Performance Comparison of RAPID, Epidemic and Prophet Routing Protocols for Delay Tolerant Networks

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***Abstract*—These Opportunistic Networks or DTN are the class of networks where the nodes do not have contemporaneous connections, but intermittent connections. In DTN, the main characteristic of packet delivery is large end-to-end path latency and a DTN routing protocols has to cope with frequent disconnections. The lifetime of packet would have large effect on the performance of routing protocols in DTN as the delay is large in DTN. In this paper we have investigated the performance of three different routing protocols namely Epidemic, Prophet and RAPID against varying message TTL. For the simulation we have used Opportunistic Network Environment (ONE) Simulator. The performance is analyzed on three metrics: Delivery Probability, Overhead Ratio, and Average Latency. From the results obtained from the simulation it is analyzed that the RAPID routing protocol gives the best performance in the considered scenario and simulation setting.**

***Index Terms*—Delay tolerant networks, epidemic, prophet, rapid, opportunistic network, opportunistic network environment (ONE)**

I. Introduction

In the recent decade, there has been tremendous technological development in the field of computing devices e.g. PDA, cell phone etc. with the wireless interfaces. The development and easily availability of these personal communication devices have made voice and data communication possible for the mobile users, achieving global connectivity via infrastructure networks (cellular, WLAN). Local connectivity among the devices may additionally be obtained by forming ad-hoc networks since the mobile devices are virtually always turned on and have the necessary radio interfaces, processing power, storage capacity and battery lifetime to act as a router. Several ad-hoc network routing schemes have been developed in recent past for ad-hoc networks but none of these routing schemes are applicable in challenging scenarios with sparse node density, intermittent connectivity and suffering frequent partitioning. Such networks are termed as Delay Tolerant Networks (DTNs) or Opportunistic Networks. Opportunistic Networks or DTN are the class of networks where the nodes do not have contemporaneous connections, but intermittent connections. These networks usually have sparse node density, and each node has short radio range. The examples of these networks include networks in the undeveloped areas without internet connections, sensor networks monitoring nature and military fields, or mobile opportunistic networks composed of moving vehicles and pedestrians.

In this study we have analyzed the performance of three different DTN routing protocols (Epidemic; Prophet; RAPID) by varying the message TTL. These protocols were analyzed on three different metrics namely Delivery Probability, Over Head Ratio and Average Latency. The detailed simulation setup and metrics is given in section 3.

The remainder of paper is organized as follows: section 2 briefly gives the introduction of the DTN routing and routing protocols viz. Epidemic, Prophet and Rapid. Section 3 gives the details of simulator and the simulation setup used to carry out the work. Section 4 discusses the results. Section 5 concludes the paper and lists the directions for future work.

II. Routing in DTN

In DTN, the main characteristic of packet delivery is large end-to-end path latency and a DTN routing protocols has to cope with frequent disconnections. Numerous routing and forwarding techniques have been proposed over the past few years (refer [1] and [2] for overview). Majority of forwarding and routing techniques uses asynchronous message passing (also referred to as store-carry-forward) scheme.

The foremost difference between different DTN routing protocols is the amount of information they have available to make routing decisions [3]. Ad-hoc DTN usually applies variants of reactive protocols. Flooding protocols such as epidemic routing [4] do not use any information. Predictive protocols such as PRoPHET [5] use past encounters of nodes to predict their future suitability to deliver messages to a certain target whereas other protocols also exploit further (explicitly configured) schedule and context information per node [6]. Furthermore, the different routing protocol differ in their replication strategies, i.e., number of copies of a message they create which, in turn, increases/decreases the network load. There are protocols which generate just a single copy [7] (e.g., First Contact [3], Direct Transmission/Delivery [7]), some protocols generate a fixed number of copies limited by the sender [8] [9], whereas epidemic [4] and probabilistic [5] routing potentially create an “unlimited” number of messages.

A. *Epidemic Routing*

Epidemic Routing [10] has been proposed as an approach for routing in sparse and /or highly mobile

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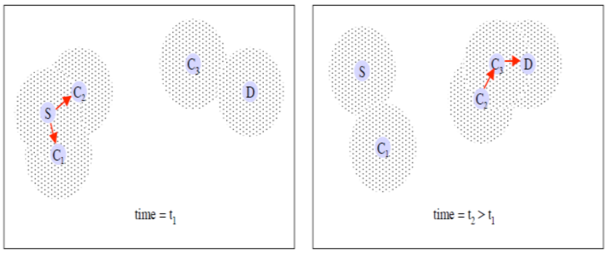

(a) (b)

Fig. 1. A source S, wishes to transmit a message to a destination but no connected path is available in part (a). Carriers C1-C3 are leveraged to transitively deliver the message to its destination at some later point in time as shown in (b).

Networks in which there may not be a contemporaneous path from source to destination. It adopts a so-called "store-carry-forward" paradigm.

In Figure 1(a), a source, S, wishes to send a message to a destination, D, but no connected path is available from S to D. S transmits its messages to its two neighbors, C1 and C2 , within direct communication range. At some later time, as shown in Figure 1(b), C2 comes into direct communication range with another host, C3, and transmits the message to it. C3 is in direct range of D and finally sends the message to its destination.

Analogous to the spread of infectious diseases, each time a packet-carrying node encounters a node that does not have a copy of that packet, that carrier is said to infect this new node by passing on a packet copy; newly infected nodes, in turn, behave similarly. The destination receives the packet when it first meets the infected node. When the traffic load is very low, epidemic routing is able to achieve minimum delivery delay at the expense of increased use of resources such as buffer space, bandwidth, and transmission power.

B. Prophet

Prophet [10] is a DTN routing protocol aiming at using knowledge obtained from past encounters with other nodes to optimize the packet delivery. Each node keeps a vector of delivery predictability estimates, and uses it to decide whether an encountered node were carrier for a DTN packet. The predictability estimates are increased every time a node encounters another node, and they are decayed exponentially. The PROPHET protocol also includes a "transitivity" mechanism (controlled by parameter β) for dealing with the case where two nodes rarely meet, but there is another node that frequently meets both of these nodes.

C. Rapid

Rapid [13] models DTN routing as a utility-driven resource allocation problem. A packet is routed by replicating it until a copy reaches the destination. Rapid derives a per-packet utility function from the routing metric. At a transfer opportunity, it replicates a packet that locally results in the highest increase in utility.

In general, Ui is defined as the expected contribution of i to the given routing metric. For example, the metric minimize average delay is measured by summing the delay of packets. Accordingly, the utility of a packet is its expected delay. Thus, rapid is a heuristic based on locally optimizing marginal utility, i.e., the expected increase in utility per unit resource used. Rapid replicates packets in decreasing order of their marginal utility at each transfer opportunity.

Protocol rapid(*X*, *Y*):

- Initialization: Obtain metadata from *Y* about packets in its buffer and metadata *Y* collected over past meetings.
- Direct delivery: Deliver packets destined to *Y* in decreasing order of their utility.
- Replication: For each packet i in node *X*'s buffer
  1) If *i* is already in *Y*'s buffer (as determined from the metadata), ignore *i*.
  2) Estimate marginal utility, ∂U_i, of replicating *i* to *Y*.
  3) Replicate packets in decreasing order of $\partial U_i / S_i$¬.
- Termination: End transfer when out of radio range or all packets replicated.

III. Simulation Setup

The above mentioned protocols performance were analyzed through simulation using the Opportunistic Network Environment (ONE) Simulator (Keranen et al. 2009). At its core, ONE is an agent-based discrete event simulation engine. The main functionality of the ONE consists of modeling 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 2. A detailed description of the simulator is available in [11] and the ONE simulator project page [12] where the source code is also available.

A. Simulation Parameters

The Table 1 summarizes the simulation configuration used for the current analysis.

B. Performance Metrics

The following are the performance metrics used for the analysis:

a) Over Head Ratio: This metric is used to estimate the extra number of packets needed by the routing protocol for actual delivery of the data packets. It is defined as

(Number of Packets Relayed - Number of Packets Delivered) /(Number of Packets Delivered)

b) Delivery Probability: It is the fraction of generated messages that are correctly delivered to the final destination within a given time period. It is defined as

Number of packets delivered /Number of packets created

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

TABLE I: Simulation Parameters

Parameter	Value
Total Simulation Time	12 Hours
World Size	4500 X 3400 m
Movement Model	ShortestPathMapBasedMovement
Routing Protocol	Epidemic; Prophet; Rapid
Node Buffer Size	5M
No of Nodes	126
Interface transmit Speed	2 Mbps
Interface Transmit Range	10 m
msgTTL	60,120,180,240,00,360
Node Movement Speed	Min=0.5 m/s Max=1.5 m/s
Message Creation Rate	One message per 25-35 sec
Message Size	500 KB to1 MB

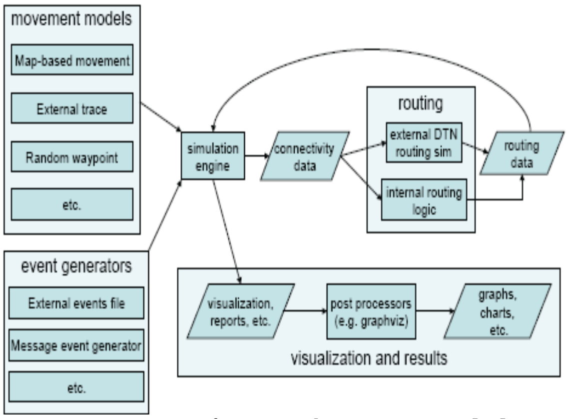

Fig. 2. Overview of ONE simulator environment [12].

IV. Results and Discussion

In the simulated environment, we have focused on comparing the performance with regard to the metrics defined above. The results presented here are obtained by running the simulations as per the parameters defined in Table 1.

A. Delivery Probability

From Fig 3, it is evident that the delivery probability of RAPID routing protocol in the considered scenario is high as compared to the delivery probability of Epidemic and Prophet routing protocol. The delivery probability of Epidemic and Prophet routing protocol is almost same and constant (approximately 0.25) as the message TTL is increased from 60 to 360 minutes whereas the delivery probability of RAPID routing protocol increases (from 0.3 to 0.4 approximately) with the increase in message TTL (from 60 to 360 minutes)

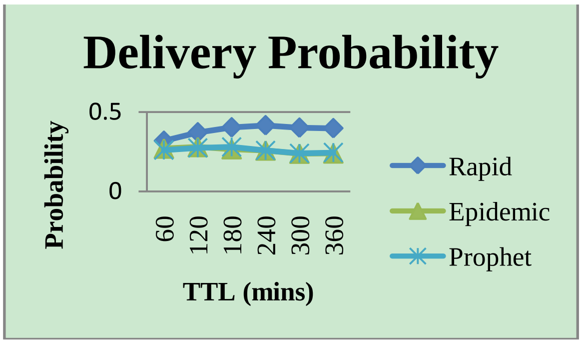

Fig. 3. Delivery probability of considered routing protocols for varying TTL

B. Overhead Ratio

Overhead ratio of RAPID routing protocol decreases marginally from 58 packets to approximately 41 packets (Fig 4.), whereas the overhead ratio of Prophet and Epidemic routing protocol increases as the message TTL is increased. Overhead ratio of RAPID routing protocol is higher than Prophet routing protocol when the message TTL is less than 100 minutes. But as the message TTL increases the overhead ratio of RAPID routing protocol decreases. In complete scenario the overhead ratio of RAPID routing protocol is approximately 50% less than the Prophet and Epidemic routing protocols.

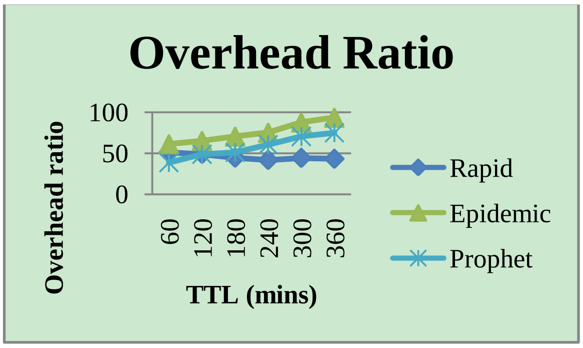

Fig. 4. Overhead ratio of considered routing protocols for varying TTL

C. Average Latency

From the Fig 5, it is evident that the average latency experienced by the packets in all the three considered routing protocol is same and increases with the increase in the message TTL. This is because as the lifetime of the packet increases the packet has to wait more and more in the buffer before it is either delivered to the destination node or it is being discarded due to lifetime expiry. So the overall latency increases with the increase in the lifetime of the message (i.e. message TTL).

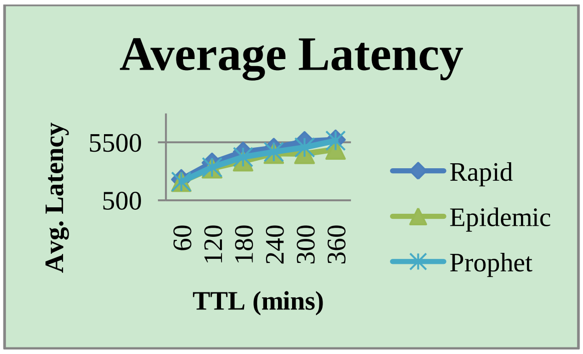

Fig. 5. Average latency of considered routing protocols for varying TTL

V. Conclusion

In this paper we have analyzed the performance of three DTN routing protocols (Epidemic; Prophet; and RAPID) by varying the message TTL. The analysis clearly shows that the RAPID routing protocol gives best results for delivery probability and overhead ratio under the considered scenario whereas the Average Latency being experienced by the messages is almost comparable in all the three considered routing protocols. So among the considered routing protocols the RAPID routing protocol gives the best performance in the given set of conditions and considered scenario.

In future we would like to further explore the performance of other routing protocols and these routing protocols in more adverse scenarios. Also It will be interesting to see the effect of malicious nodes on the performance of these routing protocols.

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