NEMO-based Mobility Management in LISP Network

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***Abstract*—Extending the basic Locator Identifier Separation Protocol (LISP), LISP-MN has been proposed to support mobility. However, LISP-MN only supports host-based mobility, and has some limitations in network mobility scenario. With the number of mobile nodes (MNs) as a group roaming among different network domains becoming larger, the signaling overhead in the system linearly increases. In this paper, we propose a NEtwork MObility supported scheme in LISP network (NEMO-LISP). In NEMO-LISP, a Mobile Router (MR) is introduced instead of a group of MNs to implement the registration and handover processes. Numerical performance analysis results show that NEMO-LISP can significantly reduce signaling overhead in the system than the existing LISP mobility scheme.**

Keywords—LISP; network mobility; handover; signaling overhead

I. INTRODUCTION

Locator Identifier Separation Protocol (LISP) [1] has received much attention in recent years. In LISP, current IP address spaces are divided into Endpoint Identifiers (EIDs) and Routing Locators (RLOCs). EIDs represent addresses of hosts, which are used as source and destination addresses of hosts. RLOCs represent locators, which are the addresses of Ingress Tunnel Router (ITR) and Egress Tunnel Router (ETR). To support mobility, a LISP based host mobility scheme named LISP-MN [2] has been proposed, in which mobile node (MN) is equipped with a light-weight Tunnel Router (TR) functionality. However, LISP-MN scheme is inefficient when a large number of MNs roam as a group in different network domains. Since each MN in the group should separately register or handle the mobility event in the system. Therefore, the signaling overhead between the ITR/ETR and Map-Server becomes larger at the same time [3].

The concept of network mobility is first proposed to address the scenario of group mobility in [4]. In [4], a mobile router is introduced in NEMO as a gateway device for a mobile network to provide mobility management for mobile nodes that attach to it. Since then, many network mobility schemes such as [5], [6], [7], have been proposed to address the network mobility issue based on different mobility management protocols, such as MIPv6 [8], PMIPv6 [9], DMM [10]. LISP is considered as an important alternative proposal for the next generational Internet standard. However, as far as we know, there is no work on extending LISP to support network mobility. Furthermore, existing mobility schemes cannot be easily and directly transplanted to support network mobility in LISP.

To provide network mobility in LISP, in this paper, we propose a NEtwork MObility supported scheme in LISP network named as NEMO-LISP. In our scheme, a Mobility Router (MR) is introduced instead of a group of MNs to implement the registration and handoff processes separately. In NEMO-LISP, a group of MNs can efficiently use a single message exchange to handover from one network domain to another with the help of MR.

The rest of this paper is organized as follows. Section II provides a brief overview of LISP and LISP-MN. Section III describes NEMO in LISP network. Section IV gives the detail of our proposed NEMO-LISP scheme. Section V establishes a numerical analysis model to analyze the existing LISP-MN and NEMO-LISP in terms of signaling overhead for registration and handover processes. Section VI we give the numerical result according to signaling overhead analysis. Section VII concludes this paper.

II. OVERVIEW OF LISP AND LISP-MN

LISP is an experimental architecture standardized by IETF in [1], which separates the IP address space into EIDs and RLOCs. Each host is assigned at least one EID address that is routable only in its local LISP domain. While each ITR/ETR is assigned one globally unique routable address which is called RLOC. To achieve this separation in LISP, a Map-Server is used to maintain the EID-to-RLOC mappings, which for ITR to implement mappings lookup to determine the data routing path to the ETR. Then ITR encapsulates the packets with RLOC as out-header and tunnels them through the Internet to the destination ETR. The ETR decapsulates data packets and then forwards them to destination node using EID which is locally routable.

LISP-MN [2] is an extension of LISP to support host-based mobility. In order to support mobility, except stationary EID configured from the first attached ITR, MN should be allocated with two addresses by every subsequently attached ITR: a locally routable address (LLOC) and a globally routable address (RLOC). LLOC is allocated from the EID prefix pool of MN current attached ITR, while RLOC is current attached ITR's address. In LISP-MN, a Map-Server is also required to maintain the EID-to-LLOC and LLOC-to-RLOC mappings, with which ITR implements query of mappings to determine

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routing path to the ETR [7]. We further give two basic phases about LISP-MN: registration and handover process.

The Registration Processs

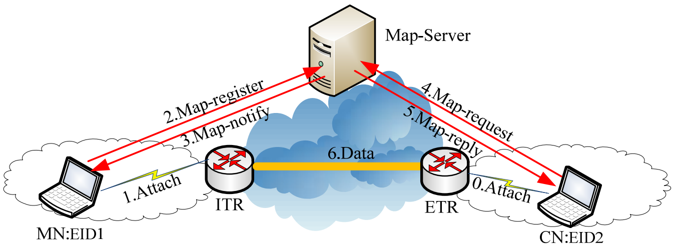

Fig.1. LISP-MN registration process

Fig.1 demonstrates the registration operation in LISP-MN. MN resides in ITR domain and configures its address EID1. We define in this phase that ITR domain address is RLOC1 and ETR domain address is RLOC2. When MN attaches to an ITR, MN is assigned a LLOC from ITR domain's EID prefix pool (Step1). Then, MN executes Map-register to Map-Server and adds an entry of the EID1-to-LLOC mapping to its database (Step 2). After receiving the Map-register message, Map-Server caches the mapping of EID1-to-LLOC and replies a Map-notify message to MN (Step 3). When CN sends packets to MN, CN first sends a Map-Request message to Map-Server to find the RLOC of MN according to destination EID1 (Step 4). After Map-Server finds out MN's RLOC1, Map-Server responds a Map-reply message with MN's RLOC1 to CN (Step 5). Finally, CN can communicate directly with MN (Step 6).

The Handover Processs

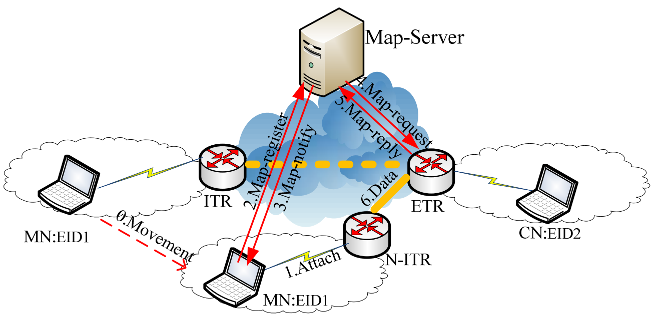

Fig.2. LISP-MN handover process

Fig.2 shows the inter-domain handover process in LISP-MN. It is assumed that MN moves from an ITR domain to a new ITR (N-ITR) domain during data transmission with CN (Step 0). After handover, MN attaches to N-ITR and configures the same address EID (EID1) as before. MN is allocated a new LLOC (N-LLOC) from N-ITR's EID prefix (Step1). Then MN registers to Map-Server to update EID1-to-(N-LLOC) mapping in Map-Server (Step2, 3). In addition, Map Request/Reply messages exchanging between ETR and Map-Server will make ETR update the database (Step 4, 5). Finally, CN can keep on corresponding with MN after handover (Step 6).

III. NEMO Support in LISP Network

The development of the Next Generation Mobile Network (NGMN) has supported the ubiquitous communications experience [11]. Meanwhile, there is a gradually increasing trend for communication services for being accessed by travelling on transportation systems, such as all MNs in busses, trains and airplanes, leading to extensive group mobility scenarios. Therefore, a lot of researches [12] have proposed a group of users moving from one domain to another on some sort of transportation as network mobility scenario.

When applied LISP-MN scheme in the scenario that a group of MNs register and handover in LISP network, each MN in the mobile group accesses to the ITR individually. After many pairs of Map-register/notify exchange between each MN and Map-Server, all MNs complete registration processes. In the handover phase, MNs in a group move from an ITR domain to a N-ITR domain. Each MN implements attachment and registration processes individually in N-ITR. The handover of large amount of MNs at approximately simultaneous time results in large signaling overhead.

To solve these problems, we proposed a NEtwork MObility supported scheme in LISP network, named as NEMO-LISP. A new network device Mobile Router (MR) is introduced for the group of MNs to implement the registration and handover processes and these processes are transparent to MNs. Thus, the registration and handover signaling overhead can be greatly reduced. Assume that the number of MNs is N. The signaling overhead of our NEMO-LISP scheme is nearly 1/N times compared to LISP-MN scheme to support network mobility, which has a significant advantage when N is large.

IV. Our Proposed NEMO-LISP Scheme

In this section, In order to provide the support of network mobility in LISP network, we propose a new scheme named NEMO-LISP. In which, we introduce Mobile Router (MR), a new network entity equipped with a light-weight Tunnel Router (TR) function to implement registration and handover processes on behalf of the whole group of MNs. MR helps those MNs attach to the new ITR (N-ITR) and incur N-ITR to update mappings from Map-Server with only single Map-Register message. Then, complete data packets communicating process between MN and CN will be demonstrated in detail.

A. Registration in NEMO-LISP

In the proposed NEMO-LISP, we assume that MN and CN with different EID addresses are located in different mobile network domains. The new introduced MR functions as tunnel router for a group of MNs and the address of MR will be used as LLOC for MNs. In addition, MR will maintain EID-to-LLOC mapping and encapsulate or decapsulate data packets to forward to the next hop. Meanwhile, ITR with address RLOC should maintain mappings of LLOC-to-RLOC. Map-Server stores both EID-to-LLOC and LLOC-to-RLOC mappings in its database. This database can be referred by ETR of CN to find out the destination RLOC of MN. Then ETR encapsulates data packets with the RLOC address and forwards them to MN. The NEMO-LISP registration architecture is shown in Fig.3.

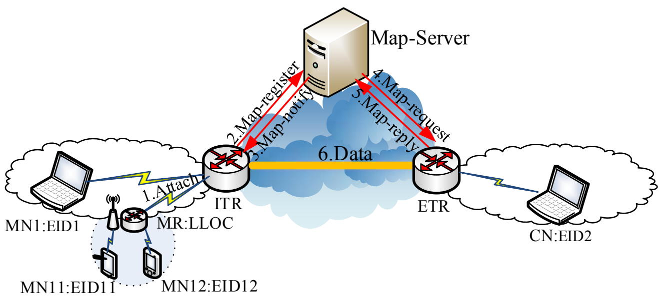

Fig.3. NEMO-LISP Registration Architecture

a) MN's Attachment and Registration

Fig.3 shows a group of MNs' attachment and registration operations in NEMO-LISP scheme. A group of MNs reside in the MR with address LLOC and correspond with CN in another ETR domain. MNs register in MR and are assigned different addresses. For example in Fig.3, two MNs in a group are separately assigned with EID11 and EID12. After this, MR stores the mappings of EID11-to-LLOC and EID12-to-LLOC. MR and its attaching MNs attach to ITR with address RLOC1. Then ITR will store two types of mappings, one is EID-to-LLOC, another is LLOC-to-RLOC (Step 1). ITR with its cached two types mappings register to Map-Server. Map-Server stores the mappings of EID11-to-LLOC with flag "1" and EID12-to-LLOC with flag "0" into its database as shown in TABLE 1 (Step 2, 3).

TABLE 1
EID-TO-RLOC MAPPINGS IN MAP-SERVER

EID	RLOC	FLAG
EID2	RLOC2	0
LLOC	RLOC1	0
EID11	LLOC	1
EID12	LLOC	1
…	…	…

Here, we define that the flag with the values "0" and "1" is used to distinguish two types of mappings. The flag "0" represents the mapping with globally routable capability while the flag "1" represents the mapping only with locally routable capability. Thus ETR of CN sends a Map-request message to Map-Server to find out LLOC-to-RLOC1 with flag "0". After finding it, Map-Server replies a Map-reply message to ETR with the address RLOC1 (Step 4, 5). In this time, CN can directly communicate with MN11 (Step 6).

b) Data Packets Transmission

The details of data flow during a group of MNs attaching to LISP domain and communicating with CN is shown in Fig.4. As an example, we consider the scenario when CN sending data packets to MN11. First, after MR with its inner-domain MNs completes attachment and registration processes as Fig.3 illustrated. Then, Map-Server stores these mappings into its database as TABLE 1 shown.

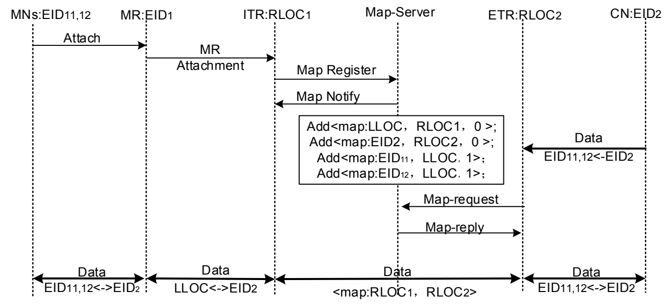

Fig.4. the message flow of data transmission

In summary, when a packet egress a LISP site from CN destined for MN11, the following communicating sequence occurs:

1) CN with address EID2 sends data packets to MN11 with address EID11. These data packets will first arrive at ETR of CN.

2) ETR first looks up its caches to find out mappings whether it has the mapping entry of EID11's globally routable address. If not, this ETR will further send a Map-request message to Map-Server.

3) Map-Server executes *Dual-query* process in its database: *The first query*, Map-Server takes EID11 as searching index. This query result is EID11-to-LLOC mapping with flag "1", without globally routable capacity. *The second query*, Map-Server takes the LLOC as searching index. The query result is LLOC-to-RLOC1 mapping with flag "0", with globally routable capacity. Thus, Map-Server will send a Map-reply message to ETR with EID11 globally routable address RLOC1.

4) ETR encapsulates data packets with an out-header. The inner-header contains source address EID2 and destination address EID11, while the out-header includes source address RLOC2 of ETR and destination address RLOC1of ITR. Data packets will be routed to ITR domain with RLOC1.

5) When these data packets arrive at ITR domain, ITR first decapsulates the out-header of these data packets. Then ITR looks up its caches with MN11 address EID11 to find out mapping of EID11-to-LLOC and forwards it to MR.

6) When data packets arrive at MR, data will be directly sent to MN11.

B. *Handover in NEMO-LISP*

The handover process in NEMO-LISP is illustrated in Fig.5. The link-layer information defined IEEE 802.21 [13] is used in NEMO-LISP handover control. One of primary design consideration of this architecture is that MN and CN are located in different network domain. When MR with a group of mobile nodes moves together between one ITR domain and another new ITR (N-ITR) domain, inter-domain mobility management process takes place.

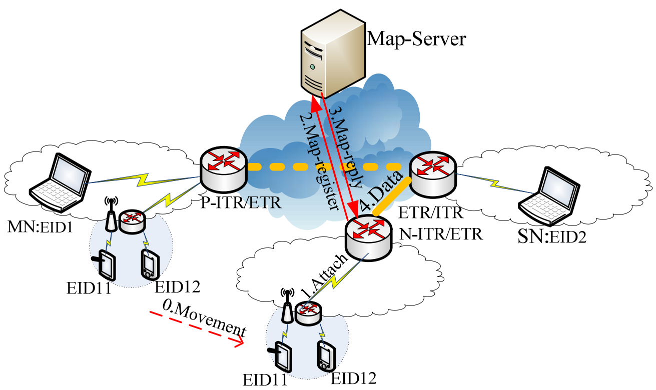

Fig.5. NEMO-LISP handover architecture

a) Handover Process in NEMO-LISP

Fig.5 shows the handover process in NEMO-LISP. We assume that MR with its inner-domain two MNs move from ITR to N-ITR (Step 0). By handover, N-ITR updates its caches after MR's link-layer trigger and adds three entries such as LLOC-to-RLOC3, EID11-to-LLOC and EID12-to-LLOC (Step 1). Then Map-register and Map-notify messages are exchanged between N-ITR and Map-Server. In addition, Map-Server will update its database and only modify one entry LLOC-to-RLOC3 (Step 2, 3).

We propose a mechanism that combines Map-Versioning [14] and data-Driven SMRs mechanism [2] to update corresponding ETR mappings. Map-Versioning is standardized by IETF in RFC6834 which is based on associating a version number to EID-to-RLOC mappings and such a number in header of LISP-encapsulated data packets. TR can detect the expired version number of its receiving encapsulated data packets and then trigger to send an SMR procedure to corresponding TR to update newest mappings.

According to link-layer trigger after handover, ITR and N-ITR can detect mobile nodes' leaving and attaching and then update the mappings with newly obtained RLOC. Meanwhile, Data packets between CN and MNs during handover time arriving at ITR. Then ITR decapsulates these packets and detects the expired map-version number. This process will trigger the SMR procedure to update newest mapping from Map-Server. After updating, CN can directly communicate with MNs (Step 4). The newest version EID-to-RLOC mappings in Map-Server are shown in TABLE 2.

TABLE 2
EID-TO-RLOC MAPPINGS IN MAP-SERVER

EID	RLOC	FLAG
EID2	RLOC2	0
LLOC	RLOC3	0
EID11	LLOC	1
EID12	LLOC	1
…	…	…

b) Data Packets Transmission

The details of data flow during a group of MNs moving from ITR with the address RLOC1 domain to N-ITR domain with the address RLOC3 is shown in Fig.6. After the handover process, we consider the scenario that CN sends data packet to MN11 as an example. First, MR with its inner-domain MNs completes handover and registration procedure as Fig.5 described.

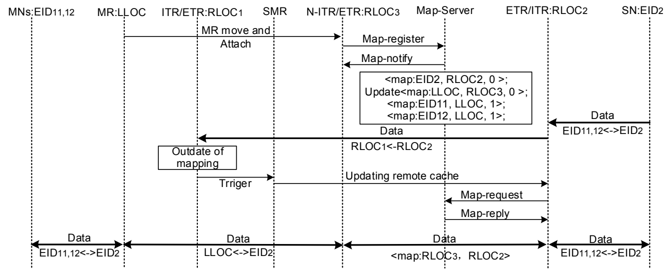

Fig.6. the message flow of data transmission

After handover, the mapping versions in Map-Server have been updated. When a packet egress a LISP site from CN destined for MN11, the following communicating sequence occurs:

1) CN with address EID2 sends data packets to MN11 with address EID11. These data packets will first arrive at ETR of CN.

2) According its locally caches, ETR encapsulates data packets with an out-header. The inner-header contains source address EID2 and destination address EID11, while the out-header includes source address RLOC2 of ETR and destination address RLOC1of ITR. Data packets will be routed to ITR domain with RLOC1.

3) When these data packets arriving at ITR domain, ITR decapsulates data packets with out-header and finds the expiration of Map version over these data packets compared with the current Map version. This procedure will trigger the SMR procedure to make ETR to update its mappings from Map-Server.

4) After receiving Map-request from ETR, Map-Server executes Two-Times query process in its database: *The first query*, Map-Server takes EID11 as searching index, the query result is EID11-to-LLOC with flag "1" without globally routable capacity. *The second query*, Map-Server takes the found LLOC as searching index. The query result is LLOC-to-RLOC3 with flag "0" with globally routable capacity. Thus, Map-Server will send Map-reply message to ETR with EID11 globally routable address RLOC3.

5) ETR encapsulates data packets with an out-header. The inner-header contains source address EID2 and destination address EID11, while the out-header includes source address RLOC2 of ETR and destination address RLOC3 of N-ITR. Data packets will be routed to N-ITR domain with RLOC3.

6) When these data packets arriving at N-ITR domain, N-ITR first decapsulates the out-header of these data packets. The source and destination address become EID2 and EID11. Then N-ITR looks up its caches with MN11 address EID11 to find out mapping of EID11-to-LLOC and forwards it to MR.

7) When data packets arrive at MR, data will be directly sent to MN11.

V. Numerical Signaling Overhead Analysis

In this section we give an overhead comparison between LISP-MN and NEMO-LISP schemes in the registration and handover processes.

A. Assumptions, Parameters and Overhead definitions

We assume a bidirectional communication model between CN and MNs. The handover signaling overhead is one of the major considerations for mobility management due to the expensive wireless bandwidth consumed by signaling overhead and resulting delay. We will calculate the average overhead required for registration cost and the binding update with Map-Server and map updating after handover. The main parameters used in the numerical analysis are listed in TABLE 3.

TABLE 3
Parameters Used In Numerical Analysis

Symbol	Description
$C_{s\text{-}d}$	The cost of delivery of a single a packet from source node to destination node
C_P	Per hop control (e.g. Map-register, Map-notify, Map-request and Map-reply) message transmission cost
C_U	The cost of node processing mapping update
C_L	The cost of node processing mapping lookup
N_{MR}	Number of active MR in the LISP domain
N_{MN}	Number of active MN in the LISP domain
$L_{s\text{-}d}$	Hops between node source and destination node in the networks
α	Unit cost of mapping update with Map-Server
β	Unit cost of mapping lookup in Map-Server
T_{MD}	Delay of movement detection
T_{AC}	Delay of address configuration
T_{L2}	Delay of link-layer switching

B. LISP-MN Signaling Overhead Analysis

1) Registration Signaling Overhead

Applying LISP-MN, MN registers at ITR in LISP network. The registration signaling consists of the messages of Map-register and Map-notify. MN obtains LLOC address which cost T_{AC}. After that, MN performs Map-register with Map-server, which takes $2L_{MN\text{-}Server}\times C_P$ and C_U, where $C_U=\alpha\log N_{MN}$, $C_P=\beta\log N_{MN}$ in [15]. Therefore, the registration signaling overhead of a group of MNs can be expressed as $C_{LISP\text{-}MN}^{reg}$:

$$C_{LISP\text{-}MN}^{reg}=N_M\times(T_{AC}+2L_{MN\text{-}Server}\times C_P+N_{MN}\times C_U) \qquad (1)$$

Here, we assume that CN sends data packet to MN. At first, Map-request/reply messages between CN and Map-Server cost $2L_{CN\text{-}Server}\times C_P$ and cost C_L to find the destination mappings. Therefore, CN costs $C_{LISP\text{-}MN}^{lookup}$ in querying can be expressed as:

$$C_{LISP\text{-}MN}^{lookup}=2L_{CN\text{-}Server}\times C_P+C_L \qquad (2)$$

2) Handover Signaling Overhead

In LISP-MN, MN's handover process can be divided into link-layer handover cost (T_{L2}), movement detection (T_{MD}). A group of MNs handover from ITR to N-ITR cost $N_{MN}\times(T_{L2}+T_{MD})$. Map-register/Reply messages exchange between MN and Map-Server cost $N_{MN}\times(2L_{MN\text{-}Server}\times C_P)$ and $N_{MN}\times C_U$. Therefore, the handover signaling overhead of a group of MNs can be defined as $C_{LISP\text{-}MN}^{handover}$:

$$C_{LISP\text{-}MN}^{handover}=N_{MN}\times(T_{L2}+T_{MD})+N_{MN}\times(2L_{MN\text{-}Server}\times C_P)+N_{MN}\times C_U \qquad (3)$$

During handover, data packets are continuously communicating between CN and MNs. To maintain data continuous, CN should update its mappings to newest mappings from Map-Server. This process costs $2L_{CN\text{-}Map\text{-}Server}\times C_P$ and costs C_U to update its mappings. Therefore, CN updates its mapping after MNs' handover defined as $C_{LISP\text{-}MN}^{update}$ can expressed as:

$$C_{LISP\text{-}MN}^{update}=2L_{CN\text{-}Map\text{-}Server}\times C_P+N_{MN}\times C_U \qquad (4)$$

C. NEMO-LISP Signaling Overhead

1) Registration Signaling Overhead

Applying NEMO-LISP, MR registers at ITR domain instead of a group of MNs. The registration messages consist of Map-register and Map-notify. MR configures its LLOC address which cost T_{AC}. After that, MR performs Map-register with Map-Server, which takes $2(L_{MN\text{-}Server}-1)\times C_P$ and $N_{MN}\times C_U$, Where $C_U=\alpha\log(N_{MR}\times N_{MN})$, $C_P=\beta\log(N_{MR}\times N_{MN})$. Therefore, the registration signaling cost $C_{NEMO\text{-}LISP}^{reg}$ can be expressed as:

$$C_{NEMO\text{-}LISP}^{reg}=N_{MN}\times T_{AC}+2(L_{MN\text{-}Server}-1)\times C_P+N_{MN}\times C_U \qquad (5)$$

In addition, CN costs $C_{NEMO\text{-}LISP}^{lookup}$ in querying can be expressed as same as LISP-MN:

$$C_{NEMO\text{-}LISP}^{lookup}=2L_{CN\text{-}Server}\times C_P+C_L \qquad (6)$$

2) Handover Signaling Overhead

In NEMO-LISP, MR completes handover from ITR to N-ITR instead of a group of MNs. After handover, MR's address LLOC and MNs' addresses EIDs keep the same with in ITR. Therefore, MR only updates its address to Map-Server to modify the mapping LLOC-to-RLOC1 to LLOC-to-RLOC3. This process costs $C_{NEMO\text{-}LISP}^{handover}$ can be defined as:

$$C_{NEMO\text{-}LISP}^{handover}=T_{L2}+T_{MD}+2(L_{MN\text{-}Server}-1)\times C_P+C_U \qquad (7)$$

During handover, data transmission is continuously communicating between CN and MNs. To maintain data continuous, we utilize a mechanism that combines Map-versioning and data-Driven SMRs to update its mappings. This procedure costs $2L_{CN\text{-}N\text{-}ITR}\times C_P$ and costs C_U to update its mappings. Therefore, CN's map updating after handover defines as $C_{LISP\text{-}MN}^{update}$ can expressed as:

$$C_{NEMO\text{-}LISP}^{update}=2L_{CN\text{-}N\text{-}ITR}\times C_P+C_U \qquad (8)$$

Therefore, substituting equal (1), (2), (3) and (4), we can obtain the total overhead about LISP-MN. Meanwhile, substituting equal (5), (6), (7) and (8), we can obtain the total overhead about NEMO-LISP scheme.

VI. NUMERICAL RESULT

In this section, we present some numerical results to evaluate the above mentioned numerical signaling overhead analysis. Now, we compare the numerical result between LISP-MN and our proposed NEMO-LISP. For analysis, the default values [15] of parameters in cost expressed are set as TABLE 4. Among these parameters in TABLE 4, we note that N_{MN} may depend on various conditions of mobile network domain. Thus, we will modify and compare the performance of two LISP scheme by varying N_{MN} parameter value.

TABLE 4
PARAMETERS USED IN NUMERICAL ANALYSIS

Symbol	α	β	T_{MD}	T_{AC}	T_{L2}	$L_{MN\text{-}Server}$	N_{MR}
Cs-d	3	2	10ms	150ms	50ms	20	1

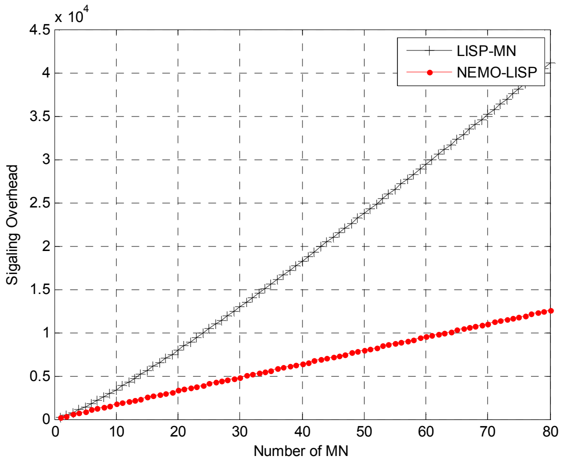

Fig.5. Impact of the Number of MN on Signaling Overhead

Fig.5. shows the impact of the number of MNs in MR on signaling overhead, from which we can see that the signaling overhead of both LISP-MN and NEMO-LISP scheme will be affected by N_{MN}. Meanwhile, NEMO-LISP will bring a better performance in comparison with the existing LISP-MN when a group of MNs attaching and roaming in networks. In NEMO-LISP, these MNs only need to register once by MR. However in LISP-MN, every MN have to register in ITR domain by itself. As a consequence our proposed NEMO-LISP scheme can reduce the larger degree of signaling overhead.

VII. CONCLUSION

In this paper, we present a NEMO-LISP scheme to solve network mobility in LISP networks. In our scheme, MR is introduced instead of a group of MNs to implement registration and handover phrases. With the help of MR, a group of MNs can efficiently use only one single message to register and handover in the Internet. From the numerical signaling overhead analysis, our proposed NEMO-LISP brings better performance compared to the existing LISP-MN when a group of MN roams in networks. In conclusion, NEMO-LISP scheme can be more efficient method for network mobility within LISP networks. In future work, we will implement a platform with our NEMO-LISP scheme to solve network mobility in LISP networks.

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