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Contact expectation based routing for delay tolerant networks

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ABSTRACT

In conventional networks, routing problem can be modeled as the design of an efficient source-to-destination route based on persistent end-to-end paths. However, in a delay tolerant network (DTN), nodes are intermittently connected and thus, the end-to-end paths will not always exist, in which routing is a challenging issue. Previous DTN routing protocols tend to make routing decision based on the nodes' contact information. In this paper, we observe that considering both the nodes' contact information and message property such as the time-to-live (TTL) would help to improve the performance. Embedded this idea, we first propose an expected encounter based routing protocol (EER) which distributes multiple replicas of a message proportionally between two encounters according to their expected encounter values. In case of a single replica of a message, EER makes the routing decision by comparing two encountering nodes' minimum expected meeting delays to destination. We further propose a community aware routing protocol (CAR) which takes advantages of the high contact frequency property of the nodes within the same community. We also propose the buffer management strategies corresponding for the two protocols. We conduct simulations to evaluate our proposed protocols and some existing ones on three metrics: delivery ratio, latency and goodput. The simulation results illustrate that our proposed EER and CAR protocols outperform other existing ones.

1. Introduction

Delay tolerant networks (DTNs) [1,2] are an emergent communication paradigm, which can be applied to many applications such as delay tolerant event collection [3], pocket switch networks [4] and social networks [5–7], etc. In typical DTNs, nodes are always mobile, making the conventional routing protocols based on persistent end-to-end paths not still applicable since they do not always exist. Due to the mobile characteristic of nodes in DTNs, the link between each pair of encountering nodes will be intermittent, thus the network topology will change over time. Therefore, it is difficult to design an efficient routing protocol for DTNs based on the intermittently connected links.

Store-carry-and-forward mechanism is widely adopted to deliver messages in DTNs. It will be relatively easier for a node to make an optimal routing decision if it is aware of global network connectivity. However, it is hard for a node to obtain the global network connectivity as it is time-varying. Fig. 1 shows a simple network with six mobile nodes which are intermittently connected. The network topology varies from time t_1 to t_4. For instance, if node A wants to send a message to node D at t_1, according to the global network connectivity, the optimal delivery path for this message is from node A to node E at t_2, then from node E to node F at t_3 and finally from node F to node D at t_4. However, node A may apply the best effort strategy to deliver message to node B at t_1 since it meets node B first, resulting in its failing to

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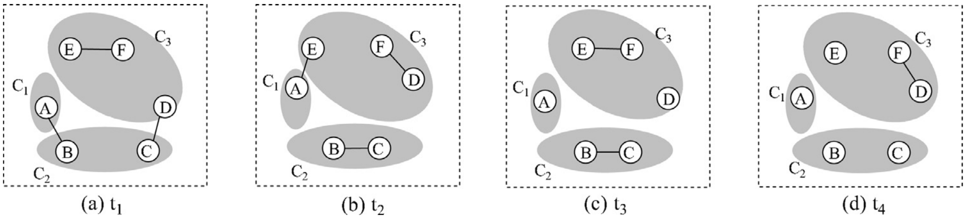

Fig. 1. A sample community aware delay tolerant network with six intermittently connected nodes at different time. C_1, C_2 and C_3 denote three different communities in the network, node A belongs to C_1, nodes B and C belong to C_2, nodes D, E and F belong to C_3.

deliver message to node D. Fortunately, by referring to historical mobility information, a node can predict its future contacts with other nodes, which may be useful in making routing decisions.

In [8], a routing protocol is proposed, in which each node estimates its future encounter value (EV) based on its contact history. When two nodes meet each other, the replicas of a message will be distributed between them according to the proportion of their estimated EVs. This approach can achieve good performance with a low overhead. However, the estimated EV in [8] is considered as a node's current property, and once a node has calculated its EV, it will make the same routing decision for all its held messages. Intuitively, it is unwise to overlook the property of different messages, such as time-to-live (TTL), in making routing decision. Since each message has its own TTL and should be delivered to final destination before expiration, a message's TTL should be taken into consideration when estimating EV. For example, if a node estimates its EV as *e* per hour, which suggests that this node will meet *e* other nodes within 1 h. However, if the residual TTL of a message is only several minutes, then it is unreasonable to distribute the replicas of this message based on *e*, since the message will *"die"* before reaching some of the *e* encounters. Therefore, a better solution is to consider the time duration when estimating EV, i.e., how many encounters the node expects to have before a message expires. In contact graph routing (CGR) [9], the TTL has been considered, in which a route that cannot deliver the message to its destination within the TTL will not be selected. However, in this paper, we tend to build a replicas distribution criteria between two encountering nodes based on each message's residual TTL.

Inspired by this idea, an improved expected encounter based routing protocol (EER) is proposed to solve this problem in this paper. EER protocol has two phases: multiple replicas distribution and single replica forwarding. In the multiple replicas distribution phase, each node disseminates the replicas of a message to different nodes as soon as possible, which can be achieved by distributing the replicas of a message according to their expected EVs. The expected EV is calculated as a function of the message's TTL, which will be more reasonable in predicting the future EV within a fixed future time interval. In the single replica forwarding phase, each node decides whether to forward message to its current encounter by comparing the minimum expected meeting delay (MEMD) to destination. The MEMD is calculated based on the past meeting intervals between each pair of nodes and the elapsed time since their last contact. A buffer management strategy based on the MEMD is also proposed to schedule the message dropping when buffer is full.

We further propose a community aware routing protocol (CAR), which takes advantages of high contact frequency property of nodes inside a community. CAR protocol includes inter-community routing and intra-community routing. In inter-community routing, each node disseminates multiple replicas of a message to the nodes from different communities as soon as possible, in which the distribution of the replicas of this message is proportional to the expected numbers of encountering communities of each pair of encounters. In case of a single replica of the message left during the propagation, the message will be delivered to the node with a higher probability to encounter at least one of the destination communities. In intra-community routing, a node in one of the destination communities distributes the replicas of a message to its encounter in the same destination community according to the proportion of their intra-community expected EVs. In case of a single replica of the message, the node in one of the destination communities decides whether to forward message to its encounter in the same destination community by comparing their intra-community MEMDs. And the buffer management in CAR protocol is also considered.

Our main contributions of this paper are summarized as follows:

- We formulate the calculation of the expected EV of each node and the minimum expected meeting delay between each node and destination, then we propose the expected encounter based routing protocol – EER;
- We propose the community aware routing protocol called CAR using the expected number of encountering communities, which takes advantages of community property;
- We propose the buffer management strategies corresponding to EER and CAR protocols;
- We conduct simulations to illustrate the effectiveness of our proposed routing protocols under different network parameters.

The rest of this paper is organized as follows. In Section 2, we discuss the existing DTN routing protocols and buffer management strategies. Section 3 proposes the system model in this work. Section 4 describes our proposed expected encounter based routing protocol. In Section 5, we propose the community aware routing protocol. The performance evaluation is conducted in Section 6. Section 7 concludes this paper.