International Journal of
Sensor Networks and Data Communications

Talukdar and Hossen, Int J Sens Netw Data Commun 2019, 8:1
DOI: 10.4172/2090-4886.1000163

Commentary Open Access

Selecting Mobility Model and Routing Protocol for Establishing Emergency Communication in a Congested City for Delay-Tolerant Network

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Abstract

In recent years, researchers are giving an alarming issue about the natural disaster like earthquake, flooding etc. These situations make the fixed infrastructure being damaged. So, the emergency of urgent communication is necessary to save life and resources which are possible by establishing an adhoc network like delay tolerant network (DTN). This network is featured by sporadic connectivity, long delay, and asymmetric data rates. Under the above scenario, our work contributes to find the right mobility model and routing to reach the first responders in the affected area. For this reason, we have considered a congested city named Dhaka in Bangladesh. In this research, the effects of DTN movement models i.e., shortest path map based (SPMB), random way point (RWP), random Walk (RW), and delay- tolerant routing schemes i.e., epidemic, binary-spray-and-wait (B-SNW), prophet and pray-and-focus (SNF) have been investigated in mobile ad hoc network. For varying buffer sizes and number of mobile nodes, performance metrics like delivery, latency, overhead, hop count, buffer time etc. are estimated. OpenJump and opportunistic network environment (ONE) tools, coded by java, are used to map building and to measure the efficiency of mobility models and protocols. The outcome of this research shows that under this scenario the best suitable routing strategy and movement model is spray-and-focus and shortest path map based movement respectively among the protocols and models considered here based on the simulation environment and parameter settings.

Keywords: Delay tolerant networks; Mobility models; One; Openjump; Simulation; Routing protocols

Introduction

Recently, there is a challenge for all human beings to cope the difficult situation during the disasters like earthquakes, floods etc. So, emergency communication to the affected people at the right time could save many lives and community resources. Actually, under such a situation, the network infrastructures may be damaged. The urgent solution will be to establish a mobile ad hoc network which can tolerate minimum delay that is why we use Delay Tolerant Network (DTN) for such a scenario. However, data transfer with low overhead, high delivery and low latency is the prime concern for any communication networks. These networks may have infrastructure, limited infrastructure or no fixed infrastructure. Based on application scenarios, these structures are applicable. However, having some limitations in traditional ad-hoc [1,2], delay tolerant networks (DTN) [3,4] are introduced which are featured by sporadic connectivity, high transmission error rate and more delays. They follow store-and-forward [4] policy during the transmission of any data source to destination. DTNs have a myriad of emergency application areas including sensor networks [5], military networks [6], interplanetary networks [7] etc. Hence, DTN has emerged as a prime research area. There are many papers on either performance measurement of DTN routing protocols or movement model with the basis of different metrics and different variations. Here, we evaluate the performance of protocols and mobility models concurrently at the single paper. The key motivation behind the paper is better understanding of protocols and mobility models, where they are applicable or not. DTNs routing strategies are classified into two schemes such as single-copy (forwarding based, minimum one copy) and multi- copy (at least two copies). Comparative study [8] of them exhibits that multi-copy (replicating based) ensures better performance than single one which motivates us to experiment on multi-copy protocols. In this research, the effects of three movement models such as SPMB, RWP and RW, and four replicating based routing protocols, namely, epidemic, B-SNW, prophet and SNF on a congested city named Dhaka are analyzed in terms of delivery probability, latency, overhead, hop count and average buffer time with varying buffer sizes and mobile nodes. Actually after sudden disasters, emergency communications become very necessary. In such scenario, it is rarely possible to judge the protocols and movement models immediately for communication. Hence, we evaluate the protocols and movement models, and prepare for urgent communication when necessary. This evaluation is done on a large and congested area, namely Dhaka map. Rest of the paper is organized as follows: section 2 describes about movement models. Section 3 briefly discusses DTN routing protocols considered here. Then, we discuss about simulation tools and simulation parameters settings in section 4. Section 5 depicts graphical results with decent analysis. Finally, section 6 discusses the conclusion with future activity.

Movement Models

Myriad of mobility models [9] have been grown based on synthetic theory and real world mobility traces in DTN environment. In addition, specific application oriented models have also been developed by many researchers. Among them following models are considered in this research.

Shortest path map based mobility

Map based mobility is upgraded into the shortest path map based mobility model [10] where nodes are randomly placed on the map area. All nodes proceed to a specific destination in the map using shortest

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Received February 21, 2019; **Accepted** April 08, 2019; **Published** April 16, 2019

Citation: Talukdar MDI, Hossen MDS (2019) Selecting Mobility Model and Routing Protocol for Establishing Emergency Communication in a Congested City for Delay-Tolerant Network. Int J Sens Netw Data Commun 8: 163. doi: 10.4172/2090-4886.1000163

path technique of Dijkstra strategy. When the nodes reach to the specific destination, they have to wait for a while and choose a new destination.

Random waypoint (RWP)

The activity of RWP [10,11] is same as random walk (RW) [10,12] except it adds the concept of pause times between each movement of a node. A node takes a pause before altering its speed and direction. RWP works similar to RW when pause time is taken zero.

Random walk

In RW [10,12] mobility, the nodes proceed randomly and freely without any constraint. In this model, every node moves towards a new randomly chosen location. The destination, motion, direction etc. are elected independently and randomly of other nodes. RW does not keep the records of previous patterns formed by the motion and place values of nodes.

Routing protocols

This section discusses about the considered DTN routing protocols briefly.

Epidemic

Epidemic [13] is the flooding based replicating routing technique wherein messages are broadcast to all neighbors and forwarded using FIFO policy with unlimited replicas. Replication mechanism ensures that a copy of message replicates to all nodes with no copy in common until it reaches the destination.

Spray-and-wait (SNW)

This routing technique [14] is constructed based on two phases, namely spray and wait that limits the message replications and follows FIFO strategy [15]. Between two versions of it, i.e., binary and vanilla, we choose binary scheme since its message dissemination rate is much faster than the vanilla. Two phases of B-SNW are:

Spray: L message copies are spread to L/2 relays.

Wait: Direct transfer of data to destination.

Prophet

Prophet [16], the extension of Epidemic, computes the delivery predictability of each node by measuring the shortest path. A node carrying higher delivery compared to other, delivers message copies to all neighbors.

Spray-and-focus (SNF)

This routing [17] is also made of two phases: spray and focus. The relay node in spraying scheme is responsible for forwarding messages to the number of different nodes. In Focus scheme, the relay will convey the copy and move to another until the destination node or TTL of the message is up. It uses utility based routing [18] strategy.

Simulation tools and simulation environment settings

Two simulation tools, namely Open Jump and ONE simulator are used in this work.

OpenJump

OpenJUMP [19] is java based free open source geographic information system (GIS) program used to read the Dhaka road map. In this work, we have used OpenJump to build Dhaka road map as a fully connected map which was disconnected initially. Even a single disconnected area from the original connected area results that map is not fully connected.

ONE simulator

ONE, written in java, is used to evaluate and imitate the DTN routing techniques in ICMNs and performs inter-node contacts, routing and message handling. It incorporates two running modes [20]: GUI mode and batch mode, and GUI mode is used in this research. It includes myriad of reporting modules which generate reports to show the simulation results. Experimental results are viewed through visualization and reports. The detail of the simulator is available at [20] and source code of ONE is also available on the internet Figure 1 [21].

Simulation settings

This section includes simulation setting parameters and routing algorithms with criteria and variation of buffer sizes and nodes as listed in Tables 1-3 respectively. Apart from different groups of nodes, two groups of nodes such as pedestrians and Cars are considered in our research. Different numbers of message copies, shown in Table 2, are chosen for SNW and SNF.

Performance metrics: Movement models and routing protocols are investigated through the following performance metrics:

i) Delivery probability: Higher delivery is desirable for any networking scenario. It ensures the better performance of a network. De-

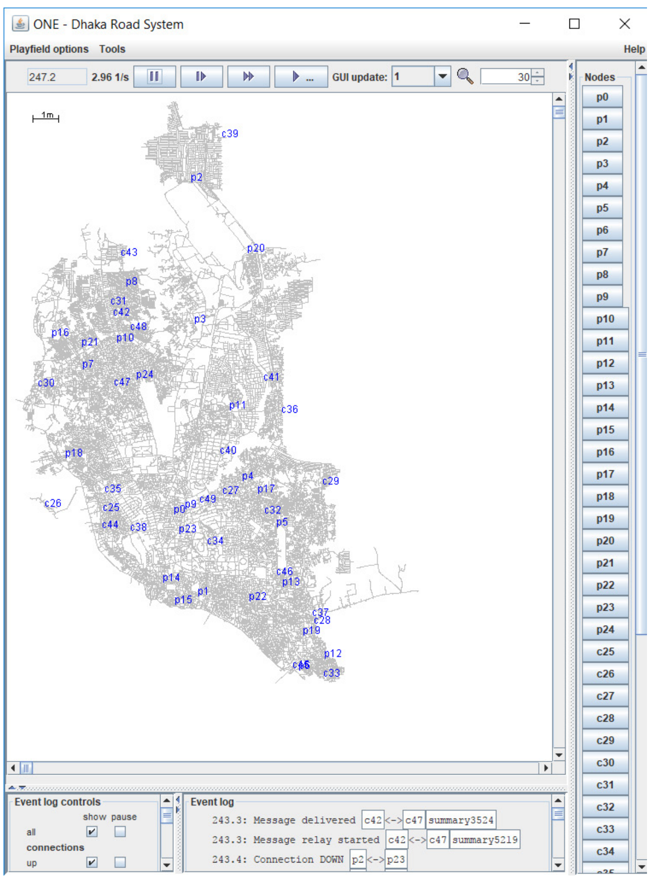

Figure 1: Simulation on Dhaka city scenario using ONE simulator (GUI mode).

Parameters	Values
Simulation time	3600s
Update interval	0.1 second
Number of nodes per group	50
Number of nodes	100
Number of host group Pedestrian' speed Cars' speed Interface Transmit speed Transmit range Routing protocols Buffer size Message sizes Message generation rate Message TTL Movement model Map	2 0.5-1.5 m/s 2.7-13.9 m/s Bluetooth interface 250 kbps 10 m Epidemic, Binary-Spray-and-Wait, PRoPHET and Spray-and-Focus 5 MB 500kB - 1MB 2, i.e., one message in 25-35 seconds 30 min (0.5 h) Shortest path map based, Random Walk and Random Way Point Dhaka road map

Table 1: General Parameters for the Simulation Setup.

Protocols	Parameters	Values
Epidemic	N/A	N/A
Prophet	Seconds in time unit	30s
B-SNW	No. of copies (L)	10
SNF	No. of copies (L)	2

Table 2: Routing Algorithms with Specifications.

Variation of Nodes and Buffers	Values
Fixed No. of node	100
Buffer sizes variation Fixed buffer size	5, 10, 15 and 20 MB 5 MB
Number of nodes variation	50, 100, 150 and 200

Table 3: Variation of Buffer Sizes and Number of Nodes.

livery probability can be estimated as the ratio of the total number of messages sent to the destination over generated at the source.

$$\text{Delivery Probability} = \frac{\text{Total Number of Message delivered}}{\text{Total Number of message sent}}$$

ii) Average Latency: Average latency refers to the average time between messages generated and received by destination node.

$$\text{Average Latency} = \sum_{i=1}^{n} \frac{T_2 - T_1}{\text{Number of messages received}}$$

Here, T_1=Time when message produced and T_2= Time when message received.

iii) Overhead Ratio: Low overhead improves performance. Overhead ratio defines how many redundant packets are relayed to convey one packet. It simply reflects the cost of transmission in a network.

$$\text{Overhead ratio} = \frac{R - D}{D}$$

Here, the amount of messages forwarded by the relay nodes is denoted by R and the number of messages delivered to their destination denoted by D.

iv) Average Hop Count: Hop count indicates the number of intermediate devices or nodes by which data are delivered from source to destination. It provides an approximate measurement of the distance between two given nodes in the network.

v) Average Buffer Time: Average time that the messages stayed in the buffer state at each node is calculated by the metrics known as average buffer time.

Results and Discussion

This section discusses the performances of mobility models and routing protocols in accordance with the buffer sizes and number of nodes.

Delivery probability on SPMB, RWP and RW

Our result shows same performance on delivery ratio for both B-SNW and SNF as shown in Figures 2-4. For varying buffer sizes, we can see that SPMB achieves the highest and RW exhibits the least delivery among the three models. It is also obvious that only SNF performs the best delivery among all routing protocols.

From Figures 5-7, we can see that SNF shows the highest delivery wherein second highest delivery is found for SNW among all protocols for varying mobile nodes. Here, we can see that the protocols perform better delivery on SPMB than RWP and RW model.

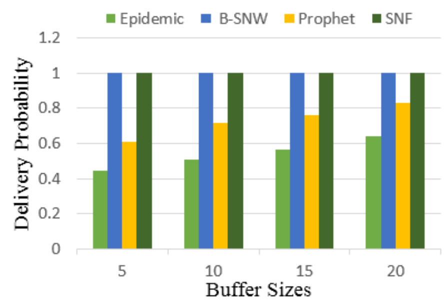

Figure 2: Delivery *vs.* buffer sizes on SPMB.

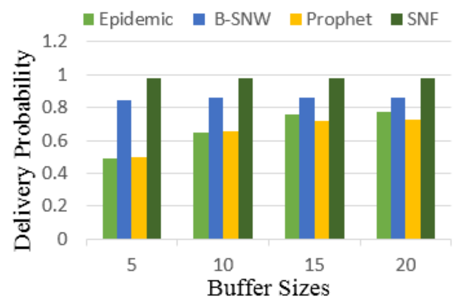

Figure 3: Delivery *vs.* buffer sizes on RWP.

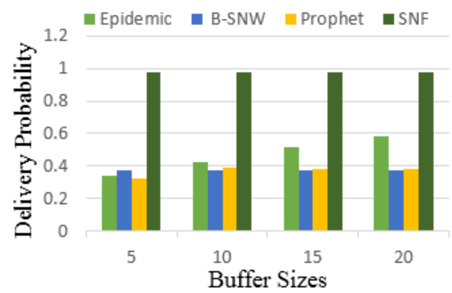

Figure 4: Delivery *vs.* buffer sizes on RW.

Average latency on SPMB, RWP and RW

In SPMB model, latency of SNF is slightly higher than SNW. But, SNF shows the least delay than other routings on RWP and RW models. In SPMB, Epidemic experiences the highest delay than others protocols. On the other hand, Prophet experiences higher latency than others on RWP and RW models. Moreover, it is clear that SPMB outperforms RWP and RW in terms of latency for the variation of buffers as shown in Figures 8-10.

With the variation of nodes, it is clear that SPMB model requires lower delay compared to others as depicted in Figures 11-13. For SNF, delay is very low as compared to others routings as shown in Figures 12 and 13.

Overhead ratio on SPMB, RWP and RW

Limited number of message copies in spray phase lead to low overhead in SNW while least overhead for SNF as it uses utility based routing [18]. Higher dissemination of data compensates for the highest overhead in epidemic protocol.

Figures below illustrate that Epidemic requires the highest overhead compared to others due to its flooding mechanism wherein

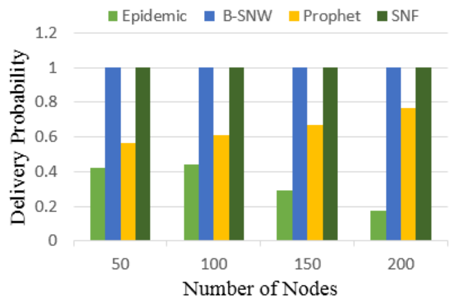

Figure 5: Delivery *vs.* nodes on SPMB.

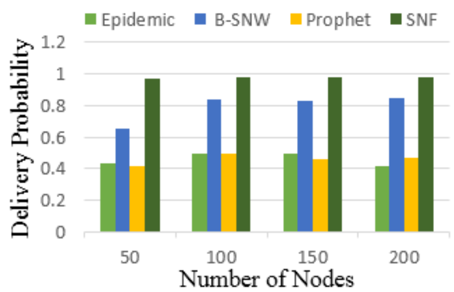

Figure 6: Delivery *vs.* nodes on RWP.

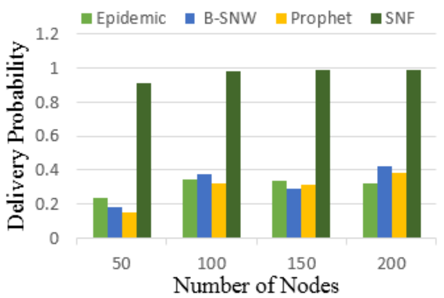

Figure 7: Delivery *vs.* nodes on RW.

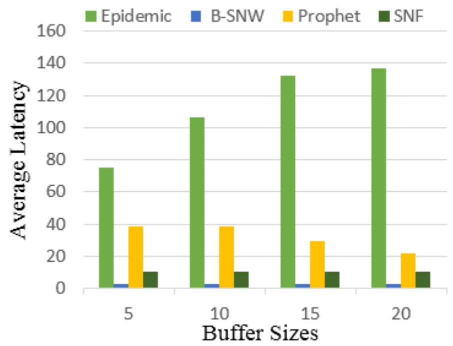

Figure 8: Latency *vs.* buffer sizes on SPMB.

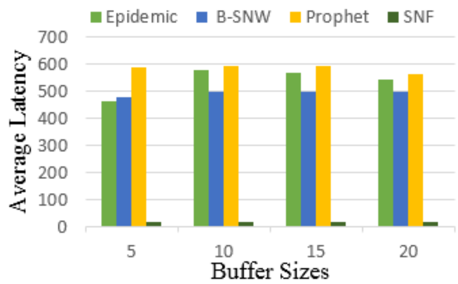

Figure 9: Latency *vs.* buffer sizes on RWP.

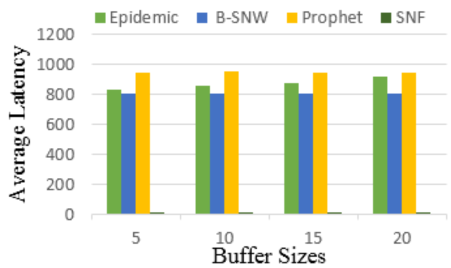

Figure 10: Latency *vs.* buffer sizes on RW.

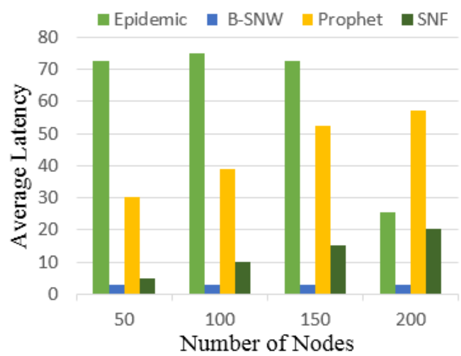

Figure 11: Latency *vs.* nodes on SPMB.

SNW requires low and SNF requires the lowest overhead regardless of both buffers and nodes variation. Here, SPMB requires higher overhead compared to others as its delivery ratio is high Figures 14-19.

Average hop count on SPMB, RWP and RW

Regardless of both buffers and nodes variations, it is clear that SNW

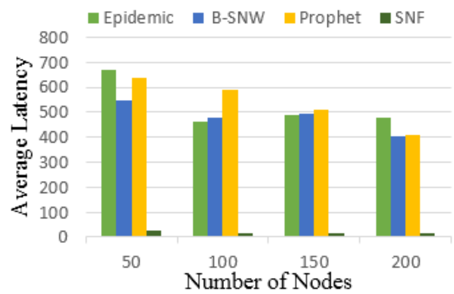

Figure 12: Latency *vs.* nodes on RWP.

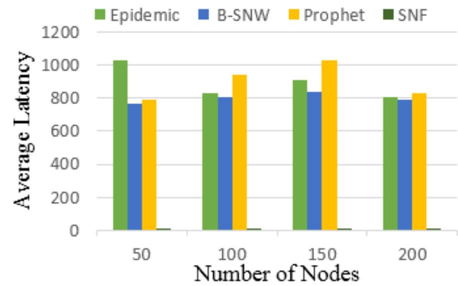

Figure 13: Latency *vs.* nodes on RW.

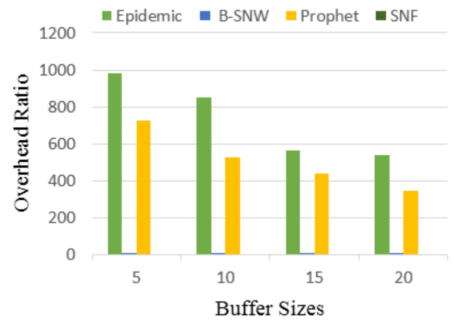

Figure 14: Overhead *vs.* buffer sizes on SPMB.

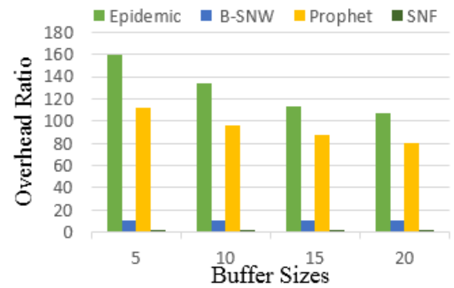

Figure 15: Overhead *vs.* buffer sizes on RWP.

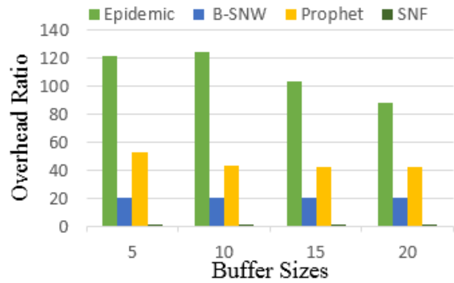

Figure 16: Overhead *vs.* buffer sizes on SPMB.

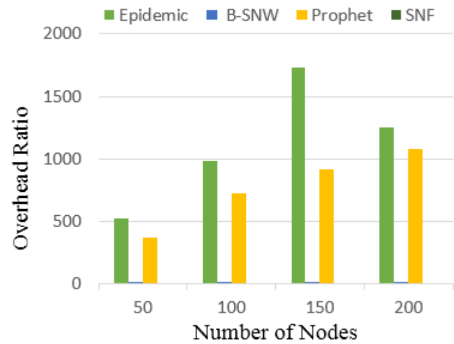

Figure 17: Overhead *vs.* nodes on SPMB.

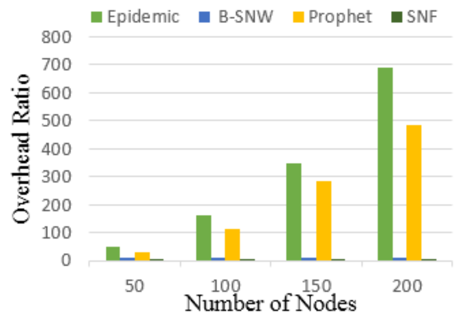

Figure 18: Overhead *vs.* nodes on RWP.

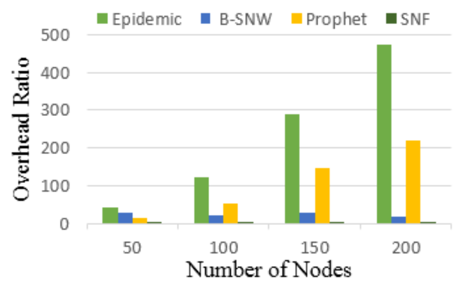

Figure 19: Overhead *vs.* nodes on RW.

and SNF exhibit the least and constant hop count as shown in Figures 20-25. Both protocols count only one hop for successful delivery of message copies in SPMB model. Also, SPMB requires low hop count value compared to RWP and RW.

Above figures undoubtedly depict that SNF protocol delivers message copies with only single hop count.

Average buffer time SPMB, RWP and RW

For varying both buffer sizes and nodes, we can see that SNW protocol shows extremely high buffer time than others and SNF shows the lowest buffer time among the protocols investigated here. It is also obvious that SPMB achieves the least buffer time compared to others Figures 26-31.

Comparison of SPMB, RWP and RW mobility models along with routing protocols

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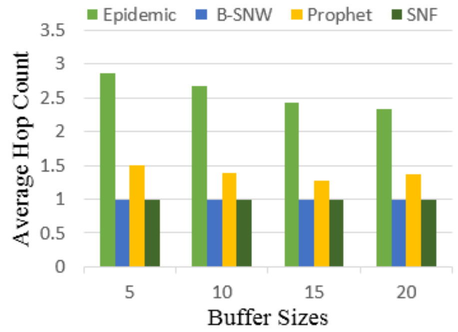

Figure 20: Hop count *vs.* buffer sizes on SPMB.

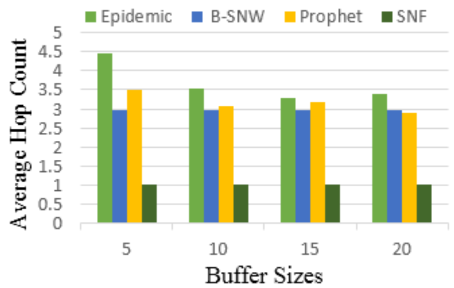

Figure 21: Hop count *vs.* buffer sizes on RWP.

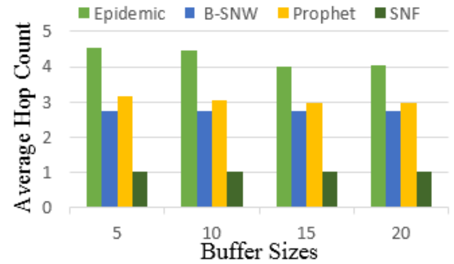

Figure 22: Hop count *vs.* buffer sizes on RW.

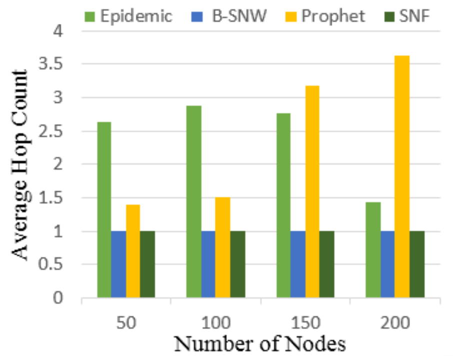

Figure 23: Hop count *vs.* nodes on SPMB.

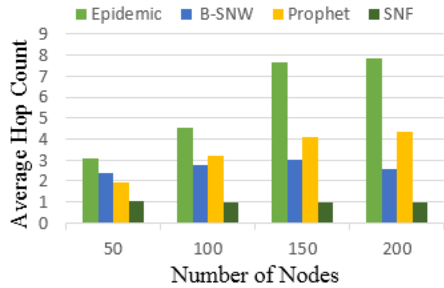

Figure 24: Hop count *vs.* nodes on RW.

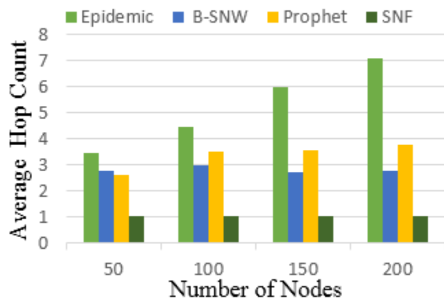

Figure 25: Hop count *vs.* nodes on RWP.

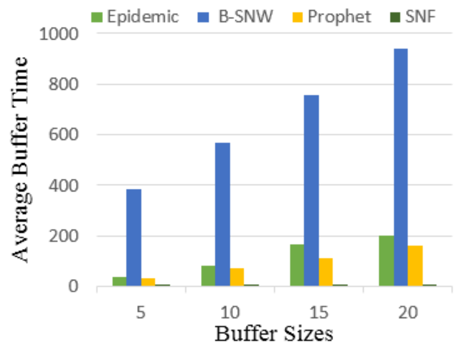

Figure 26: Buffer time *vs.* buffer sizes on SPMB.

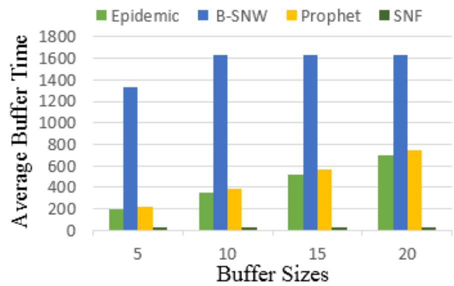

Figure 27: Buffer time *vs.* buffer sizes on RWP.

For varying both buffer size and number of nodes on SPMB movement model, it is obvious that delivery is high, same and constant for SNW and SNF. Above all, SNF routing shows good results for all models regardless of variations and SPMB model ensures maximum delivery among all.

Figures 32-37 depict undoubtedly that SPMB provides very low delay compared to RWP and RW wherein delay is maximum for RW model considering our scenario. SNF exhibits very low delay among all routing strategies with all models.

For varying buffer sizes and number of nodes, SPMB model shows maximum overhead ratio as compared to others. Again, SNF exhibits low overhead while Epidemic requires higher overhead with both variations.

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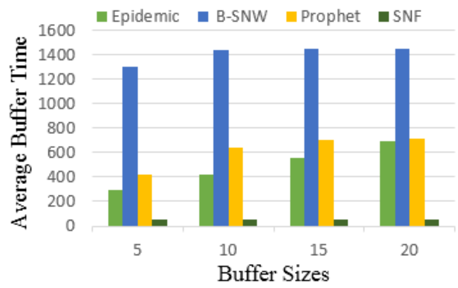

Figure 28: Buffer time *vs.* buffer sizes on RW.

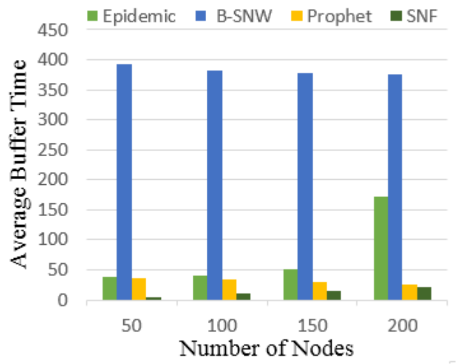

Figure 29: Buffer time *vs.* nodes on SPMB.

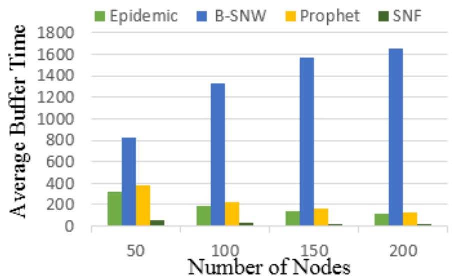

Figure 30: Buffer time *vs.* nodes on RWP.

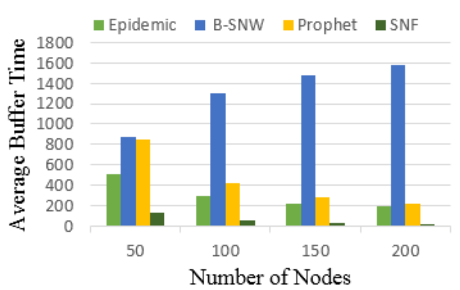

Figure 31: Buffer time *vs.* nodes on RW.

SPMB model shows minimum hop count compared to RWP and RW. Besides, in all cases we see that SNF routing shows the lowest hop count where Epidemic the highest as shown in Figures 38 and 39.

Figures 40 and 41 depict that average buffer time is found lower in SPMB model compared to others. It is also obvious that SNF requires the least buffer time compared to all routing techniques over the models wherein B-SNW needs highest buffer time [22,23].

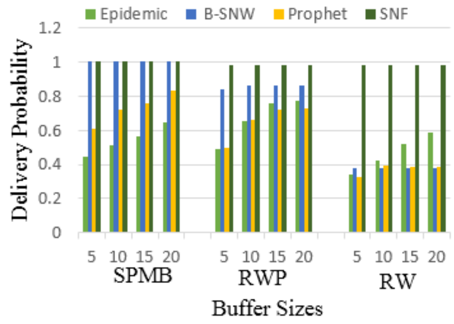

Figure 32: Delivery *vs.* buffer sizes.

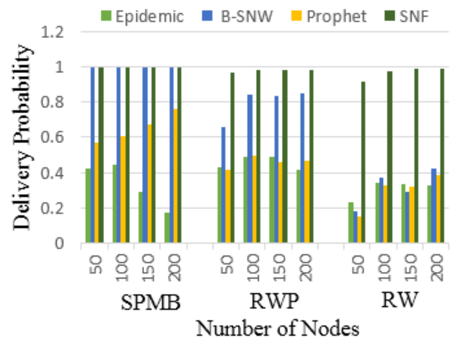

Figure 33: Delivery *vs.* number of nodes.

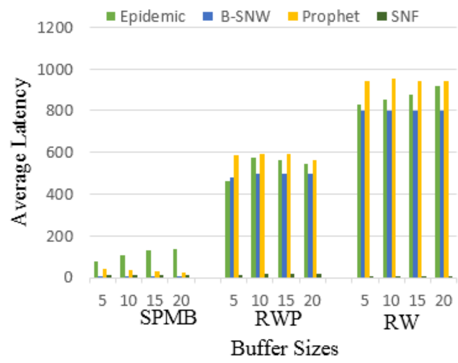

Figure 34: Average latency *vs.* buffer sizes.

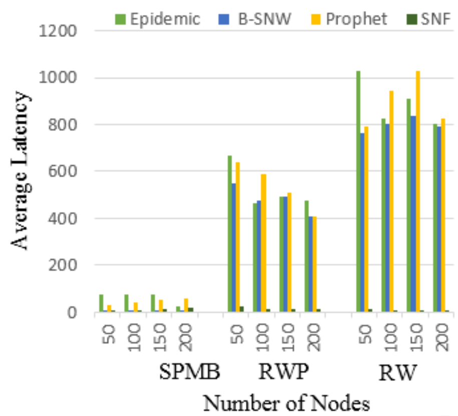

Figure 35: Average latency *vs.* nodes.

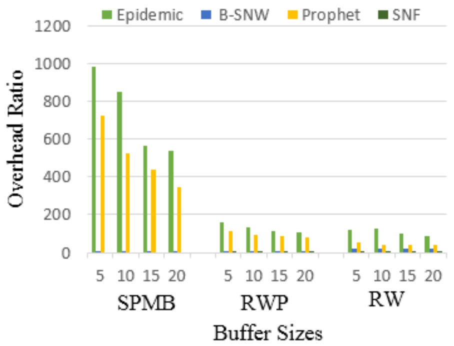

Figure 36: overhead ratios *vs*. buffer sizes.

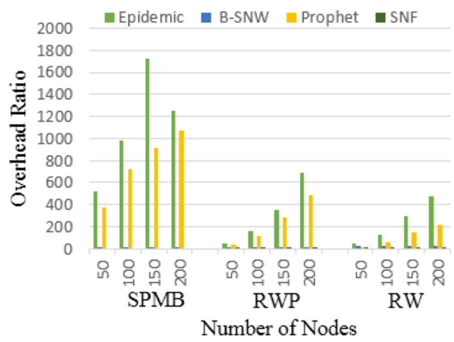

Figure 37: overhead ratios *vs*. nodes.

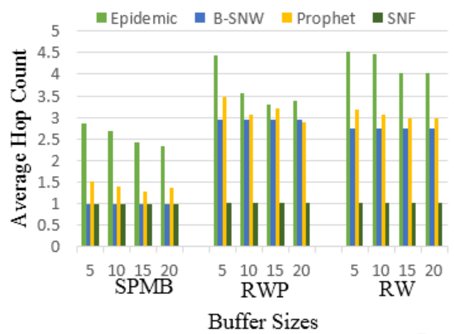

Figure 38: Hop count *vs*. buffer sizes.

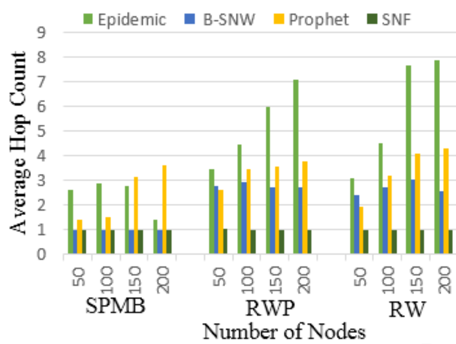

Figure 39: Hop count *vs*. number of nodes.

Conclusion and Future Work

Routing is a key concern of any routing scheme. Also, mobility takes places a vital role in network communication. Performance

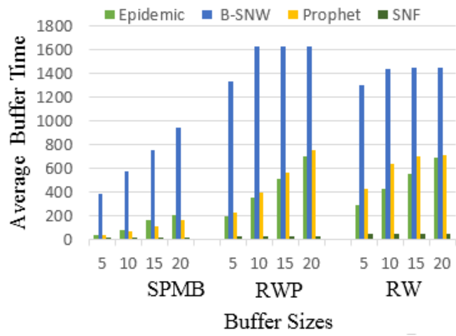

Figure 40: Buffer time *vs*. buffer sizes.

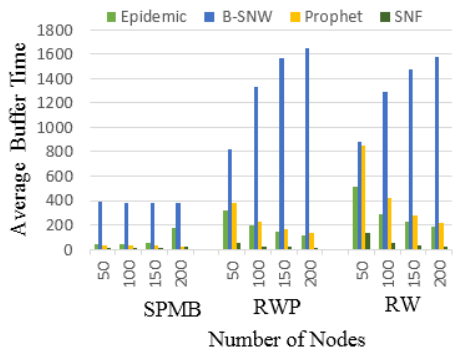

Figure 41: Buffer time *vs*. number of nodes.

of wireless networks greatly depends on both routing schemes and mobility models they used. The efficient protocol and mobility model are required to establish a wireless network. This research evaluates the effects of various movement models such as shortest path map based (SPMB) movement, random way point (RWP) and random walk (RW) movement models, and routing protocols such as Epidemic, B-SNW, PRoPHET and SNF on Dhaka map scenario using ONE simulator in delay-tolerant network through performance metrics i.e., delivery ratio, average latency, overhead ratio, hop count, buffer time etc. with varying both buffer sizes and number of nodes. This work will contribute to choose the routing strategy and mobility model in the emergency communication of the congested city, called Dhaka in Bangladesh at the time of establishing a mobile ad hoc delay tolerant network in such a situation. At emergency scenario, these selected protocol and movement model will help to establish an efficient network quickly. The graphical results with decent analysis state that the best candidate for routing messages on this scenario is spray-and-focus where use of SPMB movement model will be the good decisions to successfully deliver the secret message at the right time.

In this research work, we are just trying to find the best choice of selecting the routing strategy and mobility model. But, there is a chance to send the wrong message to the affected people during or after the disaster. So, we would like to extend this work to send a secure message to the authorized recipient at the due time.

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