Performance Evaluation of Delay Tolerant Network Routing Protocols

Vijay Kumar Samyal
Punjab Technical University
Jalandhar, Punjab, India

Sukvinder Singh Bamber
Department of CSE
Panjab University SSG
Regional Centre, Hoshiarpur,
Punjab, India

Nirmal Singh
Punjab Institute of Technology
Hoshiarpur
Punjab, India

ABSTRACT
The performance analysis of different Delay Tolerant Networks (DTNs) routing mechanisms plays a key role in understanding the design of DTNs. It gives the capacity to describe the conduct and execution of routing protocols, which encourages one to choose proper routing protocol for the application or the system under control. DTNs routing protocols have differ in the knowledge that they use in making routing decision and the number of replication they make. The performance of different DTNs routing protocols (i.e., Direct Delivery, First Contact, Epidemic, Spray and Wait, Prophet and MaxProp) are compared under the various mobility models like Random Waypoint (RWP) model, Map-Based Mobility (MBM) Model, the Shortest Path Map-Based Movement (SPMBM) model and Random Walk (RW) model. Among these protocols, the first four routing protocols do not require any knowledge about the network. The latter two protocols use some extra information to make decisions on forwarding.

General Terms
Performance, Experimentation.

Keywords
Delay Tolerant Networks (DTNs), Routing Protocols, Mobility Models, Opportunistic Network Environment (ONE)

1. INTRODUCTION
A Delay Tolerant Networks (DTNs) is a sparse dynamic wireless network where mobile nodes work on ad hoc mode and forward data opportunistically upon contacts [1]. Since the DTN is sparse and nodes in the network are dynamic, the irregular connectivity makes it difficult to assurance an end-to-end path between any nodes pair to transfer data and long round trip delays make it impossible to provide timely acknowledgements and retransmissions. The communication of nodes can only be made possible when they are in the communication range of each other. When a node has a copy of message, it will store the message and carry it until forwarding the message to a node in the communication range which is more appropriate for the message delivery. Since DTNs allow people to communicate without network infrastructure, they are widely used in battlefield, wildlife tracking, and vehicular communication etc. where setting up network infrastructure is almost impossible and costly [2]. In recent years, with the propagation of social network applications and mobile devices, people tend to share texts, photos and videos with others via mobile devices in DTNs.

Figure 1 shows a sample DTN. It depicts the network topology snapshots over three different time periods t1, t2 and t3 (t1 < t2 < t3). Node mobility leads to several pairs of nodes moving into communication range (e.g., node A and B cannot communicate at t1, but they run into communication range at t2) or moving out of communication range (e.g., node C and D are in communication range at t1 and t2, but they become unreachable at t3).

Therefore, the stable end-to-end path does not exist between any pair of nodes. The communications between a pair of nodes are often disrupted due to unstable connections. Besides, if a node wants to send a message to another node, it may suffer from large delay. This is because the data transmission between any pair of nodes requires being in the communication range. However, DTN does not guarantee that two nodes are in communication range permanently. It may take a long time period for two nodes to move into communication range. Thus the communication delay between two nodes is longer than wired networks. For instance, if source node A needs to send a message to destination node E in the sample DTN (Figure 1.), it can only deliver the data to node E at t3 when they are in communication range at this time period.

In this paper we evaluate the performance of different DTN routing protocols i.e., Direct Delivery, First Contact, Epidemic, Spray and Wait, Prophet and MaxProp in different mobility models. The performance of these routing protocol are evaluated on the three different metrics namely Delivery Probability, Average Delivery Latency, Overhead Ratio. The detailed simulation setup and metrics is given in section 3. The rest of paper is structured as follows: section 2 gives the introduction of the routing protocols in DTN. Section 4 gives the details of simulator and section 5 gives the simulation setup used in paper for performance evaluation. Section 6 discusses the results. Section 7 concludes the paper and lists the directions for future work.

2. ROUTING PROTOCOLS IN DTN
DTN routing is the core issue in the DTN study, because of intermittent connectivity, dynamic network topology and limited resources and so on characteristics. DTN routing protocol adopt the "store-carry-and-forward" paradigm. If there is no node in the communication range then the current node store and carry the data until it encounter other node. Several routing and data disseminating techniques have been proposed over the past few years (refer [3] and [4] for overview).

T. Spyropoulos et al. [5] & A. Keränen et al. [6] define Direct Delivery & First Contact single-copy DTN routing protocols. In Direct Delivery (DD) routing protocol source node send a message to the destination, the message is kept in the source node until it comes in contact with the

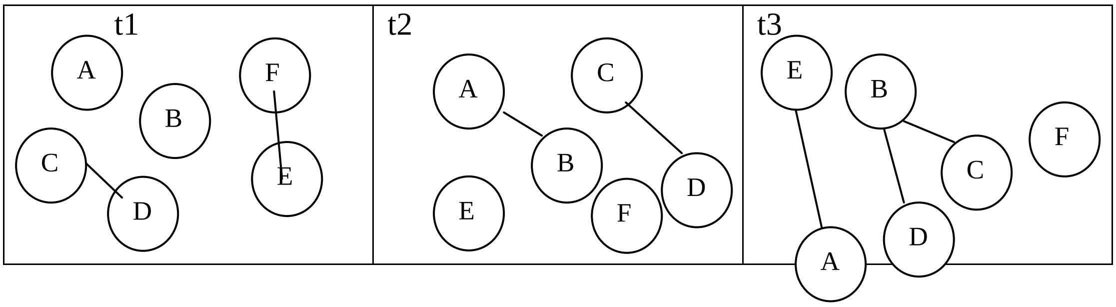

Figure 1. A solid line represents connectivity between two nodes

destination node. In First Contact, the message is forwarded to the node which encounters first and deleted, being forwarded until it reaches the destination.

Epidemic routing protocol (A. Vahdat and D. Becker [7]) is an unlimited-copy routing protocol and used flooding-based paradigm. In this routing protocol message is disseminated to all the nodes in the network. They exchange only that message which have not present in their buffer, when pair of nodes encounter. Overhead gets high due to more utilization of buffer space but delivery probability gives good value.

Spray and Wait is a n-copy routing protocol presented by T. Spyropoulos et al. [9]. The protocol is categorized into two phases i.e., spray phase and wait phase. In the spray phase message is created at the source node, n copies of that message are disseminated by the source node and possibly received by other intermediate nodes. In other wait phase, every intermediate node containing a copy of message and simply holds and carry that particular message until the destination node is encountered directly. There are two versions of this routing protocol, first is Spray and Wait and second is Spray and Wait Binary mode.

In normal mode, a node gives one copy of the message to each node encountered that does not have same copy. In Spray and Wait Binary mode (SaWBinary), half of the n copies to the first node encountered and that node transmits half of the copies to the one it encounters first this process is continue until one copy is left with the node.

Prophet (Probabilistic routing protocol using history of encounters and Transitivity) is implemented by A. Lindgren et al. [8]. It is also known as an unlimited-copy routing protocol or flooding-based. It calculates the probabilistic metric called delivery predictability. The message forwarding in this routing protocol is based on the probability of node’s contact with another node. The message is delivered to another node if it has better delivery predicatability as compared to other nodes.

MaxProp is an unlimited-copy or flooding based routing protocol introduced by J. Burgess et al. [2]. Similar to epidemic routing, it transfer all the messages not held by other node buffer, when it is in communication range. The message relay decision depends on the probability of two nodes will encounter soon the destination. According to encounter probability message should be dropped from the node buffer space when it is almost full.

3. PERFORMANCE METRICS

This section assesses the performance of different DTN routing protocols. The DTNs routing protocol need to tolerate delays resulting from the tested environment and the main requirement of such protocols is that the messages are reliably delivered. In this paper, the performances of various DTN protocols are evaluated based on the metrics like delivery ratio, average delivery latency and overhead ratio under different mobility models. These metrics are defined as follows [12]:

- **Delivery probability:** It is defined as the ratio of the number of messages actually delivered to the destination and the number of messages sent by the sender.
- **Average delivery latency:** It is defined as the average of time taken by all messages to reach from source to destination.
- **Overhead ratio:** It is defined as the ratio of difference between the total number of relayed messages and the total numbers of delivered messages to the total number of delivered messages.

4. THE ONE SIMULATOR

Simulation plays an important role in analyzing the performance of DTN routing protocols. There are numerous simulators available like NS-2 (Network Simulator, 2000), DTNSim (Delay Tolerant Network Simulator), OMNet++, OPNET and ONE. The ONE is preferred among the simulators because it supports the DTN characteristics. The NS-2 simulator only supports Epidemic routing whereas DTNSim lacks in movement models. OPNET and OMNet++ have limited support for available DTN routing protocols. The ONE simulator is a discrete event based simulator. It is a java-based tool which provides DTN protocol simulation capabilities in a single framework. A detailed description of The ONE simulator is available in [10] and ONE simulator project page [11] where source code is also available. The overview of ONE simulator [11] with its elements and their interaction are shown in Figure 2.

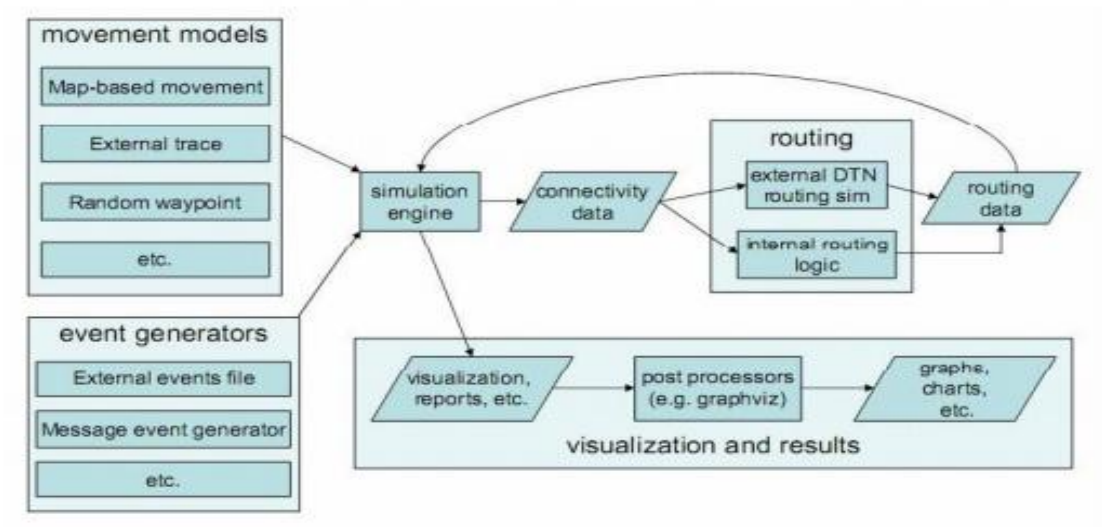

Figure 2. Overview of the One Simulator Environment [11]

5. SIMULATION SETTING

Simulation scenarios are created by defining simulated nodes and their characteristics. The simulation parameters are mentioned in Table 1. The simulation is modeled as a network of mobile nodes positioned randomly within an area (4500 x 3400 m^2). The transmission range for each node is set as 250 m with a chosen transmission speed of 2Mbps. The simulation length is 720 minutes. An event generator generates messages of size 500 KB with one new message created at an interval of every 10-15s.

Table 1. Simulation parameter setting

Parameters	Values
Number of Nodes	50
Transmit Range(m)	250
Transmit speed (Mbps)	2
Node Speed (km/hr)	10-50
TTL of message (min)	120
Buffer size	infinite
Movement Model	Random Waypoint Model (RWM), Map-Based Mobility (MBM) Model, Shortest Path Map-Based Movement (SPMBM) model and Random Walk (RW) model
Simulation Time(min)	720

6. RESULTS

The effects of variation in mobility models on the performance of different routing protocols like Epidemic, Spray and Wait, Direct Delivery, First Contact, Prophet and MaxProp protocols are evaluated. The results of performance metrics are presented in the form of graph.

6.1 Effects of Mobility Models

The effects of mobility models variation is the key factor of performance evaluation on the DTN routing protocol. Message delivery performance mainly depends on the encounter pattern. When the network is sparse the node mobility is an important factor. Node mobility is characterized by movement of nodes and its speed. In the performance evaluation, the node speed is kept constant and only structure of mobility is changed through standard mobility models. The performance of different routing protocols are compared under the various mobility models like Random Waypoint (RWP) model, Map-Based Mobility (MBM) Model, the Shortest Path Map-Based Movement (SPMBM) model and Random Walk (RW) model. In RWP model nodes move randomly to a random destination whereas MBM define node movement to predefined paths and routes are derived from real map data. The SPMBM is similar to MBM but instead of moving randomly, it uses Dijikstra’s shortest path to calculate the shortest path from source to a random destination and follows the shortest path. Figures 3 to 5 depict the effects of mobility models on delivery ratio, average delivery latency and overhead ratio respectively.

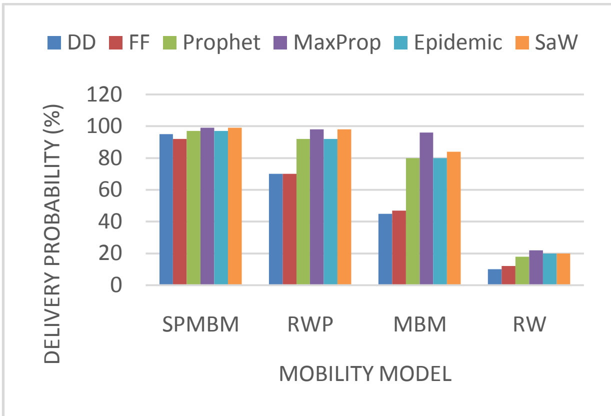

Figure 3. Delivery probability vs. mobility models

It is observed from the results as in figure 3 that the mobility models have significant impact on the delivery ratio of routing protocols. The protocols studied so far are not suitable for RW model. So the Random Walk model is not preferred for further discussion. MaxProp routing is the only protocol which performs equally well in all kinds of mobility models. Though Spray and Wait, Epidemic and Prophet performs equally well in SPMBM and RWP models, they experience a slight degradation of 12% in delivery ratio in MBM model.

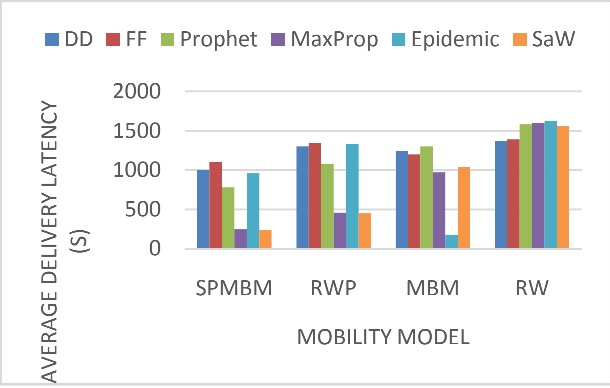

Figure 4. Average delivery latency vs. mobility models

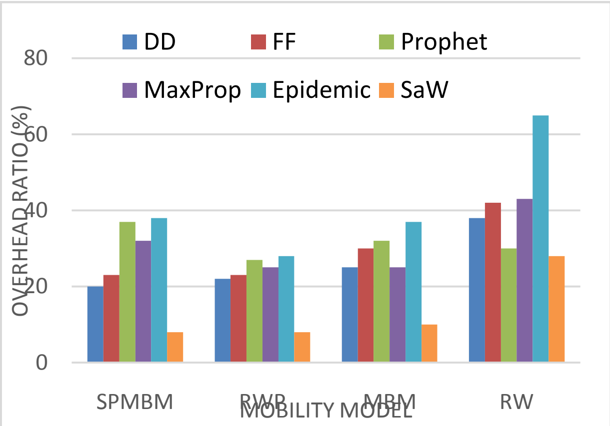

Figure 5. Overhead ratio vs. mobility models

It is concluded from the results shown in figure 4 that all routing protocols have the less delivery latency when the nodes follow SPMBM model. This is due to the fact that in SPMBM model, the nodes use shortest path to reach the destination. The results depict that among all routing protocols, the Spray and Wait and MaxProp routing have least delivery latency when nodes follow SPMBM and RWP model due to their individual characteristics. It is inferred from graph plotted in Figure 5 that only Spray and Wait has least overhead among all the routing protocols. As mentioned earlier, it is due to the fact that Spray and Wait routing restricts the number of replication of the messages which does not differ with the structure of mobility.

7. CONCLUSION

The paper concludes that the impact of mobility models on different DTN routing protocols. It is inferred from the above results that Spray and Wait, Epidemic and Prophet performs equally well in SPMBM and RWP models, they experience a slight degradation of 12% in delivery ratio in MBM model. In case of delivery latency, SPMBM mobility model have less delivery latency among all routing protocols because the node use shortest path to reach destination. In case of overhead, Spray and Wait protocol have least overhead among all the routing protocols. In future we investigate the impact of selfishness behavior of nodes in sparse network and how to reduce this selfishness in term of buffer size in different DTN routing protocols.

8. REFERENCES

[1] K. Fall, “A Delay-Tolerant Network Architecture for Challenged Internets,” Proc. On Applications, Technologies, Architectures and Protocols for Computer Communications (SIGCOMM), New York, USA, 2003, pp. 27–34.

[2] J. Burgess, B. Gallagher, D. Jensen, and B, Levine, “Maxprop: Routing for Vehicle-Based Disruption-Tolerant Networks,” Proc. 25th IEEE International Conference on Computer Communications, Barcelona, Spain, 2006, pp. 1–11.

[3] Z. Zhang, “Routing in intermittently connected mobile ad hoc networks and delay tolerant networks: Overview and challenges,” IEEE Communication Surveys and Tutorials 8, vol. 4, 2006, pp. 24-37

[4] L.Pelusi, A. Passarella, and M. conti, Opportunistic networking: Data forwarding in disconnected mobile ad hoc networks,” IEEE Comm. Magazine, 2006.

[5] T. Spyropoulos, K. Psounis, and C. S. Raghavendra, “Single-copy routing in intermittently connected mobile networks,” Proc. 1st Annual IEEE Communications Society Conference on Sensor and Ad Hoc Communications and Networks, IEEE SECON-‘04’. 2004.

[6] A. Keränen, et al., “The ONE Simulator for DTN Protocol Evaluation,” Proc. 2nd International Conference on Simulation Tools and Techniques (Simutools'09), Belgium, 2009.

[7] A Vahdat, D. Becker, “Epidemic Routing for Partially Connected Ad Hoc Networks,” Technical ReportCS-200006, Duke University, 2000.

[8] A. Lindgren, et al., “Probabilistic Routing in Intermittently Connected Networks,” Proc. SIGMOBILE Mob. Computer. Commun. Rev. 7, 3. 2003, pp. 19-20.

[9] T Spyropoulos, K. Psounis, and C. S. Raghavendra, “Spray and Wait: An Efficient Routing Scheme for Intermittently Connected Mobile Networks,” Proc. ACM SIGCOMM workshop on Delay-Tolerant Networking (WDTN ’05) ACM, New York, NY, USA, 2005 pp.252-259.

[10] A Ker¨anen, “Opportunistic network environment simulator. Special assignment report, helsinki university of technology,” Department of Communications and Networking, May 2008.

[11] Tkk/Comnet. Project page of the ONE simulator. [Online]. Available: http://www.netlab.tkk.fi/tutkimus/dtn/theone, 2009.

[12] V. K. Samyal, S. S. Bamber and N. Singh, “Impact of Buffer Size on Delay Tolerant Network Routing Protocols,” Proc. Australian Journal of Information Technology and Communication, Vol. II Issue I., 2015, pp. 44-47.