Routing Issues & Performance Of Different Opportunistic Routing Protocols In Delay Tolerant Network

Ankur Upadhyay
Department of Computer Science & Engineering
School of Engineering & Technology, IFTM University
Moradabad, India

Abhishek Kumar Mishra
Department of Computer Science & Engineering
School of Engineering & Technology, IFTM University
Moradabad, India

Abstract— **The Delay Tolerant Networks (DTN's) are wireless ad-hoc networks which is connected intermittently. The DTNs allow the communication between two or more wireless nodes in the situation in which the end to end connectivity cannot be achieved or rarely achieved. The DTNs are also known as the opportunistic networks. The DTNs are best applicable or suitable in an environment which is infrastructure-less. In the heterogeneous environment, the communication between two or more wireless nodes can be achieved by DTN. The selection of a routing protocol in DTN, is based on the application environment in which it is to be deployed. In this research paper, I've given the review of the existing DTN protocols. We have compared the performance of some existing routing protocols based on message delivery ratio, average delay and resource consumption.**

Keywords—DTN, Intermittent connectivity, Bundle Protocol, Opportunistic Routing Protocol, Flooding, Forwarding

I.   INTRODUCTION

The Delay Tolerant Network is completely different approach than regularly connected wired or wireless networks. In DTNs, there is no availability of end to end path at any point of time for transfer of data between a sender and destination node. The communication in DTNs are done with the exploiting characteristic of nodes i.e. mobility, available connections, and provided buffer space etc.

The Delay Tolerant Networks play the main role in the situation where the routes between any pair of nodes can never be achieved. In sparse network, where there is no end to end routes available, like in military battlefields, DTN provides the way to communicate. It does not require any prior knowledge of networks to forward the bundles from one node to another node. It can only be 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 behind of Delay Tolerant Network (DTN) [1] was taken from Inter Planetary Networks (IPN) [2], which was started in 1970. The IPN was invented to communicate between the mars and the earth. The DTN is a type of wireless ad-hoc network which can tolerates the intermittent connectivity.

The intermittent connectivity can be defined as the sudden change of state (ups/downs) of any communication link between the nodes. The DTN can also be defined as a wireless ad-hoc network which is connected intermittently [3] that can tolerate longer delays, intermittent connectivity and prevent data from being lost, with the use of 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. In the delay tolerant networks, the data packets are called the bundles and the bundles could be of variable sizes.

The operations of the DTN makes the use of a protocol known as the Bundle Protocol (BP), positioned above the TCP protocol in the protocol architecture stack of the DTN. The basic functions which can be provided by BP [4] are :

- Retransmission can be done at any time because the nodes hold the Custody of the message.
- Tolerate the intermittent connections
- Make use of different type of connectivity like scheduled, predicted, and opportunistic
- Supports late binding as it supports the heterogeneous environments.
- The DTN application areas are some of the challenged areas which are:
- Military Battlefield
- Deep Under Water Communication
- Natural Hazard affected Area. Etc

A. CHARACTERISTICS OF DTN

A delay tolerant network can be defined as a "Network of Regional Networks". It can also be viewed as an overlay on the top of regional networks. DTN protocols provide robustness against the issues which are mentioned above by introducing tolerance for the delays and the connectivity which is intermittent. In theory, DTN's can handle nodes or links being absent for few or some days while still being able to provide reliable data transfer due to the buffering capacity of the network. However, the DTN protocols and relevant specifications for them, are still a long work in progress.

B. *SILENT FEATURES OF DTN*

The DTN have few salient features [5] [6] which make it different than other available wireless networks.

- **Tolerates high latency:** The DTN supports the communication even when the delay is incurred in availability of next contact could be very high. The nodes are provided with buffer memory in DTN, so until the next node will come in contact, the messages are held in the buffer of the sending node.
- **Tolerates asymmetric data rates:** DTN allows the transfer of data, even when, the rate of incoming and outgoing transfer of messages are different i.e. not the same.
- **Prevent data loss:** In DTN, every node has provided with some amount of buffer memory in which node can store the messages and the node can removes the messages, only when the custody of messages have been transferred to other node.
- **Tolerates intermittent connectivity:** The Intermittent connectivity can be defined as the unexpected change of state (Ups/Downs) of any communication link. The reason DTN tolerates the intermittent connectivity because it supports the buffer and custody transfer concept.
- **Store-Carry-Forward approach:** The key principal of DTN on which it works is the Store-Carry-Forward approach, which make the use of the Bundle Protocol. Store-Carry-Forward approach enables the DTN nodes to receive the message, store it in buffer, carry it to the relay or destination node and forward it. If the relay node is not available, then save it in buffer.

II. ROUTING ISSUES IN DTN:[7]

1. **Buffer Space:** In DTN intermittent connectivity is present. So because of this intermittent connectivity, buffering of the messages can take place for a long time period, i.e. enough buffer space is required at intermediate routers for storing all the messages which are waiting for the opportunities for future communication. So there is a requirement of enough buffer space at intermediate routers.

2. **Energy:** The nodes mobility as well as the connection complexity to a power station, a node has low energy level in DTN. A node does the work of sending, receiving and storing the messages. For all of these functions, a node requires enough amount of energy. So it important that the design of a routing protocol should be energy efficient.

3. **Reliability:** In DTN, For the reliable delivery of messages between source nodes and destination nodes, the routing protocol which is used, has some acknowledgement. The successful delivery of messages between nodes is ensured by this acknowledgement.

4. **Processing Power:** The DTN is used to make a communication between two or more devices, which cannot be able to communicate by the traditional networks. In terms of the CPU and memory, these type of devices have very small processing capability. A complex routing protocol cannot be run over these nodes because nodes are not capable of running it.

5. **Security:** Security is a major problem for any kind of network either traditional or DTN. Before reaching to its final destination, a message may be passed randomly through the intermediate hosts. Depending upon the application's security, users are required a secure guarantee about the message authenticity. For a secure intermediate routing, cryptographic technique is beneficial.

III. ROUTING IN DTN:

The capacity of sending data from a source to a destination is a fundamental ability of all communication networks should possess. DTN's have been characterized by their lack of connectivity which means that there is a lack of instantaneous end to end paths. In such environment, ad hoc routing protocols such as AODV [8] and DSR [9] fail to establish routes. This happens only because of the fact that these protocols try to first establish a complete route and then after the route has been established, and forward the actual data. But in the DTN, the end-to-end connectivity can't be achieved, so the end-to-end route can't be achieved. So in the DTN the routing of the messages through one node to another is done by hop by hop. In hop by hop process, the selection of the next is done dynamically and according to the application scenario and the protocol which is used. So when a node receive a message, then according to the used protocol, this node searches the next good relay node to which it can forward the message. In DTN, depending upon the protocol used, transmission of messages can be done in two types i.e. by replicating the message or forwarding the message. In DTN literature, there are two broad categories of routing protocols:[10][11]

1. Flooding Based
2. Forwarding based

In DTN literature, there is a variety of routing protocols. This paper discusses some [12] of them.

A. *Flooding Based Routing:*

In flooding based routing, every node has a copy of each message and transmit it to the other nodes or relays in the network. All the nodes maintain the copies and store them in the buffer of the nodes until they connect with the other node.

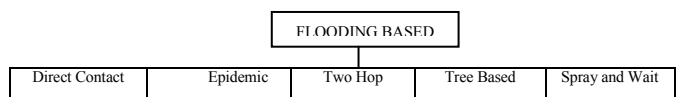| FLOODING BASED				
Direct Contact	Epidemic	Two Hop	Tree Based	Spray and Wait

Figure 1: Flooding Based Routing Protocols

The flooding based routing protocols (Figure 1) don't want any information about the network in which they are deployed i.e. nodes in the network doesn't have any information about other nodes in the network. Replication of messages is used in this type of routing which rises the probability of message delivery. The replication based routing consume more resources of the network for delivery of the single message. So many copies of that message can be hold by the whole network.

The flooding based routing is classified into two types:
- **Replication Based:** In the replication based routing, the network nodes creates the replicas of received messages. For a particular message, the maximum number of replicas in a network is **N-1. N** is the number of nodes in the network.
- **Quota Based:** In this type of routing, every message has assigned a quota, i.e. there is limited number of replicas for a particular message.

a). Direct Contact:

The bundle is forwarded directly from the source node to destination node in the Direct Contact [13] routing algorithm.. The source node firstly creates the bundle and then it will wait for the destination node. The algorithm has not any requirement of any information about the network, so it falls in the category of flooding based routing. The delay in the delivery of bundle from source node to destination node is very high and the routing cost for routing the bundle from source to destination is very low

b). Epidemic Routing:

In Epidemic routing each node replicates the message to every other node it met so far, if the other node is not having the message copy. After the checking for the summary vector, message replication is done Each node maintains the summary vector, which stores the information about all the messages, passed through this node or currently stored in its buffer. In the literature, different type of enhancements were proposed to the original Epidemic routing algorithm like prioritized epidemic and immunity based epidemic.[14]

c). Two Hop Relay:

In this approach, the source node will replicate the messages to a large number of the relay nodes. In this way, a message can only be delivered to the destination node within two hops only i.e. either the source node directly delivers the message to destination or to the relay node. Relay nodes will not further replicate it to the 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.[15]

d). Tree Based Flooding:

The concept of binary tree based algorithm was given by T. Small [12]. The algorithm works upon the concept that the source node must be in the limit with the number of replicas to control the width and depth of the tree i.e. when the nodes are limited with number of copies then they can be gone in the depth up to a certain level. Each node can be having maximum of two child nodes so that the replicas are equally distributed in between them. After this receiving phase, the offloading of the messages is started by the nodes to the collection stations, so to reach the destination.

e). Spray And Wait:

The advanced version of the epidemic routing is the Spray and Wait algorithm [16]. In this algorithm the nodes are not distributing the replicas to the each and every node but an optimal number of nodes (say m) are selected to which the source node will relay the message. Two phases exists in this approach: First is "Spray" and Second is "Wait". In Spray phase, the source node will replicate the message to the m nodes and these m nodes will further relay the message to m relay nodes. If the destination could not be found in the spray phase then the relay nodes will store the message and performs the direct transmission to the destination.

B. FORWARDING BASED ROUTING:

This type of routing takes place when the nodes in the network have some relevant knowledge about the other nodes present in the network. In this type of routing, any of the nodes in the network will not generate replicates of the messages. Each node in the network will search for the best suitable relay nodes in the network and forwards the message to them. This approach reduces the extra resource consumption because 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. Forwarding based routing protocols are classified in five types (Figure 2).
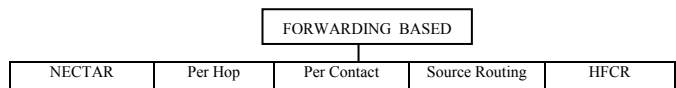
FORWARDING BASED				
NECTAR	Per Hop	Per Contact	Source Routing	HFCR

Figure 2: Forwarding Based Routing Protocols

a). NECTAR:

The concept of neighbourhood index table which is maintained at each of the node is given by the NECTAR algorithm [17]. The information about the meeting frequency of the node is stored in this table with every other node in the network. The higher index value is assigned to a node which is having a higher meeting frequency. When a node needs to forward the message to a particular destination, then it will choose one of the relay nodes that have highest index value for the respective destination.

b). Per Hop:

In Per-Hop routing [18], each intermediate node will decide the next node to which the packet is to be forwarded for a particular destination. This approach [19] 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, 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 the routes is keep going.

c). Per Contact:

The most updated information is being used in the Per-Contact Routing [20] 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 relaying of the message is done by the selection of the appropriate node, and forward the message to the most appropriate node.

d). Source Routing:

There are two phases in the Source routing [21]. One is route discovery phase and the other one is route maintenance phase. Initially control packets are sent towards the destination node for the route discovery. Each of the intermediate nodes will be appended its address in the bundle or packet. Each node also maintains a cache for the routes that the node has learnt over time. When the packet reached to its destination, the whole route is appended in the packet only. In the route maintenance phase if there is a failure of link is detected then a route error message is broadcasted by the source node.

d).Hierarchical Forwarding and Cluster Control Routing[22]:

This routing protocol introduces the phenomena of clustering i.e. grouping of the nodes on the basis of link property and characteristics of the communication. When all the clusters are formed, a cluster head is selected depending upon some criteria. In the cluster head node is selected based on the higher stability or the higher quality among all nodes within the cluster. The selected cluster head then take the routing decisions

IV. COMPARISION:

The routing protocols presented in this paper have few advantages and few disadvantages. The performance of some of them is very good, but they consumed more network resources. Some protocols give the optimal solution with the consumption of less resource. Depending upon the network scenario as well as the application environment, where the network is deployed, the routing protocol is selected. In this paper, on the basis of different type of performance metrics we have compared the existing routing protocols. In table 1, we have compared the flooding based routing protocols. In table 2, we have compared the forwarding based routing protocols.

Protocol	Number of Messages generated	Message delivery ratio	Average delay	Resource consumption
Direct contact	Single	Low	High	Less
Epidemic	N-1	High	Low	High
Two-Hop	K	Medium	Medium	Less
Tree-Based	1+log(N/2)	Medium	High	Medium
Spray And Wait	>=K	Medium	Medium	Medium

Table 1: Comparison of flooding based routing protocols

Where N= Total Number of nodes present in the network

K=optimal number of nodes to assure the delivery for Two-Hop its minimum is Q√n

Protocol	Information maintenance	Message delivery ratio	Average delay	Resource consumption
NECTAR	Medium	High	Normal	Medium
Per-Hop	Medium	Medium	Medium	Low
Per-Contact	Medium	High	Low	Medium
Source	Normal	Low	High	Low
HFCR	High	High	Normal	Medium

Table 2: Comparison of forwarding based routing protocols

V. CONCLUSION:

The DTN is new area for research and it going under the intense research for its different routing protocols and the area where they can be easily deployed. There are so many routing protocols which are proposed earlier and so may protocols will be proposed sooner. Every protocol has some advantage and disadvantage. Flooding based protocols have better delivery ratio but it consumes more resources then Forwarding based protocols.

In this paper, we have introduced DTN with some key features like intermittent connectivity, high latency tolerance, store-carry-forward approach of nodes etc. We also introduced the routing issues in DTN. We have made a comparison of flooding based routing protocols and forwarding based routing protocols on different performance metrics.

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