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전달모드 LISP-DDT 매핑 시스템에 관한 연구

A Propagated-Mode LISP-DDT Mapping System

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Abstract - The Locator/Identifier Separation Protocol (LISP) is a new routing architecture that implements a new semantic for IP addressing. It enables the separation of IP addresses into two new numbering spaces: Endpoint Identifiers (EIDs) and Routing Locators (RLOCs). This approach will solve the issue of rapid growth of the Internet's DFZ (default-free zone). In this paper, we propose an algorithm called the Propagated-Mode Mapping System to improve the map request process of LISP-DDT.

Key Words : LISP-DDT, LISP-ALT, LISP Mapping System, IP Addressing

1. Introduction

In the current Internet routing and addressing architecture, the IP address is used as a single namespace that simultaneously expresses two functions about a device: its identity and how it is attached to the network. Therefore, an visible problem of today's Internet is the continued growth of the BGP routing tables in the default-free zone (DFZ)[1]. Besides the increasing number of autonomous systems, other factors contribute to this growth, including multihoming and traffic engineering[2]. This issue was ranked in 2006 at the Internet Architecture Board Workshop on Routing and Addressing[2] as "the most important problem facing the Internet today". Many of the proposed solutions to address this issue are centered around the idea of separating the network node's identity from its topological location. Among the existing proposals[3-6] the Locator/Identifier Separation Protocol (LISP)[7] has seen important development and implementation effort.

LISP is a network architecture and set of protocols that implements a new semantic for IP addressing. In a nutshell: LISP separates the 'where' and the 'who' in networking and uses a mapping system to couple the location and identifier.

LISP solves these problems by introducing a separation between the 'who' and the 'where'. LISP follows a network-based map-and-encapsulate scheme, this means no changes to hosts are needed, everything happens in the network. Also, in LISP, both identifiers and locators can be IP addresses or arbitrary elements like a set of GPS coordinates or a Mac address.

In LISP, mapping system is essential structure used to map the EIDs to the RLOCs. Several mapping systems have been proposed: LISP+ALT[2], LISP-DHT[3], LISP-CONS[4], LISP-NERD[5], and LISP-DDT[6]. One notable mapping system is the LISP+ALT system, which is used by a LISP Ingress Tunnel Router (ITR) or Map Resolver (MR) to find the Egress Tunnel Router (ETR) that holds the RLOC mapping information for a particular EID. LISP+ALT has a hierarchical architecture that uses Border Gateway Protocol (BGP) to pass along information, including requests for mappings among the nodes of the mapping system. LISP+ALT was relatively easy to construct from existing protocols (GRE, BGP, etc), but there were a number of issues that made it unsuitable for large-scale use. Therefore, LISP-DDT is suggested as a replacement for LISP+ALT[7].

In this paper, we propose an algorithm based on LISP-DDT called a Propagated-Mode. The suggested scheme can significantly reduce the mapping latency and provide a quick response to EID-to-RLOC mapping requests.

2. The Overview of LISP and LISP Mapping System

2.1 LISP Overview

LISP is a network architecture and set of protocols that implements a new semantic for IP addressing. LISP creates two

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namespaces and uses two IP addresses: Endpoint Idenfitiers (EIDs), which are assigned to end-hosts, and Routing Locators (RLOCs), which are assigned to devices (primarily routers) that make up the global routing system. Performing this separation offers several advantages, including:

- Improved routing system scalability by using topologically-aggregated RLOCs
- Provider-independence for devices numbered out of the EID space (IP portability)
- Low-OPEX multi-homing of end-sites with improved traffic engineering
- IPv6 transition functionality
- IP mobility (EIDs can move without changing - only the RLOC changes!)

LISP is a simple, incremental, network-based implementation that is deployed primarily in network edge devices. It requires no changes to host stacks, DNS, or local network infrastructure, and little to no major changes to existing network infrastructures.

2.2 LISP Mapping System

2.2.1 LISP-ALT

The LISP Alternative Topology (LISP+ALT) [8] is a mapping system distributed in an overlay. All the participating nodes connect to their peers through static tunnels. BGP is the routing protocol chosen to maintain the routes on the overlay. Every ETR involved in the ALT topology advertises its EID prefixes making the EID routable on the overlay. Note though, that the mappings are not advertised by BGP. When an ITR needs a mapping, it sends a Map-Request to a nearby ALT router. It starts by constructing a packet with the EID, for which the mapping has to be retrieved, as the destination address, and the RLOC of the ITR as the source address. The ALT routers then forward the Map-Request on the overlay by inspecting their ALT routing table. When the Map-Request reaches the ETR responsible for the mapping, a Map-Reply is generated and directly sent to the ITR's RLOC, without using the ALT overlay.

2.2.2 LISP-DHT

LISP-DHT [9] is a mapping system based on a Distributed Hash Table (DHT). The LISP-DHT mapping system uses an overlay network derived from Chord [12]. Choosing this particular structured DHT over others (e.g., CAN, Pastry, Tapestry or Kademlia) was motivated by the algorithm used to map search keys to nodes containing the stored values. In a traditional Chord DHT, nodes choose their identifier randomly. In LISP-DHT, a node is associated to an EID prefix and its Chord identifier is chosen at bootstrap as the highest EID in that associated EID prefix. This enforces mapping locality that ensures that a mapping is always stored on a node chosen by the owner of the EID prefix, see [9] for details. When an ITR needs a mapping, it sends a Map-Request through the LISP-DHT overlay with its RLOC as source address. Each node routes the request according to its finger table (a table that associates a next hop to a portion of the space covered by the Chord ring). The Map-Reply is sent directly to the ITR via its RLOC.

2.2.3 LISP-NERO

LISP-NERD is a flat centralized mapping database, using the push-model. Because any change requires a new version of the database to be downloaded by all ITRs, this approach is unlikely to scale to the needs of a future global LISP mapping system. The main advantage of NERD is the absence of cache misses that could degrade traffic performance.

2.2.4 LISP-CONS

The Content distribution Overlay Network Service for LISP, LISP-CONS [10], is a hierarchical content distribution system for EID-to-RLOC mappings. It is a generalization of LISP+ALT, which does not use the BGP routing protocol. On the other hand, it adds support for caching in intermediary nodes. In this paper we do not consider LISPCONS as it does not seem to evolve anymore.

2.2.5 LISP-DDT

LISP-DDT is a hierarchical distributed database which embodies the delegation of authority to provide mappings, i.e. its internal structure mirrors the hierarchical delegation of address space. It also provides delegation information to MRs, which use the information to locate EID-to-RLOC mappings. A MR that needs to locate a given mapping will follow a path through the tree-structured database, contacting, one after another, the DDT nodes along that path until it reaches the leaf DDT node(s) authoritative for the mapping it is seeking.

2.3 Map Request Process of LISP-DDT

The Map Request in LISP-DDT is an iterative model, in that the Map Request is repeatedly sent to DDT nodes and receives Map Referral replies from those nodes until it reaches the ETR of the requested XEID. This has shown better performance compared to recursive model[8]. However, the current Map Request process in the DDT results in mapping latency, especially when the MR sends requests to DDT nodes whose authoritative XEID prefixes do not match with the requested XEID. The MR will then continue to send Map Requests to the other DDT nodes.

Figure 1 shows the process of searching RLOC for a requested Extended EID (XEID)[6].

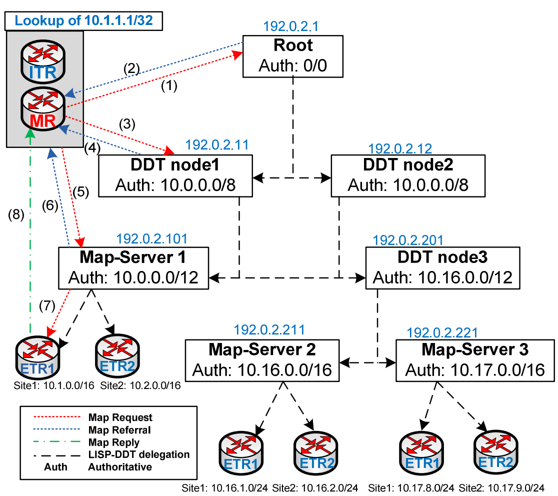

Fig. 1 Map Request Process of LISP-DDT

1) After receiving the request for an XEID from ITR, MR sends a Map Request to one of the root DDT nodes in case there are multiple nodes.
2) The DDT root node responds with a Map Referral Message, which includes information about its delegated nodes.
3) Based on the Map Referral Message, the MR will send a new Map Request to one of the DDT nodes delegated from the root DDT node.
4) The DDT node checks whether its XEID prefix matches the requested XEID. If so, it will send a Map Referral as Step 3 to the MR. If not, it will send a negative Map Reply.
5) , 6) Like Step 3 and 4, but the DDT node is a Map Server, it will attach the action code MS_ACK into the Map Referral sent to MR and forward the Map Request to the ETR in Step 7
7) The ETR sends a Map Reply to the MR.

3. The Proposed Algorithm : Propagated-Mode

In this section we introduce the proposed scheme for LISP-DDT Map Request Process, called Propagated-Mode. We will explain how this scheme works. In section 1 the principle of the proposed scheduling algorithm is presented. Then next sections provide a signaling description for proposed scheme. Final, we compare the Propagated-Mode with original scheme used in LISP-DDT

3.1 Principle

The Map Request is propagated to all Root's delegated nodes to achieve the quickest Map Reply. If there are many Roots, the Map Resolver will base on the priority to send the first Map Request to 1st Root. Then, that Root will forward the Map Request to all its delegated DDT nodes. Continuously, the DDT nodes receive Map Request will forward to its delegated DDT nodes if its XEID prefixes matching the requested XEID. On contrary, DDT node will return its parent node with a Negative Map Referral. By apply this scheme, we guarantee the quickest Map Reply to Map Resolver. The signaling cost could be increased, but we can use Negative Map Referral to update the network topology for MR.

3.2 Signaling Description

To solve the issue mentioned above, we propose a propagated-mode to the Map Request procedure in order to reduce mapping latency. In this scheme, the DDT node that receives a Map Request will continue forwarding it to its delegated nodes if the authoritative XEID matches the requested XEID. So when the Map Server with a matching XEID prefix, it will send the Map Referral back to MR with all referral information accumulated from the previous DDT nodes to the MR to update the cache. Therefore, a modification in the Map Referral Message format is necessary. Then, the next Map Request to ETR, a security signature named LISP-SEC, is included if it has been initiated in the ITR Encapsulated Map Request.

The proposal Map Request process, shown in Figure 2, is explained below:

1) After receiving the request for a XEID from ITR, MR sends a Map Request to all root DDT nodes in case there are multiple root nodes as (1).
2) The root DDT node then forwards the request to its delegated DDT nodes as (2) and (2'). If the requested XEID does not match the DDT node's XEID prefix, that DDT node will send a negative Map Reply walk-back to the root DDT node as (4') and (5'). Then, the root DDT node will wait a pre-defined time to accumulate the

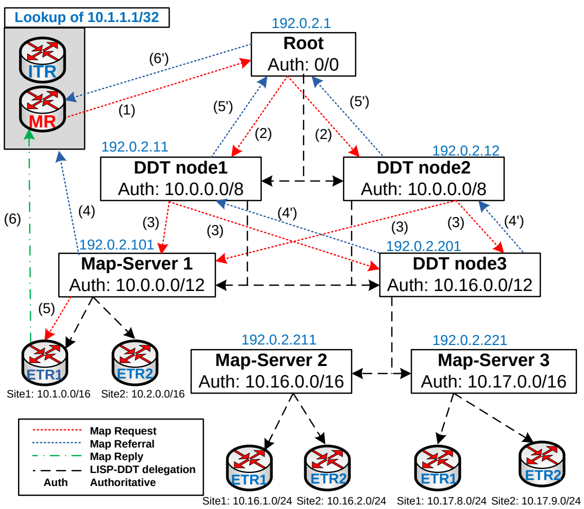

Fig. 2 Propagated-mode scheme

Table 1. Parameters used for mapping cost analysis

N1	Number of DDT root (L1)
N2	Number of root's delegated nodes (root's child nodes in L2)
N3	Number of one L2 DDT node's delegated nodes in L3
P_{MReq}	The cost for processing a Map Request
H_{a-b}	Number of hops between node a and node b
T_{a-b}	Transmission cost between node a and node b
P_{MR}	The packet processing cost in Map Resolver
P_{Ms}	The packet processing cost in Map Server
P_{DDT}	The packet processing cost in DDT node
L_w	The unit of transmission cost for wired link
n	Total time for reaching the correct ETR
M_n	Number of DDT nodes which have XEID prefix matching the requested XEID at Ln
m	Number of layer to reach the desired ETR
μ	The probability indicates number of DDT nodes at L2 that MR sends Map Request until reaching correct branch (contain the desired ETR)

response from its delegated DDT node and sent the Map Referral to MR as (6').

3) If the XEID prefix matches the requested XEID, the DDT node will forward the request to its delegated DDT nodes as (3).
4) When the DDT node, which is a Map Server, receives the Map Request, it will send a Map Referral back to MR with the action code MS-ACK to indicate it is a Map Server as (4) and forward the Map Request to ETR as (5)
5) MR receives the Map Referral Message from the Map Server and updates information in its cache for serving future Map Requests
6) ETR sends a Map Reply to MR as (6).

4. Performance Analysis

4.1 Mapping Cost Analysis

To analyze the Mapping Cost, we consider the time which MR receive the Map Request from ITR through the MR receive the Map Reply from the desired ETR matching requested XEID.

4.1.1 LISP-DDT Map Request Model

P_{MReq} is the cost for processing when MR receive an Map Request from ITR. It then checks its Referral Cache for requested XEID. If there is no existing information, a query will be started from Root.

As the signaling described in Figure 1, the cost of this process, C_{DDT}, is calculated as below:

$$\begin{aligned} C_{DDT} = \; & P_{MReq}+2L_w\cdot H_{MR-Root}+P_{Root}+n\cdot 2L_w\cdot H_{MR-DDT}+ \\ & n(P_{DDT}+P_{MR})+2L_w\cdot H_{MR-MS}+P_{MS}+P_{MR}+L_w\cdot \\ & H_{MS-ETR}+P_{ETR}+L_w\cdot H_{ETR-MR}+P_{MR} \\ = \; & PMReq+2Lw(HMR-Root+n\cdot HMR-DDT+HMR \\ & -MS+(1/2)\cdot HMS-ETR+(1/2)\cdot HETR-MR)+ \\ & PRoot+(n+2)\cdot PMR+PMS+PETR+n\cdot PDDT \end{aligned} \quad (1)$$

4.1.2 Propagated-Mode

As the signaling described in Figure 2, the cost of proposal scheme is calculated as below:

C_1 is the cost without the calculation for Negative Map Referral Message cost from DDT nodes that not matching the requested XEID.

$$\begin{aligned} C_1 = \; & P_{MReq}+2L_w\cdot H_{MR-Root}+P_{Root}+ N_2\cdot 2L_w\cdot H_{Root-DDT} \\ & +N_2\cdot P_{DDT}+M_2\cdot N_3\cdot 2L_w\cdot H_{DDT-DDT}+M_2\cdot N_3\cdot \\ & P_{DDT}+(m-2)\cdot 2L_w\cdot H_{DDT-MS}+(m-2)\cdot P_{DDT}+ \\ & L_w\cdot H_{MS-MR}+P_{MS}+P_{MR}+L_w\cdot H_{MS-ETR}+P_{ETR}+ \\ & L_w\cdot H_{ETR-MR}+P_{MR} \\ = \; & P_{MReq}+2L_w(H_{MR-Root}+N_2\cdot H_{Root-DDT}+M_2\cdot N_3\cdot \\ & H_{DDT-DDT}+(m-2)\cdot H_{DDT-MS}+(1/2)\cdot H_{MS-MR}+ \\ & (1/2)\cdot H_{MS-ETR}+(1/2)\cdot H_{ETR-MR})+P_{Root}+ \\ & (N_2+M_2\cdot N_3+m-2)\cdot P_{DDT}+P_{MS}+2P_{MR}+P_{ETR} \end{aligned} \quad (2)$$

C_2 is the cost that DDT nodes which have XEID prefix not matching the requested XEID, send back to DDT root for accumulating and sending to MR. It shows in Figure 2 by (4'), (5') and (6').

$$C_2 = 2L_w \cdot (N_2+M_2) \cdot H_{DDT\text{-}Root} + (N_2+M_2) \cdot P_{Root} + L_w \cdot H_{Root\text{-}MR} + P_{MR} \quad (3)$$

We obtain the total cost of Propagated-Mode

$$C_{PM} = C_1 + C_2 \quad (4)$$

To analyze the Mapping Cost for LISP-DDT Map Request Process and the proposed scheme, Propagated-Mode, we assume the value as in Table 2.

Table 2. Parameters used for mapping cost analysis

Parameter	$H_{MR\text{-}Root}$	$H_{MR\text{-}DDT}$	$H_{MR\text{-}MS}$	$H_{MS\text{-}ETR}$
Value	8	8	8	2
Parameter	$H_{ETR\text{-}MR}$	$H_{Root\text{-}DDT}$	$H_{DDT\text{-}DDT}$	$H_{DDT\text{-}MS}$
Value	8	8	8	4
Parameter	L_w	n	μ	N_1
Value	1	$\mu \cdot N_3 \cdot N_2$	0.2~0.3	1
Parameter	N_2	N_3	M_2	m
Value	20	100	50	6
Parameter	P_{MReq}	P_{MR}	P_{Root}	P_{DDT}
Value	5	5	5	5
Parameter	P_{MS}	P_{ETR}		
Value	5	5		

From the analytical result, we can see when the μ increase from 0.1 to 0.5, the total time that MR sends Map Request until it reaches the correct ETR will increase equivalently. Therefore, the mapping cost of LISP-DDT is higher.

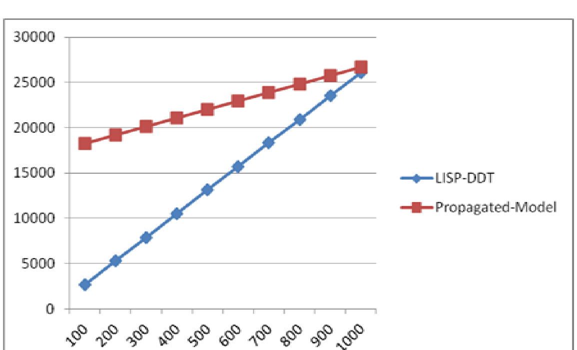

Fig. 3 Mapping cost with μ = 0.1

Fig. 3~Fig. 7 show that as μ increase from 0.1 to 0.5, the mapping cost of suggested algorithm is lower than that of conventional LISP-DDT.

4.2 Mapping Latency Analysis

The mapping latency is defined as the duration from the time that MR receive Map Request from ITR through it

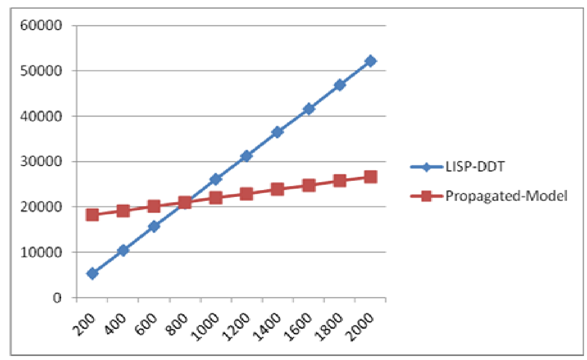

Fig. 4 Mapping cost with μ = 0.2

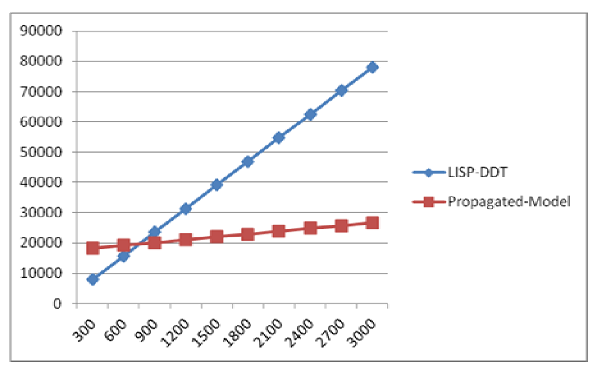

Fig. 5 Mapping cost with μ = 0.3

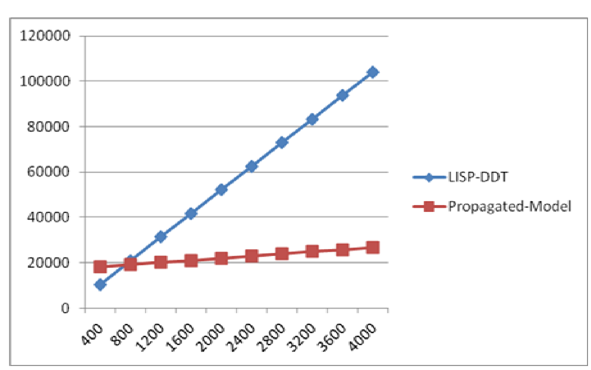

Fig. 6 Mapping cost with μ=0.4

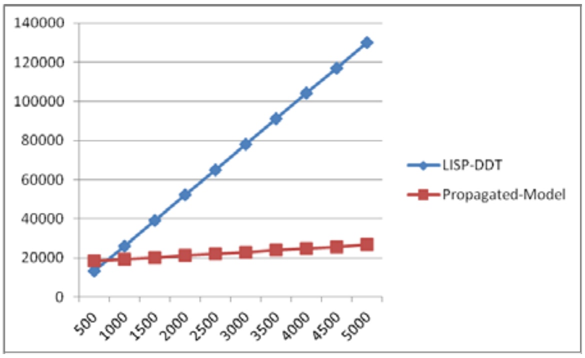

Fig. 7 Mapping cost with μ=0.5

Table 3. Parameters used for mapping latency analysis

$t_{a\text{-}b}$	Transmission time between node a and node b
$t*_a$	Processing time at node a
n	Number of time for sending Map Request until reach the destination ETR
m	Number of layer to reach the desired ETR
μ	The probability indicates the amount of DDT nodes at Layer 3 that MRs send Map Request until reaching correct branch(contain the desired ETR)
N_1	Number of DDT root (L1)
N_2	Number of root's delegated nodes (root's child nodes in L2)
N_3	Number of one L2 DDT node's delegated nodes in L3

receives the Map Reply from the correct ETR that matching the requested XEID. So that, it is not included the total time of Negative Map Referral message from DDT nodes which their XEID prefixes don't match the requested XEID. Table 3 provides the parameters and their definition used in mapping latency analysis.

4.2.1 LISP-DDT Map Request Model

In LISP-DDT Map Request procedure, the mapping latency includes the time MR processes Map Request from ITR, send Map Request and receive Map Referral, process the Map Request and Map Referral.

$$t_{LISP\text{-}DDT} = t*_{MR}+(2t_{MR\text{-}Root}+t*_{Root})+(2n\cdot t_{MR\text{-}DDT}+n\cdot t*_{DDT})+(2t_{MR\text{-}MS}+t*_{MS})+t_{MS\text{-}ETR}+t_{ETR\text{-}MR}+t*_{ETR}+t*_{MR} \quad (5)$$

$$t_{LISP\text{-}DDT\text{-}Model} = 2t*_{MR}+t*_{Root}+n\cdot t*_{DDT}+t*_{MS}+t*_{ETR}+2t_{MR\text{-}Root}+2n.t_{MR\text{-}DDT}+2t_{MR\text{-}MS}+t_{MS\text{-}ETR}+t_{ETR\text{-}MR} \quad (6)$$

4.2.2 Propagated-Mode

In Propagated-Mode scheme, the mapping latency include the time MR process Map Request from ITR, the processing time at MR, Root, DDT nodes, MS and ETR, the time to forwarding Map Request from Root through the correct ETR.

$$t_{PM} = t*+(t_{MR\text{-}Root}+t*)+(t_{Root\text{-}DDT}+t*)+(m-2)\cdot(t_{DDT\text{-}DDT}+t*)+(t_{DDT\text{-}MS}+t*)+t_{MS\text{-}ETR}+t*+t_{ETR\text{-}MR}+t* \quad (7)$$

$$t_{PM} = 2t*+t*+(m-1)\cdot t*+t*+t*+t_{MR\text{-}Root}+t_{Root\text{-}DDT}+(m-2)\cdot t_{DDT\text{-}DDT}+t_{DDT\text{-}MS}+t_{MS\text{-}ETR}+t_{ETR\text{-}MR} \quad (8)$$

Assume $t_{MR\text{-}Root}$~$t_{Root\text{-}DDT}$, $t_{MR\text{-}MS}$~$t_{DDT\text{-}MS}$, we eliminate the same value between $t_{DDT\text{-}Model}$ and t_{PM} equation, the result is as below:

$$t_{DDT\text{-}Model} = n\cdot t*_{DDT}+2n\cdot t_{MR\text{-}DDT}+2t_{MR\text{-}MS} \quad (9)$$

$$t_{PM} = (m-1)\cdot t*_{DDT}+(m-2)\cdot t_{DDT\text{-}DDT} \quad (10)$$

The value n = $\mu\cdot N_2\cdot N_3 \gg m$

Table 4. Parameters used for mapping cost analysis

Parameter	$t*_{MR}$	$t*_{MR}$	$t*_{DDT}$	$t*_{MS}$
Value	6	6	6	6
Parameter	$t*_{ETR}$	n	N_1	N_2
Value	6	$\mu \bullet N_3 \bullet N_2$	1	20
Parameter	N_3	$t_{MR\text{-}Root}$	$t_{MR\text{-}DDT}$	$t_{MR\text{-}MS}$
Value	50	6	6	6
Parameter	$t_{MS\text{-}ETR}$	$t_{ETR\text{-}MR}$	$t_{Root\text{-}DDT}$	$t_{DDT\text{-}DDT}$
Value	3	6	6	6
Parameter	$t_{DDT\text{-}MS}$	M		
Value	6	6		

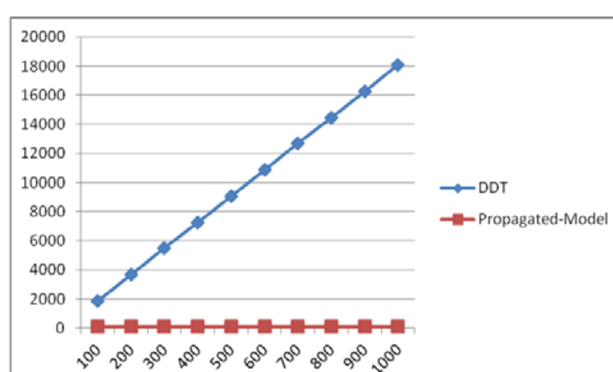

Fig. 8 Mapping latency

We can conclude that the latency from proposal scheme is reduced significantly compare to the original LISP-DDT Map Request Process. We assume the parameter values to analyze the mapping latency as in Table 4. The result show in Figure 8 Mapping Latency again demonstrates the good result from proposed scheme.

5. Conclusions

LISP is a routing architecture that implements a new semantic for IP addressing to solve current internet routing issues. LISP provides scalability and flexibility to adapt with the rapid increase of internet users. With LISP, the mapping system plays an important role in network performance. Although there are many proposed mapping systems, the best current candidate is LISP-DDT. However, its Map Request process can result in high latency for mapping systems. Our proposal, the Propagated-Mode, can avoid this issue by propagating the Map Request to acquire quick response to EID-to-RLOC mapping requests.

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References

[1] D. Farinacci, V. Fuller, D. Meyer, and D. Lewis, "The Locator/ID Separation Protocol (LISP)", IETF, RFC 6830, Jan. 2013.

[2] D. Farinacci, V. Fuller, D. Meyer, and D. Lewis, "Locator/ID Separation Protocol Alternative Logical Topology (LISP+ALT)", IETF, RFC 6836, Jan. 2013.

[3] L. Mathy and L. Iannone, "LISP-DHT: Towards a DHT to map identifiers onto locators", in ReArch, Dec. 2008.

[4] S. Brim, N. Chiappa, D. Farinacci, V. Fuller, D. Lewis, and D. Meyer, "LISP-CONS: A Content distribution Overlay Network Service for LISP", IETF, draft-meyer-lisp-cons-04, Apr. 2008, work in progress.

[5] E. Lear, "NERD: A Not-so-novel EID to RLOC Database", IETF, draftlear-lisp-nerd-04, Apr. 2008, work in progress.

[6] V. Fuller, D. Lewis, V. Ermagan, A. Jain, "LISP Delegated Database Tree", IETF, draft-ietf-lisp-ddt-01, Mar. 2013, work in progress.

[7] J. N. Chiappa, "An Architectural Perspective on the LISP Location-Identity Separation System", IETF, draft-ietf-lisp-architecture-00, Oct. 2012, work in progress.

[8] Lor´ and Jakab, Albert Cabellos-Aparicio, Florin Coras, Damien Saucez, and Olivier Bonaventure, "LISP-TREE: A DNS Hierarchy to Support the LISP Mapping System", IEEE journal on Selected Area Communications, vol. 28, no. 8, October 2010.

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