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GAR: Group aware cooperative routing protocol for resource-constraint opportunistic networks

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ABSTRACT

Opportunistic networks are a new evolution of mobile ad hoc networks composed of intermittently connected nodes, in which the routing based on the dynamic topology is a challenging issue. In opportunistic networks, the mobile nodes with common interest or close relationship may form into groups and move together, which brings us a good feature to employ when designing the routing protocol for the resource-constraint opportunistic networks. Our main idea in this paper is to maximize the message delivery probability with the consideration of the group feature in the opportunistic network under the constraints of bandwidth and buffer space. Embedded this idea, we propose a cooperative routing protocol called GAR, which includes a cooperative message transfer scheme and a buffer management strategy. In the cooperative message transfer scheme, the limited bandwidth is considered and the message transfer priorities are designed to maximize the improved delivery probability. In the buffer management strategy, by considering the constraint of buffer space, we propose a cooperative message caching scheme and the dropping order of the messages is designed to minimize the reduced delivery probability. We also propose an improved strategy to utilize the extra contact duration between each pair of encountering nodes to further improve the performance. Finally, we conduct the simulations to demonstrate the effectiveness of our proposed GAR protocol under different network parameters.

1. Introduction

As one type of Delay Tolerant Networks (DTNs), opportunistic networks are composed mainly by mobile nodes that do not have persistent connections among them. In opportunistic networks, routing is a challenging issue since the path from a source to a destination is intermittently connected. The conventional routing protocols are generally not applicable, and the store-carry-and-forward mechanism is therefore adopted to deliver messages in such kind of networks. In most of the routing protocols used for opportunistic networks, each node decides the message transfer order independently when it meets its encounter. Due to the sporadic node density and unpredictable node mobility, the contact duration between each pair of nodes may not last long enough for them to transfer all the messages. It is desirable if the two encountering nodes can cooperate with each other to build the message transfer order which can efficiently make use of the limited contact duration [1].

Opportunistic networks can be formed by mobile nodes such as the portable devices carried by the human beings [2]. In this scenario, the mobile nodes with common interest or close relationship may form into groups and move together. One typical application scenario is the disaster recovery system [3]: imagine an intense earthquake that devastates most infrastructures of cellular networks, leading to the collapse of cellular network services for a long time. In this post-earthquake scenario, the survivors would tend to move in groups to assist each other in case of secondary disasters. The mobile phones carried by the survivors can construct an opportunistic network with the group feature. Under such a critical scenario, the survivors would try to communicate with their relatives or friends to enquire their safety as early as possible, which will trigger a huge traffic burst that may overburden the limited bandwidth and buffer space of mobile nodes.

Such critical scenario motivates us to design a routing protocol for the resource-constraint opportunistic network. As the nodes within a group likely encounter each other more frequently and the intra-group links are relatively stable, a source node can leverage the group feature by first delivering the message to the

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destination group, and then letting the message be routed to the destination via the intra-group links. Moreover, the nodes within the same group can cooperatively share their limited buffers in caching the messages. Therefore, we can integrate the group feature into the design of efficient routing and buffer management strategies for opportunistic networks.

Fig. 1 shows a sample opportunistic network, in which the nodes form into four groups, G_1, G_2, G_3 and G_4. Suppose that the source node S wants to send a message m_k to node D at time t_1 (Fig. 1(a)), it can adopt the following routing procedure: when node S encounters node A at time t_2 (Fig. 1(b)), node S can forward m_k to node A. After node A receives many messages from its encounter node S, its buffer may be full. As nodes A and B are in the same group and currently connected, node A can transfer m_k to node B and drop m_k from its local buffer space to make more room for receiving other messages from node S. At time t_3 (Fig. 1(c)), node B meets node C. As node C can predict that the probability it will meet the destination group G_4 is larger than that of node B, node B will forward m_k to node C. Finally at time t_4 (Fig. 1(d)), node C encounters D and delivers m_k to node D successfully. We can see that, by using the group feature, the message can be delivered in the opportunistic network more efficiently.

In this paper, we propose a group aware cooperative routing protocol for opportunistic networks called GAR, which aims to maximize the message delivery probability under the resource constraints of both bandwidth and buffer space. The proposed GAR protocol includes a cooperative message transfer scheme and a buffer management strategy. In the cooperative message transfer scheme, the limited bandwidth available for mobile nodes is considered and two encountering nodes will exchange messages cooperatively to maximize the delivery probability. In the buffer management strategy, we further consider the constraint of mobile nodes' buffer space, and propose the cooperative message caching scheme, in which the message dropping priorities are set to minimize the reduced delivery probability. We also propose an improved strategy to utilize the extra contact duration of the encountering nodes to further improve the performance.

The main contributions of this paper are summarized as follows:

- We propose the cooperative message transfer scheme for opportunistic networks using the group feature, in which the limited bandwidth is considered and the message transfer priorities are set to maximize the improved delivery probability;
- By considering the constraint of mobile nodes' buffer space, we propose the buffer management strategy in which the cooperative message caching scheme is proposed and the message dropping priorities are set to minimize the reduced delivery probability;
- We propose an improved strategy to utilize the extra contact duration of the encountering nodes to further improve the performance;
- We implement our proposed GAR protocol in the ONE simulator and conduct the simulations to illustrate its effectiveness under different network parameters.

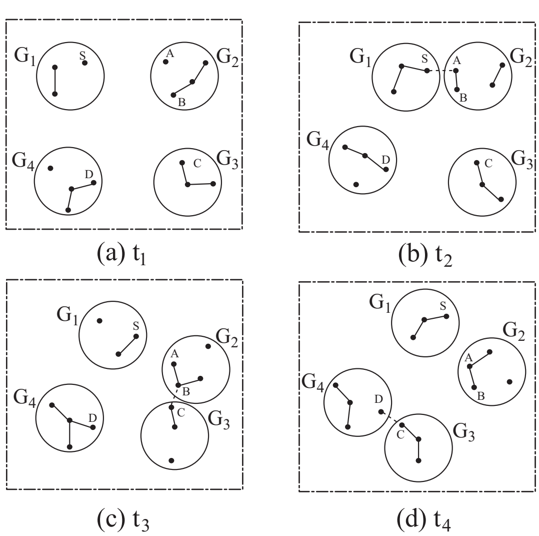

Fig. 1. Message delivery in a sample opportunistic network with group feature. G_1, G_2, G_3 and G_4 are four groups in the network.

The rest of this paper is organized as follows. In Section 2, we discuss the existing opportunistic network routing protocols and the buffer management schemes. The system model is presented in Section 3. Section 4 describes our proposed cooperative routing protocol using the group feature. The performance evaluation is briefly presented in Section 5. Section 6 concludes this paper and puts forward our future work.

2. Related work

Routing and buffer management issues in opportunistic networks have been well studied in recent years [4–7].

The routing protocols in opportunistic networks can be classified into three categories: *epidemic-based*, *forwarding-based* and *quota-based* routing protocols. Epidemic routing [8] is the earliest proposed routing scheme to deliver message in the opportunistic networks, in which each message is replicated and flooded to the entire network resulting in greatly consuming the limited bandwidth and buffer space. Some other epidemic-based routing schemes [4]910 are proposed to reduce the overhead. In Prophet [4], the likelihood of meeting the destination is used as the metric to determine whether a node will replicate and forward a message to its encounter. In MaxProp [9], each node schedules both the messages to be replicated to its encounter and the message to be dropped in case of buffer insufficiency. In the delegation forwarding [10], the message is replicated and forwarded by a node to its encounter only if its encounter has a better quality metric such as the delivery rate, average delay, and cost. BUBBLE Rap [11] is a social-based forwarding algorithm using the properties of social network and it is designed for pocket switched networks. In BUBBLE Rap, the node, which has a message destined for another node, will first forward this message to its encounter with a higher global ranking until the message reaches a node in the same community as the destination. After that, the message will be forwarded to the node with a higher local ranking until it reaches the destination.

Some forwarding-based routing schemes [12–17], in which each message only has one single replica in the network, are proposed to reduce the overhead. In [12], the delay tolerant network routing problem is formulated, and several routing algorithms corresponding to the percentage of knowledge are proposed. Jones et al. [13] design a practical single copy routing mechanism based on the minimum estimated expected delay, which is calculated based on the average meeting interval between each pair of nodes in the network using the Dijkstra's algorithm. The predict and relay (PER) [14] scheme relies on predicting the future contacts based on the semi-markov process. CREST [15] is a DTN routing protocol that uses the *conditional residual time* to opportunistically forward messages between pairs of encountering nodes. In CREST, the residual time between a pair of nodes is proved to be dependent on their previous time of contact. Based on CREST, CSRP [16] is proposed which routes the messages over conditional shortest paths by defining the cost of links as the conditional inter-meeting times rather than the conventional inter-meeting times. Gao et al. [17]