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Effect Of The Number Of Messages On The Performance Of Delay Tolerant Networks For Few Mobility Models

Sumit Kumar[1], Md. Ashraful Islam[2], Md. Firoz Ahmed[3], Md. Mazedur Rahman[4]
[1,4]*(Department of ICE, University of Rajshahi,Rajshahi,Bangladesh)*
[2,3]*(Assistant Professor, Department of ICE, University of Rajshahi,Rajshahi,Bangladesh)*
Corresponding author Sumit Kumar

ABSTRACT : *Delay Tolerant Networks (DTNs) are the class of wireless ad hoc networks used to enable communication in such challenging environment where, usually at any given instance of time, there is a low probability of having a complete path from source to destination. Therefore, DTN is characterized by intermittent connectivity, long or variable delay, asymmetric data rate, and high error rates. In this paper we have investigated the performance of four mobility models, namely Random Direction (RD), Random Walk (RW), Random Waypoint (RWP), and Shortest Path Map Based (SPMB) movement over four different DTN routing protocols namely: Epidemic, PRoPHET, Binary-Spray-And-Wait(B-SNW) and Spray-And-Focus (SNF). We have used Opportunistic Network Environment (ONE) simulator as the simulation tool for evaluating the performance in the opportunistic environment. The performance is analyzed under three performance metrics: Delivery Probability, Overhead Ratio, and Average Latency. From the simulation results, it is observed that the SPMB movement model is the best mobility model for all DTN routing and RW mobility model is the worst mobility model in the considered scenario and setting.*

KEYWORDS –*DTN,SPMB, RD, RW, RWP,Opportunistic Network Environment (ONE) simulator*

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I. INTRODUCTION

Nowadays we can share our thoughts, data, and information within an instance of time throughout the world via infrastructure-based networks (cellular, WLAN). This traditional communications system uses TCP/IP protocol. In TCP/IP model, at least one continuous end-to-end path must be guaranteed between the source node and the destination node [1][2]. Local connectivity among the devices may additionally be obtained by forming ad-hoc networks since the mobile devices are virtually turned on and have the necessary radio interfaces, processing power, storages capacity and battery lifetime to act as a router [4]. Delay Tolerant Networks (DTNs) are the class of wireless ad-hoc networks where no end-to-end path exists between the source and the destination node for a long period of time [3]. There are many routing schemes that have been developed for ad-hoc networks in the recent past but none of these applicable for DTNs because DTNs can be characterized by their lack of connectivity due to node mobility and dynamic topologies, network partitions, unbalanced data rates, long variable delays, and high bit error rate of transmission medium [1]. Therefore, DTNs are as Opportunistic Networks, and such environment is termed as denied and hostile environment. DTNs use store-carry-forward approach to deliver packets from source to destination. In this approach an intermediate node receives a packet, then the node stores the packet in its buffer and waits until the encounter with the next intermediate nodes. This mechanism is known as store-carry-forward approach [3]. DTN applications examples are satellite communication networks, sparse mobile ad-hoc networks, wildlife tracking sensor networks, military battlefield networks, exotics media network. DTNs can also be widely applicable for underwater communications, fire tracking, and so on.

The rest of the paper is organized as follows: Section II gives an overview of DTN routing protocols. Section III includes the description of mobility models used in DTN. Section IV represents the introduction of simulator, simulation environment setup and performance metrics. Section V provides analysis of obtained results and finally, section VI indicates the conclusion and future works.

II. ROUTING PROTOCOL IN DTN

This section contains the overview on the classification of DTN routing schemes, and a brief description of the design of replication-based DTN routing protocols namely Epidemic, PRoPHET, Spray-and-Wait, and Spray-and-Focus.

Routing is very important factor in delay tolerant networks as there is a limited memory to store message and forwarding it to its destination. Standard routing protocols require an end-end path. But DTN tries to find the best path from the few available paths. Thus, DTN is designed for more practical scenarios. Routing protocols in DTN are classified into two categories as described in [5], i.e., replication based and knowledge-based protocols.

A. Epidemic

Epidemic routing is the first developed DTN routing protocol. Epidemic routing protocol is based on flooding mechanism in nature. This protocol blind replicates the message copies in the network. This ensures higher delivery probability but it is a resource consuming protocol as large number of messages is present in the network. Also, it creates congestion in the network.

B. Probabilistic Routing Protocol Using History of Encounters and Transitivity (PRoPHET)

In order to improve the delivery probability and proper utilization of network resources than epidemic routing protocol, earlier in 2004, A. Lindgren, A. Doriaetet al.,proposed probabilistic routing protocol using history of encounter and transitivity (PRoPHET). In PRoPHET, messages are forwarded based on the calculation of probability (also called delivery predictability) by each node to each destination node. When nodes are encountered with each other, messages are delivered to the node which has the higher delivery probability. Delivery probability is managed by an internal delivery vector and gets updated whenever nodes meet each other.

C. Spray-and-Wait (SNW)

SNW routing protocol produces an improvement over epidemic routing protocol by limiting the number of messages spreading in the network. Like epidemic routing protocol, spray-and-wait routing protocol requires no knowledge of network topology and node mobility. The difference is that it spreads only L copies of the messages [6]. This protocol has two phases: spray phase and wait phase. In spray phase, each message originating at the source, initially L message copies are distributed by the source and possibly other nodes receiving a copy to L distinct relays. In wait phase, each node which has message copy waits for direct transmission rather than sparing message.

D. Spray-and-Focus (SNF)

Simple spraying schemes proposed in [7], generate and distribute ("spray") a small, fixed number of copies or "forwarding tokens" to a number of distinct relays. This routing scheme eliminates the limitation of simple spraying algorithms. SNF scheme [8, 9], consists of two phases: in the first phase it distributes a fixed number of copies of the message to the few nodes encountered, and in the second phase, the nodes that have message copy wait for direct transmission. If the destination is not encountered, the relay nodes quickly forward the message copy to the immediate neighborhood.

III. MOBILITY MODEL

This section gives an overview of mobility model that is used in this research.

i. Shortest Path Map-Based (SPMB) Mobility Model

The more sophisticated version of the map-based movement model is the shortest path map based movement. This model restricts the node movement in a predefined path from a map. In SPMB model, nodes use the shortest path from all available paths, the shortest path is chosen on the basis of Dijkastra algorithm [10].When nodes have reached the destination, they have to wait for a while and select a new destination.

ii. Random Waypoint (RWP) Mobility Models

Random Waypoint (RWP) mobility model is one of the simplest mobility models in DTN. In this model, the node moves randomly in an arbitrary direction. The moving speed is also assigned to each node from a predefined range, and nodes of a network are independent of one another [11]. It includes pause times between changes in direction and/or speed. Mobile nodes start from one location and then randomly travel any direction.

iii. Random Direction (RD) Mobility Model

Random Direction (RD) mobility models drive nodes up to the boundary of the simulation area before changing direction and speed. The distribution of movement angle in RWP is not uniform [12]. This model is able to overcome non-uniform spatial distribution and density wave problems. In the RD model, the mobile node randomly and uniformly chooses a direction by which to move along until it reaches the boundary with a speed. When the node reaches the boundary of the simulation field, it stops with a pause time. Then it randomly and uniformly chooses another direction to travel.

iv. Random Walk (RW) Mobility Model

Many entities in nature move in extremely unpredictable ways, the random walk mobility model was developed to imitate this erratic movement. This model introduced by Einstein in 1926 [13]. In this model, mobile node moves from its current location to a new location by randomly choosing a direction and speed in which to travel. The new speed and direction are both chosen from predefined ranges, (speedmin; spee max) and (0, 2) respectively. Each movement occurs at either a constant time t or a constant traveled distance d, at the end of which a new direction and speed are calculated.

IV. SIMULATOR

In this paper, we analyzed the performance of Epidemic, PRoPHET, MaxProp, B-SNW, and SNF routing protocols in Delay-Tolerant Networks. All these routing protocols are simulated using Opportunistic Network Environment (ONE) simulator of version 1.6. This section explains ONE simulator, simulation environment setup, and the performance metrics.

i. The ONE Simulator

ONE simulator is an agent-based discrete event simulation engine. A detailed description of the ONE simulator is available in [14]. The ONE simulator project page [15] where the source code is also available. Figure 1 shows an overview of the ONE simulator.

ii. Simulation Environment Setup

Parameters of simulation setup and routing algorithms are specified in table I and Table II respectively. Table I shows the simulation configuration of routing algorithms. Table II shows the simulation configuration for analyzing the performance metrics by varying message generation rates i.e., 2, 3, 4, 5, 7.5, 10for each mobility models i.e., RW, RD, RWP, and SPMB respectively.

TABLE I. PARMETER FOR ROUTING ALGORITHMS

Routing Algorithm	Parameters	Value
Epidemic	N/A	N/A
PRoPHET	Seconds in Time Unit	30
B-SNW	No. of L copies (L)	10
SNF	No. of L copies (L)	10

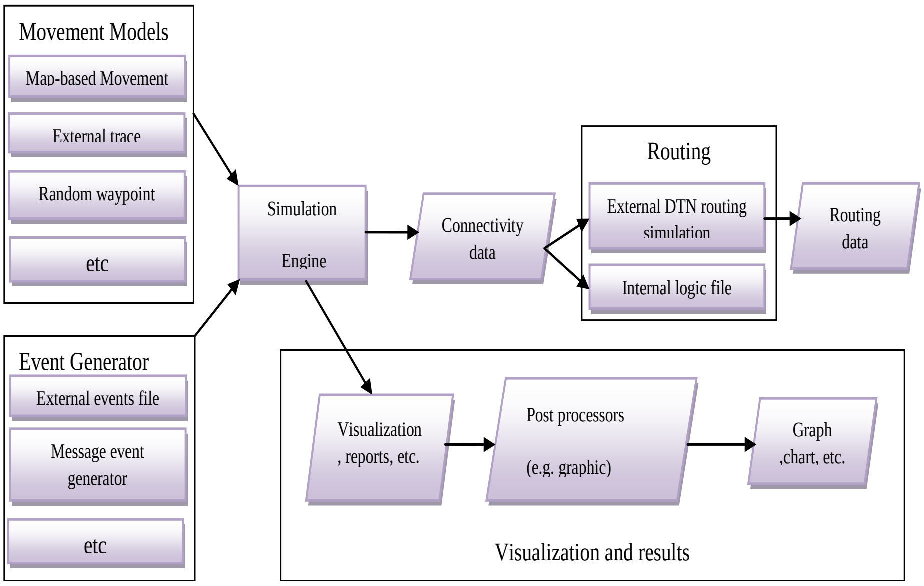

Fig. 1. Overview of an ONE simulator.

TABLE II. SIMULATION ENVIRONMENT PARAMETERS

Parameters	Value
Simulation Time	86400s
Update Interval	1s
Number of Nodes in Group	50
Interface	Bluetooth Interface WiFi Interface High Speed Interface
Interface Type	Simple Broadcast Interface
Transmit Speed	250kbps-1375 kbps
Transmit Range	10-1000 m
Routing Protocols	Epidemic, PRoPHET, B-SNW, SNF
Buffer Size	5 M
Message Generation Rate (message/min.)	2, 3, 4, 5, 7.5, 10
Message TTL	300 minutes
Movement Model	Random Walk (RW), Random Direction (RD), Random Waypoint, and Shortest Path Map Based (SPMB)
Message Size	200 KbB-1 MB
Simulation Area	4500×3400 m

V. PERFORMANCE METRICES

In this paper, the performance of various DTN routing protocols is analyzed according to three performance metrics in the opportunistic network environment, namely: delivery probability, average latency, and overhead ratio.

(a) Delivery Probability

This is the ratio of a total number of packets created to total number of packets delivered to the destination. Mathematically,

Delivery probability=D/G …………………………….(1)

Where, D is a number of messages delivered to the destinations and G is a number of created messages.

(b) Average Latency

It is defined as the average time between messages is generated and when it is received by the destination.

(c) Overhead Ratio

The overhead ratio reflects how many redundant packets are relayed to deliver one packet. It simply reflects transmission cost in a network.

Overhead Ratio=(R-D)/D …………………………………….(2)

Where R is a number of messages forwarded by relay nodes and D are a number of messages delivered to their destination.

VI. RESULT AND DISCUSSION

The purpose of this section is to clearly present the significant effect of mobility model on the performance investigation of DTN routing protocols. The performance is evaluated in terms of delivery probability, latency average and overhead ratio. Data visualization is accomplished primarily through the use of line graphs. DTN network protocol performance is evaluated properly by analysis the simulation result of different mobility model and choosing an appropriate mobility model for this network.

A. Delivery Probability

From Figure 2, it is evident that as message generation rates increases, delivery ratio of packets decreases. The delivery probability of SPMB mobility model has the maximum value and RW mobility model has the worst value for all routing protocols in our considered scenario. Hence SPMB mobility model is the best candidate.

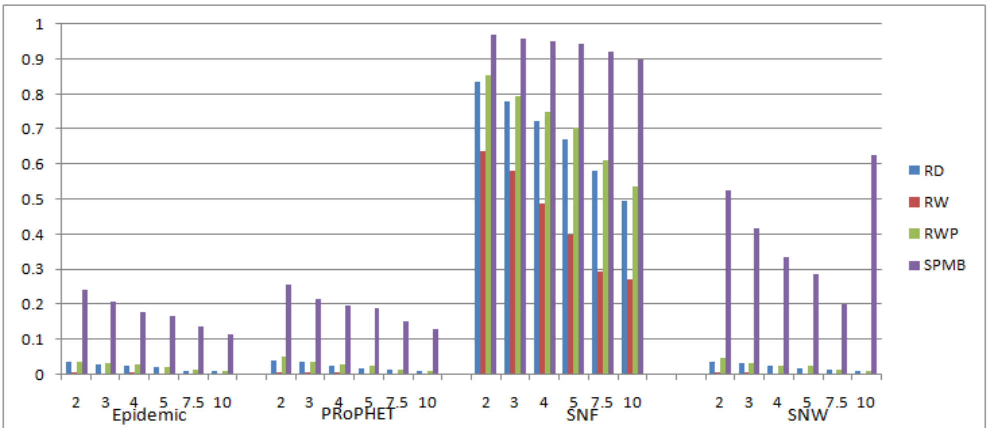

Fig. 2. Message Generation Rates vs. Average Latency.

B. Overhead Ratio

Figure 3, shows overhead ratio with varying message generation rates for four mobility models. The overhead ratio decreases continuously as the message generation rates increases except for random walk mobility model because of their node mobility characteristics. Again, random direction and random waypoint mobility model exhibit minimum overhead ratio compared to other two mobility model. Random walk mobility model has the maximum overhead ratio as compared to other mobility models.

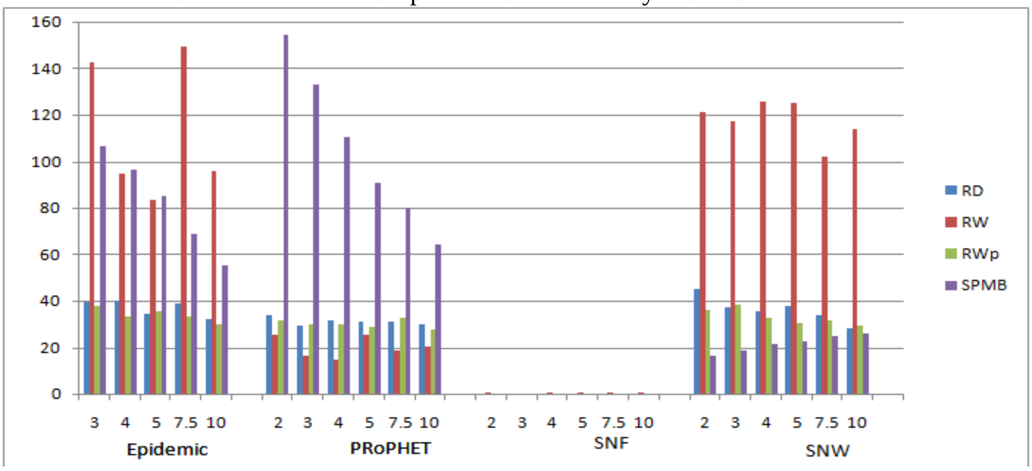

Fig. 3. Message Generation Rates vs. Overhead Ratio.

C. Average Latency

From the figure 4, it is evident that the average latency decreases as the message generation rate increases for all mobility models. SPMB mobility model has the overall minimum average latency than other mobility models and RW mobility model has the overall maximum average latency. Hence SPMB mobility model is the best selection and RW mobility is the worst selection in case of DTN routing.

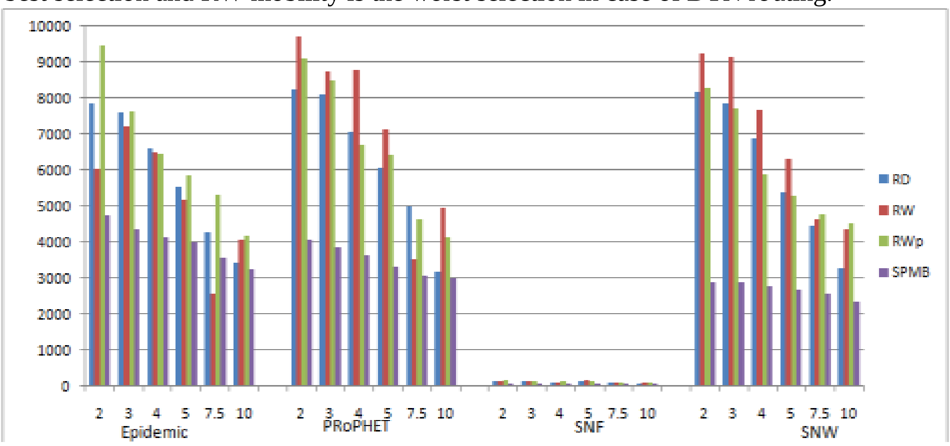

Fig. 4. Message Generation Rates vs. Average Latency.

VII. CONCLUSION

The performance of the above-mentioned DTN routing protocols are evaluated based on four different mobility models namely Shortest Path Map Based (SPMB), Random Direction (RD), Random Walk (RW), and Random Waypoint (RWP) movement model. The simulation results show that Shortest Path Map Based (SPMB) mobility model exhibits the best performance and Random Walk (RW) mobility model exhibits the worst performance against varying message generation rates. Hence SPMB mobility model is the best candidate and RW mobility model is the worst candidate in the considered simulation environment.

Future work is to investigate routing protocols with some other movement models e.g., working day, office activity, map-based, home activity, and evening activity movement models etc. In future try to improve the limitations of mobility models and also try to implement a new mobility model.

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