Routing Protocol Approaches in Delay Tolerant Networks

Shivi Shukla[1], Amit Munjal[2] and Y. N. Singh[2]
AIM & ACT Dept., Banasthali Vidyapith, Rajasthan[1]
EE Dept., Indian Institute of Technology, Kanpur[2]

Abstract

The Delay Tolerant Network (DTN) is an intermittently connected wireless ad-hoc network that allows the communication between the wireless nodes in the scenario where end to end connectivity can never be achievable or when the delay associated in relaying data could be very high. The DTN is also known as opportunistic networks. The DTN's are suitable for work in the infrastructure-less environment. It also allows the communication between wireless nodes in the heterogeneous environments as well. The selection of routing protocol in DTN depends on the application environment in which it is to be used. In this paper, we have made an attempt to review the existing DTN routing protocols in the literature. We have also made a comparison of the existing routing protocols of DTN for the different performance metrics such as number of data message generated, message delivery ratio and average delay.

1) Introduction to DTN

The idea of Delay Tolerant Network (DTN) was taken from interplanetary Networks (IPN), which was started in 1970s. IPN was invented to communicate between earth and mars. The DTN is a wireless ad-hoc network which tolerates the intermittent connectivity. DTN can also be defined as intermittently connected wireless ad-hoc network [1] that can tolerate the longer delays, intermittent connectivity and prevent data from being lost by using store-carry-forward approach. Intermittent Connectivity can be defined as the sudden change of state (up/down) of any communication link between the nodes. The Store-carry-forward approach enables the nodes to take the message, store it in buffer and forward the same whenever new node comes in its communication range.

In DTN [2], nodes have minimal knowledge about the network scenario. The DTN allows the communication between the wireless nodes in the scenario where end to end connectivity could never be achievable or when the delay associated in relaying data could be very high. The operation of DTN makes use of Bundle Protocol (BP), positioned above the TCP protocol in the protocol architecture stack of DTN. The main functions a BP can provide are [3]:

- Retransmission can be done any time as because the nodes hold the Custody of the message.
- Tolerate the intermittent connections
- Make use of different connectivity like scheduled, predicted, and opportunistic
- Supports late binding as it supports the heterogeneous environments.

The application areas of DTN are challenged environments like military battlefields, deep under water communication, natural hazard affected areas or remote area social networking etc.

The advantage of DTN over other wireless networks is that DTN can tolerate intermittent connectivity and assure the data delivery even with very limited knowledge of network. In other traditional networks if the communication link goes down at any point of time of communication then the data loss is assured but in DTN, if the communication is in process and the link goes down then the data get stored in the sender/receiver node's buffer rather being lost. This is because, in DTN the message forwarding is done by replicating the message to other nodes i.e. the sender and receiver both the nodes can have the copy of the same message stored in their buffer.

2) Routing in DTN

In traditional networks, 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 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 the literature of DTN, the routing protocols are categorized into two broad categories [4] [5] as shown in Fig 1:

- Flooding Based
- Forwarding Based

In the literature, there exists a variety of routing algorithms for DTN. Here, in this paper we have discussed some [9] of them.

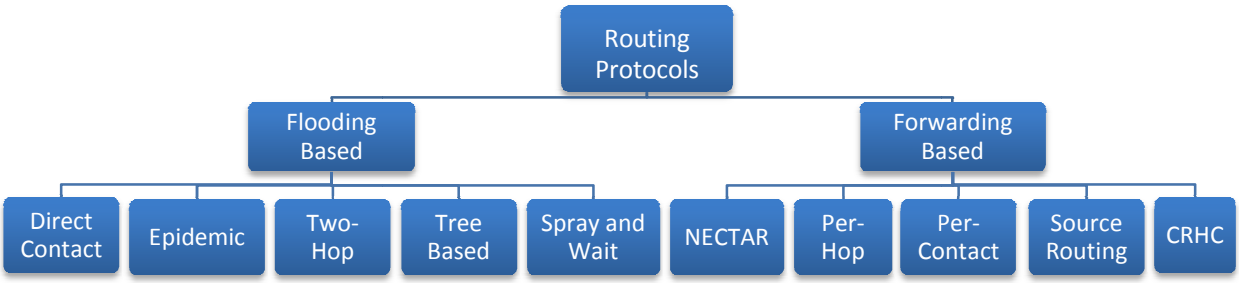

Figure 1: Categorization of DTN routing approaches

2.1) Flooding Based Routing

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.

2.1.1) Direct Contact

In Direct Contact [6] 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.

2.1.2) Epidemic Routing

In Epidemic routing [7] each node replicates the message to every other node it met so far. 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 the literature, different enhancements were proposed to the original Epidemic routing algorithm such as prioritized epidemic and immunity based epidemic.

2.1.3) Two-Hop Relay

In this approach [8], 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.

2.1.4) Tree Based Flooding

T. Small et al [9] 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 N_c -1. 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.

2.1.5) Spray and Wait

The Spray and Wait [10] 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 & 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

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 resources are limited.

2.2.1) NECTAR

The NECTAR [11] algorithm has given the concept of neighborhood index table that is maintained at each of the node. This table stores the information about the meeting frequency of the node with every other node in the network. The node with higher meeting frequency will be assigned a higher index value. When a node needs to forward the message to a particular destination, then it will select one of the relay nodes that have highest index value for the respective destination.

2.2.2) Source Routing

The Source routing [12] 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.

2.2.3) Per-Hop Routing

In Per-Hop routing [13], each intermediate node will decide the next node to which the packet is to be forwarded for a particular destination. This approach [16] has better performance than Source routing because the more updated information is used than Source Routing.

2.2.4) Per-Contact Routing

The most updated information is being used in Per-Contact Routing [14] because when any intermediate node receives any message for a particular destination then the intermediate node checks the current Up contacts and select the appropriate node for relaying the message and then forward to these Up contacts.

2.2.5) Hierarchical Forwarding and Cluster Control Routing [15]

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 [15] 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 this cluster head.

3) Comparison

The routing algorithms discussed in this paper have advantages as well as disadvantages. Some of them will perform very well but consumes more network resources, while some of the algorithms give optimal solution with less resource consumption. The selection of routing algorithms is very important and it depends on the network scenario and the application where the network is deployed. So, we have made an attempt to compare the existing routing algorithms on the basis of different performance metrics. The Table 1 shows the comparison of flooding based routing algorithms and table 2 shows the comparison of forwarding based routing algorithms.

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 **Error! No sequence specified.**: Comparison of flooding based routing algorithms*

N= Number of nodes in the network

K= optimal number of nodes to assure the delivery for Two-Hop its minimum is $\Theta\sqrt{n}$

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
CRHC	High	High	Normal	High

Table 2: Comparison of forwarding based routing algorithms

4) Conclusion

The Delay Tolerant Networks are under the intense research for its various routing algorithms and the areas of its applicability. Many routing algorithms are proposed and many are still in line. Each algorithm has its own pros and cons. The algorithms based on flooding have a better delivery ratio but consume more resources comparatively to Forwarding based algorithms. The algorithms used for routing protocols in DTN are not limited only to the algorithms defined in this paper. For the selection of algorithms to be implemented, it is useful to check them comparatively and select the best as per the application scenario.

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