Reducing Message Overhead using Community-based Message Transmission for Delay Tolerant Networks

Regin Cabacas*, In-Ho Ra**
*,**Kunsan National University, Korea
E-mail : rcabacas@kunsan.ac.kr*, ihra@kunsan.ac.kr**

1. Introduction

Delay Tolerant Networks (DTN) are networks comprised by constrained resource nodes and is characterized by unavailability of end-to-end path, frequent connection disruption and network partitions. This constrained resource nature of nodes in DTN is a primary challenge and has been a continuous popular research area. Energy-efficient algorithms and policies for Delay Tolerant Networks are crucial for maximizing the message delivery probability and reducing the delivery cost [1] and are basically admirable for DTN applications.

In the past decades, many routing protocols have been designed for DTN. Most of them employ probabilistic, deterministic and stochastic approaches to achieve high message delivery rate. Routing protocols can also be categorized by how many message copies are generated in the network namely; flooding or multi-copy, quota-based and single-copy [2]. Some of protocols in these three category use metric for decision making in message transmission. However, similarly for these categories, delivery cost is mostly compromised over delivery rate. In this paper, the aim of this proposed scheme is to be able to balance out the number of replication without sacrificing delivery cost. Moreover, we discuss transmission strategies and presented problems in existing DTN routing protocols in section 2. Section 3 depicts the proposed approach followed by the concluding statement in section 4.

2. Motivation and overview

Replication approaches employs greedy approach of creating duplicates of messages as node meets and exchange messages. This is commonly done to cope with the uncertainty of transmission opportunities between mobile nodes which ensures successful delivery. Replication offers both advantages and disadvantages in routing protocol designs [2]. For example, in flooding-based routing protocols such as Epidemic and Spray and Wait, replication improves delivery rate but increases delivery cost. Single-copy or forwarding strategies on the other hand ensures one message copy that is relayed to selected nodes having the most likelihood of delivery to the destination.

To the best of our knowledge combining the two approaches is not commonly employed in routing protocol design. For this problem, we identify several inadequacies in existing protocols that results to high message delivery cost, which include the following: (1) inability of other nodes to know if the message they carry have been delivered or not. Nodes replicate messages without knowing if it has already been delivered or not. Routing protocol often leaves out delivered messages to be replicated over and over. Furthermore, due to the buffer constrained resource nature of the nodes, these messages stay too long in the buffer and reduces other message's chances of being forwarded and delivered [3]; (2) Number of message quota is set beforehand. Setting the quota too high or too low affects the routing performance and message delivery in general [4]; (3) choosing the best message carrier for delivery. Flooding and quota protocols use oblivious approach and do not make use of any metric to identify better forwarders. Thus, for every encounter each message is replicated, the number of replications is directly proportional to the unique encounters and the message quota. Moreover, probabilistic approach makes use of one or several metric to replicate or forwards the message which mostly results in attaining high delivery and low message overhead.

3. Proposed approach

This section particularly explains the details of the proposed routing protocol. Specifically it aims to provide solutions for the problems stated in section 2 through the following: (1) provide a way for nodes to exchange list of delivered messages upon contact to discard delivered messages in the buffer and prevent further replication; (2) enable nodes to dynamically set the number of replica for each message destination based on previous delivery encounters; (3) utilized message forwarding and replication intelligently in the network and; (4) exploit nodes social properties like community association and centrality as basis for selecting the best forwarder to reduce message replication while ensuring high probability of delivery.

From the routing protocol limitations stated on section three (3) we identify three aspects that affects routing performance namely; message delivery management, queue management and forwarding decision and are discussed as follows.

A. Message Delivery Management

Several protocols like that of [4] utilize hop counts to limit the number of message replicas. In the proposed scheme, every time node replicates or forwards the message to other nodes, the number of hops is recorded and will be basis for dynamically setting the number of message copies that is needed to reach the destination. However, in [4], the replica does not conform to any maximum value thus still resulting in high overhead. Taking this into consideration we set a threshold value for the number of replica. This strategy aims to make sure that the number of replica stays within certain limit, prevents unnecessary copy, achieve effective message delivery and reduce overhead.

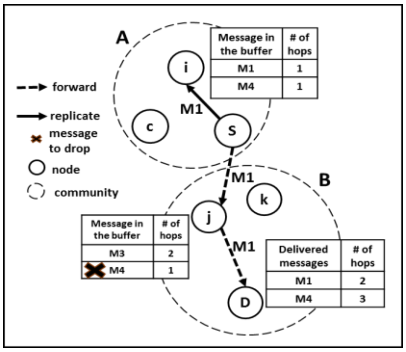

Figure 1. Illustration of community-based message transmission

```
if i is message destination
        forward message
        update delivery_list table
        update contacts table
end if
if d and i belongs to the same community
        if centrality of i is greater than s
                forward message
                update contacts table
        else
                replicate message
                update contacts table
        end if
else if s and i belongs to the same community
        if delivery probability of i is greater than s
                forward message
                update contacts table
        end if
end if
```

Algorithm 1. Transmission decision rule of the proposed approach

B. Queue Management

Message queuing plays an important role in the performance of routing protocols [4]. Effective queuing should give fair chances to all messages to be forwarded and delivered. Message with high probability of delivery will be prioritized in the head of the queue and is sorted based on the message size and contact node's community. Prioritizing messages with small size but according to the contact nodes community guarantees that messages will be transmitted within the contact time and before its time-to-live (TTL) expires.

C. Forwarding Decision

The forwarding decision of the proposed design is driven by two common attribute that can be obtained in nodes that forms a social network namely; community and centrality. A community is a defined as structural subunit of a social network with high density of internal links [5]. Authors in [3] stated that, individuals in the same community may meet each other more frequently [3] providing more contact opportunity for delivery. Furthermore, the community structure has significant impact on people's mobility patterns and is beneficial for choosing the appropriate forwarding path. K-clique [3] is used to identify nodes community and is assumed that each node knows which community they belong. Centrality is used to describe important and prominent nodes in a social graph. This feature represents that people have various roles and popularities in society and a node with high degree of centrality has stronger capability of connection with other nodes [5]. Centrality is calculated using Freeman's degree shown in equation 1, where N is the number of nodes, D is maximum degree and m is the number of edges. The forwarding process is illustrated in figure 1 and the transmission decision process conforms to the rule shown in algorithm 1.

Equation 1. $$Ci = (N * D - m) / ((N-1)(N-2))$$

4. Conclusion

Reducing of delivery cost benefits the resource constrained characteristics of a node in DTN. This paper presents a new routing protocol that either forward or replicate based on the community with intermediate nodes. The idea is attributed from community formation of nodes as explained in social network analysis. We presented several limitations of existing routing protocols and discussed several strategies that are integrated in the proposed scheme. The next step is to evaluate the proposed approach using simulation and compare with existing routing protocols.

5. Acknowledgement

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2013054460).

6. References

[1] Y. Li, Z. Wang, D. Jin; L. Su, L. Zeng, S. Chen, "Optimal Beaconing Control for Epidemic Routing in Delay-Tolerant Networks," IEEE Transactions on Vehicular Technology, 2012, pp. 311-320.

[2] S. Ali, J. Qadir, A. Baig, "Routing protocols in Delay Tolerant Networks - a survey," 2010 6th International Conference on Emerging Technologies (ICET), 2010, pp. 70-75.

[3] F. Xia, L. Liu, J. Li, J. Ma, A.V. Vasilakos, "Socially Aware Networking: A Survey," IEEE Systems Journal, 2013, pp.1-18.

[4] K. Henmi, A. Koyama, "A DTN Routing Protocol Based on Mobility and Maximum Number of Replications," 2013 Seventh International Conference on Complex, Intelligent, and Software Intensive Systems (CISIS), pp. 293- 298, 3-5 July 2013

[5] F. Li, J. Wu, "LocalCom: A community-based epidemic forwarding scheme in disruption-tolerant networks," In Proceedings of IEEE SECON, 2009, pp. 1–9.