Network-Based Distributed Mobility Control in Localized Mobile LISP Networks

Moneeb Gohar and Seok Joo Koh

Abstract—**In Locator-Identifier Separation Protocol (LISP), the existing mobility control scheme is based on a centralized approach, in which the Map Server is used as a mobility anchor. However, such a centralized scheme has some limitations, including traffic overhead at central server, service degradation by a single point of failure, and larger handover delay. In this Letter, we propose a network-based distributed mobility control in localized mobile LISP networks. From numerical analysis, it is shown that the proposed distributed scheme can provide better performance than the existing centralized scheme in terms of the signaling loads for binding update/query and the handover delay.**

Index Terms—**LISP, mobility, distributed control, analysis.**

I. Introduction

The Locator Identifier Separation Protocol (LISP) [1] was proposed, which gives a lot of scaling benefits by separating the current IP addresses for Endpoint Identifiers (EIDs) and Routing Locators (RLOCs). To support the LISP mobility, a host-based scheme was proposed, LISP-MN [2], in which each mobile node (MN) implements the Tunnel Router (TR) functionality. This scheme is based on a centralized approach by using Map Server (MS) [3] as a mobility anchor. However, such a centralized scheme has some limitations. As the number of MNs increases, the overhead of MS gets larger, since all of the messages are delivered by way of the central MS. Moreover, the centralized scheme is subject to the services degradation by a single point of failure [4].

In this Letter, we propose a network-based distributed mobility control scheme in localized mobile LISP networks. The proposed scheme can reduce signaling loads for binding update/query and also the handover delay.

The rest of this Letter is organized as follows. In Section II, we review the existing LISP mobility scheme. Section III describes the proposed distributed mobility control scheme. In Section IV, we analyze the existing and proposed schemes in terms of signaling loads for binding update/query and handover delay. Section V concludes this paper.

II. Existing Centralized Mobility Control

In LISP-MN [2], MN implements the TR functionality and MS is used as an anchor point for MN. In this Letter, we consider a variation of LISP-MN, named LISP-MN-LOCAL [5], which was proposed for localized mobility control by introducing Local LOC (LLOC) and Local MS (LMS).

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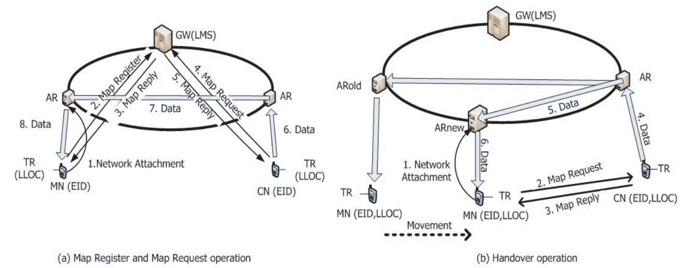

Fig. 1. Existing LISP-MN-LOCAL operations.

Fig. 1(a) shows the Map Register and Request operations of LISP-MN-LOCAL, in which it is assumed that both MN and correspondent node (CN) are within the same mobile network. When MN goes into a new network, it is attached to an Access Router (AR), as described in Step 1. MN shall configure its LLOC by using an IP address configuration. Then, MN sends a Map Register to LMS (Step 2). This LMS may be configured on the gateway (GW) of mobile domain. LMS responds with a Map Reply to MN (Step 3). Now, CN sends a data packet to MN. First, CN sends a Map Request to LMS to find the LLOC of MN (Step 4). LMS responds to CN with a Map Reply, after lookup of its database (Step 5). Now, CN can send the data packet directly to MN (Step 6, 7, 8).

Fig. 1(b) shows the handover operations of LISP-MN-LOCAL. It is assumed that MN moves from AR_{old} to AR_{new} during data transmission with CN. By handover, MN is attached to AR_{new} (Step 1). MN/TR shall configure a new LLOC address using IP address configuration. In addition, the Map Request/Reply messages are exchanged between CN and MN to update the new LLOC (Step 2 and 3). Finally, the data packet is forwarded from CN to MN (Step 4, 5, 6).

III. Proposed Distributed Mobility Control

In this section, we describe a network-based distributed mobility control scheme, named LISP-AR-DMC.

A. Assumptions

In this Letter, we focus only on intra-domain mobility control within a mobile domain, since there are various possible scenarios for inter-domain communication. We assume that both CN and MN are located within the same mobile network.

In the proposed scheme, each AR functions as TR and an IP address of AR will be used as LLOC. LMS is not used within the mobile domain. In addition, each TR shall maintain its EID-LLOC cache (ELC) to manage the EID-LLOC mappings for the other hosts in mobile domain, which will be referred to by AR/TR to transmit data packets to the remote hosts in mobile domain. The other functionality follows the LISP [1].

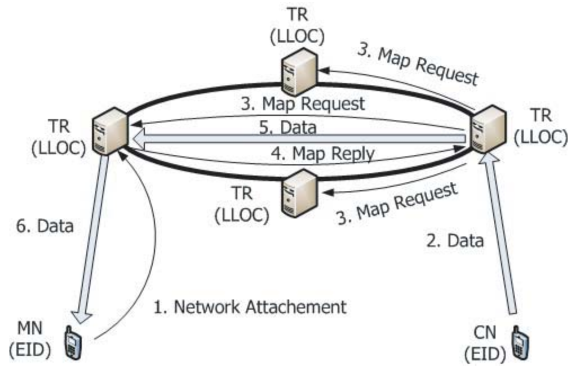

Fig. 2. Map request and data delivery of LISP-AR-DMC.

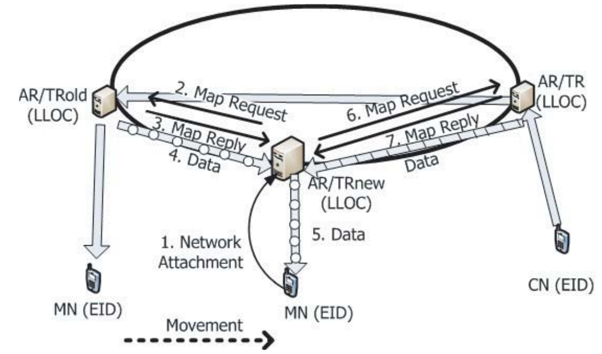

Fig. 3. LISP-AR-DMC handover operations.

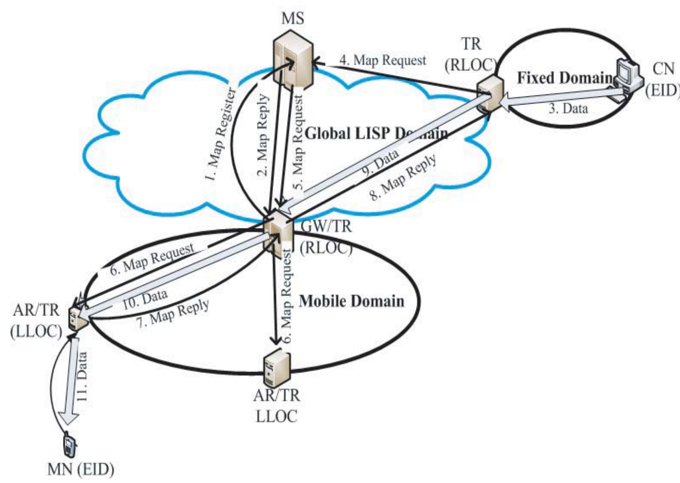

Fig. 4. Interworking with legacy LISP networks.

B. Map Request and Data Delivery

Fig. 2 shows the Map Request and data delivery operations of LISP-AR-DMC. MN is connected to TR (Step 1). Note that the Map Register operation is not performed. CN sends a data packet to MN (Step 2). Then, TR of CN sends a Map Request to all TRs in the mobile domain by multicast to find LLOC of MN (Step 3). In multicast transmission, we assume that all ARs in the domain have already been subscribed to a specific multicast address in the initialization process. We note that this assumption is reasonable because the multicast transmission will be allowed only within the local LISP domain, and all ARs in the domain are under the control of the same network administrator. Only the TR of MN will respond with a Map Reply to TR of CN (Step 4). TR of CN will update its ELC cache and send the data packet to TR of MN (Step 5). Finally, the data packet is forwarded to MN (Step 6).

C. Handover Control

We assume that the link-layer information defined in the IEEE 802.21 is used for handover control. Fig. 3 shows the handover control of LISP-AR-DMC. Before handover, CN is communicating with MN (in AR_{old}). MN is now attached to AR_{new} by handover, and AR_{new} will update its ELC cache for MN (Step 1). AR_{new} can obtain the location of AR_{old} by using the link-layer trigger of IEEE 802.21. It then exchanges Map Request and Map Reply with AR_{old} for handover control (Step 2 and 3). The Map Reply message shall include the mapping information of EID-LLOC for CN, which is recorded into the ELC of AR_{old}. After that, a handover tunnel is established for data forwarding between AR_{old} and AR_{new}. Then, AR_{old} will forward data packets to AR_{new}, and then AR_{new} will forward data packets to MN (Step 4 and 5). Now, AR_{new} sends a Map Request message to AR of CN for route optimization (Step 6). On reception of the Map Request message, AR of CN will update its ELC cache and send a Map Reply to AR_{new} of MN (Step 7). CN and MN will now use the optimized route.

D. Interworking with Legacy LISP Networks

For completion of the proposed scheme, we describe how the proposed scheme can interwork with the legacy fixed LISP networks. For communicating with an external CN, a gateway (GW) will perform the Map Register operation with MS to bind its RLOC, as done in LISP [1]. That is, GW will act as a local mobility anchor to MN. The other operations follow the original LISP.

Fig. 4 shows an example of interworking operations. MN is connected to an AR within mobile network, and GW performs Map Register with MS (Step 1 and 2). Now, an external CN sends a data packet to TR (Step 3). Then, TR of CN sends a Map Request to MS to find the RLOC of MN (Step 4). MS forward the Map Request to GW of MN (Step 5). Then, GW sends a Map Request message to all TRs in the domain by multicast to find LLOC of MN (Step 6). Only the TR of MN will respond with a Map Reply to GW (Step 7). Then, GW will respond with a Map Reply to TR of CN (Step 8). TR of CN forwards the data to GW of mobile domain (Step 9). GW can now forward the data packet to MN (Step 10 and 11).

IV. Numerical Analysis

A. Analysis Model

For analysis, we consider intra-domain movement in localized mobile LISP network. We analyze the signaling loads required for binding update with LMS and for binding query from CN to MN for candidate schemes. We also analyze the delay required for handover from old AR to new AR. Table 1 defines the parameters used for numerical analysis.

B. Signaling Load

We calculate the signaling load as the sum of the loads required for Binding Update (BU) and Binding Query (BQ).

TABLE I
PARAMETERS USED FOR NUMERICAL ANALYSIS

Parameter	Description
T_{a-b}	Transmission cost of a packet between nodes a and b
P_c	Processing cost of node c for binding update or lookup
$N_{Host/AR}$	Number of active hosts per AR
N_{AR}	Number of AR in the mobile LISP domain
H_{a-b}	Hop count between nodes a and b in the network
S_C	Size of a control packet (in byte)
α	Unit cost of binding update with LMS/GW or TR
β	Unit cost of lookup for MN at LMS/GW or TR
T_{AC}	Address configuration delay
T_{MD}	Movement detection delay
T_{L2}	Link switching delay

1) LISP-MN-LOCAL: In LISP-MN-LOCAL, MN shall configure its LLOC, which takes T_{AC}. After that, MN performs Map Register with LMS/GW, which takes $2T_{MN-GW}$ and P_{GW},where $P_{GW}=\alpha \log(N_{AR} \times N_{Host/AR})$ by assuming that P_{GW} is proportional to the total number of hosts in the domain $(N_{AR} \times N_{Host/AR})$ in the log scale by using a tree-based data structure. Accordingly, BU of LISP-MN-LOCAL can be represented as follows.

$$T_{AC} + 2T_{MN-GW} + P_{GW}$$
$$= T_{AC} + S_C \times 2(H_{MN-AR} + H_{AR-GW}) + \alpha \log(N_{AR} \times N_{Host/AR}).$$

The BQ can be calculated as follows. CN sends a Map Request to LMS/GW. Then, LMS/GW looks up the LLOC of MN, which takes $P_{GW} = \beta \log(N_{AR} \times N_{Host/AR})$. LMS/GW replies with a Map Reply to CN, which takes $2T_{CN-GW}$. Thus, we obtain the BQ of LISP-MN-LOCAL as follows.

$$S_C \times 2T_{CN-GW} + P_{GW}$$
$$= S_C \times 2(H_{CN-AR} + H_{AR-GW}) + \beta \log(N_{AR} \times N_{Host/AR}).$$

2) LISP-AR-DMC: In LISP-AR-DMC, no Map Register is performed. Thus, the BU of LISP-AR-DMC will be '0'. The BQ is performed by AR/TR of CN, before transmission of data packet. First, a data packet of CN is delivered to AR of CN. Then, the AR sends Map Request to all ARs by multicast, which takes $T_{AR-AR} \times N_{AR}$. Only the AR of MN responds to AR of CN with a Map Reply after lookup of its EID list, which is equal to $P_{AR}+T_{AR-AR}$. Accordingly, we get the BQ of LISP-AR-DMC as follows.

$$S_C \times T_{AR-AR} \times (N_{AR}+1) + P_{AR}$$
$$= S_C \times H_{AR-AR} \times (N_{AR}+1) + \beta \log(N_{Host/AR}).$$

C. Handover Delay

Let us calculate the handover delay (HD) for each scheme.

1) LISP-MN-LOCAL: The HD of LISP-MN-LOCAL can be divided into link switching delay (T_{L2}), movement detection delay (T_{MD}), address configuration Delay (T_{AC}), Map Request and Map Reply messages between MN and CN ($2T_{MN-CN}$), delay of data between CN and AR (T_{CN-AR}), delay of data between AR and AR_{new} (T_{AR-AR}), and delay of data between AR_{new} and MN (T_{MN-AR}). Then, we get the HD of LISP-MN-LOCAL as follows.

$$T_{L2} + T_{MD} + T_{AC} + 2T_{MN-CN} + T_{CN-AR} + T_{AR-AR} + T_{MN-AR}$$
$$= T_{L2} + T_{MD} + T_{AC} + 3H_{MN-AR} + 3H_{AR-AR} + 3H_{CN-AR}.$$

2) LISP-AR-DMC: The HD of LISP-AR-DMC consists of link switching delay (T_{L2}), movement detection delay (T_{MD}), Map Request and Map Reply messages between AR_{old} and AR_{new} ($2T_{AR-AR}$), delay of data between AR_{old} and AR_{new} (T_{AR-AR}), and delay of data between AR_{new} and MN (T_{AR-MN}). Then, we obtain the HD of LISP-AR-DMC as follows.

$$T_{L2} + T_{MD} + 2T_{AR-AR} + T_{AR-AR} + T_{AR-MN}$$
$$= T_{L2} + T_{MD} + 3H_{AR-AR} + H_{AR-MN}.$$

D. Numerical Results

Based on the cost analysis, we now compare the numerical results. For analysis, the default values of cost parameters are set as follows:α=3,β=2,H_{MN-AR}=H_{CN-AR}=1, $N_{Host/AR}$=1000, N_{AR}=30, H_{AR-GW}=20, $H_{AR-AR} = \sqrt{N_{AR}}$, S_C= 50 bytes, T_{AC}=150 ms, T_{MD}=10 ms, T_{L2} =50 ms which are similar to the values given in [6]. In addition, we define δ as the ratio of H_{AR-AR} over H_{AR-GW} (= H_{AR-AR}/H_{AR-GW}). The default value for δ is 0.2. Among these parameters, we note that $N_{Host/AR}$, N_{AR}, H_{AR-GW}, T_{L2} and T_{AC} may depend on various conditions of mobile network domain. Thus, we will compare the performance of candidate schemes by varying those parameter values.

Fig. 5 shows the impact of $N_{Host/AR}$ (the number of hosts per AR) on signaling load, in which we can see that the signaling loads of LISP-MN-LOCAL and LISP-AR-DMC are not nearly affected by $N_{Host/AR}$. In the meantime, the proposed LISP-AR-DMC gives better performance from the existing LISP-MN-LOCAL, since the proposed scheme can reduce the messages for binding update with Map Register, compared to LISP-MN-LOCAL.

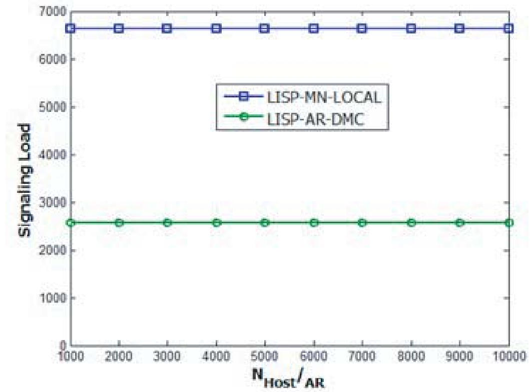

Fig. 5. Impact of the $N_{Host/AR}$ on signaling load.

Fig. 6 shows the impact of N_{AR} on signaling load. In the figure, we see that LISP-AR-DMC depends on N_{AR}, since it uses the multicast transmission for Map Request. However, the

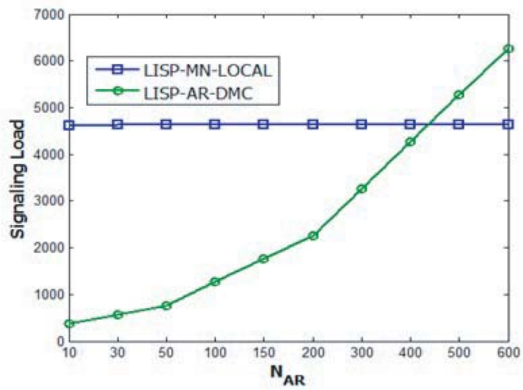

Fig. 6. Impact of the N_{AR} on signaling load.

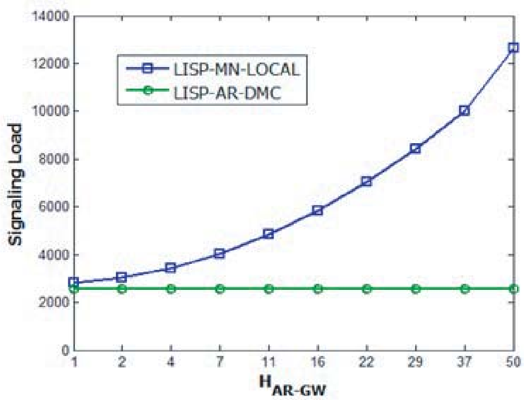

Fig. 7. Impact of the H_{AR-GW} on signaling load.

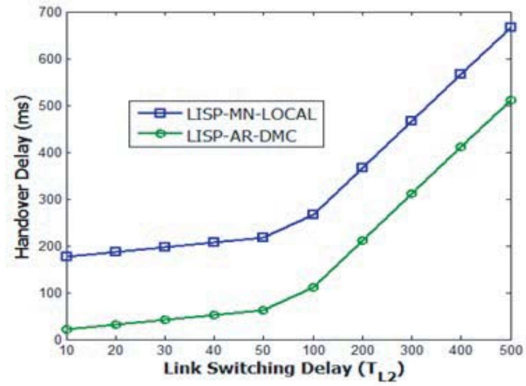

Fig. 8. Impact of link switching delay on handover delay.

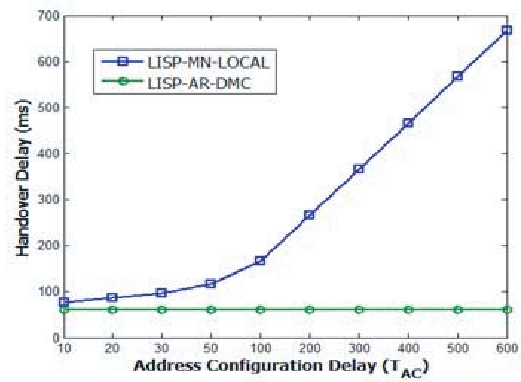

Fig. 9. Impact of address configuration delay on handover delay.

proposed scheme can give better performance than the existing scheme for the mobile networks with N_{AR} of less than 500, which is a reasonable network size in the real world.

Fig. 7 compares the signaling load of candidate schemes for different H_{AR-GW} (hop counts between AR and GW). We can see that H_{AR-GW} gives a significant impact on LISP-MN-LOCAL. This is because LISP-MN-LOCAL uses LMS/GW for binding updates and for binding query. On the other hand, LISP-AR-DMC is not affected by H_{AR-GW}.

The handover delay is depicted in Fig. 8 as a function of the link switching delay (T_{L2}). We observe that the handover delay is proportional to the link switching delay for LISP-MN-LOCAL and LISP-AR-DMC. It is noted that the proposed LISP-AR-DMC outperforms the existing LISP-MN-LOCAL, and the gap of performance gets larger as T_{L2} increases.

Fig. 9 shows the handover delay for different T_{AC}. In the figure, we can see that the proposed LISP-AR-DMC scheme is not affected by T_{AC}, and that the gaps of performance between candidate schemes increase, as T_{AC} get larger.

V. Conclusion

In this Letter, we presented a network-based distributed mobility control scheme, in which each AR implements the TR functionality, and no Map Register is performed within a local mobile network. From the numerical analysis, we see that the proposed LISP-AR-DMC scheme can give better performance than the existing LISP-MN-LOCAL scheme in terms of the signaling load for binding update/query and handover delay, in the mobile network with a reasonable number of ARs.

In conclusion, the proposed LISP-AR-DMC scheme can be used for mobility control within a mobile LISP network, and it can possibly interwork with the legacy LISP networks in the global domain.

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