we find improvement in all the routing protocols. Sparay and Wait protocol shows a significant decrease in delivery latancy when transmission range go beyong 60m.

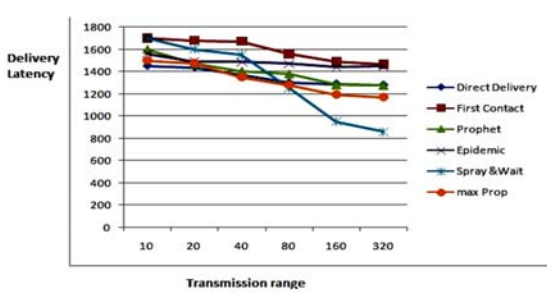

Figure-6. Average delivery latency vs. transmission range.

Since there are more opportunities to transfer the messages with increased transmission range transfers among the nodes increases causing overhead ratio to be increased. It can be seen in Figure-7 that overhead ratio increases with increase in transmission ranges. Using Spray and Wait routing protocol number of copies to be delivered is controlled even if more opportunities to transfer the messages are available. Hence Spray and Wait maintains the overhead ratio low in comparision to others.

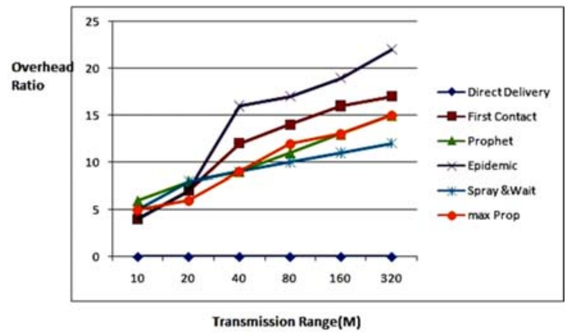

Figure-7. Overhead ratio vs. transmission range.

Effects of varying no. of nodes

The results presented in Figure 8 demonstrate that increase in node density affect the delivery probability in random manner for most of the routing protocols. However routing protocols MaxProp and Spray and Wait experience minor improvement in delivery probability when the node density increases.In some other similar experiments we found Prophet shows moderate improvement in delay when node density is increased.

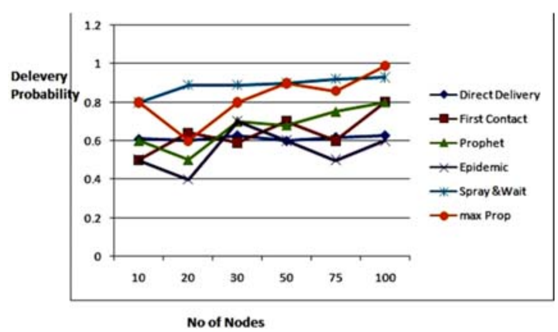

Figure-8. Delivery probability vs. number of nodes.

5. CONCLUSIONS

In this paper we investigated the various important routing porotocols used in Delay tolerant networks. Many researchers in last few years have shown their interest in this field. Performance of routing protocol evaluated on ONE simulator. The results have been generated for some well established matrices like delivery probability, delivery latency and overhead ratio. Delievery Probability improves in most of the protocols when more time is given and in Spray and Wait it goes upto 0.99. Effects of varying transmission range was also observed in terms of delivery probability where routing protocols

Maxprop and Spray and wait perform well giving more than 0.8% delivery probability. Spray and Wait routing protocol gives better results when transmission range is higher in terms of overhead ratio. Very minor changes observed in routing protocols with increased number of nodes. This paper presents a way for the researchers to evaluate more recent works that have been proposed in this field.In future we aim to develop framework which can be used for evaluating protocols related to the field like GeoOpp [9], GeoSpray [10], SPIN-MI [11], ProPHETv2[12] and many others.

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