

## A hierarchical Mapping System of ID/Locators Split Architecture

Zhang Aihua, Lu Meilian, Wang Wendong, Gong Xiangyang and Xu Xiaohu

State Key Lab of Switching & Networking Technology, Beijing University of Posts and  
Telecommunications, Beijing, China

Huawei Technologies Co., Ltd

aihua9@gmail.com, mllu@bupt.edu.cn, wdwang@bupt.edu.cn, xygong@bupt.edu.cn,  
xuxh@huawei.com,

**Abstract**—As a global infrastructure, mapping system provides ID/Locators Mapping Management for ID/Locators split architecture. In this paper, a novel and detailed ID/Locators Mapping System Model (ILM) based on DNS is proposed under the Routing Architecture for the Next Generation Internet (RANGI), one of the ID/Locators split architectures. The structure of ILM is an organizational hierarchical one according to hierarchical host IDs in RANGI. With this structure, ILM achieves clear trust boundaries since host IDs can be stored in the corresponding nodes according to their organizational structure. At the same time, ILM supports mobility and multi-homing. In addition, this paper introduces an Analytical Model to evaluate the performance of ILM for mobility supporting. The result shows that ILM not only implements ID/Locators mapping management but also has good performance for the mobility and multi-homing capability.

**Keywords**—ID/Locators mapping system; organizational hierarchical structure;ILM; multi-homing; mobility

### 1. Introduction

RANGI [1] is one of the host side ID/Locator split architectures. These kinds of architectures introduce a host identifier (ID) layer between the network layer and the transport layer. As a result, the transport-layer associations are no longer bound to IP addresses, but to the host IDs. When a package is sent from application layer down to the ID layer, the ID layer queries the global mapping system to get the according locators. Mapping system as a global infrastructure is very important, providing ID/Locators Mapping Management. Considering that mapping system should benefit business model and trust boundaries, mapping system should be hierarchical. Besides, there are more and more mobile hosts and multi-homed hosts, so mapping system should provide support for mobility and multi-homing.

But, RANGI has no detailed implementation mechanism of mapping system. Considering that HIP [2] and ILNP [3] have the similar architecture, and they all introduce mapping system, this paper will analyze these mapping systems and proposes novel and detailed mapping system implementation mechanism under RANGI. HIP Mapping System has three kinds of mechanisms: 1) Using traditional DNS by adding new HIP Resource Record. This mechanism reuses existing DNS mechanism, but it requires each host has FQDN [4]; 2) Using flat DHT technology. In this mechanism, all the ID/Locators mappings randomly are stored in arbitrary node in one organization, which can't benefit business model and trust boundaries [5]; 3) Using two-level design in DNS solves previous problems, but this mechanism requires two recursive queries spending more time [6]. ILNP also implements mapping system using traditional DNS [7], but ILNP host must have a FQDN for corresponding locations by searching mapping system, and the mapping system also includes two recursive queries.

Therefore, we propose ID/Locators mapping model (ILM) based on DNS under RANGI. The structure of ILM is an organizational hierarchical structure according to hierarchical host ID. Different mappings are

stored in different organizations according to ID. This paper has three contributions: (1) proposes an detailed implementation mechanism of mapping system with organizational hierarchical structure; (2) provides a method supporting multi-homed hosts; (3) provides a method supporting mobile hosts and introduces RANGI ILM Analytical model to study the performance of ILM supporting mobile hosts.

## 2. Related Works

There are two common measurements for implementing mapping system. 1) Dedicated mapping system. The benefits of this mechanism includes that it uses mature ideology and is suitable for dedicated architecture, but this mechanism needs to dramatically change traditional network infrastructure. For example: ALT technology in LISP [8]. 2) Domain Name system (DNS) [9] [10]. DNS itself is a global distributed storage database. For example, AAAA resource record (RR) in DNS can map the Fully Qualified Domain Name (FQDN) to Locator. Besides, DNS doesn't need to dramatically change network. In addition, the structure of DNS is organizational hierarchical structure which is similar to hierarchical RANGI-host ID.

The namespace of DNS is hierarchically partitioned into non-overlapping regions. DNS delegates the responsibility for each domain to a set of name servers called authoritative name servers. The authoritative name servers of a domain manage all information for names in that domain. Each domain can authorize sub-domains to maintain some names in that domain. This process continues recursively until bottommost domain doesn't authorize any more. The hierarchical structure is built from this process. Every domain in the DNS system can be managed by the different organizations.

Therefore, DNS outperforms other mechanisms for RANGI mapping System.

## 3. ID Locator Mapping System Model

ID Locator Mapping System Model (ILM) is based on DNS, as shown in Figure 1. ILM is used to manage ID/Locators mapping information which is different from traditional DNS.

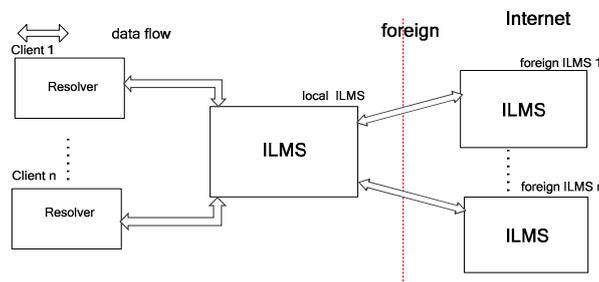


Figure 1. The structure of DNS.

ILM contains Resolver, ID/Locator Mapping Server (ILMS). Resolvers are part of routines of RANGI host, which serves the host, including constructing and sending DNS mapping query/update packages, receiving and resolving DNS mapping query/update response packages. Resolvers just interact with ILMS. ILMS has two types: 1) Local ILMS; 2) Authority ILMS. Local ILMS located within the site as a resolver proxy recursively interacts with the authority ILMS. Authority ILMS delegates the responsibility of mapping domain, which is the new-added sub-domain of reversed arpa domain. Mapping domain maintains the entire RANGI ID space, so that arbitrary ID/Locators Mapping can be indexed by the ID and stored in authority domain.

In RANGI, ID doesn't specify length in each field. In order to implement the organizational hierarchical structure of Mapping System, we partition and encode each field according to E.164 standard [11], as shown in figure 2.

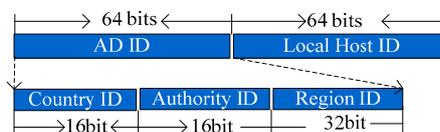


Figure 2. Partition of RANGI ID.

According to this partition, mapping domain can be divided into several sub-domains, shown in Figure 3.

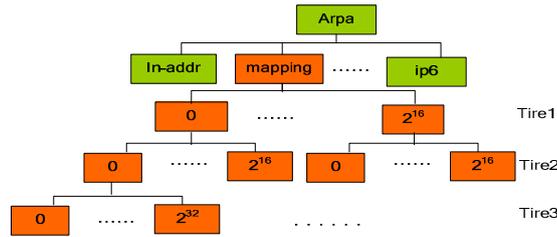


Figure 3. Organizational hierarchical structure of ILM.

Mapping domain can authorize Tire1-level sub-domains, which is also called country domain, with the total number ranging from  $2^0$  to  $2^{16}$ . Tire1-level domains can authorize Tire2-level sub-domains, Tire2-level domain is also called authority domain, with the total number ranging from  $2^0$  to  $2^{16}$ . Tire2-level domains can authorize Tire3-level sub-domains, Tire3-level domain is also called region domain, with the total number ranging from  $2^0$  to  $2^{32}$ . Tire3-level domain usually is no longer authorizing sub-domains, but manages ID/Locators mapping. Authority ILMs is delegated with the responsibility of each domain in mapping domain. Every domain authorizes sub-domain according to the current number of ID/Locators mappings, which shows flexibility and scalability of ILM.

Data in the name space are called resource record (RR), stored in the Zone file. There have four types of RR in ILMs: SOA, NS, A / AAAA and Map. Each zone file has only one SOA RR, identifying the beginning; NS RR describes the name of authorized sub-domain; A / AAAA RR describes the location of ILMs corresponding to the NS RR; Map RR is the new defined RR describing ID/Locators mapping, shown in Figure 4(1). By the map RR, one can find locators when given an ID.

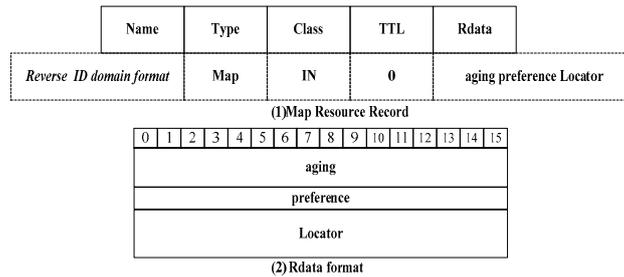


Figure 4. Map RR.

The value “name” field is a reversed ID of RANGI host, which is the domain name where the ID/Locators mapping can be found. The original ID is reversed shown in figure 2. The ID has been divided into four sections, and the lengths are: 2, 2, 4, 8 bytes respectively. The content of each section is not reversed, but the sequence of section will be reversed. For example, ID is 30010da8021500000000000000000001, the corresponding domain is 0000000000000001.02150000.0da8.3001.mapping.arpa.

The value “type” field is a map, which is an encoded 16 bit value that identifies the ID/Locator Mapping.

The value “class” field is IN, which is an encoded 16 bit value that identifies protocol family.

The “TTL” field value is zero, which indicates that the map RR is not cached.

The “Rdata” field includes three sections, shown in figure 4(2): 1) the “aging” section, which is set by ILMs with the current time. With this field ILM implements automatically deleting mechanism on ILMs and locator choosing algorithm on the host; 2) the “preference” section, which is set by RANGI host with certain factors, such as: locator was assigned by wire network with higher priority than wireless network. The smaller value has higher priority. This field and the aging field can implement the locator choosing algorithm on the host; 3) the “locator” section, which is set by host, with the routable IP in the internet.

With aging and preference section, ILM implements automatically deleting mechanism on server and locator choosing algorithm on host. For automatically deleting mechanism, each Authority ILMs can set different expiration time according to their organization. If the aging value of map RR compared with the



Step 1: The application calls the resolver to construct and sends DNS map query package to the local ILMS.

Step 2: the local ILMS doesn't cache any information such as the AAAA which is used to locate the authority ILMS. Local ILM recursively sends a query package. Firstly, it sends this package to the root DNS.

Step 3: when the root DNS receives a DNS map query package, it resolves this package and searches for required RR in database. If no result is returned, the root DNS will construct and send a DNS response package with the A/AAAA RR of ARPA domain to the local ILMS.

Step 4: Local ILMS caches A/AAA of Arpa, and sends the same DNS map query package to the arpa domain. Arpa domain also doesn't manage required map RR, it will construct and send a DNS response package with the A/AAAA RR of mapping domain to the local ILMS.

Step 5: Local ILMS caches A/AAA of mapping domain, and sends the query package to the mapping domain. Mapping domain also doesn't manage required map RR, it will construct and send a DNS response package with the A/AAAA RR of country domain to the local ILMS.

Step 6: This process will be recursive; until this package is sent to authority ILMS which manages the required map RR. Authority ILMS will construct and send DNS map response package with required RR to the local ILMS.

Step 7: When the Local ILMS receives DNS map response package with required RR, it will send this package to the resolver of client.

Step 8: if the host sends the same DNS map query package to the local ILMS lately, local ILMS will use cached information for reducing the query time.

The update process is similar to the query process, except step 6, 7. In these steps the Authority ILMS will update the RR described in the update package, and return DNS map response package with the failure or success code.

## 4. Evaluation Model of Mobility for Ilms

The evaluation of ILM as a mapping system for the mobile host is how powerful it can provide the Communication Node (CN) with correct location when communicating with Mobile Node (MN). The evaluation method refers to [16] [17] [18], including terminology of residence time, critical time and success rate.

### 4.1 Critical time

The interactive process of MN and CN can be seen from the figure7.

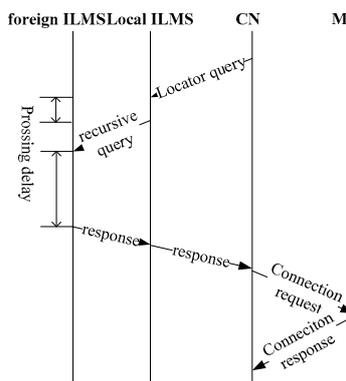


Figure 7. Commucation established process

The total time spending on CN establishing connection with the MN is noted Tcon:

$$T_{con} = T_c + T_d + T_p. \quad (1)$$

where,

Tc is the package transmission delay between CN and MN.

$T_d$  is the package transmission delay between CN and ILMS.

$T_p$  is the package processing delay at ILMS.

We suppose it is on the wireless network. When the MN moves, the time of overlapped areas between two AP is:

$$T_{over} = T_2 - T_1. \quad (2)$$

where,

$T_2$  is the moment before MN leaves overlapped area.

$T_1$  is the moment after MN enters the overlapped area.

Formula (2) can also be represented to:

$$T_{over} = \frac{d_{over}}{E[v]}. \quad (3)$$

where,

$d_{over}$  is the radius of overlap

$E(v)$  is the average MN speed of moving

The current Locator of MN successfully serves the CN, when

$$T_{con} \leq T_{over}. \quad (4)$$

We can deduce critical time  $T_{cr}$  from formula (1),(2),(4):

$$T_{cr} = T_{con} - T_{over}. \quad (5)$$

## 4.2 Resident time

Zonoozi proposed a mobility model computing the resident time in the origin subnet and moved subnet. The time depends on the current location, moving direction and speed of MN. Zonoozi defined four variables:

$T_n$  the new connection subnet resident time.

$T_h$  the handoff subnet resident time.

$V_m$  the maximum velocity of the mobile node.

$R$  Maximum velocity of the MN

The probability density function of  $T_n$  represented by  $f_{Tn}(t)$  and  $T_h$  represented by  $f_{Th}(t)$  are shown as follows.

$$f_{Tn}(t) = \begin{cases} \frac{8R}{3\pi V_m t^2} \left\{ 1 - \left[ 1 - \left( \frac{V_m t}{2R} \right)^2 \right]^{\frac{3}{2}} \right\}, & 0 \leq t \leq \frac{2R}{V_m} \\ \frac{8R}{3\pi V_m t^2}, & t > \frac{2R}{V_m} \end{cases}, \quad (6)$$

$$f_{Th}(t) = \begin{cases} \frac{4R}{\pi V_m t^2} \left\{ 1 - \left[ 1 - \left( \frac{V_m t}{2R} \right)^2 \right]^{\frac{1}{2}} \right\}, & 0 \leq t \leq \frac{2R}{V_m} \\ \frac{4R}{\pi V_m t^2}, & t > \frac{2R}{V_m} \end{cases}. \quad (7)$$

From the density function (6), (7), we can deduce  $T_n$  and  $T_h$ :

$$E[T_n] = \int_0^{\infty} t \cdot f_{Tn}(t) dt = \frac{8RE\left[\frac{1}{V}\right]}{3\pi}. \quad (8)$$

$$E[T_h] = \int_0^{\infty} t \cdot f_{Th}(t) dt = \frac{\pi R}{2E[V]}. \quad (9)$$

If MN handoffs from the origin subnet to n-other subnet, the total resident time is:

$$T_{res} = E[Tn] + nE[Th]. \quad (10)$$

### 4.3 Success rate

The success rate is related to the query number in the resident time ( $E[\chi \times (Tres)]$ ) and the critical time ( $E[\chi \times (Tcr)]$ ). We represent the  $\lambda$  as query request arrival rate.

$$E[\chi(Tres)] = \lambda T_{res}. \quad (11)$$

$$E[\chi \times (Tcr)] = \lambda T_{cr}. \quad (12)$$

The success rate  $\Phi$  can be defined as:

$$\Phi = \frac{E[\chi \times (Tres)] - E[\chi \times (nTcr)]}{E[\chi \times (Tres)]} = \frac{\frac{8R}{3\pi E[v]} + n * \frac{\pi R}{2E[v]} - n * (Tc + Td + Tp) + n * \frac{dover}{E(v)}}{\frac{3R}{3\pi E[v]} + n * \frac{\pi R}{2E[v]}}. \quad (13)$$

### 4.4 assess

From formula (13), we get the success rate. For testing the result with the success rate, we set up ILM on test bed. The  $T_p$  of ILM is 0.0007418 from test bed, shown in figure 8.

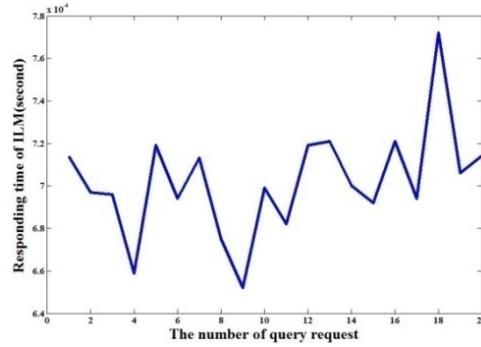


Figure 8. Average process time of ILM

We suppose the time on  $T_d$  is:  $3s \leq T_d \leq 21s$ , the dover range is:  $0m \leq dover \leq 50m$ , the  $R$  is 750m, the  $CN$  is 2s, the average movement of  $MN$  is 20mps, the number of handoff is 9. From these we can deduce the result from figure 13, if the delay of package from  $MN$  to the ILM is 9s, the success rate will be 80%, if delay reduces to 3s, the success rate can reach 1.

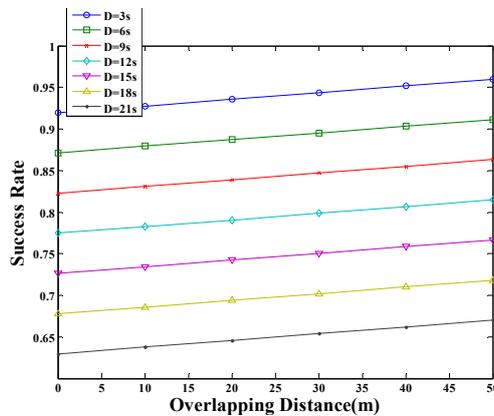


Figure 9. success rate for different transmission delays

## 5. Conclusion

There has no detailed mapping system mechanism in RANGI. This paper proposes an ILM based on DNS, which implements the ID/Locators management under RANGI. Compared with similar architecture like HIP and ILNP, ILM supports the mobility and multi-homing. This paper introduces RANGI mobility analytical

model to study the performance of ILM supporting mobility. Finally, we can draw a conclusion from this paper, ILM as RANGI mapping system meets the function and performance requirements.

## 6. Acknowledgment

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