

# A Simple Cost Analysis of Host ID-LOC Separating protocol using SDN Features

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**Abstract** The IP address used in the Internet has the role of both identifier and locator to bind a host and the application, however, this binding restricts some functions such as mobility and multi-homing. As a result, we suggested a host ID-LOC separation protocol using DHT with SDN features. The proposed scheme is a network-based scheme, and uses IPv6 addresses. The underlying network is partitioned into Host Identity domain and IP domain for identifiers and locators. In this paper, we present a simple cost model for analyzing both the proposed scheme and one of the previous works, the MOFI. The result of cost analysis shows better performance of the proposed scheme.

**Key Words** : Cost analysis, ID-LOC separation, Network-based protocol, SDN, IPv6 address

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## 1. Introduction

An Internet Protocol (IP) address is generally represented an address which assigned to most computing devices for connecting to the network and communicating to other devices using Internet Protocol. This IP address serves two kinds of principal functions such as host identification and location addressing. However, these characteristics have some limitations like mobility, multi-homing, and extensibility support. The exponential growth of the mobile devices incurs the node deployment problem, addressing, and scalability problems on the network. Therefore, to solve the problems about addressing, scalable routing, and deployment with mobility support, two functions of IP address have to be separated.

Several proposals were introduced to separate the functions of identifier (ID) and locator (LOC) from the IP address. However, these proposals still had some constraints such as the requirements of central server

for mapping ID and LOC, tunneling for sending packets, or host modification [1,2,3,4,5,6].

To solve these problems, we proposed a network-based ID-LOC separating protocol in Software-Defined Networking (SDN), called NHILS, recently [7]. In the proposed scheme, the network is divided into two domains: Host Identity (HI) domain for IDs and IP domain for general IP packets, and the HI domain is overlaid on the IP domain. To make the ID and LOC routable on the network, we adopted one of the DHT algorithm and its structure, and the SDN facilities such as OpenFlow-enabled switches and controllers [8,9,10].

In this paper, we evaluate performance of the proposed scheme. For the comparison, we configure a simple cost model on the signaling and packet delivery, and calculate costs according to the cost model. Then we compared the costs of the proposed NHILS to them of the 'Mobile Oriented Future Internet (MOFI)' protocol which operates similar to the proposed scheme.

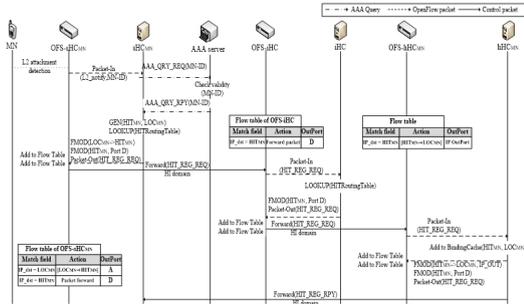
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## 2. Protocol Operation

### 2.1 Proposed Scheme (NHLS)



[Fig. 1] Registration of the proposed scheme

In the proposed scheme, network consists of OpenFlow-enabled Switches (OFSs) and controllers (HCs) such as SDN environments. The network resources are virtualized to accommodate the HI domain and IP domain. The IP domain is used for normal IP routing, while, the HI domain is used for delivering HIT packets and is logically overlaid over the IP network.

The HCs are classified into three types according to their roles: home HC (hHC), serving HC (sHC), and intermediate HCs (iHCs). The hHC has to manage the HIT-LOC mapping information, and it has the

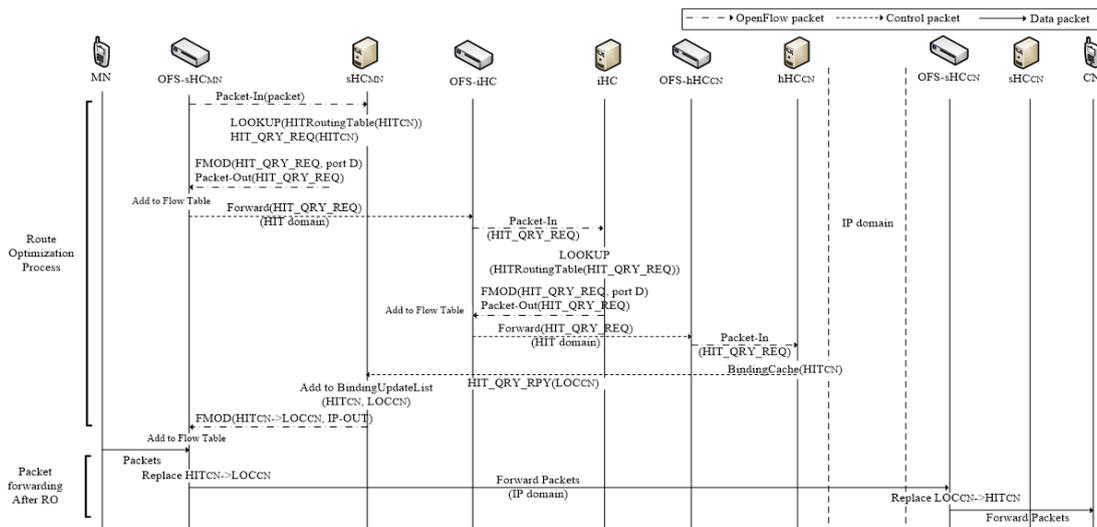
responsibility to send the corresponding LOCs for the HIT queries. The sHC manages a zone in which an MN is physically located, and assigns a LOC for the HIT of the attached MN. It announces and updates the HIT-LOC binding information to the MN's hHC. The iHCs are located between the hHC and sHC, and forward received packets to the nearest zone of the destination according to the preconfigured flow table for HIT routing.

Each HC manages a set of OFSs. The OFSs forward the received packets based on the matching rules of its flow table. If no matching rules founded from the received packet, the OFS sends the packet to its HC.

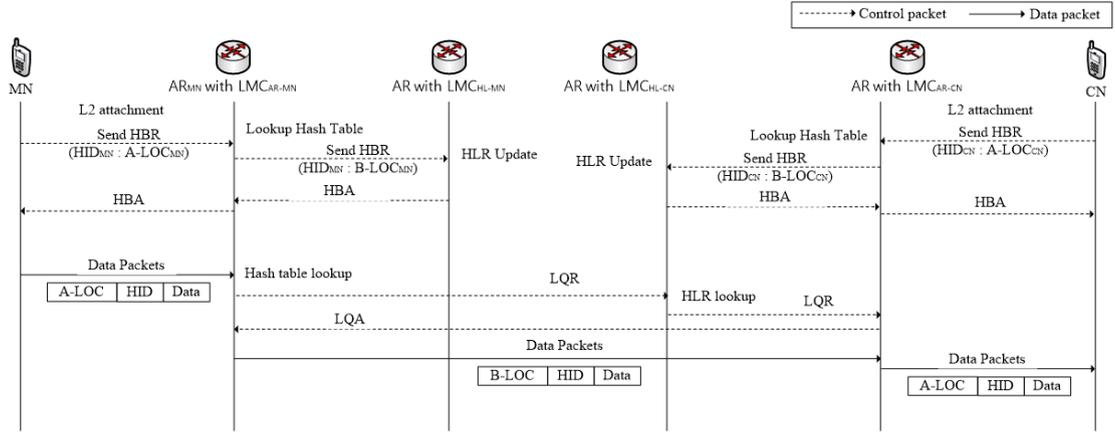
The proposed scheme is operated by three phase: registration, packet forwarding, and route optimization. Fig. 1 shows registration process, and Fig. 2 describes packet forwarding and Route optimization (RO) procedures.

### 2.2 MOFI

In MOFI, communication between a mobile node (MN) and a corresponding node (CN) is processed by means of Access Routers (ARs). Each AR contains a Local Mapping Controller (LMC) with a hash table and



[Fig. 2] Packet forwarding and RO process of the proposed scheme



[Fig. 3] Registration and packet forwarding in MOFI

an HID-LOC Register (HLR).

MOFI adopts query-first driven approach in the data delivery model for the optimal data path. Also, the MOFI uses the distributed mapping control mechanism for the HID-LOC mapping information, and the mapping control traffic is distributed on each AR.

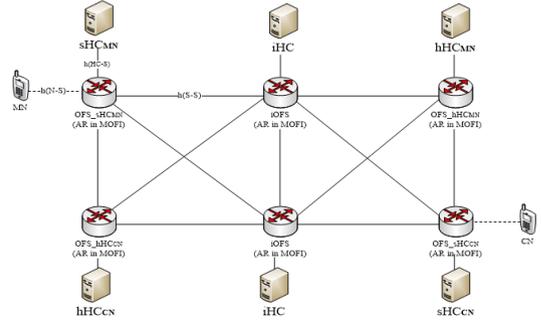
The HIDs are used for end-to-end communication between two nodes, while LOCs are used for delivering packets in the access and backbone networks. The packet encapsulation is used for the packet delivery.

For packet delivery, MOFI uses two kinds of LOCs. An Access-LOC (A-LOC) is used within the access network, while a Backbone-LOC (B-LOC) is used in the backbone network. The packet routing is locally performed in the access or backbone network, therefore, each AR is responsible to process the LOC transition between A-LOC and B-LOC. Fig. 3 illustrates the registration and data packet delivery procedures in MOFI.

### 3. Cost Model

For calculating the signaling and packet delivery costs, we configure the network topology as shown in the figure 4 based on [11]. The network consists of six HCs and OFSs, an MN, and a CN. Each OFS is connected to each other, and each HC. MOFI and

NHILS require different entities, it is assumed that some functions of the network entities are substituted.



[Fig. 4] Network Topology for comparison

Each AR in MOFI includes an LMC with a hash table and a HLR, and it manages HID-LOC mapping information with distributed manner [4]. In contrast, each AR in NHILS is capable to include all the facilities of the OpenFlow switch.

In Fig. 4,  $h_{(X-Y)}$  means the average number of hops between X and Y as following:

$h_{(N-S)}$  : average number of hops between a node and an OFS (AR)

$h_{(HC-S)}$  : average number of hops between an HC and an OFS (AR)

$h_{(S-S)}$  : average number of hops between OFSs (ARs)

For the comparison between MOFI and the proposed scheme, we formulate signaling cost and packet delivery cost. Signaling cost ( $C_s$ ) and packet delivery cost ( $C_{PD}$ ) can be represented as the message size in bytes, and calculated as the multiplication of the lengths of the path in hop count via the route for transmission. Total cost is calculated as the sum of  $C_s$  and  $C_{PD}$ . For the simplicity, we denote the costs of MOFI and the proposed scheme as  $C_S^{MOFI}$  and  $C_S^N$ , respectively.

### 3.1 Signaling Cost

#### 3.1.1 MOFI

In MOFI, each procedure for HID-LOC binding and LOC query has to be processed before the packet forwarding, therefore, the signaling cost is calculated as the sum of binding cost and query cost:

$$C_S^{MOFI} = C_{BI}^{MOFI} + C_{LQ}^{MOFI}. \quad (1)$$

In above equation,  $C_{BI}$  and  $C_{LQ}$  indicate HID-LOC binding cost and LOC query cost, respectively. After L2 attachment is established, the MN sends an HID Binding Request (BR) message to the attached AR ( $LMC_{AR-MN}$ ), and the  $LMC_{AR-MN}$  forwards the BR to an LMC ( $LMC_{MN}$ ) which maintains the MN. The  $LMC_{MN}$  sends a Binding Acknowledgement (BA) to the MN after it processed the BR message. It is assumed that the HID-LOC binding cost of an MN is same with the cost of a CN, so the binding cost is calculated as following:

$$C_{BI}^{MOFI} = 2(L_{BR} + L_{BA})(h_{N-S} + h_{S-S}). \quad (2)$$

In the equation, L means the length of BR and BA. When  $LMC_{AR-MN}$  receives first data packet from an MN to a CN, it starts LOC query procedure to get the proper LOC of the CN. Thus, the LOC Query Request (LQR) is delivered to the  $LMC_{AR-CN}$  via  $LMC_{CN}$ . The LOC query cost is calculated as following:

$$C_{LQ}^{MOFI} = 2h_{S-S} * L_{LQR} + h_{S-S} * L_{LQA} \quad (3)$$

#### 3.1.2 NHILS

In the proposed scheme, MN and CN should be registered to their hHCs. Before the registration, each sHC to which the MN and CN are attached sends a registration request (RR) to each hHC, and a query request for the RO. The RR cost is made up of RR cost and registration reply (RP) cost. The RR cost is presented by the sum of RR delivering cost (DRR) and the OpenFlow signaling cost(ORR). The RR message is forwarded from  $sHC_{MN}$  to  $hHC_{MN}$ , the expression is shown as following:

$$\begin{aligned} C_S^N &= 2(C_{RRQ}^N + C_{RO}^N), \\ C_{RRQ}^N &= C_{DRR}^N + C_{ORR}^N + C_{RP}^N \end{aligned} \quad (4)$$

The DRR cost is calculated as the product of number of hops between OFSs and RR length. The ORR cost is expressed by the sum of RR cost for each HC. Thus the RR cost of each HC is calculated as following:

$$\begin{aligned} C_{RR}^{sHC} &= h_{(HC-S)}(2L_{FMOD} + L_{RPOUT}), \\ C_{RR}^{hHC} &= h_{(HC-S)}(2L_{FMOD} + L_{RPIN}), \\ C_{RR}^{iHC} &= (L_{RPIN} + 2L_{FOMD} + L_{RPOUT}) * (h_{(S-S)} - 1) \\ &\quad * h_{(HC-S)} \end{aligned} \quad (5)$$

In above expression,  $h_{(HC-S)}$  indicates the number of hops from HC to the switch,  $L_{FMOD}$  means the length of flow modification (FMOD) message, and  $L_{RPIN}$  and  $L_{RPOUT}$  represent the Packet-In (PIN) and Packet-Out (POUT) message lengths including the RR.

The RP cost is made up of the sum of RP delivery cost (DRP) and OpenFlow signaling cost (ORP). Therefore, each cost for the reply is calculated as

$$\begin{aligned} C_{DRP}^N &= h_{(S-S)} * L_{RP}, \\ C_{ORP}^N &= h_{(S-S)} * (L_{RPPIN} + L_{RPPOUT}) \end{aligned} \quad (6)$$

The  $L_{RP}$ ,  $L_{RPPIN}$ , and  $L_{RPPOUT}$  indicate the length of RP, POUT for RP, and PIN for RP respectively.

The cost for RO ( $C_{RO}^N$ ) is also expressed by the sum of query cost ( $C_{ROQ}^N$ ) and reply cost ( $C_{ROR}^N$ ).

$C_{ROQ}^N$  is consisted of ROQ delivery cost (ROQD) and OpenFlow signaling cost (ROQO), so  $C_{ROQ}^N$  is calculated as following:

$$C_{ROQ}^N = h_{(s-s)} * L_{ROQ} + h_{(HC-s)} * (L_{RQPIN} + L_{RQPOUT}). \quad (7)$$

In above equation,  $L_{RQPIN}$  and  $L_{RQPOUT}$  represent PIN and POUT message lengths including ROQ.

The  $C_{ROR}^N$  is also calculated by the sum of ROR delivery cost ( $C_{RORD}^N$ ) and Openflow signaling cost ( $C_{RORO}^N$ ). The  $C_{RORD}^N$  is calculated as the product of  $h_{(s-s)}$  and  $L_{ROR}$ . Also, the  $C_{RORO}^N$  is calculated as the sum of ROR cost at each HC, similar to the Eq. 5. Therefore, the ROR cost of each HC is calculated as

$$\begin{aligned} C_{ROR}^{sHC} &= h_{(HC-s)} * (L_{FMOD} + L_{ROPOUT}), \\ C_{ROR}^{hHC} &= h_{(HC-s)} * (L_{FMOD} + L_{ROPIN}), \\ C_{ROR}^{iHC} &= h_{(HC-s)} * (h_{(HC-s)} - 1) * (L_{ROPIN} + L_{FMOD} + L_{ROPOUT}) \end{aligned} \quad (8)$$

### 3.2 Packet Delivery Cost

Packet delivery cost is calculated with the number of packets and the length of packets. Because the packet delivery manner of MOFI is differ from that of NHILS, the cost formula is also different.

#### 3.2.1 MOFI

For the packet delivery, an additional header contained the LOC information is required. The LOC query is already processed before delivering packets because of the characteristics of Query First Data Delivery (QFDD) [4], therefore, packets can be forwarded to direct path. The packet delivery (PD) cost is calculated as following:

$$C_{PD}^{MOFI} = N(p) * (L_{DP} + L_{LH}) * (2h_{(N-s)} + S_{(s-s)}) \quad (9)$$

In the expression,  $N(p)$  indicates the number of data packets, and  $L_{DP}$  represents the length of data packets.  $L_{LH}$  indicates LOC header length.

#### 3.2.2 NHILS

Packet delivery cost ( $C_{PD}^N$ ) of the proposed scheme is divided into packet forwarding cost ( $C_{PF}^N$ ) and OpenFlow delivery cost ( $C_{OD}^N$ ). In the proposed scheme, the first packet is forwarded through non-optimal path via OFSs and HCs. However, when the route optimization is completed, all packets should be routed by the optimal path. Therefore,  $C_{PF}^N$  is calculated as following:

$$C_{PF}^N = r_{no} * N(p) * L_{DP} * (2h_{(N-s)} + 2h_{(s-s)}) + (1 - r_{no}) * N(p) * L_{DP} * (2h_{(N-s)} + h_{(s-s)}) \quad (10)$$

In above equation,  $r_{no}$  represents the packet delivery ratio at un-optimal path.

The  $C_{OD}^N$  is only generated by the  $sHC_{MN}$  and iHCs, thus, it calculated as the product of  $sHC_{MN}$  ( $C_{sODP}^N$ ) cost and iHCs ( $C_{iODP}^N$ ) cost. When the first packet is delivered to the destination, flow table entries for the reverse path cannot be created until the reply message is sent back. Thus,  $C_{sODP}^N$  and  $C_{iODP}^N$  are expressed as following:

$$C_{sODP}^N = h_{(HC-s)} * (L_{fPIN} + L_{FMOD} + L_{fPOUT}) \quad (11)$$

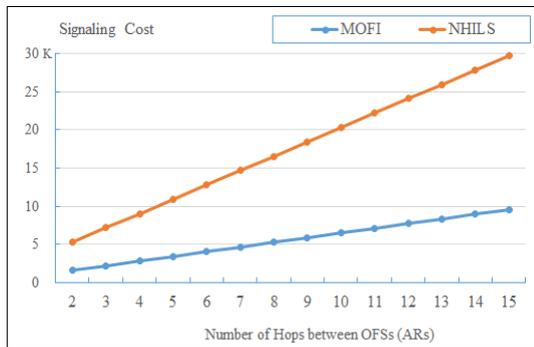
$$C_{iODP}^N = h_{(HC-s)} * (h_{(s-s)} - 1) * (L_{fPIN} + L_{FMOD} + L_{fPOUT}) \quad (12)$$

In the equation,  $L_{fPIN}$  and  $L_{fPOUT}$  represent the PIN and POUT lengths that include the first data packet.

## 4. Numerical Results

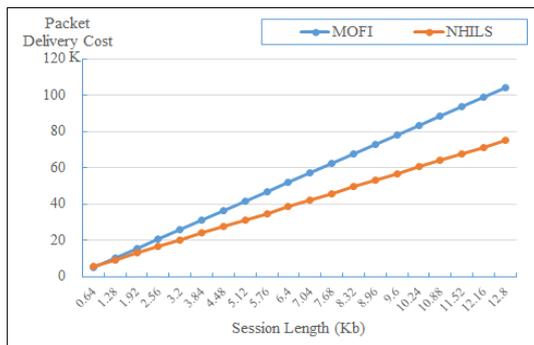
For the comparison between MOFI and the proposed scheme, NHILS, we evaluate the signaling and packet forwarding costs. For the evaluation, we set some parameters and packet lengths. Binding and query related packet lengths are set to 88bytes, POUT and PIN message lengths except first packet are set to 246 bytes and 254 bytes respectively. POUT and PIN message lengths for the first packet are set to 334

bytes and 342 bytes. The packet delivery cost is set to 128 bytes, and the packet delivery ratio of the un-optimal path is set to 0.1. All packet lengths include the upper layers of the network layer. OpenFlow messages are delivered using TCP, so 60 bytes of TCP ACK size are involved in the packet length. According to these parameter set, the result of signaling and packet delivery costs calculation is as shown in Fig. 5 and Fig. 6. The total cost is illustrated in Fig. 7.



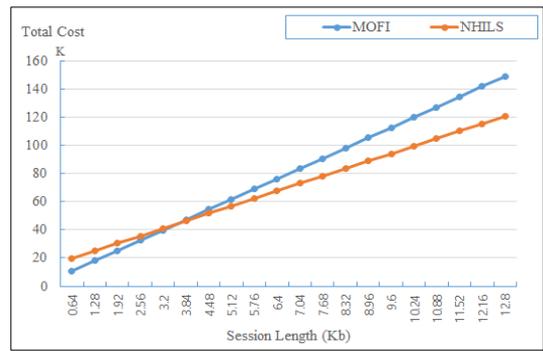
[Fig. 5] Signaling Cost Comparison

Fig. 5 shows the variation of signaling cost between MOFI and NHILS. The signaling cost of NHILS is always higher than MOFI. Since the OpenFlow messages which transfer the control messages in HI domain are exchanged between HCs and OFSs in the proposed scheme, it is reasonable that the proposed scheme generates more signaling cost than MOFI. In MOFI, the communication cost between LMC and AR does not appear because the LMC is located in AR.



[Fig. 6] Packet Delivery Cost Comparison

Fig. 6 illustrates the packet delivery cost according to the variation of session length. In contrast with the signaling cost, NHILS is shown better performance than MOFI. Because MOFI performs packet encapsulation for transmitting packet, it requires an additional header. In contrast, the proposed scheme only performs the field replacement, and forwards packets to the destination. Thus, it is believed that packet encapsulation leads the performance degradation in case of packet transmission.



[Fig. 7] Total Cost Comparison

The total cost is calculated as the product of signaling and packet delivery costs. Fig. 7 describes that MOFI shows better performance than NHILS under the session length of 3.84KB. However, performance of NHILS is changed to be better over 3.84KB. The signaling cost is not influenced by the session length, but the session length is the major factor in the increase of the packet delivery cost. As the session length is increasing, the extra overhead of encapsulation for data packet is more collected.

## 5. Conclusion

In this paper, we configure a network topology, and suggest a cost model for evaluating the signaling and packet forwarding costs. From the results, MOFI has lower signaling cost than the proposed scheme, NHILS. However, it consumes much cost in packet delivery

because of tunneling. The total cost is influenced by the number of hops between OFSSs and session length. It is shown that the signaling overhead is negligible although the exponential increase of session size is considered in today's network. The results illustrate that the proposed scheme can be adapted in SDN environments as well as current network environment, and that SDN can be efficiently used for ID-LOC separation.

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