A Novel Congestion Control Technique in Delay Tolerant Networks

Saeid Iranmanesh, Department of Computer, Islamic Azad University-Robatkarim Branch, Robatkarim, Iran
Maryam Saadati, Department of ITS, Technikum Wien, University of Applied Science, Vienna, Austria

ABSTRACT

Delay Tolerant Networks (DTNs) are characterized by the lack of contemporaneous paths between any source and destination node. As a basic forwarding strategy, nodes may flood their bundles to every encountered node. This results in congestion and unnecessarily consumes precious network resources. Another strategy is to take advantage of quota based protocols in which only a limited number of copies or replicas are disseminated throughout the network in order to reduce resource usage. However, they suffer from low delivery ratios as their dissemination rate is low. In this paper, the authors propose an Adaptive Message Replication Technique (AMRT) that is fit onto quota protocols to intelligently limit the number of replicas for each generated message. In other words, a source node under AMRT considers the congestion exist amongst the neighbours in order to generate a proper number of replicas for the generated messages. The simulation studies show that when AMRT is applied onto the quota protocols namely, SprayAndWait, EBR, and DBRP, the network performance such as delivery ratio and delay is improved.

KEYWORDS
Congestion Control, Delay Tolerant Network, DTN Routing, Message Replication, Quota Protocol

1. INTRODUCTION

Delay Tolerant Networks (DTN) (DTN Research Group, www.dtnrg.org) provides communications between source and destination nodes where there is no direct path between any source and destination at a same time. In such environment, intermediate nodes are involved in order to receive messages from sources and carry them for a while until forwarding opportunities arise. Hence, messages are routed based on store-carry-forward manner. However, as the network may have limited resources such as buffer size, energy, and bandwidth, the network performance, namely delivery ratio, delivery delay and, overhead is affected by the following problems (Balasubramanian, Levine & Venkataramani, 2007). Firstly, if messages are flooded throughout the network, congestion may happen in the network which results in the network with high network overhead, low delivery ratio and large delays (Elwhishi, Ho, Naik & Shihada, 2013; Krifa, Barakat & Spyropoulos, 2012; Krifa, Barakat & Spyropoulos, 2008). On the other hand, in order to reduce the signaling overhead, number of replicas may be limited that in turn, due to low dissemination rate, decreases delivery ratio and increases delay.

Many routing protocols are proposed to address the issue of routing in DTNs (Elwhishi, Ho, Naik & Shihada, 2013). These routing protocols are categorized into two groups (Iranmanesh, Raad & Chin, 2014; Nelson, Bakh & Kravets, 2009) (1) Flooding-based and (2) Quota-based. In the first group, although nodes are able to replicate messages infinitely, these protocols may reduce the number of replications such that the network overhead decreases. It should be noted that when the
network resources are not limited, despite of high energy usage (Juang, Wang & Martonosi, 2002), these protocols provide a high network performance such as high delivery ratio and low delivery delay. However, the overhead of these protocols is high and they suffer from low delivery ratio when the network resources are limited. Contrary to flooding based routing protocols where the number of replicas is dependent on the number of encounters, quota protocols limit the number of replicas for each generated message. These protocols reduce the network overhead and consume less energy compared to flooding based protocols. However, these protocols suffer from low delivery ratio and large delays due to low messages dissemination. In addition, without respect to the network’s capacity i.e., nodes’ buffer size and nodes’ service rate, the number of replicas for all messages is fixed. This means if a quota protocol generates a large number of replicas for each message when congestion happens in the network, the protocol similar to flooding protocols will suffer from high ratio of dropped messages. On the other hand, if the number of generated replicas is small and traffic is low in the network, the protocol suffers from low delivery ratio.

To address the aforementioned problems, this paper takes advantage of the following observations under quota protocols. Consider node A moves in high node density area where the rate of message dissemination is high. As a result, node A is expected to experience a high service rate. Service rate is defined as the number of messages that are received by a given node upon a contact. Now, assume that node A generates a message for a destination D. As traffic congestion exists in this area, generating a large number of replicas for a message is not a good idea. This is because, it will make the congestion worse and a large number of replicas will be dropped. Consequently, the delivery ratio decreases. Note that, under quota protocols, no provisions are provided to replace dropped replicas. Now, consider that the network traffic is light. In this case, the network will have a high delivery ratio, if a large number of replicas are disseminated throughout the network. This is because when nodes have enough buffer space, they can store messages for a long time until a proper forwarding opportunity arises. Henceforth, based on aforementioned observations, this paper presents an Adaptive Message Replication Technique (AMRT) that tackles the problem of congestion in DTNs such that message delivery ratio increases. In this technique, contrary to current quota protocols that number of replicas is fixed for all generated messages, the number of replicas for each generated message will be varied based on the congestion exist in the network. Accordingly, if a source node detects that congestion has occurred amongst its neighbours, a small number of replicas will be generated for its new messages. On the other hand, if the detected traffic is low, a large number of replicas will be generated for its new messages. To this end, AMRT is known as a quota protocol that adaptively allocates different number of replicas for each generated message in order to control the network congestion.

Henceforth, this paper makes the following contributions:

- An understanding and broad review of the related work, covering routing protocols. Moreover, strong pints and problems of the protocols are discussed.
- Proposing the first congestion control technique namely AMRT which is specifically designed for quota protocol. In this technique, although same as previous quota protocols the number of replicas for each generated message is limited, it is not fixed for all messages. This implies that number of replicas for each message may be varied.
- AMRT control the congestion over links such that the ratio of incoming and dropped messages converges to an acceptable level. This technique controls the number of injected replicas to the network over time as the traffic varies on links.
- The simulation studies show that all well-known quota protocols that use AMRT improve the network performance such as delivery ratio and delay.

The remainder of this paper has the following structure. Section 2 presents the related work, and Section 3 proposes AMRT, a message replication technique for quota protocols that exploits said observations. Section 4 describes our simulation setting and is followed by our experimental results. Lastly, Section 6 concludes this paper.
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