Cooperative Caching in Mobile Ad Hoc Networks

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ABSTRACT

Mobile ad hoc network (MANET) presents a constrained communication environment due to fundamental limitations of client’s resources, insufficient wireless bandwidth and users’ frequent mobility. MANETs have many distinct characteristics which distinguish them from other wireless networks. Due to frequent network disconnection, data availability is lower than traditional wired networks. Cooperative caching helps MANETs in alleviating the situation of non-availability of data. In this paper, the authors present a scheme called global cluster cooperation (GCC) for caching in mobile ad hoc networks. In this scheme, network topology is partitioned into non-overlapping clusters based on the physical network proximity. This approach fully exploits the pull mechanism to facilitate cache sharing in a MANET. Simulation experiments show that GCC mechanism achieves significant improvements in cache hit ratio and average query latency in comparison with other caching strategies.

Keywords: Cache State Node, Cluster, Cooperative Caching, Global Cache State, MANETs

1. INTRODUCTION

Due to information overflow, people can no longer be disconnected from their information systems. Caching plays a vital role in providing access of data to the information systems in case of disconnection. This is a well established way of providing faster data in the area of web caching, proxy servers and browsers (Malpani, Lorch, & Berger, 1996). With the advent of mobile ad hoc networks (MANETs), which is demand based infrastructureless network, being resource poor, caching plays a pivotal role in making MANETs a success in many applications like rescue operations, military operation, etc. A mobile node (MN) is envisioned to be equipped with more powerful capabilities, like sufficient storage space, more processing power, etc. Even though there is no dearth of storage space in present scenario, it is always

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better to utilize the resources optimally. With caching, the data access delay is reduced since data access requests can be served from the local cache, thereby obviating the need for data transmission over the scarce wireless links. However, caching techniques used in one-hop mobile environment may not be applicable to multihop ad hoc environment since the data or request may need to go through multiple hops. Variable data size, frequent data updates, limited client resources, insufficient wireless bandwidth and clients’ mobility make cache management a challenging task in mobile ad hoc networks. As mobile nodes in ad hoc networks may have similar tasks and share common interest, cooperative caching, which allows the sharing and coordination of cached data among multiple nodes, can be used to reduce the bandwidth and power consumption.

To date there are some works in literature on cooperative caching in ad hoc networks, such as consistency (Yin & Cao, 2004; Chiu & Young, 2009), and placement (Tang, Gupta, & Das, 2008). In this paper, we investigate the data retrieval challenge of mobile ad hoc networks and propose a novel scheme, called global cluster cooperation (GCC) for caching. The goal of GCC is to reduce the cache discovery overhead and provide better cooperative caching performance. GCC partitions the whole MANET into equal size clusters based on the geographical network proximity (Figure 1). To enhance the system performance, within a cluster, individual caches interact with each other and within a network, the designated CSN of clusters interact with each other such that combined result is a larger cumulative cache. In each cluster, GCC dynamically chooses a “super” node as cache state node (CSN), to maintain the global cache state (GCS) information of different nodes within the network. The GCS for a client is the list of cached items along with their time-to-live (TTL) field. Simulation experiments are performed to evaluate the proposed GCC caching scheme and compare it with existing strategies in the ad hoc networks.

The rest of the paper is organized as follows. Related work is described in Section 2. Section 3 describes the system model. Clustering strategy employed in GCC is presented in Section 4. Section 5 describes the proposed GCC caching scheme for data retrieval. Section 6 is devoted to performance evaluation. Section 7 concludes the paper.

2. RELATED WORK

In context of ad hoc networks, it is beneficial to cache frequently accessed data not only to reduce the average query latency but also to save the wireless bandwidth. Hara (Hara & Madria, 2006) proposed several replica allocation methods to increase the data accessibility and tolerate network partitions in MANETs. In these schemes, the replicated data are relocated periodically based on access frequency and overall network topology. Although replication can improve data accessibility, the overhead for relocating replicas periodically is significantly high. Due to updates at server, the cost of maintaining the consistent copy of replicas is quite high. Lim et al. (2006) suggested a caching algorithm to minimize the delay while acquiring data. To the best of our knowledge, only few of previous works (Chand, Joshi, & Misra, 2006; Chiu & Young, 2009; Chand, Joshi, & Misra, 2007) have exploited clustering as caching mechanism in MANETs. Cooperative caching has been studied in web environment (Malpani, Lorch, & Berger, 1996), but efficient cache management is still a hot research area in MANETs. CacheData and CachePath have been proposed in (Yin & Cao, 2004). Unlike the previous methods, these protocols do not rely on flooding or broadcast for discovering a cached copy of the requested data item. With CacheData, intermediate nodes may cache a data item to serve future requests while forwarding the item for another node. In contrast, CachePath caches the information of a path to the request originator and uses the information to redirect future requests to the nearby caching site. The Hybrid protocol HybridCache combines CacheData and CachePath in an attempt to avoid their weakness. In HybridCache, when a mobile
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