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An Efficient Buffer Management Policy for DTN

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Abstract

Delay or Disruption Tolerant Networks (DTNs) are challenged networks where an end-to-end path may not always exist, due to which it is necessary to use a store-carry-forward paradigm for routing messages from source to destination. DTNs have emerged from MANETs, inheriting their typical properties like mobility, network partitioning, sparse network structure, etc., differing in the inability to use IP. Due to the high mobility of nodes, and limited radio transmission range, two nodes may not always be able to communicate with each other. Thus, communication is established with the help of encounter opportunities between nodes. So intelligent relay selection plays an important role in routing performance. But apart from relay selection, effective buffer management policies also have an impact on routing performance. In this paper we have discussed existing buffer management methods in literature and proposed a novel buffer management scheme based on hop-count and TTL, which uses partial network knowledge. Experimental results show that the proposed buffer management scheme outperforms existing buffer management policies in terms of higher delivery rate and lower overhead ratio.

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Keywords: Buffer management, Delay Tolerant Network

1. Introduction

Delay or Disruption Tolerant Networks (DTNs) are challenged networks where an end-to-end path may not always exist, due to which it is necessary to use a store-carry-forward paradigm for routing messages from source to

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destination. DTNs have emerged from MANETs, inheriting their typical properties like mobility, network partitioning, sparse network structure, etc., differing in the inability to use IP. Due to the high mobility of nodes, and limited radio transmission range, two nodes may not always be able to communicate with each other. Thus, communication is plausible only at the encounter opportunities between nodes. Therefore, these networks are also called Intermittently Connected Networks (ICNs)

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 handheld 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. Eg. Epidemic routing protocol [1] achieves an optimal delivery ratio with infinite buffer, but with a limited buffer scenario, the routing performance is degraded.

Also, most of the DTN routing protocols do not have any message scheduling mechanism. The reason behind that, they are assuming infinite bandwidth without any interruptions, which is an unrealistic assumption, related to the DTN application scenarios. So the ordering of message transmission is important in real-time applications. In this aspect we have designed an optimal buffer management policy together with message scheduling mechanism.

In this paper we have discussed existing methods for buffer management and proposes a novel buffer management and scheduling policy and compared it traditional buffer management schemes. The proposed method uses partial network knowledge so that it is most suitable DTN characteristics. Extensive simulations on data sets show that the traditional buffer management policies fail and are sub-optimal compared to the proposed policy.

2. Related Works

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. We will discuss some of them in this section.

Lindgren, et al. [2], have observed that right combination of buffer management and routing policy improves the performance of DTN routing protocols. They have proposed a probabilistic routing approach with a combination of routing and buffer management policy, which improves message delivery, and reduces overhead and end-to-end delay. The authors have also discussed several queuing policies such as, FIFO, MOFO, MOPR, SHLI, and LEPR. Simulation results show that combinations of queuing policies with forwarding strategies have an impact on the routing performance.

Li, et al [3] proposed a queue management MAC protocol (Q-MAC) for Delay Tolerant Mobile Sensor Networks (DT-MSN). DTMSN is a type of WSN with dynamic network topology and limited network connectivity. In Q-MAC, Minimal Probe Frame (MPF) method is used for neighbor discovery among nodes in case of limited connectivity. Also, the priority based queue method is used for scheduling the transmission of the message as well as replacing message when queue is full. Messages are classified based on priority as high and low and stored in the queue. When more than one such message exists in the queue, messages are ordered and transmitted based on priority.

Chuah, et. al. [4], have proposed a buffer management scheme for DTN using dedicated message ferry. In the scenario of limited connectivity, dedicated nodes called as *message ferry* will visit other nodes regularly and collect messages and deliver it to the destination. Since ferries having limited buffer, buffer management scheme based on max-min fairness model has been proposed. In such a model, ferry accepts data from different source nodes and store in the buffer, only if it maximizes the minimum data rate any of the nodes. Also, a buffer efficient routing scheme has been proposed with fair buffer allocation, where route selection is based on path delay and ferry transportation cost.

Das, et. al. [5], have proposed a priory aided storage based scheduling strategy for Homing Pigeon based DTN (HoP-DTN). In HoP-DTN, dedicated nodes, called, pigeon takes messages from source and deliver to destination. Effective utilization of buffer space is important in case of storage based pigeon in which messages will not be delivered until buffer is full thereby forcing high priority messages to wait. The proposed scheduling policy reduces the delivery delay for high priority messages by scheduling messages based on priority. The messages are given priority values from 1 (highest) to size of buffer (lowest) and a replica of messages is the difference between the size of the buffer and its priority value. So the highest priority message is replicated maximum and makes the buffer full causing it to transmit immediately.

Li, et al. [6], have proposed an adaptive optimal buffer management scheme for DTN, where bandwidth is limited and messages of varying size. The term adaptive means, node mobility model is adjusted according to the historical mobility information of all nodes. The message management policy maximizes the average delivery rate and minimizes average delivery delay.

Yin, et al. [7], have proposed optimal buffer management strategy based on optimal theory and an overall optimization strategy where optimal function considers all the performance metrics such as delivery ratio, delay and overhead simultaneously.

An optimal Global knowledge Based Scheduling and Drop policy (GBSD) have been proposed in [8], which requires global network information and integrates scheduling policy together with drop policy. For each message utility is calculated with respect to the optimization metric (delivery ratio, delay, etc.) and a node replicate message with decreasing order of utilities in case of scheduling and drop the message with lowest utility among those in the buffer and the new message. But such a method requires global network information for optimizing routing metric which is impractical incase of DTN. So the authors also proposed a distributed History Based Scheduling and Drop (HBSD) policy which estimates global network information using statistical learning. The scheme assumes unicast communication and uses an epidemic forwarding strategy for routing.

3. Proposed Buffer Management Scheme

Since DTNs have intermittent connectivity and the absence of instantaneous end-to-end path between two nodes, message delivery in DTN (and the performance of routing scheme) is directly affected by the selection of appropriate relay. The unavailability of any sort of global information to DTN nodes regarding the network, e.g, the topology, contact duration, etc. make relay selection an extremely challenging task. There are mainly two solutions adopted to overcome this challenge. The first solution is to predict the future contacts, but it requires a lot of information exchange between nodes and heavy computations which can drain the limited power in DTN nodes. The other way is to assume the existence of oracles or availability of global knowledge, which limits the implementation of such schemes in real life scenarios.

We observed that in addition to smart relay selection, effective buffer management and effective utilization of limited encounter duration between nodes are two major factors that affect the performance of DTN routing scheme.

As DTNs comprise of handheld devices and sensor nodes, memory is an important constraint. Therefore, the messages which are more valuable in terms of performance metrics must reside in the buffer. All the efforts done in relay selection will be wasted if the buffer at the chosen relay is full. This situation may frequently arise in scenarios like dense networks and high traffic networks. In literature, there are only a few schemes e.g. MaxProp [9] and Rapid [10], which address the issues related to buffer size constraints.

Though DTNs have emerged from MANETs, the buffer management schemes for MANETs cannot be applied to DTNs as the goal of buffer management in MANETs only addresses a drop-policy in case the buffer is full. But as pointed in MaxProp, buffer management in DTNs is a combination of message scheduling, to deal with the constraint of limited encounter duration and message drop policy, to deal with buffer-full situation. Also, a node in MANET will drop the message if no further connected path to its destination is found. But, a node in DTN will carry it until an appropriate relay is found. Therefore, when a message arrives at a node in DTN, it has to judge which messages to carry so as to achieve optimal performance. On the other hand, when a message arrives at a node in MANET, it has to judge for which message it has shortest path available at that moment.

To achieve better performance, routing schemes in DTNs have to also effectively utilize the limited encounter opportunity. Therefore, message prioritization in a node’s buffer is required, so that messages which optimize the performance must be scheduled to be transferred first.Thus, there is a requirement of a routing scheme which can be applied in real life situations. Considering the constraints a DTN has and utilizing the available information to effectively manage buffer and schedule messages.

We assume that every node has a fixed and limited sized buffer. The contacts between different nodes are limited in bandwidth and duration both. We also assume that nodes do not have any information regarding future network connectivity, or their future movements. All the messages are of the same priority initially. Practically, the operation of DTN is carried out in the following three stages:

- **Node Discovery:** Nodes have to discover each other before the transfer of the messages can take place.

- **Message Transfer:** After discovery, nodes start exchanging messages with each other. The amount of data that can be transmitted in a transfer opportunity is limited.

- **Buffer Management:** New messages are received in the node's buffer. Every node, then manages the finite buffer. They must sort the messages according to the buffer management scheme. The messages which have the current node as the destination are passed up to the application layer and are deleted from the buffer.

These mechanisms are handled by the logical partitioning of the buffer based on a threshold on hop-count value. The messages with hop-count lower than the threshold are sorted according to their hop-count and those having higher hop-count than the threshold are sorted according to their Time to Live (TTL) values.

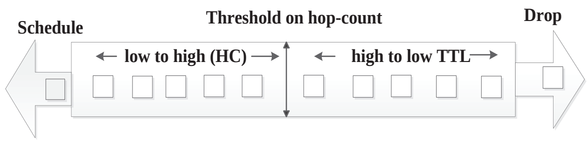

Fig. 1. Logical division of buffer space.

The logical division and sorting of the buffer is shown in Fig. 1. The Messages which have a lowest hop-count are scheduled to be transmitted first. This is because, low hop-count depicts that the message hasn't travelled far from the source and is still far from the destination. Therefore, such message must be prioritized for transmission to create more copies so as to achieve higher delivery rate and lower delivery delay.

The message which has higher hop-counts and low TTL are the first to be dropped. This is because, these messages have low probability to reach the destination from the current node because of low TTL and since their hop-count is high, it is safe to assume that they have been sufficiently spread into the network that one of the copies will reach the destination if the current copy is dropped.

4. Results

We have simulated our algorithm on the ONE (Opportunistic Network Environment) Simulator [11], which is a well-known DTN simulator. Epidemic routing is one of the first schemes for routing in DTN environment, and is a flooding-based approach. This scheme is based on the idea that the message will eventually find its destination through transitive exchanges between nodes, if it is spread in the connected portion of the network. The epidemic routing protocol can achieve a delivery rate of 100% in partitioned networks where ad hoc routing protocols fail entirely. But flooding results in high resource consumption in terms of both power and storage. We did an analysis on the performance of Epidemic routing by applying various drop-policies such as, Drop Largest [12], Drop Least Forwarded (DLF) [2], Drop Most Forwarded (DMF) [2], Drop Most Recently Received (DMRR) [13], and Drop Least Recently Received (DLRR)[13].

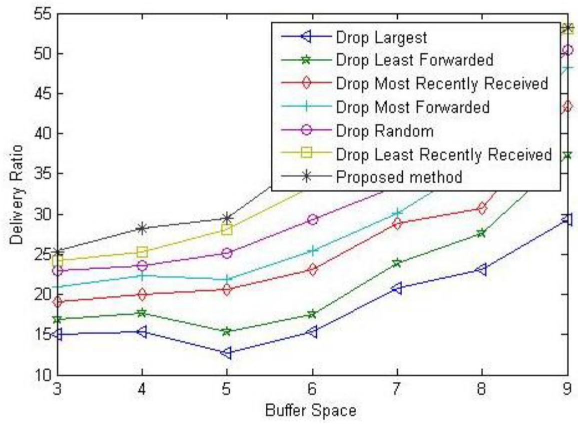

Fig. 2. Delivery ratio of Epidemic routing.

The delivery ratio increases with increase in buffer size (as in Fig.2) while the associated overhead decreases (Fig.3). This is because as the buffer size increases, more room becomes available to store and carry more messages, thereby enhancing the performance. Among all the drop policies, our proposed buffer management scheme achieves a higher delivery ratio and lowest overhead ratio.

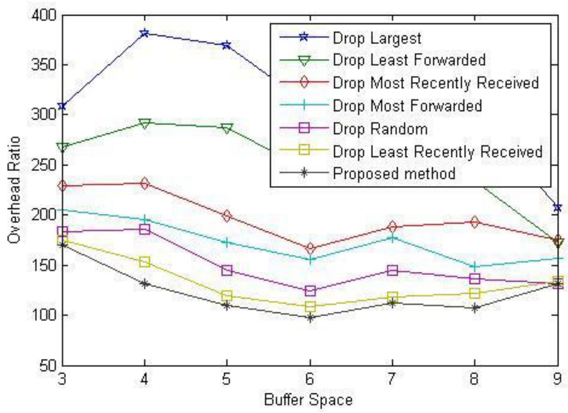

Fig. 3. Delivery delay of Epidemic routing.

We have simulated these routing methods under two different scenarios. In the first scenario, the network consisted of cars and pedestrians moving around a city. We set the mobility model to Map-based movement, where cars and pedestrians are restricted to move in predefined paths and routes derived from real map data. We used the map data of the Helsinki downtown area (roads and pedestrian walkways) provided with the simulator. Nodes choose a random point on the map and then follow the shortest route to that point from their current location. Messages are generated using a uniform random distribution from within a predefined interval, and assigned a random source and destination. With this model, we conducted two experiments with different number of nodes, N. The first experiment simulates a small network with N = 20, with 10 cars and 10 pedestrians. The second experiment expands the network to N = 60. In all the scenarios, we vary the size of buffer to see the effect on delivery ratio and the message overhead. The results of these simulations are discussed in the next section. Each of these scenarios are simulated for 12 hours, with similar network parameters, which are shown in Table 1.

Table 1. Simulation settings

Parameter	P	C
Hosts	50	50
Speed (m/s)	0.5-1.5	2.7-13.9
Buffer Capacity	3-9 MB	
Message Size	512 KB-1 MB	
Message Inter-arrival Time	25-35 seconds	
Message TTL	5 hours	
Transmission Speed	5 Mbps	
World Size (meters)	4500×3400	
Simulation Time	12 hours	

5. Conclusion

We have proposed an efficient buffer management scheme for DTN routing, particularly in the context of real DTN deployment. It comprises of intelligent decisions for message transfer and message drop for buffer management, as well as a smart relay selection for routing. Moreover, many other mechanisms for efficient buffer management and improving the routing performance are presented. We have compared the performance of our scheme with six other buffer management schemes and have shown that our scheme outperforms them significantly.

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