An Efficient Handoff Mechanism with Web Proxy MAP in Hierarchical Mobile IPv6[1]

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Abstract. In Mobile IPv6, when a MN (Mobile Node) moves from home network to the foreign network, it configures a new Care-of-Address (CoA) and requests the Home Agent (HA) to update its binding. This binding process requires high signaling load. Thus, Hierarchical Mobile IPv6 (HMIPv6) has been proposed to accommodate frequent mobility of the MN and reduce the signaling load in the Internet. In this paper, we propose hierarchical management scheme for Mobile IPv6 where MAP (Mobility Anchor Point) has web proxy function for minimizing signaling load in HMIPv6. The performance analysis and the numerical results presented in this paper shows that our proposal has superior performance to the HMIPv6

1 Introduction

The Internet users have desire for high quality of service at anywhere. Mobile device users keep increasing by growth of mobile device and wireless techniques. Mobile IPv6 [1] proposed by IETF (Internet Engineering Task Force) provides a basic host mobility management scheme. Mobile IPv6 specifies routing support to permit IPv6 hosts to move between IP subnetworks while maintaining session continuity. Mobile IPv6 supports transparency above the IP layer, including maintenance of active TCP connections and UDP port bindings. To accomplish this, when a MN moves from home network to the foreign network, it configures a new Care-of-Address (CoA) and requests the HA to update it's binding. This binding allows a mobile node to maintain connectivity with the Internet as it moves between subnets. However, binding process requires high signaling load. Thus, HMIPv6 has been proposed to accommodate frequent mobility of the MN and reduce the signaling load in the Internet. In HMIPv6, when a MN moves into new AR domain, MN may perform one or two types of binding update procedures: both the global binding update and the local binding update (intra-MAP) or only the local binding update (Inter-MAP). However, HMIPv6 focused on the intra-MAP domain handoff, not on the inter-MAP domain handoff [4]. In this paper, we propose hierarchical management scheme for Mobile IPv6 where MAP has web proxy cache function for minimizing signaling load in HMIPv6.

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2 Overview of Hierarchical Mobile IPv6 System

The HMIPv6 protocol separates mobility management into intra-domain mobility and inter-domain mobility. A MAP in HMIPv6 treats the mobility management inside a domain. Thus, when a MH moves around the sub-networks within a single domain, the MN sends a BU message only to the current MAP. When the MH moves out of the domain or moves into another domain, Mobile IPv6 is invoked to handle the mobility.

The basic operation of the HMIPv6 can be summarized as follows.

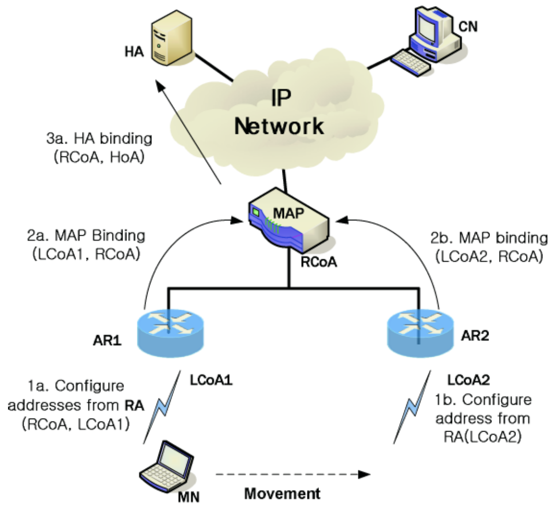

Fig. 1. The basic Operation of the HMIPv6

In HMIPv6, the MN has two addresses, an RCoA on the MAP's link and an on-link CoA (LCoA). When a MN moves into a new MAP domain, it needs to configure two CoAs: an RCoA on the MAP's link and an on-link CoA (LCoA). After forming the RCoA based on the prefix received in the MAP option, the MN sends a local BU to the MAP. This BU procedure will bind the MN's RCoA to its LCoA. The MAP then is acting as a HA. Following a successful registration with the MAP, a bi-directional tunnel between the MN and the MAP is established. After registering with the MAP, the MN registers its new RCoA with it's HA by sending a BU that specifies the binding (RCoA, Home Address) as in Mobile IPv6. When the MN moves within the same MAP domain, it should only register its new LCoA with its MAP. In this case, the RCoA remains unchanged.

3 MAP with Web Proxy in HMIPv6

In this paper, the MAP of proposed scheme has web proxy function to reduce signaling cost with CN. Thus, the MAP can transmit data to MN directly instead of CN.

This procedure reduces the number of connecting CN. The performance of proposed system depends on hit ratio of web proxy. Fig.2 shows proposed system model.

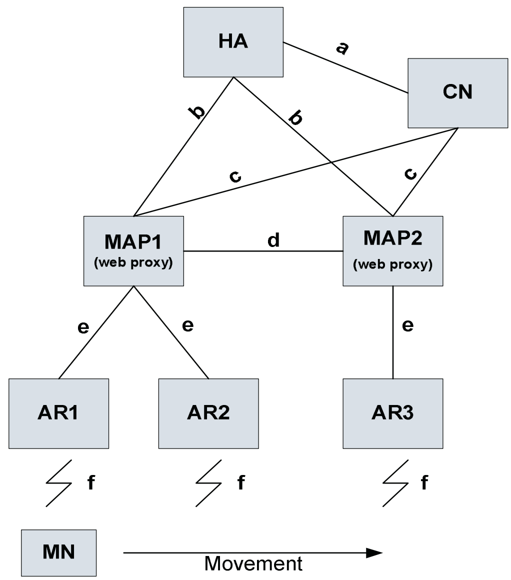

Fig. 2. System model of the proposed scheme

When MN moves from AR1 to AR2, the procedure of proposed system is same to HMIPv6's. While, MN moves from AR2 to AR3, proposed system operates as follows:

1. A MN detects movement by receiving router advertisement message from AR3.
2. A MN configures LCoA and RCoA.
3. A MN sends a local binding update to the MAP for binding new LCoA to new RCoA.
4. A MN sends a global binding update to the HA for binding new RCoA to Home Address (HoA).
5. In order to speed up the handoff between MAPs and reduce packet loss, a MN sends a local binding update to its previous MAP specifying its new LCoA.
6. The MAP1 can forward packets to a MN.
7. When a MN receives a tunneled from CN, a MN sends binding update to a CN. The probability of connecting to CN becomes smaller than normal HMIPv6's.

4 Performance Analysis

4.1 Mobility Model

In this paper, we assumed hexagonal cellular network architecture, as shown in Fig. 3. Each MAP domain is assumed to consist of the same number of range rings, R. Each range ring r (r ≥ 0) consists of 6r cells. The center cell is innermost cell 0. The cells labeled 1 formed the first range ring around cell "0," the cells labeled 2 formed the second range ring around cell 1 and so on. Therefore, the number of cells up to ring R, N(R) is calculated using the following Eq.(1).

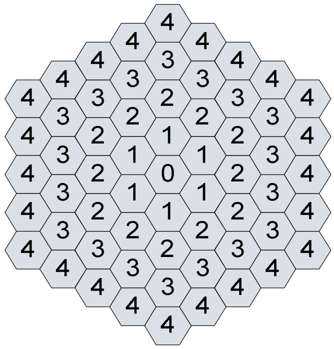

Fig. 3. Hexagonal cellular network architecture

$$N(R) = \sum_{r=1}^{R} 6r + 1 = \frac{6R(R+1)}{2} + 1 \tag{1}$$

In terms of user mobility model, random-walk mobility model are taken into consideration as commonly used mobility model. The random-walk model is appropriate for pedestrian movements where mobility is generally confined to a limited geographical area such as residential and business buildings [4].

In terms of random-walk mobility model, we consider the two-dimensional Markov chain model used in [5]. In this model, the next position of an MN is equal to the previous position plus a random variable whose value is drawn independently from an arbitrary distribution [5]. In addition, an MN moves to another cell area with a probability of 1−q and remains in the current cell with probability, q. In the cellular architecture shown in Fig. 2, if an MN is located in a cell of range ring r (r > 0), the probability that a movement will result in an increase or decrease in the distance from the center cell is given by

$$p^{+}(r) = \frac{1}{3} + \frac{1}{6r} \text{ and } p^{-}(r) = \frac{1}{3} - \frac{1}{6r} \tag{2}$$

We define the state r of a Markov chain as the distance between the current cell of the MN and the center cell. This state is equivalent to the index of a range ring where the MN is located. As a result, the MN is said to be in state r if it is currently residing in range ring r. The transition probabilities $\alpha_{r,r+1}$ and $\beta_{r,r-1}$ represent the probabilities of the distance of the MN from the center cell increasing or decreasing, respectively. They are given as follows:

$$\alpha_{r,r+1} = \begin{cases} (1-q) & \text{if } \boldsymbol{r} = 0 \\ (1-q)p^{+}(r) & \text{if } 1 \leq \boldsymbol{r} \leq \boldsymbol{R} \end{cases} \tag{3}$$

$$\beta_{r,r-1} = (1-q)p^{-}(r) \qquad \text{if } 1 \leq \boldsymbol{r} \leq \boldsymbol{R} \tag{4}$$

where q is the probability that an MN remains in the current cell.

Let $P_{r,R}$ be the steady-state probability of state r within a MAP domain consisting of R range rings. As Eq.(3) and Eq.(4), $P_{r,R}$ can be expressed in terms of the steady state probability $P_{0,R}$ as follows:

$$P_{r,R} = P_{0,R} \prod_{i=0}^{r-1} \frac{\alpha_{i,i+1}}{\beta_{i+1,i}} \qquad \text{for } 1 \leq \boldsymbol{r} \leq \boldsymbol{R} \tag{5}$$

With the requirement $\sum_{r=0}^{R} p_{r,R} = 1$, $P_{r,R}$ can be expressed by

$$P_{0,R} = \frac{1}{1 + \sum_{r=1}^{R} \prod_{i=0}^{r-1} \frac{\alpha_{i,i+1}}{\beta_{i+1,i}}} \tag{6}$$

where $\alpha_{r,r+1}$ and $\beta_{r,r-1}$ are obtained from Eq.(3) and Eq.(4)

4.2 Cost Functions

In order to analyze the performance of HMIPv6 [2] and proposed scheme, the total cost, consisting of location update cost and paging cost, should be considered. In normal HMIPv6, we divide the total cost into location update cost and packet delivery cost. Respectively, in proposed scheme, we divide total cost into new location update and packet delivery cost. The location update cost, new location update and the packet delivery cost are denoted by $C_{location}$, $C_{new\text{-}location}$, and C_{packet}, respectively. Then, the total cost of HMIPv6 (C_{total}) and proposed scheme ($C_{new\text{-}total}$) can be obtained as follows:

$$C_{total} = C_{location} + C_{packet} \tag{7}$$

$$C_{new-total} = C_{new-location} + C_{packet} \tag{8}$$

4.2.1 Location Update Cost

In HMIPv6, the MN has two addresses, an RCoA on the MAP's link and an on-link CoA (LCoA). When a MN moves into a new MAP domain, it needs to configure two CoAs: an RCoA on the MAP's link and an on-link CoA (LCoA). After forming the RCoA based on the prefix received in the MAP option, the MN sends a local BU to the MAP. This BU procedure will bind the MN's RCoA to its LCoA. The MAP then is acting as a HA. Following a successful registration with the MAP, a bi-directional tunnel between the MN and the MAP is established. After registering with the MAP, the MN registers its new RCoA with it's HA by sending a BU that specifies the binding (RCoA, Home Address) as in Mobile IPv6. When the MN moves within the same MAP domain, it should only register its new LCoA with its MAP. In this case, the RCoA remains unchanged.

When a MN moves into new AR domain, MN may perform one or two types of binding update procedures: both the global binding update and the local binding update or only the local binding update. C_g, C_{new-g} and C_l denote the signaling costs in the global binding update, the global binding update of proposed scheme and the local binding update, respectively. In the IP networks, the signaling cost is proportional to the distance of two network entities. C_g, C_{new-g} and C_l can be obtained from the below equations.

$$\begin{aligned} C_g &= 2\cdot(\kappa\cdot \mathrm{f} + \tau\cdot(\mathrm{b}+\mathrm{e})) + 2\cdot \mathrm{N_{CN}}\cdot(\kappa\cdot \mathrm{f} + \tau\cdot(\mathrm{b}+\mathrm{c})) \\ &\quad + \mathrm{PC_{HA}} + \mathrm{N_{CN}}\cdot \mathrm{PC_{CN}} + \mathrm{PC_{MAP}} \end{aligned} \tag{9}$$

$$\begin{aligned} C_{new-g} &= 2\cdot(\kappa\cdot \mathrm{f} + \tau\cdot(\mathrm{b}+\mathrm{e})) + 2\cdot \mathrm{N_{CN}}\cdot(1-\mathrm{HR_{proxy}})\cdot(\kappa\cdot \mathrm{f} + \tau\cdot(\mathrm{b}+\mathrm{c})) \\ &\quad + \mathrm{PC_{HA}} + \mathrm{N_{CN}}\cdot(1-\mathrm{HR_{proxy}})\cdot \mathrm{PC_{CN}} + \mathrm{PC_{MAP}} \end{aligned} \tag{10}$$

$$C_l = 2\cdot(\kappa\cdot \mathrm{f} + \tau\cdot \mathrm{e}) + \mathrm{PC_{MAP}} \tag{11}$$

where τ and κ are the unit transmission costs in a wired and a wireless link, respectively. As Fig. 2, b, c, e and f are the hop distance between nodes. PC_{HA}, PC_{CN} and PC_{MAP} are the processing costs for binding update procedures at the HA, the CN and the MAP, respectively. N_{CN} denotes the number of CNs which is communicating with the MN. HR_{proxy} denotes a hit ratio of web proxy. In proposed scheme, we reduce the probability of connecting to CN using web proxy. Thus, the number of N_{CN}, in proposed scheme, is smaller than normal HMIPv6's

In terms of the random walk mobility model, the probability that a MN performs a global binding update is as follows:

$$\mathrm{p_{R,R}}\cdot\alpha_{r,r+1} \tag{12}$$

Specifically, if a MN is located in range ring R, the boundary ring of a MAP domain composed of R range rings, and performs a movement from range ring R to range ring R + 1. The MN then performs the global binding update procedure. In other cases, except this movement, the MN only performs a local binding update procedure. Hence, the location update cost of normal and proposed scheme per unit time can be expressed as follows:

$$C_{location} = \frac{\mathrm{p_{R,R}}\cdot\alpha_{R,R+1}\cdot C_g + (1-\mathrm{p_{R,R}}\cdot\alpha_{R,R+1})\cdot C_l}{T} \tag{13}$$

$$C_{new-location} = \frac{\mathrm{p_{R,R}}\cdot\alpha_{R,R+1}\cdot C_{new-g} + (1-\mathrm{p_{R,R}}\cdot\alpha_{R,R+1})\cdot C_l}{T} \tag{14}$$

where T is the average cell residence time.

4.2.2 Packet Delivery Cost

The packet delivery cost, C_{packet}, in HMIPv6 can then be calculated as follows:

$$C_{packet} = C_{MAP} + C_{HA} + C_{CN-MN} \tag{15}$$

In Eq.(15), C_{MAP} and C_{HA} denote the processing costs for packet delivery at the MAP and the HA, respectively. $C_{CN\text{-}MN}$ denotes the packet transmission cost from the CN to the MN.

In HMIPv6, a MAP maintains a mapping table for translation between RCoA and LCoA. The mapping table is similar to that of the HA, and it is used to track the current locations (LCoA) of the MNs. All packets directed to the MN will be received by the MAP and tunneled to the MN's LCoA using the mapping table. Therefore, the lookup time required for the mapping table also needs to be considered. Specifically, when a packet arrives at the MAP, the MAP selects the current LCoA of the destination MN from the mapping table and the packet is then routed to the MN. Therefore, the processing cost at the MAP is divided into the lookup cost (C_{lookup}) and the routing cost ($C_{routing}$). The lookup cost is proportional to the size of the mapping table. The size of the mapping table is proportional to the number of MNs located in the coverage of a MAP domain [4]. On the other hand, the routing cost is proportional to the logarithm of the number of ARs belonging to a particular MAP domain [4]. Therefore, the processing cost at the MAP can be expressed as Eq.(17). In Eq.(17), λs denotes the session arrival rate and S denotes the average session size in the unit of packet. α and β are the weighting factors.

Let N_{MN} be the total number of users located in a MAP domain. In this paper, we assume that the average number of users located in the coverage of an AR is K. Therefore, the total number of users can be obtained as follows:

$$N_{MN} = N_{AR} \times K \tag{16}$$

$$\begin{aligned} C_{MAP} &= \lambda_s \cdot S \cdot (C_{lookup} + C_{routing}) \\ &= \lambda_s \cdot S \cdot (\alpha N_{MN} + \beta \log(N_{AR})) \end{aligned} \tag{17}$$

In MIPv6, using the route optimization, only the first packet of a session transmits the HA. Subsequently, all successive packets of the session are directly routed to the MN. The processing cost at the HA can be calculated as follows:

$$C_{HA} = \lambda_s \cdot \theta_{HA} \tag{18}$$

where θ_{HA} refers to a unit packet processing cost at the HA.

Since HMIPv6 supports the route optimization, the transmission cost in HMIPv6 can be obtained using Eq.(19). As mentioned before, τ and κ denote the unit transmission costs in a wired and a wireless link, respectively.

$$C_{CN-MN} = \tau \cdot \lambda_s \cdot ((S-1)\cdot(c+e) + (a+b+e)) + \kappa \cdot \lambda_s \cdot S \tag{19}$$

In proposed scheme, we reduce the probability of connecting to CN using web proxy. Thus, $C_{new\text{-}MAP}$ and $C_{new\text{-}CN\text{-}MN}$ can be calculated as follows:

$$\begin{aligned} C_{new-MAP} &= \lambda_s \cdot (1-HR_{proxy}) \cdot S \cdot (C_{lookup} + C_{routing}) + \lambda_s \cdot HR_{proxy} \cdot S \cdot (C_{porxy} + C_{routing}) \\ &= \lambda_s \cdot (1-HR_{proxy}) \cdot S \cdot (\alpha N_{MN} + \beta \log(N_{AR})) + \lambda_s \cdot (1-HR_{proxy}) \cdot S \cdot (\gamma N_{MN} + \beta \log(N_{AR})) \end{aligned} \tag{20}$$

$$\begin{aligned} C_{new-CN-MN} &= \tau \cdot \lambda_s \cdot (1-HR_{proxy}) \cdot ((S-1)\cdot(c+e) \\ &\quad + (a+b+e)) + \kappa \cdot \lambda_s \cdot (1-HR_{proxy}) \cdot S \end{aligned} \tag{21}$$

where Cporxy denotes processing cost of web proxy. A web proxy also is affected with the number of MN. γ is the weighting factors. Therefore, the packet delivery cost of proposed scheme can be calculated as follows:

$$C_{packet} = C_{new-MAP} + C_{HA} + C_{new-CN-MN} \tag{22}$$

5 Numerical Results

This section presents performance analysis of proposed scheme as compared with normal HMIPv6. The parameter values for the analysis were referenced from [4], [6] and [7]. They are shown in Table 1.

Table 1. Numerical simulation parameter for performance analysis

parameter	α	β	γ	θ_{HA}	τ	κ	A	b
value	0.1	0.2	0.05	20	1	2	6	6
parameter	c	d	e	f	N_{CN}	PC_{HA}	PC_{MAP}	PC_{CN}
Value	4	1	2	1	2	24	12	6

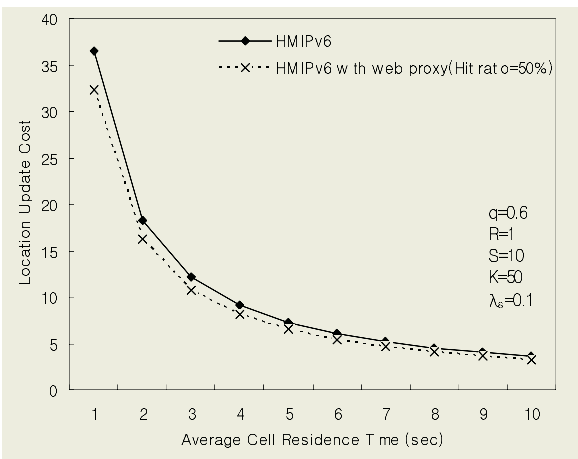

Fig. 4. Location update cost as a function of average cell residence time of MN

Fig 4 shows the variation in the location update cost as the average cell residence time is changed in the random-walk model. The location updates cost becomes less as the average cell residence time increases. This must be true because a MN becomes static by residing in a cell longer, the frequency of location update to HA become reduced. In a comparison of proposed scheme with HMIPv6, proposed scheme reduces the location update cost by 10% approximately.

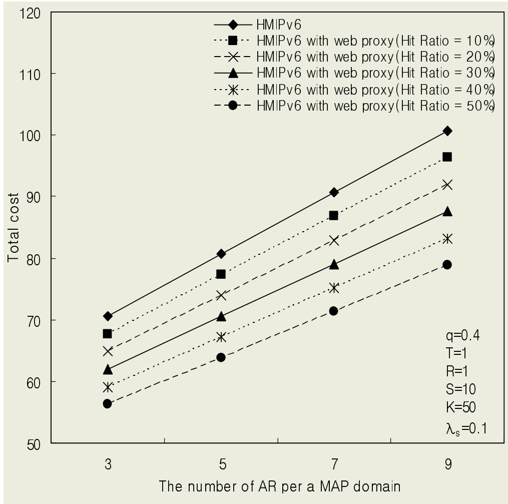

Fig. 5. Total cost as function of the number of AR per a MAP domain

In HMIPv6, the MAP needs to lookup the destination MN on mapping table (Binding Cache table). The cost for this lookup procedure depends on the number of MNs in a MAP domain. Therefore, the packet delivery cost increases as the number of MN in the MAP domain increases. In Eq.(16), the number of MN is $N_{AR} \times K$. Fig. 5 shows the impact of the number of AR per a MAP domain on the total cost in a random-walk model. As shown in Fig. 5, the total cost increases linearly as the number of AR increases. In a comparison of proposed scheme with HMIPv6, proposed scheme reduces the total cost by 4% (hit ratio = 10%) and 21% (hit ratio=50%) approximately.

6 Conclusions

HMIPv6 has been proposed to accommodate frequent mobility of the MNs and reduce the signaling load in the Internet. However, HMIPv6 focused on the intra-MAP domain handoff, not on the inter-MAP domain handoff [4]. In this paper, we propose MAP has web proxy cache function for minimizing signaling load in HMIPv6. The performance analysis and the numerical results presented in this paper shows that our proposal has superior performance to the HMIPv6 when hit ratio of web proxy on MAP is high. The proposed scheme reduces the location update cost by 10% and the total cost by 4% (hit ratio = 10%) and 21% (hit ratio=50) approximately.

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