Congestion Control in DTN

Peeyush Patil
Department of Information Technology
MIT College of Engineering
Pune, India
peeyush.uttamrao.patil@gmail.com

Milind Penurkar
Department of Information Technology
MIT College of Engineering
Pune, India
milind.penurkar@mitcoe.edu.in

***Abstract*—In Delay Tolerant Network (DTN), the key resources such as buffer size, bandwidth, are easily got consumed and become limited for further usages, resulting into congestion in network and affecting the performance, Due to DTN's network characteristics and 'store-carry-forward' transfer mechanism the standard TCP congestion control mechanism is not suitable. The congestion control in DTN widely researched sector in DTN because as establishment of a network in an unfavorable environment where network infrastructure is not available and even after its successful deployment the high priority messages should not be dropped as it affects the foundation of DTN, because some applications are fond to be sensitive. Some of the well-known congestion control strategies have been discussed, compared after which a CASE routing algorithm is proposed by studying them.**

Keywords—CASE; Congestion Avoidance; Congestion Control; Delay Tolerant Network; DTN;

I. INTRODUCTION

UNLIKE Wireless Sensor Networks (WSN) where paths and connections between the intermediate nodes which are responsible for connecting source and the destination can easily be established because of high node availability among which end-to-end connections can easily be established using traditional mechanisms, DTN is a network which is dynamic, sparse, extreme or intermittently connected which is able to establish the connections between several communicating ad-hoc [1], heterogeneous [2] nodes even after lacking the availability of any network infrastructure [3].

Categorization of any network as a DTN depends upon the availability degree of connections. In DTN, the density of nodes, the amount of nodes per unit area is less and the nodes are distant. The network may remain partitioned into for longer periods [3],[4]. It is susceptible to often changes in the positions of highly mobile nodes which communicates opportunistically [4] only when they come in contact by coming in each other's broadcasting range. They also shut the links down periodically in order to conserve energy. With DTN, the traditional routers are replaced with DTN nodes, which have Storage capability, if a link is down, a DTN node will hold the bundle until the link comes up. The message(s) from the source node can have to wait in one or more intermediate nodes for substantial amount of time [5till the connection is re-established.

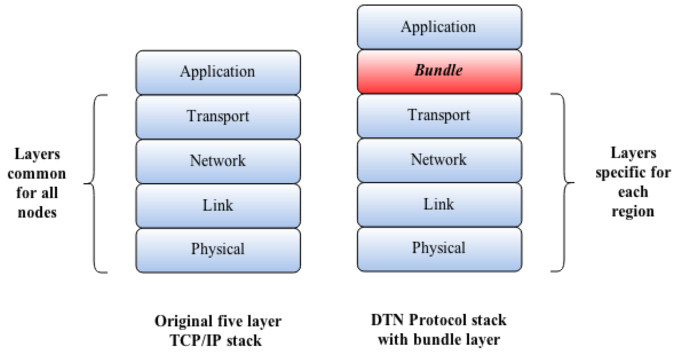

Fig. 1 DTN Specific Stack [10]

DTN uses mechanism of *store-carry-forward* [1] so as to handle disruptions in the end-to-end path, so all bundles travel the network via being relayed [6] from one node to another either by inter-community or intra-community packet transfer mechanism which works on utility, centrality or sociality matric [7],[8] of a node or relaying node until they reach their destinations. Sometimes even if the link is up for a DTN router, a packet or a bundle can still be lost en-route. Hence, the data is retransmitted in both the protocols either in DTN or in standard TCP/IP. In DTN the bundled data is transferred using hop-by-hop custody transfer, where successive nodes takes the custody [9] and the bundle migrates towards the destination if a bundle is lost, and custody isn't acknowledged by the next node, the last custodian retransmits and maintains the reliability.

According to RFC 5050 and RFC 4838 the *bundle* is defined and implemented respectively in DTN architecture in. From Fig 1The Bundle Protocol provides six Classes of Service (CoS) [10]: Custody Transfer, Custody Transfer Notification, Bundle Forwarding Notification, Return Receipt, Priority of Delivery (bulk/normal/expedited), and Authentication. Since DTNs allows to communicate without network infrastructure, they are widely used in battlefield military operations, wildlife tracking, vehicular communication, maritime environment [11], and inter planetary deep space communications etc. where setting up network infrastructure is hard and costly [12]. Such unique application areas make the disruption/delay tolerant networks (DTNs) an important component of future internetwork.

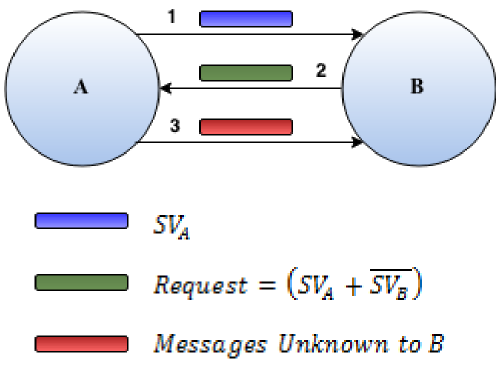

Fig. 2 Epidemic Routing Protocol when Node-B connects with Node-A

II. RELATED WORK

In DTN, many algorithms have been proposed for forwarding the packets and a many research works are also going on in this area, but dissimilar to other traditional protocols used in TCP where the path could be established before forwarding the packet, In DTN the fully flooding Epidemic Routing Protocol [8] is widely used and utilized for its features of forwarding non fragmented bundled packets in FIFO order, Node- A sends its *Summary Vector* (SV) to Node-B, which is a compact representation of messages being buffered and are indexed by hash table it also has a cache containing the list of nodes which were previously connected, followed by Node-B requesting Node-A for those packets which are not with Node-B, so that all the packets which are not with Node-B are delivered completely and this mechanism has helped Epidemic Router to result in better delivery ratio and end-to-end delay as a function of buffer size and bandwidth. Hence, it outperforms in QoS than any other DTN protocol.

In-spite of its high performing features and fairness to deliver packets to single or multiple destinations [6], epidemic routing has one of its drawbacks of overloading a neighboring node with high amount of data which in turn makes it susceptible for congestion and as a result, next incoming packets are dropped because of buffer being congested and there are the chances of High priority messages being dropped. To overcome such conditions several congestion mechanisms have been proposed and some of them are discussed below:

A. A Novel Congestion Control Strategy in Delay Tolerant Networks [13]

It is based on AFNER [Average Forwarding Number for Epidemic Routing] congestion control reactive mechanism which means that it will trigger only after the occurrence of congestion within a node. It works on the assumption that the forwarding packets are non-fragmented message bundles that are arranged in ascending order of their forwarding numbers and the message reaches its destination when the forwarding number of a packet is greater than Average Forwarding Number of the packets residing in the whole buffer. Epidemic routing mechanism is used for forwarding the messages between two connecting nodes. A node receives the packets if its buffer is capable of holding all the incoming messages or it checks for congestion otherwise. Here the author has focused on the Average forwarding number of the packets which are arranged in the buffer of the node in ascending order and the packets are forwarded in FIFO order. The packets are dropped if its forwarding number is greater than or equal to the Average forwarding number of all the packets currently stored in the buffer of that particular node so as to control the congestion in it.

B. N-Drop: congestion control strategy under epidemic routing in DTN [14]

Similar to AFNER Strategy which is built upon Epidemic routing, N Drop is also a congestion control reactive approach based on the information which is stored with the node, If the node is capable to store the messages to be forwarded in its buffer it stores them otherwise checks for congestion and stores the packets by erasing already stored packets on comparing with the threshold value (N), which is the function of the buffer size. The idea behind is that , the forwarding number of every packet in the node will be compared with N, which is the Threshold applied to the forwarding numbers of packets since they have been created at the source and those packets whose has forwarding number greater than or equal to N are erased. If there are no such packets whose forwarding number is not greater than the threshold (N), than the last received packet in the buffer will be erased.

C. Token Based Congestion Control for DTNs [15]

Unlike the N Drop and AFNER Congestion control mechanism, TBCC is a congestion avoidance mechanism which is a proactive approach, only nodes who are holding the valid token could inject or forward the messages within the network which is as same as Token Ring. The tokens are distributed uniformly initially and then they are randomized. The aim of the TBCC is to match the quantity of data entering in the network with the total network capacity which means that any network or node must receive that much of data as much as it can deliver. Unlike Token Ring, TBCC needs token to inject data inside the network or to a single node in contact, which is reclaimed when the message exits the network in favorable or in unfavorable manner. The number of tokens to be distributed in the network varies and it has the mechanism of sharing the extra tokens with the neighboring nodes. The TBCC is independent of routing algorithms unlike AFNER and N Drop. When tested on the discrete event simulator it has shown better performance of delivery ratio which is directly proportional to the connectedness between the nodes which is evaluated using Greatest Connected Component (GCC) metric. In comparison with other congestion control mechanisms so far it has shown better performance because it avoids the congestion before it has occurred, in-spite of this effort there could be the uncertainty of token starvation and not being able to send the packets to a node (source/intermediate) coming in contact with another node having better chances of meeting the destination or with better parameters of connectedness, similarity, centrality in the network and also because of the similar reason the high priority messages couldn't be forwarded or might get dropped which is unfavorable.

III. Comparison between the discussed strtegies

The discussed strategies are compared and brought together in tabular form as shown in TABLE I, which categorizes and explains the comparison drawn between them. The categories are elaborated as follows:

TABLE I. COMPARISON TABLE [13-15]

Strategies	Categories		
	Type	***Approach***	***Based on?***
AFNER	Congestion Control	Reactive	Comparing the forwarding numbers of every packet with average the forwarding number of a node
N-Drop	Congestion Control	Reactive	N, which is the threshold applied to the forwarding number of the packets since creation
TBCC	Congestion Avoidance	Proactive	Matching the amount of data entering in network with total network capacity

A. *Based on Strategies*

These mechanisms comes in to picture when the node suffers from congestion problem during buffer management otherwise, it directly stores the messages which are to be forwarded towards its destination. These strategies are helpful so that the transfer of data packets is carried out without any issue. In DTN Epidemic Routing is widely used because of its exceptional performance compared to other DTN protocols AFNER is like an extension to the epidemic routing with the mechanism of forwarding numbers, and it works on the comparison between the forwarding number of every packet with average forwarding number of the node overall. The N-Drop works on the similar principals but it has the concept of a Threshold (N), which is the function of buffer-size, similarly TBCC is a mechanism in which every node must have the valid token so as to inject the messages in to the network or to another neighboring node and it tries to match the amount of data entering the network with total network capacity, tokens are initially serially distributed then randomly.

B. *Based on Type and Approach*

There are basically two types of Congestion Control Mechanisms: *a) Congestion Control*, It is a Reactive approach. The congestion is first allowed to occur then it is tried to remove after its detection. *b) Congestion Avoidance*, It is a Proactive approach. The congestion is tried to avoid before it occurrence. AFNER and N-Drop Congestion control strategies fall under the reactive approach where as TBCC is the proactive approach.

IV. Proposed work

In any network loosing packets while communication is an important issue to focus, similarly in DTN the issues of congestion, leading to packet drops or messages getting erased, is as important issue as, establishing the connections between nodes where end-to-end connectivity is not promised. There is a fair chance of high priority messages being dropped along with other packets after the occurrence of congestion within a node or within a network, and it is not desirable in a DTN to drop high priority messages as the environment is already not favorable. There must be a way to reduce the number of packet drops, and even if they are allowed to be, there must be a way to serve at least the high priority messages and not allowing them to be dropped, by using more effective mechanism of congestion avoidance. To strengthen our new objectives we are bringing an idea by integrating the core concepts of the discussed strategies during congestion within a node:

In case of congestion in a node even if the node has to drop the last received message(s), which can be based on any one of the packet drop strategies as discussed in either AFNER [13] or in N-Drop [14]. However, the performance of the

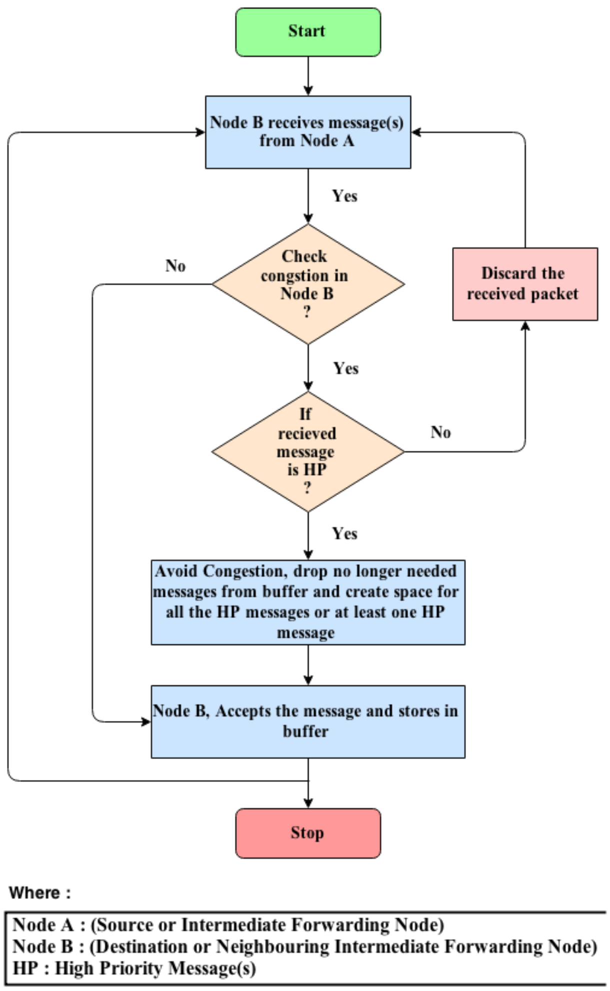

Fig. 3 Congestion Avoiding Strategic Epidemic Routing Algorithm (CASE) for DTN [16]

network will depend upon the type of packet dropping strategies selected. The received high priority message(s) should be rechecked for accommodation, if not all at least one should be allowed to be received and served by the respective forwarding node. From the comparative analysis it is clear that congestion avoidance (proactive) approach is preferred over congestion control (reactive) approach as discussed in TBCC [15] because it keeps the system or the network in the safe state and away from congestion by taking appropriate actions before it happens.

From Fig. 3, it describes the proposed *Congestion Avoiding Strategic Epidemic Routing* (CASE Routing) Algorithm to avoid and control the congestion in a DTN node. The node can be either source, destination or any neighboring intermediate forwarding node between the source and destination pair.

Before describing, some assumputions have been made: Nodes other than destination node are creating messages. Every message has unique identification, can be generated at any node and can vary in sizes. The Epidemic router is used which is fully flooding based algorithm and hence increases the chances of congestion. The following algorithm in relation with the flowchart in Fig. 6. can be used to avoid the congestion in DTN which is as follows:

***Algorithm**: Congestion Avoiding Strategic Epidemic Routing (CASE Routing) in DTN*

begin

Assume: Routing-Epidemic, Message(s)-Bundles (FIFO)

***while** Node B receives messages from Node A*

if** Node B is congested **then

if** High Priority message(s) received in message **then

Avoid Congestion;

***else** Discard last received message(s)*

***else** Accept the message(s) and store in buffer*

Step 1: Begin
Step 2: If node B connects with node A. If No, go to step 6.
Step 3: If node B is not congested, go to step 5
Step 4: Avoid the congestion by removing messages with.
Step 5: Create the message and go to step 2.
Step 6: Stop.

V. Experimental Results

To carry out the implementation of the proposed idea there are some system requirements. The system should support a Java based IDE integrated with Opportunistic Network Environment (ONE) simulator, which is a discrete event based simulator and highly recommended for carrying out DTN related experimental simulations and observe the desirable results. We are using Eclipse as an IDE which is integrated with ONE 1.5 in our set up.

TABLE II. Initial results for observing buffer behavior while message transfer

Parameters					
Nodes	*Buffer size (Mb)*	*Packets Dropped*	*Delivery Probability*	*Average latency*	*Overhead Ratio*
20	1	4303	0.2917	3521.89	37.59
	5	7654	0.5613	3528.86	44.10
50	1	13260	0.2935	3380.75	120.84
	5	37070	0.5050	3221.04	214.83
80	1	32527	0.2734	3088.34	310.07
	5	119041	0.5296	2404.36	605.33
100	1	56029	0.2599	2332.07	556.94
	5	189545	0.5223	2285.78	962.34

From Table II, it is clear that the size of the buffer has effect on the delivery probability because of the congestion experienced.

VI. Expected Results

The mentioned CASE routing algorithm will try to avoid the congestion before it occurs. There is the possibility of increased number of packet drops but the delivery probability might be increased because of the reduced overhead ratio because of the network not being congested.

VII. Conclusion and Future work

DTN is a kind of network which is sparse, extreme, intermittently connected or high dynamic in its topology. The network infrastructure is not readily available, and the node communicates opportunistically upon contacts. Every network can be categorized as a DTN depending upon the degree of connections available to it as the node density per unit area in case of DTN is comparatively less. As DTN is susceptible to the frequent changes in topology, it is able to establish connections between the nodes, which is hard and costly. Hence it has variety of application areas where it is widely researched, developed and applied. There are various mechanisms for routing in DTN, Epidemic routing is widely used and extend due to its high performance features, but there is a fair chance of a communicating node being congested and high packet drops. Few congestion control strategies that have been developed so far, are discussed and compared, and the CASE Routing algorithm is proposed to avoid the congestion in DTN.

In future we will extend the CASE Routing Algorithm and avoid the congestion by controlling separately, the native message(s) creation and remote message(s) reception by every node in DTN.

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