OpenFlow-Based Implementations of Distributed ID-LOC Mapping System in Mobile Internet

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Abstract. The future Internet will be evolved to mobile-oriented environments, and thus the mobility support is a key issue in the design of future Internet. This paper proposes a distributed identifier-locator mapping system (DMS) for the future mobile-oriented Internet environment. The proposed DMS scheme is implemented over Linux platform by using the OpenFlow and Click Router software. From the experimentations over the real testbed network of Korea Research Education Network (KOREN), we can see that the proposed DMS scheme can perform the mobility management operations effectively for mobile Internet hosts.

Keywords: Mobile Internet, ID-LOC Separation, Distributed ID-LOC Mapping System, OpenFlow Implementation, Testbed Experimentation.

1 Introduction

It is noted that the current Internet was historically designed for fixed network environment, rather than for the mobile network environment. This has enforced Internet to add a lot extensional features to satisfy the mobility requirements, as shown in the example of Mobile IP (MIP) [1, 2]. However, this patch-on approach seems to be just a temporal heuristic to the problems in the mobile environment, rather than an optimization. Thus, a variety of research activities have been made to design the future Internet for mobile environment, which include eMobility [3], 4WARD [4], FIND [5], MobilityFirst [6], GENI [7], and AKARI [8]. It is also noted that many challenging works are in progress with the identifier-locator separation principle, as shown in Host Identity Protocol (HIP) [9], Locator-Identifier Separation Protocol (LISP) [10], and Identifier-Locator Network Protocol (ILNP) [11].

With these observations, we design the architecture of Mobile Oriented Future Internet (MOFI) [12] to support the mobile environment of future Internet. The MOFI is designed with the following functional blocks: Host Identifier and Local Locator (HILL) and Distributed Mapping System (DMS). The details of the MOFI architecture are described in [12].

This paper specifies a distributed mapping system (DMS) to support the identifier-locator (ID-LOC) mapping management based on the ID-LOC separation. The DMS control operations include HID-LOC binding for HID-LOC registration and LOC

Y.-S. Jeong et al. (eds.), *Ubiquitous Information Technologies and Applications*,
Lecture Notes in Electrical Engineering 280,
DOI: 10.1007/978-3-642-41671-2_10,

query for data delivery. The DMS functional entities include Local Mapping Controller (LMC) at AR and Global Mapping Controller (GMC) at gateway (GW). For intra-domain communication, LMC is used to maintain the Local Map Register (LMR) to keep the list of HID-LOC mapping for the hosts. For inter-domain communication, GMC is used to maintain a Global Map Register (GMR) for HID-LOC mapping management for the hosts in the other domain.

This paper is organized as follows. Section 2 briefly summarizes the MOFI architecture. In Section 3 we describe the HID-LOC mapping control operations for DMS. Section 4 describes the Linux-based implementation using the OpenFlow and Click Router platform and the experimental results performed over the Korea Research and Education Network (KOREN) network. Section 5 concludes this paper.

2 MOFI Architecture Overview

2.1 Host ID and Local Locator (HILL)

HID is used to identify a mobile host. LOC is used to represent the location of a host in the network and also used for delivery of data packets. In addition, a LOC is a locally routable address that has only to be locally unique in the concerned network. As a LOC, we use the IP address of an access router that a host is attached to. These IP addresses may be local in the network.

Figure 1 shows the data delivery operations with global HID-based communication and local LOC-based routing in MOFI [12].

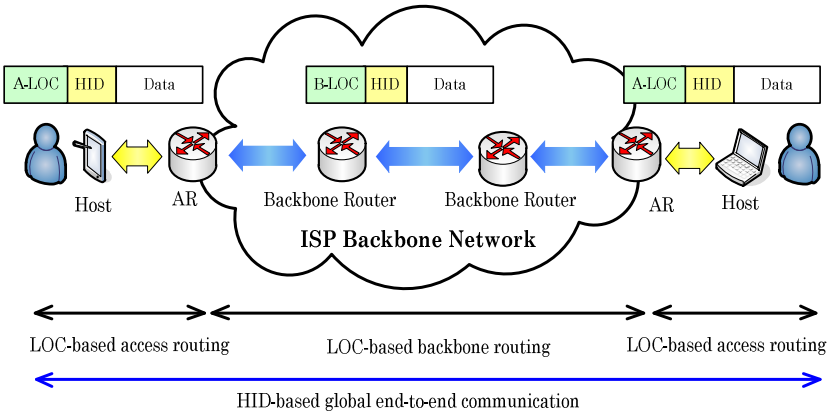

Fig. 1. HID-based Communication and LOC-based Routing

In the figure, the communication between two hosts is performed with HIDs, whereas LOCs are used for packet delivery. For packet delivery, an access LOC (A-LOC) is used as LOC within access network, whereas the IP address of AR will be used as backbone LOC (B-LOC) in the backbone network. The data packet routing is performed locally in the access and backbone networks.

2.2 Distributed HID-LOC Mapping System (DMS)

The mapping between HID and LOC of MOFI is managed by DMS. For description of DMS, we divide the network reference model into intra-domain and inter-domain cases. And for DMS MOFI assume that many of Cache and Register. [Table 1] is show the Cache and Register information.

Table 1. Caches and Registers

Category	Entity	Cache/ Register	Usage
Intra domain	AR	LBC	Data forwarding (host – AR)
		DFC	Data forwarding (AR –AR , AR – GW)
	LMC	LMR	DHT-based mapping control
Inter domain	GW	DFC	Data forwarding (GW – GW)
	GMC	GMR	Domain-based mapping control

The mapping between HID and LOC is managed by DMS. For description, we divide the network reference model into intra-domain and inter-domain cases. Figure 2 shows the overall network model for HID-LOC mapping control of DMS, in which a domain represents the network domain of an ISP.

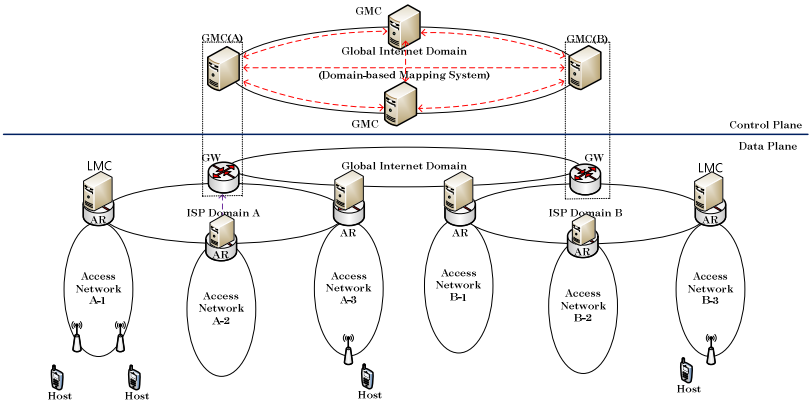

Fig. 2. Mapping Control Model of DMS

In the figure, the control plane is separated from the data plane. In the data plane, an Access Router (AR) maintains a Local Mapping Controller (LMC) that maintains the list of HID-LOC of the locally attached hosts. Each domain gateway (GW) maintains its Global Mapping Controller (GMC), which is used to the HID-LOC mapping information for all of its domain hosts.

3 HID-LOC Mapping Control in DMS

The HID-LOC mapping control by DDMS is further divided into 'intra-domain' and 'inter-domain' cases. This paper focuses on the 'inter-domain' mapping control. The discussion of intra-domain case is omitted in this paper. Because intra-domain is substitute Openflow Click system. First I show this table. [Table 2] shows the list of the messages for mapping control.

Table 2. Control Messages for Mapping Control

Message	Full Name	From	To
HBR	HID Binding Request	Host/GMC	GMC/GMC
HBA	HID Binding ACK	GMC/GMC	GMC/Host
LQR	LOC Query Request	GMC	GMC
LQA	LOC Query ACK	GMC	GMC

The HBR and HBA control messages are exchanged between host and GMC, or between GMCs. On the other hands, the LQR and LQA messages are exchanged between GMCs. Each control message is encapsulated into UDP.

3.1 HID-LOC Binding Operation

With network attachment of host, the HID-LOC operation is performed, in which HID and LOC of the host will be registered with LMC. LMC will maintain and update its Local Mapping Register (LMR) the information of bindings between HIDs and LOCs for all of the hosts that are attached to the LMC/AR.

In HID-LOC binding, the HID Binding Request (HBR) and HID Binding ACK (HBA) messages are exchanged as shown in Figure 3. After the HID-LOC binding between host and LMC/AR, the LMC/AR of the host sends a HBR message to the GMC/GW. The HBR message contains the HID of the host and the LOC (IP address of LMC). Based on the received HBR, the GMC updates its Global Mapping Register (GMR) and responds with a HBA message to LMC of the host.

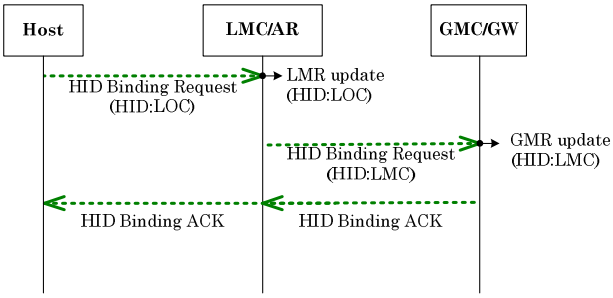

Fig. 3. HID-LOC binding between host and LMC/GMC

3.2 LOC Query and Data Delivery Operations

In the LOC query operation, LMR and GMR will be used to find the AR and GW that a mobile host is attached to. Figure 4 shows the LOC query and data delivery operations for inter-domain case. In this case, we assume that a sending host (SH) is attached to LMC/AR1 and a receiving host (RH) is connected to LMC/AR2 via GW1and GW2.

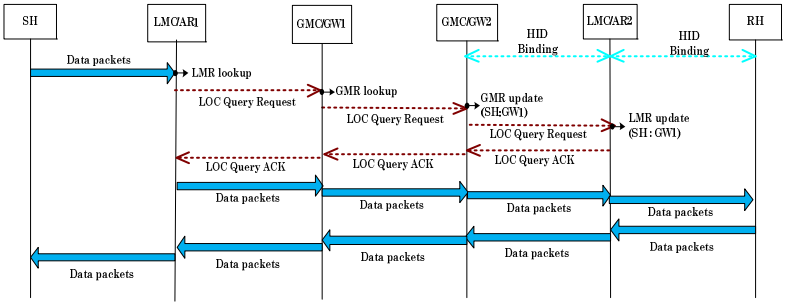

Fig. 4. LOC query and data delivery for inter-domain case

When a data packet arrives from SH, the LMC/AR1 sends a LOC Query Request (LQR) message to GMC/GW1. On reception of a LQR message, GMC1 sends LQR to GMC2, and then GMC2 will send the LQR message to LMC/AR2. After looking up the LMR, LMC/AR2 responds with a LOC Query ACK (LQA) message to GMC/GW2. Then, GMC/GW2 sends LQA message to GMC/GW1 and further to LMC/AR1. AR1 of SH can now send a data packet to RH via GW1, GW2 and AR2.

4 OpenFlow-Based Implementation and Experimentation

To validate the proposed DMS scheme, the mapping control operations were implemented using UDP socket programming [13], OpenFlow [14] and Click Modular Router [15] over the Linux platform.

4.1 Intra-Domain Communications

For intra-domain implementation, we use the OpenFlow software and an arbitrary IPv4 address as the HID. Figure 5 shows the network model for intra-domain implementation. For implementation of AR/LMC, we employ OpenFlow switch and NOX controller. The OpenFlow switch will function as AR, and it forwards the data packets. All of the LMRs in the domain are implemented over the OpenFlow NOX Controller. In HID-LOC binding operation, a flow table is maintained by OpenFlow Switch so as to manage all of the hosts that are attached to the AR. The LMR managed by NOX Controller will maintain the list of all hosts that are attached in the domain. The Packet-in and Packet-out messages of OpenFlow are used as the HBR and HBA

messages of DMS. In the LOC query operations for data delivery, the flow table of Openflow switch will be updated. It is noted that the Packet-in/Flow-Mod messages of OpenFlow correspond to the LQR/LQA messages of DMS.

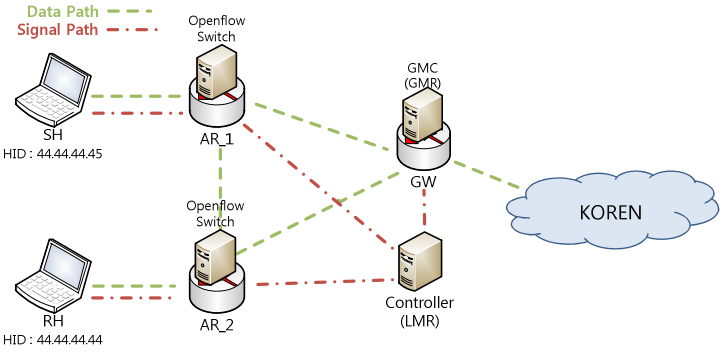

Fig. 5. Intra-domain implementation by OpenFlow and Click Router

Figure 6 shows the packet capturing results for intra-domain communication by using the WireShark tool [16]. The test environment is the same with Figure 5. From the figure, we can see that the data packets are delivered between the two hosts with the help of the DMS operations.

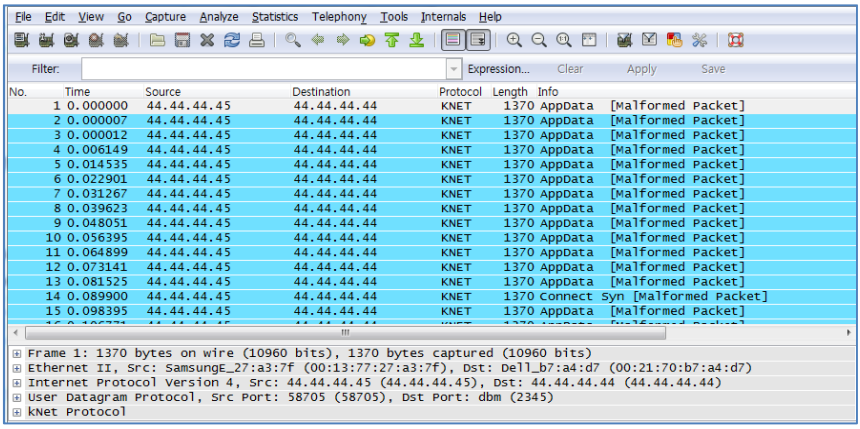

Fig. 6. Intra-domain Packet Capture

Figure 7 shows the information of LMR that is updated by the HID-LOC binding operation. From the figure, 2c2c2c2c is the hexadecimal representation of the HID (44.44.44.44), and the number of 210.114.94.174 represents the location of AR that the host is attached to. From the figure, we can see that the LMR of LMC is updated as per the HID-LOC binding operation.

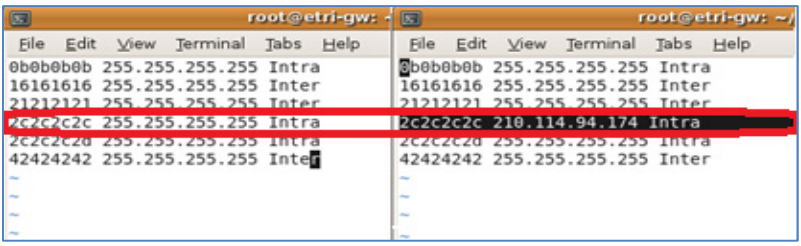

Fig. 7. LMR update

4.2 Inter-Domain Communications

For implementation of inter-domain mapping control, we use the UDP socket programming. Fig. 8 shows the testbed configuration for inter-domain implementation of the proposed DMS scheme. There are the two domains, one is located at the KNU site and another one is located at the ETRI site, and the two domains are connected by Korea Research and Education Network (KOREN) [17].

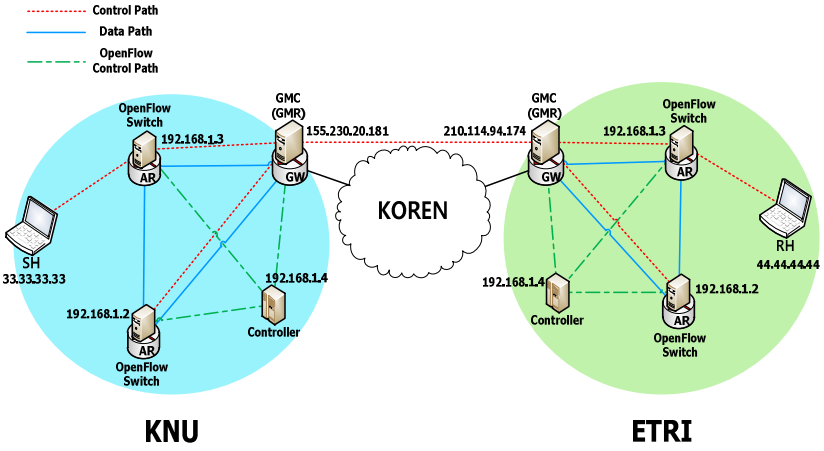

Fig. 8. Testbed Network for Inter-domain Implementation

Figure 9 shows the packet capturing results that are measured by GW for inter-domain communication between KNU and ETRI domains. From the figure, we can see that the data packets are delivered between the source and destination hosts via the domain GWs. In addition, the data packets are encapsulated by using the IP-in-IP tunneling scheme at each GW.

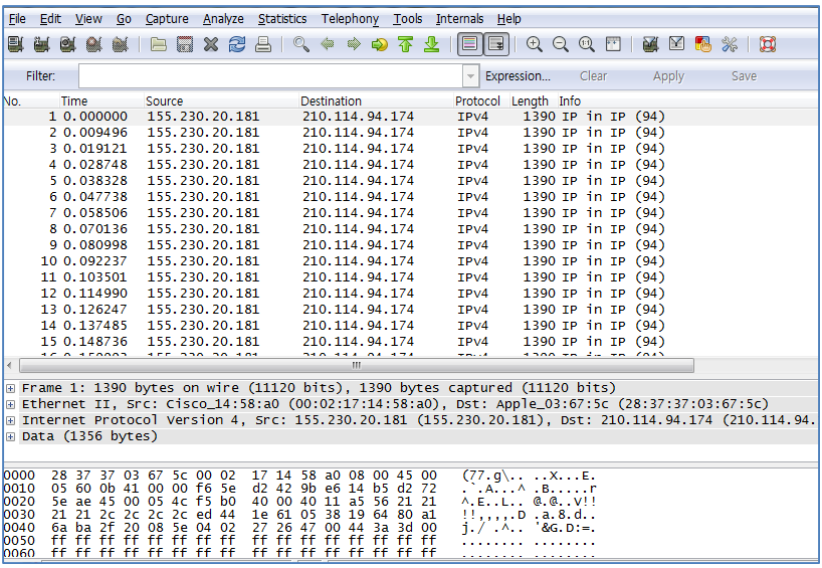

Fig. 9. Gateway packet capture

5 Conclusions

Until now, we have described the distributed identifier-locator mapping system (DMS) for the future mobile-oriented Internet environment. For validation, we implemented the proposed DMS scheme over Linux platform by using the OpenFlow and Click Router software. From experimentations over the real testbed network of Korea Research Education Network (KOREN), we can see that the proposed DMS scheme can perform the mobility management operations effectively for mobile Internet hosts.

For further works, the implementations and experimentations of DMS/MOFI need to be further extended by considering the real world network environments.

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