Experimental Evaluation of Routing Schemes in Delay Tolerant Network Environment

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Abstract: -
Delay Tolerant Network (DTN) is a network originated from Interplanetary Networks and currently being used in a number of applications. Frequent network interruptions, asymmetric links and long delays are basic characteristics of DTN. It uses the store to carry and forward strategy to provide reliable communication. Numbers of routing schemes have been proposed for DTN and effectiveness of these are evaluated based on a number of different routing parameters such as message delivery, overheads, latency time etc. Comparative analysis of DTN routing protocols helps us in better understanding of the design of DTNs. This paper presents an experimental evaluation of different DTN routing protocols using Walchand College of Engineering, Sangli Scenario. The various DTN routing protocols considered for comparison are Direct Delivery, First Contact, Epidemic, PRoPHET, Spray and Wait, Bubblerap and Buddy Router with replication. These simulations carried out using Opportunistic Network Environment (ONE) simulator. We presented the simulation results along with its analysis.

Keywords: Delay Tolerant Network, Routing, Store-carry-and-forward strategy.

I.INTRODUCTION

Delay tolerant network is an evolution that permits communication of nodes yet on huge distance and over tremendous delays. The Kevin Fall initially anticipated the idea of Delay Tolerant Network in 2003 [1]. It tries to provide reliable transmission with intermittent connectivity, in various networks, and in case of long delays. Due to intermittent connectivity routing a message in a DTN environment is a challenging task. Routing protocols of DTN include node having an ability to store data and hold it for a while, awaiting the connection with the destination re-established.

1.1 What is DTN?

The Delay-Tolerant-Network is an approach for communication among heterogeneous networks. It is distributed, flexible, and connectionless network, which allows mobile nodes to produce communications along with others. It is the network, which works on complex overlay networks as well as when there may be no possibility of the instantaneous path towards destination nodes from the source.
For Example, NASA uses Delay Tolerant Network for interactions between earth and spacecraft where distance is an extreme measure; while communication in space and keep away from data loss during data transmissions [2].

DTN makes use of "Store-Carry-and-Forward" technique inside the network to answer Intermittent Link Connectivity problem. The DTN conquer the problems related to disconnectivity of nodes, variable delays, constant errors and asymmetric data rates by store-carry-and-forward message switching technique which is an extended known form of the postal system. The storage blocks denoted in figure1 can handle satisfactorily large data which is called persistent storage. Persistent storage is essential in two conditions, one is communication link is not available or quality of link is not right for a long time. Second is node cannot communicate reliably with other node and retransmission settled on every error.

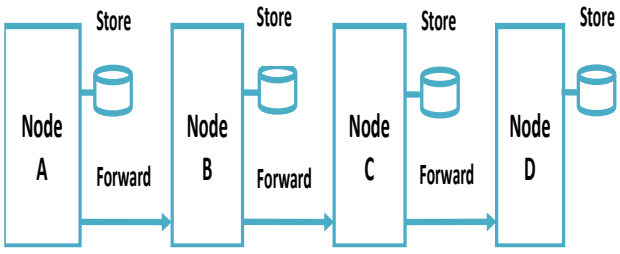

Figure 1: Store-Carry-and-Forward Message switching Technique

II.ARCHITECTURE OF DTN

DTN consists of essential layers physical layer, link layer, network layer, transport layer, application layer and additional bundle layer with new features.

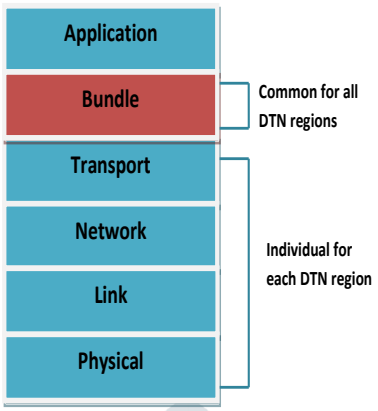

Figure 2: Layered Architecture of DTN

- Bundle Layer

The basic purpose of Bundle [1] layer is to provide connectivity in multiple subnets into single networks. It supports custody based retransmissions and can store data for a long period of time. The key advantage of the bundle protocol is elasticity. It is suitable to easily link with the existing TCP/IP protocol.

The data transfer can is prepared safely by storing and forwarding the whole bundles of connecting nodes. Bundles encompass a default layout with two or more blocks of data. Every block might insist on application data or information concerning communication. Bundles are isolated into different parts called fragments during transmissions. These fragments are reassembled anywhere to make the novel bundle. Endpoint identifiers (EID) are used to identify bundles bundle's source and destination.

The DTN architecture pretends to a network links are persistently accessible. As an alternative it expects to facilitate nodes can select to gather bundles for a specific moment. The majority of DTN nodes decide to apply persistent storage on the disk and backup the bundles to survive when system restarts.

III.CLASSIFICATION OF ROUTING PROTOCOLS

DTN routing has been identified as one of the major challenge, which tries to achieve efficient message transfer in a minimum amount of time and with lesser overheads. A lot of research carried out and number of routing strategies presented to provide efficient message routing. DTN routing mainly classified as Single Copy and Multiple Copy based on message forwarding copies [8].

3.1 Single Copy: -

In this, a single message copy is available in the DTN network. In the influence of store carry and forward technique, only one custodian distributes a single copy of a message [3].

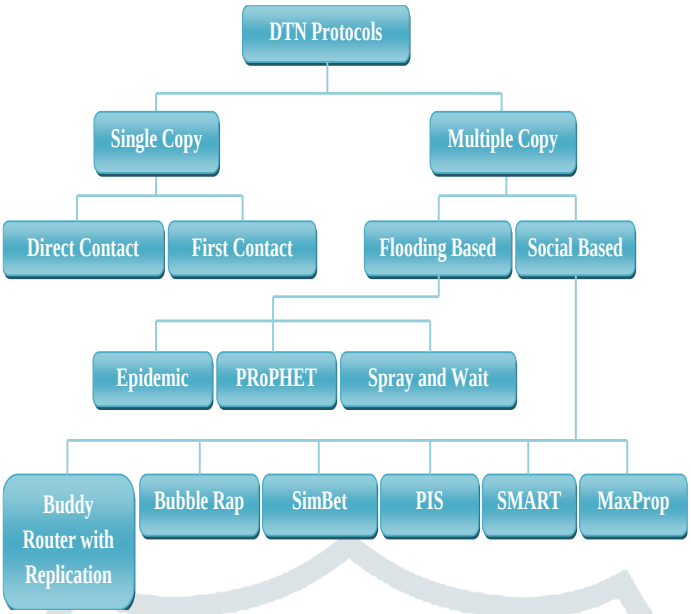

Figure 3: Classification of DTN Protocols

Direct-Contact: the simplest routing scheme called as Direct Delivery protocol, where the source node keeps the message until it reaches the final destination [4]. It delivers the message directly to the destination node itself. In the First Contact strategy, the node forwards the messages randomly to the first node encountered after message custody. It forwards the message immediately to the first encountered node and it drops that message from its queue [4].

3.2 Multiple-Copy:

Multiple replicas of a message do exist in multiple copy protocols to provide reliable delivery. It has two categories as flooding based routing and social based routing [5]. In flooding, multiple copies/replicas are created and forwarded with uncontrolled flooding or controlled flooding method.

3.2.1 Flooding Based Approaches:

- Epidemic Routing:

Epidemic routing [6] is one of the elementary routing protocols.

The goal of Epidemic Routing is to:

– Maximize message delivery rate
– Minimize message delivery latency
– Minimizing the aggregate system resources consumed in message delivery

The epidemic routing protocol uses a FIFO queuing strategy for messages. It broadcast messages to all the neighbours meet with node. When there is no space for a new message, the first message ejected from the buffer. The summary vector exchanged when two nodes encountered. Then the packet transmission is stared and stops only when the contact duration expires. Nodes transfer all the uncommon packets and guarantee the packet delivery of all to the destinations.

- PRoPHET Routing:

It is the probabilistic routing along with the unique history of encounters and transitivity. When nodes meet, they swap their summary vectors, which contain the delivery probability. The delivery probability is high if two nodes meet recurrently and low if they are not good forwarders and delivery probability value reduces with time. For a given message if encountered node is having higher delivery predictability than itself then it transfers message to that node. The delivery predictability is calculated based on frequency of encounters with that node, age of that encounter and existence of transitive property of mutually encountered node.

The delivery predictability is based on three factors [7]:

1. Initialization:

The two nodes in communication range of each other, it calculates delivery predictability with the following equation:

$$P(a,b) = P(a,b) + \big(1 - P(a,b)\big) \times P_{init} \quad \text{(I)}$$

Where P_{init} can initialization constant.

2. Ageing:

The two nodes are not in communication range of each other, there is an obligation to do the aging with the following equation:

$$P(a,b) = P(a,b)old \times P\,\gamma^{k} \quad \text{(II)}$$

Where γ can be the aging constant and k is the number of time units.

3. Transitive Property:
The node A frequently encounters with node B, Node B is frequently encountered with node C, then the node C is probably good node to forward the message to node A and then it calculates delivery predictability with the following equation:

$$P(a,b) = P(a,b)old + (1 - P(a,b)old) \times P(a,b) \times P(b,c) \times \beta \quad \text{(III)}$$

Where β can be the scaling constant and which resolves how effects on transitivity on delivery predictability.

- Spray and Wait:

This one is highly scalable and efficient protocol, which uses controlled flooding for better performance. It initially starts spreading the messages to guarantee that at least one reach the destination quickly. After a packet reproduction process, it transferred to another node with a count of further reproduction to else. When the allowed number of duplicate value touches 1, then the node stops creating a new copy of the message.

This protocol is designed aimed with phases [8]
– Spray Phase: This phase is initiated by message forwarding until copies allowed for the distribution. There are an L number of copies originated and transferred with the intention of nodes other than source will receive these distinct copies.

– Wait Phase: If the spray phase does not find the target, copies establish a direct path to do contact with destination for achieving the aim.
One variant of spray and wait is binary spray and wait. In this scheme, the source node keeps L/2 copies and distributes remaining copies to the first encountered node. The forwarder node carries L/2 copies and recursively this distribution continues until each node left with only one copy of message.

3.2.2 Social Based Approaches: Social routing finds the relationship between humans and community with the use of most used electronic devices such as Smartphone, e-book readers, and multimedia players. It provides reliable communications in delay tolerant network. It decides the properties of node mobility and reliability based on human behaviour and makes effective routing decisions in a packet switched network [9].

- Buddy Router with Replication:

The Buddy Router is single copy protocol. It uses multi parameter composite attribute called as Buddy metric which uses three parameters. Buddy Router with replication uses Buddy metric. Buddy metric tries to exploit social relation in terms of friendship relations between users. Buddy metric is composite, multi parameter metric which based on three parameters- contact duration, encounter frequency and contact recency and stored in Buddy metric.
– $F(c)$ Contact frequency is the total number of time two nodes encounter with each other over a time T.
– $D(c)$ Aggregate contact duration is the total amount of time two nodes encounter with each other over a time T.
– $R(c)$ Last parameter Recency reflects how recently the other node was in contact.
In BuddyRouter_Rep each node maintains table and take message forward decision by calculating buddy metric value with following formula:

$$BM\ (i,j) = wf * F(c) + wr * 1\ /\ R(c) + wd * D(c) \quad \text{(IV)}$$

$$0 <= wf <= 1, 0 <= wr <= 1\ and\ 0 <= wd <= 1 \quad \text{(V)}$$

And

$$wf + wd + wr = 1 \quad \text{(VI)}$$

Where, the wf is the weight assigned to frequency; hence higher frequency provided contact duration less as well as recency weight. The wr is weight for contact recency and wd is weight for contact duration.
BuddyRouter with Time window is variation of BuddyRouter protocol, which is inspired from working day movement model. Daytime is divided in different time windows and protocol forwards message by selecting the best forwarder within time window [10].
The BuddyRouter_Replication is replication-based protocol, which forwards replicas of the message to its neighbors which are having better buddy metric value than itself.

- Bubble Rap:

Bubble Rap combines the knowledge on the community structure and the centrality of the nodes to decide whether to forward. Each message has two types of ranking, global and local (related to its community). Forwarding is done using the global ranking until the message reaches a node that is in the equivalent community of the destination node. Then, local ranking use until the destination reach or the message terminates. Each node forwarding a broadcast does not destroy its copy saving the message is delivered to the community of its destination. In this case, forwarding is socially based, and replication is unlimited.

Forwarding algorithms used in Bubble Rap by [11]-

1. LABEL Algorithm-

This algorithm designed for notices a transferable node which belongs to the homogeneous group. A single node has the label to show attachment with that helps to transmit messages. The disadvantage is to deliver a message far from source to the node whose social distance is rare to reach a destination.

2. RANK Algorithm-

Each node has information about the own ranking also the ranking of nodes with whom it joins. The message forwarding to nodes has a higher rank than the current node.

3. BUBBLE Algorithm-

BUBBLE algorithm developed by combining the label and the Rank algorithm. The feature of pushing the messages to nodes having higher centrality value and within the same label group (Label, Rank) implemented for the development of bubble algorithm.

This algorithm considering the following Assumption: People have alternating roles and communities in society.

- SimBet Routing:

The SimBet is one of the first routing algorithms which directly implements social metrics specifically similarity and Betweenness [12].

The similarity metric is an identification of whether two nodes compatibly social with each other.

$$Simt\ (d)\ =\ |\ Nt\ \cap\ Nd\ |; \tag{VII}$$

With Nx= Contacts history vector of node x

Betweenness metric is an identification of how the two nodes are interconnected that means either they obtain methodology to be in contacts or they do not be in contact

$$Bett\ =\ \Sigma\ A'i,j; \tag{VIII}$$

With $A'\ = A2 * (1 - A)$ and A= Contact history matrix

- MaxProp routing:

The MaxProp routing algorithm has the feature of a list with the ranks of captured packets. The packets are managed by cost and code by likelihood delivery of the message to the destination. This strategy gives a solution to the source which packets needs to transmit and deleted. It satisfies with sending an acknowledgement to all existing nodes in the network. It allocates high priority value to new messages and avoids message duplication [13].

In MaxProp if contact happens, then all the messages not carried by the connection will be replicated and transferred. The MaxProp routing protocol effectively concludes that which messages should be transmitted first and which of the messages should be released first. It uses an ordered queue based on the destination of each message, ordered by the likelihood of a future transitive path to that appropriate destination. When two nodes meet each other, they exchange their estimated node encounter likelihood vectors. Rather, each node will have an up to date vector from every other node. With those 'n' vectors, the node can measure the shortest path on the basis of a depth-first search where path weights indicate the probability that the link does not happen.

- PIS Routing:

The PIS routing protocol identified as a proximity-interest-social relationship. It implements compound social properties composite with time harmony. Interests store a collection as well as a pair of interest and degree. Social relationship stores prediction of their contact probability and classify into a direct-indirect social relationship [14].

It performs investigations on human movement patterns. As the physical location of mobile users changes, more permanent factors should be considered to produce competent and capable routing decisions. In the Social Aware Networking (SAN), PIS has taken multiple social features of users into consideration to design a stable routing protocol. The three social factors are:

1. Physical proximity: Physical proximity indicates direct contacts among mobile nodes.
2. Interests: Interests indicate their preferences for data.
3. Social relationship: Social relationship indicates friendship, family or colleagues which describes the user's personal relations.

- SMART Routing:

The feature of SMART [15] has distributed community partitioning. It simplifies the message delivery from one community to another community over remote connections. SMART prepares local contact table for recording local contacts and remote contact table for recording remote contacts. Filter the location by the value of family and strangers. SMART works different processes: intracommunity communication and intercommunity communication.

IV.EXPERIMENTATION

ONE(Opportunistic Network Environment) simulator which is Java-based discrete event-based simulator has been used for simulations. Its open source and capable of simulating the mobility pattern of nodes and message exchanges in between. We have created a scenario of Walchand College of Engineering Sangli, map. This scenario created using OpenJUMP 1.6.3 and Google map. We have considered 40 mobile users and which are pedestrians. Figure 5 depicts this sample scenario used in the simulation. Table 1 present the simulation parameters used. The simulation was run on the whole data set and the total number of messages generated was 1456.

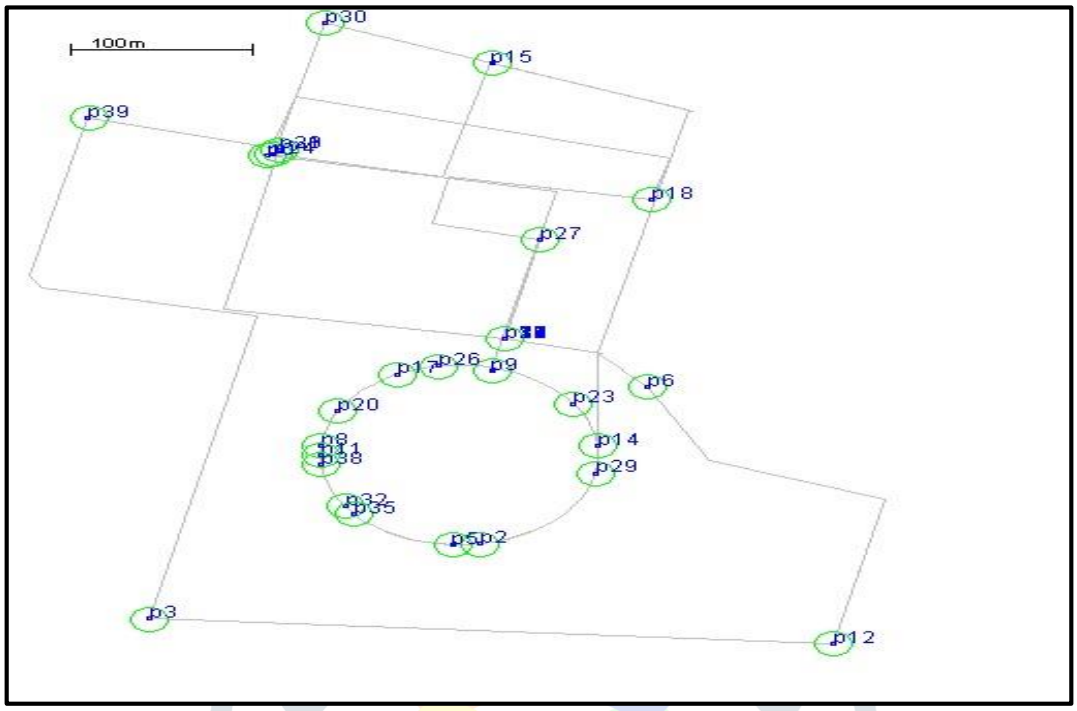

Figure 5: WCE Sangli Scenario

Parameter	Value
Tool Used	ONE (Opportunistic Network Environment)
Nodes	40
Simulation Duration	43000s
Movement Model	Map Route Movement
Transmit Speed	2 Mbps
Transmit Range	10 meters
Speed	0.05 to 0.5 meter/sec
World's Size	3500 * 4500 meters
TTL	300min
Buffer Size	50 M
Message Size	50 KB – 150 KB

Table 1: Simulation parameters

The message size was varied and was in between 50KB to 150 KB. As we have considered pedestrians we have considered node movement speed of 0.05 to 0.5 meter/sec. message lifetime, TTL (Time to Live) was set for 5 Hrs and total simulation time is 43000 seconds.

We evaluated the performance of single-copy protocols, which are Direct Contact, First Contact, BuddyRouter and BuddyRouter with Time Window. Multiple copy protocols we considered are Epidemic, Spray and Wait, PRoPHET and Bubblerap.

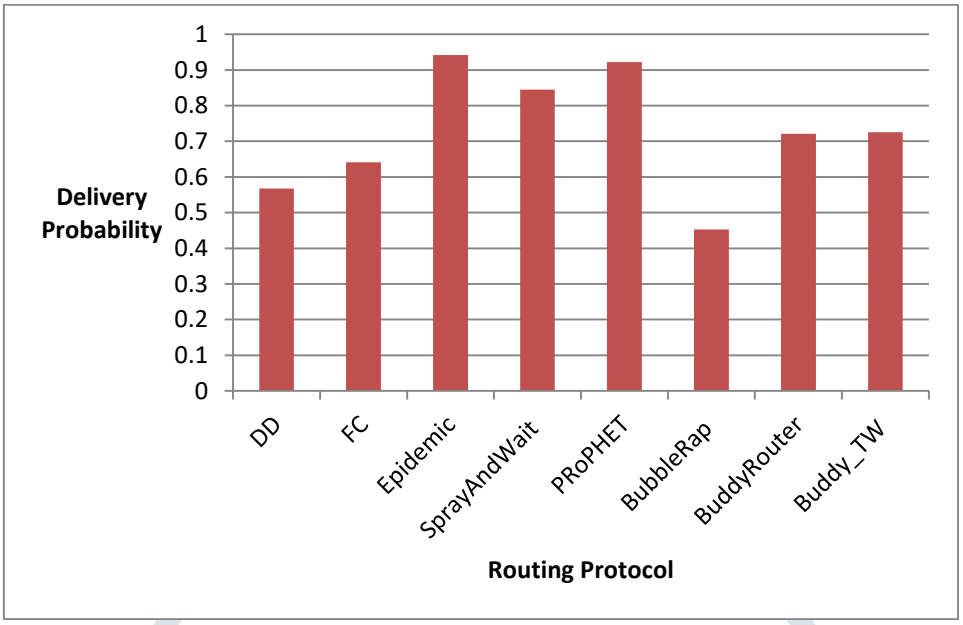

Figure 6: Delivery Probability

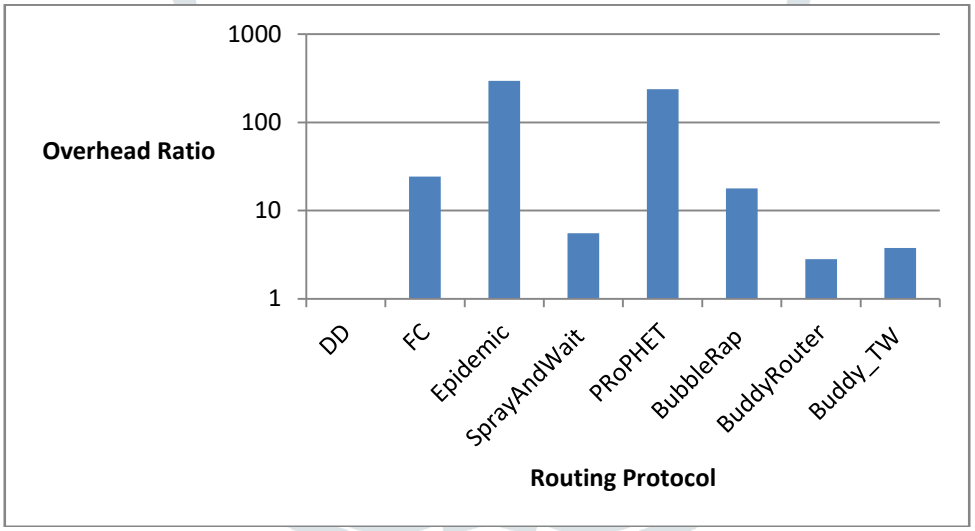

Figure 7: Overhead Ratio

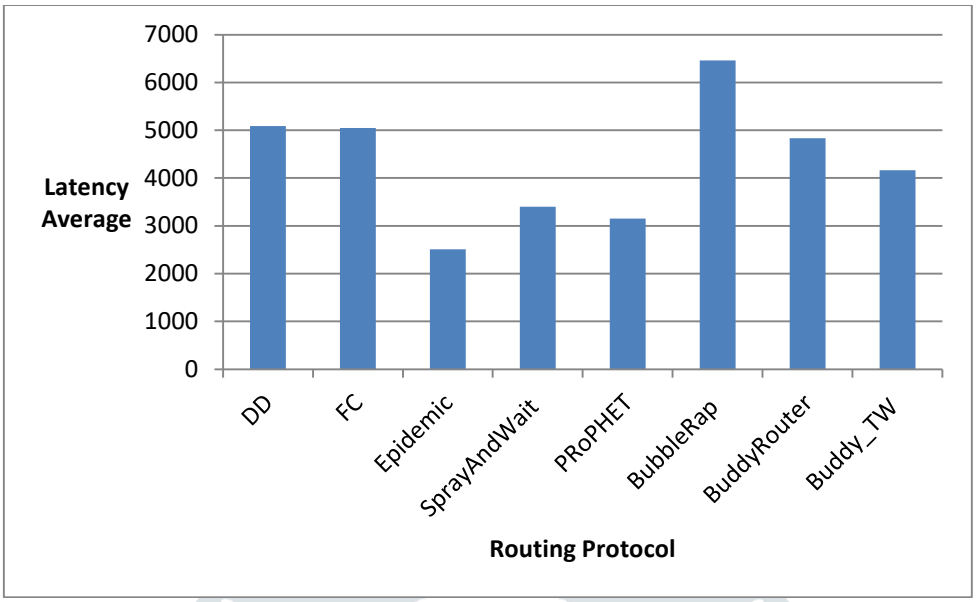

Figure 8: Latency Average

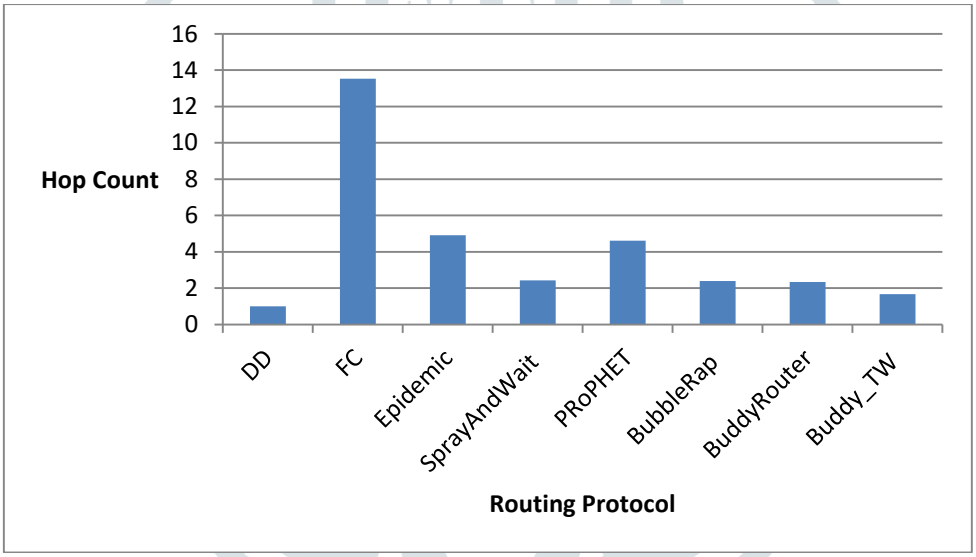

Figure 9: Hop Count Average

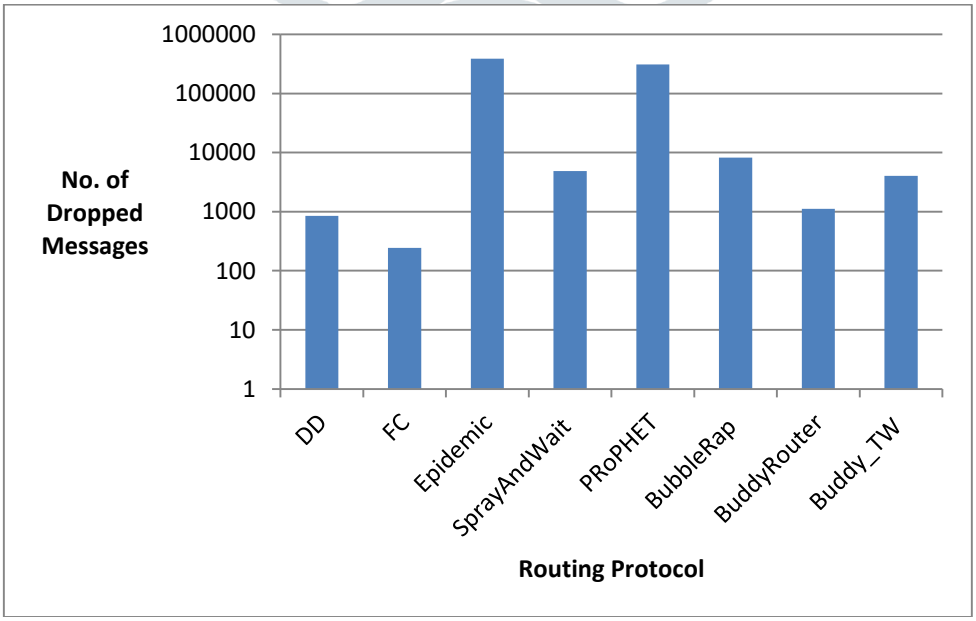

Figure 10: Number of Messages Dropped

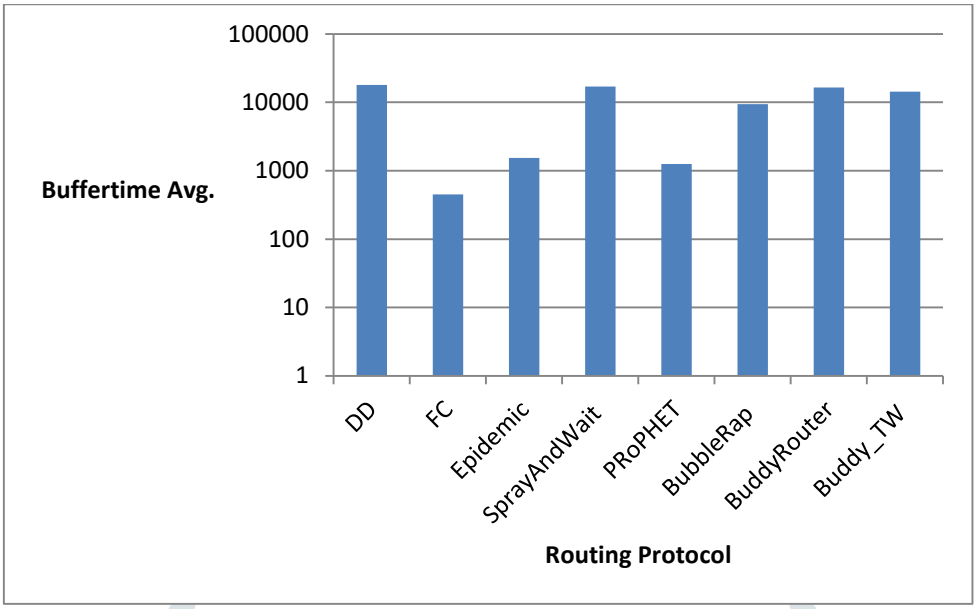

Figure 11: Buffer time Average

- **Results and Discussion:**

Figure 6 depicts a successful message delivery in a given WCE scenario. The x-axis represents the routing algorithm and the y-axis represents delivery probability. As we can see message delivery ratio of multicopy protocols is much higher than single copy protocols. The epidemic is having highest delivery ratio along with the PRoPHET. Spray and Wait is also having a delivery ratio close to 84 percent. Interestingly Buddy router along Buddy_TW exhibits better message delivery than Bubblerap routing protocol. All these three employs social relations for routing so we may need to employ a Working Day Movement model with more simulation time. As expected optimal delivery probability exhibited from multicopy protocols but with increased overheads. Buddy router protocol is better than Direct Contact, First Contact and Bubblerap in terms of message delivery.

Figure 7 shows the message overheads. This represents the ratio of total messages forwarded vs. total messages successfully delivered. Using this approach we will come to know about the amount of traffic generated per delivered message. Its nothing but delivery cost. The greater the delivery cost it inversely affects delivery performance. As we can see in figure 6 Epidemic and PRoPHET exhibits the highest delivery cost than other protocols. The delivery cost of BuddyRouter and its variant BUDDY_TW is much less than its counterparts that is Bubblerap and First Contact. Direct Contact does not have any delivery cost associated with it. Latency average of BuddyRouter and Buddy_TW is much higher than multi-copy protocols as it takes time to make a wise decision to forward message towards the destination as reflected in Figure 8.

Figure 9 shows the Hop Count Average of First Contact is very high as compared to any other protocols as its very naïve method and delivers a message to the first encountered node. Buddy Router and Buddy_TW exhibit better hop count average than all other protocols. Figure 10 shows that all multi-copy protocols i.e. Epidemic, ProPHET, Spray and Wait Protocols has higher message dropping and Buddy Router, Buddy_TW, Direct Delivery, Bubble Rap has good results. Figure 11 shows the buffer time average of First Contact and PRoPHET is much better than other routing schemes. Messages will occupy buffer space more amount of time in other routing protocols as it takes more time to make routing decisions.

CONCLUSION:

DTN provides communication in distributed areas which previously not possible. Routing algorithms have challenges but use novel approaches to achieve fast, reliable, long distance, without data loss communication. The routing has different classifications - single-copy defined as direct-contact and first-contact and multiple-copy defined as flooding-based and social-based. These various routing protocols mentioned in the paper provide a ratio of message delivery in distributed communication.

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