

# 계층적 모바일 IP 네트워크에서 2 계층에 기반한 Inter-MAP Handoff Rate 의 감소기법

정종필\*, 정민영\*, 추현승\*  
\*성균관대학교 정보통신공학부  
e-mail : [jpjeong@ece.skku.ac.kr](mailto:jpjeong@ece.skku.ac.kr)

## Reduction of Inter-MAP Handoff Rate Based on 2-Layers in Hierarchical Mobile IPv6

Jongpil Jeong\*, Min Young Chung\*, Hyunseung Choo\*  
\*School of Information and Communications, Sungkyunkwan University

### 요 약

Many schemes to reduce the inter-MAP handoff delay in hierarchical mobile IPv6 have been proposed but the previous schemes waste relatively large network resources to decrease the path rerouting delay. In this paper, we propose the 2-layered MAP concept, where the seamless inter-MAP handoff can be supported regardless of path rerouting time. As a result, the waste of wired resources and the rate of the inter-MAP handoff can be reduced. From the performance analysis and simulation, the inter-MAP handoff rate for non-real-time traffic is only about 1/3 of the conventional result. Such advantageous features of the proposed scheme neither incur any increase of the total handoff rate nor require additional MAPs.

### 1. 서론

In a wireless mobile network [1-6], the path rerouting between a terminal and its new access router (AR) is one of important issues which increase the handoff delay. If the original AR and the new AR are connected to the same mobility anchor point (MAP), there is no need to re-establish the new path for the migration of the terminal since the path between the MAP and the target terminal is the same. In consequence, the impact of a path re-establishment to the handoff time is negligible when the handoff occurs between ARs that are connected to the same MAP. The group of ARs connected to an MAP is called cluster. The handoff between ARs in the same MAP is then called intra-MAP handoff.

On the contrary, the handoff between ARs which are connected to the different MAPs is called inter-MAP handoff. When inter-MAP handoffs occur serially between two neighboring ARs which are connected to the different MAPs, i.e., when a mobile node (MN) migrates from cell a in MAP A to cell b in MAP B and continuously turns back to the cell a, the second handoff from cell b to cell a is called inter-MAP pingpong handoff [7]. In these cases, the handoff time delay is not negligible. The path re-establishment of an inter-MAP handoff is similar to the case of the new session establishment in the (wired) mobile networks and it needs new path routing and hop-by-hop connection setup along the new path. Therefore, the re-establishment of the path may require more time than the allowed maximum delay limit.

Most of the existing researches on this problem [8- 12] have been conducted to reduce path re-establishment time. These schemes describe the schemes to decrease path re-establishment time by finding common crossover switches between original and new routes or by making direct

connection between original and new MAPs. These attempt scan make path re-establishment time short. However, it is still difficult to execute inter-MAP handoff within the required maximum delay. Besides, the network resources are wasted by the new established routes which may not be optimized.

In this paper, a new scheme using the concept of 2-layered MAP is proposed to overcome the problems in the previous research. In the proposed scheme, one AR is connected to two mobility enhanced MAPs. In other words, one cell belongs to two MAPs at the same time. Using this scheme, it is possible to transmit the traffic to a new AR after full re-establishment of the path, in the case of inter-MAP handoff. The quality of service (QoS) negotiation and another route tracking are also practicable within the maximum delay. Moreover, the proposed scheme can effectively reduce both the inter-MAP handoff rate and the inter-MAP pingpong handoff rate using the same channel capacity. Besides the number of required mobility enhanced MAPs in the proposed system is the same as that in the conventional single layered network.

Following this introduction, we describe the proposed scheme in Section 2. In Section 3, we analyze the performance of the suggested scheme based on the inter-MAP handoff rate and the inter-MAP pingpong handoff rate. Finally, we make conclusions in Section 5.

### 2. 제안기법의 설명

#### 2.1. 2-Layered MAP Concept

The 2-layered Clustering is the cell Clustering methodology for a seamless inter-MAP handoff in a wireless mobile

network. It differs from the existing Clustering method in that the proposed concept allots two MAPs for one cell by having a AR be connected to two mobility enhanced MAPs. The two MAPs that contain the same cells belong to different layers respectively, and the MAPs in each layer are distributed in contact with each other like existing MAP structures.

The example of cellular configuration with this proposed concept is shown in Fig. 1 and 2. In Fig. 1, one MAP layer (layer 0) is distributed as in (a), and the other layer (layer 1) is distributed as in (b). Fig. 2 shows these two layers simultaneously. The arrangements of cells and MAPs in each layer vary, according to the radio environment and the mobile network structure.

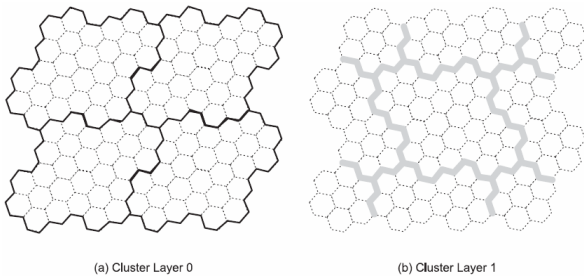


Figure 1. The example of 2-layered MAPs.

In the proposed 2-layered Clustering environment, the number of cells in one MAP is twice that of the single layered case, if the capacity of mobility enhanced MAPs is the same as that in the single layered case. To prove this, let the total wired capacity of the whole mobility enhanced MAPs be  $T$ , the capacity of one MAP be  $C$ , and the number of cells in the whole network be  $N_{cell}$ . The required capacity of each layer is then  $T/2$ , which is half of the total capacity and the number of MAPs per layer is  $T/2C$ . Then, the number of cells per MAP is given by  $\frac{2C}{T}N_{cell}$ , which is the number of total cells over the number of MAPs per layer. Hence, the number of cells per MAP of the network with the proposed concept is twice the number of cells in an 1-layered MAP,  $\frac{C}{T}N_{cell}$ .

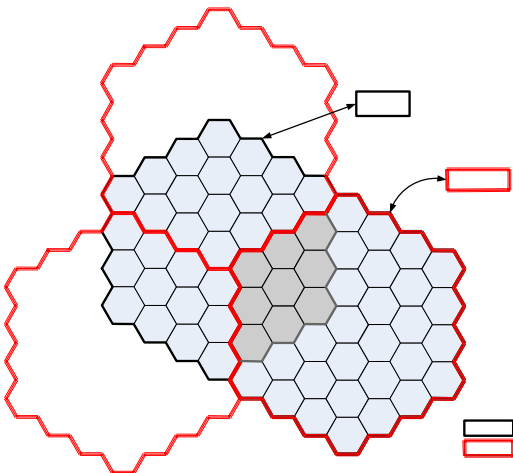


Figure 2. The example of wireless mobile cellular configuration with 2-layered MAP concept.

## 2.2. Handoff Scheme

When a new session arrives at a cell, the corresponding AR selects one of two MAPs connected to it. The AR tries to make a connection to the MAP in a way that the center of corresponding MAP is closer to the cell where the new session arrives. To easily select the closer MAP, we assume that the information about the arrangement of MAPs is stored in each AR.

When a radio hints such as router advertisement (RA) message from neighboring ARs are received by an MN, the corresponding AR of the current cell ( $AR_{OLD}$ ) checks the location of the AR of the newly migrating cell ( $AR_{NEW}$ ). If  $AR_{NEW}$  and  $AR_{OLD}$  are connected to the same mobility enhanced MAP, a new connection between  $AR_{NEW}$  and the connected MAP is setup first. The old connection between  $AR_{OLD}$  and the MAP is then released after the new connection setup is made. While MN communicates with the fixed network through the old channel before new connection setup, it communicates with new path after the connection to  $AR_{NEW}$ . Therefore, the time required for path re-establishment is approximately only a single-hop connection setup time. Because the path re-establishment time of intra-MAP handoff is within the required *maximum delay limit*, intra-MAP handoff does not make the forced termination.

The inter-MAP handoff needs more complex operations than the intra-MAP handoff. Two different schemes are applied to delay-sensitive real-time traffic such as real-time variable bit rate (rt-VBR) and constant bit rate (CBR) class applications, and to delay-insensitive nonreal-time traffic such as the cases of nonreal-time variable bit rate (nrt-VBR), available bit rate (ABR) and unspecified bit rate (UBR) classes.

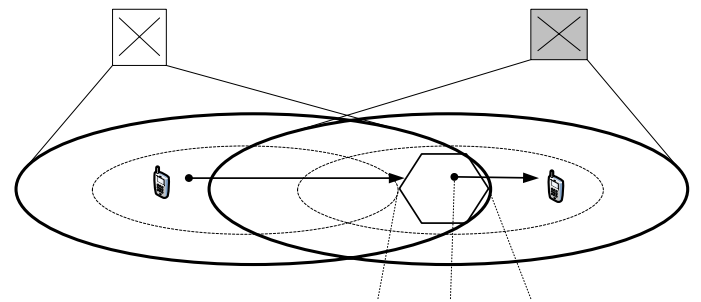


Figure 3. The inter-MAP handoff operation for real-time traffic.

As for the real-time traffic, the path re-establishment delay is critical for guaranteeing the required *maximum delay limit* to avoid a forced termination of a handoff session. To accomplish the path re-establishment and the end-to-end QoS negotiation within a limited time, the radio handoff and the path re-establishment should be executed independently. When the MN with a real-time traffic session enters a border cell of the current MAP, the new path related with its another MAP is established. In other words, the MN is switched from the current MAP to the overlaid one. The path rerouting method can be one of many path rerouting schemes such as

the full re-establishment, the path extension [14] and the partial re-establishment [15], but in this case, relatively much time is needed for rerouting because it starts when the MN migrates into the border cell and must be ended before the MN migrates out of that cell. The described handoff scheme for real-time traffic is shown in Fig. 3.

The proposed scheme thus can employ the full re-establishment scheme first. If the time is too short to execute the full re-establishment, the partial re-establishment can be used with fast crossover switch discovery methods. In the worst case, if the MN migrates too fast, the trial of path extension maybe made as for the last case. Each timeout factor for the selection of the rerouting scheme can be determined by the cell size, the radio environment and the multiple access schemes.

If the traffic has a non-real-time attribute, a major portion of the inter-MAP handoff scheme is the same as that in the real-time case, except that the new path is re-established with only radio hint. If the radio hint is also used in the case of real-time traffic to determine when to reroute a new path, the threshold value of a radio hint power for a non-real-time case is much higher than that for a real-time case to decrease the number of inter-MAP handoffs. Consequently, the new path is re-established simultaneously with radio handoff and the number of inter-MAP handoffs for the non-real-time traffic is much smaller than that for the real-time case. The shortcoming of the proposed scheme in the non-real-time case is the relatively long path re-establishment time, but it is not so critical as to violate the QoS required for non-real-time traffic. The described handoff scheme for non-real-time traffic is shown in Fig. 4.

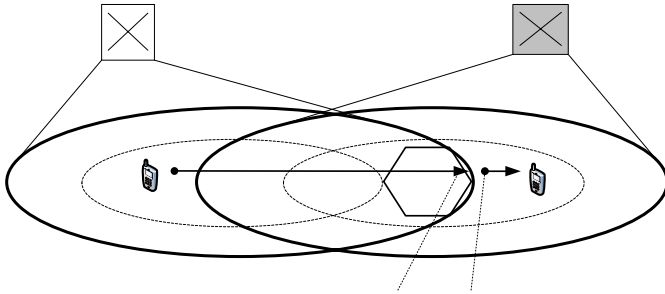


Figure 4. The inter-MAP handoff operation for non-real-time traffic.

### 3 Performance Analysis

In this section, the mathematical model of the cellular environment for wireless mobile networks is described and the performance analysis of the proposed scheme will be made. We assume that a AR is assigned to each cell and the overlapping of cells results in a cell having an equilateral hexagonal shape. Although the proposed system model adopts the square-like shapes of MAPs, we assume that the shapes of MAPs in the analysis model are hexagonal for the convenience of the analysis. Referring to Fig. 2, a ring is defined as a single or a group of boundary cells. A MAP, however, is made up of several rings. Here, inter-edges are defined as the boundary edges of the outermost ring of a

MAP and all the other remaining edges are termed as intra-edges.

Let  $I_E(N)$  and  $I_A(N)$  be the numbers of inter- and intra-edges in a MAP with  $N$  rings (where  $N = 1, 2, 3, \dots$ ) respectively. Let  $C(i)$  be the number of cells in ring  $I$  (where  $i=0, 1, 2, \dots, N-1$ ), and  $T_C(N)$  be the total number of cells in a MAP with in  $N$  rings. Then, the following relationships can be derived [17]:

$$I_E(N) = 12N - 6 \quad (1)$$

$$C(i) = \begin{cases} 1 \\ \frac{1}{2} \{6 + I_E(i)\} \end{cases} \quad (2)$$

$$T_C(N) = C(0) + \sum_{i=1}^{N-1} C(i) = 3N^2 - 3N + 1 \quad (3)$$

$$I_A(N) = \frac{1}{2} \{6T_C(N) - I_E(N)\} = 9N^2 - 15N + 6 \quad (4)$$

We denote  $R_{E,k}(N)$  as the inter-MAP handoff rate of the  $k$ -layered Clustering case with  $N$  rings in one MAP. From Eq. (1) and (4),  $R_{E,1}(N) = I_E(N) / 6T_C(N)$  is derived as,

$$R_{E,1}(N) = \frac{2N - 1}{3N^2 - 3N + 1} \quad (5)$$

In the case of 2-layered Clustering with real-time traffic, the rate of inter-MAP handoffs means the rate of migrations of an MN from the inner cells in a MAP to border cells. In addition, we assume that all new ARs and all handoff ARs migrate into inner cells of a new MAP (in real case, the exceptions can be existent but negligible).

Therefore,  $R_{E,2,RT}(N) = I_E(N-1) / 6T_C(N-1)$ , the inter-MAP handoff rate in the case of 2-layered Clustering with real-time traffic can be derived as,

$$R_{E,2,RT}(N) = \frac{2N - 3}{3N^2 - 9N + 7} \quad (6)$$

In the case of non-real-time traffic, the rate of inter-MAP handoffs means the probability that an MN migrates from an inner cell in a MAP to a border cell and migrates from the border cell to a cell in another MAP serially with the same assumption as that in the case of real-time traffic. The inter-MAP handoff rate in the case of 2-layered Clustering with non-real-time traffic,

$R_{E,2,NRT}(N) = R_{E,2,RT}(N) I_E(N) / 6C(N-1)$ , can be derived as,

$$R_{E,2,NRT}(N) = \frac{2N - 3}{3N^2 - 9N + 7} \cdot \frac{2N - 1}{6N - 6} \quad (7)$$

When  $N$  is large enough to ignore the remaining terms except highest order,  $R_{E,1}(N)$  and  $R_{E,2,RT}(N)$  converge to the same rate  $\frac{2}{3N}$ ,  $R_{E,2,NRT}(N)$  converges to  $\frac{2}{9N}$ . This convergence result means that the 2-layered real-time case has a similar rate to 1-layered case, and 2-layered non-real-time case has about one third of the other two rates.

In the simulated wireless mobile network environment, it is assumed that the cells located at the border of a MAP are folded, so that every cell has its neighbors to avoid the edge effect. In other words, the simulation environment has a spherical geometry.

The simulated network for the 1-layered case is Clustered into 7 MAPs with  $N$  rings where  $1 \leq N \leq 7$ , and in the case of 2-layered Clustering, one layer in the simulated

environment has 4 MAPs and one MAP is made up of 4 sets of cells with  $N$  rings as shown in Fig 2 where  $1 \leq N \leq 5$ .

The numerical results of analysis in the previous section and computer simulations are shown in Fig. 5.

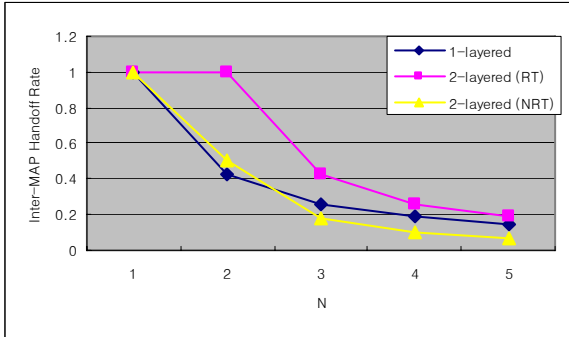


Figure 5. The rate of inter-MAP handoffs in total handoffs.

Fig. 5 shows the rate of inter-MAP handoffs to total handoffs. We see that the inter-MAP handoff rate in the 2-layered case for real-time traffic is larger than that in the 1-layered case, but the difference decreases with the growing of the number of cells in one MAP. Hence, the overall inter-MAP handoff rate decreases as the size of a MAP increases. As mentioned in the previous section, the inter-MAP handoff rate in the 2-layered case for real-time traffic converges to that of the 1-layered case by the increment of the number of cells per MAP and the handoff rate for non-real-time traffic in 2-layered systems is about  $\frac{1}{3}$  of the other two cases.

## 4 Conclusions

One of the most important topic of existing inter-MAP handoff schemes for wireless mobile networks is to minimize the impact related with the communication path rerouting which might generate forced terminations of some delay-sensitive connections due to the long handoff delay.

In this paper, the new proposed scheme with the layered arrangement of MAPs is proposed to solve this problem. The ARs in the wireless mobile networks of the proposed layered MAP concept are connected directly to two mobility support MAPs, and this configuration of network enables the path re-establishment before a radio handoff when an inter-MAP handoff occurs. The proposed handoff scheme using the layer MAP concept for the wireless mobile networks can effectively reduce the time delay for an inter-MAP handoff, the number of overall inter-MAP handoffs and the inter-MAP pingpong effects. It also manages the wired resources more efficiently. Besides, the number of required MAPs and base stations for the same capacity are invariable comparing with existing single layered methodologies. Moreover, only small modifications on wired networks for mobility support and the connection between each AR and corresponding two MAPs are needed.

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## 참고문헌

- [1] Johnson, D., Perkins, C., Arkko, J., "Mobility Support in IPv6," IETF RFC 3775, 2004.
- [2] Soliman, H., Malki, and K. El, "Hierarchical Mobility management," IETF RFC 4140, 2005.
- [3] N.Montavont et al., "Handover Management for Mobile Nodes in IPv6 Network," IEEE COMMUN, August 2002.
- [4] C. Perkins, "IP mobility support for IPv4," IETF RFC 3344, August 2002.
- [5] IETF Mobile IP WG: <http://www.ietf.org/html.charters/mobileip-charter.html>
- [6] E. Gustafsson, A. Jonsson, and C. Perkins, "Mobile IPv4 Regional Registration," IETF Internet-Draft, November 2005.
- [7] I. Akyildiz, J. McNair, J. Ho, H. Uzunalioglu, and W.Wang, "Mobility Management in Next-Generation Wireless Systems," Proceedings of the IEEE, Vol. 87(8), pp. 1347-1385, August 1999.
- [8] J. Xie and I. F. Akyildiz, "A Distributed Dynamic Regional Location Management Scheme for Mobile IP," IEEE Transactions on Mobile Computing, Vol. 1, No. 3, July 2002.
- [9] S. Pack and Y. Choi, "A Study on Performance of Hierarchical Mobile IPv6 in IP-based Cellular Networks," IEICE Transactions on Communications, Vol. E87-B, No. 3, pp. 462-469, March 2004.
- [10] Z. D Wu, "An Efficient Method for Benefiting the New Feature of Mobile IPv6," Proceeding of IASTED, pp. 65-70, October 2002.
- [11] I. F. Akyildiz and W. Wang, "A Dynamic Location Management Scheme for Next-Generation Multitier PCS Systems," IEEE Transaction on Wireless Communications, Vol. 1, No. 1, January 2002.
- [12] J. Jeong, M. Y. Chung, and H. Choo, "Reducing Location Update Cost Using Multiple Virtual Layers in HMIPv6," LNCS 4239, pp. 357-367, 2006.
- [13] X. Zhang, J.G. Castellanos, and A.T. Capbell, "P-MIP: Paging extensions for mobile IP," ACM Mobile Networks and Applications, Vol.7, No. 2, pp. 127-141, 2002.
- [14] K. Keeton, "Providing Connection Oriented Network Services to Mobile Hosts," in Proc. of USENIX Symposium on Mobile & Location Independent Computing, pp. 83-103, 1993.
- [15] P. Agrawal et al., "SWAN: A Mobile Multimedia Wireless Network," IEEE Personal Communication Magazine, Vol.3, No.2, pp.18-33, 1996.
- [16] Y.-B. Lin, S. Mohan and A. Noerpel, "Queueing Priority Channel Assignment Strategies for PCS Hand-Off and Initial Access," IEEE Trans. on Veh. Tech., Vol.43, No.3, pp.704-712, 1994.
- [17] P. Agrawal and Q. Zeng, Introduction Wireless and Mobile System, 2<sup>nd</sup> Edition, Thomson Publishing, 2006.