

Probability and Receiver List based Multicast Routing in DTNs

Minghui Ma¹, Zhaoxiang Zhang², Xudong An³, Chao Li¹, Yuanda Cao¹

¹School of Computer Science, Beijing Institute of Technology

²Network Optimization Center, China Mobile Communications Corporation Beijing Co., Ltd.

³Telecommunication Metrology Center of MIIT

maminghui01@gmail.com zhangzhaoxiang@bj.chinamobile.com anxudong@emc.cit.com lichao0503@gmail.com
ydciao@bit.edu.cn

Abstract—Delay/Disruption Tolerant Networks (DTNs) enables nodes to communicate by means of asynchronous sending messages without the need for an end-to-end path. In this paper, we study the problem of multicasting in DTNs. Several schemes have been proposed for multicast routing assuming the group of message receivers is known by sender, and the group members do not change during the process of message delivery. In this paper, we propose a Probability and Receiver List based multicast routing scheme to address the message routing problem, which can handle multicast group members changing problem. Simulation results show that our routing strategies can achieve higher message delivery ratios and lower delivery latency than existing approaches.

Keywords- Delay tolerant networks; multicast; routing

I. INTRODUCTION

Delay / Disruption Tolerant Networks (DTNs) [1] are characterized by intermittent connections because of node movement and low network density. These networks have a variety of applications including deep-space communication, vehicular communication, habitat monitoring, and military battlefield communication.

DTN multicast also supports a broad range of applications. For example, in a disaster relief scene, it is essential to disseminate information about victims among rescue workers; in military battlefields, it is important to deliver commands to soldiers, and so on.

Although multicast in the Internet and mobile ad hoc networks has been studied extensively (e.g. MOSPF [2], MAODV [3], ODMRP [4], and AMRoute [5]), these protocols are not suitable for DTNs due to the

intermittent connections and long latency. Since we cannot always get an end-to-end path from source to intended receivers [6], it is unreasonable to use Internet or mobile ad hoc networks (MANET) algorithms to deliver messages.

The existing multicast routing algorithms cannot fulfill the multicast demand in DTN very well. In this paper, we propose a Probability and Receiver List based routing scheme (PRL) which improves the performance of routing algorithm significantly. PRL computes the probability of every node meeting the destinations (also noted as intended receivers¹ in this paper). The probability of meeting the destinations is computed according to the formula in PROPHET algorithm [12]. Every message has its intended receivers, and the information, including the probabilities, of these receivers is stored in a segment of this message. Based on the probability, PRL selects the direction of transmission and next hop.

Through the simulations, we compare our routing algorithm to other multicast routing approaches using the Random Way Point (RWP) mobility model. The simulation results show that our PRL scheme can achieve a better delivery ratio and less delivery latency than existing DTN multicast algorithms.

The rest of this paper is organized as follows. We first review related research in Section II. Section III presents the idea of PRL routing scheme. The simulation and performance evaluation are discussed in Section IV. We conclude the paper with Section V.

II. RELATED WORK

Unicast routing algorithms [7], [8], [9] for DTNs have been studied extensively since 2003. However, similar research on multicast routing schemes in DTNs has been rare. Multicast for DTNs is a fundamentally different and hard problem

compared to multicast for Internet or MANET due to the frequently intermittent connections. Thus, the classic routing strategies are ineffective for message delivery because the networks are highly partitioned. Zhao et al. [6] designed several classic tree-based multicast routing algorithms for DTNs, such as Static Tree-based Routing (STBR) and Dynamic Tree-based Routing (DTBR). In STBR, the nodes construct a shortest path tree in the DTN graph from the source to the estimated intended receivers when the messages are generated. The messages are then forwarded along the tree. If a message misses a contact, it needs to wait for the next chance to connect to this node, which may significantly increase the delivery latency. DTBR builds up a shortest path multicast tree dynamically. It determines the next hops by computing the shortest paths from the current node to the intended receivers, and can utilize the latest information about connections, in contrast to STBR. Ye et al. [10] proposed an On-demand Situation-aware multicast (OS-multicast) approach which is an advanced dynamic tree-based strategy. However, those schemes are all based on knowledge about the overall network topology, which is extremely difficult or impossible to obtain in DTNs, to select the next hop. Yang and Chuah [11] proposed a Context-Aware Multicast Routing (CAMR) scheme to improve the performance of multicast routing. CAMR makes use of extra information about node locations and velocities, and the mobility of a node can be controlled in such a scheme. These limitations constrain the applications of this strategy because it is resource-consuming to obtain the node location and velocities, and it is ridiculous to try to control the movement of the nodes.

III. CORE IDEA OF PROBABILITY AND RECEIVER LIST BASED MULTICAST ROUTING

A. Probability Computing

In this paper, the probability of meeting the intended receivers is computed according to the same algorithm in PROPHET:

The probability of node meeting each other is

$$P_{(a,b)} = P_{(a,b)old} + (1 - P_{(a,b)old}) \times P_{init}$$

The probability decreasing with elapsed time is

$$P_{(a,b)} = P_{(a,b)old} \times \gamma^k$$

where γ is the attenuation rate.

The probability of node meeting in two hops scope is:

$$P_{(a,c)} = P_{(a,c)old} + (1 - P_{(a,c)old}) \times P_{(a,b)} \times P_{(b,c)} \times \beta$$

B. Probability and Receiver List Routing

In the multicast networks, every message has a group of destinations. So, there is a segment in each message to store these intended receivers which is named Receiver List, $\{d_0, d_1, d_2, \dots, d_n\}$.

On the other hand, there is also a segment to store the probability of meeting other nodes, $\{P_0, P_1, P_2, \dots, P_n\}$, where

P_i is the probability of node i meeting node j . The comparison of two probability list is illustrated in figure 1.

There are four rules to deliver messages.

- Rule 1:** if node a carrying message m is a relay node, it meets a node b that is the destination of m , and b doesn't carry message m , then m will be transmitted to node b .
- Rule 2:** if node a carrying message m is one of the intended receiver of m , it meets a node b that is another destination of m , and b doesn't carry message m , then m will be transmitted to node b .
- Rule 3:** if node a carrying message m is one of the intended receiver of m , it meets a node b that is a relay node, then m will be transmitted to node b .
- Rule 4:** if node a carrying message m is a relay node, it meets a node b that is also a relay node, then m will be transmitted according to figure 2

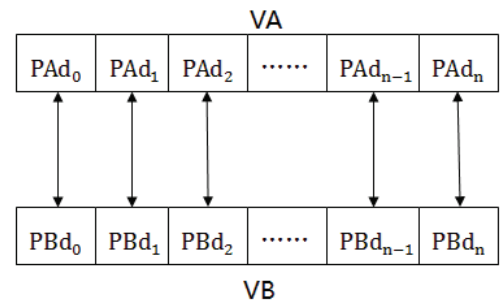


Fig. 1 comparison of two probability list

IV SIMULATION RESULTS AND ANALYSIS

In this section, we describe simulations with the following steps: (1) deploy the simulation environment and set general parameters; (2) evaluate the performance of PLR. The performance metrics we monitored include: (1) message delivery ratio, which is defined as the number of unique multicast bundles successfully delivered to all receivers over the total number of unique messages that could be received; (2) overhead, which is the ratio between the average number of duplicated business messages in the network and the messages received by the intended receivers; and (3) message delivery latency, which is described as the average transmission latency from the source to all of the intended receivers; (4) relayed refers the number of messages that are relayed.

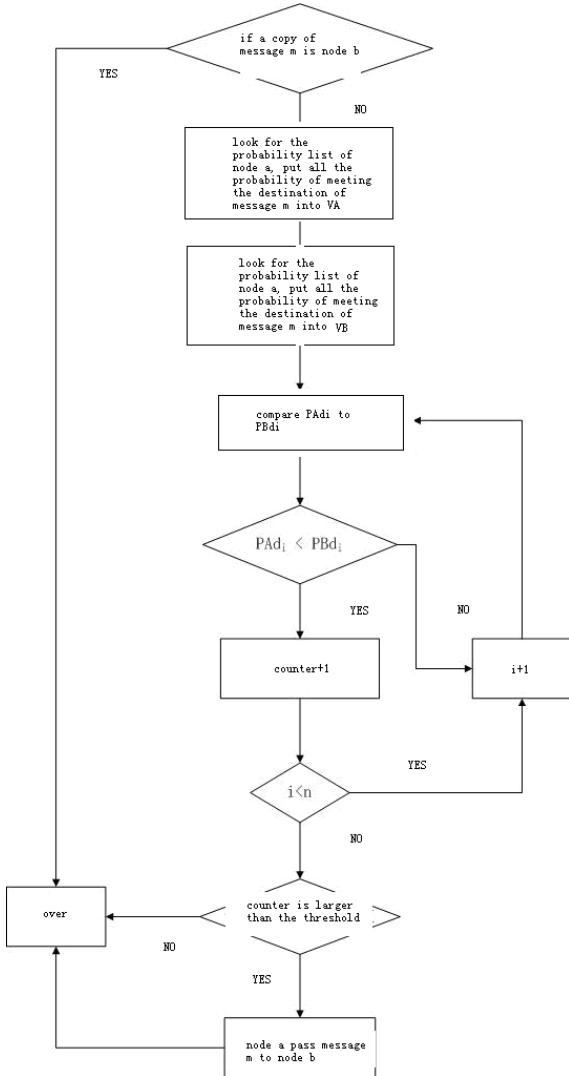


Fig. 2 PRL algorithm

A. Simulation Environment and Parameter Settings

All simulations were performed in the simulator ONE [13] in a 4500 m by 3500 m area. The nodes moved within the area according to the Random Way Point (RWP) model. In order to detect other nodes to communicate with, each node sent out beacon messages every 500 milliseconds. Each simulation lasted for 43000 seconds. The TTL of every message was infinite. The message sizes were uniformly distributed between 750KB and 1.5MB. All of the results are the average of 50 simulations.

B. Performance Evaluation of PRL

In this subsection, we evaluate the performance of PRL.

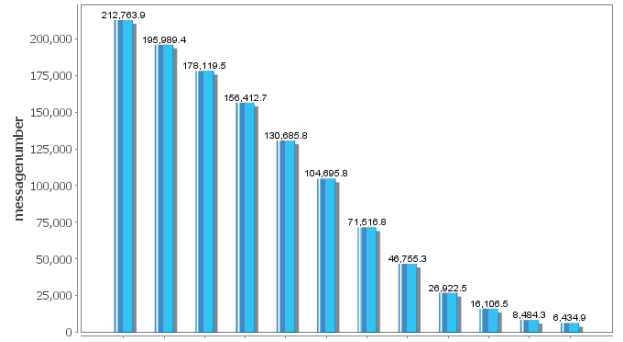


Fig. 3 message relayed VS. probability threshold

From figure 3, we can find that with the increasing of probability threshold, the number of message relayed decreases sharply. When the probability threshold is 100%, message relay is only 4% of that in Epidemic algorithm.

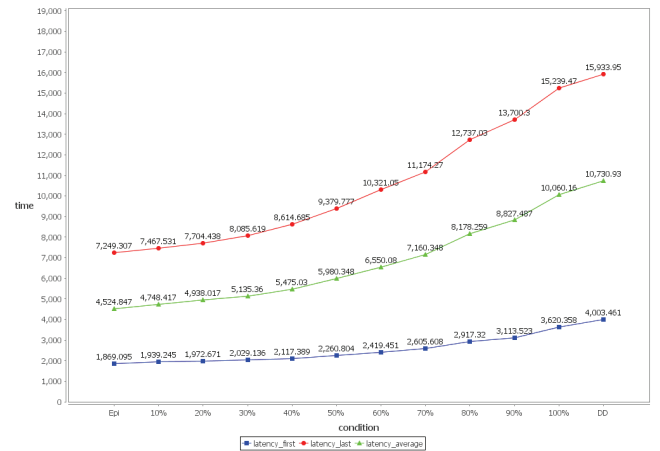


Fig. 4 delay VS. probability threshold

From figure 4, we can find that with the increasing of probability threshold, it is more difficult to relay messages, which results in the longer delay to deliver packets from the source to the destination.

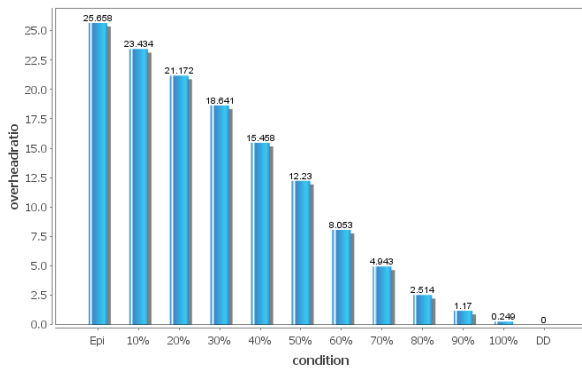


Fig. 5 overhead VS. probability threshold

From figure 5, due to the limited buffer space, messages are out and in frequently, which results in amount of overhead. With the increasing of the threshold, the overhead drops significantly.

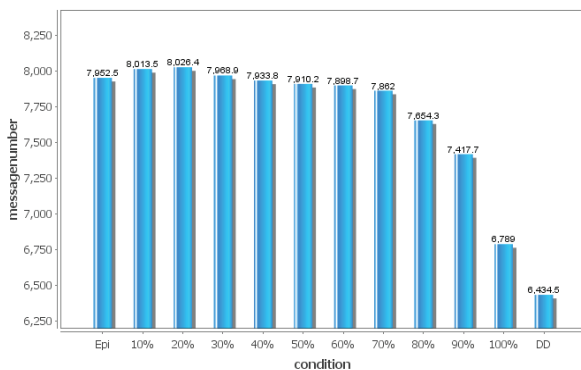


Fig.6 delivered messages VS. probability threshold

From figure 6, due to the limited buffer size, messages are in and out of the buffer frequently, which undermines the delivery ratio. When the threshold is 10% and 20%, it decreases the floatability, and the delivery ratio is improved. However, when the threshold is near 100%, the condition of message delivering is harsh, so the delivery ratio decreases.

From these simulation results, we can conclude that: without any prior knowledge about the networks, the PRL routing scheme performs very well in general.

V CONCLUSION

In this paper, we have developed a Probability and Receiver List based multicast routing for DTNs. Our scheme allows nodes dynamically to join and to withdraw the multicast members during the message delivery, which is the main character of multicast in DTNs. We evaluated the PRL scheme. The simulation results show that the PRL scheme is more efficient and can provide high delivery ratio and low delivery delay. For future work, we intend to integrate PRL scheme with other mobility pattern of nodes to adapt more complex DTN scenarios. Last but not least, we intend to implement our scheme in a DTN tested for empirical evaluations.

REFERENCE

- [1] K. Fall, "A delay-tolerant network architecture for challenged internets," in *Proc. ACM SIGCOMM*, pp.27-24, 2003.
- [2] J. Moy, "Multicast extensions to OSPF", *IETF RFC 1584*, 1994.
- [3] E.M. Royer and C.E. Perkins, "Multicast Operation of the Ad hoc On-Demand Distance Vector Routing Protocol", in *Proc. ACM/IEEE MOBIKOM*, pp.207-218, 1999.
- [4] S.H. Bae, S.J. Lee, W. Su, and M. Gerla, "The design, implementation, and performance evaluation of the on-demand multicast routing protocol in multihop wireless networks", *IEEE Network*, vol. 14, pp.70-77, 2000.
- [5] J. Xie, R.R. Talpade, A. Mcauley and M.Y. Liu, "AMRoute: ad hoc multicast routing protocol", *Mobile Networks and Applications*, vol. 7, pp. 429-439, 2002.
- [6] W. Zhao, M. Ammar and E. Zegura, "Multicasting in delay tolerant networks:semantic models and routing algorithms", in *Proc. SIGCCOM Workshop in DTN*, pp.268-275, 2005.
- [7] A. Balasubramanian, B.N. Levine, A. Venkataramani, "DTN Routing as a Resource Allocation Problem," in *Proc. ACM SIGCCOM*, pp. 373-374, August 2007
- [8] J. Leguay, T. Friedman, V. Conan, "Dtn routing in a mobility pattern space," in *Proc. ACM SIGCOMM Workshop on Delay Tolerant Networks*, pp.276-283, 2005.
- [9] L. Yin, H. M. Lu, and Y. D. Cao, "Probabilistic Delay Routing for Delay Tolerant Networks", in *Proc. ICACT2008*, pp. 191-195, 2008
- [10] Q. Ye, L. Cheng, M. Chuah and B.D. Davison, "On-Demand Situation Aware Multicasting in DTNs", in *Proc. IEEE VTC*, pp. 96-100, 2006
- [11] P. Yang and M.C. Chuah, "Context-Aware Multicast Routing Scheme for Disruption Tolerant Networks", in *Proc. PEWNS*, pp. 239-254, 2004.
- [12] A. Lindgren, A. Doria, and O. Schelen, "Probabilistic Routing in Intermittently Connected Networks," in *Proc. SAPIR*, pp.183-189, 2005
- [13] A. Keränen, J. Ott, "Increasing Reality for DTN Protocol Simulations," *Technical Report*, Helsinki University of Technology, Networking Laboratory, 2007.