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LISP-HNM: Integrated Fast Host and Network Mobility Control in LISP networks

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***Abstract*—At present, the well-known LISP-MN protocol for LISP mobility can only support end-host IP mobility, and need to implement lightweight version of LISP's ITR/ETR functionality on mobile nodes. Because of this, the LISP-MN protocol is hard for deployment, and lack of the support for network mobility. In this paper, we present LISP-HNM, a network-based end-host and network mobility support protocol in LISP networks. With LISP-HNM, end-hosts and networks mobility are controlled through the same access register protocol, while the core network provides the fast mobility support with a extensional mapping push operation. All end-hosts and hosts in mobile networks are assigning unchangeable IP addresses regardless of their network attachment points. This paper describes the protocol and presents a modelling performance comparison between LISP-HNM and LISP-MN.**

Keywords—LISP; host mobility; network mobility; LISP-MN

I. INTRODUCTION

Locator/ID Separation Protocol (LISP)[1] is proposed to avoid the semantic overload of IP addresses through decoupling the locator address from the host identifier. In this way, LISP supports mobility more easily than current IP architecture. LISP is a network-based identifier locator split protocol[2], which operates at the network level, usually on the border routers at the core network backbone, and no modifications are required on the end-hosts. However, the LISP-MN[3] proposed to support the mobility of LISP needs to implement lightweight version of LISP's ITR/ETR functionality on mobile nodes, which makes itself quite hard for large-scale deployment.

In this paper, we present LISP-HNM, a network-based end-Host and Network Mobility support protocol in LISP networks. The LISP-HNM consists of an access register protocol and a mapping push operation extension of LISP. The access register protocol is used by independent end-hosts or mobile router (MR) of the mobile network to register to xTR (Ingress/Egress Tunnel Router), end-hosts of the mobile network register to its MR, and to get the routing configuration parameters for data forwarding for both conditions. Meanwhile the access register protocol maintains the access state of end-hosts or MR in the registered xTR, and the access state of end-hosts in the registered MR of the mobile network by keepalive messages. Therefore, if end-hosts or networks moved, xTR or MR can be aware as soon as the keepalive timers timeout. All end-hosts and hosts in mobile networks are assigning unchangeable IP addresses as identifiers regardless of their network attachment point. The modelling performance comparison proves that LISP-HNM outperforms LISP-MN in aspects of mobile handover delay, mobile handover cost and packet drop rate.

The rest of the paper is organized as follows: In Section II, related works of current LISP mobility support protocols are given. In Section III, we describe the LISP-HNM scheme in detail. In Section IV, we illustrate the neutral accessing implementation of LISP-HNM. Section V presents the analytic results for performance evaluation. Finally, we conclude the paper in Section VI.

II. RELATED WORKS

LISP-MN supports the end-host mobility by implementing the lightweight version of LISP's ITR/ETR functionality on mobile nodes, such as requesting mapping system (MS), caching mappings and encapsulating/decapsulating data packets. When the mobile node (MN, i.e. end-host) moves and accesses to a new site, MN will register to MS for a new mapping, and update the mapping cache of the old xTR. Meanwhile, MN will announce the new mapping to the corresponding node which is currently communicating with to continue the session. Normally, LISP-MN needs to encapsulate the data of MN twice, while the source EID of the first encapsulation is the unique EID of MN, and the source EID of the second encapsulation, i.e. LLOC, can be dynamically obtained (e.g. DHCP) from the xTR. Above all, the cost of LISP-MN can be very large and have no support for the network mobility yet.

LISP-NEMO[4] proposes a network mobility support scheme which avoids the double encapsulation of LISP-MN. Inspired by the idea of NEMO[5], LISP-NEMO employs mobile router (MR) to manage and represent the mobile network, and the IP address of the interface accessing to the xTR is the LLOC. MR stores the EID-LLOC mapping for data forwarding, while xTR and MS stores two types of mappings, one is EID-to-LLOC, the other is LLOC-to-RLOC. In this way, when MR moves and accesses to another site, MS and xTR can only change the LLOC-RLOC if the end-host constitution of the mobile network does not change. However, the number of mapping lookup of end-host in the mobile network is doubled, which increases the communication cost finally. Meanwhile, since LISP-NEMO uses the expiration scheme of Map version which triggers SMR (Solicit-Map-Request) procedure to update the remote xTR, the handover delay could be large to wait for the coming data packet with old Map version.

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LISP-ROAM[6] also extends the standard LISP to support network-based end-host mobility that allows end-hosts to stay unmodified. Mobility support is provided by some additional/modified network components (e.g. DHCP servers, authentication servers and LISP xTRs) that cooperate to assign always the same IP address regardless of the host network attachment point, even when the user terminal attaches to a different provider. However, the user authentication by 802.1x and IP assignment to keep the same IP address for each end-host would cost more network resources than the constant IP address in our proposal. Meanwhile, since the previous xTR is notified for the end-host mobility only until the map-server receiving a map-register message for a newly adding mapping, the end-host mobility aware time would be very large.

III. LISP-HNM

A. Access Register Protocol

The access register protocol is mainly used for end-hosts and mobile router to interact with xTR to maintain the access state, and for end-hosts to interact with its belonged mobile router to maintain the mobile network constitution. As is shown in Fig. 1, the access register protocol consists of four phases: register phase, update phase, keepalive phase and deregiseter phase. In the first three phases, the register and keepalive operations are performed by five messages, i.e. register request/update/reply messages and keepalive request/reply messages, while the deregister operation is triggered automatically by the timeout event of keepalive timers.

All above five messages are layer-2 messages, and the register request message is broadcast by independent end-hosts/MR to find the available xTR/MR with its EID inside. The register reply message sent by the xTR/MR contains its EID and destines to the access node without broadcast. Meanwhile, xTR/MR will record the access node in the register node information list. If independent end-hosts/MR register to xTR directly, xTR will write the new mapping <EID, RLOC> with the RLOC of this site to its mapping database.

After the register operation succeeds, end-hosts/MR need to send keepalive request message to the xTR/MR to maintain the access state. After receiving the keepalive request message, the xTR will reset the keepalive timers for corresponding end-hosts and mobile router which is responsible for all end-hosts and nested mobile networks in it, and then send the keepalive reply message to confirm its existence as well. If the keepalive timer has timeouted and the xTR does not still received the keepalive request message, the xTR recognizes the mobility of end-hosts or mobile router. The xTR will delete the mapping in the mapping database and execute the mapping update process of LISP.

In addition, if some end-hosts join or leave the mobile network, the mobile router will be aware of these events by new register request messages or keepalive timer timeout, and then the mobile router will send register update message with all EIDs of end-hosts it maintained to xTR to imply the new constitution of the mobile network. And the xTR will send the register reply message to the mobile router for confirmation.

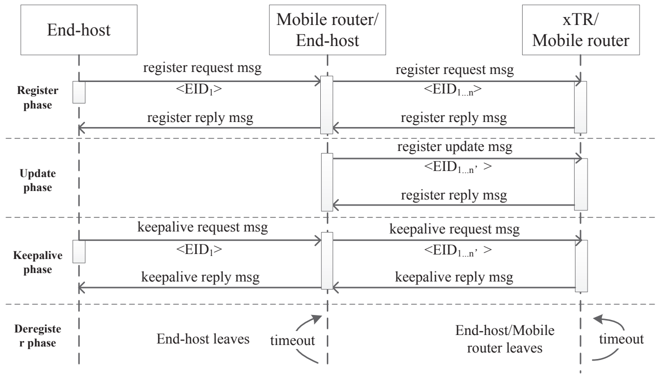


Fig. 1. Access register protocol

B. Active Notification Scheme of LISP

When an end-host or mobile router leaves or joins the xTR, the xTR will be aware of the mobility through the access register protocol and execute the mapping update process to maintain the consistence of the mapping system. In LISP-HNM, the xTR will send the map-register message with all mappings of this site to its belonged map-server, and then the map-server compares the current registered mappings with the old mappings from the xTR to find out the change, and send the changed mapping to the mapping system (i.e. DDT root in OpenLISP) through the map-push message, which is introduced by LISP-HNM. The DDT root will send the map-push message to other map-servers to update the mapping, and the map-server will send the map-push message to all xTRs registered to it and requested for the mapping before for final update. Every xTR receiving the map-push message will update (e.g. add, delete or replace) its mapping cache with new mappings in the message. The mapping update process of LISP-HNM is illustrated in Fig. 2.

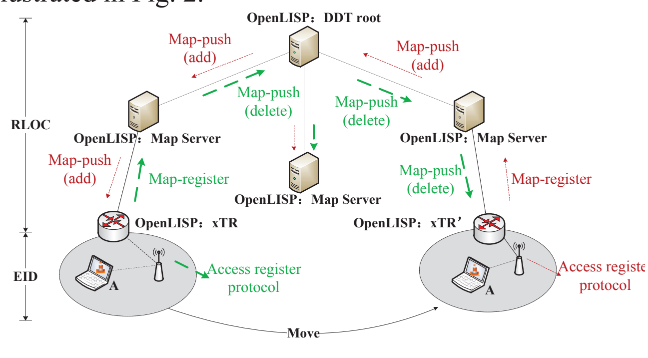


Fig. 2. Mapping update process of LISP-HNM

IV. NEUTRAL ACCESSING IMPLEMENTATION

Neutral accessing is the basic characteristic of LISP to support end-host and network mobility. However, if the neutral accessing function is implemented in current IP based network system, the route configuration is needed. For example, when an end-host with IP address IP_1 192.168.0.1/32 (i.e. its EID) connects to the xTR's interface with IP address IP_2 50.0.0.1/32, the register request message sent by end-host contains IP_1, the register reply message sent by xTR contains IP_2 and the RLOC address of another interface connected to the core network as the routing space. Then end-host will configure two routes for data sending as follow:

"route add -host 50.0.0.1 gw 192.168.0.1"

"route add -net default gw 50.0.0.1"

And the xTR will add a route for data forwarding as follows:

"route add -host 192.168.0.1 gw 50.0.0.1"

Meanwhile, when the end-host or mobile router leaves, according to the access register protocol, the end-host, mobile router and xTR will delete the above routing configurations at the time of keepalive timer timeouts. The routing configurations between end-hosts and MR, and between MR and xTR are processed in the same way.

V. Numerical Analysis of Protocol Overhead

The LISP architecture is shown in Fig.3 and the symbols for numerical analysis are concluded in Table I.

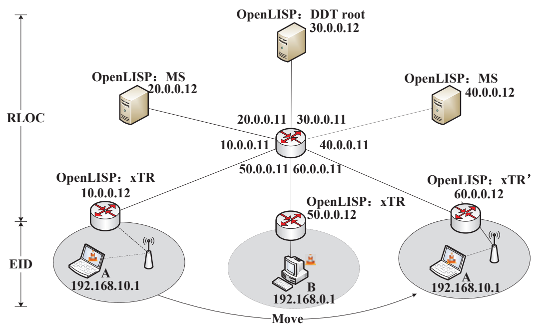


Fig. 3. LISP architecture

TABLE I. Symbols for Numerical analysis

Symbols	Explanation
t_{ho}	overall delay of handover
t_{an}	overall delay of active notification scheme
t_{ll}	link layer handover delay
$T_{keepalive}$	end-host/mobile router keepalive period
$t_{movement}$	end-host/mobile router move time
t_{reg}	delay of end-host/mobile router registering to xTR
t_{au}	delay of xTR sending map-register/map-push msg to MS
t_{dis}	delay of MS distributing map-push msg
t_{up}	delay of xTR processing map-push msg
$H(s, d)$	hops between s and d
t'_{au}	per hop transmission delay of map-resiger/map-push msg
t'_{dis}	per hop transmission delay of map-push msg
t_{lookup}	delay of mapping lookup
t'_{re}	per hop transmission delay of map-request/map-reply msg
C_{ho}	overall signalling overhead of handover
C_{an}	overall signalling overhead of active notification scheme
c_{au}	per hop processing cost of map-register/map-push msg to MS
c_{dis}	per hop processing cost of map-push msg
C_{reg}	signalling overhead of end-host/mobile router registering to xTR
C_{au}	signalling overhead of xTR sending map-register/map-push msg to MS
C_{dis}	signalling overhead of MS distributing map-push msg
C_{up}	signalling overhead of xTR processing map-push msg

A. Mobile Handover Delay

As is shown in Fig.4, the mobility handover delay includes link layer handover delay t_{ll}, delay of end-host/mobile router registering to xTR t_{reg} and the delay of active notification scheme which is composed of three parts: delay of new accessed xTR sending the map-register message to MS t_{au}, delay of MS distributing map-push messages to all xTRs t_{dis} and delay of xTR processing the map-push message t_{up}.

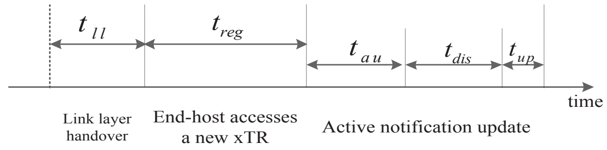


Fig. 4. Illustration of end-host/mobile router handover delay

The overall mobility handover delay is:

$$t_{ho} = t_{ll} + t_{reg} + t_{an} \tag{1}$$

The delay of active notification is:

$$t_{an} = t_{au} + t_{dis} + t_{up} \tag{2}$$

The delay of new accessed xTR sending the map-register message to MS is:

$$t_{au} = t'_{au} \cdot H(xTR_{new}, MS) \tag{3}$$

where $H(xTR_{new}, MS)$ defined in Table I denotes the number of hops between the new xTR and the MS.

The delay of MS distributing the map-push messages to all xTRs:

$$t_{dis} = t'_{dis} \cdot H(MS, xTR_{CN}) \tag{4}$$

From equations(1)~(4)we can get:

$$t_{ho} = t_{ll} + t_{reg} + t'_{au} \cdot H(xTR_{new}, MS) + t'_{dis} \cdot H(MS, xTR_{CN}) + t_{up} \tag{5}$$

Since the handover signalling of mobile network is mainly operated by the mobile router, and the handover procedure of mobile router is similar to that of end-host, the delay analysis given above can also represent the network mobility condition.

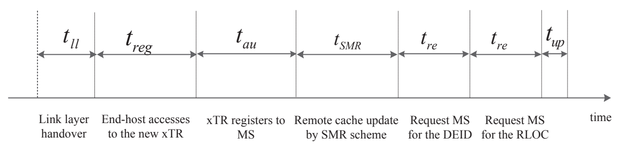


Fig. 5. Illustration of the handover delay of end-host mobility in LISP-MN

In LISP-MN, the end-host and the newly accessed xTR will send the map-register message to MS after the handover is done. However, the mapping of end-host registers to MS is EID-LLOC, while the the mapping of end-host registers to MS is LLOC-RLOC. The LLOC is the EID it gets from the xTR by DHCP. After registering, we assume that end-host notifies the xTR of the corresponding node with SMR message[7] to update the remote cache, and the xTR of the corresponding node will send map-request to MS to get the new mapping of

EID-LLOC. But because the LLOC is not global routable, the corresponding node'xTR will send map-request to MS again to gain the new RLOC. Then, the session between end-host and corresponding node can be continued. The handover delay of end-host mobility in LISP-MN is shown in Fig.5.

From the analysis above, we can get that except for the link layer handover delay t_{ll}, the delay of end-host/mobile router registering to xTR t_{reg}, the handover delay of LISP-MN also includes the mapping register delay, SMR request delay and twice mapping request delay. The mapping register delay is calculated only once because the end-host and xTR can register to MS at the same time after the access procedure. And because the end-host needs to get the map-reply message of the map-register message to send the SMR message, the mapping register delay is the round trip time of $2t_{au}$.

Therefore, the mobility handover delay of LISP-MN is:

$$t_{ho}^{LISP-MN} = t_{ll} + t_{reg} + 2t_{au}^{'} \cdot H(xTR_{new}, MS) + t_{SMR} + 2t_{re}^{'} \cdot H(MN, CN) + 2t_{re}^{'} \cdot H(CN, MS) + t_{up} \quad (6)$$

where t_{SMR} can be calculated as $t'_{re} \bullet H(MN, CN)$. $H(xTR_{new}, MS)$ and $H(CN, MS)$ are all estimated as average network radius, and $H(MN, CN)$ is estimated as average network diameter, which is calculated as follows[8],

$$l = \lceil 0.35 + 2.06 \log_2(N) \rceil$$

where N is the network scale, and the relationship between network scale and network diameter is shown in Table II.

TABLE II. THE VALUE OF NETWORK DIAMETER UNDER DIFFERENT NETWORK SCALE

N	l	N	l	N	l
10	8	10^4	28	10^7	49
10^2	15	10^5	35	10^8	56
10^3	21	10^6	42	10^9	62

The parameters in the analysis are shown in Table III, some of which are introduced from [9].

TABLE III. PARAMETERS FOR THE NUMERICAL ANALYSIS OF MOBILITY HANDOVER DELAY

Parameter	Value
t_{ll}	50ms
t_{reg}	150ms
t'_{au}	0.5ms
t'_{re}	0.5ms
t_{up}	0.3ms
$T_{keepalive}$	150ms

The handover delay comparison of LISP-MN and LISP-HNM is shown in Fig. 6. As the network scale increases, the handover delay of LISP-MN and LISP-HNM increases at the same time, and the increase ratio of LISP-MN is larger than LISP-HNM. When the network scale is 8, the handover delay of LISP-MN is 1.07 times of LISP-HNM. And when the network scale is 56, the handover delay of LISP-MN is 1.49 times of LISP-HNM.

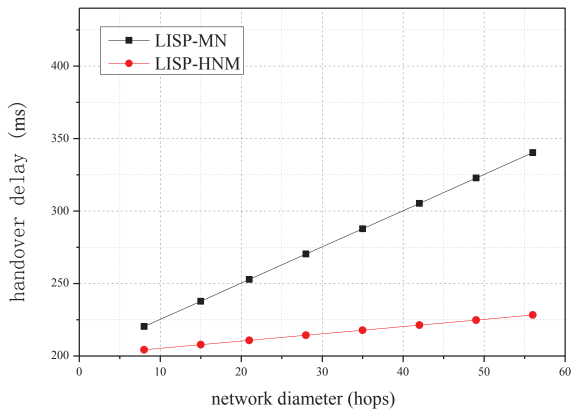


Fig. 6. Handover delay comparison of end-host/mobile router

B. Mobile Handover Overhead

As is described in Section V.A, the handover signalling overhead includes the signalling overhead of end-host/mobile router registering to xTR C_{reg}, overall signalling overhead of active notification scheme C_{an}, which is consist of three parts: the signalling overhead of xTR sending the map-register message C_{au}, the signalling overhead of MS distributing the map-push message C_{dis} and the signalling overhead of xTR processing the map-push message C_{up}. Although the keepalive request/reply message helps the old xTR be earlier aware of the leave of end-host/mobile router, and it is truly useful to optimize the handover delay, however, the cost of sending keepalive request/reply message does not contribute to the handover overhead, so it is not analyzed here.

The overall handover overhead is:

$$C_{ho} = C_{reg} + C_{an} \quad (7)$$

The overall signalling overhead of active notification scheme is:

$$C_{an} = C_{au} + C_{dis} + C_{up} \quad (8)$$

The signalling overhead of xTR sending the map-register message is:

$$C_{au} = c_{au} \cdot H(xTR_{new}, MS) \quad (9)$$

The signalling overhead of MS distributing the map-push message to the xTR of CN is:

$$C_{dis} = c_{dis} \cdot H(MS, xTR_{CN}) \quad (10)$$

From equations(7)~(10)we can get:

$$C_{ho} = C_{reg} + c_{au} \cdot H(xTR_{new}, MS) + c_{dis} \cdot H(MS, xTR_{CN}) + C_{up} \quad (11)$$

Since the handover procedure of mobile router is similar to that of end-host stated above, the overhead analysis of the end-host mobility condition can also represent the network mobility condition.

In LISP-MN, since the network mobility is not supported, the handover overhead of m end-hosts move simultaneously is:

$$C_{ho}^{LISP-MN} = m \cdot (C_{reg} + 2c_{au} \cdot H(xTR_{new}, MS) + C_{SMR} + 2c_{re} \cdot H(MN, CN) + 2c_{re} \cdot H(CN, MS) + C_{up}) \quad (12)$$

where the calculation method of C_{SMR} is equal to $c_{re} \bullet H(MN, CN)$, and C_{up} is calculated as follows[10]:

$$C_{up} = \beta \log(m)$$

The value of rest parameters are shown in Table IV.

The mobility handover overhead comparison between LISP-MN and LISP-HNM is shown in Fig.7. The scale of simultaneously moving end-hosts has seldom effect on LISP-HNM, while affects largely on LISP-MN. This is because in LISP-HNM, the handover overhead of network mobility is almost equal to the handover overhead of end-host mobility, while the the handover overhead of network mobility is almost m times of the handover overhead of end-host mobility in LISP-MN, where m is the number of end-hosts in the network. When a single end-host handovers, the overhead of LISP-MN is 3.08 times of LISP-HNM. When the network scale is 100, the mobility handover overhead of LISP-MN is nearly 199 times of LISP-HNM.

TABLE IV. THE VALUE OF PARAMETERS IN NUMERICAL ANALYSIS FOR MOBILITY HANDOVER OVERHEAD

Parameters	Value
C_{reg}	2
c_{au}	1
c_{re}	1
C_{up}	2
N	1000
$H(xTR_{new}, MS)$	5
$H(MN, CN)$	10
β	2

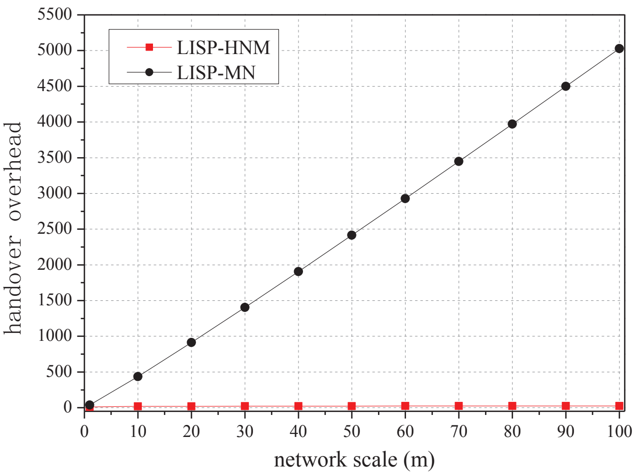


Fig. 7. The mobility handover overhead comparison

C. Packet Drop Rate

There are two conditions to cause the packet dropping:

1) The first packet coming up to xTR

Under this condition, the cache miss event occurs. xTR sends the map-request message to MS and receives back the map-reply message. We assume that all the data packets received during this period and destined to the cache missed EID will be discarded.

The mapping request delay is:

$$t_{lookup} = t'_{re} \cdot (H(xTR, MS) + H(MS, xTR)) \quad (13)$$

Assume that the average flow rate is v MB/s, and the average packet length is δ bytes, so the number of packets per second in the flow is:

$$n' = \frac{v}{\delta} M \quad (14)$$

The number of discarded data packets per second is:

$$n = n' \cdot t_{lookup} = \frac{v}{\delta} M \cdot (t'_{re} \cdot (H(xTR, MS) + H(MS, xTR))) \quad (15)$$

In LISP-MN, it needs to request the MS twice to get the RLOC, so the number of discarded packets is:

$$n^{LISP-MN} = n' \cdot t_{lookup}^{LISP-MN} = \frac{v}{\delta} M \cdot (2t'_{re} \cdot (H(xTR, MS) + H(MS, xTR))) \quad (16)$$

2) The end-host/mobile router handover

From the analysis of Section V.A, we can get that the number of discarded data packets per second is:

$$n = n' \cdot t_{ho} = \frac{v}{\delta} M \cdot ((t_{ll} + t_{reg} + t'_{au} \cdot H(xTR_{new}, MS) + t'_{dis} \cdot H(MS, xTR_{CN}) + t_{up}) \quad (17)$$

The number of discarded data packets per second in LISP-MN is:

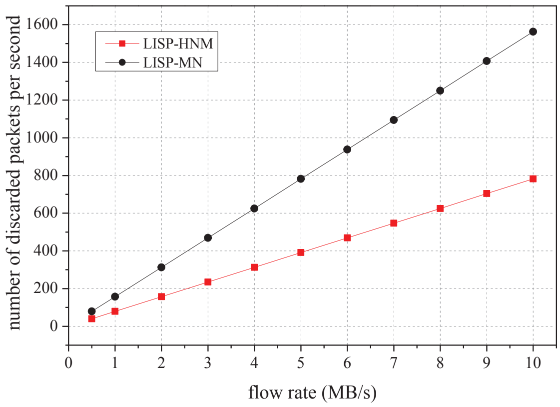
$$n^{LISP-MN} = n' \cdot t_{ho}^{LISP-MN} = \frac{v}{\delta} M \cdot (t_{ll} + t_{reg} + 2t'_{au} \cdot H(xTR_{new}, MS) + t_{SMR} + 2t'_{re} \cdot H(MN, CN) + 2t'_{re} \cdot H(CN, MS) + t_{up}) \quad (18)$$

Part of the value of parameters are shown in Table III, and the rest of them are shown in Table V.

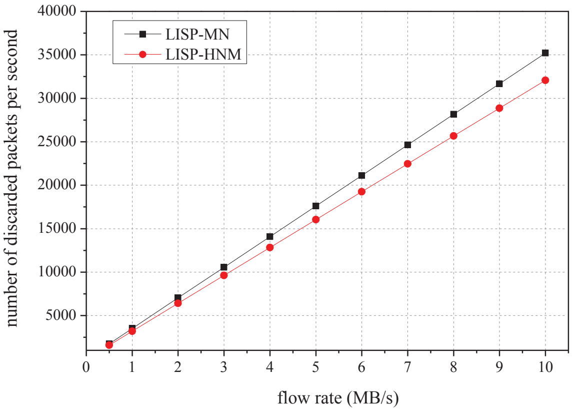
TABLE V. THE VALUE OF PARAMETERS FOR PACKET DROP RATE ANALYSIS

Parameter	Value
δ	64
N	1000

The packet drop rate comparison between LISP-MN and LISP-HNM is shown in Fig. 8. In the condition of mapping request phase caused by cache missed, the packet drop rate of LISP-MN is twice of LISP-HNM. This is because LISP-MN needs to perform two times of mapping request to MS. Under the condition of end-host/mobile router handover, the number of discarded packets of LISP-MN is nearly 1.1 times of LISP-HNM.



(a) Cache miss condition for the first packet coming up to xTR



(b) End-host/mobile router mobility handover condition

Fig. 8. Comparison of packet drop rate

VI. Conclusions

In this paper, a new access register protocol and active notification scheme is proposed to support the end-host and network mobility in LISP networks. The LISP-HNM is theoretically compared with LISP-MN in aspects of mobility handover delay, mobility handover overhead and packet drop rate. Analysis results show that the LISP-HNM outperforms LISP-MN in large network scale, and the handover overhead of network mobility in LISP-HNM is much smaller than LISP-MN under the equal network scale. Meanwhile, the packet drop rate of LISP-HNM is smaller than LISP-MN in all.

Acknowledgment

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