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Impact of node distance on selfish replica allocation in a mobile ad-hoc network

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ABSTRACT

Many data replication techniques have been proposed to minimize performance degradation caused by network partitioning in a mobile ad hoc network. Most of them assume that all mobile nodes collaborate fully in terms of sharing their memory space. However, in reality, some nodes may selfishly decide to only cooperate partially, or not at all, with other nodes. Recently, a new approach to selfish replica allocation has been proposed to handle node selfishness. However, there is still much room for improvement. We empirically observe that the previous selfish replica allocation strategy suffers from long query delay and poor data accessibility, because it utilizes only non-selfish nodes that may be faraway nodes. In this paper, we propose a novel replica allocation strategy in the presence of selfish nodes, that takes into account both selfish behavior and node distance. Moreover, through a novel node leveling technique, we utilize the memory space of all connected nodes, including selfish nodes. The conducted simulations demonstrate that the proposed strategy outperforms existing replica allocation techniques in terms of data accessibility, query delay, and communication cost.

1. Introduction

A mobile ad-hoc network (MANET) is attracting considerable attention with the advance in wireless technologies and mobile devices [11,28]. A MANET has a collection of autonomous mobile nodes that can move freely and unpredictably to form a temporary network, without the need of any infrastructure, such as a base station. Each node in a MANET acts as a router and communicates with each other. Since a MANET requires minimal configuration and is quickly deployed, it has been applied in a variety of applications [21]. For example, a MANET can be used in special situations where the installation of infrastructure may be difficult, or even infeasible, such as natural disasters or military conflicts. A mobile peer-to-peer (P2P) file sharing system is yet another interesting application [6,16].

In a MANET, the mobility of the nodes results in frequent network partitioning, which can lead to problems such as low data accessibility, and long query delay [9,29]. These problems are critical in a MANET applications, such as a mobile P2P file sharing systems, because most users are not willing to participate in the system with the problems. To cope with the problems of network partitioning and disconnections in a MANET, a considerable amount of research has been conducted on replica allocation [9,11,21,28,29].

In general, if mobile nodes in a MANET have sufficient memory space to hold the replicas of all data items, then data replication can simultaneously increase data accessibility and reduce query delay. However, since most mobile nodes have limited memory space for replicas of data items, there is often a trade-off between data accessibility and query delay [29]. This trade-off may lead to the *selfish behavior* of mobile nodes in a MANET [5], e.g., using their

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limited memory space only for their own benefit. A node would like to enjoy the benefits provided by the resources of other nodes, but does not make its own resources available to others.

The recent work presented in [5] addresses the problem of node selfishness within the context of replica allocation in a MANET. The work refers to the problem as the *selfish replica allocation* and proposes self-centered friendship (SCF) tree based replica allocation techniques. Basically, the techniques consist of three steps: (1) A node detects selfish nodes by calculating the *degree of selfishness* for all connected nodes. (2) It removes detected selfish nodes, and makes its own partial graph using only non-selfish nodes. (3) It builds its own SCF tree and allocates replicas to nodes in its own SCF tree in a fully distributed manner. SCF technique executes above steps during at every relocation period [9].

Our current work is motivated by the observation that the SCF technique [5] loses information about the original network topology, because they exclude selfish nodes during the construction of the SCF tree, resulting in suboptimal performance. We observe that the loss of information concerning the original network topology may lead to long query delay and poor data accessibility. For instance, in the SCF technique [5], after detecting selfish nodes, e.g., shaded nodes N_3 and N_4 in Fig. 1a, N_1 makes its own topology graph in Fig. 1b prior to building its SCF tree. The network topology graph in Fig. 1b is quite different from the graph in Fig. 1a, e.g., N_5 and N_6 are just one hop away from N_1, while in reality they are three hops away. In the SCF technique, N_1 builds its SCF tree based on the graph in Fig. 1b, and allocates replica to nodes N_2, N_5 and N_6 accordingly. In this case, if N_1 preferably allocates replica to N_5 or N_6 that is three hops away, rather than N_2 that is just one hop away, N_1 is likely to experience long query delay. In addition, N_5 and N_6 are more likely to disconnect from N_1, because they are further away from N_1 than N_2. Thus, if N_1 preferably allocates replica to N_5 or N_6, it might suffer from poor data accessibility.

To solve the aforementioned problems, we devise an optimized version of the SCF technique, called *SCF⁺ trees based replica allocation technique*. In the SCF⁺ technique, a node regards all connected nodes as friends and categories friends into different levels by considering *integrated degree of selfishness* which measures both *selfish behavior* and *node distance* in an *integrated* manner. Based on the integrated degree of selfishness, a node allocates frequently used data items to nodes that are close and have a low degree of selfishness. By applying this strategy, we are able to improve query delay and data accessibility, while still incurring low communication cost.

In this paper, we assume a mesoscale ad hoc network consisting of a few dozen mobile hosts, which is similar to a MANET employed in [9]. Thus, our methodology is mainly designed for such a mesoscale network. We verify the effectiveness of our proposed methods by simulation experiments. The technical contributions of this paper can be summarized as follows:

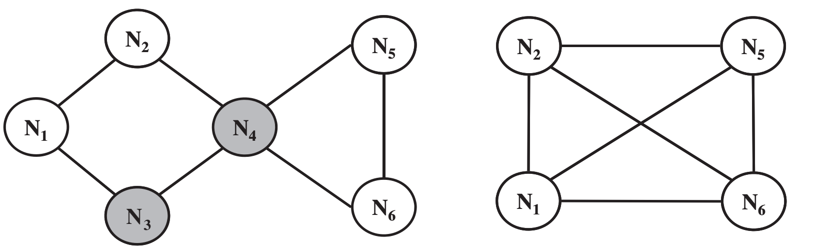
- **Incorporating node distance into the degree of selfishness**: We measure the integrated degree of selfishness by taking into account selfish behavior and node distance.
- **Utilizing all connected nodes through a leveling technique**: We devise a node leveling technique that takes into account the integrated degree of selfishness. During replica allocations, a node regards all connected nodes as its friends. Consequently, the proposed replica allocation strategy can utilize all connected nodes, including selfish nodes as well as non-selfish nodes.
- **Allocating replicas based on SCF⁺ trees**: We devise a novel replica allocation technique that uses SCF⁺ trees to improve query delay and data accessibility, while still incurring low communication cost.
- **Verifying the proposed strategy**: The conducted simulation results verify the efficacy of our proposed strategy.

The remainder of this paper is organized as follows. Section 2 describes the system model and the outline of SCF technique [5]. Section 3 presents the proposed methodology, and Section 4 evaluates the performance of our methodology. We present related work and conclude the paper in Sections 5 and 6, respectively.

2. Preliminaries

2.1. System model

Our system model is similar to that employed in [5] [9]. Each node has limited local memory space and simultaneously acts as a data provider and data consumer. Each



(a) Original network topology graph (b) Partial network topology graph without selfish nodes

Fig. 1. Network topology graph in SCF tree based approach from N_1's perspective.