An Identifier / Locator Split Architecture for Multi-homing and Mobility Support

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Summary
In this paper, we propose a new naming system to split an address into separate Identifier and Locator and a network architecture based on our naming concept, in order to solve multi-homing problem and to support mobility and seamless communication. Also our solution aims to solve the routing scalability problem. Our solution consists of the following core concepts. First, we propose a new addressing method to separate the identifier and the locator and to support multi-homing hosts. Second a location managing system to support mobility is suggested. Third, our architecture uses core-edge separation concept for routing and addressing. Fourth, to improve performance, we present a two level mapping system to manage identifiers and locators.
Key words:
Future Internet, naming and addressing, ID/Locator split, multi-homing, mobility

1. Introduction

By the diffusion of high-end terminals such as smart-phones, it has even become possible that a mobile device supports several interfaces, that is, one terminal can connect to a number of access networks simultaneously. The demand and necessity for the multiple paths use of an end-terminal are increasing, as it can give benefits of advanced services and efficient management of network resources and traffic. The physical performance of networks (such as speed, capacity, etc) which consist of the Internet has been remarkable improved as well. However, the current Internet architecture has limitations in dealing with numerous requests of mobile hosts, multi-homed hosts and mobile networks.

There are much active researches focusing on re-examining the Internet architecture and designing new Internet, called Future-Internet in domestic and foreign countries in order to overcome the limitations of current Internet. (such as FIND [1] and GENI [2] in the United States, AKARI[3] in Japan, FIF[4] in Korea, and EIFFEL[5] in Europe)

Such extensive studies on the Future-Internet include new designs of routing/addressing architectures, multi-homing, mobility, security, etc., but particularly designing a new addressing architecture is recognized as the most basic problem.

Current IP (Internet Protocol) address plays roles of an “identifier” to identify the interface of a host which is connected to Internet and a “locator” to locate host simultaneously. This architecture makes it hard to provide new requirements of the Future Internet such as mobility, multi-homing and so on.

Moreover, according as de-aggregation addresses have been flowing into Internet backbone areas in large quantities due to allocation of provider independent addresses, multi-homing and traffic engineering, etc., this caused the rapid growth of BGP (Border Gateway Protocol) routing tables. [6] shows that the current BGP (border gateway protocol) routing tables has about 400,000 entries in the default-free zone (DFZ) and is growing uncontrollably. It has been recognized as the main reason of the routing scalability problem.[7, 8, 9].

To solve the above mentioned problems, studies on Identifier/Locator Split solutions such as HIP[10], Shim6[11], LISP[12], GSE[13], ILNP[14], vLIN6[15], GLI-Split[16], etc. have been currently carried out. However, most of them have not shown perfect solutions for the above problems yet.

We propose a new locator/ID split network architecture called ILSMM (Identifier/Locator Split architecture for Multi-homing and Mobility) that can support host-multi-homing and mobility and solve the routing scalability problem.

ILSMM proposes an improved addressing model on the basis of the conventional IPv6 address method. It enables one IP address to maintain locator and identifier, where the locator can be easily changed due to its location, but the identifier that has a lasting character is maintained constantly. The identifier of a multi-homed device can include the information of each interface.

Moreover, to solve the routing scalability problem, it separates addressing/routing of global IP transit network from edge networks.

ILSMM proposes a new ID/Locator mapping mechanism which includes a location managing server and a locator mapping system. The location managing server manages the movement of mobile nodes and the locator mapping system is used to distribute locator information.

The rest of this paper is organized as follows. In section II, the existing representative Location/ID split solutions are introduced briefly. In section III, we describe in detail

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the proposed locator/ID split network architecture, Section IV explains the communication procedures to support mobility. Advantages of the proposed mechanism and further issues are discussed in Section V. Finally, in section VI, we make some conclusions.

2. Identifier/Locator Split Architecture

The ID/Locator split is recognized as a precondition when designing the new Internet architecture. Though various researches including HIP[10], Shim6[11], LISP[12], GSE[13], ILNP[14], vLIN6[15] and GLI-Split[16] are in progress currently, none of them is able to meet all the requirements of the future Internet yet. In this section three protocols related to the proposed solution are explained and the pros and cons of them are indentified.

2.1 ILNP(Identifier Locator Network Protocol)

Basically, ILNP uses each IPv6 address with a 64-bit Locator followed by a 64-bit Identifier. It is derived from the previous concept of GSE/8+8[13].

The ‘Locator’ of ILNPv6 is a ‘routing prefix’ that is used only for routing and forwarding. On the other hand, the ‘Identifier’ indicates a host instead of an ‘Interface ID’.

The clearest difference from conventional IPv6 is that an IP address of ILNPv6 can be used as Locator in network layers and as Identifier in transport layers.

Likewise, the separation of Locator from Identifier makes it advantageous to support mobility and multi-homing.

Moreover, unlike Mobile IP, ILNPv6 doesn’t use Home Agents. Instead, it uses Locator values stored in DNS. But it has some disadvantages such as difficulties in coping with rapid changes of a locator of a mobile host promptly because of using the existing DNS system.

2.2 LISP(Locator ID Separation Protocol)

LISP, proposed by CISCO, is basically a network based solution similar to GSE, but proposes ID-Locator separation architecture through Map-n-encap instead of address translation.[12, 17]

LISP implements routing separation of the edge network from the backbone network. In an edge network, it uses a provider independent address.

Each edge network is connected to the backbone network through TRs (Tunnel Router). When one edge network transmits packets to another one, they communicate with each other by tunneling between TRs. In this time, as the address used for tunneling is an address of TR respectively, the provider independent address used in the edge network is unseen with aspects of the backbone network.

The address of each TR is used as the RLOC (Routing locator) and an actual address used in the edge network is used as the EID (Endpoint Identifier) in end-to-end.

LISP needs a separate mapping system for managing mapping between EIDs and RLOCs, now various mapping systems such as LISP-ALT[18] and LISP-DHT[19] are proposed.

LISP has a fundamental purpose to solve the routing scalability problem and a difficulty in supporting the host mobility and multi-homing.

2.3 GLI-Split(Global Locator, Local Locator, and Identifier Split)

GLI-Split implements a separation between global routing (in the global Internet outside edge networks) and local routing (inside edge networks) to make routing in the core of the Internet more scalable [16]. It uses global and local locators (GLs, LLs) and identifiers (ID). A separate static ID is used to identify endpoints and independent of the current location.

GLI-Split is backwards-compatible with the conventional IPv6, because locators and IDs are encoded in IPv6 addresses. The higher order bits store either a GL or a LL while the lower order bits contain the ID.

Users in GLI-domains can change providers without internal renumbering.

GLI-Split can utilize multi-homed edge networks for multipath forwarding, in addition to traffic engineering, and mobility support. However, it does not deal with multi-homed end hosts.

3. Architecture of ILSMM

In this section, we introduce the overall architecture of the ILSMM.

3.1 Addressing Method

ILSMM is based on the ID/locator split concept and reuses the conventional IPv6 address architecture to support backward-compatibility.

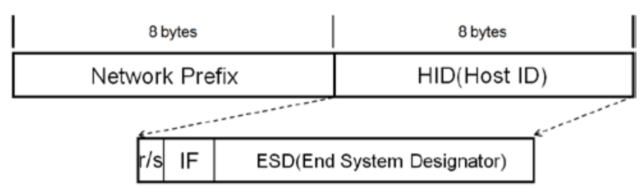

Figure 1. ILSMM-address model.

As shown in the figure 1, the upper 64bits are filled with a network prefix which indicates the current interface locator and the lower 64bits are filled with a host identifier named HID (Host Identifier).

In many cases, it is very useful that a specific interface of a multi-homed device is identified to solve multi-homing issues such as multi-paths use. Therefore, we injected interface information into HID. HID consists of a two bits marker(r/s), a six bits interface identifier field and ESD (End System Designator). Each field is described as follows:

- The marker indicates whether the HID contains information of a specific interface.
- The interface identifier field used to indicate which interface is being used for a specific connection
- ESD is a unique representation of the end-device and more than two end hosts can't have same ESD. The method of creating and distributing ESD is beyond the focus of this paper.

Especially, the HID that does not contain an interface id is called as HRID (Host Representative ID). HRID identifies the end-device itself.

By allocating a network prefix to the upper 64bits, ILSMM has the advantage of using the conventional IPv6 routing architecture when transmitting or forwarding packets.

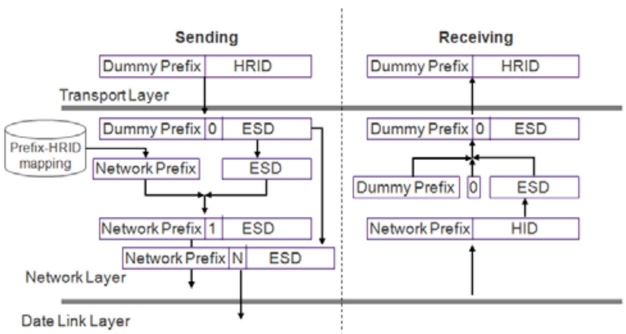

Figure 2. Sending and receiving procedure in end hosts.

Figure 2 shows how an ILSMM-address would be used in an end host. A transport layer and its upper layer use an address that is filled with a constant value in the upper 64 bits. On the other hand, the network layer uses an ILSMM-address replaced with an actual routing network prefix in the upper 64 bits. Each end host has the Prefix-HID mapping cache which keeps the mapping between a HID and a network prefix value. Accordingly, upon the movement of the mobile host (MH) though a network prefix value is changed, the transport layer and the application keep the same address, and as a result the communication session will be maintained.

3.2 Architecture Overview

As shown in figure 3, ILSMM consists of a global IP transit network, edge networks and a ID/Locator mapping system which includes a LoCation Managing System (LCMS), a locator mapping system (LMS).

The global IP transit network that consists of backbone networks takes charge of transmitting packets between edge networks. Edge networks are connected to the global IP transit network through edge routers (ER) and provide network access to various end hosts.

ILSMM separates the naming and routing in edge networks from the global IP transit network. Provider independent addresses are used in each edge network. The advertised network prefix within an edge network is called local network prefix (LNP). An IP address made by using the LNP is and the HID is called local IP address, and is used as a local locater (LL) in the edge network. The local IP address is locally routable only in the edge network.

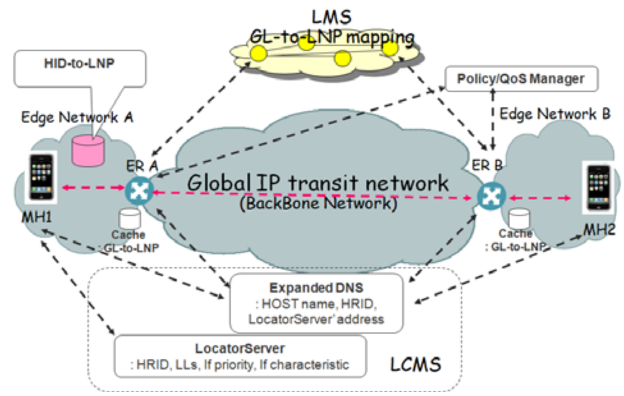

Figure 3. ILSMM architecture.

Routers in the global IP transit network are not aware about LLs. Therefore, a IP-over-UDP tunneling approach is used in order to forward packets between edge networks. We exploited the LISP's tunneling feature.

Each ER has IP addresses that are globally routable in the global IP transit network and it is used as the global locator (GL) in the global IP transit network. Each edge network is identified by its GLs. The tunneling is done by encapsulating the original packet in an UDP segment. While the inner (original) IP header uses LL, the outer IP header uses addresses from the LL space. The encapsulation is performed by ERs of the packets' source edge network, while the decapsulation by ERs of packet's destination edge network.

3.3 ID/Locator Mapping System

The mapping system is required for managing mapping relations of HRID, LL and GL. ILSMM's mapping system is classified into a LoCation Managing System (LCMS) and a locator mapping system (LMS).

3.3.1 LoCation Managing System (LCMS)

The LCMS stores location information of a mobile host (MH) and maintains the latest location information whenever the location changes.

The LCMS in based on DNS. Many locator/ID split solutions use DNS to manage location information of MHs, but it is not appropriate that DNS manages the location information of many mobile hosts which frequently move.

Therefore, we adopt the concept of the locator server (LS) which is used to track the locations of a MH.

The LS stores the following information of a MH.

- HRID
- Allocated LLs to each interface
- The priority of each interface
  : In order to reflect user's demands, each interface has a priority. In case of using multiple-interfaces, the mobile users may choose their preferred paths to send data traffic probably based on the price paid and on the quality of the service offered by various service providers.
- Interface characteristic
  : Interface type (Wi-Fi, 3GPP, etc) ,
  Network behavior (best effort transmission, QoS enabled transmission, etc)

A MH should send its location information to the LS periodically even though there are no changes. If a LS does not receive a MH's location information in certain time interval, it would be deleted.

The eDNS (expanded DNS) stores the HRID of the MH and the address of the LS that takes charge of the MH.

Because the AAAA resource record type [20] supported by the current DNS is a record specific to the Internet class that stores a single IPv6 address, we define a new resource record model shown in figure 4.

The IP address field indicates the HRID of the mobile host. The LS Numbers field indicates the number of the LSs that manage the mobile host. The Locator Servers field indicates the IP address(es) of one or more locator server(s).

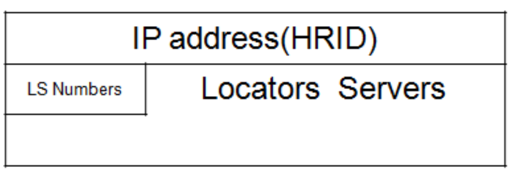

Figure 4. ILSMM-DNS resource record format.

3.3.2 Locator Mapping System (LMS)

The LMS is a global distributed database to store GL-to-LNP mappings, and is managed in the global IP transit network.

Every edge router organizes the logical control network to share and distribute this mapping information. Each edge router typically contains a small piece of GL-to-LNP mappings. The same database mapping entries MUST be configured on all ERs for a given locator.

Because the local locator is routable only in the edge network, the local locator should be encapsulated with the global locator within the global IP transit network.

Each edge network manages the cache table to store the information of every mobile host which is attached to the edge network. This table stores bindings between HIDs and LNPs.

Nowadays, studies on mapping systems of LISP such as LISP-DHT, LISP-ALT, etc. are actively under research, and they will be good solutions for LMS.

3.4 Edge Router (ER)

ERs managed by ISPs are located on the border of global IP transit network and edge networks. ERs manage the IP addresses of all incoming/outgoing packets and perform the encapsulation, and decapsulation at each site's ingress and egress points.

4. Communication Procedures

This section explains the communication procedures of ILSMM.

4.1 Address Registration Procedure

Figure 5 shows the address registration procedure.

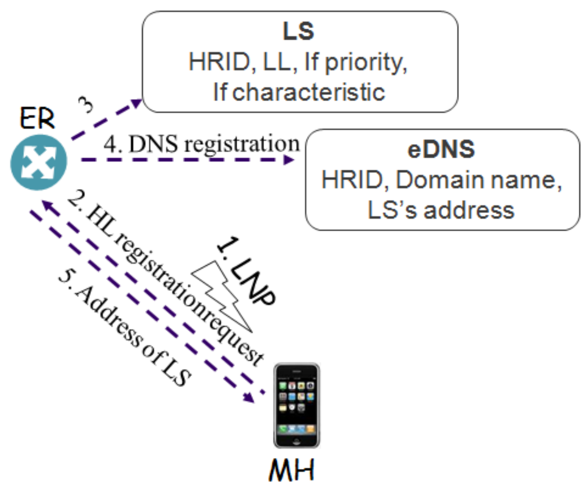

Figure 5. Address registration procedure.

When entering an edge network area, the MH receives a new LNP. The MH generates the local IP address by using its own HID and the received LNP. The MH sends host-location registration request to the ER to register its domain name and position to the LCMS (A MH may specify a specific LS). A MH can set up the interface priority and characteristic of its current attachment point. After choosing proper location server, the ER forwards the received request to the server. The requested server stores the domain name and HRID of the MH and its LL. After the ER registers the domain name and LS address of the MH to eDNS, the ER returns IP address of the locator server to the MH. ER adds the HID of the MH and the LL to the cache.

4.2 Address Query and Communication

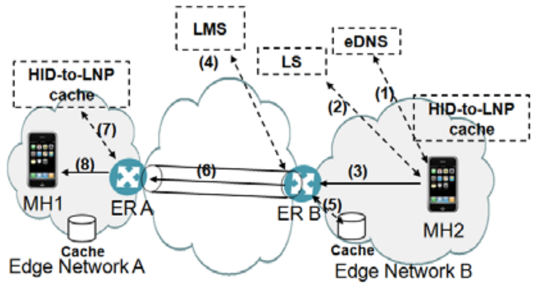

Figure 6. Address query and communication procedure.

In figure 6, the edge networks are called, 'Edge Network A' and 'Edge Network B' and each ER and MH positioned in the edge network are called, 'ER A' and 'ER B', and 'MH1' and 'MH2'.

It is assumed that MH2 wants to communicate with MH1 and knows the domain name of MH1. First, MH2 performs DNS lookup and acquires MH1's HRID and the IP address of the LS which manages MH1's location (Arrow 1 in Fig.6). MH 2 queries the LS about the LLs of MH1, and the LS sends back the LLs list of MH1 (Arrow 2 in Fig.6). MH2 selects one LL from MH1's LLs list(by referring the interface priority and characteristic of LLs list).

MH2 starts to send data packets with the LL of MH1. Because the IP address is not routable in edge network B, ER B receives the packets from MH2 (Arrow 3 in Fig.6). ER B can acquire the GL(the IP address of ER A) of correspondent LNP by inquiring of LMS and its cache server (Arrow 4 in Fig.6). ER B stores GL/LNP binding in its GL-to-LNP cache server managed by ER B for the fast lookup (Arrow 5 in Fig.6). A tunnel is established between ER B and ER A and packets are forwarded (Arrow 6 in Fig.6). When the packet arrives at the edge network A, ER A decapsulates and transmits it into the edge network A (Arrow 8 in Fig.6). Finally, MH1 receives the packet transmitted from MH2

4.3 Mobility Support

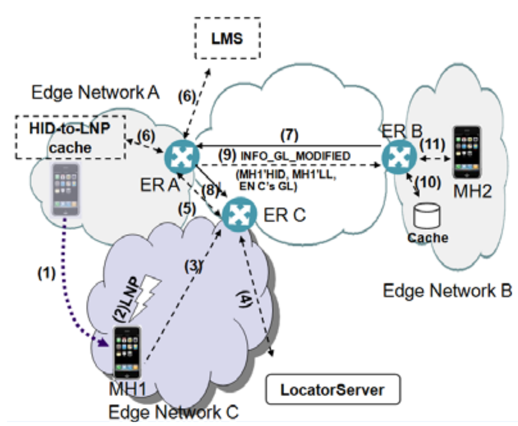

Figure 7. Mobility Signaling.

Figure 7 shows a signaling procedure to support mobility.

It is assumed that MH1 positioned in the edge network A and MH2 in the edge network B communicate with each other and MH1 immediately leaves the edge network A to move into the edge network C.

If MH1 detects movement, it updates the local locator using the LNP advertised within edge network C. MH1 sends to ER C a LNP_update_request message containing the IP address of the LS which manages MH1's location (Arrow 3 in Fig.7). ER C forwards it to the LS. Receiving it, the LS returns MH1's previous LL to ER C and updates MH1's LL (Arrow 4 in Fig.7). Once ER C receives MH1's previous LL(ER A), ER C informs ER A that the location of MH1 is changed (Arrow 5 in Fig.7). ER A erases information of MH1 from the HID-to-LNP cache of the edge network A (Arrow 6 in Fig.7). ER A keeps MH1's information and ER C's information as a cache.

ER B that doesn't recognize the movement of MH1 still transmits a packet to the edge network A (Arrow 7 in Fig.7). ER A that receives a packet from ER B forwards the packet into the ER C (Arrow 8 in Fig.7). Moreover, ER A transmits an INFO_GL_MODIFIED message to ER B in order to inform ER B that the location of MH1 was changed (Arrow 9 in Fig.7). The INFO_GL_MODIFIED message contains the HID and new LL of MH1 and the GL of EN C. ER B that receives the message updates its cache server with new information (Arrow 10 in Fig.7). To inform MH2 that MH1's locator was changed, ER B sends INFO_LC_CHANGED to MH2. This message contains the HID and new LL of MH1 (Arrow 11 in Fig.7). Receiving this message, MH1 updates its Prefix-HID mapping cache with the received values.

5. Discussion

This section analyses advantages of ILSMM in terms of the multi-homing, the mobility and routing scalability.

5.1 Handling Multi-homed edge-networks

When an edge network is multi-homed, it is connected to the global IP transit network through multiple edge routers. It means that its nodes have multiple paths to destinations in other domains. Figure 8 shows a simple example of multi-homed edge-networks.

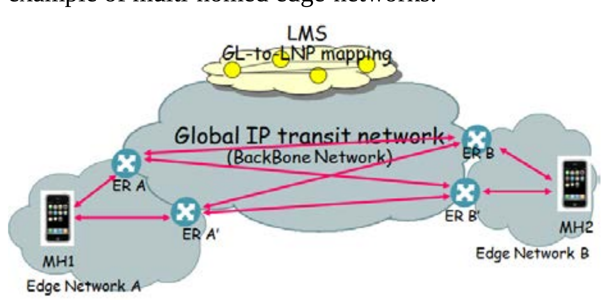

Figure 8. Multi-homed Edgenetorks.

To maximize network bandwidth efficiency of multiple paths, the ILSMM can share traffic among those paths. It facilitates backbone-level traffic engineering.

5.2 Mobility

Most of ID/Loc split solutions which have been recently suggested use two methods in general to support the mobility. One is to extend DNS and then to allow the DNS to manage the IDs and locators of MHs directly. The other is to use direct signaling between MHs. However, the current DNS can not cope with the fast-growing number of MHs and their rapid movement. Moreover, using direct signaling between MHs also gives heavy loads to a MH.

Accordingly, the ILSMM suggests a separate location server as a method for managing location of the MH through separation from DNS, so it allows the ILSMM network to detect and apply the location in real time, even though the state of MHs is rapidly and dynamically changed. Moreover, if MHs move during communication, a series of operations for management of sessions are managed by ERs, thus it reduces loads of a MH.

5.3 Routing Scalability

An edge network uses a provider independent address. The routing of edge networks is separated from that of global IP transit network, and a GL is only used in global IP transit network. Accordingly, an address used in the Edge network is completely unseen with aspects of global IP transit network. In other words, it is possible to prevent increase of BGP routing table in the backbone network.

It is possible to avoid address renumbering overhead due to ISP changes, because, even though an edge network changes an ISP, irrespective of ISPs, in the Edge network the same LNP is used, and only in global IP transit network, GL-to-LNP mapping information of the relevant edge network is changed.

5.4 Interface Consideration

If a node ID only identifies the device itself, to distinguish interfaces, the mapping between locators and interfaces is necessary. To avoid this complexity, HID consists of interface id that identifies the attachment point. It is very useful to know exactly which interface is being used to process a given connection.

To support multipath use at the upper layer, the interface id can be utilized as well for the effective management of interfaces. If HID only identifies the device itself, to distinguish interfaces, the mapping between locators and interfaces is necessary.

6. Conclusions and Future Works

In this paper we suggested a new locator/ID split network architecture that is capable of solving multi-homing problem and the routing scalability problem and supporting the mobility.

We suggested an address model based on ‘8+8’ concept capable of storing Identifier and Locator information simultaneously and changing locators easily, and achieved efficient management of addresses in the edge network due to separation of the edge network from global IP transit network and increase of routing scalability in global IP transit network.

Particularly, we introduced a concept of a location server in order to manage the fast-growing number of MHs and their dynamic movement.

Now, we are planning to modify BSD kernel to implement the architecture suggested by this paper. We’ve analyzed which part of the BSD kernel would be altered, and are planning to construct an experimental network using a test-bed in our laboratory.

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