Routing in Delay Tolerant Network

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ABSTRACT
At present, the internet has grown exponentially due to its wide connectivity with different sets of devices. The only issue is the tolerances towards delay which leads to disconnection in case the delay is above tolerance level. Delay Tolerant Network (DTN) is the latest development to sustain longer delays by allowing disconnected operations. Among the various problems like buffering, resources allocation and energy consumption, routing is a major issue. The present study reviews many proposals regarding routing problem and its solution and the state of the art analysis is presented.

General Terms
Networks, delay, flooding, forwarding.

Keywords
Delivery ratio, DTN, latency, Routing protocols.

1. INTRODUCTION
Internet have connected communicating devices around the world. They are connected by using the TCP/IP protocol. All the network connected through internet use TCP/IP protocol to send the data from source to destination with less delay and high reliability. However, there are many regions where the assumptions of the internet cannot be upheld. If there is no available route from source to destination , the TCP/IP may cease to function properly. So a new network must be created so as to connect nodes independently. Such networks are called DTN.DTN works in disconnected network. As the networks are not connected, DTN uses the store, carry and forward.

2. LITERATURE REVIEW
The current internet architecture and protocols are successful in providing different communication services in wired and wireless network by using the TCP/IP protocols. But these protocols may not work properly in disconnected networks. In such cases, DTN are used. The main object that affects the performance of information delivery is routing protocols. Many research work have tried to improve the routing protocols originally proposed for wired and wireless networks to case of DTN's. AODV, DSR and OSLR are few examples that provide good performances in MANET's. But these protocols do not work properly in intermittent connections. The major restriction of these protocols is that they can work and find a route only if there is an end-to-end connectivity between end systems. Otherwise, the packets will be dropped by the intermediary nodes if no link to the next hop exits at the moment.

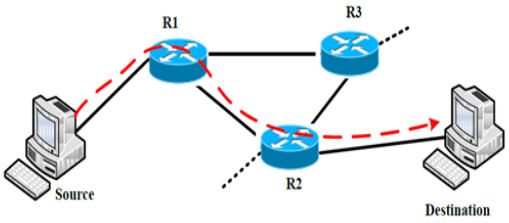

Fig 1: Traditional routing protocol schemes[11]

Figure 1 shows the traditional routing protocol schemes where there is end-to-end connectivity between the source and the destination. In DTN's network there no connectivity between the end systems so the use the bundle protocols so that they can store and forward the data till it reaches the destinations.

2.1 Related Work
There are many proposals and research papers based on DTN. In this section, we will go through few papers.

Paritosh Puri et al., proposed a combined study on Delay Tolerant Networks which was originally designed for interplanetary internet. It describes the basics of DTN area and Routing techniques used in DTN. Also comprises the comparisons of different routing protocols in DTN. [1]

K. Fall, proposed a network architecture and application interface structured around optionally-reliable asynchronous message forwarding, with limited expectations of end-to-end connectivity and node resources. The architecture operates as an overlay above the transport layers of the networks it interconnects, and provides key services such as in-network data storage and retransmission, interoperable naming, authenticated forwarding and a coarse-grained class of service. [2]

S.Jain et al., proposed a framework for evaluating routing algorithms in the environments where messages are to be moved end-to-end across a connectivity graph that is time varying but whose dynamics may be known in advance.[3]

E.P.C.Jones et al., proposed the area of routing in delay tolerant networks and presents a system for classifying the proposed routing strategies. [4]

Harminder Singh Bindra et al., have investigated the performance of three different routing protocols namely Epidemic, Prophet and Rapid against varying message TTL.[5]

After going through the papers from literature survey we have extracted the issues like routing, energy, buffer space and resource allocation. As each issue itself is a big challenge so we shortlisted routing for our analysis work. The present study analyses the fundamental issues of routing in DTN and the state of the art analysis have been presented in succeeding chapters.

3. DTN ROUTING PROTOCOLS

Routing issue is very important issue as there are limited resources available for storing the message and forwarding it. The Routing issues are considered by many researchers and this have resulted in many routing protocol based on Flooding and Forwarding Approach.

In standard routing protocols paths are been selected from the available options. But DTN tries to find the best path from the few available paths. Thus DTN is designed based on the practical scenarios these protocols are classified on how they find the destination and if the replicas of messages are transmitted or not. Thus the routing protocols are classified as Replica based (flooding) protocols and Knowledge based (store and forward) protocols. Below we have gone through Replica based protocols in detail.

3.1 Replica based (flooding) protocols

Replication based protocols allow for better message delivery ratios than in forwarding-based protocols. These schemes work by making several replicas of the original message or packet. Each node maintains a number of copies of each message and retransmits them upon connection establishment. These protocols are also referred to as flooding based protocols. Higher the number of copies more the probability of the message reaching to the destination. Replica based (flooding) protocols are resource hungry. So they are unable to tackle network congestions and is not scalable. Decision making for the priority of message replication and dropping under constrained environments is a challenging task. Protocols characterized under the replica based family include the direct contact, two hop relay, tree based flooding, epidemic routing, rapid.

3.1.1 Direct Contact

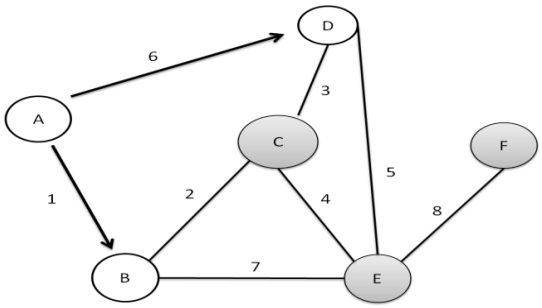

Fig 2: Direct Contact routing example [4]

The direct contact waits till the source meet with the destination before it forwards the data. Unlike the otherflooding based protocols, in direct contact the relay nodes consists of only the destination. Once we get a single route from source node to target node, the data is been sent. This method requires only one hop and requires no knowledge about the network. Such networks are considered as flood strategy.

It follows a simple approach so it will not consume more resources and uses only one message to be transmitted. As it follows a very simple approach, it consumes a very less resources. Its uses exactly one messages for message transmission. However, it only works if the source contacts the destination.

In fig 1 according to shortest path method source A can send data to destination D via B and C but this is not possible in direct contact routing. Source A will send the data to D directly as it one hop away.

3.1.2 Two hop relay

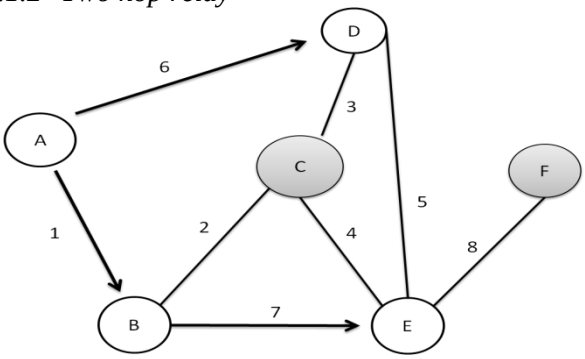

Fig 3: Two-hop routing example[4]

Here source copies the data to the 1st n neighbors. The source and the relays keeps the message and passes it to the destination. Now in a network there are n+1 message. So this will require more bandwidth and more storage. Latency can be reduced by increasing the number of copies. As the n+1 nodes meets the target, the message will be delivered. The disadvantage in two hop relay is as follows:

1. In two hop relay there n+1 copies of the message in the network so more bandwidth and storage is consumed.
2. There is a possibility that the n+1 node never reaches the destination node. In such conditions the message will not be delivered to the destination.

In example, if node A wants to send a message to node E. It firsts send copies to both nodes B and D as shown in fig 3.

Now if the node B is connected to node C. It would not send the message as node C is not the destination. At time 7, when node B connects node E which is the destination, the message will be delivered. Finally all the nodes A, B, D and E have the message. Node A can reach the entire node through two hop relay. But node F is an exception as it takes minimum 3 hops. In scenarios where mobility is random, it can be weird, but networking with structured connectivity can be very common.

3.1.3 Epidemic Routing

In this routing, the message is sent to all the available paths and nodes present in the network. In Epidemic algorithms there are many number of random exchanges of data. Thus all nodes will eventually receive all messages. So there is confirmation that the target node will get the data. Working of Epidemic Routing: Here the message which is sent is kept in buffer and its given a unique ID. When two nodes meet each other they first exchange all the message IDs that are present in the buffers called the summary vector. Now all the nodes have same messages in their buffer. This routing method has lots of redundancy as every nodes receive every message. This makes the method robust to node and network failures. It also reduces the time it take to deliver the message and the total resources consumed. Considering example in fig 4 data sent via A-B-C-E. Every nodes will get the message except node F. Because node E does not replicate messages that are destined for itself. Node F will not get the message from E. Because node E is the destination.

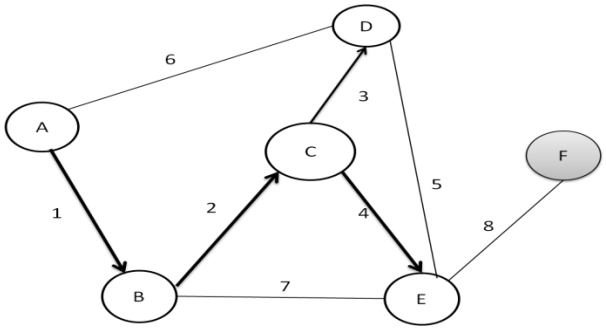

Fig 4: Epidemic Routing Example[4]

3.1.4 Tree based flooding

This strategy is a improvement to two-hop relay. Here the task of making copies are given to other nodes. When a message is copied to a relay, there an indication of how many copies the relay should make. In tree-based flooding, the relays are treated as tree nodes and root as source. There are many ways to decide how to make copies. One method is to permit all node to generate unlimited copies. And it should bind the message to traverse to a max of n hops from source. This limits the depth of the tree, but places no limit on its breadth. A refinement is to also limit the node to make atmost m copies. These will reduce the total number of copies to max of $\sum_{i=0}^{n} m^n$.

Another method is to limit to N copies. First a node creates a copy. Then it gives the duty of forming half of its current copies to other node. It keeps half of the copies with itself. This method works best if the internodes contact probabilities are independent and evenly distributed.

In the example, if node A wants to send a message node E. Also there is a condition that a maximum of 4 more copies can be made. At time 1, a copy to node B with directions to make 1 copy $\frac{4-1}{2}$, as in Figure 4. Node A keeps two copies for itself $\frac{4-1}{2}$. At time 2, node B attaches node C, Bs extra copy is delivered. At time 3, node C connects to node D. However, it cannot send D a copy because it has no copies to distribute. At time 4, C delivers the message to the E. At time 6, A transmits D a copy, as it does not know that the message is already been sent. Now, node A has one copy left that it will send if it contacts other node.

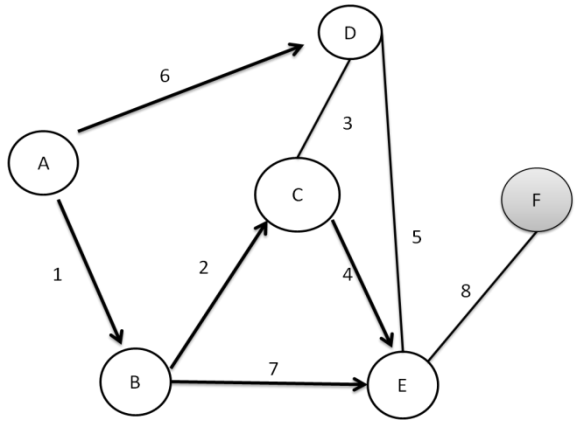

Fig. 5: Tree based flooding[4]

3.1.5 Rapid

Rapid [9] represents as a utility-driven resource allocation problem. Here many number of packets are created till the packet reach the destination. Rapid protocol extracts utility function of every packet from the routing metric. When data are been exchanged it replicates that packet who shows highest increase in utility.

Here we take Ui where i is generated from the given routing metrics. The metric reduces the average delay that is measured by adding the delay of packets. Thus the utility of a packet is taken as expected delay. Rapid protocol analytical depends on expected increase in utility per unit resource used. Rapid replicates packets in decreasing order of their minimal utility for every time it gets to send the data.

Rapid (A, B):

- Initialize: Get the metadata from B about packets present in buffer and metadata B obtained from previous meetings.
- Direct delivery: Deliver packets destined to B in decreasing order of their utility.
- Replication: For each packet i in node As buffer

1. If i is already in Bs buffer (as determined from the metadata), ignore i.
2. Estimate marginal utility, δUi, of replicating I to B.
3. Replicate packets in decreasing order of δUi=Si¬

- Termination: End transfer when out of radio range or all packets replicated.

4. COMPARATIVE ANALYSIS

From all the DTN proposals we have analyzed that in DTN the Routing protocols can be broadly classified as Replica based (flooding) protocols and Knowledge based (store and forward) protocols. The protocols characterized in replica based protocols are direct contact, two hop relay, tree based flooding, epidemic routing and rapid. After analyzing these protocols on the basis of number of hops the direct contact flooding protocols is better as there are least number of hops but there is a disadvantage that cannot always reach the destination in 1 hop. With latency, rapid protocols has less delay among the all flooding protocols. Resource consumption, delivery ratio, scalability, information usage, loop free, multipath support, routing table and effectiveness derive that rapid protocols gives better results among all the routing protocols in flooding based strategy. The most common of these metrics include hop count, latency, resource consumption, delivery ratio, scalability and overall effectiveness. Multipath support, loop freeness, information usage and use of routing table is also included in the comparison table to have a deep insight into the overall performance assessment.

Table 1: Comparison among flooding strategy

	Direct Contact	**Two Hop Relay**	**Tree Based Flooding**	**Epidemic Routing**	**Rapid**
Number of Hops	1 hop	2 hops	Many	Many	Many
Latency	Large	Large	Large	Large	Less delay
Resource Consumption	Low	Low but more than direct	High	Maximum	Low
Delivery Ratio	Low	Low	Low	Maximu	High

		but better than direct		m	
Scalability	Low	Low	High	High	Low
Information Usage	Low	Low	Moderate	Moderate	High
Loop free	Yes	Yes	No	No	Yes
Multipath Support	No	Yes	Yes	Yes	Yes
Routing Table	No	No	No	Yes	No
Effectiveness	Low	Low	Low	Moderate	Good

From the comparison tables given below, following conclusions are inferred:

1. Replication has higher delivery ratio.
2. Forwarding based families have overall low resource utilization.
3. Direct Contact in flooding family has an overall low performance and effectiveness while RAPID seems to be a good choice.

5. CONCLUSION

The traditional network requires end-to-end connection to route packets from source to destination. The increase in delays due to various reasons keeps the network disconnected frequently. Delay tolerant network is a new paradigm which opens a horizon for disconnected operations. Routing is made simplified by studying and analyzing various routing protocols for Delay tolerant network. So its concluded that resource allocation protocol for intentional DTN (rapid) proposal is better one from flooding based approach.

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