Routing Protocols in Delay Tolerant Networks

Ashima Mittal[1], Ananya Sharma[2], Sarthak Arora[3] , Preeti Nagrath[4] and Sandhya Aneja[5]
[1,2,3] Student, Department of Computer Science Engineering
Bharati Vidyapeeth College of Engineering, New Delhi, India
[4] Assistant Professor, Department of Computer Science Engineering
Bharati Vidyapeeth College of Engineering, New Delhi, India
[5] Faculty of Integrated Technologies
Universiti Brunei Darussalam, Brunei
[1]ashimamittal96@gmail.com
[2] sharma.ananya_25@yahoo.com
[3] arora.sarthak96@gmail.com
[4] preeti.nagrath@bharatividyapeeth.edu
[5] sandhya.aneja@ubd.edu.bn

***Abstract* - Delay Tolerant Network (DTN) can be defined as an approach to Computer Network Architecture which provides a promising solution that seeks to address the technical issues in the regions where end-to-end network connectivity may lack continuously or is not available. These problems are aggravated by end nodes with limited power or memory resources. In DTNs, the intermediate nodes on a Transmission path are expected to store, carry, and forward the in-transit messages (or bundles) in an opportunistic as well as conciliatory way, which is called opportunistic data forwarding i.e. it follows Store and Forward Technique(SFT). To make imparting of information possible, intermediate nodes take responsibility or charge of the data being imparted or transferred and forward it as the opportunity arises. Both links and nodes may be inherently fickle and disconnections may be lasting. To realize the DTN vision, routes must be found over multiple unreliable, at regular intervals connected hops.**
To address the apt routing protocols in DTNs, we in this paper have discussed the various routing protocols in DTN and their comparisons on performance, cost, delay, probability of message delivery etc.

***Keywords* - DTN-routing protocols-Data centric routing-Cluster based routing.**

1. INTRODUCTION

Over the past decade, DTN researches have gone from being a little niche research area to being evolved into a conventional research topic within networking. Some great advancements have been carried out in this area. The ability to transport, or route, data from a source or sender to a destination or receiver is a fundamental ability that all transmission networks should have. Delay and disruption-tolerant networks (DTNs), are distinguished by their lack of connectivity, out-turning in lack of instantaneous end-to-end paths.

In these challenging environments, popular ad hoc routing protocols such as Ad hoc On-Demand Distance Vector (AODV) and Dynamic source routing (DSR) fail to establish routes [2]. This is because these protocols first try to establish a complete route between source and destination and when the route has been established, the actual data is forwarded. However, when instantaneous end-to-end paths are difficult or impossible to set up, routing protocols must take a "store and forward" approach, in which data is incrementally moved and stored throughout the network i.e. DTN offer asynchronous transmission or communication in which arbitrarily sized messages are sent by the initiator and stored by intermediate nodes (and possibly physically carried) until a suitable next hop or the final destination becomes available to forward the message.

The architecture of DTN consists of an overlay, called the bundle layer. A bundle can be defined as a number of messages to be delivered together. DTN nodes forms an overlay on implementing the bundle layer that employs persistent or diligent storage to overcome network intrusions. The bundle layer stores and forwards bundles between the DTN nodes i.e. Store and Forward Technique. The bundle layer is situated below the application layer and above the transport layer, thus allowing environment-specific underlying protocols. The bundle layer facilitates hop-by-hop reliability and retransmission. It also implements a naming scheme that uses late binding i.e. the name is not mapped onto an address until topologically near the target of transmission [3]. The bundle layer provides an overlay or cover to hide disconnections and delays from the application layer and transparent communication between different regions. Delay tolerant Network (DTN) provides a network architecture independent messaging services. A common technique used to increase the probability of a message being successfully transferred is to replicate or reproduce many copies of the message so that one will succeed in reaching its destination or receiver [4]. DTN is required to store messages in non-volatile memory when reliable delivery is required.
Examples of such networks are those operating in mobile or extreme terrestrial environments, or planned networks in space. [1]

In order to exploit available scheduled and opportunistic ad-hoc connectivity in the deployed area, an efficient routing scheme is needed. Much of the focus of DTN research has been in routing protocols, with a multitude of protocols presented in research papers.

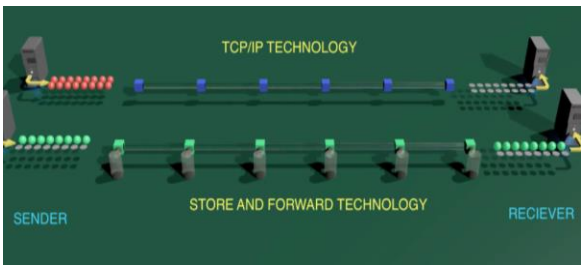

Figure 1. Store and Forward technique in DTN

2. ROUTING PROTOCOLS IN DTN:

Both routing and forwarding are processes used in the network layer of the communication protocol stack for data transmission. In the forwarding function, the received messages are transferred from an input link to an output link. Whereas, routing process helps in deciding the route for data transmission. It utilizes the knowledge acquired by means of routing protocols to decide the routes or paths to transfer data packets from source to destination. The routing protocols may use different routing algorithms for choosing the appropriate transmission path. The maximum number of hop counts, the shortest path, available bandwidth are some of the criteria that are used by different routing algorithms in the decision making process.
In DTN, the main characteristic of packet delivery is large end-to-end path latency and a DTN routing protocols has to cope with frequent disconnections. Numerous routing and forwarding techniques have been proposed over the past few years. Majority of forwarding and routing techniques uses asynchronous message passing (also referred to as store-carry-forward) scheme.
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, protocols are categorized into two broad categories:
Routing is of two types: Data centric and Cluster based routing.

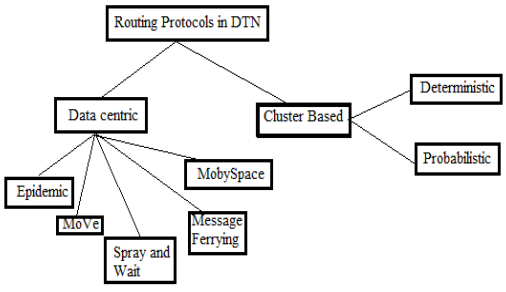

Figure 2. Routing protocols in DTN

2.1 *DATA-CENTRIC ROUTING*

In such a routing system, the destination sends queries to certain regions and waits for data from sensors in these regions. Since data is requested through these queries, attribute-based naming is essential to specify the properties of data.

A. Epidemic Routing

In such a protocol, the message is replicated to every node encountered that does not contain the message copy. It uses a store-carry-forward paradigm. Analogous to the unfurling of infectious diseases, each time a packet-carrying node comes across a node that does not have a copy of that packet, that carrier infects this new node by passing on a packet copy [8]. The newly infected nodes, in turn, behave similarly. The destination receives the packet when it meets the infected node for the first time.

Such a routing protocol guarantees transmission of message to the destination irrespective of deliver delay but at the cost of network congestion. Multiple copies of the same message in the network also result in large overhead and increased use of resources such bandwidth, transmission power and buffer space [9].

B. Spray and Wait

This routing scheme sprays a number of copies of the message into the network and waits till one of these nodes delivers the message to the destination. It associates a number 'n' to messages that indicates the maximum allowable copies of the message. It consists of two phases, the spray phase and wait phase [9]. In the spray phase the source node sprays 'n' copies of the message to 'n' distinct nodes. After receiving the message copy all the 'n' nodes go into wait phase till the message is delivered to its destination. There are two types of Spray and Wait namely Source Spray and Wait and the Binary Spray and Wait. In the Source Spray and Wait the source node forwards all 'n' copies to the first 'n' distinct nodes. In Binary Spray and Wait the source of a message initially starts with L copies. When it encounters first node with no copies then it gives [n/2] copies to that node and keeps the remaining [n/2] .This process is repeated for both source and nodes that has n> 1 message copies, and when either is left with only one copy, it switches to wait phase till the direct transmission to the destination. It has fewer transmissions, delivery delay close to optimal, scalable with respect to node density or node size and requires low network knowledge [10]

C. Message Ferrying

In this protocol, special nodes known as ferry nodes and designed course is used for communication. The main idea in this approach is to introduce non-randomness in the movement of nodes and use this non-randomness to deliver data [10]. Depending upon the entity initiating the communication, there are two forwarding techniques: Node initiated message ferrying (NIMF) and Ferry initiated message ferrying (FIMF). According to the former approach ferry nodes choose their path using a predefined pattern known by other nodes. In the latter approach nodes broadcast requests whenever they need to send or receive messages. The nearest ferry node is responsible for responding and moving towards the nodes to pick up messages.

D. Motion Vector (MoVe)

The Motion vector (MoVe) [10] scheme uses the knowledge of relative velocities of a mobile router and its neighboring nodes to predict the shortest distance they are predicted to cover to get to the destination.

E. MobySpace

The principle behind this approach is that two nodes with similar trajectories have a high probability of meeting each other. Each node forwards the received message to the encountered node provided that they have similar trajectories with the destination node. The closer nodes have a higher probability of communicating with each other, so the messages are forwarded towards the

nodes that are as close to the destination as possible [11].

LIMITATIONS OF DATA-CENTRIC PROTOCOLS

Such protocols give reasonable performance when applied to small networks and when applied to large networks their performance drastically decreases and so does the delivery performance.

A comparison is made between the various routing protocols on the basis of different performance metrics:

Protocol	Message Delivery Ratio	Resource Consumption	Average Latency	Overhead Ratio
Epidemic	High	High	Medium	High
Spray and Wait	High	Medium	Medium	Low
Message Ferrying	High	Medium	High	Medium
Moby Space	High when stable mobility patterns exist otherwise medium	Low	Low when stable mobility patterns exist otherwise high	Low
Motion Vector	Medium	Medium	Medium	High

Table 1. Comparison between different data centric routing protocols

2.2 CLUSTER-BASED ROUTING

Clustering is defined as the procedure of organizing objects into group whose constituents are similar in some way. The main idea of clustering is to group numerous nodes with similar domain pattern into a cluster which can then interchangeably share their resources. Clustering based methods can be broadly classified in to deterministic and probabilistic models:

A. Probabilistic Routing Protocol

i) Probabilistic Routing Protocol using History of Encounters and Transitivity (PROPHET) is another routing protocol used for intermittently connected networks. It uses knowledge obtained from past encounters with other nodes to optimize the packet delivery. If a node has visited a location several times, then there is a possibility that this pattern will repeat in the future [9]. Each node keeps a vector of delivery predictability estimates [8]. The predictability estimates are increased every time a node comes across another node, and they are decayed exponentially [12]. It also includes a "transitivity" mechanism for dealing with the case where two nodes rarely meet, but there is another node that frequently meets both of these nodes. When two nodes meet, they exchange the delivery predictability vector for destinations known by the nodes. They will also update the probability between them. This protocol improves the delivery probability and reduces the wastage of network resources experienced in Epidemic Routing. However it has higher average delay when the buffer size of the nodes is increased.

ii) Clustering using EWMA

This idea groups nodes with similar mobility pattern into a cluster so that they can share their resources for overhead curtailment and load balancing [10]. An exponentially weighted moving average (EWMA) [20] is used for updating nodal contact probability. Each time a contact goes up or down, we update the estimate as follows:

$$D = \alpha D + (1 - \alpha)di$$
$$C = \alpha C + (1 - \alpha)ci$$
$$E = D^2/2(D + C)$$

Where E is the estimated delay, D is the average disconnection time, and C is the average connection time. With this calculation, α is a tuning parameter, where a higher value means that the metric will react slowly to changes, but will be resilient to short term perturbations. This implementation has the advantage that it requires fixed resources to execute. Unfortunately, it also has a built-in tendency to underestimate the average waiting time. The reason is that the averaging of D weights all disconnection periods

equally. However, the exact conjectured delay computation weights long disconnections much more than small disconnections because in those periods a message must wait longer and because there is a higher probability of arriving during a long wait period [13].

B***. Deterministic Routing Protocol***

For computing the optimal route between a source and a destination in deterministic routing protocols, it is completely based on predictable information about the node future mobility pattern and the various links available between the nodes [5]. It can be classified as follows:

i) Oracle Based Routing:

Oracles (Knowledge centres) are used to make routing decisions. Such routing algorithms use information about network topology and traffic characteristics. According to the amount of information needed to compute the routes, these algorithms are classified into complete knowledge and partial knowledge. Oracle-based algorithms are suitable for networks with controlled topology or with existing full or partial information about the same [6][7].

ii) Link State Based Routing:

This is a routing mechanism which is entirely position based that predicts the spacecraft or satellite's paths to make routing decisions. Flooding is performed at first in the suggested routing and then the prediction of trajectory nodes [11]. Characteristics such as latency, error rates, link availability and link states are then updates. Finally, every individual node re-computes its own routing table independently using Dijkstra algorithm [14]. Link state basically tells the connectivity status of nodes in a network and provides a complete picture of the topology when aggregated. As the entire topology picture is provided by the nodes, network configuration and remote management is simpler. By interrogating a single node, the whole network topology is available [15].

iii) Space Time Based Routing

In this protocol, it is assumed that every node knows its own moving state as well as that of the other nodes [16]. Unlike conventional routing where routing tables are made using only connectivity information, this protocol provides a space-time routing table that relies on information about arrival and destination of messages. These two characteristics are used to choose the next hop in the route. So, the forwarding decision is a function of both time and destination [17].

iv) Hierarchical Clustering

It [10] is a method of deterministic clustering in which the nodes periodically switch on and then transmit the data. All the nodes in the network are analogous and begin with the same initial energy and the buffer space has a constant power supply and so, there are no energy constraints.

• Intra Cluster routing: - If Nodes i and j are in the same cluster, they have a greater chance of meeting each other, thus Node i will transmit the data message to Node j when they meet.

• Solitary Hop Inter Cluster Routing: - If they are not in the same cluster, node i will look up the gateway information to Node j's cluster in its gateway table. If an entry is found, Node i sends the data message to that gateway. Upon receiving the data message, the gateway will forward it to any node, e.g., Node k, in Node b's cluster. Node b in turn delivers the data message to Node j via Intra-cluster Routing.

Cluster based Deterministic Routing Protocols	*Cluster based Probabilistic Routing Protocols*
All the nodes in the network are homogenous and well defined. They provide a picture of the pertinent parameters at regular intervals.	Nodes are not rigidly defined within a cluster and an exponentially weighted moving average is used for updating nodal contact probability which in turn defines the clusters.
They are well suited for applications requiring episodic data monitoring	They are well suited for applications requiring continuous data monitoring
Example- Hierarchical Clustering	Example – Clustering using EMWA

Table 2. Comparison between different cluster based routing protocols

3. CONCLUSION

DTN routing comes across as a rich and challenging problem. In this paper we study the different data centric protocols and cluster based routing protocols in delay tolerant networks. Data centric routing protocols have many disadvantages as compared to cluster based routing protocols. Cluster based routing protocols outperform the data-centric routing protocols in terms of scalability and efficacy. In this paper an attempt to investigate different protocols in handling Delay tolerant Networks has been made. The cluster based scheme manages to overcome the shortcomings of data-centric protocols and improves the routing performance in DTN.

4. PROPOSED WORK

Numerous existing routing protocols have been studied in this paper. DTN offers a number of challenges to its efficient routing design due to its unique characteristics. To overcome those challenges, we intend to create and implement a new protocol that can control the number of replication of message to the encountered node and can give better performance than the existing protocols in terms of overhead, delay and increasing the message delivery rate.

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