An Alternative IEEE 802.21-Assisted PMIPv6 to Reduce Handover Latency and Signaling Cost

Pyung Soo Kim

Abstract—**In this paper, an alternative IEEE 802.21-assisted Proxy Mobile IPv6 (PMIPv6) mechanism is proposed for reducing handover latency and signaling cost in heterogeneous wireless networks. The proposed mechanism comes to support fast vertical handover for the mobile node (MN) irrespective of the presence or absence of Media Independent Handover (MIH) functionality as well as IP mobility functionality. That is, the MN does not need to be participated in any MIH related signaling for handover procedure, which can be consistent with the essential objective of the PMIPv6. The base station with MIH functionality performs handover on behalf of the MN. Therefore, the proposed mechanism can reduce burden and power consumption of MNs with limited resource and battery power. In addition, analytical evaluation, experiment and simulation show that the proposed mechanism can outperform the existing mechanism in terms of handover latency and total number of over-the-air signaling messages. Thus, the proposed mechanism can be expected to reduce the packet loss and the bandwidth consumption of wireless links during handover procedure comparing with the existing mechanism.**

Index Terms—**Proxy Mobile IPv6, IEEE 802.21 MIH, Fast vertical handover, Handover latency, Signaling cost.**

I. Introduction

To access the Internet, today's mobile computers often have multiple heterogeneous wireless network interfaces [1], [2], [3], [4], [5], [6]. Thus, users can select and use the most appropriate network interface depending on the network environment, particularly in wireless networks which are mutable and less reliable than wired networks. As an IP mobility and handover solution for heterogeneous as well as homogenous wireless networks, the Proxy Mobile IPv6 (PMIPv6) has been developed and applied successfully [7], [8], [9], [10], [11]. The PMIPv6 protocol does not require the mobile node (MN) to be participated in the IP mobility signaling required for handover procedure. The mobility access gateway (MAG) performs the IP mobility signaling required for handover procedure on behalf of the MN. However, since the MN moves between different two MAGs in PMIPv6, the handover latency cannot be avoided. Therefore, in order to reduce handover latency, various fast handover PMIPv6 mechanisms have been researched recently. Among them, to deal with heterogeneous wireless networks, several IEEE 802.21-assisted PMIPv6 mechanisms have been researched based on the exchange of IEEE 802.21 Media Independent Handover (MIH) related signaling messages as well as IP mobility related signaling messages [12], [13], [14], [15], [16], [17]. Although these approaches can reduce the handover latency through the interaction between cross layers, the MN has to implement MIH functionality. However, this can be inconsistent with the essential objective of the PMIPv6 that does not require the MN to be participated in the IP mobility required for handover procedure. In addition, the MIH functionality can be somewhat burdensome and power consumptive for MNs with limited resource and battery power. Moreover, there can be the number of MIH related signaling messages for handover procedure, which can cause considerable traffic overhead over wireless links as the number of MNs grows.

Therefore, to resolve the problem of existing mechanisms in [12], [13], [14], [15], [16], [17], an alternative IEEE 802.21-assisted PMIPv6 mechanism is proposed for fast vertical handover in heterogeneous wireless networks. The main objective of the proposed mechanism is to support fast vertical handover for the MN irrespective of the presence or absence of MIH functionality as well as IP mobility functionality, whereas the MN in existing mechanisms in [12], [13], [14], [15], [16], [17] has to implement MIH functionality. That is, the proposed mechanism does not require the MN to be participated in MIH related signaling required for handover procedure, which can be consistent with the essential objective of the PMIPv6. The base station (BS) with MIH functionality performs handover procedure on behalf of the MN. Therefore, the proposed mechanism can reduce burden and power consumption of MNs with limited resource and battery power. In addition, from analytical evaluation, experiment and simulation, the proposed mechanism can be shown to outperform the existing mechanism in terms of handover latency and total number of over-the-air signaling messages. Thus, the proposed mechanism can be expected to reduce the packet loss and the bandwidth consumption of wireless links during handover procedure comparing with the existing mechanism.

II. IETF PMIPv6 and IEEE 802.21 MIH

In recent, the Proxy Mobile IPv6 (PMIPv6) was standardized in Internet Engineer Task Force (IETF) [7][8]. This protocol to supporting mobility does not require the mobile node (MN) to be involved in the signaling required for mobility management. The mobility access gateway (MAG) in the network performs the signaling and does the mobility management on behalf of the MN. However, since the MN moves between different two MAGs in PMIPv6, the handover latency cannot be avoided. Therefore, the need to communicate efficiently on the move and to minimize the packet loss caused by a handover is becoming increasingly important because the handover latency is unacceptable for real-time IP services and throughput sensitive applications.

To provide general solutions for the vertical handover in heterogeneous access networks, the IEEE 802.21 standards group developed the media independent handover (MIH)

Manuscript received December 9, 2012.
Pyung Soo Kim is with the Department of Electronic Engineering, Korea Polytechnic University, Shiheung-City, Gyeonggi-Do, 429-793, KOREA e-mail: pspeter.kim@gmail.com.

(Advance online publication: 21 May 2013)

function [3], [4], [5]. The major purpose of MIH function is to provide abstracted services to upper layers by means of a unified interface and thus to enhance users' experience of mobile devices by supporting handover between heterogeneous networks. These services provided by MIH function help the upper layers in maintaining service continuity, service adaptation to varying quality of service, battery life conservation, and network discovery and link selection.

III. Main Results

As shown in Figure 1, the proposed mechanism requires a new entity, an MIH capable wireless base station (MIH-BS). The MIH-BS manages the MIH related signaling on behalf of the MN that is attached to its L2, which is the key idea of the proposed mechanism.

A. Operation Procedure

1) Acquirement of Information on Adjacent Networks: When the MN in the serving network senses the signal strength of the serving MIH-BS is becoming too weak, the MN decides the L2 handover. Then, the MN's L2 produces a handover trigger and sends it to the serving MIH-BS. This L2 trigger can be reused by the existing standard message. Then, the serving MIH-BS sends *MIH_Link_Going_Down_Indication* to the serving point of service (PoS) located in the serving access router. The serving PoS queries the MIIS(Media Independent Information Service) Server to retrieve information about available adjacent networks to which the attached MN may handover. This retrieval is done through exchanging *MIH_Get_Information Request* and *MIH_Get_Information Response*.

2) Determination of Handover Target: The serving MIH-BS triggers a network-initiated handover by sending the *MIH_Net_HO_Candidate_Query Request* message to the serving POS. The serving PoS sends the *MIH_N2N_HO_Query_Resource Request* messages to different candidate PoSs (can be more than one) to query the availability of resource to provide QoS at candidate networks. The candidate PoS responds by sending the *MIH_N2N_HO_Query_Resource Response* message to the serving PoS. The serving PoS determines the target network and the new MAG (NMAG) for the handover based on the resource availability information of candidate networks through the received *MIH_N2N_HO_Query_Resource Response* message. The serving POS responds by sending the *MIH_Net_HO_Candidate_Query Response* message to the serving MIH-BS to inform that the target network is determined.

3) Handover Preparation: The serving MIH-BS requests handover commitment to the serving POS in the serving network by sending the *MIH_Net_HO_Commit Request* message to the serving POS. The serving PoS also notifies the target PoS of the fact the MN is about to move to the network and connect to the NMAG through the *MIH_N2N_HO_Commit Request* message. The target PoS replies the result of the handover commitment by sending *MIH_N2N_HO_Commit Response* to the serving POS. The serving POS responds by sending the *MIH_Net_HO_Commit Response* message to the serving MIH-BS to inform the result of the handover commitment. Upon receiving the *MIH_N2N_HO_Commit Request* message, the NMAG in the target network queries the incoming MN's profile information to a policy store such as AAA server. As a result, the NMAG obtains profile information for PMIPv6 processes corresponding to the MN.

4) Handover Execution: Once the MN establishes L2 connection to the target MIH-BS in the target network, the NMAG detects the MN's attachment and then sends Router Advertisement (RA) message to the MN. The RA message is constructed with the queried MN's profile information. It can be solicited by Router Solicitation (RS) message from the MN and periodically transmitted. MN configures IP addresses on its interface, currently used to connect to the NMAG, based on the received RA message. The NMAG in the target network registers the current MN's location to LMA by sending Proxy Binding Update (PBU) message. After reception of PBU, the LMA updates the lifetime for the MN's entry in binding cache table, and replies with Proxy Binding Acknowledgement (PBA) message, then starts transmission of the buffered data through the tunnel between LMA and NMAG. Thus, the PMIPv6 procedures are completed and then MN receives packets through both NMAG and LMA.

5) Handover Completion: After the PMIPv6 procedure, the target MIH-BS sends the $MIH\_Net\_HO\_Complete\ Request$ message to the target PoS. The target PoS and the serving POS exchange messages *MIH_N2N_HO_Complete Request* and *MIH_N2N_HO_Complete Response*. Then, the target POS sends the $MIH\_Net\_HO\_Complete\ Response$ message to the target MIH-BS, which completes overall handover procedure.

IV. Performance Evaluations

In this section, the proposed mechanism is shown to outperform the existing mechanism through analytic performance evaluation, experiment and simulation.

A. Analytical Evaluation

The proposed mechanism can support fast vertical handover for the MN irrespective of the presence or absence of MIH functionality as well as IP mobility functionality, whereas the MN in existing mechanisms [12], [13], [14], [15], [16], [17] has to implement MIH functionality. That is, the proposed mechanism does not require the MN to be participated in MIH related signaling required for handover procedure, which can be consistent with the essential objective of the PMIPv6. The MIH-BS performs handover on behalf of the MN. Therefore, the proposed mechanism can reduce burden and power consumption of MNs with limited resource and battery power.

The handover latency can be defined by the time required for two steps "Handover Execution" and "Handover Completion" from Figure 2. Then, handover latencies for the proposed mechanism and the existing mechanism in [12], [13], [14], [15], [16], [17] can be represented as shown in Table 1. The term $T_{\alpha:\beta-\gamma}$ in Table 1 defines the time required for the exchange of α related signaling messages between two entities β and γ. The handover latency of the proposed mechanism is shown to be explicitly shorter

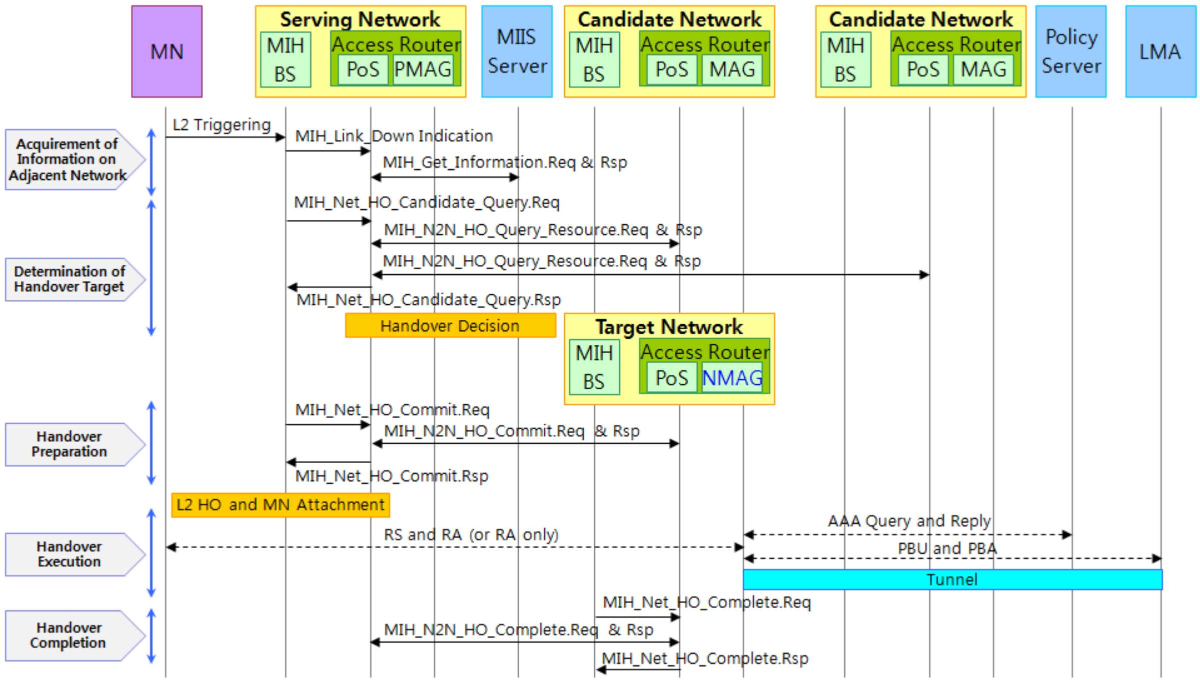

Fig. 1. Operation procedure of proposed IEEE 802.21-assisted PMIPv6

than that of the existing mechanism due to the exchange time $T_{MIH:MN-BS}$ of over-the-air signaling messages. Especially, the term $T_{MIH:MN-BS}$ can be varied diversely due to the dynamic nature of wireless technologies. Meanwhile, the signaling cost can be defined by the total number of over-the-air signaling messages between MN and BS during overall handover procedure, that is, five steps. As shown in Table 1, the proposed mechanism can reduce 6 signaling messages over wireless links between MN and BS comparing with the existing mechanism in [12], [13], [14], [15], [16], [17], which means that the proposed mechanism can reduce considerably traffic overhead over wireless links.

From the above analysis, the proposed mechanism can be shown to outperform the existing mechanism in terms of handover latency and total number of over-the-air signaling messages. Thus, the proposed mechanism can be expected to reduce the packet loss and the bandwidth consumption of wireless links during handover procedure comparing with the existing mechanism in [12], [13], [14], [15], [16], [17].

B. Experiment for Packet Loss Measurement

To demonstrate the practical usefulness of the proposed mechanism, experiments are performed to measure packet loss for a real-time audio streaming service. It is noted that the packet loss could be appreciable for real-time and throughput-sensitive Internet services such as multimedia streaming, VoIP, and IPTV [6], [18], [19]. Hence, minimizing packet loss is an important issue in the practical environment. The testbed for experiments has two MAGs, PMAG and SMAG, and a single MN communicating with a correspondent node (CN) over IEEE 802.11n wireless network environment. For this testbed, the traffic is generated by the audio streaming server that plays a role of the CN. Then a single MN RTP/UDP streaming service between two MAGs is experimented for the proposed mechanism and the existing mechanism. To make a clearer, 50 handovers are performed and then lost packets are measured. As shown in Fig. 2, experiments show that the proposed mechanism can minimize packet loss more than the existing mechanism.

C. Simulation for Signaling Cost Measurement

Simulations are also performed to measure signaling cost, that is, the number of over-the-air signaling messages between MNs and BS for MNs' handovers. As shown in Table 2, 50 MNs are considered and they are assumed to perform randomly 2∼8 handovers for 60 minutes. As shown in Fig. 3, simulations show that the proposed mechanism can outperform remarkably the existing mechanism, which means that the proposed mechanism can reduce considerably traffic overhead over wireless network environment during handover procedure.

V. Conclusion

This paper has proposed an alternative IEEE 802.21-assisted PMIPv6 mechanism for reducing handover latency and signaling cost in heterogeneous wireless networks. The proposed mechanism can support fast vertical handover for the MN irrespective of the presence or absence of MIH functionality as well as IP mobility functionality, whereas the MN in existing mechanisms has to implement MIH functionality. In other words, the MN does not need to participate in any MIH related signaling for handover procedure in the proposed mechanism, which can be consistent with the essential objective of the PMIPv6. On behalf of the MN, the BS with MIH functionality performs handover. Therefore, the proposed mechanism can reduce burden and power consumption of MNs with limited resource and battery power since MNs are not required to be participated for the handover procedure. In addition, the proposed mechanism has been shown to outperform the existing mechanism in terms of handover latency and total number of over-the-air signaling messages through analytical evaluation, experiment and simulation. Thus, the proposed mechanism can be expected to reduce the packet loss and the bandwidth consumption of wireless links during handover procedure comparing with the existing mechanism.

TABLE I
ANALYTICAL EVALUATION

	Handover latency	Signaling cost
Proposed mechanism	$T_{L2} + T_{PMIPv6:AR-LMA}$ $+T_{MIH:BS-AR}$	1
Existing mechanism	$T_{L2} + T_{PMIPv6:AR-LMA}$ $+T_{MIH:MN-BS} + T_{MIH:BS-AR}$	7

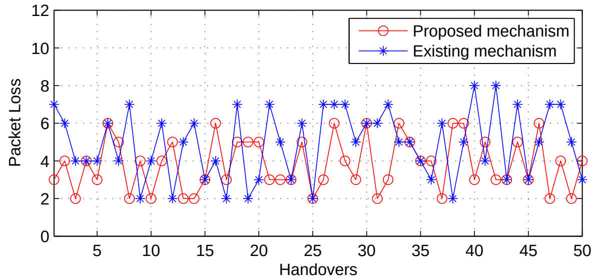

Fig. 2. Experiment result : Packet loss measurement.

TABLE II
SIMULATION CONDITION FOR SIGNALING COST MEASUREMENT

Number of MNs	50
Simulation duration	60 Min
Number of handovers for each MN	2∼8 times

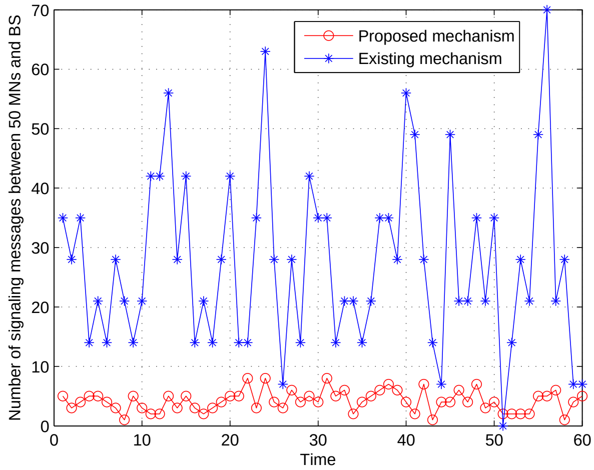

Fig. 3. Simulation result : Signaling cost measurement.

REFERENCES

[1] M. Kassar, B. Kervella, and G. Pujolle, "An overview of vertical handover decision strategies in heterogeneous wireless networks," *Computer Communications*, vol. 31, no. 10, pp. 2607–2620, 2008.

[2] A. Maheshwari, S. Agrawal, H. Venkataraman, and G.-M. Muntean, "PRIoritized Multimedia Adaptation scheme over two-hop heterogeneous wireless networks (PRiMA)," *Engineering Letters*, vol. 18, no. 2, pp. 119–134, 2010.

[3] K. Taniuchi, Y. Ohba, V. Fajardo, S. Das, M. Tauil, Y.-H. Cheng, A. Dutta, D. Baker, M. Yajnik, and D. Famolari, "IEEE 802.21: Media Independent Handover: features, applicability, and realization," *IEEE Communication Magazine*, vol. 47, no. 1, pp. 112–120, 2009.

[4] J. Marquez-Barja, C. Calafate, J.-C. Cano, and P. Manzoni, "Evaluation of a technology-aware vertical handover algorithm based on the IEEE 802.21 standard," in *Proc. of the 2011 IEEE Wireless Communications and Networking Conference*, 2011, pp. 617–622.

[5] F. Kronestedt, A. Furuskar, S. Landstrom, L. Falconetti, and K. Johansson, "Heterogeneous networks - Increasing cellular capacity," *Ericsson Reivew*, vol. 88, no. 1, pp. 4–9, 2011.

[6] P. S. Kim, "An optimized vertical inter-MAP handover scheme for HMIPv6 in heterogeneous wireless networks," *International Journal of Innovative Computing, Information and Control*, vol. 9, no. 9, p. Accepted for publication, 2013.

[7] S. Gundavelli, K. Leung, V. Devarapalli, K. Chowdhury, and B. Patil, *Proxy Mobile IPv6*. IETF RFC 5213, August 2008.

[8] K.-S. Kong, Y.-H. Han, M.-K. Shin, and H. You, "Mobility management for All-IP mobile networks: Mobile IPv6 vs. Proxy Mobile IPv6," *IEEE Wireless Communication*, vol. 15, no. 2, pp. 36–45, 2008.

[9] H. Luo, H. Zhang, and Y. Q. V. Leung, "An approach for building scalable Proxy Mobile IPv6 domains," *IEEE Trans. on Network and Service Management*, vol. 8, no. 3, pp. 1932–4537, 2011.

[10] S. Jeon and Y. Kim, "Cost-efficient network mobility scheme over Proxy Mobile IPv6 network," *IET Communications*, vol. 5, no. 18, pp. 2656–2661, 2011.

[11] J. Kim, R. Haw, E. Cho, C. Hong, and S. Lee, "A 6LoWPAN sensor node mobility scheme based on Proxy Mobile IPv6 ," *IEEE Trans. on Mobile Computing*, vol. 11, no. 12, pp. 2060–2072, 2012.

[12] L. A. Magagula and H. A. Chan, "IEEE 802.21-assisted cross-layer design and PMIPv6 mobility management framework for next generation wireless networks," in *Proc. of the 2008 IEEE International Conference on Wireless & Mobile Computing, Networking & Communication*, 2008, pp. 159–164.

[13] I. Kim, Y. C. Jung, and Y. Kim, "Low latency proactive handover scheme for Proxy MIPv6 with MIH," *Lecture Notes In Computer Science*, vol. 5297, pp. 344 – 353, 2008.

[14] S. Jeon, N. Kang, and Y. Kim, "Enhanced predictive handover for fast Proxy Mobile IPv6," *IEICE Trans. Commun.*, vol. E92-B, no. 11, pp. 3504–3507, 2009.

[15] H. Song, J. Kim, J. Lee, and H. S. Lee, "Analysis of vertical handover latency for IEEE 802.21-enabled Proxy Mobile IPv6," in *Proc. of the 13th International Conference on Advanced Communication Technology (ICACT)*, 2011, pp. 1059 – 1063.

[16] T. Melia, F. Giust, R. Manfrin, A. de la Oliva, C. J. Bernardos, and M. Wetterwald, "IEEE 802.21 and Proxy Mobile IPv6: A network controlled mobility solution," in *Proc. of the 2011 Future Network and MobileSummit Conference*, 2011, pp. 1–8.

[17] J. Jose and A. Prithiviraj, "PMIPV6-HC-MIH: An approach for improving handover performance in NGWN," in *Proc. of 2012 International Conference on Computing, Electronics and Electrical Technologies (ICCEET)*, 2012, pp. 910–914.

[18] M. Gorius, J. Miroll, M. Karl, and T. Herfet, "Predictable reliability and packet loss domain separation for IP media delivery," in *Proc. of the IEEE International Conference on Communications (ICC)*, 2011, pp. 1–6.

[19] Z. Li, X. Zhu, A. Begen, and B. Girod, "IPTV multicast with peer-assisted lossy error control," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 22, no. 3, pp. 434 – 449, 2012.

Pyung Soo Kim He received the M.S. degree in Control and Instrumentation Engineering and the Ph.D. degree at the School of Electrical Engineering and Computer Science from Seoul National University, Korea, in 1996 and 2001, respectively. From 2001 to 2005, he was a senior researcher at the Digital Media R&D Center of Samsung Electronics Co. Ltd., Korea. During 2012, he was a visiting research scholar at Center for Embedded Computer Systems, University of California, Irvine, USA. Since 2005, he has been with the Department of Electronics Engineering at Korea Polytechnic University, Korea. He is currently teaching and researching wireless mobile networks, future Internet, optimal state estimation filtering, statistical signal processing, and related subjects.