A Novel Approach to Improve Delivery Ratio in DTN Routing

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Abstract : Routing in DTNs (Delay Tolerant Network) is a key component in providing and maintaining high performance networking. The main performance metrics are delivery ratio, network overhead, and the average delay. Although many routing protocols have been proposed to provide high performance routing, they were captivated to reducing the delay at the expense of the other metrics. Each node has limited resource in terms of message buffering capability, battery power, as well as processing capacity. This paper presents a novel BSnW+ to improve delivery ratio, latency and network overhead. Moreover, it also demonstrates the performance by varying buffer size.

***IndexTerms* - DTN, routing, ONE, delay, flooding, forwarding.**

I. Introduction

Opportunistic networks or OppNets are designed for operation in environments (such as battlefields, underwater communications, and deep space exploration) characterized by lack of end-to-end connection, large delays, intermittent connectivity, and high error rates. Due to these characteristics, OppNets have present significant research challenges. With the proliferation of wireless mobile devices, OppNets are being used in a wide variety of areas including disaster recovery, military deployment, and wildlife. OppNets encompass different technologies, such as ad hoc networks, wireless sensor networks, peer-to-peer (P2P) systems, grid networks, and delay-tolerant networks (DTN).

The Delay Tolerant Network is totally different approach than regularly connected wired or wireless networks. In DTN, there is no end to end path available at any point of time for transferring data between a pair of sender and destination node. The communication in DTN is done by exploiting the characteristic of nodes i.e. mobility, available connections, and provided buffer space etc. The Delay Tolerant Networks play the main role in the scenario where the routes between any pair of nodes could never be achieved. In sparse network scenario where there are no end to end routes available, like in military battlefields, DTN provides the means to communicate.

It does not require any prior knowledge of networks to forward the bundles from one node to another. It is based upon the store-carry-forward approach. In internet where routing means to choose the best optimal path whereas in DTN routing means to ensure the delivery of bundles to destination with minimum delay incurred. The idea of Delay Tolerant Network (DTN) [1] was taken from Interplanetary Networks (IPN) [2], this was started in 1970s. The IPN was invented to communicate between earth and mars. The DTN is a type of wireless ad-hoc network which tolerates the intermittent connectivity. The intermittent connectivity can be defined as the sudden change of state (up/down) of any communication link between the nodes. The DTN can also be defined as intermittently connected wireless ad-hoc network [3] that can tolerate longer delays, intermittent connectivity and prevent data from being lost by using store-carry-forward approach. The Store-carry-forward approach enables the nodes to take the message, store it in the buffer provided at each node and forward the same whenever new node comes in its communication range.

Some times DTN is confused with MANET [4]. In traditional networks [5], the routing of packets between a pair of nodes aims to select the optimal path with minimum cost incurred. In these networks an optimal route needs to be established before the actual transmission of message. As in DTN the end to end route can never be achieved so the routing [6-8] of packets in DTN is done hop by hop, in which the selection of next hop is done dynamically as per the application scenario as well as the algorithm used. In general, when a node receives any bundle (or message) then as per the algorithm, that node will search the good relay node to which it can forward the bundle. The transmission of message in DTN can either be done by replicating the message or forwarding it, that depends on the type of algorithm used.

In DTN, Self-Delimiting Numeric Value (SDNV) [9] scheme is used which provides the extensibility and scalability in encoding the messages. These extensible messages are given a specific name in DTN called bundles. The format of bundle block contains the Primary Bundle Block and Bundle Payload Block. All the fields in the bundle block are of variable size. In DTN, we need to generate multiple copies of the same message (known as replicas) to forward it to the available relay nodes. The number of replicas [10] created for a message is directly counted as the cost incurred in the delivery of a particular message. The need and distribution of replica can be understood as at a single point of time a node can communicate to all the available active nodes so it would create copies of the message for those particular nodes. Because in DTN, if the relay links are not available then the message get stored in the buffer of sender node so the nodes only generate the replica when the relay nodes are available. So nodes check at the moment that how many relay links are up at the moment and generate the same number of copies. When again a node needs to send a copy to other nodes it will again create the replicas. The replicas can be created at once i.e. on the Source node or can be created distributive i.e. on relay nodes.

Custody Transfer is done by the sender and Custody acceptance is done by the relay nodes and it is the assurance of holding the bundle by the receiving node until it finds any other good relay node or destination to forward it. The node which takes the custody of the bundle is called Custodian. Many custodians can be present in the network for a particular bundle at a particular time.

II. Literature Survey

In the literature of DTN, the routing protocols are categorized into two broad categories:

- Flooding based routing approaches
- Forwarding based routing approaches

In the literature, there exists a variety of routing algorithms for DTN. Here we have discussed some of them.

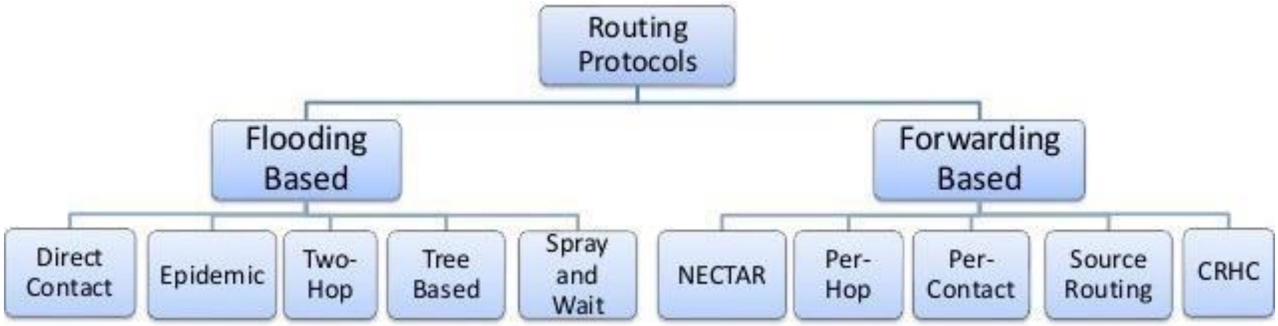

Figure 1 Routing Protocols for DTN

2.1 Flooding based Routing Approach

This type of routing strategy can be opted even when the nodes have no knowledge about the nodes in the network. In such case, epidemic routing algorithm is chosen in which the sender node replicates the message to each node it met so far. Replication based routing can comparatively give better results but it consumes more network resources because for a single message to be delivered the whole network could be holding so many copies of that message. The Flooding based routing is further classified into two types:

•Replication Based: Replication based routing allows the network nodes to create the replicas of the received message. The maximum number of replicas generated within a network for a particular message could be n-1, where n denotes the number of nodes in the network.

•Quota Based: In Quota based routing each message is assigned with fixed quota i.e. the number of replicas for a particular message is limited.

Direct Contact

In Direct Contact [11] routing algorithm, the source node will directly forward the bundle to the destination node. The source node first creates the bundle and then waits for the destination node. As the algorithm does not require any information about the network so it falls in the category of flooding based routing. The amount of delay incurred in delivery of bundle is very high and the cost involved in routing the bundle is very low.

Epidemic Routing

In Epidemic routing [12] each node replicates the message to every other node it met if the other node is not having the message copy. The message replication is done after checking the summary vector. The summary vector is maintained at each node that stores the information about all the messages that are passed by that node or currently stored in its buffer. In PRoPHET [13], the delivery predictabilities increase when two nodes regularly encounter each other, and decrease if these nodes have no chance of encountering each other due to network disruption. If these nodes encounter each other again after some time, then delivery predictabilities return to the previous value. This results in a routing jitter problem.

Two-Hop Relay

In this approach [7], the source node replicates the message to a large number of relay nodes. In this approach a message will be delivered to the destination within two hops only i.e. either the source node directly delivers the message to destination or the relay node. Relay nodes will not further replicate it to any other node except the destination node i.e. after one hop transmission of message, the direct contact delivery approach is used and the relay node wait for the destination to come in contact.

Tree Based Flooding

T. Small et al [14] have given the concept of binary tree based algorithm. The algorithm works upon the concept that the source node must be limit with the number of replicas to control the width and depth of the tree i.e. when the nodes are limit with number of copies then they can go in depth up to a certain level. Each node can have max of two child nodes so the replicas are equally distributed in between them. After this receiving phase, the nodes start offloading the message to collection stations so to reach the destination.

Spray and Wait

The Spray and Wait (SnW) [15] algorithm is the advanced version of the epidemic routing. In this algorithm the nodes are not distributing the replicas to each and every node but an optimal number of nodes (say m) are selected to which the source node will relay the message. There are two phases in this approach: Spray and Wait. In Spray phase, the source node replicates the message to the m nodes and these m nodes will further relay the message to m relay nodes. If the destination is not found in spray phase then the relay nodes will store the message and performs direct transmission to the destination.

2. 2 Forwarding based Routing Approach

This type of routing takes place when nodes have some relevant knowledge about the other nodes in the network. In this type of routing no node will generate replicates of the messages. Each node will search for the best suitable relay nodes and forwards the message to them. This approach reduces the extra resource consumption as replication of messages is not permitted. This type of routing is used when the network resources are limited such as buffer size at each node, battery life, etc.

Source Routing

The Source routing [16] consist of two phases i.e. route discovery phase and route maintenance phase. Initially a route is discovered by sending control packets towards a destination node. Each of the intermediate nodes will append its address in the packet. Each node also maintains a cache for the routes that the node has learnt over time. When the packet reaches at the destination the entire route is appended in the packet only. In route maintenance phase if a link failure is detected then a route error message is broadcasted by the source node.

Per-Hop Routing

In Per-Hop routing [17], each intermediate node will decide the next node to which the packet is to be forwarded for a particular destination. This approach has better performance than Source routing because the more updated information is used than Source Routing. The source node sends the message to all the connected nodes, and then these nodes search for the closeness of the destination node and the node have the destination node as closest will further broadcast it. This process goes on and thus the refinement of routes keeps going.

Per-Contact Routing

The most updated information is being used in Per-Contact Routing [18] because when any intermediate node receives any message for a particular destination then it will update its routing table and will check the current up contacts and select the appropriate node for relaying the message and forward the message to the most appropriate node.

Hierarchical Forwarding and Cluster Control Routing

This approach introduces the concept of clustering (i.e. grouping) of nodes on the basis of link property and communication characteristics. After formation of clusters, a cluster head is selected depending upon some criteria. In [19], the cluster head node is selected based on the higher stability or the higher quality among all nodes within the cluster. The routing decisions are then taken by the selected clusterhead.

Replication based Routing

In 2017, Li et al. [20] have proposed NDDR protocol. NDDR is a named data based DTN routing approach which makes routing decisions for named data based on topological distance information. Specifically, the authors introduced named data to the design of routing protocol and used the typical NDN communication model, i.e., the exchange of Interest and Data, to drive the communication, as well as the typical components of a NDN router, i.e., Pending Interest.

III. Proposed BSnW+ Routing Protocol to Improve Delivery Ratio

Binary Spray and Wait routing protocol improves the performance of SnW protocol. Our proposed BSnW+ (Binary Spray and Wait +) is an extension of Binary Spray and Wait routing protocol.

Algorithm of BSnW+ is as follows:

Variables:

SN	Source Node
DN	Destination Node
$RN_1, RN_2, \ldots RNx$	Relay Nodes
nrofCopies	No. of message copies
SNLastSeenTime()	Last time when *SN* meets *DN*
Timediff	Threshold value
RN_x*LastSeenTime()*	Last time when RN_x meets *DN*

1) Source node *SN* wants to send a message to destination node *DN*.
2) SN initially creates *nrofCopies* number of message copies.
3) Whenever *SN* finds a relay node RN_1, it verifies whether $DN = RN_1$ or not.
4) If true, *SN* sends the message to *DN* through Direct Contact.
5) If $DN \neq RN_1$ && (*SNLastSeenTime() + timediff* < RN_x*LastSeenTime()*)

```
messageTransferred()
while(nrofCopies!=1)
/* loop will run until nrofCopies at any node are more than one */
{
nrofCopies = (int)Math.ceil(nrofCopies/4.0);
}
else
{
nrofCopies = nrofCopies - 1; /* for simple SnW */
}
```

IV. Result Analysis and Discussion

There are two well-known simulators used widely in DTN research, the Network Simulator 2 (NS-2) and The Opportunistic Network Environment simulator (ONE). NS-2 is an event driven simulator, developed through wide collaboration between several colleges and research firms, and models link layer through application layer network behavior. The ONE Simulator is also an event based simulator that was developed at the Helsinki University of Technology specifically for simulating DTN routing protocols [21]. There are various performance parameters but we are here focusing on following primary parameters.

4.1 Delivery Ratio

The delivery ratio, or the number of messages that reach the destination divided by the total number of messages generated, is usually the primary measure of DTN routing protocol performance. After all, routing protocol exist to deliver messages to the destination. Furthermore, if the given message does not reach the destination, any resources consumed in routing that message are wasted and add to overhead. Delivery ratio is tracked in every comparison and evaluation of protocols.

4.2 Latency or Delivery Delay

Latency, also called delivery delay, is the measure of the amount of time it takes for a message to reach its destination after it is generated. The relative importance of latency depends largely on the applications running above the routing protocol. Latency is important when evaluating network performance for applications where the user experience is tied to the wait time between messages.

4.3 Overhead Ratio

Overhead ratio is the total amount of data transmitted over the data used to transmit messages that reached their destination. It is used to measure the network congestion status and is calculated as the ratio of difference of total number of successfully relayed messages and the number of delivered messages to the number of delivered messages.

Table 4.1: Simulation Parameters

Simulation Parameters	Their Values
Routing Approaches	Epidemic [12], PRoPHET [13], Spray and Wait [15], NDDR [20], Proposed Algorithm (BSnW+)
Map Size	4500m*3400m
No. of Nodes	50, 100, 150
Simulation Duration	0.5 – 4 hours
Message Creation Interval	10 s
Message Sizes	50 KB – 1 MB
Message TTL	Infinite
Node Buffer Size	10 – 50 MB
Node Speed	13 – 15 m/s
Node Transmission Range	150 m
Mobility Model	Shortest Path Map Based Movement

Simulation of our proposed algorithm is performed using one_1.4.1. In this section, graphical analysis and comparison is done among Epidemic, Prophet, SnW, NDDR and our proposed BSnW+ protocol. In figure 2 and 4, the simulation duration is fixed as 4 hr and the number of mobile nodes is varied from 50 to 150 for the comparison purpose. In figure 3 & 5, the number of mobile nodes is fixed as 100 and the simulation duration is varied from 0.5 hr to 4 hr for the comparison purpose. In figure 6, the protocols are compared on the basis of delivery ratio by varying the buffer size from 10 MB to 50 MB. In figure 7, the protocols are compared on the basis of overhead ratio by varying the buffer size from 10 MB to 50 MB. In figure 8, the protocols are compared on the basis of avg. latency by varying the buffer size from 10 MB to 50 MB.

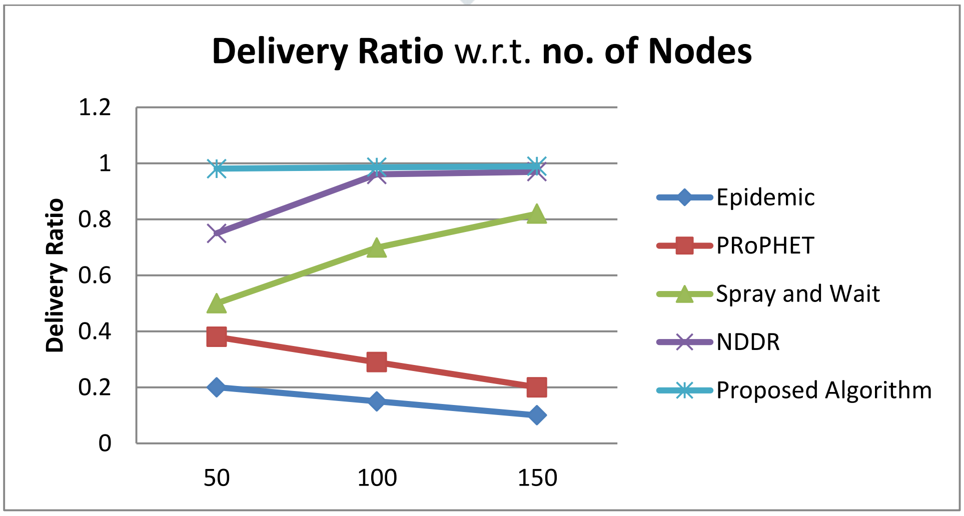

Figure 2: Delivery Ratio w.r.t. no. of Nodes

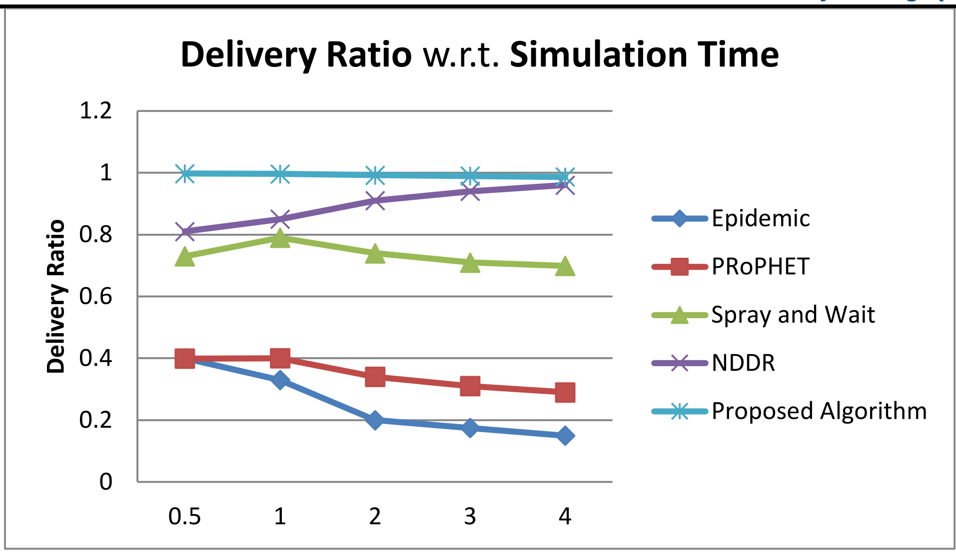

Figure 3: Delivery Ratio w.r.t. Simulation Time

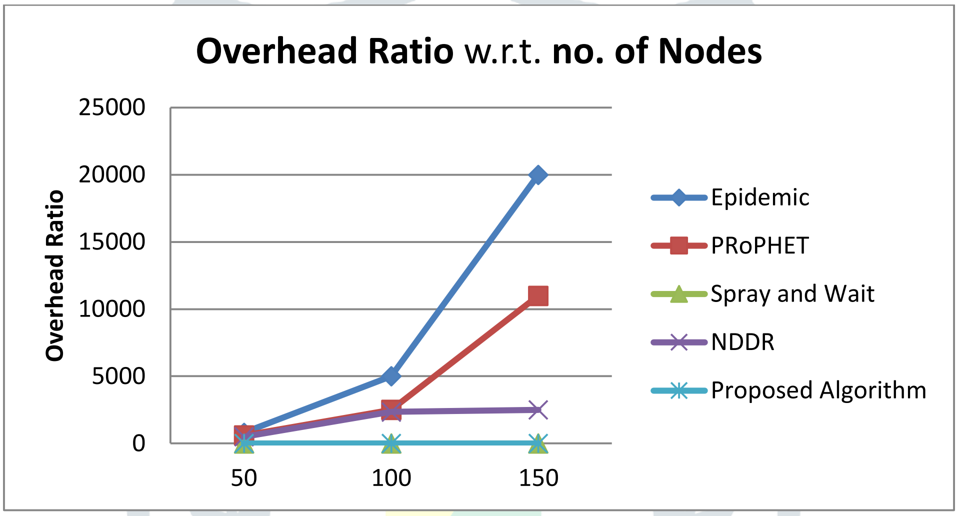

Figure 4: Overhead Ratio w.r.t. no. of Nodes

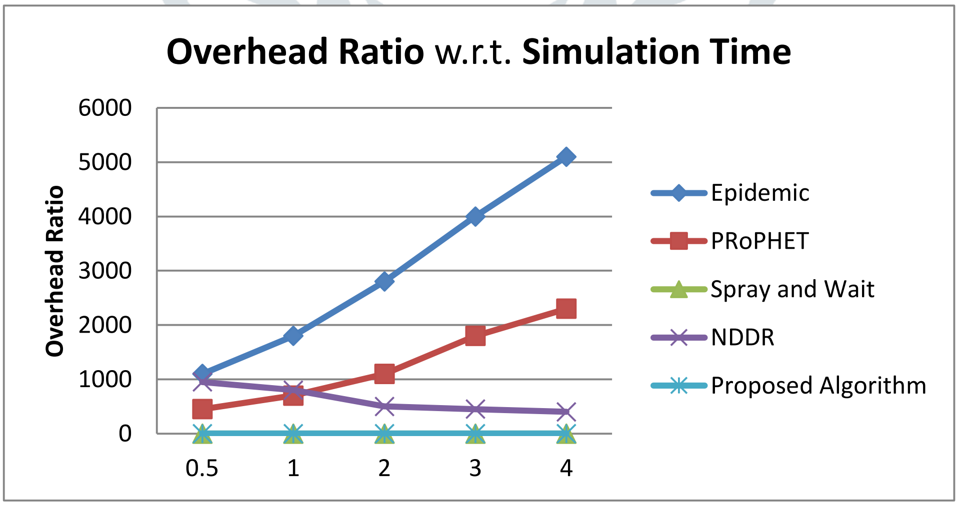

Figure 5: Overhead Ratio w.r.t. Simulation Time

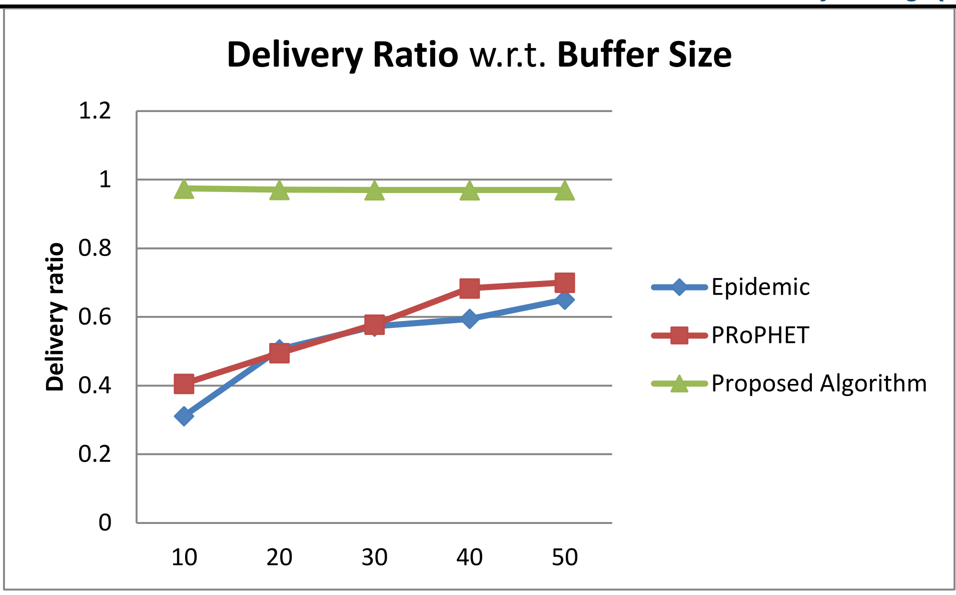

Figure 6: Delivery Ratio w.r.t. Buffer Size

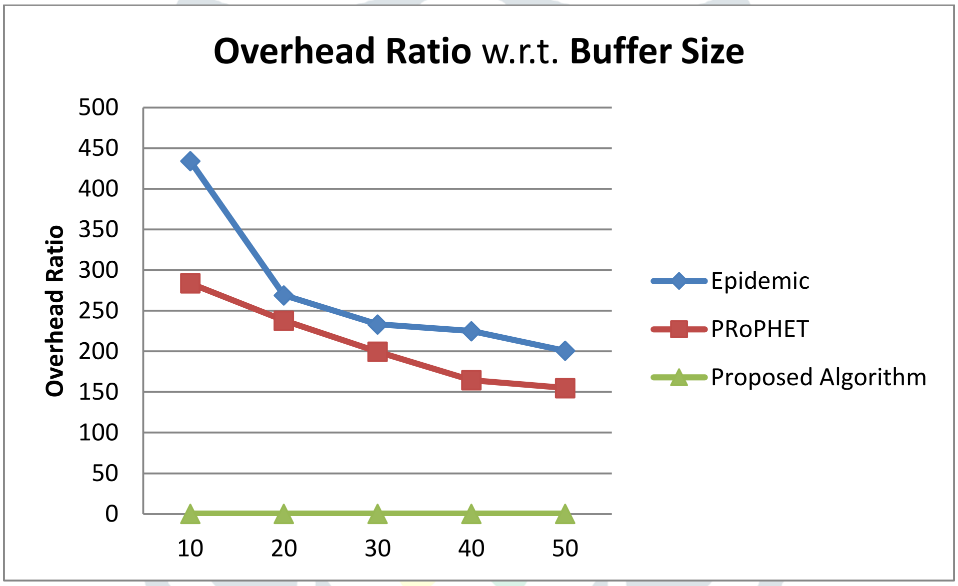

Figure 7: Overhead Ratio w.r.t. Buffer Size

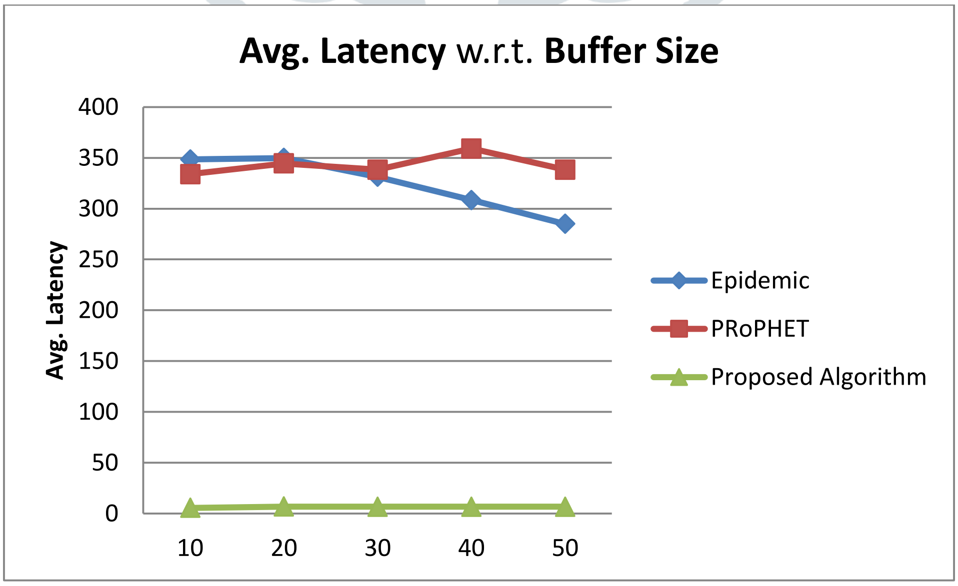

Figure 8: Avg. Latency w.r.t. Buffer Size

V. CONCLUSION

In this paper, the proposed BSnW+ protocol is compared with the basic DTN routing protocols i.e. prophet, epidemic, spray and wait and NDDR protocol on the basis of delivery probability and overhead ratio. It is observed that the proposed BSnW+ protocol performs better as compare to all the four protocols. The simulation is run for a maximum of 150 nodes and it is found that the delivery probability and overhead ratio obtained by our protocol is better. Moreover, our protocol is also tested by varying the buffer size from 10 MB to 50 MB.

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