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Performance analysis of distributed mapping system in ID/locator separation architectures ☆, ☆☆

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ABSTRACT

An ID/locator separation architecture is one of the most recognized technologies that enable the Future Internet. In ID/locator separation architecture, an ID/locator mapping system is indispensable to provide location management in mobile environments. This paper conducts a comparative study on two different ID/locator mapping approaches: centralized and distributed ID/locator mapping systems. We develop analytical models on the signaling cost incurred in location update and location query procedures of the centralized and distributed ID/locator mapping systems. Numerical results demonstrate that the distributed ID/locator mapping system with enhanced distributed hash table (DHT) has comparable signaling cost to the centralized ID/locator mapping system while providing higher scalability and robustness.

1. Introduction

With the increase of smart devices and demand for new networking applications (i.e., online games, social networking services, and high definition multimedia), Internet has been explosively grown in terms of data traffic and the number of connected devices in recent years (Saleh and Simmons, 2011). However, current Internet routing and addressing systems are facing various challenges such as routing scalability, mobility support, multihoming support, etc., due to the use of an IP address as a single namespace simultaneously expressing an identifier and a location of a mobile node (MN) (Meyer et al., 2007). In order to address the single namespace issue in the Internet, several ID/locator separation architectures have been proposed and widely recognized as a promising technology for the Future Internet (Kafle and Inoue, 2012).

ID/locator separation architectures can be categorized into two approaches: host-based approach and network-based approach. Host-based approaches, such as host identify protocol (HIP) (Moskowitz et al., 2008), Shim6 (Nordmark and Bagnulo, 2009), and identifier-locator network protocol (ILNP) (Atkinson et al., 2010), decouple IDs from locators in the host's protocol stack. On the other hand, network-based approaches separate core networks and edge networks by means of routers. Locator/identifier separation protocol (LISP) (Farinacci et al., 2012) is a representative example of network-based ID/locator separation architectures. Mobile-oriented Future Internet (MOFI) is another proposal for network-based ID/locator separation protocol in mobile environments (http://www.mofi.re.kr/). As reported in Kim et al. (2008), since network-based approaches have some advantages (e.g., low implementation cost and easy deployment) over host-based approaches, a network-based approach similar to LISP is assumed throughout this paper.

Figure 1 shows a LISP architecture where ingress tunnel routers (ITRs) and egress tunnel routers (ETRs) are gateways between core and edge networks. When an MN moves to ITR/ETR2 from ITR/ETR1, ITR/ETR2 registers the ID/locator binding of the MN to a mapping system. If a packet destined to the MN arrives at ITR/ETR0, ITR/ETR0 requests the MN's location information from the ID/locator mapping system. After obtaining the location

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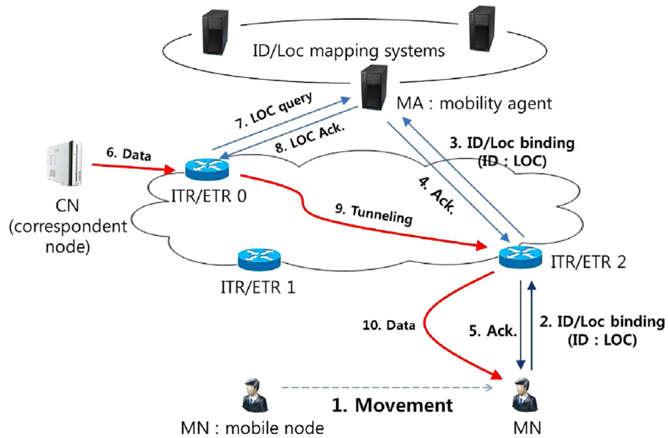

Fig. 1. ID/locator separation architecture.

information, ITR/ETR0 can transmit the packet to the MN through ITR/ETR2.

As shown in Fig. 1, an ID/locator mapping system consisting of one or multiple mobility agents (MAs) is indispensable to register and retrieve the location information of MNs.[1] The ID/locator mapping system can be organized in centralized and distributed manners. A centralized mapping system (CMS) employs only one MA and thus the MA can be a single point of failure and bottleneck. On the contrary, several MAs are employed in a distributed mapping system (DMS) and thus an additional mechanism is needed to find out the serving MA for a specific MN. In the literature, DMS with multicast and DMS with distributed hash table (DHT) have been suggested (Fischer et al., 2008; Zhai et al., 2011; Gohar and Koh, 2012). However, to the best of our knowledge, no works on comparative study among these mapping systems have been reported.

In Kim et al. (2012), we developed analytical models for evaluating CMS, DMS with multicast, and DMS with DHT in ID/locator separation architectures. The analytical models evaluate the signaling and processing overheads for location update and location query procedures. Two well-known topologies (i.e., mesh and tree) are considered to represent the both ends of network deployments. By extending out previous work (Kim et al., 2012), we propose an enhanced DHT to reduce the signaling overhead incurred in DMS with DHT and develop its analytical model. We also present a new analytical model on the processing latency at the mobility agent to assess the scalability of the mobility agent. Numerical results demonstrate that DMS with enhanced DHT provides higher scalability with comparable or low signaling overhead compared with other mapping systems (i.e., CMS, DMS with multicast, and DMS with DHT).

The remainder of this paper is organized as follows. Related works and the detailed descriptions of CMS and DMS are described in Sections 2 and 3, respectively. Section 4 describes the analytical models for CMS, DMS with multicast, DMS with DHT, and DMS with enhanced DHT. Numerical results and concluding remarks are given in Sections 5 and 6, respectively.

2. Related work

As mentioned before, the ID/locator separation architecture requires a mapping system to resolve the MN's ID to the corresponding locator. A number of ID/locator mapping systems have been proposed in the literature that can be classified into (1) centralized mapping system (CMS) and (2) distributed mapping system (DMS).

LISP-NERD is one of the examples for CMS (Lear, 2012). In LISP-NERD, a mapping server located at ITRs/ETRs is refreshed at the regular time interval. To this end, the mapping server pushes the updated mapping information to all ITRs/ETRs. That is, LISP-NERD can provide the strong consistency on the ITR/ETR mapping at the expense of high traffic overhead.

Gohar and Koh (2012) introduce a multicast-based DMS in localized mobile LISP networks. When an ITR/ETR receives a packet destined to an MN, the ITR/ETR sends a request message on the ID/locator mapping to all other ITRs/ETRs. In spite of the use of multicast, the signaling overhead is not quite high since only a local LISP domain is considered.

LISP-TREE (Jakab et al., 2010) is a partially distributed mapping system. In LISP-TREE, IDs are assigned in a hierarchical manner, and a discovery domain is defined to provide the ID/locator mapping information. Since the discovery domain is organized in a hierarchical manner, the request on the ID/locator mapping can be resolved iteratively. For example, when an ITR/ETR receives a packet destined to an MN, the ITR/ETR asks the ID/locator mapping information to the low-level discovery domain in LISP-TREE. Only when the low-level discovery domain cannot resolve the request, the request is forwarded to the upper-level discovery domain. Although LISP-TREE can improve the scalability, it does not pay attention to the mobility.

Qiu et al. (2009) propose a hierarchical DMS to avoid the bottleneck of a centralized mapping server. At the top level, multiple mapping servers are connected by means of DHT. On the other hand, mapping servers at the intermediate levels maintain the ID/locator mapping information of MNs currently located in their domains. The proposed hierarchical mapping system can reduce the signaling overhead and guarantee higher scalability than the centralized mapping system.

Luo et al. (2011) propose a scalable and robust proxy mobile IPv6 (SARP) where mobile access gateway (MAG) and local mobility anchor (LMA) are co-located. In conventional PMIPv6, only LMA provides the ID/locator mapping function in the PMIPv6 domain. On the other hand, the ID/locator mapping function is distributed to every MAGs for better scalability and robustness in SARP. Also, a DHT based ID/locator mapping system is introduced. Similarly, LISP-DHT (Mathy and Iannone, 2008) defines a fully distributed mapping system based on DHT. Due to the properties of DHT, LISP-DHT can provide salient features such as self-organization, robustness, and load balancing. However, a longer path is expected to deliver signaling messages.

3. CMS and DMS

In this section, we describe the procedures for location management in CMS, DMS with multicast, DMS with DHT, and DMS with enhanced DHT. In terms of network topology, we consider both the mesh topology and the tree topology. In the mesh topology, all access routers (ARs) are directly connected to each other. A centralized MA is located at the root node in the tree topology if CMS is applied. On the other hand, in DMS, MAs are located at leaf nodes in a balanced binary tree.

3.1. CMS

Figure 2 shows the location update and location query procedures of CMS on the mesh and tree topologies. As shown in Fig. 2, there is only one MA and the MN informs the MA of the changed

[1] The MA is a general term for representing an ID/locator mapping data storage server throughout this paper.