Comparing Delay Tolerant Network Routing Protocols for Optimizing L-Copies in Spray and Wait Routing for Minimum Delay

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Abstract

Delay Tolerant Network (DTN) is special type of wireless mobile ad hoc network characterized by intermittent connectivity, long or variable delay, asymmetric data rate and high error rates. In this paper we compare some of the well-known routing protocols namely Epidemic, Spray and Wait (SaW), Probabilistic ROuting Protocol using History of Encounters and Transitivity (PROPHET), and MaxProp. Simulation results show that delivery ratio is almost equal for both MaxProp and SaW and the overhead ratio is much less for SaW as compared to MaxProp. Average delay of SaW is slightly higher**.** Simulation results also show that 20%-25% L copies of the total number of nodes in the network gives better delivery ratio and less overhead with minimum average delay in SaW.

Keywords: Delay tolerant network, routing protocols, delivery ratio, average delay and overhead ratio.

1. Introduction

Delay Tolerant Network[1] (DTN) is evolved from Mobile ad hoc Network. It is Intermittent and sparsely connected because of limited transmission range and mobility. DTN is characterized by intermittent connectivity, long or variable delay, asymmetric data rate and high error rates. DTN uses “Store and Forward” strategy for routing of messages where message is successively moved and stored in the buffer throughout the network in hops that it will finally reach its destination. In these challenging environments the traditional ad-hoc routing protocols such as Ad hoc On-Demand Distance Vector[2] (AODV) or Dynamic Source Routing[3] (DSR) do not work well in DTN because they require fully connected path between source and destination for communication to be possible.

The rest of paper is organized as follows. Section II, reviews routing in DTN and presents routing protocols in DTN. Section III describes simulation setup and performance metrics. Section IV describes the simulation results to analyze the routing protocols. Section V concludes this paper.

2. Routing Protocol in DTN

Routing protocols in DTN are classified according to the type of information gathered by nodes to take the routing decision. They can be broadly classified as flooding based routing protocol and forwarding based routing protocol. Flooding based routing protocols from Refs 4, 5 and 6 spread the message and it’s replica in the network. They vary according to their spreading mechanism and number of copies forwarded.

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Forwarding based routing protocols from Refs 7, 8, 9 and 10 uses different mechanism to efficiently selecting the relay nodes to enhance the delivery probability in case of limited resources and storage. They gather information about other nodes in the network to select relay nodes.

2.1. *Epidemic routing*

Epidemic routing[4] was historically the first DTN routing protocol. It is flooding based routing in nature. In Epidemic routing, every node continuously replicates messages to newly arrived nodes that do not already have the message copy. The message distribution is transitive through ad hoc networks, with messages eventually reaching their destination. Epidemic routing protocol provides guaranteed transmission of message irrespective of delivery delay. It has very high overhead and has a large number of message copies in a network which results in network congestion.

2.2. *Spray and wait*

Spray and Wait[5] protocol limits the blind forwarding message strategy of Epidemic routing by associating a number L to messages that indicates the maximum allowable copies of the message. It consists of two phases spray phase and wait phase. In the spray phase the source node initially spray L number of message copies to L distinct relay nodes. After receiving the message copy all L relay nodes go into the wait phase and wait till the direct transmission to the destination. There are two types of SaW namely Source Spray and Wait and Binary Spray and Wait. In Source Spray and Wait the source node forward all L copies to the first L distinct nodes it encounters. In Binary Spray and Wait the source of a message initially starts with L copies. When it encounters first node with no copies then it hands over $\lceil L/2 \rceil$ copies to that node and keeps $\lfloor L/2 \rfloor$. Now this process is repeated for both source and relay that has L > 1 message copies, and when the node either is left with only one copy, it switches to wait phase and wait till the direct transmission to the destination.

The simplicity and thriftiness of direct transmission with the speed of Epidemic routing make SaW well in the terms of performance than Epidemic routing.

2.3. *PROPHET*

To improve the delivery probability and reduce the wastage of network resources in Epidemic routing a new type of routing protocol has proposed called PROPHET.[7] In PROPHT if a node has visited a location several time then there is a possibility that this pattern will repeated in the future. In PROPHET every node uses probabilistic metric called delivery predictability to transfer messages to a reliable node. The higher delivery predictability for a node indicates that it is more reliable than other nodes to forward message to destination. PROPHET outperforms Epidemic routing. However, PROPHET has higher average delay than Epidemic routing when the buffer size of nodes are decreased. PROPHET has lower overhead than Epidemic routing.

2.4. *MaxProp*

MaxProp[8] is forwarding based routing protocol. In MaxProp routing each node initially set a probability of meeting to all the other nodes in network and also exchanges these values to its neighbor nodes. The probability value is used to calculate a destination path cost. Each node forwards messages through the lowest cost path. MaxProp also uses an ordered queue which is divided into two parts according to an adaptive threshold. MaxProp assigns a higher priority to new messages and forward it first with low hop count and drops a message with the highest cost path when buffer is full. MaxProp has poor performance when nodes have small buffer sizes because of the adaptive threshold calculation. MaxProp performance is better with large buffer size.

3. Simulation Setup and Performance Metrics

3.1. *Model*

There are some assumptions that have been taken for the purpose of simulation. Similar assumptions have been made in previous works see Refs. 4, 5, 7 and 8. Each node has an unlimited buffer for messages that they originate.[8] For relaying the messages originated at other nodes a fixed size buffer is assumed. A first-in-first-out (FIFO) queuing system has been implemented for scheduling and dropping of messages in Epidemic, SaW, and PROPHET. The movement model is Shortest Path Map Based Movement (SPMBM).

Table.1. Number of L copies

Network size	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Small network(N=10)	1	2	3	4	5	6	7	8	9	10
Large network(N=100)	10	20	30	40	50	60	70	80	90	100

Table.2. Small network parameter

Parameter	Pedestrians	Vehicle
Number of hosts	5	5
Speed(m/s)	0.5-1.5	2.7-13.9
Packet Inter arrival time	250-350 sec	250-350 sec
Buffer size	2-10 MB	2-10 MB
Packet TTL	5 hours	5 hours
Simulation time	12 hours	12 hours
Transmission speed	5 MBps	5MBps
Number of L copies in SaW	5	5
Movement	SPMBM	SPMBM

Table.3. Large network parameters

Parameter	Pedestrians	Vehicle
Number of hosts	60	40
Speed(m/s)	0.5-1.5	2.7-13.9
Packet Inter arrival time	25-35 sec	25-35 sec
Buffer size	10-50 MB	10-50 MB
Packet TTL	5 hours	5 hours
Simulation time	12 hours	12 hours
Transmission speed	5 MBps	5MBps
Number of L copies in SaW	20	20
Movement	SPMBM	SPMBM

3.2. *Simulation setup to analyze impact of varying buffer size on performance metrics*

To realize the performance of routing protocols discussed in section 2, they have been implemented on Opportunistic Networking Environment (ONE) simulator.[12]Two experiments have been conducted with different number of nodes, N. The first experiment simulates a small network with N =10. The second experiment have a large network with N=100. Table 2 and 3 show the simulation parameters for small network and large network respectively. The impact of varying the buffer size has been studied with a large Time to Live (TTL) value on the three metrics namely Delivery ratio, Average delay and Overhead ratio.

3.3. *Simulation setup to analyze the impact of varying L copies on the performance metrics*

To realize the performance of SaW, the algorithm has been implemented with different percentage of L copies of the total number of nodes in the network on ONE simulator. Two experiments have been conducted with small (N=10) and large (N=100) network by varying L (number of copies) from 10% to 100% of the total number of nodes in the network in a step of 10. Table 2 and 3 shows the simulation parameters for small network and large network respectively. Table 1 shows the varying number of L copies.

3.4. *Performance metrics*

The three metrics to measure the performance of the different protocols:

- Delivery Ratio: The delivery ratio is the ratio of total number of messages delivered to their destination to total number of created messages at source node.

$$\text{Delivery ratio} = \frac{D}{G} \quad (1)$$

  where *D* is a number of messages delivered to destination, and *G* is a number of created messages.
- Overhead Ratio: The overhead ratio reflects how many redundant packets are relayed to deliver one packet. It simply reflects transmission cost in a network.

$$\text{Overhead Ratio}=\frac{R-D}{D} \quad (2)$$

  where *R* is a number of messages forwarded by relay nodes, and *D* is a number of messages delivered to their destination.
- Average delay: The average delay is the time between messages is created and the messages are received at a destination.

$$\text{Average Delay}=\frac{\sum_{i=1}^{n}(R_i - G_i)}{n} \quad (3)$$

  where n is a number of messages delivered to their destinations, R_i is the time when a message i reaches to its destination, and G_i is the time when a message i is created.

4. Simulation Results

4.1. *Impact of varying buffer size*

As shown in Figures 1and 2, increasing buffer size increases delivery ratio for all the protocols for N=10and N=100 respectively because as buffer size inc-