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# Hierarchical DHT and proportional replication based mobility management for large-scale mobile Internet☆

Yujia Zhai [a,*], Yue Wang [a], Jian Yuan [a], Yong Ren [a], Ilsun You [b,*]

[a] Department of Electronic Engineering, Tsinghua University, Beijing, China

[b] School of Information Science, Korean Bible University, Seoul, Republic of Korea

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ABSTRACT

A considerable amount of research on distributed hash table (DHT) based mobility support schemes, which are highly user scalable and load balanced, has been done. But these schemes have shortcomings in query performances and network scalability. It is because although routing of overlay is effective, there is inconsistency between logical and physical topologies, so the actual physical network performances are not necessarily efficient. In this paper, we introduce a replication technology based DHT-based mobility support. Then all queries from any subnet can get responses as early as possible, i.e., the query distances are reduced, and the scopes of the effect of topological inconsistency are limited. We investigate the effect of the number of mapping replicas on query performances for DHT-based mobility support. And we find that replicating mobile nodes' mappings in proportion to their call-mobility-rates minimizes the query delay and ensures fairness in the query load distribution. Moreover, we combine the hierarchical structure with the domain-level DHT-based (dDHT) structure, to reduce the expense of replication on update performances. We propose a hierarchical DHT and proportional replication based mobility management (HDPRMM) scheme. The numerical results show HDPRMM optimizes the query and update performances of dDHT, and achieves better fairness and network scalability than MIP and dDHT.



## 1. Introduction

In mobile Internet era, the information locked in a fixed site will be released into space and time, and the flowing world will deeply change our lives anytime and anywhere. One direction of mobile Internet is large-scale development, and scalable mobility support is an important task. In typical mobile Internet architectures, a few types of mobility agents are used to maintain the mobility of a mobile node (MN): a home agent (HA) in Mobile IPv6 (MIPv6) [1], a mobility anchor point (MAP) in Hierarchical MIPv6 (HMIPv6) [2], and a local mobility anchor (LMA) in Proxy MIPv6 (PMIPv6) [3]. If a high burden of tasks is concentrated on a single mobility agent, the mobility agent may become a bottleneck node. How to distribute the network load among multiple mobility agents is an important issue.

To address the scalability problem, a number of P2P-based mobility supports were proposed [4–13]. In our work [14], by classifying these schemes and comparing them with the traditional MIP mechanisms, we showed that the P2P-based mobility supports are highly user scalable and load balanced, but these schemes have shortcomings in query and update

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* Corresponding authors.
*E-mail addresses:* zhaiyujia@tsinghua.edu.cn, zhaimaomao@gmail.com, zhaiyujia@mail.tsinghua.edu.cn (Y. Zhai), isyou@bible.ac.kr (I. You).

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performances especially for a large-scale network. It is because although routing of the overlay itself is effective, there is inconsistency between logical and physical topologies, so the actual physical network performances are not necessarily efficient. Moreover, we showed that the DHT-based information spreading way and the information replication method of P2P networks have the reference value for mobility management. However, the related works only used the distributed structured information spreading way, but did not notice that using the information replication method may obtain benefits on the query performance, load balancing and data availability.

In this paper, we introduce replication into DHT-based mobility management. Then all queries from any subnet can get responses as early as possible, i.e. the query distances are reduced, and the scopes of effect of topological inconsistency are limited. We construct the optimization problems with the objectives of optimizing query performances, and choose the optimal replica distribution by theoretical analysis. We show that DHT-based query is optimized when the number of mapping replicas is proportional to the MN's call mobility rate, and such a replica distribution also ensures query load balance. In addition, to reduce the expense of replication on update performances, we combine the hierarchical structure with the dDHT management structure, and propose a hierarchical DHT and proportional replication based mobility management scheme, called HDPRMM. The numerical results show HDPRMM uses the relationship between performances and user behaviors better, and greatly enhances query performances, update performances, fairness, and scalability compared with dDHT, MIPv6 and HMIPv6.

The rest of this paper is organized as follows. Section 2 describes the structure and performance problems of DHT-based mobility supports, and summarizes the related works on replication problem. The system parameters and assumptions are given in Section 3. Section 4 models the replication problem and analyzes the optimal replica distribution. In Section 5, we present the hierarchical DHT and proportional replication based mobility management scheme HDPRMM. The performance evaluation results are presented in Section 6. Conclusions are given in Section 7.

## 2. Problem statement

### 2.1. DHT based management structure

In [14], we classified the P2P-based mobility supports into the subnet-level DHT-based (sDHT) scheme and the domain-level DHT-based (dDHT) scheme according to the ways of overlay construction. Fig. 1 shows the management structure of dDHT, where the network is divided into multiple management domains, and each domain includes multiple subnets and is equipped with a mobility agent (MA). The MAs form a DHT-based overlay network.

There are three identifiers for each MN. Home Address (HoA) is a stable IP address to identify the MN. Care-of-Address (CoA) is a temporary IP address acquired in a foreign network when moving, and indicates MN's current location. Object Identifier (oID) is obtained by hashing the HoA, and is used in overlay network. Moreover, each MA in the overlay network has a Node Identifier (nID), which is obtained by hashing MA's IP address. The MAs keep the mappings between the oIDs and the CoAs.

### 2.2. DHT-based mobility support operations

For a general DHT approach, update operations involve the following steps: ① When an MN moves into the area of a new access router (AR), discovery of the new AR and determination of movement is performed through the messages exchange between MN and AR. ② Through the address configuration, the MN obtains a new unique CoA. ③ The MN's AR reports the new mapping information to its bootstrap mobility agent (aMA), which is the nearest MA to the AR in physical distance. ④ According to MN's HoA, the aMA obtains its oID, and performs binding update to the home mobility agent (hMA), whose nID is the nearest to the MN's oID, through the overlay network. ⑤ In addition, if the route optimization (RO) is adopted, BUs are sent to all active correspondent nodes (CNs) by the MN in Mid-Call mobility.

The operations of the query separate the mapping information query and the data delivery, and do not use the tunneling technology: ① The CN knows the MN's HoA. The destination address in the packet which the CN sends to the MN is MN's HoA. ② After the correspondent router (CR) receives the first packet, the correspondent mobility agent (cMA) sends the mapping query request message to the overlay network. ③ After receiving the query response message which includes the MN's mapping information, CR replaces the destination address of the data packets with MN's CoA, and directly delivers the packets to the MN.

### 2.3. Performance problem

In [14], we presented a performance analysis model for DHT-based mobility management schemes, and compared such schemes with MIPv6 [1] and HMIPv6 [2]. The results show DHT-based mobility management schemes enable improvement in terms of load balance and user scalability compared with the traditional mechanisms. And the load balance of sDHT and dDHT is not affected by user distributions and movement models, and keeps good in various scenes. So it is very necessary to introduce the distributed information spreading way into mobility management.

But there exist shortcomings in query and update performances and network scalability. Although the performances of dDHT are better than sDHT, the delay performances of DHT-based schemes are worse than MIP schemes, especially