Chapter XIV

Cooperative Data Caching and Prefetching in Wireless Ad Hoc Networks

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ABSTRACT

This article proposes a cooperative data caching and prefetching scheme for Mobile Ad Hoc Networks (MANETs). In this scheme, multiple hosts cooperate in both prefetching and caching commonly used data. To reduce communication and computational overhead, we use a clustering architecture for the network organization. A weak consistency based on time to live value was used to maintain data consistency. A hybrid cache replacement policy that uses frequency of access and the reference time was employed. The effects of cache size, mobility, and prefetching threshold on the network performance were investigated in a discrete event simulation environment. The contribution of intra-cluster and inter-cluster information to overall data accessibility ratio was also investigated. The simulation results indicate that the proposed scheme improves both data accessibility and query delay at relatively lower prefetch thresholds, larger cache sizes, and moderate mobility.

INTRODUCTION

In the past few years, most of the research devoted to MANETs has focused on the development of routing protocols to increase connectivity among mobile hosts in a constantly varying topology (Johnson & Maltz, 1996; Perkins & Bhagwat, 1994). Although development of routing protocols is one of the main challenges that must be addressed, improved data accessibility is the ultimate goal of such networks. In order to enable quick deployment of MANETs, development of reliable and efficient data management schemes suitable for this network environment is crucial. Data caching and prefetching techniques used in traditional wireless networks can be extended to
be used in MANETs. In this article, we investigate the use of caching and prefetching techniques for improving data accessibility and reducing latency in MANET environments.

Caching has been utilized extensively in wired networks, such as the Internet, to increase the performance of Web services (Fan et al., 1998; Rousskov & Wessels, 1999; Wang, 1999; Wessels & Claffy, 2005). However, existing cooperative caching schemes cannot be implemented directly in MANETs due to host mobility and resource constraints that characterize these networks. Consequently, new approaches have been proposed to tackle these challenges (Cao, Yin, & Das, 2004; Hara, 2002; Lim, Lee, Cao, & Das, 2003; Papadopouli & Schulzrinne, 2001; Wang, 2005; Yin & Cao, 2006). These approaches have been introduced to increase data accessibility and reduce query delay in MANETs. A cooperative cache-based data access scheme is subsequently proposed for ad hoc networks (Cao et al., 2004; Yin & Cao, 2006).

Three caching techniques, namely CacheData, CachePath, and HybridCache, are utilized as caching approaches. In CacheData, the intermediate hosts, which are located along the path between the source host and the destination host, cache frequently accessed data items. In CachePath, the intermediate hosts record the routing path information of passing data. CachePath only records the data path when it is closer to the caching host than the data source. The HybridCache technique represents a combination of CacheData and CachePath. This technique performs better than either the CachePath or CacheData approach. The cache replacement algorithm in HybridCache is based upon the access frequency of a data item and the distance to the same cached copy or to the data source. However, due to the inherent mobility of the host, such distances can change frequently. Moreover, the authors did not consider prefetching and multiple data sources in their study. In Lim et al. (2003), a similar approach is proposed for data caching in a network that integrates ad hoc networks with the Internet.

In Hara (2002), a replica allocation scheme with periodic data item updates is proposed. This scheme focused on improving data accessibility with the main goal of decreasing the data access failure in response to network division. The schemes presented in Sailhan and Issarny (2003) and Wang (2005) are based on a specific routing protocol. The scheme in Sailhan and Issarny (2003) used popularity, access cost, and coherency as criteria to replace cached data items when a mobile host’s cache space is full. In Wang (2005), a transparent cache-based mechanism based on a new on-demand routing protocol called dynamic backup routes routing protocol (DBR2P) is proposed. The routing protocol and the cache mechanism allow the caching of data. In order to guarantee data access, this scheme allowed the cached data to be moved to a backup host in response to a link failure. Another study proposed the implementation of an architecture similar to cooperative caching, which defines two protocols to share and disseminate data among mobile hosts (Rousskov & Wessels, 1999). However, the scheme focused on data dissemination in a single-hop rather than cooperative caching in a multi-hop environment. Another study utilized a novel architecture for database caching based on the separation of queries and responses (Artail, Safa, & Pierre, 2005). The experimental results indicated that the scheme improved data accessibility by reducing response time in the presence of host mobility.

Cooperative caching is an effective mechanism for increasing data accessibility in both wired and wireless networks. However, caching alone is not sufficient to guarantee high data accessibility and low communication latency in dynamic systems with limited network resources. In this article, we propose an integrated cooperative caching and prefetching mechanism for MANETs.

This article provides the following contributions to increasing the efficiency of data management in MANETs. First, we use a clustering architecture that allows localized and adaptive