Host Identifier and Local Locator for Mobile Oriented Future Internet: Implementation Perspective

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Abstract—It is envisioned that the future Internet will be evolved to mobile oriented network environment, and the mobility support is a key issue in the design of future Internet. This paper proposes an architecture of Host Identifier and Local Locator (HILL) for the future mobile-oriented Internet. The proposed HILL architecture is implemented over Linux platform by using netfilter, iptables, and 6to4 tunneling. In addition, the handover performance is analyzed over the experimental testbed. In the experimental result, we can see that the handover operation is completed within one second.

Keywords— Host ID; Local LOC; ID-LOC separation; implementation

I. INTRODUCTION

With an explosive growth of the number of subscribers of mobile cellular systems and also other wireless data systems such as WiFi and WiMAX, the mobile networks snow become the key driver toward the future Internet. In addition, a variety of wireless access networks, such as adhoc network and sensor network, are emerging, and they will be the major access means to future Internet.

However, 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, 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]. First, a HID contains the domain information of an ISP that a host belongs to. LOC represents the location of a host in the network and it is used for delivery of data packets in the network. In addition, a HID shall be globally unique in Internet, whereas a LOC is a locally routable address that has only to be locally unique in the concerned network. In MOFI, the mappings between HIDs and LOCs will be managed in the dynamic and distributed manner.

The ID-LOC separation structure of MOFI is different from the other ID-LOC separation schemes such as host Identity Protocol (HIP) [9], Locator Identifier Separation Protocol (LISP) [10], and Identifier Locator Network Protocol (ILNP) [11]. First, a HID is allocated to a host itself, not its interface. Next, a LOC is given to the network (rather than a host) that a host is attached to. Moreover, LOC is ‘local’, rather than ‘global’

1) Host identifier (HID)

In MOFI, it is assumed that a host should be identified by HID and given by an ISP in a static and secure manner. At present, we consider the format of 128-bit (16-byte) HID, which is designed for compatibility of IPv6 applications

2) Locator (LOC)
LOC is used for delivery of data packets between objects in the network. In MOFI, the IPv4/IPv6 addresses of the Access Router (AR) and Gateway (GW) are used as LOCs. There IP address may be private in the network. The LOC is used for end-to-end communication between the two hosts through one or more networks. In mobile environments, a host with a single HID may change its LOCs by movement.

### B. Functional Entities

1) **Host identifier (HID)**

   HID. The end-to-end communication is governed by HID. Each data packet has the MOFI header which includes the HIDs of source and destination hosts.

   For data delivery, a host sends or receives data packets to or from AR by using the Access Delivery Protocol (ADP). AR receives the data packets from its local host and delivers them to the network, and it receives data packets from the network and forwards the packets to the local hosts by using ADP. The host may have two or more Access LOCs (A-LOCs) in the case of host multi-homing.

   Each ISP domain may use its own routing scheme in its backbone network, which is called Backbone Delivery Protocol (BDP). BDP is responsible for packet routing between ARs, possibly via one or more backbone routers. In MOFI, the current IPv4/IPv6 protocol is used as BDP. MOFI uses the LOC-based local delivery. The LOC used in the BDP may be local (private). Each LOC has only to be unique within the ISP domain.

2) **Access Router (AR)**

   Each AR keeps its local binding cache that maintains the mapping information of HID and A-LOC for the local hosts. AR also has its data forwarding cache with the list of HID-LOC for data packet forwarding to active hosts, which will be updated in the signaling operations for LOC query.

### C. Data Delivery Model

In HILL, each host has a globally unique HID, by which global communication is accomplished. In the meantime, one or more LOCs are used for packet routing in the network. Each LOC may be used locally in the transit networks, without any assumption on global uniqueness of LOC. A-LOC is used for forwarding of data packet between hosts and AR in the access network. The format of A-LOC is specific to the underlying access network.

Figure 1 shows the packet delivery operations with Global HID-based Communication and Local LOC-based Routing in the HILL architecture.

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For implementation of host, we use the Linux Ubuntu 10.04 version. The HID is implemented by using the well-known 6to4 tunneling scheme. This is because most of the Linux platforms support the 6to4 tunneling scheme [13].

The conventional method of making the IPv6 6to4 tunnel address from an IPv4 address is shown in Figure 3. In the figure, an IPv4 address is translated into hexadecimal digits and inserted into 3–6 byte positions of the IPv6 address.

```
IPv4: 192.0.2.4
IPv6: 2002:c000:0204::/48
```

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Figure 1. HID-based communication and LOC-based routing

### III. IMPLEMENTATIONS

In this section we discuss implementations of HILL architecture over Linux platform. The HILL architecture is implemented on Host and AR.

A. **Host**

Figure 2 shows the network model for implementation of HILL. Each host has the protocol stack of MOFI/ADP, rather than the legacy IP, in which the MOFI layer is responsible for HID-based global communications between two end hosts and the ADP layer performs the packet delivery between host and AR. The packet delivery between AR and BR or between BRs is governed by BDP, as shown in the figure.

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Figure 2. Network model for implementations

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The conventional method of making the IPv6 6to4 tunnel address from an IPv4 address is shown in Figure 3. In the figure, an IPv4 address is translated into hexadecimal digits and inserted into 3–6 byte positions of the IPv6 address.
In HILL, an IPv6 address for the 6to4 tunneling is used as HID, whereas an IPv4 address is used as LOC. The 128-bit HID includes 2-byte prefix for 6to4 tunneling, 4-byte AS number, and subscriber ID (10 bytes), as shown in Figure 4.

<table>
<thead>
<tr>
<th>Prefix (2)</th>
<th>Domain Identifier (4)</th>
<th>Subscriber Identifier (10)</th>
</tr>
</thead>
</table>

**Figure 4. 128-bit HID format**

In implementations, each HID has the following format, as shown in Figure 5. In the figure, a HID includes the 4-byte AS number in the 3-6 byte positions. Note that aaaa:bbbb and cccc:dddd represent the 4-byte AS numbers and ‘1’ is a subscriber ID.

**Figure 5. 128-bit HID format used in HILL**

The legacy Linux platform (at AR) does not support this type of 6to4 tunnel address. Accordingly, the associated AR modules in Linux need to be modified is required to support the HID, which will be described in the subsequent section.

### B. Access Router (AR)

In this section we describe how to implement an Access Router (AR) over the HILL architecture. The implementation of AR is based on netfilter and iptables [14].

Figure 6 shows the protocol model of AR. It is assumed that each AR uses ADP (and A-LOC) for packet delivery between AR and host, and it uses BDP (and LOC) between ARs. It is noted that each AR performs the LOC query and update operation to find the location of the correspondent AR, before data transmission. This is called “Query-and-Encapsulation”, which is described in [12] more in details.

**Figure 6. Protocol model of AR**

When a data packet is delivered from a host, AR should translate the A-LOC (for ADP) to LOC (for BDP). In our implementation, a private IPv4 address is used as A-LOC, and a public IPv4 address is used as LOC. For this LOC translation, we use the netfilter and iptables over the Linux 10.04 version

1) Host and Network

The netfilter is a well-known tool used in Linux, which is used for LOC (and header) translation in the implementation.

Figure 7 shows the netfilter functions given in Linux. In the figure, the shaded boxes (functions) are used to support the LOC translation at AR. Those functions are called the netfilter hooking points. When a data packet arrives from the host, the AR performs the LOC translation (and packet encapsulation) from A-LOC (for APD) to LOC (for BDP). The encapsulated data packet will be delivered to the correspondent AR, and the AR will perform the LOC translation from LOC to A-LOC with the netfilter functions.

**Figure 7. Netfilter hooking points at AR**

For implementation of HILL, the iptables is used together with netfilter. Typically, iptables are used for packet filtering, such as packet drop and packet forward. In the HILL architecture, the iptables are used for packet forwarding between AR and host.

2) Iptables

Figure 8 shows the use of iptables at AR to perform the packet forwarding to host. In the figure, the iptables are configured to support the packet delivery based on the HILL architecture at AR.

```bash
# echo "1" > /proc/sys/net/ipv4/ip_forward
# iptables -t nat -A POSTROUTING --to Host IP -j SNAT --to AR's public IP
# iptables -t nat -A PREROUTING --to AR's public IP -j DNAT -to Host IP
```

**Figure 8. Configuration of iptables at AR**
B.2. Kernel Compile

With the configured netfilter and iptables, the Linux kernel needs to be re-compiled. In the Kernel compile, only the concerned (modified) modules will be compiled by using the ‘micro-kernel’ compilation process, rather than the entire compilation. Note that this micro-compilation can reduce the phenomenon of kernel panic.

Figure 9 shows the kernel modules associated with the LOC (IP address) change at AR. Note that this code is a part of the entire source code for IP address change. In the figure, the A-LOC (and the concerned IP header) of the host is translated to the LOC (and the concerned IP header).

```c
#include <linux/erratomic.h>
#include <linux/fplib.h>
#include <linux/init.h>
#include <linux/ipv6.h>
#include <linux/kernel.h>
#include <linux/proc.h>
#include <linux/smp.h>
#include <linux/fcntl.h>
#include <linux/socket.h>
#include <linux/skbuff.h>
#include <linux/netdevice.h>
#include <net/netfilter.h>
#include <net/netfilter_ipv4.h>
#include <net/netfilter_ipv6.h>
#include <netinet/in.h>
#include <netinet/tcp.h>
#include <netinet/sctp.h>
#include <net/tcp.h>
#include <net/ipv4.h>
#include <net/ipv6.h>
#include <sys/socket.h>
#include <arpa/inet.h>

static struct nf_hook_ops netfilter_ops;

unsigned int main_hook(unsigned int hooknum, struct sk_buff *skb,
                        const struct net_device *dev, int hook)

    struct iphdr *ih = skb->ip_hdr(skb);
    if (!ih->saddr == in_addr("Host IP"))
        return NF_ACCEPT;

    netfilter_ops.hook = main_hook;
    nf_register_hook(&netfilter_ops);
    return 0;

void cleanup_module()
    nf_unregister_hook(&netfilter_ops);
```

Figure 9. Kernel module for IP address change

IV. EXPERIMENTATIONS

This section discusses how to make the testbed and how to test the applications on the HILL architecture. In testbed experimentation, we employ the VLC video player as the upper layer application on top of UDP.

A. Identifier And locator

Figure 10 shows the testbed network configuration, in which the two hosts (Host 1 and Host 2) and three routers (AR1, AR2, and AR3) are used. In the testbed, Host1 acts as the video server (sender) and Host2 plays a role of the video client (receiver). In the figure, the HID binding and LOC update represent the control operations of MOFI (please refer to [12] for more details).

Figure 10. Testbed network

During experimentation, Host2 will move from AR2 to AR3 by handover. By performance analysis, the handover delay will be measured.

Figure 11 shows the snapshot of the real machines associated with in the testbed of Figure 10.

Figure 11. Testbed snapshot

B. Experimental Result

In experimentation, the test scenario can be summarized as follows. First, Host1 is connected to AR1, and Host2 is attached to AR2. For VLC video streaming services, Host2 receives the video data traffics from Host1 by using UDP. During the video transmission, Host2 moves from AR2 to AR3, and the handover delay is measured.
Figure 12 shows the packet capturing results for the packets from Host1 to AR1, by using the Wireshark [15]. Similarly, Figure 13 and 14 show the packet capturing results from AR1 to AR2, and from AR2 to Host2, respectively. In the figures, we can see that Host1 uses the HID of 2002:aaaa:bbbb::1 and Host2 uses the HID of 2002:cccc:dddd::1.

On the other hand, LOCs are changed in each network region. For example, in Figure 12, Host1 uses the A-LOC of 192.168.0.100. In Figure 13, AR1 uses LOC of 155.230.105.215 (public IP address), and AR2 uses LOC of 155.230.105.217 (public IP address). It is noted that LOCs are changed by network region, whereas HIDs of Host1 and Host2 are not changed.

Figure 12. Packet capture (Host1 to AR1)

1. Frame 1: 511 bytes on wire (4088 bits), 511 bytes captured (4088 bits)
   - Ethernet II, Src: GigaBit:2e:6f:58:01 (192.168.0.100), Dest: GigaBit:2e:6f:58:01 (192.168.0.100), Len: 511, Ttl: 64
   - Data (429 bytes)

2. Frame 2: 1460 bytes on wire (11680 bits), 1460 bytes captured (11680 bits)
   - Ethernet II, Src: Ethernet:03:04:05:06:07:08, Dest: Ethernet:03:04:05:06:07:08, Len: 1460
   - Data (1460 bytes)

Figure 13. Packet capture (AR1 to AR2)

1. Frame 1: 511 bytes on wire (4088 bits), 511 bytes captured (4088 bits)
   - Ethernet II, Src: GigabitEth:2e:6f:58:01 (192.168.0.100), Dest: GigaBit:2e:6f:58:01 (192.168.0.100), Len: 511, Ttl: 64
   - Data (429 bytes)

2. Frame 2: 2014 bytes on wire (16112 bits), 2014 bytes captured (16112 bits)
   - Data (16112 bytes)

Figure 14. Packet capture (AR2 to Host)

1. Frame 1: 511 bytes on wire (4088 bits), 511 bytes captured (4088 bits)
   - Ethernet II, Src: GigabitEth:2e:6f:58:01 (192.168.0.100), Dest: GigaBit:2e:6f:58:01 (192.168.0.100), Len: 511, Ttl: 64
   - Data (429 bytes)

2. Frame 2: 2014 bytes on wire (16112 bits), 2014 bytes captured (16112 bits)
   - Data (16112 bytes)

Figure 15. LOC update message (AR3 to AR1) by handover

1. Frame 1: 72 bytes on wire (576 bits), 72 bytes captured (576 bits)
   - User Datagram Protocol, Src Port: 65549 (65549), Dest Port: 155301 (9393)
   - Data (72 bytes)

Figure 16. Packet capture (AR1 to AR3) after handover

Finally, we measured the handover delays for 10 handover trials, as shown in Figure 17. For each trial, the handover delay is calculated by difference between the reception time of data packet at AR3 and the reception time of data packet at AR2. In the figure, we can see that the handover is performed within one second for all the handover trials, and the average handover delay is 0.540 second for 10 trials.

Figure 17. Handover delay
V. CONCLUSIONS

In this paper, we discuss the HILL architecture for ID-LOC separation for mobile-oriented future Internet. The details of implementation for the HILL architecture are described at the host and AR sided. For implementation, we configure the HID with the AS number from the 6to4 tunneling address. Each AR is implemented on the Linux platform by using netfilter and iptables so as to support the LOC and header translations between A-LOC and LOC. For experimentation, the testbed is configured and we measured the packet capturing results for the traffic between Host and AR, and between ARs. From the handover analysis, we can see that the handover delay is completed within one second.

For further works, the implementations and experimentations need to be extended by considering the real wide-area networks. In addition, the HILL architectural concept is integrated into the overall MOFI architecture more elaborately.

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