LETTER

P2P Based Social Network over Mobile Ad-Hoc Networks

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SUMMARY In this paper, we design an efficient P2P based mobile social network to facilitate contents search over mobile ad hoc networks. Social relation is established by considering both the locations and interests of mobile nodes. Mobile nodes with common interests and nearby locations are recommended as friends and are connected directly in a mobile social network. Contents search is handled by using social relationships of the mobile social network rather than those of the whole network. Since each mobile node manages only neighboring nodes that have common interests, network management overhead is reduced. Results of experiments have shown that our proposed method outperforms existing methods.
key words: *mobile social network, mobile ad-hoc network, mobile peer to peer network, location based network*

1. Introduction

Nowadays, contents-sharing services using social networks such as Facebook and Twitter are becoming popular. Social networks allow required data to be rapidly discovered by retrieving friend relationships. However, for most of the existing social networks, mobile users interact with each other via Internet accesses and rely on centralized management servers. The rapid development of wireless technologies makes it possible to build mobile social network services over mobile ad-hoc networks (MANET) [10]. In mobile social networks, mobile devices are communicated via short-range wireless technologies such as Wi-Fi and Bluetooth [11]. The mobile social networks enable users to share their contents without the need to access Internet within a small scale area. Such social network services can be used in specific areas, such as a bar, office, trains, campus, and shopping mall.

Some mobile social network services [5], [6], [9] have been proposed for contents sharing over MANET. However, these mobile social network services concentrate on application services rather than how to efficiently construct and maintain mobile social networks. In a previous work [1], an efficient social P2P management scheme based on interesting keywords for searching resources has been presented. However, resources search in this method adopts flooding methods [7], [8]. Request messages are flooded throughout whole network. The flooding based methods generate high overhead due to tremendously transmitted messages in the network. A dynamic social grouping based routing algorithm was introduced [2]. It forms series of social groups according to contact pattern of mobile users. However, this algorithm cannot be directly used for MANET because contact frequency information cannot be obtained easily in MANET. User similarity calculation for a social network using semantics of locations was proposed [4]. However, this method focused on mining similarity of trajectory data in centralized servers, while we aim to construct mobile social networks in a distributed manner. Although some similar previous works have been proposed [3], they assume that stable index nodes exist. The index nodes are used to manage index of all related information within the whole network. As a result, it will incur unaffordable network management overhead when nodes move fast. Additionally, contents search queries have to be forwarded to index nodes first and then sent to related destination nodes. This procedure will fail in mobile environments, which decreases success rate of contents search.

In this paper, we attempt to construct a P2P based mobile social network over mobile ad-hoc networks. Our goal is to construct a mobile social network with low network management overhead and high success rates of contents searches. The proposed method does not rely on stable nodes. Construction and maintenance of a mobile social network over MANET pose big challenges compared to traditional social networks due to constrained resources, limited connectivity, and dynamic network topology. It is important to take into account physical locations of mobile nodes when constructing mobile social networks over MANET. Routing paths between remote nodes are difficult to be maintained. In our approach, mobile social relation is established by considering both common interests and locations of different mobile nodes. Each node only manages nearby nodes with common interests. Remote nodes can be reached via intermediated friend nodes. By doing this, success rate of contents search is increased. Since the proposed method does not need index nodes, network management overhead is decreased.

2. Proposed Mobile Social Network

2.1 Overview

A mobile social network can be viewed as a social graph of interactions among mobile users. The overview architecture of the proposed method is shown in Fig. 1. The proposed method consists of two layers, virtual social network layer and physical layer. In the virtual social network layer, nodes

Manuscript received July 29, 2013.
Manuscript revised October 11, 2013.
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DOI: 10.1587/transinf.E97.D.597

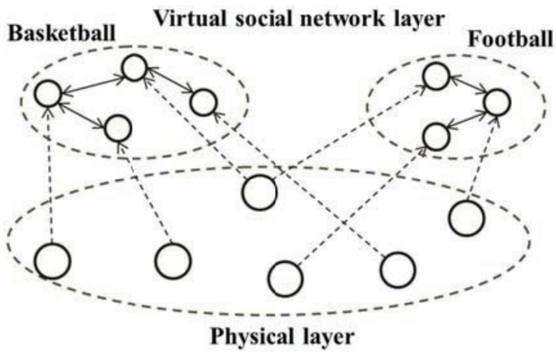

Fig. 1 Two layers of proposed mobile social network.

with common interests and nearby locations are connected by logical links. For example, nodes with common interests 'basketball' and 'football' are connected separately. In the physical layer, communication between mobile devices is achieved by multi-hops message propagation. Two neighbor nodes within the transmission range between each other can communicate directly. Remote nodes are communicated by hop to hop manner. Therefore, one hop logical link in the virtual social network layer is composed of several hops in the physical layer. We assume that the mobile devices are equipped with short range wireless communication functions (e.g. Bluetooth) and GPS functions.

2.2 User Similarity

As mentioned in previous sections, we construct mobile social network over MANET by considering the common interests and nearby positions of different mobile nodes. We assume that each user has profile information which consists of static information (e.g. name, gender, and interests). In order to easily explain the proposed method we assume that the static information is user interests.

The interests of each node is expressed by a keywords list which can be represented by a tuple such as $K(k_1, k_2, \ldots, k_n)$, where k_i denotes i-th keyword of the node. When two nodes meet with each other, they exchange their profile information by '*hello*' messages. After obtaining and comparing the keywords lists of two nodes, matching value is computed when they have common keywords. Let $f(k_i, k_j)$ be the matching value between keywords k_i and k_j and it is calculated as follows:

$$f(k_i,\ k_j) = \begin{cases} 0, & \textit{if}\ k_i \cap k_j = \emptyset \\ 1, & \textit{if}\ k_i \cap k_j \neq \emptyset \end{cases} \tag{1}$$

$k_i \cap k_j = \emptyset$ means that keywords k_i and k_j are not matched and the result of $f(k_i,\ k_j)$ equals 0. Otherwise, the result equals 1. The similarity value of two mobile nodes u and v is evaluated by computing summation of matching values of keywords contained by mobile nodes u and v. Similarity value function $Sim(u,v)$ is as follows, where m and n denotes the number of keywords, m and n represent the number of keywords contained by mobile nodes u and v.

$$Sim(u, v) = \sum_{\substack{0<i\leq m \\ 0<j\leq n}} f(k_i, k_j) \cdot w_i \cdot w_j \tag{2}$$

$f(k_i, k_j)$ in Eq. (2) is matching value between keywords k_i and k_j, w_i and w_j refers to weight value of keyword k_i and k_j that represents importance of the keyword in interest keywords list.

2.3 Mobile Social Network Construction

In this section, we explain process of mobile social network construction. Each mobile node automatically detects surrounding mobile nodes and constructs a mobile social network distributively. Suppose that two mobile nodes with high similarity are connected together. If the physical locations of the two mobile nodes are remote, it is difficult to maintain routing path between them. Namely, although the similarity between two nodes is high, the communication between them is expensive or impossible if they are remote. Therefore, the location information is necessary for low cost communication. The mobile nodes with similar interests and nearby position are more recommended than the mobile nodes with similar interests and remote position. The function *RSim*() is used to determine the optimal nodes to connect in the mobile social network.

$$RSim(u,\ v) = \alpha \cdot Sim(u,\ v) + \beta \cdot \frac{d}{D(u,\ v)} \tag{3}$$

u and v denote two mobile nodes that can communicate with each other. $Sim(u,v)$ denotes the similarity value of mobile nodes u and v, which is computed by only considering the common interest keywords. $D(u,v)$ is the Euclidean distance between the two mobile nodes u and v. α and β is the weighting factor between $Sim(u,v)$ and $D(u,v)$, and $\alpha + \beta = 1$. d is a constant value which is used to make the values of $Sim(u,v)$ and $D(u,v)$ in a common scale. High similarity value indicates that they are highly related in the social network. Nearby position indicates that it is easy to manage underlying network topology to reduce the network maintenance cost. If $RSim(u,v)$ is larger than a predefined threshold value, the mobile node u is proposed to connect mobile node v in the mobile social network layer.

Next, we propose process of mobile social network construction. We consider a network with n mobile nodes. First, let a mobile node A broadcast a '*hello*' message to its neighbor nodes. The '*hello*' message contains node A's interest keywords and location information. The neighbor nodes within the transmission range of mobile node A can receive the '*hello*' message. After comparing the received information, a friend request message will be sent by a neighbor node when the value of *RSim*() is larger than a predefined threshold value. If the friendship request is accepted by node A, a social link between node A and the neighbor node is established. However, when a neighbor node of node A has no common interest with it, the received '*hello*' message will be forwarded to the neighbor node's neighbors. Since each mobile node may receive multiple friend request

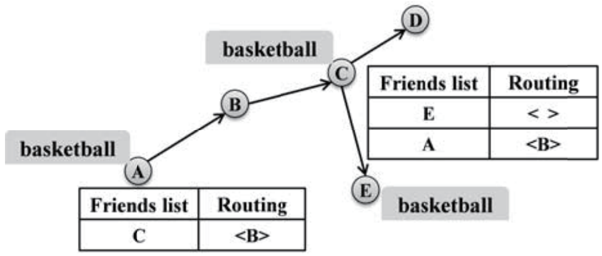

Fig. 2 Structure of proposed mobile social network.

messages, in order to reduce maintenance overhead of the network, only k most similar nodes are connected by each mobile node. The k most similar nodes are determined by Eq. (3). Since the value k will affect the success rate of contents search, we experimentally show the effect of k in Sect. 3.

Figure 2 shows a simple example of the proposed mobile social network. Each mobile node maintains a table which contains k most similar friends' information and physical routing paths. We assume that node A is interested in '*basketball*'. It broadcasts a '*hello*' message with its interest keywords and position to its neighbors. Since node B is not related with node A, it forwards the received '*hello*' message to its neighbor node (node C). Since node C is related with node A, node C sends a friend request message to node A. And then, the relationship between node A and node C is established in the mobile social network. By using the same method, node C is connected to node E. Note that, node E can be reached to node A by using the friend of friend relationship in the mobile social network.

3. Performance Evaluation

Since the MANET environment of the existing method [3] is the same with that of our proposed method, in this section, we compare the proposed method with the existing method [3] through the network management overhead and the contents search success rate. Experiments were executed in a period of 400 s. The network is dynamic that each peer arrives and departs freely. Mobile nodes are generated by networked-based generator [12]. All of the experiments were coded in Java. The α and β of Eq. (3) are set to 0.5 and 0.5 respectively. Table 1 summarizes parameters and corresponding values of the performance evaluation.

Performance is measured by network management overhead and search success rate of contents. The network management overhead is the total number of messages generated during maintenance of the mobile social network. The success rate of contents search is measured by proportion of the success times that required contents have been searched over total search time. The success is identified by contents search queries that are successfully reached to the destination nodes which contain required contents.

We first examine the network management overhead. Figure 3 compares the existing method and the proposed method according to different moving speeds of mobile

Table 1 Value of parameters.

Parameter	Value
Development area	500m × 500m
Maximum speed of nodes	0 m/s ~ 5 m/s
The total number of nodes	400
Communication range	30m

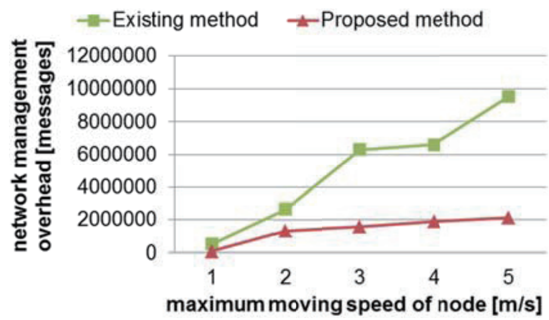

Fig. 3 The network management overhead according to different maximum moving speeds of mobile nodes.

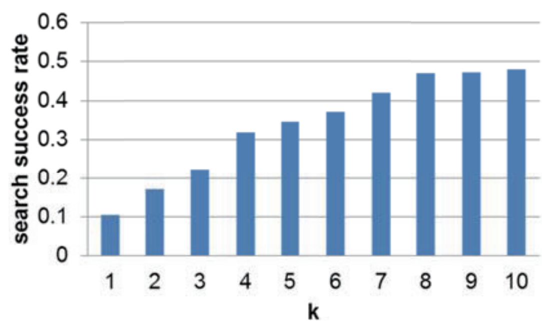

Fig. 4 The search success rate according to k.

nodes. The network management overhead increases fast with the increase of the mobile nodes. This is because the faster the movement of mobile nodes, the higher the frequency of the network re-organizing. The results show that the existing method is not suitable for high-speed movement of mobile nodes as index nodes have to manage all of the nodes with common interest in the whole network, which needs high management overhead. Since only the nearby nodes of each mobile node are managed, the advantage of network management of the proposed method is obvious.

In the second experiment, we evaluate the contents search success rate according to the number of social neighbors of each mobile node. Contents search queries are initiated from participated peers randomly. We use k to represent the number of neighbor nodes of a mobile node. The maximum speed of mobile nodes is random from 1 m/s to 3 m/s. As shown in Fig. 4, with the increase of k, the search success rate of contents is increased. This is because the more the social neighbors of each mobile node are increased, the more contents can be searched. However, when k reaches a certain value ($k = 8$), the search success rate is slightly increased. This is because each node already has a good

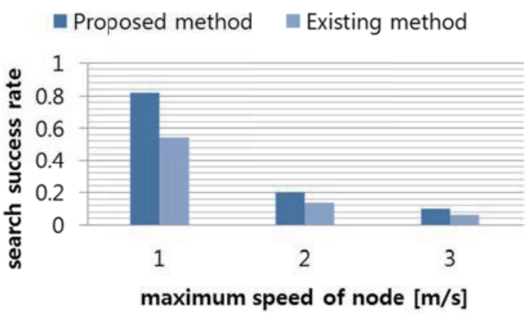

Fig. 5 The search success rates according to different maximum moving speeds of mobile nodes.

knowledge of the contents contained in the social network and further increasing the value *k* does not bring more benefit. In the other experiments, *k* is set to 8.

Figure 5 shows the success rates of contents searches according to different maximum speeds of mobile nodes. In this experiment, 400 queries are initiated from the participated mobile nodes randomly. The experiments are performed by varying the different maximum speeds of nodes, e.g. 1 m/s, 2 m/s, and 3 m/s. The results show that the success rate of a contents search is decreased when the maximum moving speed of each node is increased. This is because the search query is difficult to be sent to the destination nodes in a highly moving environment. Especially, for the existing method, the contents search query has to be forwarded to the index node first and then sent to the destination nodes, this procedure will fail in highly moving environments. Additionally, the fast moving speed of mobile nodes makes index nodes difficult to manage all of the other nodes' information within the same community. Therefore, the proposed method is superior than the existing method.

4. Conclusion

In this paper, we proposed a P2P based mobile social network over MANET. The social relations are established by considering both common interests and locations of mobile nodes. The contents search in the network can be performed by using the friend relationships. Therefore, in our proposed method, the network management overhead is decreased and the success rate of contents search is increased. Results of experiments have shown that the proposed method is more efficient than the existing methods.

Acknowledgments

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 (2012R1A1A2041898, 2012R1A1A2A10042015) and the MSIP (Ministry of Science, ICT and Future Planning), Korea, under the CPRC (Communications Policy Research Center) support program supervised by the KCA (Korea Communications Agency) (KCA-2013-003).

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