

Analysis of Different Buffer Management Strategies in Delay Tolerance Network Routing

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Abstract—Delay Tolerant Networks or DTNs are the results of the evolutions in the mobile ad hoc networks (MANETs). In such environments the link between the pair of nodes is frequently disrupted due to the dissemination nature, mobility of nodes, and power outages. Because of the environment nature in Delay Tolerant Networks like under water, ocean sensor networks etc., the delays may be very extensive. To obtain data delivery in such challenging and harsh networking environments, researchers have proposed a technique in which the messages is stored into the buffers of intermediary nodes until it is forwarded to the destination. The DTNs are based on the concept of store-carry-and-forward protocols. So, node have to store message for long or short period of time and when connection established replica will be sent to encountered node. A critical challenge is to determine routes through the network without even having an end-to-end connection. This combination of long term storage and message replication imposes a high storage and bandwidth overhead. Thus, efficient scheduling and dropping policies are necessary to decide which messages should be discarded when nodes' buffers operate close to their capacity. If a relay buffer is full and needs to store a new packet, it has to decide either to keep the current message or to drop it. This paper will give survey on different transmission and dropping policies with their mechanism, their performance in different routing and their limitations.

Keywords—DTN, Epidemic routing, Spray and wait protocol, PROPHET routing, MAXPROP routing, DL, FIFO, MOFO, E-DROP, N-DROP, Routing protocol, Dropping policy

I. INTRODUCTION

Delay Tolerance Network is popularly known as disruption tolerance network. Initially as a concept it was proposed by NASA for interplanetary communication.

The main difference between MANET and DTN is that, MANET works in two phases. The first phase is setting up a route from source to destination while the second phase is transmitting data and maintaining the route information. This methodology cannot be used in DTN. In DTN two nodes are in contact then they will exchange the information. The storage capacity of the node is different, for both MANET and DTN. Delay-tolerant networks are intended to function in different and dissimilar environments that are characterized by three prime features respectively: i) there is no persistent end-to-end connectivity among the nodes, ii) there are long delays in paths and iii) frequent packet drops. DTNs apply in many application instances, especially in developing regions lacking network infrastructure. The concept of delay-tolerant networks emerged when the traditional TCP/IP protocol failed to work in environments that use acoustic or optical modulation with frequent interruptions, terrestrial mobile networks with no constant end-to-end connectivity and sensor nodes with limited end-node power and CPU capability. Such networks violate the functioning of TCP/IP suite and are often termed as Challenged Networks. In these networks, no end-to-end path between source and destination nodes prominently exists. Hence, in those types of scenario TCP/IP network starts to work inappropriately or even stops to work at all. A good example of such environment is the communication in Interplanetary Internet where speed-of-light delay to outer

planets from Earth becomes significantly higher. A normal file transfer initiated from Earth to Mars might take about an hour. The main limitations that are prevalent in aforesaid challenged network are namely: frequent disconnections, non-existent routing paths, low data rate, high latency, bandwidth limitation, lack of power and energy. These shortcomings gave way to ascertain some network characteristics like contact, contact schedules, waiting time, queuing time, propagation and transmission delay respectively [9].

DTN is an evolutionary approach that can provide connectivity in intermittent heterogeneous network. It is characterized by high latency, i.e. any two nodes may or may not meet each other. Due to the long latency of data delivery it has low data rate. It also suffers from frequent disconnections thus is often called Intermittently Connected Network [3]. Because there is no guarantee of end-to-end connectivity in delay-tolerant networks, the routing protocols which have good performance in the conventional networks are not suitable for delay-tolerant networks. DTNs are characterized by latency, bandwidth limitations, error probability, node longevity, or path stability [9].

DTN works as an overlay on top of an already existing TCP/IP stack which supports intermittent connectivity and overcomes communication disruptions as well as delays. To provide its services 'Bundle Protocol' sits at application layer. DTN provide store-carry-forward mechanism to deliver message to the destination node by coping message at intermediate node in case of disconnection and forward it whenever there is connection established with another node

II. ARCHITECTURE OF DTN

The architecture of Delay tolerant networks is designed as an overlay of existing networks which works on the following concepts:

A. Bundle layer

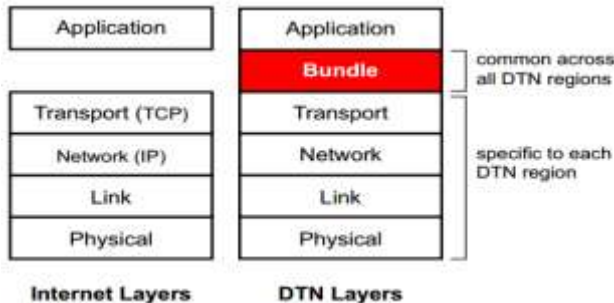


Figure 1.

Architecture of DTN introduce an overlay just above the transport layer in existing network is called bundle layer. Bundles are also called messages. Data transfer takes place by storing and forwarding entire bundles between the nodes. The bundle has user-data, control information, a bundle header. When two nodes come to contact with each other this bundle layer is already easily linked with TCP/IP to provide a gateway.[10].

B. Store-carry-forward technique

The mechanism of store and carry forward overcome the problem of traditional protocol that may be lack of connectivity, irregular delay etc. in traditional protocol if there is any connection lost then message will be lost. In DTN, intermediate nodes store messages when there is no direct destination node, carry that message until another node comes in communication range and forward that message to encountered node.

As shown in Figure 2 each node has a persistent storage to back up the messages just in case the network fails during transmission.

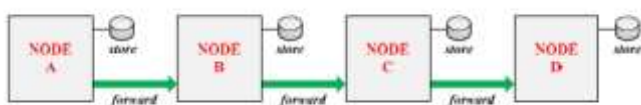


Figure 2.

C. Custody transfer mechanism

Bundle layer uses the custody transfer mechanism to realize the message retransmission and confirm among nodes, thus increasing the reliability of message transmission. The message in bundle layer is called bundle which is consisted of bundle header, control information and application data unit (ADU), which provides some services such as custody transfer, receipt of accepting, announcement of custody transfer, announcement of forwarding bundle, priority and authentication.

III. ROUTING PROTOCOLS

A. Epidemic routing

In nature, epidemic routing protocol is flooding based routing protocol as it continuously replicate message to all encountered node. When two node comes in communication range of each other then they exchange summary vector and transmit those messages which are not in another node's buffer. Receiving node has complete autonomy to accept or reject new message. In this routing no acknowledgment when message reaches its destination.

B. Spray and wait protocol

This is no limit in replicas in epidemic routing protocol but this lead to buffer overflow therefore, to put limit on replicas spray and wait protocol is used. As name suggests, in this protocol node spays some specific number of replicas and wait until one of those replicas reach to destination.

C. PROPHET routing

This is probability based routing as delivery predictability is calculated when two nodes come in communication range. Exchange summary vector and update their delivery predictability towards destination. High delivery predictability of message will get chance to forward first.

D. MAXPROP routing

This is also probability based routing. Probability is calculated as in PROPHET routing but the difference is, in MAXPROP routing it sorts messages with hope count so high delivery predictability and low hope count will forward first and low delivery predictability and high hope count will drop first in case buffer full. Performance overhead ratio and delivery ratio of this routing is good as compare to other.

IV. PERFORMANCE MATRICS

A. Delivery ratio

Suppose that N be the set of all messages created in the network and M_d be the set of all messages delivered. Then the delivery ratio is computed as:

$$M_d/N.$$

B. Average packet delay

Average delay of message delivery. Now let the i^{th} delivered message was created at time c_i and delivered at time d_i . Then the average message delivery latency is computed as:

$$(\sum_{i=1}^n (d_i - c_i)) / M_d$$

C. Overhead Ratio

Overhead Ratio is defined as how many replica packets are forwarded to deliver one packet. Overhead ratio is defined as:

$$(\text{Number of total forwarded message} - M_d) / M_d$$

V. LITRATURE SURVEY

Substantial effort made by researchers for developing routing protocols for DTN applications, buffer management is not paid that much attention. Many of the routing protocols theoretically assume infinite buffer and in simulation they consider finite buffer with FIFO replacement policies. But in

many of the DTN applications uses hand held devices which are having limited storage and energy. This constraint on buffer size degrades the performance of routing protocols in terms of increasing the delivery delay and decreasing the delivery ratio which is not shown in their simulation results. E.g. Epidemic routing protocol achieves an optimal delivery ratio with infinite buffer, but with a limited buffer scenario, the routing performance is degraded [4].

There are a number of buffer management schemes that can be adopted by various DTN applications. These can be broadly classified into two categories: schemes that do not require global knowledge or network-wide information and select the message to drop/schedule using local information like arrival time, TTL and size, etc. and schemes that require partial or complete network information like number of copies of the message in the network, contact rates between nodes and shortest path knowledge between various nodes etc. [4].

- Drop largest

In Drop Largest (DLA) buffer management technique, message having large size will be selected to drop first [11].

- Drop Front

Drop Front (DF) FIFO. This technique drops the messages on the basis of the order in which they entered into the buffer, for example the first message that entered the queue will be the first to be dropped [11].

- LEPR (Evict least probable first)

LEPR technique works by a node ranking the messages within its buffer based on the predicted probability of delivery of the messages, the message with the lowest probability is dropped first. This technique is used only for probability based routing protocol (e.g. PROPHET routing and MAXPROP routing) [11].

- MOFO (Evict most forwarded first)

MOFO policy, message that forwarded most number of times will be dropped first from buffer. In [11] it has compared all policies and concluded that MOFO gives better performance as compared to other policies.

- E-DROP (equal drop)

E-DROP policy, when buffer is full and want to store new message then in this policy message having equal or greater

size than new message will be dropped from buffer. This strategy improves performance of first contact routing protocol with decrease overhead ratio, decrease average latency and decrease in hop count as compared to MOFO dropping algorithm. Hop count result is good in first contact and PROPHET routing but increase in average latency in epidemic and PROPHET routing algorithm. This approach gives less overhead ratio in all routing protocols as compared to MOFO dropping strategy [12].

Under Epidemic routing, packets can be delivered completely between every two nodes if every node buffer is big enough and the communication time is long enough after one node contacts another one. But congestion will occur easily at a node if the buffer of this node is limited under Epidemic routing in DTN. In order to solve this problem, a congestion control strategy was introduced. If a node buffer is full and it needs to store a new packet, every packet in the node buffer will be checked, in order to find out the packets whose numbers of forwarding are over N and then erase them. If there is no packet whose number of forwarding is over N the last packet will be erased. The strategy is called N-Drop [5].

TTL based MAXPROP routing This approach splits buffer into two parts. Threshold values are used to decide in which portion new message will store. Message having hop count less than threshold value will be placed in first portion and sorted by hop count and time to live. A packet has lower hop count and higher time to live value that means the packet has not seen many nodes and it has not spent much time in the network, schedule it to be transmitted first. On the contrary, if a packet has lower hop count and lower time to live value that means the packet has spent enough time in the network but has not met enough peers, schedule it to be transmitted last because there is a chance that that message may expire before it reaches to destination. When two packets have the same time to live value, the tie is broken by their hop counts. whichever has the smaller hop count is given priority. Message having hop count equal to or greater than threshold value will be placed in second part and sorted by delivery likelihood [7].

VI. COMPARISON ON DIFFERENT BUFFER MANAGEMENT STRATEGY IN DTN ROUTING

TABLE I. COMPARISON ON DIFFERENT BUFFER MANAGEMENT

Strategies	Mechanism	Simulator	Advantages	Limitation
Drop Largest[11]	Message having large size will be selected in order to drop.	ONE	Dropping largest size message will leave more free space for another new coming message.	That largest size message may have next node as destination node.
First in First Out[11]	Drop the messages on the basis of the order in which they entered into the buffer	ONE	Fair decision of dropping.	There is a chance that oldest message may have more priority than new coming message.
LEPR[11]	Based on the delivery probability of the messages, the message will be dropped first having lowest probability.	ONE	Prediction is done based on past log history.	Only apply on prediction based routing algorithm
MOFO[11]	Message will be dropped first which has been forwarded for the largest number of	ONE	Message was forwarded to maximum number of nodes so there is another more copies of that	Latency is not better than DLA.

	times.		message which may have chance to reach to destination	
E_DROP[12]	Messages having equal or greater size then new message will be dropped first.	ONE	Hope count result is good in first contact and PROPHET routing. less overhead ratio in all routing protocol as compare to MOFO dropping strategy	increase in average latency in epidemic and PROPHET routing.
N-Drop[5]	Erase that packet whose forwarded hop is over N. If not so then erase Last packet.	ONE	Maximum Forwarded number is given as N.	FIFO packet when there is forwarded hopes less then N for all packets in buffer.
TTL based MAXPROP routing[7]	New message's hope count is less then threshold then Sort message with hop count and time to live. Otherwise sort messages with delivery likelihood.	ONE	This approach improves performance of MaxProp routing protocol.	This approach applied on transmission part only.

VII. CONCLUSION

There are many different buffer management policies as forwarding policies and dropping policies which improve performance of different routing algorithms based on their behaviors in network. Some strategies use combination of max hope count and time to live value to sort messages in buffer. Different strategies have different improvement in performance parameters. We have seen that strategy which use replica count number in sorting policy has used global knowledge information to get number of replicas. But in reality, this global knowledge information is not possible. Therefore, some strategy should consider to get replica count with local information to improve overhead ratio of routing.

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