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# Performance Study of Mobility Management for Mobile IPv6
# (モバイルIPv6における移動性管理方式の性能評価)

Chang Woo Pyo* Jie Li, and Hisao Kameda†

**概 要**

Mobile IPv6 is being designed to allow transparent routing of IP version 6 (IPv6) packets and seamless connectivity to mobile nodes roaming over the Internet. However, there is still much room for practical use. Performance analysis plays an important role for the purpose of implementation and system design. In this paper, we perform simulation to study the effects of various parameters on the performance of Mobile IPv6. The parameters include mobile node mobility patterns, network link and traffic conditions, and network topologies. Our study provides an insight into the operation of Mobile IPv6 and useful results to the Mobile IP network design.

## 1 Introduction

*Mobility management* for the Internet Protocol (IP), i.e., how to transfer IP packets to the mobile nodes that freely move from place to place over the Internet, is one of the important issues in mobile networks. The proposed standard protocol, Mobile IP (MIP) [1][2], is designed to enable mobile nodes to send and receive packets via the Internet without restriction of their attachment points, and without changing their IP addresses. Here we consider Mobile IPv6 (MIPv6) [3] that is the extension of the IP version 6 protocol, designed to support mobility of IPv6 nodes.

In mobility management for MIPv6, there are two basic operations: *binding update* and *packet delivery*. Binding update is the process to confirm the identity of a mobile node as it away from its home network. In packet delivery, when packets for a mobile node arrive at its home network, the packets are transfered to the mobile node by Mobile IPv6's tunneling scheme [1][2]. These two operations significantly affect the performance of Mobile IPv6 mobility management. For high rates of handoffs, a mobile node frequently requires a new binding update. High binding updates are the reason of performance degradation. In addition, if the distance between a visited network and a home network is large, the binding update and packet delivery delay is significant. For the purpose of more clearly understanding Mobile IPv6 mobility management, performance analysis plays an important role. Furthermore, it is also important to implement mobility management and system design.

In this paper, we study the performance of Mobile IPv6 mobility management by using simulation. For the purpose of measuring performance, we establish the mobility model and network topology model for the Mobile IP network and examine the signaling latency of binding update and packet delivery while changing the system parameters. The considered simulation parameters include mobile node mobility patterns, network link and traffic conditions, and network topologies. Simulation study provides an

*Doctoral Program Systems & Information Engineering University of Tsukuba, Tsukuba Science City, Ibaraki 305-8573, Japan, cwpyo@osdp.is.tsukuba.ac.jp

†Institute of Information Science & Electronics University of Tsukuba, Tsukuba Science City, Ibaraki 305-8573, Japan {lijie, kameda}@is.tsukuba.ac.jp

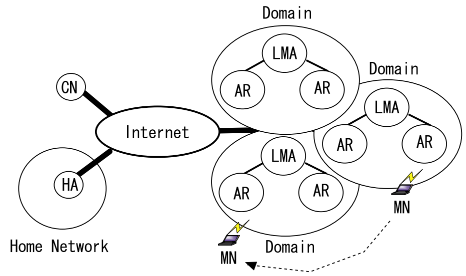


図 1: Mobility Management Model

insight into the Mobile IPv6 mobility management, and also useful results to the Mobile IP network design.

The rest of this paper is organized as follows. Overview of Mobile IPv6 mobility management is presented in Section 2. In Section 3 we describe the simulation model for studying the performance of mobility management. Section 4 describes the signaling delay of binding update and packet delivery for the performance analysis. The effects of changing important parameters on the performance are studied in Section 5. Section 6 concludes this paper.

# 2 Mobile IPv6 Mobility Management

In this section, we describe the basic protocol of the domain-based approach. Fig.1 illustrates a simple network model for domain-based mobility management. A *domain* is actually an arbitrary structure. It contains one or more IP subnets or networks such as a campus network, a company network, and a set of LANs or even a single LAN. A domain is connected to the rest of the Internet via one or several interconnection routers referred as *access routers* (ARs). ARs are default routers residing on the edge of a network and offer IP connectivity to mobile nodes. A mobile node uses a specially purposed mobility agent called *local mobility agent* (LMA) as a local home agent while roaming within a domain. The LMA is a router on a domain that maintains a binding per mobile nodes within its domain.

To confirm the point of attachment, a mobile node uses two types of care-of addresses to the mobile node: a *foreign care-of address* (FCoA) and an *on-link care-of address* (LCoA). The FCoA is an address obtained by the LMA and is assigned to the LMA's domain. An LCoA is an address obtained by the current attachment AR of a mobile node. A mobile node performs binding update by its two kinds of mobility called *"inter-domain mobility"* and *"intra-domain mobility"*. The inter-domain mobility occurs whenever a mobile node moves from one domain to another, whereas the intra-domain mobility occurs whenever a mobile node changes its attachment AR within the same domain. Fig.2 shows the binding update process for intra and inter-mobility and the packet delivery process in domain-based mobility management.

## 2.1 Intra-domain mobility

When a mobile node moves to a new AR belonging to the same domain, it gets a new LCoA on the new AR by receiving a *router advertisement message*. Alternatively, it may send a *router solicitation message* to an AR for router discovery. The mobile node registers its LCoA with the associated LMA by

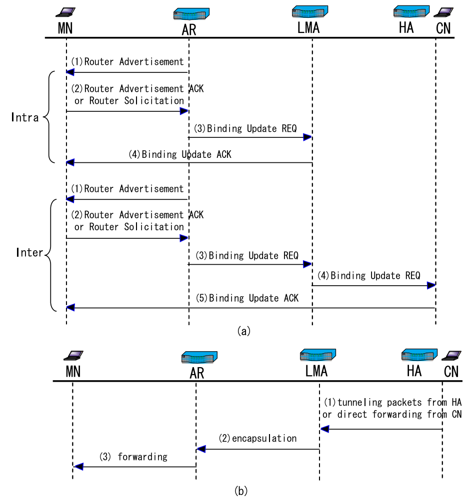


図 2: Binding update for intra and inter-mobility (a) and packet delivery (b)

sending a *binding update request message* containing its destined FCoA. The LCoA is used as the source address and the FCoA is specified in the Home Address field of Mobile IPv6. The LMA stores its LCoA in its binding cache to be able to forward packets to their final destination when received from CNs or a home agent. The LMA sends a *binding update acknowledge message* to the mobile node.

### 2.2 Inter-domain mobility

When a mobile node moves outside of the current domain, it gets an FCoA and an LCoA via a new AR in a new domain by receiving a router advertisement message or sending a router solicitation message. The LMA stores the LCoA of the mobile node in its binding cache and it registers the new FCoA with its home agent (HA) or CNs with the binding that specifies the FCoA and the HA's address in Mobile IPv6. The HA and CNs send a binding update acknowledge message to the mobile node.

### 2.3 Packet Delivery

When CNs or a home network sends data packets to a mobile node, these packets are intercepted by the home agent and encapsulated to the registered care of address. However, the CN may have up-to-date bindings in its binding cache and may transfer packets directly to the care-of address by using routing headers instead of encapsulation. This care of address is the FCoA of the target mobile node. When the LMA receives packets addressed to the mobile node's FCoA, these packets will be tunneled from the LMA to the mobile node's LCoA. The mobile node will decapsulate the packets and will process the packets in the normal manner.

## 3 Simulation results

Each mobile node in a Mobile IP network resides in a wireless area serviced by its associated AR for a random period of time and moves into another area. For demonstration purposes, we assume that the

| | |
|---|---|
| The number of mobile nodes in a network | 50 |
| Average residence time in an AR | 180s (3m)<br>300s (5m)<br>600s (10m) |
| The number of arriving Packets | 1/s, 10/s, 100/s |
| Latency between LMA and HA | 100ms<br>200ms<br>500ms |
| Latency per router (hop) | 10ms |

( m: minute, s: second, ms: milisecond )

表 1: Performance Analysis Parameters

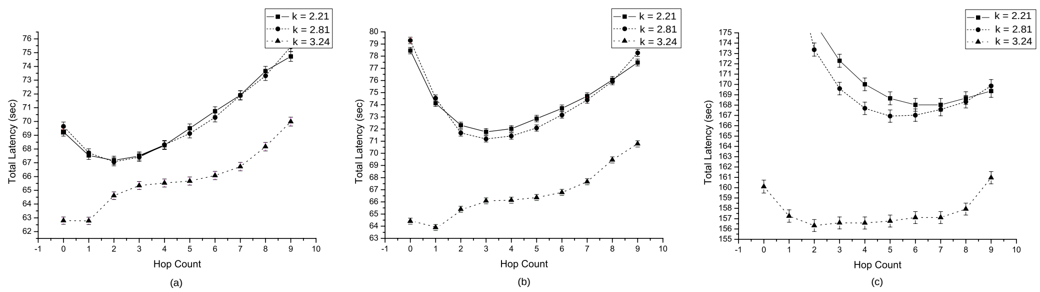


図 3: Signaling latency on network topologies and AR residence time with (a) 600s, (b) 300s and (c) 180s

mobile node's residence time of an AR is an independent identically distributed random variable with a gamma distribution of appropriate parameters. The gamma distribution is a rather general distribution and is widely used for the user mobility of the wireless networks. Assume that inter-domain mobility is performed if each mobile node crosses the pre-defined domain, defined by the set of ARs with the hop count from an LMA less than or equal to the pre-defined hop count. In all other cases, intra-domain mobility is performed. Let the number of mobile nodes in a network be 50 mobile nodes, and packets for mobile nodes from a home agent and CNs arrive in a network following a Poisson process and each arrival packet transfer to mobile nodes randomly under a shortest-path routing algorithm within a domain. Table1 shows the assumed parameters for simulation. Simulation results show the total signaling latency of 10 minutes interval and each result has a 95% confidential interval.

## 3.1 Effects of residence time and network topologies

Fig.3 shows the effects of network topologies and AR residence time on the signaling latency upon changing the size of a domain. Table2 shows the hop count minimizing the signaling latency of Fig.3. The hop count is the average number of hops from an LMA to ARs within a domain. The size of a domain, i.e., the average number of ARs in a domain, increases by the term $(degree)^{hop-count}$ as the hop count increases. As the average AR residence time of mobile nodes in a network decreases, the hop count

| | average residence time | | |
|---|---|---|---|
| | 600s | 300s | 100s |
| k=2.21 | 2 | 3 | 7 |
| k=2.81 | 2 | 3 | 5 |
| k=3.24 | 0 | 1 | 2 |

表 2: Optimal hop count

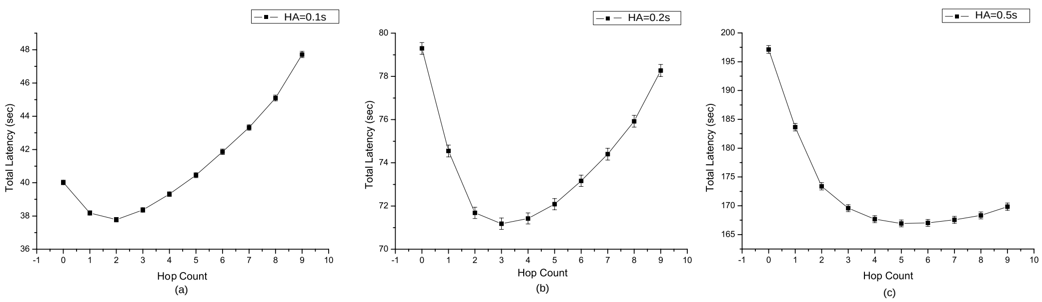


図 4: Signaling latency on different network links for $k$=2.81

of minimizing the signaling latency increases, which means that the optimal size of a domain increases. In addition, the optimal size of a domain decreases as the degree of network topology increases, meaning the optimal domain decreases as the network is more connected. This result is clear when the residence time in an AR is small.

### 3.2 Effects of link delay

Fig.4 shows the effects of network topology and network link delay on the signaling latency upon changing the size of a domain. The link delay between an HA and an LMA increase, which showing that the delay of performing a binding update for inter-domain mobility is larger than that for intra-domain mobility. As the link delay between an HA and an LMA increases, the optimal size of a domain increases that the optimal hop count values 2, 3, and 5 at 100ms, 200ms, and 500ms for the delay between HA and LMA, respectively.

## 4 Conclusion

In this paper, we study the performance of Mobile IPv6 mobility management by using simulation. Summing up the results,

**Mobile node mobility patterns :** The high mobility of a mobile node causes to increase the size of a domain to improve the performance. Thus, the larger the size of a domain, the more beneficial for high mobility roaming mobile nodes.

**Network link delay :** As the signaling delay of performing the binding update of inter-domain mobility is larger than that of intra-domain mobility, the larger size of a domain is more beneficial to the improvement of performance.

**Network topologies :** The size of a domain decreases as network complexity increases. However, as a network has highly complicated connections, the size of a domain has little affect on the performance.

The global mobility management solution in terms of a domain consisting of one AR, that the binding of mobile nodes updates at any time they change ARs, can not provide the solution for general Mobile IP networks with various mobile node mobility and network conditions. The domain-based solution is more useful to general networks. Our study provide an insight into the mobility management of Mobile IPv6 and also interesting results to the Mobile IP network design.

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