COMPARATIVE ANALYSIS OF DIFFERENT ROUTING PROTOCOLS IN DELAY TOLERANT NETWORKS

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Abstract— The modern wireless networks have provided a wide range of applications making it possible to successfully interconnect devices and systems which have the wireless connection facility, such as mobile phones, tablets, laptops etc. all around the world. Modern Internet protocols exhibits inefficient performance in those networks where the connectivity between end nodes has intermittent property due to dynamic topology such as Mobile Ad-hoc Networks (MANET) or Vehicular Ad-hoc Networks (VANET). The network environments where the nodes are characterized by opportunistic connectivity are referred to as Delay Tolerant Networks (DTNs). DTNs have been one of the growing areas of interest characterized by the significant amount of research efforts invested in this area over the past decade. Routing is one of the major issues affecting the overall performance of DTN networks in terms of resource consumption, data delivery and latency. Over the past few years a number of routing protocols have been proposed for DTN networks. In this paper mainly three DTN routing protocols: Direct Delivery, Epidemic Routing and Spray and Wait Routing, are advocated and compared in terms of Average Packet Delivery Probability and Average Latency. To better judge the performance of these routing protocols, the series of simulations are carried out in The ONE simulator with program version of 1.4.1

Keywords- DTN, Epidemic Routing, Spray and Wait Routing, Packet Delivery Probability, Average Latency

I. INTRODUCTION

Delay Tolerant Network is also referred as the Intermittently Connected Mobile Network [1]. It is the wireless network in which at any given time instance, the probability that there is an end-to-end path from a source to destination is low. Since most of the nodes in a DTN are mobile, the connectivity of the network is maintained by nodes only when they come in to the transmission ranges of each other. If any node has data to send but it is not connected to another node, it stores the message until an appropriate communication opportunity arises. A communication opportunity between two nodes is called a contact in DTN's. Since DTN represents a large group of networks several different kinds of contact have been identified. A contact can be persistent i.e. the contact is always available, On-demand i.e. a contact can be initiated when needed, scheduled i.e. the contact and its characteristics is known in advance or opportunistic contacts, called opportunistic DTN.

Generally, MANET routing protocols are built with the assumption that the network is dense enough so that it is fully connected i.e. that there always exists a path between every node in the network or that paths are down for a very short period of time. So, traditional routing protocols for MANETs do not work well for DTNs [2], since they try to discover a full path before sending any data. If no path between the sender and the destination exists, these protocols will not succeed to send any data.

To overcome the problem with intermittent connectivity and partitions in the network, DTN routing protocols utilize the mobility of the nodes and buffering of messages, this makes is possible for a node to carry a message and in that way bridge partitions in the network. It is also known as store-carry-forward (SFC) [3]. When a message is created it gets stored at the source node, when a contact becomes available to a next-hop node the message is sent over this contact. The message gets stored at the new node until the next-hop in the path is found and so on, until the destination is found. This results in a path from the source node to the destination without a guarantee for a contemporaneous path.

Research on routing in DTN is still in its infancy. However, so many routing protocols are proposed and classified for DTN till date and there are several parameters of interest to judge the performance of them. Some of them are: delivery probability, delivery latency, resource usage, information gathering and usage, hop count, number of copies of message in the network. In this paper we have mainly concentrated only on three DTN routing protocols which are Direct Delivery, Epidemic routing and Spray and Wait routing and to examine the performance of them we have concentrated mainly two parameters which are Packet Delivery Probability and Average Latency.

This paper is organized as follows: First the detailed explanation of Direct Delivery, Epidemic and Spray and Wait routing protocols are given in section II. In section III, the whole simulation strategy is discussed. A result analysis of Packet Delivery Probability and Average Latency are discussed in section IV. The final concluding remark is given in section V.

II. ROUTING PROTOCOLS IN DTN

A. Direct Delivery Routing

Direct delivery routing uses a simple hand to hand message delivery strategy [4]. In the direct delivery routing Scheme the source hold the data until it comes in contact with the destination. This simple strategy uses one message transmission. It is a degenerate case of flooding family, requiring no info about network but requires a direct path between source and destination. Hence if no contact occurs, message is not delivered.

B. Epidemic Routing

Epidemic routing algorithm was the method which firstly introduced by Demers et al. [5] to synchronize database which use replication mechanism. This algorithm was modified by Vahdat et al. (2000) and proposed as a flooding-based forwarding algorithm for DTNs. In the epidemic routing scheme, the node receiving a message, forwards a copy of it to all nodes it encounters. Thus, the message is spread throughout the network by mobile nodes and eventually all nodes will have the same data. Although no delivery guarantees are provided, this algorithm can be seen as the best effort approach to reach the destination. Each message and its unique identifier are saved in the node's buffer. The list of them is called the summary vector. Whenever, two adjacent nodes get opportunity to communicate with each other, they exchange and compare their summary vectors to identify which message they do not have and subsequently request them. To avoid multiple connections between the same nodes, the history of recent contacts is maintained in the nodes caches [6].

Assuming sufficient resources such as node buffers and communication bandwidth between nodes, the epidemic routing protocol finds the optimal path for message delivery to destinations with the smallest delay. The reason is that the epidemic routing explores all available communication paths to deliver messages [7] and provides strong redundancy against node failures [8]. The major disadvantage of epidemic routing is wastage of resources such as buffer, bandwidth and nodes power due to forwarding of multiple copies of the same message. It causes contentions when resources are limited, leading to dropping of messages. It is especially useful in those conditions when there are no better algorithms to deliver messages.

C. Spray And Wait Routing

Wasteful resource consumption in the epidemic routing, could be significantly reduced if the level of distribution is somehow controlled. Spyropoulos et al. (2005) proposed the spray and wait mechanism to control the level of spreading of messages throughout the network. Similar to the epidemic routing, the spray and wait protocol assumes no knowledge of network topology and nodes mobility patterns and simply forwards multiple copies of received messages using flooding technique. The difference between this protocol and the epidemic routing scheme is that it only spreads L copies of the message. The authors in [9] proved that the minimum level of L to get the expected delay for message delivery depends on the number of nodes in the network and is independent of the network size and the range of transmission.

The spray and wait method consists of two phases, spray and wait phase. In the spray phase the source node after forwarding L copies of message to the first L encountered nodes, goes to wait phase, waiting for delivery confirmation. In the wait phase all nodes that received a copy of the message wait to meet the destination node directly to deliver data to it. Once data is delivered confirmation is sent back using the same principle.

To improve the performance of the algorithm Spyropoulos et al. (2005) purposed the binary spray and wait scheme. This method provides the best results if all the nodes' mobility patterns in the network are independent and identically distributed with the same probability distribution. According to the binary spray and wait, the source node creates L copies of the original message and then, whenever the next node is encountered, hands over half of them to it and keeping the remained copies. This process is continued with other relay nodes until only one copy of the message is left. When this happens the source node waits to meet the destination directly to carry out the direct transmission [9].

III. SIMULATION STRATEGY

A. The ONE Simulator

A series of simulations are carried out to judge the performance of above mentioned protocols using the Opportunistic Network Environment (The ONE) simulator (Keranen et al. 2009) with program version of 1.4.1. At its core, ONE is an agent based discrete event simulation engine. The main functionality of the ONE consists of modelling of node movement, inter-node contacts using various interfaces, routing, message handling and application interactions. Result collection and analysis are done through visualization, reports and post processing tools. The elements and their interactions are shown in Figure 1. A detailed description of the simulator is available in [10] and the ONE simulator project page [11] where the source code is also available.

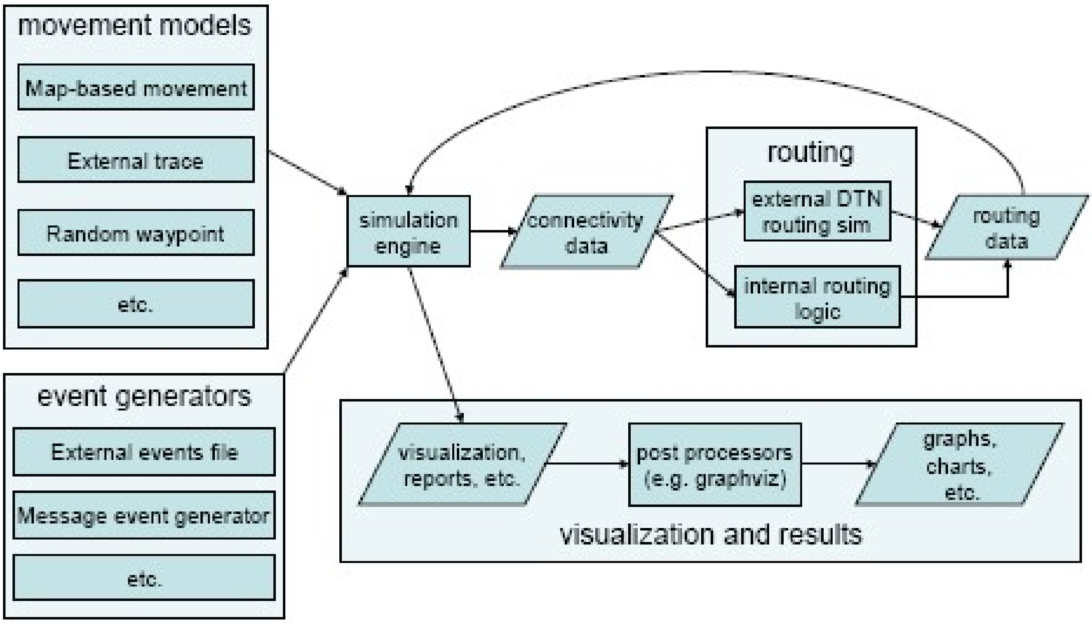

Figure 1. Overview of ONE Simulator Environment [11].

B. Simulation Setup Information

In our simulation we have assigned simple broadcast type blue tooth interface with the transmit speed of 2 Mbps to all the nodes. To make our simulation scenario comparable to real time application, we have assigned random way point mobility to all the nodes with mobility varies from 0.5 to 1.5 m/sec. To better judge the performance of all the three routing protocols, we have assigned 10Mb buffer size to each node and also their transmit range is limited to 10 m only. So, during store-carry-forward methodology each node can carry messages only up to 10Mb and node can forward messages to those nodes only which are in 10m range of it. This situation will increase packet drop probability during the transmission of messages.

As ONE simulator supports external event generator, we have set message event generator in such a way that it generates the messages in every 25 to 35 seconds and every time message size can also be varied from 500 Kb to 1Mb. To advocate the performance of the Direct Delivery, Epidemic and Spray and Wait routing, we have run the simulation for 10000 seconds for each routing protocols separately and we have noted that every time message event generator feds 342 messages in 10000 seconds in network. The complete simulation setup information is given in Table I.

To advocate the performance of routing protocols we have mainly concentrated on two performance metrics:

(i) Packet Delivery Probability: It is the fraction of generated messages that are correctly delivered to the final destination within given time period.

(ii) Average Latency: It is the measure of average time between messages is generated and when it is received by the destination.

TABLE I. SIMULATION SETUP PARAMETERS

PARAMETERS	VALUE
Simulation Time	10000 sec
Interface	Blue tooth Interface
Interface Type	Simple Broadcast
Transmit Speed	2 Mbps
Transmit Range	10 m
Mobility	Random Way Point
Buffer Size	10 MB
Routing Protocols	Direct delivery, Epidemic, Spray and Wait
Total No. of nodes	5, 10, 20, 50, 100
Speed of nodes	0.5 to 1.5 m/sec
Message Size	500Kb to 1 MB
Message Interval	25 to 35 sec
Message TTL	300 minutes

IV. RESULT ANALYSIS

A. *Packet Delivery Probability*

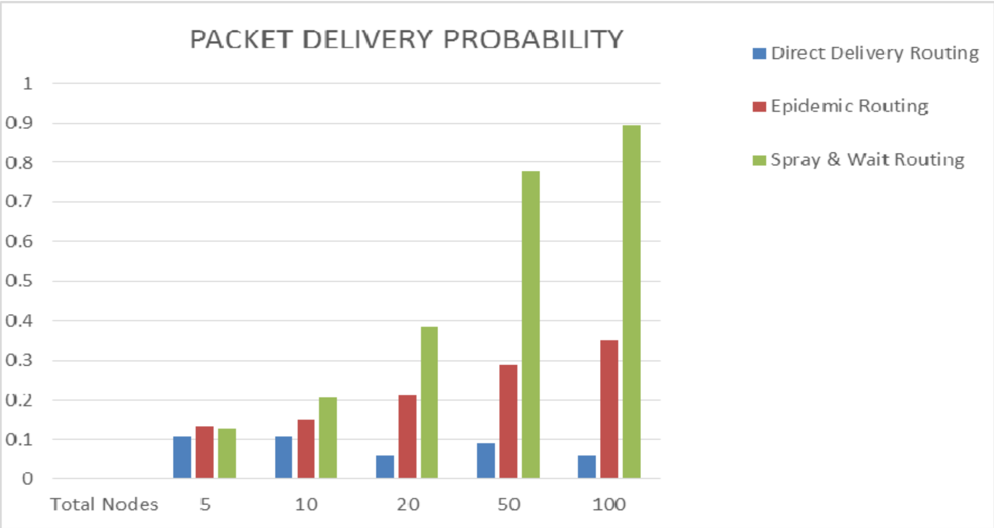

Figure 2. A Comparison Chart of Packet Delivery Probability.

Figure 2 shows the comparison chart of packet delivery probability for Direct Delivery Routing, Epidemic Routing and Spray and Wait Routing. From the chart it can be noticed that when 5 nodes are there at that time packet delivery probability given by all the three routing protocols are almost equal. Whereas in the case when total number of nodes are 10, 20, 50 and 100, the Epidemic Routing and Spray and Wait routing shows increment in packet delivery probability but at the same time packet delivery probability of Direct Delivery routing decreases. It is just because the Direct Delivery routing uses hand-to-hand packet delivery strategy. So, as the total number of nodes increase the possibilities to meet with the destination node in the Direct Delivery routing decreases. If we only concentrate Epidemic routing and Spray And Wait routing then from the graph it is clearly noticed that still performance of Epidemic routing is not up to mark whereas Spray and Wait routing shows excellent performance in terms of packet delivery probability.

B. *Average Latency*

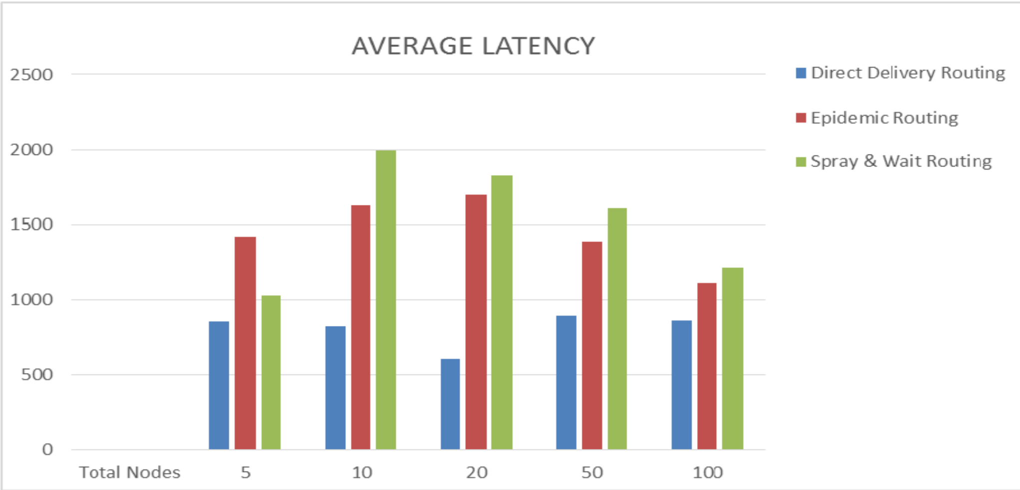

Figure 3. A Comparison Chart of Average Latency.

Figure 3, shows the comparison chart of average latency for Direct Delivery Routing, Epidemic Routing and Spray and Wait Routing protocols. From the comparison chart it can be noticed that average latency of Epidemic routing is quite higher than Direct Delivery routing and Spray and Wait routing when the total number of nodes are 5 only. In the case when total numbers of nodes are 10, average latency for Spray and Wait routing is much higher than the Direct Delivery and Epidemic routing. Not only that, but in the another cases when the total nodes are 20, 50 and 100, the average latency of Spray and Wait routing is quite higher than Epidemic routing whereas direct delivery shows very less average latency.

V. CONCLUSION

After analyzing both the comparison chart of packet delivery probability and average latency for Direct Delivery Routing, Epidemic Routing and Spray and Wait Routing we can conclude that Direct Delivery Routing is no more suitable for real time application because of its very poor packet delivery probability. Whereas Epidemic routing and Spray and Wait routing is suitable for real time applications. Among this two routing protocols, Spray and Wait routing shows the excellent overall performance than Epidemic routing.

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