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Survey of Buffer Management Techniques in Delay Tolerant Network

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Abstract

Delay Tolerant Networks are the kind of networks in which an end-to-end path between any source and destination pair may never exist. In DTN, nodes use store-carry-forward mechanism for data transmission. Currently the key method to solve information exchange in DTN is to select forwarding nodes effectively, Made the information deliver to the destination successfully within a short time and reduce resource overhead. At the same time, the load of selected nodes will be increased and the requirement to the buffer also increased, so the management of the buffer becomes particularly important.

Keywords: *Delay Tolerant Network, Routing, Buffer Management, Storage Management*.

1. Introduction

The internet has accomplished a profound success in interconnecting communication devices across the globe. This is achieved by implementing a homogeneous set of communication protocols, called the TCP/IP protocol suite. Connectivity on the internet relies primarily on wired links, however new wireless technologies begin to appear. The wired links are continuously connected in end-to-end, low-delay paths between sources and destinations. They have low error rates and relatively symmetric bidirectional data rates. New types of networks emerge recently but do not conform to the assumptions made on the internet [1].

A DTN is a network designed to operate effectively over extreme distances such as those encountered in space communications or on an interplanetary scale. In such environment, long latency is inevitable. The DTNs are based on the concept of store-carry-and forward message switching. This means that all sent data are grouped into a single entity: the message. Each node has a persistent storage area. When it receives a message from another node, it stores this message until it succeeds to send it to the next node. In order to increase the probability of delivery, DTN routing mechanisms may require nodes in the network to store and carry messages in their local buffer, and for long periods of time, until new communication opportunities arise. There are various routing protocols available for DTN. Generally, they differ in terms of the knowledge that they use in making routing decisions, and the number of replication they make [1].

2. Architecture of DTN

Delay network architecture is designed as an overlay of existing networks which divided into regions that are homogeneous. It provides an end-to-end path based on the following principles:

a) Enhancement of the ability for good path selection to use for transfer of long stream data packets.

b) Store-carry-forward fashion support to store data within the network until reached at destination.

c) The infrastructure is protected from unauthorized access by different security mechanisms.

2.1 Concept of bundle layer

DTN architecture introduce an overlay just above the transport layer is called bundle layer. Bundles are also called messages. By storing and forwarding entire bundles between the nodes, data transfer takes place. The bundle comprises with source nodes user-data, control information, a bundle header. This layer is already easily linked with TCP/IP to provide a gateway when two nodes come to contact with each other. Flexibility is the major advantages [6].

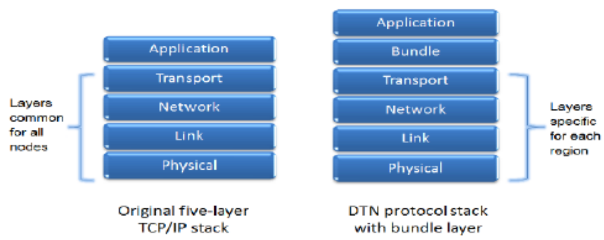

Fig. 1 Bundle Layer

2.2 Store-carry-forward technique

The concept of store-carry-forward overcomes the problem associated with traditional protocols that may be bidirectional data rates, lack of connectivity, irregular delays etc. This method is very similar as like the real life postal service. Before reaching at the destination a letter has to processed and forwarded through a set of post officers. Like in this technique a complete message or some portion of the message is transferred and successively stored in the nodes until it reaches at the destination through in a network.

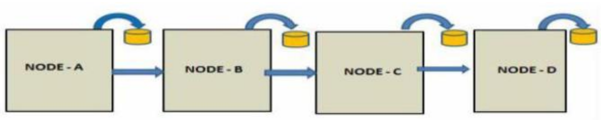

Fig. 2 Store-Carry-Forward Technique

2.3 Types of contacts in DTN

In DTN, whether or how the nodes make contacts with each other broadly classified as opportunistic and scheduled. The opportunistic contacts are an unscheduled contact which can occur instantly. The node do not have any idea regarding a contact may be direct or indirect in the future. Moving people, automobiles, airplanes etc. make this type of contact and transfer of message as they have sufficient energy for communication. On the other hand in scheduled contact the information is directly or indirectly known to the node for establishment a contact path at a particular time, for a particular duration. Synchronization of time in every node is the major drawback. Example of schedule contact is a interplanetary communication [5].

2.4 Custody Transfer

Bundle layer offered retransmission of message in case-of corrupted or lost data through the concept of bundle layer. The custodian node stores the message until successfully transferred to the next node and takes the custody of next node and takes the custody of that message until TTL expires.

3. Existing Buffer Management Techniques in DTN

3.1 Effective Buffer and Storage Management

Stylianos Dimitriou [3] has proposed a system which implements a mechanism that aims to minimize packet transfers between buffers and persistent storage. The buffer consists of two queues; a low-delay traffic (LDT) queue and a high-delay traffic (HDT) queue.

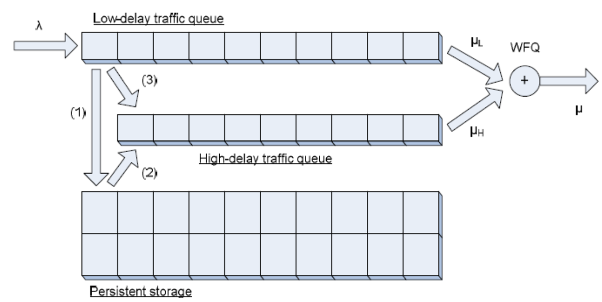

Fig. 3 Proposed Model [3]

Moving packets from buffer to storage and back, is allowed in following three cases:
1) From LDT buffer to persistent storage. Packets that can move in this direction are either new packets that belongs to a high-delay flow, or old packets that belong to a low-delay flow and the LDT buffer is full.
2) From persistent storage to HDT buffer, Packets that can move in this direction are packets that were previously in persistent storage and currently they have a communication opportunity.
3) From LDT buffer to HDT buffer upon packets arrival. Packets belonging to a high-delay flow, will move to HDT buffer if there is currently a communication opportunity with a next hop.

3.2 Buffer Management Policy based on Prediction in DTN

Behrooz Farkiani [2] has proposed a novel buffer management policy which uses intermeeting time estimation based on time series analysis and kalman filters forecasting techniques. This policy does not need global and detailed information about mobility model and the network situation. This policy does not impose any message passing overhead. Its computation is not complex and it is not necessary to store history of meetings. The messages whose destination node will be observed in further estimated time relative to the destination of other messages, will be removed from the node's buffer. Problem with this system is, in order to improve the performance of prediction based policy (PBP), as it is not possible to estimate the next contact time of messages that their destination nodes have not been seen yet.

3.3 LPS: Efficient Buffer Management Policy

With LPS [4] policy, a node drops from its buffer the message with the lowest delivery probability, only if, a minimum number of replicas were previously disseminated in the network. This minimum number of replicas is defined by the spread threshold α, which is a parameter tuned according to the network characteristics such as connectivity degree and inter-contact time. The current number of replicas of a given message is estimated by using a counter added to the message's header. This counter is incremented by one whenever the message is replicated.

The LPS spread threshold aims to solve the premature message drop problem. It has been noted that with the LEPR policy, a good amount of messages are dropped at the source. This is because messages may have lower delivery probability at their origin. In real scenarios, messages are frequently generated in nodes far from destination. If none of the messages stored in buffer reached the spread threshold, LPS drops the oldest message in the buffer, according to the FIFO policy.

3.4 LRF: Efficient Buffer Management Policy

The LRF [4] policy aims to drop messages that have already been disseminated in the network and have reached most or all nodes contacted frequently by a given node. Therefore, with LRF, a node first drops the message not forwarded for the longest period of time, i.e., the least-recently message forwarded in buffer. In order to ensure the initial spread of messages, LRF does not drop messages that have not yet been forwarded by nodes. If none of the messages stored in buffer was previously forwarded by a node, LRF drops the oldest message in the buffer, according to the FIFO policy.

LRF explores the fact that real users do not move in an entirely random fashion. In general, real users follow a predictable path, according to behavioral patterns and social relationships. Thus, a node that visits a certain place several times probably will visit it again in the future. Hence, the longer the time a node carries a message, the greater the probability that this message had already been forwarded to nodes contacted frequently.

3.5 Partially Observed Markov Decision Process Framework in DTN

A POMDP [1] is a generalization of Markov Decision Process to situations in which system states are not fully observable. In order to act optimally, an agent might need to take into account all the previous history of observations and actions, rather than just its current state. A POMDP is an MDP in which the agent does not know the real state of the process. It is defined by the following tuple $\{S, A, O, T, \Omega, R\}$:

- S : is a set of states;
- A : is a set of actions;
- O : is a set of observations;
- T : is a transition function.
- Ω: is an observation function;
- R : is a reward function.

1) State: It is assumed that each relay can store one message in its buffer. The state buffer occupancy can be denoted by $S(t)= \{0, 1\}$ where $s(t) = 0$ means that the node does not maintain cooperation (keeps its message and does not accept the new one) and $s(t) = 1$ means that the node maintains cooperation at time t (drops its message and accepts the new one).

2) Action: The relay can be inactive, active and keep-ing its own message, or active but it drops its message to accept a new one. Therefore, each relay has 3 actions:

A(t)= 0,stay inactive;
1,active and keep its own message;
2,active and drop its message to accept a new one.

3) Observation: When a node transmits a packet with custody transfer, it can observe the buffer occupancy of another node, thanks to the acknowledgment mechanism. The buffer A must decide whether to keep its message or transmit it to B, if A receives an ACK, that means the message is transmitted. Therefore, observation is obtained when both relays are in the same transmission range, and each relay can recognize the state of occupancy of the other through acknowledgment mechanism. Let θ be the observation outcome. We set $\theta = 1$ if the node has received an ACK otherwise $\theta = 0$.

4) Belief state: The state $S(t)$ of the buffer of a relay cannot be directly observed by other nodes. Let $\lambda(t)$ be the probability that the node maintains cooperation at time t. It is referred to as the belief of the relay immediately before the transition from $s(t)$ to $s(t + 1)$.

The update rule of the belief state is given by:

$\lambda(t + 1) = \Lambda(\lambda(t)|a(t), \theta(t))$

where $\Lambda(\lambda(t)|a(t), \theta(t)) =$

$$\begin{cases} \alpha & \text{if } a(t) = 2 \\ \beta & \text{if } [a(t) = 1, \theta(t) = 0] \\ \alpha\lambda(t) + (1-\lambda(t))\beta & \text{if } a(t) = 0 \end{cases} \quad (1)$$

5) Number of transmission: A relay tries to transmit a packet to another relay and waits for its response. The choice is based on the number of transmissions NT. This number NT is incremented by 1 after the message is accepted by a new node.
The relay keeps the message which has the smallest value at the number of transmission. The message can be deleted if NT >= NTmax where NTmax is the number of maximum allowable transmissions.

6) The instantaneous reward: it is comprised of two components: positive and negative. A positive component U representing the gain of the node when the transmission of the message is successful. A negative component corresponds to the consumed energy and the cost of the contact time.

4. Conclusion

In this paper, a survey of various buffer management schemes proposed in the literature for delay tolerant networks. As DTNs use store and forward method for forwarding the message to the destination, buffer scheduling and dropping policies play a very important role in the efficient delivery of messages. It may be seen that a number of message parameters have been used in different works for efficient buffer management. Buffer management schemes in a DTN should be designed considering the limited storage of nodes and the short contact duration between the nodes. In this paper we have tried to present a variety of buffer management schemes that are generic for any routing protocol. It would be interesting to combine various message scheduling and message dropping policies and study their effects on various routing protocol designed for DTN.

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