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# A Dynamic IP Paging Algorithm based on the Velocity of Mobile Node for Proxy Mobile IPv6

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### *Abstract*

*Significant IP mobility mechanisms have been designed to minimize the handover overhead of mobile nodes. Although many efficient algorithms such as Mobile IP, HMIP and PMIP have been proposed, they did not attempt to upgrade their paging mechanisms that also heavily affect the power consumption of mobile nodes. Considering a good paging scheme is important because more than 95% of mobile nodes are moving in the idle state and change their states to active only for paging area updates. However, existing paging schemes assume the configuration of fixed paging areas and do not explore the dynamic nature of a paging area size depending on the states of mobile nodes. In this paper, we propose a novel dynamic IP paging scheme, where a paging area size is configured dynamically based on the speed and direction of a mobile node. The performance evaluation results demonstrate that the proposed IP paging scheme reduces the power consumption, compared to a fixed IP paging scheme.*

***Keywords:*** *Dynamic paging, PMIP Paging, Speed and Direction of Mobile Node*

## 1. Introduction

As the number of Mobile Nodes (MNs) increases rapidly, host-based mobility protocols such as Mobile IPv6 [1], Hierarchical Mobile IPv6 [2, 3] have been designed for the mobility support. However, the host-based mobility protocol requires MN to be involved in the mobility management process, which causes a waste of signal cost. To solve the problem, IETF NETLMM WG (Network-based Localized Mobility Management Working Group) recently proposed a network-based mobility protocol called Proxy Mobile IP (PMIP) [4].

Although many efficient mobility algorithms such as Mobile IP, Hierarchical Mobile IP and PMIP have been proposed, they did not attempt to upgrade their paging mechanisms that also heavily affect the power consumption of MNs. Considering a good paging scheme is important because more than 95% of MNs are moving in the idle state and change their states to active only for paging area updates [5]. Since Mobile IP requests MN to update its location periodically even while the MN is idle, it may produce the unnecessary signaling overhead. To remove the inefficiency of Mobile IP, Paging Extensions for Mobile IP (P-MIP) [6] added a paging function to Mobile IP.

On the other hand, an important design factor of IP Paging is the size of a paging area because the overall system performance may depends on the factor. Several studies on IP paging have been progressed for determining the paging area size dynamically [7, 8, 9]. However, those studies considered the speed of MN only at the calculation of the paging area size and suggested that the paging area size of MN should expand as its speed increased,

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Since the larger paging area may cause the more routers to go through the signaling overhead for paging area updates, those approaches have to be further refined. This paper attempted to reduce the signaling overhead by proposing a novel dynamic IP paging scheme, where a paging area size is configured dynamically based on the velocity of MN as well as its direction.

The remainder of this paper is organized as follows. Section 2 reviews previous work about current Proxy Mobile IP and IP Paging schemes. Section 3 presents our Paging scheme for PMIPv6 in which the paging areas are configured dynamically according to the velocity of the mobile node. Then, simulation results demonstrate the performance of our proposed scheme in Section 4. Finally this paper is concluded in Section 5.

## 2. Relate Works

### 2.1. Proxy Mobile IP

To Network-based Localized Mobility Management (NetLMM) working group of IETF has made an effort to achieve the basic principle of the mobility management technology that requires any mobility function not to be installed in any MN. The architecture of NetLMM consists of Localized Mobility Domain (LMD), Localized Mobility Anchor (LMA) and Mobile Access Gateway (MAG).  MAG detects the network access of MN and sends a Binding Update message to LMA. LMA connects and maintains the communication route to MN while the MN exists within the NetLMM domain. The basic protocol used for the interface between LMA and MAG is Edge Mobility Protocol (EMP), which is later optimized to Design Team Protocol (DTP) and Proxy-MIP (PMIP) based on the MIP technology. PMIPv6 provides the improvement of working without any change in the IP stack of MN by shifting the MIP function in a mobile device to MAG, a network node [10].

MAG plays the role of monitoring the movement of MN and sending the signaling message related to MN’s handovers to LMA on behalf of the MN. LMA takes charge of the role of HA in its PMIPv6 domain. LMA is the Anchor Point on the topology of Home Network Prefix (HNP) assigned to MN and manages the reachability state information of MN within the domain. Generally, the function of MAG can be built in Access Router and LMA can be located in the Gateway of the domain. IP tunnel is created between LMA and MAG to transfer signaling messages and data packets destined to/from MN. When MN is connected to a wireless link, MAG obtains ID and profile information of the MN through MN_Attach. This profile mandatorily contains MN’s ID, IPv6 address of LMA and IP address setting method on the access link, as well as IPv6 home network address of MN optionally. After obtaining the profile of MN, MAG transfers Proxy Binding Update (PBU) message to LMA for the registration of the MN’s current location. LMA, when receives PBU, returns PBA message containing MN’s HNP information to MAG and creates Binding Cache Entry (BCE) and a bi-directional IP tunnel between MAG and LMA to maintain the reachable state of the MN. After receiving PBA, MAG sets up the IP tunnel between MAG and LMA and the routing table for the data transfer to the MN. After that, MN obtains the information of its HNP address setting method through RS/RA procedure and sets up its IP address. When the address set-up process ends and LMA receives packets destined to MN within its PMIPv6 domain from any node outside of the domain, it transfers them to MAG through the IP tunnel between MAG and LMA. Sequentially, MAG forwards them to the MN. Conversely, every packet transmitted by MN reaches to MAG and transverses the IP tunnel to LMA, and then sent to the destination.

 

### 2.2. IP Paging

IP Paging represents a mechanism that allows an idle MN to perceive a group of Access Routers as one region called Paging Area (PA) and to move freely within this region without any location update notification to Home Agent. By using IP Paging, an idle MN does not need to send any Binding Update message as far as it does not go across the Paging Area, so that the battery consumption of the MN is reduced and the overall network overhead decreases. IP paging schemes that enable idle MNs to use paging in Mobile IP are as follows: Home Agent Paging, Foreign Agent Paging and Domain Paging [11]. Home Agent Paging stores the packets from CN in HA before the target MN is determined through the paging process. HA paging has a limitation in scalability and reliability because it may impose a heavy load to HA. FA paging requires the FA registered most recently to start paging. Since each FA shares the role of paging, this scheme has an advantage in scalability. Domain Paging allows every AR within the domain to play the role of paging. All ARs within the domain manage the paging information of MN as a soft state. Although Domain Paging enhances the reliability by distributing the paging load to every AR, all ARs within the domain have to endure the burden of managing all MN's information. On the other hand, there are several paging algorithms that find the current location of MN when a packet destined to the MN arrives. Examples are Fixed paging, Hierarchical paging and Last-location paging [9].

## 3. Proposed Paging Algorithm

### 3.1. PMIPv6 Architecture for IP Paging

Figure 1 shows a PMIPv6 architecture to which the proposed paging scheme is applied. In this architecture, there are multiple Paging Areas containing several MAGs, where each MAG is connected to LMA.

The paging function is implemented in the MAGs. A MN that is at MAG1, and that has not transmitted packets for a period of time, goes into a sleep mode. When this happens, information message which is included speed and direction of MN is transmitted to the MAG1. In case that MN is active, the mobility of the MN is supported by the original handover function of PMIP. MAG1 within PA1 informs other MAGs in the same paging area and LMA of the state information of the MN. From this point on, MAGs do not send any Binding Update messages while it moves around within the paging area (PA1). On the other hand, when MN goes out of PA1 and moves into an adjacent paging area PA2, MAG3 within PA2 performs a Binding Update process with LMA and informs other MAGs in PA2 of the paging state information of the MN without sending a RA message to the MN. After that, if CN sends to LMA packets destined to MN, the LMA sends a Paging Request message to the paging area (PA2) where MN exists in order to locate the MN. As soon as MAG3 of PA2 receives the Paging Request message, it returns a Paging Reply message to the LMA and sends a RA message to the MN at the same time. Then, data packets from the CN are sent to the MN through IP tunneling between LMA and MAG3.

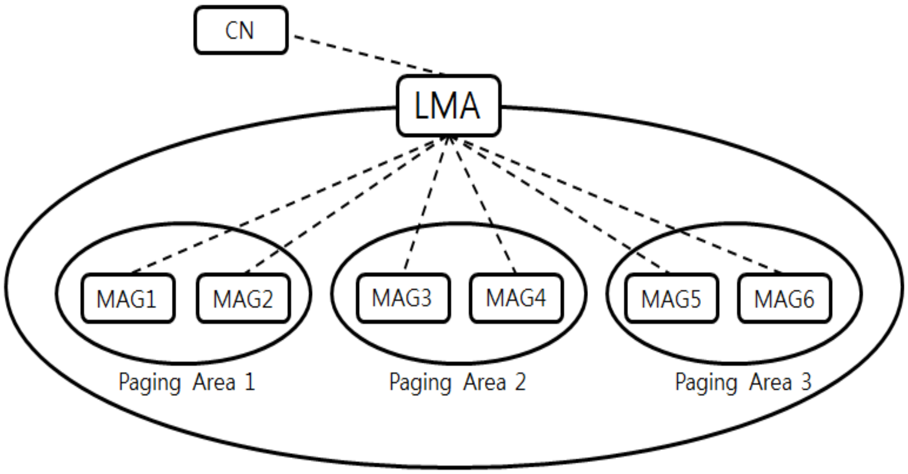


**Figure 1. PMIPv6 architecture for IP paging**

### 3.2. A Dynamic IP Paging Scheme

There are researches for IP paging in PMIP [12, 13]. However, previous researches just considered MN's speed and fixed PA. In this paper, our aim is to reduce paging and update costs by applying dynamic PA according to the mobile speed and direction. The random processes for speed change and direction change are modeled as completely independent of each other. However, it is normally not true in reality [14]. If the fixed PA is optimized for very low-speed MNs, the probability of crossing the PA boundary for high-speed MNs will increase significantly, and vice versa. Therefore, it is desirable to have a more adaptive PA, i.e., the paging area is shaped as taller-than-wider for high-speed MNs and wider-than-taller for low-speed MNs as shown in Figure 3.

Here, we propose a principle that models typical movement patterns of mobile nodes. Movement patterns correlate the direction change with the speed change. It is assumed that the direction is varied exponentially according to the mobile speed. Equation 1 shows the relationship between direction and speed. v indicates the current MN's speed, and f(v) indicates direction change. The angular span of PA is used to determine the dynamic PA as a function of the MN's speed. α is defined as the gradient of angular span.

$$f(v) = \begin{cases} 2\pi e^{-\alpha v} & if \quad v>0 \\ 0 & if \quad v=0 \end{cases} . \qquad \textbf{(1)}$$

Figure 2 shows the angular span according to the mobile speed. In this paper, the paging update period is set to 10 min. Figure 3 shows the proposed paging area (PA) according to the mobile speed.

 

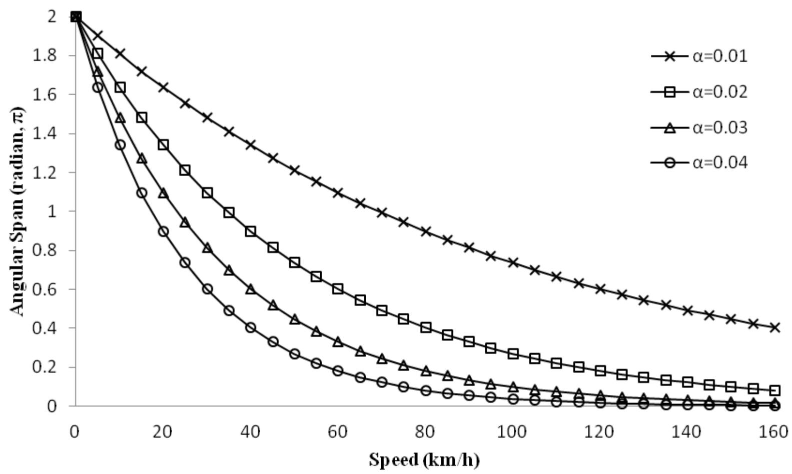


**Figure 2. Angular span according to the mobile speed**

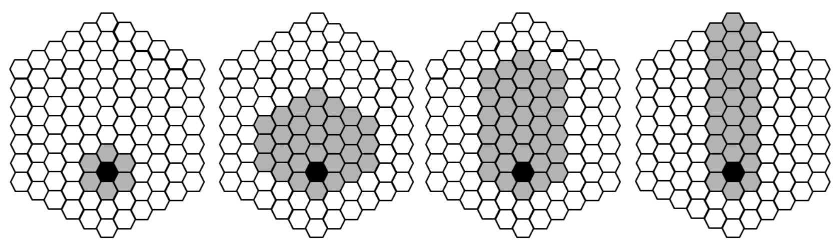


**Figure 3. Paging areas according to the mobile speed**

## 4. Performance Evaluation

In this section, we carry out an evaluation of the proposed paging algorithm. We estimate the bandwidth cost of location update and paging in the access network. Total cost is calculated in Equation 2.

$$C = C_{update} + C_{paging} \, . \qquad (2)$$

where $C_{update}$ is update cost and $C_{paging}$ is paging cost. To estimate these costs, we define the following variables.

- $C_b$: bandwidth cost
- $\lambda_c$: rate of session arrival
- $\lambda_s$: the number of times an MN goes to sleep-mode per unit time
- $\rho$: MN density per unit area
- $R_{cc}$: the number of MMs that cross the Paging Area boundary per unit time in fluid-flow mobility
- $N_p$: the number of paged cell.
- $L$: perimeter of Paging Area
- $R$: cell radius
- $v$: speed of mobile node

According to this algorithm, update packets are sent at the following times. When a MN switches to sleep-mode, it sends a status packet to the MAG to notify it of this status. This packet is propagated to the MAG, which places this MN on a paging list. It will receive an acknowledgement. Therefor the send/receive cost for sleep-mode is proportional to bandwidth cost, λs and ρ. Equation 3 shows the cost for sleep-mode.

$$C_{sleep\text{-}mode} = 2\rho\lambda_s C_b \cdot \qquad (3)$$

When an MN receives a page, it responds through the serving AR by updating its current location. This occurs at session arrival rate. Therefor the cost for a response is proportional to bandwidth cost, $\lambda_c$ and $\rho$. Equation 4 shows the cost for a response.

$$C_{response} = \rho\lambda_c C_b \cdot \qquad (4)$$

We use the fluid flow mobility model [15,16] to estimate the number of MNs that cross the PA boundary per unit time. This model assumes that the number of subscribers in a cell is a constant, the user move in an uncorrelated way and the direction of these movements for each user is uniformly distributed in [0,2π]. Considering an area with perimeter L where ρ terminals per unit of area are located. The crossing probability out of the area borders per unit of time is given by Equation 5.

$$R_{cc} = \frac{\rho v L}{\pi} \cdot \qquad (5)$$

Where v is the average speed of the MNs. Equation 6 shows the cost of crossing the boundary.

$$C_{crossing} = \rho R_{cc} C_b \cdot \qquad (6)$$

Paging costs depends on the number of cells that are paged before an MN is found. The average bandwidth cost of paging a single MN is estimated in Equation 7.

$$C_{paging} = \rho N_p C_b \cdot \qquad (7)$$

The overall cost of update and paging for MNs based on our algorithm is represented by Equation 8.

$$C = \rho\left(2\lambda_s + \lambda_c + R_{cc} + N_p\right)C_b \cdot \qquad (8)$$

The parameter values used to estimate the costs are shown in Table 1.

**Table 1. Parameter values used for simulation**

| λs | Λc | R | Cb | v |
|---|---|---|---|---|
| 0.2~0.8 | 0.2~0.8 | 1 km | 1 | 0~150 km/h |

Figure 4 shows the overall bandwidth cost according to the mobile speed with the parameter of gradient ($\alpha$). The overall bandwidth cost consists of paging cost and update cost. The lower the gradient ($\alpha$), the smaller the paging area. Since the paging area becomes smaller, the paging cost ($C_{paging}$) becomes lower. However, because the probability of crossing the boundary ($R_{cc}$) is increased, the cost of crossing the boundary ($C_{crossing}$) is increased. Therefore, we choose the optimal gradient value ($\alpha$=0.02) in that the overall bandwidth cost is the lowest on the average over the entire speed ranges.

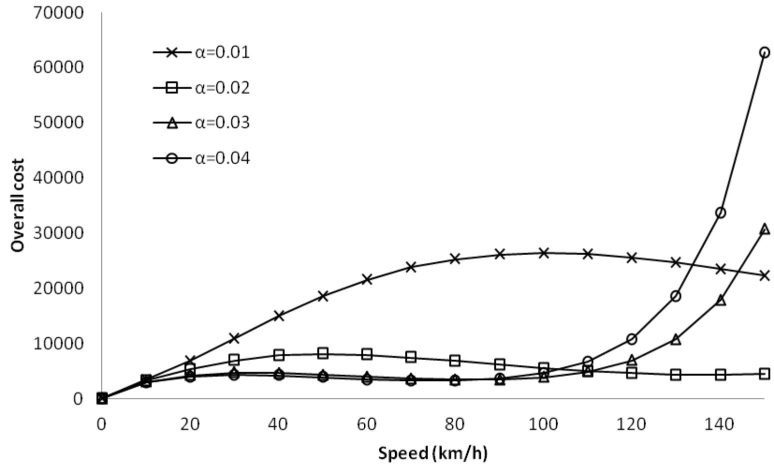


**Figure 4. Overall bandwidth cost of paging and update according to the mobile speed for different gradient values**

We simulate about the values of the parameters ($\lambda_c$ and $\lambda_s$). Figure 5 shows the overall cost of paging and updates according to user $\lambda_c$ and $\lambda_s$. The overall cost increase with increasing user density. The overall cost is similar according to the values of $\lambda_c$ and $\lambda_s$. Generally, idle state is longer than call state. So we use the values ( $\lambda_c$ = 0.4, $\lambda_s$ = 0.6). Also, $C_b$ is the bandwidth cost. Bandwidth cost value is defended on network environment. In this paper, we define that $C_b$ is 1 for simply calculate.

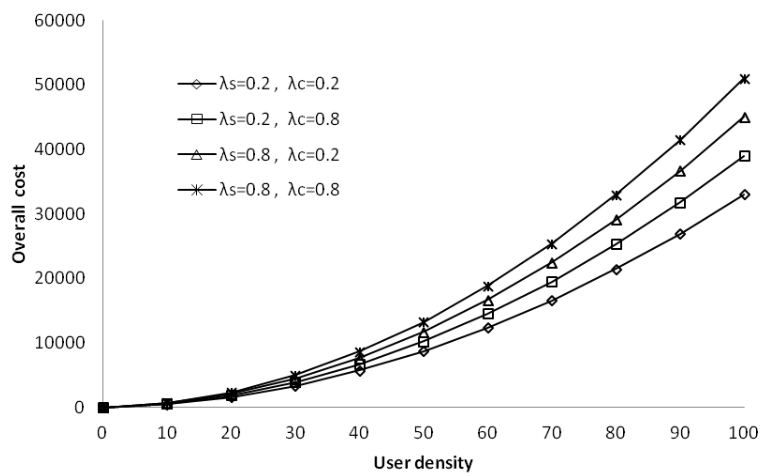


**Figure 5. Overall cost of paging and update according to user density**

Figures 6 and 7 shows the overall cost increase with increasing user density and speed. Figure 6 shows that the overall cost is increased by increasing the user density and speed. In Figure 7, there are 3 cases for simulation. Fixed PA is considered without speed and direction, Proposed PA (with speed) is just considered with speed, finally and Proposed PA (with speed and direction) is considered with speed and direction. The overall cost of paging and updates is reduced by over 50% when the proposed algorithm is with direction. Furthermore, it is reduced by over 70% when the proposed algorithm is with speed and direction.

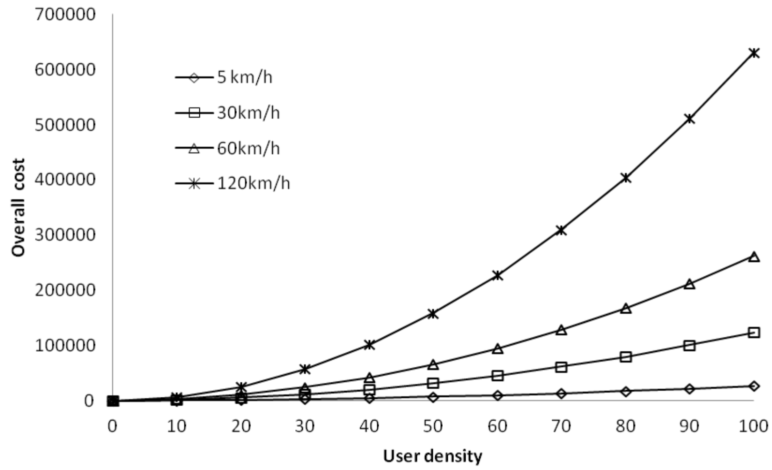


**Figure 6. Overall cost of paging and update according to user density**

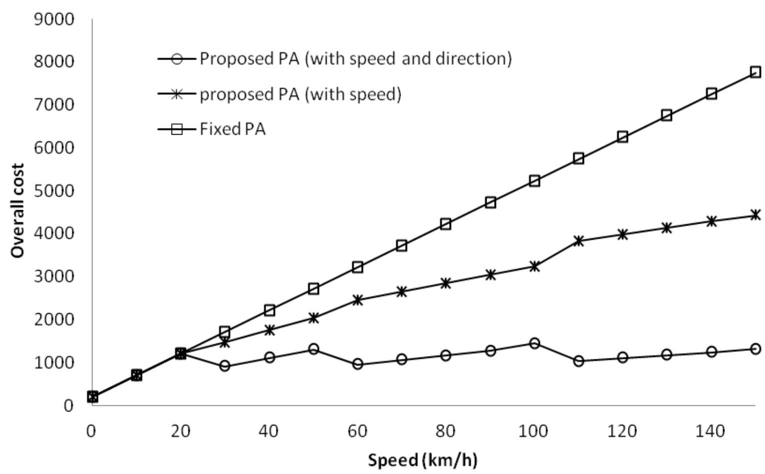


**Figure 7. Overall cost of paging and update according to mobile speed**

## 5. Conclusions

Both of the handover and the paging are two important functions of the mobility mechanism. Many IP handover schemes have been developed but IP paging schemes have not gathered much attention due to the simplicity and efficiency of the existing fixed paging. This paper explored the dynamicity of the paging area depending on the speed and the direction of MN for the first time. Throughout the analytic study and OPNET simulation, we proved that the proposed paging scheme outperformed the fixed paging and the dynamic paging with the speed of MN only considered in terms of the overall cost.

 

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