HMS: Towards Hierarchical Mapping System for ID/Locator Separation

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ABSTRACT

Recently, Internet Default Free Zone (DFZ) is facing a scalability problem due to the double use of the current Internet Protocol (IP) namespace. IP namespace is used for both the location finding and host identification. However, scalability is not the only problem, mobility is difficult to achieve due to the dual use of IP. Therefore, Identifier and Locator separation is proposed and discussed in the research community as a way to solve the above problems. But, this solution further creates a big challenging issue in designing a mapping system to support efficient mobility of users while providing scalability. In this paper, we propose a hierarchical mapping system based on today's IP allocation/assignment. We evaluate our mapping system and show that scalability, and short lookup time can be achieved. However, to maintain scalability in the case of mobility is a challenge. Therefore, we provide a smooth location management scheme for mobility with a low signaling cost compared to the approach based on distributed hash table. Signals due to node movement are kept locally in each edge network.

Categories& Subject Descriptors

C.2.1 Network Architecture and Design

General Terms

Future Internet, Addressing, Design

Keywords

Id/Locator separation, Mapping System, Identifiers, Locators

1. INTRODUCTION

Over the Internet, Internet Protocol (IP) represents not only the location of a host, but it also represents the host Identifier. This use of IP has been a source of many problems in the current routing and addressing system of the Internet. One of these problems is mobility support; that is whenever a host moves from one network to another network its IP changes and all the previous established sessions interrupt causing the host to reestablish the connection.

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However, mobility is not the only issue caused by the dual role of IP on the Internet; the routing table scalability is affected as well [1].

To solve these limitations, the two roles have been separated into Identifiers (EID, for the end-systems) and Locators (RLOC for routing) for a new architecture commonly known as ID/Locator separation. This approach will not only allow a host to keep the ongoing session even when it has moved from its home network, but also will reduce the numbers of the routing table's entries considerably while providing multihoming as well to customer networks. There have been many proposals which apply the ID/Locator separation [13] [14] [8] to solve current Internet problems. While [13] [14] architecture are based on the rewriting scheme, [8] uses the map-and-encap scheme to route the packet from one edge to another. In this work, we consider the map-and-Encap scheme proposal since it allows an incremental deployment on the current architecture [8]. Nevertheless, both approaches require a mapping system, since ID/Locator separation only the Locators are used during the routing process. The mapping system plays a crucial role which is how to map a node to its new location and to its Locator in the case of movement and in the case of normal routing, respectively. Therefore, it can act as the bottleneck for ID/Locator separation approach if not well designed.

However, most of previous promising works [2] [3] [5] tackled the mapping system design by using overlay networks. Overlays raise constraints on the physical infrastructure control as well as inefficient usage of network resources.

In this paper, based on an aggregate distribution of EIDs, we propose a Hierarchical Mapping System (HMS) based on IP allocation/assignment hierarchy [11] to remove the overlay network constraints. HMS uses partially [4] mapping distribution to reduce the resolution time while supporting scalability. Since the two elements determine the main concern in the design of a mapping system. They are also used as metrics to validate a design as shown in [4].

HMS hierarchy consists of two components known as mapping servers. One is in the Internet Allocation Number Authority (IANA) level and the second in the Regional Internet Registry (RIR) level. The main assumption in HMS is that the allocation/assignment of EIDs is done in the same way as for IP or [15], with RIR as the lowest level of the hierarchy. An analytical evaluation proves HMS feasibility for the two previously stated metrics. However, the scalability of HMS design is challenged by the mobility which breaks the EIDs aggregation. Therefore, we also propose a location management scheme to maintain mobile node mapping information updates inside its home network. The proposed scheme is evaluated with regards to mobility signaling cost. Results shows better performance compared to the approach based on DHT P2P overlay network [7]. Numerical analysis supports the analytical model based on update cost and packet forwarding cost metrics used for the scheme evaluation.

The rest of the paper is organized as follows; section 2 describes some of the related works in the design of LISP based mapping system. In section 3, we have introduced HMS for ID/Locator separation. Section 4 describes HMS performance evaluation. Section 5 describes the location management scheme to support mobility. Section 6 discusses the analytical evaluation model for HMS mobility support and numerical performance results to validate our scheme, and finally, we conclude our work with some discussion in section 7.

2. RELATED WORK

Many proposals provide different ways of designing a mapping system. Here are some of them based on Locator and Identifier Separation Protocol (LISP) currently discussed in IETF [8].

In [2], Fuller et al. proposed LISP alternative topology (LISP-ALT), in which the mapping information EID-to-RLOC is stored in a distributed way in different ETR, which are interconnected using an overlay network of ALT-routers. Here, the scalability problem is removed at the cost of the complexity of the overlay network maintenance due to the use of GRE and another kind of BGP. This adds another level of indirection. LISP-CONS [3] are almost like LISP-ALT but remove the use of BGP. LISP–NERD [4] to remove resolution delay introduces a scalability concern at Tunnel Routers (TR) and finally for LISP-DHT [5] though scalability and robustness are provided but due to the use of DHT structure, resolution time remains very critical since this depends on the number of nodes involved in the DHT. When Chord ring is used the resolution time depends on (O(logN).) LISP-TREE proposes a different approach based on DNS and removes the overlay cost but based on either recursive or iterative mode the resolution delay still requires improvement to assure fast end-to end communication.

Therefore, we have designed a hierarchical mapping system based on the currently used IP allocation/assignment hierarchy also known as delegation principle also used in LISP-TREE [15] proposal. However, HMS hierarchy stops at RIR level because we consider Provider Independent (PI) EIDs assignment from RIR. Moreover, HMS implements a different mapping retrieval and registration process from the one used in LISP-TREE as it will be shown in the next section. HMS mechanism takes also advantage of the LISP-NERD [4] distribution process. HMS aims to remove the overlay cost as well as reducing the resolution time through a hierarchical mapping system approach while providing scalability.

3. ID/LOCATOR HIERARCHICAL MAPPING SYSTEM

Figure1 summarize ID/Locator separation packet forwarding process. A packet is forwarded from one network to another after a Locator of the destination EID retrieval for the routing has been well resolved by the mapping system.

We designed a mapping system that would remove the overlay cost of the previously proposed mapping system by taking the advantage of the IP allocation/assignment hierarchy as well as LISP-NERD distribution approach.

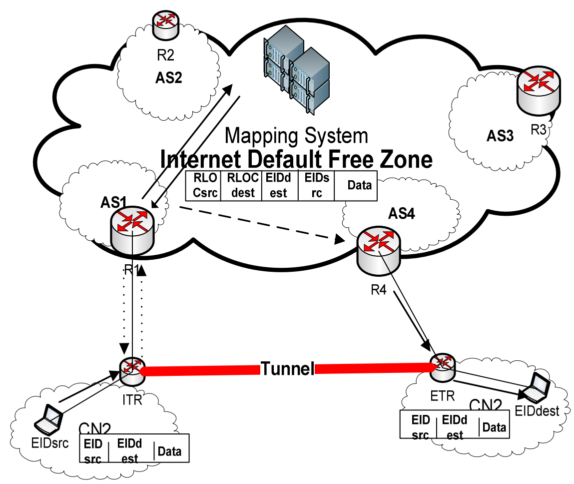

Figure 1. ID/Locator Overview

The mapping system (as shown in Figure 2) has two main components; IANA Mapping Server (IMS) and Registry Mapping Server (RMS). IMS stores mapping information of EIDspace allocated to registry (EIDspace-to-RMS) and, the second component which stores the real mapping information (EIDpref-to-RLOC) is the RMS. RMS stores the mapping information as the DNS using specific records attached to each assigned EIDpref. Among the record one will be to notify the mobility enablement. However, the record specification is out of the scope of this paper.

The mappings information of IMS is downloaded by TR pointing it directly to the registry in charge of the EID space for EID resolution. IMS distributes its information to the tunnel router (TR) using LISP-NERD approach.

Moreover, IANA and RIR can deploy more than one IMS and RMS respectively to increase robustness and decrease latency while providing load balancing and can be deployed using today anycast as deployed for today DNS.

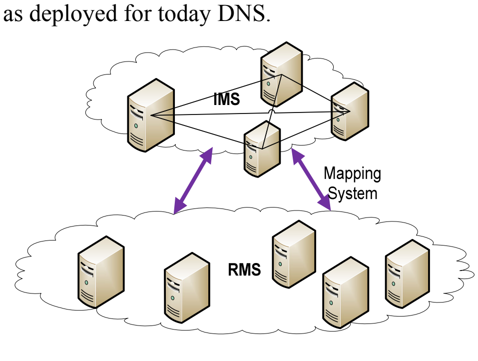

Figure 2. HMS component hierarchy

3.1 Mapping Registration Process

As depicted in the Fig.3 the mapping information from customer's networks is registered following these steps.

Step 1. ITR/ETR receives the connection from the ISP.

Step 2. ITR/ETR downloads the IMS mapping information.

Step 3. Using the longest prefix match in the downloaded IMS mapping table, TR determines to which RMS the mapping information should be sent.

Step 4. After RMS has received the mapping information and it does not exist in the mapping table, the mapping information is stored. In the case it already exists, RMS just updates the mapping table with the new mapping information.

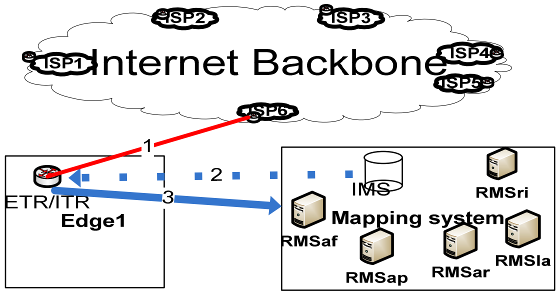

Figure 3. Mapping Information registration process

3.2 Mapping Information Retrieval Process

To resolve EIDs Locator, first TR applies the longest prefix on the received information from IMS and directly sends the map-request to the concerned RMS. RMS then replies to TR with the corresponding Locator of the prefix to which the EID belongs to. The steps are explained in details in Figure 4.

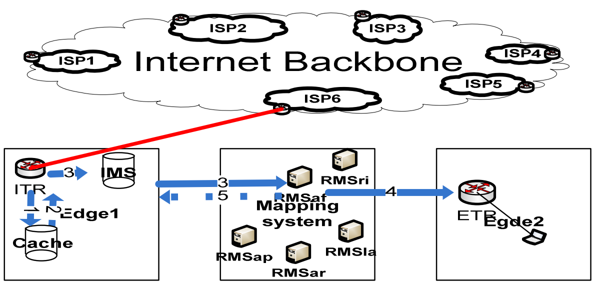

Figure 4. Mapping Information Retrieval Process

Upon the reception of the mapping information the packet can be forwarded from one edge network to another using a tunnel. Figure 5 illustrates the packet forwarding process.

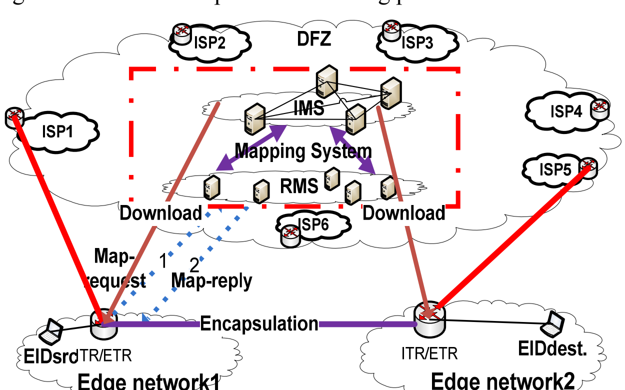

Figure 5. Packet forwarding using HMS

4. HMS PERFORMANCE EVALUATION

This section describes metrics used for HMS evaluation.

4.1 Scalability

It is one of the reasons ID/Locator separation architecture has been proposed. Our proposal has adopted LISP-NERD metric for the evaluation of its feasibility.

$$E * (30 + 20 * (R - 1)) \quad (1)$$

Where, E is the number of EIDs and R is the number of RLOCS attached to the EIDs.

During our evaluation, we consider IPv6 as the space assigned to identifiers. Therefore, IMS stores 4096pools of/12 IPv6 subnet allocated to registries. Considering our architecture, TR also downloads the same amount of entries as in [4]. The shorter length of prefixes stored in IMS compared to 64bits used in [4] and the assumption of RMS identified to one locator reduce equation1 into equation2.

$$E * 6 \quad (2)$$

Therefore, IMS and TR are required to store around 24576Bytes in case of a full allocation which is way much smaller than what servers and routers can handle today [16]. As for TR in case of IPV6 like EIDs space full allocation is still 100 times smaller than what today BGP routers are supporting, leaving enough space for the local EIDs mapping information to be stored.

For RMS we consider that EIDs are randomly distributed among registries. Therefore, each RMS will store a 1/5 of the LISP-NERD approximated usable space [4] independently. This result leads us to a conclusion that the space used is way much smaller compared to the analysis made of LISP-NERD single database. Moreover, mappings information are stored as prefixes which reduce as well the needed space of RMS compared to when single EID are used. Although [17] shows that in reality some registry can hold more addresses than others depending on the users in that region. In any case RMS will still scale compared to LISP-NERD and per registry existing technics can still be used to assure intern scalability of storage and robustness since RMSs are independent from one another.

From figure 6 and previous analysis on IMS and TR, we show that scalability in HMS is satisfied in all HMS components. Moreover, more than one IMS and RMS in an anycast fashion to support robustness and load balancing as well as decreasing latency.

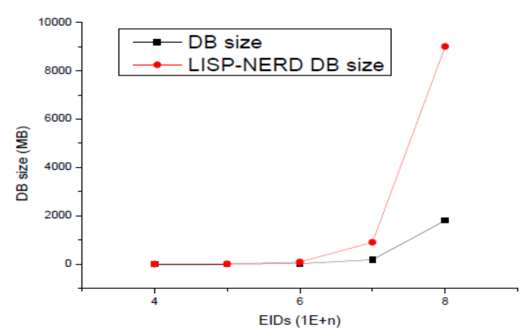

Figure 6. Scalability performance

4.2 Overhead Analysis

Overhead can be caused by the high frequency of requests and updates. IMS updates its table in case of a new pool assignment and RMS mapping information is updated in case of a provider change which also does not happen frequently. Therefore, the overhead is bearable if we consider that TR will have a scheduled time to request updates from IMS. However, IMS is evaluated using processing time needed to spread the mappings to TR. We considered the following parameters 1Gbps bandwidth under the assumption that 10 or 100servers ares deployed for IMS and receive simultaneous requests from TR. Under the above assumption for one TR request the IMS processing time is estimated to 0.2ms. The results are described in table1 showing that the time needed is bearable and shorter than the time needed by LISP-NERD [4].

Table 1 IMS processing time of simultaneous requests

#Simultaneous request	10 Servers	100 Servers
100	2ms	0.2ms
1000	20ms	2ms
10000	200ms	20ms
100000	2000ms	200ms
1000000	20000ms	2000ms

Moreover, the processing time can still be improved by the download of available updates in the IMS database instead of the entire database. Changes happen when a new pool of/12 is allocated to a registry, which happens not before at least 20month for the registry with the highest assignment speed [18]. On the other hand the overhead at RMS is reduced by the caching approach implemented in TR. Finally, updates in RMS has a very low frequency because edge networks don't change frequently their provider, hence their mapping information remain stable.

The above analysis leads us to the conclusion that overhead due to updates and simultaneous request are manageable compared to the LISP-NERD from which HMS borrows the distribution model.

4.3 Resolution Delay

Through this approach the resolution time is considerably reduced as compared to approaches based on overlay network. There is no specific routing added to mapping retrieval process, therefore we estimates the time using the end to end delay between involved component adapted to today Internet

We have evaluated the resolution delay as follow:

T_1 : Time a packet takes from the PC to the TR; we assume T_1=1ms

T_2 : Time used by the TR to process the request before generating or not a map request, we assume T_2 = 2ms

T_3 : The time map-request takes from the TR to the RMS, we assume that this depends on the RTT between the network and the RMS

T_4 : processing time in the RMS, we assume T_4 = 0,420ms based on [12] estimation with more than 25millions of search/second

T_5 : Time the map-reply takes from the RMS to the ITR is same as T_3

Therefore, the resolution delay is obtained as follow:

$$T_{tot} = T_1 + T_2 + T_3 + T_4 + T_5 = 2\text{RTT} + 3.420\text{ms} \quad (3)$$

We can see that HMS resolution delay depends on the RTT. If the RTT is lower than T_{tot} is low but if RTT is high the T_{tot} will be high also. Considering smokeping [10] tool results of RTT between edge networks and roots server is measured around 100 ms, which we consider to same as T_3 in our architecture.

Therefore, the resolution delay T_{tot} = 103,420ms, which is better than the one proposed in [9]. Figure7 shows the variation of T_{tot} based on different RTT values.

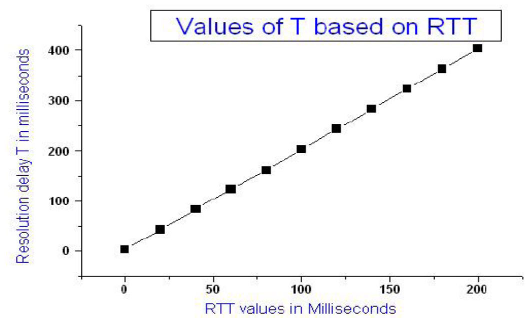

Figure 7. Resolution Delay approximation

5. MOBILITY SUPPORT SCHEME

Mobilty need is very much required by users nowsdays. However, for ID/Loc architecture mobility is supported by a dynamic updates of the mapping system. That is why for HMS we have proposed a scheme to support mobility with minimum cost of signaling. However previous works based on the ID/Locator approach have provided mobility for users. The table below provides the summary of some previously proposed mapping service and the element in charge of mobility support.

Table 2 ID/Locator's protocol Comparison

Protocol	Routing approach	Mapping System	Mobility
HIP	Rewritting	DNS+RSV	RSV
ILNP	Rewritting	DNS	DNS
LISP	Map-and-Encap	LISP-ALT	M N

HMS is the mapping system designed to remove the overlay cost of LISP protocol. Therefore, to support mobility in HMS, we have added one more component called Mobility Mapping Server (MMS) known by mobile node. Each network has its own MMS to keep mapping updates of local nodes, just as the home agent (HA) in MobileIP [19] keep updates of local node care of address. HMS mobility scheme is not designed to allow mobility since mobility is supported by the fact that EIDs don't change during a session. Rather MMS is deployed to avoid scalability concerns in RMS during mapping system updates caused by change of point of attachment. Figure 8 describes the update and packet forwarding process with respect to the location management scheme.

MMS: maintains the mapping information of the new position of the home network nodes. It replies to mapping request of mobile nodes. It updates RMS whenever mobility is enabled by one or many nodes movement. Also keeps packet sent to node before their movement the time of its location update and forward the packet to the new TR as the destination

NODE N: It is responsible of informing the MMS about its new location through an update message sent from the visited TR.

RMS: it is in charge to updates it record with MMS address whenever it is contacted for the first movement in the home network. This will specify that mobility is enabled and therefore the map request will be recursively sent to the MMS for resolution.

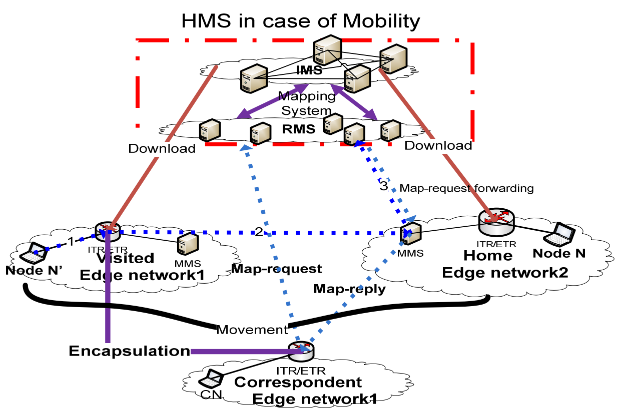

Figure 8.Location Update and Packet Forwarding

5.1 Location Update

The movement of nodes from one network to another need to be updated in the mapping system since the point of attachment changes while the identifier remains the same. Whenever a foreign network is visited, nodes need to inform their home network about their new location.

As stated before each network has a location manager to assure mobility of its users (MMS). The location update is performed as follows:

Step 1. When a node moves to a new network, it issues a location update message to its own MMS by way of the visited TR. The update message includes the identifier mapped to the visited TR Locator address.

Step 2. Upon reception of this information, MMS stores it in a table and send an update to the RMS to update the EIDpref records and put it in the mobility with MMS address as mobility record.

Considering our mapping system design we avoid propagating the location update in the upper level to avoid any scalability problem as faced in the recent protocol's routing table due to the break of prefixes. When the node comes back to its original network, MMS will discard that information about the movement and TR restores the previously discarded EID due to mobility.

5.2 Packet Forwarding in Mobility

When a node wants to communicate with other nodes, the packet forwarding can be performed using the steps below:

Step 1. When TR receives a packet with EIDdest, it first looks up in its local table. If the EIDdest is a home / visitor EID, the packet is forwarded directly to the destination. Else go to step2.

Step 2. If EIDdest is not a local EID/visitor EID the TR generates a map-request to find the Locator of the network owner of EIDdest through HMS to RMS.

Step 3. RMS finds the MMS responsible for that specific EIDpref mobility recursively forward the map-request. And the MMS sends the map-reply to the requesting TR with the TRvisited.

Step 4. TR encapsulates the packet and sends to TRvisited of EIDdest.

Note that when the EIDdest has visited the EIDsrc network no mapping retrieval is done, since both have the same point of attachment. Therefore, the resolution is faster.

6. ANALYTICAL PERFORMANCE EVALUATION FOR MOBILITY

Our evaluation focuses more on the cost of signaling generated by both location update packet forwarding rather than the mechanism by itself. We have adopted the idea of [7]. The following table describes the metrics considered in our evaluation

In our proposal, we assume N number of TR representing edges networks with one TR per edge network while nodes can move randomly from a network to another one.

Table 3. System parameters

Notations	Description
c_{mt}	Transmission cost between TR and MMS
c_{mr}	Transmission cost between MMS and RMS
c_{tr}	Transmission cost between TR and RMS
α_t	Processing time at TR
α_m	Processing time at MMS
α_r	Processing time at RMS
T_f	Average time a MN stays in a visitor network
β_i	Packet arrival rate at the Node

A node moves to the new TR with a probability of. $1/(N-1)$

When a node moves from one TR to another, a location update is sent to the MMS. Let, U_m be the location update cost.

$$U_m = c_{mt} + c_{mr} + \alpha_t + \alpha_m + \alpha_r \quad (4)$$

We assume that the average time a node stays in a given network before making a movement is equal to T_f Thus, the average location update cost per unit of time is.

$$U_c = [1/(N-1) * U_m]/T_f \quad (5)$$

We have not only evaluated the update cost but also the cost introduced by the packet forwarding.

For this purpose, we have considered the following categories:

If the EIDdest moved in EIDsrc network, the communication is done without any signaling cost.

Otherwise the signaling cost can be calculated on these terms when EIDdest would be away from its home network.

$$Pf_c = \beta_i * [2\ c_{tr} + 2\ c_{mr} + \ c_{mt} + \alpha_t + \alpha_r + \alpha_m \quad (6)$$

Here β_i is average packet arrival rate of each node.

Based on this calculation, we can say that the Total signaling cost is the summation of the update cost and the packet forwarding cost.

$$T_c = U_c + Pf_c \quad (7)$$

6.1 Numerical Evaluation

The following numerical analysis evaluates and gives a result of the total cost. Since we have adopted the idea of [8], some part of the analysis is made to compare the numerical results using the same metric as in [7]. N =200, L =20, K =5, $c_{mt}=c_{mt}$ =6, $c_{im}=c_{rm}$ =10, $c_{ii}=c_{tr}$ =20, α_t =5, α_m=10, $\alpha_r = \alpha_i$ =20. The performance of our proposal is evaluated using these numerical data comparatively to [7] for mobility support signaling cost. We use the same definition of session mobility ratio (SMR) as in [7] as the ratio of the packet arrival rate to the mobility rate, i.e., SMR= $\beta_i T_f$.

According to Figure 9, the total signaling cost decreases when the SMR increases. Our proposal compared to the three level DMS achieves a better performance.

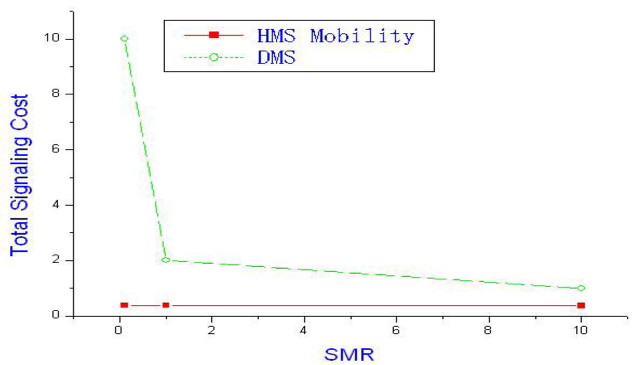

Figure 9.Signaling cost results

This is because our proposal has only one level of update and therefore, the cost is very low compared to DMS, which has to update in different levels based on how the node has moved. Therefore, with our mapping system, mobility is supported with a minimum signaling cost without affecting HMS scalability.

7. CONCLUSION

ID/Locator separation architecture aims to resolve the scalability problem, that the Internet routing system is facing today, as well as to provide smooth mobility.

However, this approach requires a high consideration in the design of its mapping system, which is considered as a vital element of the inter domain packet routing process.

In this paper, we have designed a mapping system that is able to support mobility while being scalable with short resolution time named HMS.

HMS relies on today's IP allocation/assignment hierarchy [11]. Its two main components through evaluation have satisfied scalability, low overhead cost and resolution delay. Therfore we have achieved our goal of designing a mapping system which removes the need of any overlay network to achieve the above metrics.

An extra component is added to HMS to provide mobility support. Our analysis and numerical evaluation of signaling cost has proven that our approach for mobility provides a better performance compared to the proposal based on Distributed Hash Tables [9].

Finally, HMS design as LIPS-DNS provides ovelay network removal but with a better resolution time of EIDs. This conclusion is due to the fact to get a mapping information LISP-DNS pass through three level, when HMS on has one level and some times two due to mobility which has not been addressed in the design of LISP-DNS.

ACKNOWLEDGMENT

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