Comparison of IPv6 mobility management schemes: a focus on network mobility

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Abstract - ***In this paper, we compare IPv6 mobility management schemes that support network mobility. A few schemes have been proposed to support network mobility considering the mobility of an entire network as a single unit. The mobile network includes one or more mobile routers (MRs), which connect it to the global Internet. NEMO basic support protocol (NBSP) is based on mobile IPv6 with prefix registration. Hierarchical mobile IPv6 (HMIPv6) introduces the mobility anchor point (MAP) that handles intra-domain handoffs locally. HMIPv6 can be extended to support network mobility by collocating mobility anchor point (MAP) and MR. Location independent network for IPv6 (LIN6) solves the triangular routing problem by introducing the concept of "mapping agent (MA)," which manages the current location of the mobile network. NBSP and HMIPv6 basically follow mobile IPv6 protocol and therefore the data packets from correspondent hosts are forwarded to the mobile node (MN) via its home agent. LIN6 forwards the data packets directly to the MN without visiting the home agent at the cost of signaling for location resolution. We carry out analysis to compare the above three schemes in terms of packet transfer delay, signaling cost, and response time***

1. Introduction

With the advent of ubiquitous computing, a sheer number of electronic devices are capable of communicating through wireless technologies by using their IP addresses. MIP6 Working Group in Internet Engineering Task Force (IETF) has proposed Mobile IPv6 (MIPv6) [1] to provide transparent internet connectivity while a device is moving. In MIPv6, a mobile node has two addresses: one is home address (HoA) allocated when the mobile node is at home network and the other is care-of address (CoA) allocated when the mobile node is attached at foreign network. Whenever the mobile node gets a new CoA, it sends the binding update message to its home agent (HA). Binding update message contains information about the current point of attachment of the mobile node. Therefore, when the HA intercepts a packet toward the mobile node, the HA encapsulates and redirects the packet to the current location of the mobile node.

Not only a single mobile device but also a group of mobile devices can be connected to the Internet. For example, a radio, a PDA, and a mobile phone in a vehicle can be organized as a subnet that contains one or more mobile routers (MRs), which connect the subnet to the global Internet. Host mobility and network mobility are illustrated in Fig. 1. The host mobility is concentrated on the mobility management of a mobile node but the network mobility manages the mobility of a group of devices. For example, without addressing network mobility, as the train with hundreds of mobile nodes moves through the railroad, mobile nodes inside the train should perform location registration individually and that will cause heavy signaling overhead. However if the train has MRs to serve (or represent) the hundreds of mobile nodes locally, only MRs perform location registrations to their HAs, as the train moves between access routers (ARs). Since the MR manages the movement instead of the mobile network nodes (MNNs), the movement of the entire mobile network is transparent to the nodes behind the MR.

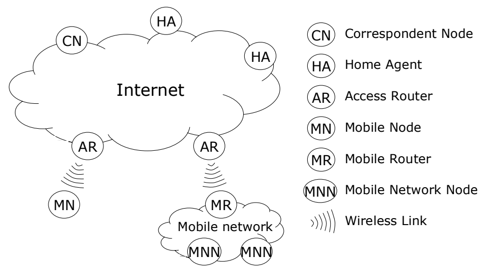

Figure 1. Host mobility and Network mobility

To support network mobility a few schemes have been introduced: NEMO basic support protocol (NBSP) [2], hierarchical mobile IPv6 (HMIPv6) [3], and location independent network for IPv6 (LIN6) [4].

NBSP and HMIPv6 are based on the MIPv6 mechanism. Since the MIPv6 mechanism is already standardized as the host mobility protocol, MIPv6 based approaches can be justified and easily integrated with existing host mobility scheme. However, when network mobility schemes adopt the MIPv6 based mechanism, they have inherited both strength and weakness of MIPv6. For example, in NBSP and HMIPv6, the data packets destined for a mobile network are forwarded via the home agent, which is so-called the triangular routing problem.

LIN6 is based on location independent network architecture (LINA) [5] and can be applied to the network mobility with minor changes. LIN6 adopts "mapping agent (MA)" for location registration and management but the MA is differ from the HA in MIPv6 as the MA does not encapsulate or redirect data packets toward mobile node. The MA only replies to a request about current location of mobile node like a DNS server. In this way, the correspondent node (CN) can know the current point of attachment of the mobile node, and send data packets to the MN without triangular routing. However, LIN6 suffers some lags for location resolution before sending data packets. Furthermore, LIN6 should modify the IPv6 stack and hence is hard to integrate with existing host mobility schemes.

In Section 2, this paper introduces three network mobility schemes: NEMO basic support protocol, hierarchical mobile IPv6 (HMIPv6), and location independent network for IPv6 (LIN6). In this paper, we compare and analyze these schemes in terms of packet transfer delay, signaling cost, and response time. Sections 3 and 4 of this paper analyze and evaluate these network mobility schemes from the perspective of route optimization from CN to MNN. Finally, Section 5 concludes this paper with future work.

2. Network mobility support protocols

This paper select three network mobility schemes to compare in terms of route optimization.

- NEMO basic support protocol (NBSP)
- Hierarchical Mobile IPv6 (HMIPv6)
- Location Independent Network for IPv6 (LIN6)

2.1 NEMO Basic Support Protocol

Network Mobility (NEMO) working group in IETF investigated this issue and extended the existing Mobile IP to support network mobility. A mobile network includes one or more mobile routers that connect it to the global Internet. A mobile network can contain both fixed and mobile nodes behind the MR. Mobile nodes are classified again into local or visiting. Especially, visiting mobile node (VMN) should conform to existing MIPv6 operations. If we use existing mobile IP protocol for mobile network and the egress interface of the MR follows MIPv6 operation, the packets from a CN to the MR are successfully delivered but the packets destined to the nodes behind the MR are dropped at the HA since binding cache in the HA has no information about the nodes behind the MR. To support the network mobility, the binding cache in Mobile IP must have information about the mobile network prefix of the MR's ingress interface.

2.2 Hierarchical Mobile IPv6

Hierarchical mobility management for MIPv6 (HMIPv6) was introduced to improve the performance of MIPv6 in terms of binding update traffic using the mobility anchor point (MAP). Since the MAP acts like a local HA, mobile nodes and mobile routers register their CoAs to the HA and the MAP. Moreover HMIPv6 can support both host mobility and mobile networks in the extended mode of operation. In the extended mode, an MR also has the MAP functionality to serve its MNNs. HMIPv6 has no advantage in terms of packet transfer delay compared to NBSP, but HMIPv6 can reduce the location registration signaling overhead and binding update latency by localizing the movement of the mobile network inside a MAP domain.

2.3 Location Independent Network for IPv6

LIN6 is a new protocol based on location independent network architecture (LINA). LIN6 provides mobility to IPv6 without impact on the existing IPv6 infrastructure and maintains compatibility with traditional IPv6. LIN6 does not use any extension headers of IPv6 while MIPv6 uses the destination options header for the home address option and the routing header for optimal routing. LIN6 introduces a mapping agent (MA) which can be located and replicated anywhere in the Internet. A LIN6 node should register the mapping of its current network prefix and its identifier with the MA. LIN6 keeps end-to-end communication model, that is, LIN6 does not use any packet interceptor or forwarder such as the HA of MIPv6. The LIN6 address is composed of network prefix as locator (higher 64-bits) and LIN6 ID as identifier (lower 64-bits). At network layer, the LIN6 generalized ID is translated to the LIN6 address by the MA. The MA maintains the mapping relation between the LIN6 ID and the current network prefix. The relation between the domain name or LIN6 ID of the mobile node and the address of the MA is registered with the DNS. To support network mobility with LIN6, route advertisement (RA) message and the mapping entry in the MA should be extended with an MRID field and an indirect bit, respectively.

3. Performance analysis

3.1 Analysis criteria

Performance analysis is carried out for NEMO basic support, HMIPv6, and LIN6. We define cost as delay. Delay is composed with processing delay and link delay. This paper assumed that the processing delay is relatively small and trivial to the link delay. Packet transfer delay, signaling cost and response time are selected to performance metric. The packet transfer delay means the time to deliver a packet from the CN to the MNN. That is, it is the sum of the link delays between relevant entities (e.g. HA). Signaling cost is focused on the binding update procedure. We define the signaling cost as the product of the number of messages and the link delay for each inter-domain handoff. Finally, the response time is the sum of the packet transfer time and the signaling (i.e. time to perform name and location resolution).

C: packet transfer delay

S: signaling cost

R: response time

3.2 Analysis

In this paper, we choose the simplest network model with a mobility agent and an MR for each scheme and analyze the three schemes as a function of the link delays between entities. The analysis is performed for the scenario that a packet destined from a CN to the MNN is routed through the relevant entities.

3.2.1 NEMO Basic Support Protocol

For the NBSP, a packet generated from the CN is routed to the HA. And then the HA intercepts the packet and encapsulates it to the MR via an appropriate AR. The MR decapsulates the packet and forwards it to the MNN. As a result, the packet transfer delay can be derived as (1). For the signaling cost, the MR needs just one binding update message to the HA as shown in (2). And finally, we can find out that the packet is routed without any additional signaling before packet delivery, so the response time is the same as the packet delivery delay (3).

$$C_{NBSP} = D_{CH\rightarrow HA} + D_{HA\rightarrow AR} + D_{AR\rightarrow MR} + D_{MR\rightarrow MNN} \quad (1)$$
$$S_{NBSP} = D_{MR\rightarrow AR} + D_{AR\rightarrow HA} \quad (2)$$
$$R_{NBSP} = C_{NBSP} \quad (3)$$

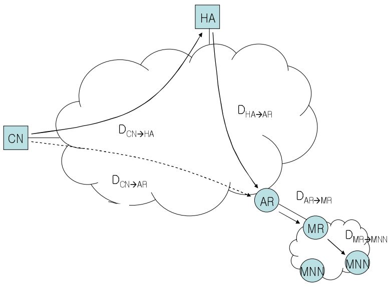

Figure 2. NEMO Basic Support Protocol

3.2.2 Hierarchical Mobile IPv6 (HMIPv6)

HMIPv6 needs an additional entity called a MAP to the network model of the previous analysis in Section 3.2.1. So the link delay between the AR and the MR is divided into two parts (AR-MAP and MAP-MR). When the other conditions are equal to that of Section 3.2.1, the packet transfer delay can be derived as (4). For the signaling cost, HMIPv6 needs two BUs: one to the HA and another to the MAP. (5) shows the signaling cost for the two BUs. The response time is also the same as the packet transfer delay (6) as similar to NBSP.

$$C_{HMIPv6} = D_{CH\rightarrow HA} + D_{HA\rightarrow AR} + D_{AR\rightarrow MAP} + D_{MAP\rightarrow MR} + D_{MR\rightarrow MNN} \quad (4)$$
$$S_{HMIPv6} = 2 * D_{MR\rightarrow MAP} + D_{MAP\rightarrow AR} + D_{AR\rightarrow HA} \quad (5)$$
$$R_{HMIPv6} = C_{HMIPv6} \quad (6)$$

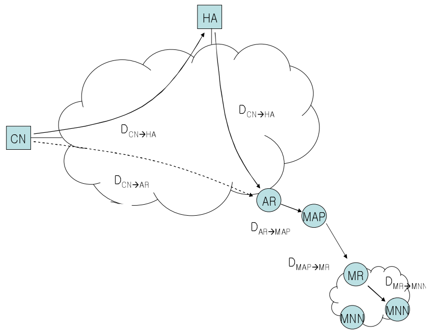

Figure 3. Hierarchical Mobile IPv6

3.2.3 Location Independent Network for IPv6 (LIN6)

As LIN6 is not based on MIPv6, there are no HA in the network model. LIN6 registers its location to a mapping agent (MA) instead of HA. To find the address of the MA related to a specific MR, LIN6 needs assistance from the DNS. When a CN wants to send a packet to an MNN, the CN performs a name lookup to the DNS, and the DNS replies with the address of the MA. Then, the CN sends a query to the MA to get the current location of the MR. When the CN successfully get the location, the CN can send the packet directly to the MR. (7) shows the optimal packet transfer delay to the destination. As each MR needs to register its location with the MA, the signaling cost can be derived as (8). However, LIN6 has a penalty in terms of the response time. To send a packet to the destination, the CN needs at least two queries: one for the DNS and another one for the MA. (9) shows the response time in terms of the link delay.

$$C_{LIN6} = D_{CH\rightarrow AR} + D_{AR\rightarrow MR} + D_{MR\rightarrow MNN} \quad (7)$$
$$S_{LIN6} = D_{MR\rightarrow AR} + D_{AR\rightarrow MA} \quad (8)$$
$$R_{LIN6} = 2 * D_{CN\rightarrow DNS} + 2 * D_{CN\rightarrow MA} + C_{LIN6} \quad (9)$$

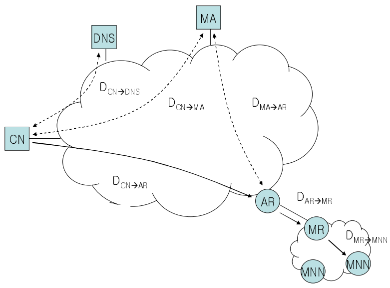

Figure 4. Location Independent Network for IPv6

4. Evaluation

4.1 Routing Cost

For the routing cost, the delay from the CN to the AR is optimal routing and let it be fixed as a constant *b* (10). And the triangular packet transfer delay through the mobility agent is equal for all the cases and is denoted by X bigger than b (11). For the packet transfer delay from the AR to the MNN is set to c for NBSP and LIN6, and h for HMIPv6, respectively (12)(13).

$$D_{CH \to AR} \rightarrow b \quad (10)$$
$$(D_{CH \to HA} + D_{HA \to AR}) = (D_{CH \to MA} + D_{MA \to AR}) \rightarrow X \geq b \quad (11)$$
$$D_{AR \to MR} + D_{MR \to MNN} \rightarrow c \quad (12)$$
$$D_{AR \to MAP} + D_{MAP \to MR} + D_{MR \to MNN} \rightarrow h \quad (13)$$

Packet transfer delays: CNBSP, CHMIPv6, and CLIN6 are plotted as in Fig. 5. In the case of NBSP and HMIPv6, the packet transfer delay increases linearly as X increases. For LIN6, the routing cost is independent of X and always constant. Difference between c and h means the routing overhead to transit the MAP.

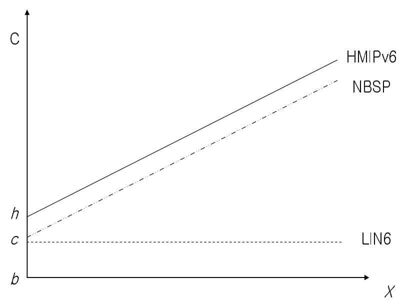

Figure 5. Packet transfer delay

4.2 Signaling Cost

The signaling costs of three schemes for a single inter-domain handoff is calculated in (2), (5), and (8). However, the signaling cost for some time period is in proportion to the number of handoffs. In the case of HMIPv6, the increasing rate will be the minimum.

4.3 Response time

For the response time, we denote the link delay between the CN and the mobility agents (including HA, MA, and DNS) by a variable X (14). In the case of the NBSP and HMIPv6, the response times are proportional to X with offset c and h, respectively (15)(16). For the response time of LIN6, LIN6 needs two round trip times more than NBSP (17). As a result, the response times: R_{NBSP}, R_{HMIPv6}, and R_{LIN6} increase linearly to X. However, the increasing rate of the LIN6 is five times sharper than that of other schemes.

$$D_{CH \to HA} = D_{CH \to MA} \rightarrow X \quad (14)$$
$$R_{NBSP} = X + c \quad (15)$$
$$R_{HMIP6} = X + h \quad (16)$$
$$R_{LIN6} = R_{NBSP} + 4 * D_{CH \to MA} = 5X + c \quad (17)$$

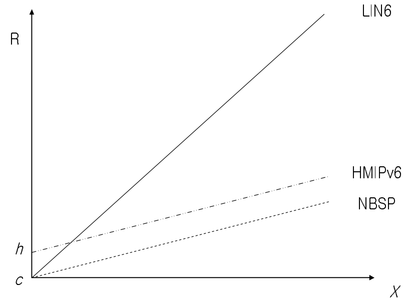

Figure 6. Response time

Conclusion

In this paper, we compared IPv6 mobility management schemes with a focus on network mobility. NEMO basic support protocol (NBSP) is the basic scheme to support network mobility by augmenting on MIPv6 infrastructure. Hierarchical MIPv6 is also based on MIPv6. The original purpose of HMIPv6 is to reduce the signaling overhead due to handoffs. However, the extended operation of HMIPv6 can support the network mobility. LIN6 is based on LINA, which separates the locator and the identifier. LIN6 finds out the location of a destination using DNS and MA.

We compare these schemes by analyzing the packet transfer delay, the signaling cost, and the response time. Especially, the analysis is concentrated on the effect of the triangular routing. As HMIPv6 is specialized on reducing the signaling cost, NBSP shows better performance than HMIPv6 for both packet transfer delay and response time. On the other hand, LIN6 outperforms MIPv6 based schemes in terms of the packet transfer delay. However, the response time of LIN6 is getting worse as the distances to the mobility agents are getting longer. The result will be helpful to the further works on the route optimization for the simple and complicated mobile networks.

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