차세대 이동통신 네트워크를 위한 향상된 이동성 관리 프레임워크

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Enhanced Mobility Management Framework for Future Generation Networks

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요 약

차세대 이동통신 네트워크는 다양한 이종 접속 시스템들이 통합된 환경에서 vertical 핸드오버와 seamless 핸드오버를 지원하여야 한다. IEEE 802.21은 이를 위해 이종 접속 네트워크에서 효율적인 핸드오버 서비스를 지원하는 Media Independent Handover (MIH) 서비스를 제안하였다. 그리고 IETF는 호스트 이동성을 지원하고 핸드오버 지연을 감소시킬 수 있는 Fast handover for MIPv6 (FMIPv6) 기술을 제안하였다. 본 논문에서는 MIH 서비스와 FMIPv6 기술을 융합하여, 차세대 이동통신 네트워크 환경에 적합한 이동성 관리 프레임워크를 제안한다. 제안하는 프레임워크는 무선 네트워크 구간에서 오버헤드로 작용하던 핸드오버 시그널링 메시지들의 사용을 줄이고, 새로운 MIH 메시지 및 로컬 프리미티브를 사용한다. 또한, 사용자 단말에서 수행하던 많은 핸드오버 처리 절차들을 Serving Access Router (SAR)가 수행하도록 제안한다. 따라서 제안된 이동성 관리 프레임워크는 기존의 프레임워크에 비해 핸드오버 시그널링 오버헤드, 핸드오버 지연 및 패킷 손실을 감소시킬 수 있고, 수치해석과 네트워크 시뮬레이션을 통해 이를 검증한다.

Key Words : Mobility, MIH, FMIPv6, Heterogeneous, FGN

ABSTRACT

The Future Generation Networks(FGNs) are proposed to integrate various heterogeneous access technologies, and further expected to support both vertical and seamless handovers. In this motivation, the IEEE 802.21 specifies Media Independent Handover(MIH) services to enhance the mobile user experience by optimizing handovers between heterogeneous access networks. Additionally, Fast handover for MIPv6(FMIPv6) is introduced to provide transparent host mobility and to improve handover performance by reducing handover delay as well. This paper focuses on the coordination of FMIPv6 and MIH, and introduces an enhanced mobility management framework suited for FGN. This novel framework replaces handover signaling messages used in wireless networks with novel MIH messages and local primitives. Moreover, Serving Access Router(SAR) performs most of handover processes instead of Mobile Node(MN). Therefore, the proposed mobility management framework reduces handover latency, packet loss, and signaling overhead significantly. We further evaluate the performance of the proposed framework by using both numerical analysis and network simulations.

Ⅰ. Introduction

In recent years, various wireless access technologies such as Global System for Mobile communications(GSM), Code Division Multiple Access 2000 (CDMA2000), Universal Mobile Telecommunications

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System(UMTS), Wireless Local Area Networks (WLAN), and Worldwide Interoperability for Microwave Access(WiMax) have tremendously evolved and deployed all over the world. Moreover the user demands for higher service quality including higher data rate, higher mobility, and Quality of Service(QoS) have continuously grown in these days. However, such user demands have not been fulfilled by each wireless access technology alone. The complementary characteristics of WLAN, faster but stationary, do not provide high mobility but high data rate, while the complementary characteristics of CDMA 2000, slower but highly mobile, do not provide high data rate but high mobility. Therefore, the Future Generation(or 4G) Networks (FGNs) are integrating those multiple heterogeneous access technologies into a common convergence network[1],[2].

The convergence network has been broadly applied to the common effort among mobile operators and standards bodies to achieve the ubiquitous, the key point of the FGNs. Such ubiquitous networks are expected to guarantee 'any-service with any-device through any-network at any-where in any-time'. In order to support this ubiquitous service, there are crucial requirements which are very high data rate for 'any-service', multi-interface systems for 'any-device', integrated heterogeneous networks and high mobility for 'any-network', and so on. Consequently, it is essential that multi-interface systems handover seamlessly across heterogeneous wireless access networks.

Lots of efforts are devoted to inter-working and seamless handover techniques between heterogeneous access networks. IETF has proposed and discussed a number of mobility management solutions across IP domains. Especially, mobility support for IPv4 and which for IPv6, called Mobile IPv4(MIPv4) and MIPv6 respectively, have been specified and widely accepted for mobility solution. They provide transparent host mobility but with limitations mainly for delay-sensitive multimedia applications such as Voice over IP(VoIP). So, Fast handover for MIPv6 (FMIPv6) is introduced to enhance handover performance by reducing handover delay. In addition, IEEE 802.21 introduces the Media Independent Handover (MIH) Services to improve the handover performance across heterogeneous access networks, i.e. vertical handover, and to optimize the service(or session) continuity during handovers, i.e. seamless handover. For this reason, MIH provides generic link layer intelligence and other related network information to upper layers. Particularly, MIH offers the message flow between handover-related entities to provide information on handover candidate networks and to deliver handover commands[3]-[5].

In this paper, we propose the enhanced mobility management framework coordinating IEEE 802.21 MIH and IETF FMIPv6, suited for FGNs. There have already been some researches combining MIH and FMIPv6. In [6], handover latency for FMIPv6 is reduced by removing the router discovery phase in accordance with the assist of MIH. In [7], the router discovery delay of FMIPv6 and the network discovery delay of link layer(L2) is reduced by using MIH. However, both have not met the condition of seamless handover due to the lack of the regard for wireless signaling overhead and processing overhead of MN. Especially, the insufficient regard for wireless signaling overhead of MIH causes not only handover latency but also packet loss and power loss of MN as well. In this motivation, we focus on the network-based "calm" service and the balance in order to facilitate vertical and seamless handover. The calm service denotes that user may not notice when, where, and how the handover occurs. So the enhanced mobility management framework suggests that network entities, such as Access Router(AR) and Point of Attachment(PoA), perform most of handover processes. Moreover, the balance is assumed to mean that the more resources there are, the greater message capacity there are. Note that wired networks have much more resources(or bandwidth) than wireless networks. So it is balanced that the networks above PoAs, i.e. wired networks, are given more signaling messages to process than the networks beyond PoAs, i.e. wireless networks. In these motivations, we define the novel MIH messages and MIH primitives in the proposed mobility management framework. Furthermore, we evaluate the performance of the proposed framework by using both the numerical analysis and the NS-2 network simulations, in terms of handover latency, signaling overhead, and packet loss.

The rest of this paper is organized as follows. In the next section, we explain the emerging mobility management techniques that are MIH and FMIPv6. In section 3, we describe the proposed mobility management framework coordinating both MIH and FMIPv6. Section 4 evaluates and analysis the performance of the proposed mobility management frameworks, and then we conclude this paper in Section 5.

Ⅱ. Related Works

2.1 IEEE 802.21 MIH Services

MIH introduces a framework that defines Media Independent Handover Function(MIHF). It is logically designed as a shim layer between the L2 and upper layers in the protocol stack of both MN and network element. Figure 1 shows the placement of MIHF within the mobility management protocol stack and the interaction of MIHF with the link layer and upper layers. As using this interaction, MIHF facilitates both vertical and seamless handovers across heterogeneous access networks. Especially, MIHF employs three kinds of services as the key element of the interaction. These services are responsible for provision of handover-related information such as link status, link layer intelligence, serving and neighboring access networks information, and operation policies. In addition, they help upper layers coordinate and manage handovers, while supporting both network-initiated and mobile-initiated handovers. The above three services are Media Independent Event Service(MIES), Media Independent Command Service(MICS), and Media Independent Information Service(MIIS)[4]-[10]. MIH offers well defined Service Access Points(SAPs) which provide a set of primitives as illustrated in Figure 2. First, the access between MIH and upper layers is supported by MIH_SAP using media independent primitives. Secondly, the access between MIH and link layer is provided by MIH_LINK_SAP using media dependent primitives preexisting in each access networks. The third one is MIH_NMS_ SAP which connects MIH and Network Management System (NMS) for management functions. Lastly, MIH_NET_SAP supports the exchange of MIH information and messages between the local and the remote MIHF instances.

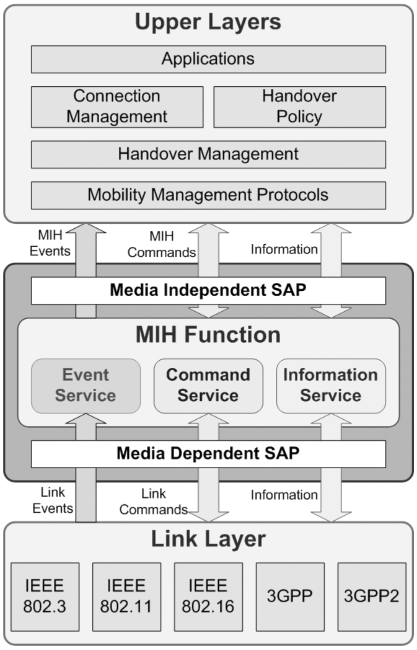

Figure 1. MIHF location and MIH key services
그림 1. MIHF 구조와 MIH 서비스 구성

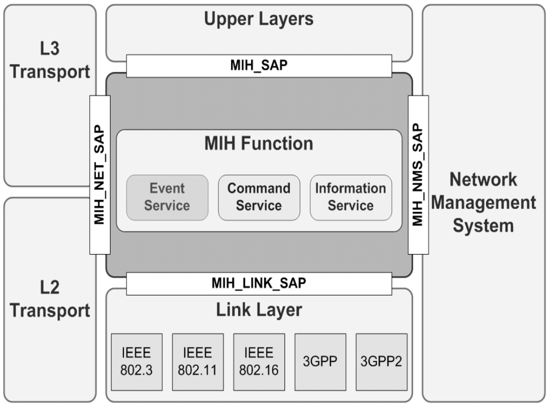

Figure 2. MIH service access points
그림 2. MIH service access points 구조

2.2 IETF FMIPv6

As mentioned in Section 1, MIPv6 is standardized by the IETF in order to facilitate handover across IP domains. During MIPv6 assisted handover, there is a period during which MNs are unable to send or receive packets because of link switching delay and IP protocol operations. This handover latency, namely movement detection, new Care-of Address(CoA) configuration, and Binding Update (BU), is often unacceptable to real-time traffic such as Voice over IP(VoIP). So the IETF has defined the FMIPv6 to reduce the MIPv6 handover latency. FMIPv6 enables MNs to quickly detect that it has moved to a new network by providing the information of the new PoA and the associated subnet prefix when the MN is still connected to its serving network. It also allows MNs resolve PoA identifiers to subnet router information by employing Router Solicitation for Proxy Advertisement(RtSolPr) and Proxy Router Advertisement(PrRtAdv) messages at any convenient time, for instance as a response to some link-specific event or simply after performing router discovery. Hence, the latency due to new prefix discovery subsequent to handover is eliminated. In order to reduce the BU latency, FMIPv6 further sets a binding between the old CoA and the new CoA by sending Fast Binding Update(FBU) message to its previous serving PoA to establish tunnel[3].

Ⅲ. Mobility Management Frameworks

3.1 Legacy MIH-FMIPv6 Framework

The IEEE 802.21 MIH offers a framework of the message flows between handover-related entities to provide information on handover candidate networks and to deliver commands about handovers. It defines both mobile-initiated and network-initiated handover frameworks. Both consist of MIH discovery, MIH selection, mobility management, and MIH completion. During the MIH discovery phase,

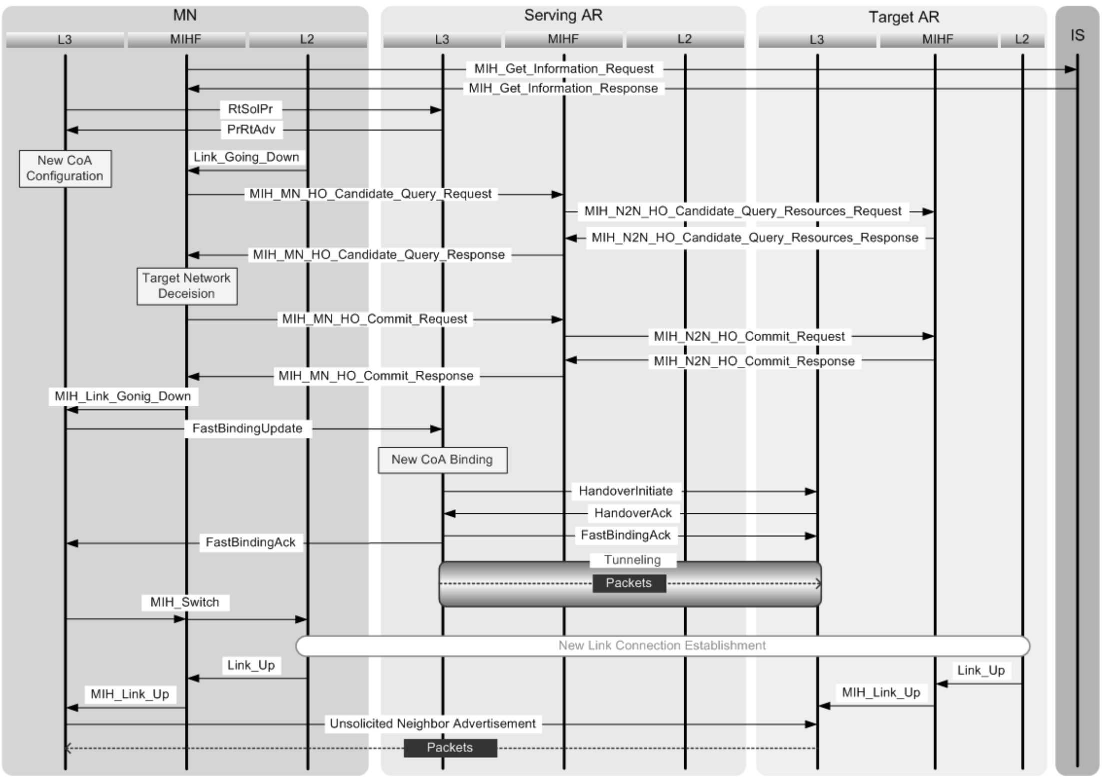

Figure 3. Mobility management framework using IEEE 802.21 MIH-assisted IETF FMIPv6
그림 3. IEEE 802.21 MIH 서비스와 IETF FMIPv6 기술을 통합한 이동성 관리 프레임워크

the information query to IS is performed by using MIH_Get_Information_ Request/Response messages. This information query may be attempted as soon as MN is first attached to the network. The network selection phase allows the handover initiator, i.e. either MN or Serving AR(SAR), to check the resource availability through candidate networks by employing MIH_MN_HO_Candidate_Query_Request/ Response and MIH_N2N_HO_Candidate_Query_ Resources_Request/Response messages. It further enables the handover initiator to decide the handover target network, and then requests resource preparation to the Target AR (TAR). The following phase is the mobility management. It comes up with both the handover process, i.e. FMIPv6, and the establishment of link layer and upper layer connections. Lastly, resource release is performed by either MN or TAR[11].

The IETF FMIPv6 provides two modes of frameworks, predictive and reactive modes, of which purpose is to reduce handover latency by pre-configuring new CoA and delivering the packet in the new PoA at the earliest. In both modes, MN sends a RtSolPr message to the SAR after discovering one or more neighboring networks. In response, SAR sends a PrRtAdv message that includes identifiers and information of neighboring ARs. Then MN formulates a prospective new CoA with the information provided in the PrRtAdv. MN sends a FBU message containing new CoA to the SAR at a time determined by link-specific events, aiming at authorizing SAR to bind the old CoA to the new CoA. In the predictive mode, FBU is sent through the link with SAR while sent through TAR's link in the reactive mode. Upon receipt of FBU message, the SAR confirms with the TAR as to whether the new CoA is valid by exchanging Handover Initiate (HI) and Handover Acknowledge (HAck) messages. Once HAck message is received, the SAR sends Fast Binding Acknowledgement (FBack) message on both links to the MN and the TAR in order to inform that the new CoA is ready and the tunnel is established. As soon as MN attaches to the TAR, it sends an Unsolicited Neighbor Advertisement (UNA) message to TAR so that TAR can forward arriving and buffered packets to MN[3]. In Figure 3, explained mobility management framework is illustrated in detail.

3.2 Proposed MIH-FMIPv6 Framework

The legacy framework simply combines MIH and FMIPv6 scheme regardless of efficiency, and so still has critical problems including handover latency. To solve them, works have been done on using MIH services as a way to reduce the handover latencies in [6] and [7]. In these works, legacy MIH messages bring neighbouring network information to MN instead of RtSolPr/PrRtAdv messages, accordingly the handover latency caused by RtSolPr/PrRtAdv messages delay is reduced. However, there are still many reasons degrading handover efficiency. Particularly, a number of wireless signaling messages are still used in those works that induce handover latency, packet loss, and power loss of MN as well.

Therefore, we concentrate the coordination of FMIPv6 and MIH in order to minimize wireless signaling overhead, and thus propose an enhanced mobility management framework suited for FGN as shown at Figure 4. The concept of the enhanced framework is the calm service. The calm service denotes that user may not notice when, where, and how the handover occurs. So the enhanced framework entrusts most of handover processes to network entities by employing a MICS message, i.e. MIH_MN_HO_Grant, and two MIES primitives, i.e. Link_Going_Down and MIH_BindingUpdate. They are newly defined(or modified) after the manner of cross-layer design in order to carry the handover-related L2 information to the network layer(L3). Table 1 and 2 describe novel messages and primitives specified(or modified) for the proposed framework, respectively. Regard that the information of modified messages(or primitives) explains changed part only.

In addition, we focus on the balance of the MIH message flows. The balance is assumed to mean that the more resources there are, the more message capacity there are. Note that wired networks have much more resources(or bandwidth) than

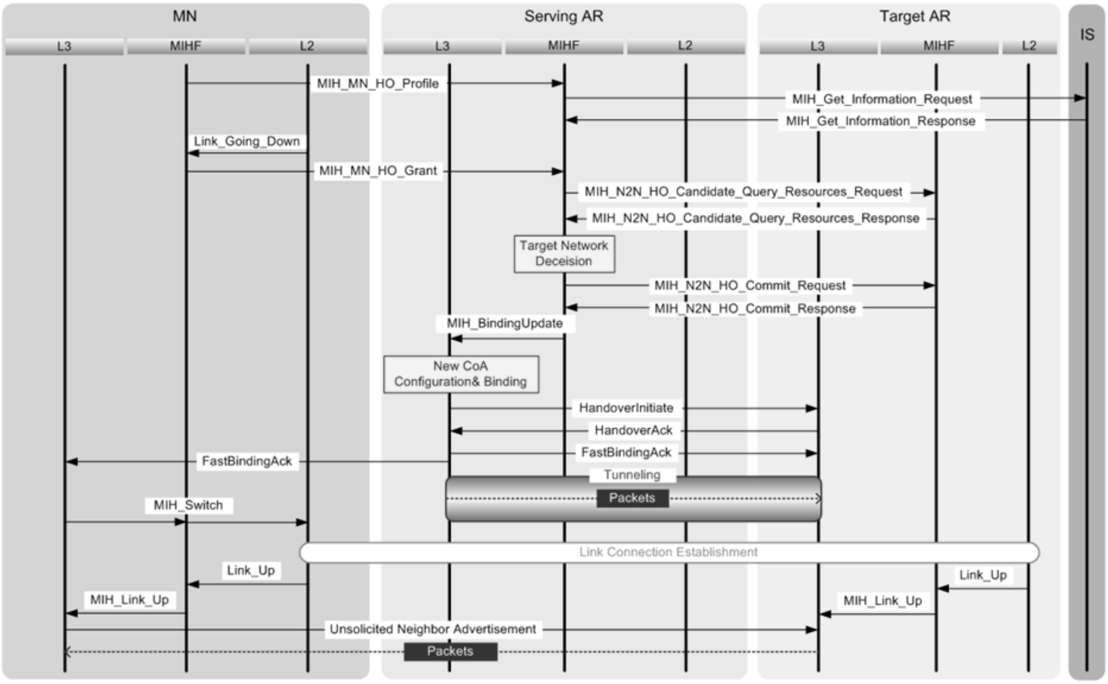

Figure 4. Proposed mobility management framework coordinating IEEE 802.21 MIH and IETF FMIPv6
그림 4. IEEE 802.21 MIH 서비스와 IETF FMIPv6 기술을 통합한 제안하는 이동성 관리 프레임워크

Table 1. Information of novel messages specified (or modified) for the proposed framework
표 1. 제안된 프레임워크에서 정의하는 새로운 메시지와 수정된 메시지들 포맷

Name	Field	Description
MIH_MN_HO_Profile	Source Identifier	The identifier of entity where the request is initiated.
	Destination Identifier	The destination identifier of request or response.
	Current Link Identifier	This identifies the current access net work over which the command needs to be sent.
	Handover Profile	This specifies user's handover preference such as data rate, accounting, power and etc.
	QoS Profile	This specifies user's service preference such as voice, best effort, multimedia and etc.
MIH_MN_HO_Grant	Source Identifier	Same as above.
	Destination Identifier	Same as above.
	Current Link Identifier	Same as above.
	Current Link Information	Same as above.
	Handover Mode	The handover mode may influence the manner in which links are prepared for handover
	Current Link Action	This specifies suggested action on old link once handover procedures have been executed.
MIH_N2N_HO_Candidate_ Query_Response	Current Link Information	This specifies the current link information such as frame rate, packet error rate and etc.
MIH_N2N_HO_Commit_ Response	New Router IP Address	The IP address of target access router.
FBAck	M (flag)	This indicates that serving router's MIHF initiated Fast Binding Update.

Table 2. Information of novel primitives specified (or modified) for the proposed framework
표 2. 제안된 프레임워크에서 정의하는 새로운 프리미티브와 수정된 프리미티브들 포맷

Name	Service	Field	Description
Link_Going_Down	MIES	Current Link Information	This specifies the current link information such as frame rate, packet error rate, and etc.
MIH_BindingUpdate	MIES	Source Identifier	LINK ID
		Destination Identifier	MIHF ID
		New Router IP Address	The IP address of target access router
		New Router Link Address	The link-layer address of the target access router
		New PoA Link Address	The link-layer address or identification of the target access point

wireless networks have. So the balance means that the networks above PoAs, i.e. wired networks, is given more messages to process than the networks beyond PoAs, i.e. wireless networks. In this motivation, we design the balanced mobility management framework to reduce signaling overhead in wireless networks. First of all, it provides the information about user's handover policies to the SAR by deploying a novel handover profile message, namely MIH_MN_HO_Profile. This message enables the SAR to decide target network without further request messages for handover information to MN, it thus reduces handover latency. Secondly, the balanced framework offers SAR the information on neighboring networks by employing MIH_Get_Information_Request/Response messages. So the message overhead of MIH_MN_HO_Grant, which replaces legacy MIH_MN_HO_Candidate_Query_Request, is dropped by removing the preferred neighboring network information from the message. Last, the SAR's local primitive, i.e. MIH_BindingUpdate, provides the identifiers and the information about neighboring ARs required to formulate the prospective new CoA. Hence, the PrRtAdv message originally outfitting MN with neighbor information is no longer adopted in the proposed framework. Note that the configuration of new CoA is performed by SAR. Moreover, MIH_BindingUpdate allows the SAR to bind old CoA to new CoA so that the FBU is also eliminated in the framework. Consequently, the exclusion of those messages causes both the handover latency and the signaling overhead to be reduced.

Ⅳ. Performance Evaluation

4.1 Numerical Analysis

We analysis the numerical result of the proposed mobility management framework compared with legacy ones in terms of handover latency and wireless signaling overhead. First of all, we derive each part of handover latency including the delay of preparation, initiation, and execution. Equation (1) and (2) describe handover preparation latency, i.e. MIH latency, of legacy mobility management framework(T_{old_MIH}) and which of proposed framework(T_{new_MIH}), respectively.

$$T_{old\_MIH} = 6D_{MN-SAR} + 4D_{SAR-TAR} + 2D_{SAR-IS} \quad (1)$$

$$T_{new\_MIH} = 2D_{MN-SAR} + 4D_{SAR-TAR} + 2D_{SAR-IS} \quad (2)$$

Regard that D_{X-Y} is the message delivery latency between X and Y. In these equations, the legacy framework uses 6 of signaling messages between MN and SAR, while the proposed framework uses only 2 of them.

Handover initiation latency, i.e. FMIP latency, is derived in equation (3) and (4), where D_Z is the delivery latency of message Z. Note that RtSolPr/PrRtAdv, FBU, and FBack are delivered between MN and SAR, while HI and HAck are delivered between SAR and TAR.

$$\begin{aligned} T_{old\_HI} &= D_{Pr/Rd} + D_{FBU} + D_{FBack} + D_{HI} + D_{HAck} \\ &= 4D_{MN-SAR} + 2D_{SAR-TAR} \end{aligned} \quad (3)$$

$$T_{new\_HI} = D_{FBack} + D_{HI} + D_{HAck} = D_{MN-SAR} + 2D_{SAR-TAR} \quad (4)$$

Equation (5) shows handover execution latency consisted of link connection establishment (T_{L2}) and Unsolicited Neighbour Advertisement (UNA).

$$T_{HE} = T_{L2} + D_{UNA} = T_{L2} + D_{MN-TAR} \quad (5)$$

Second of all, we derive total handover latency using above equations as shown at equation (6) and (7).

$$T_{old\_HO} = T_{old\_MIH} + T_{old\_HI} + T_{HE} = 10D_{MN-SAR} + 6D_{SAR-TAR} + 2D_{SAR-IS} + T_{HE} \quad (6)$$

$$T_{new\_HO} = T_{new\_MIH} + T_{new\_HI} + T_{HE} = 3D_{MN-SAR} + 6D_{SAR-TAR} + 2D_{SAR-IS} + T_{HE} \quad (7)$$

From these results, it is verified that the proposed framework significantly reduces not only MIH latency but also FMIP latency, thus decreases total handover latency as well. Particularly, since the wireless section, i.e. between MN and SAR(or TAR), is much slower and congested than the wired section, the wireless signaling overhead degrades the handover performance critically. In the wireless section, legacy framework deploys 6 of MIH signaling messages that are MIH_Get_Information_Request/Response, MIH_MN_HO_Candidate_Query_Request/Response, and MIH_MN_HO_Commit_Request/Response, and also 4 of FMIP signaling messages which are RtSolPr/PrRtAdv, FBU, and FBAck. On the other hand, the proposed framework deploys only 2 of MIH signaling messages which are MIH_MN_HO_Profile and MIH_MN_HO_Grant, and only a FMIP signaling message that is FBAck. Therefore, the wireless signaling overhead is significantly reduced due to our balanced mobility management framework.

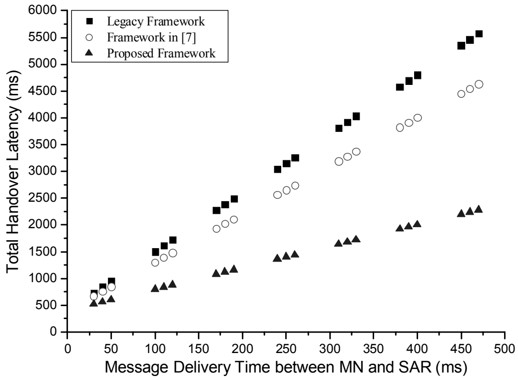

Figure 5. Comparison of handover latency vs. D_{MN-SAR}
그림 5. D_{MN-SAR} 에 따른 핸드오버 지연 시간 비교

Last of all, we compares the handover performance of the proposed framework with legacy frameworks including[7]. In Table 3, both handover preparation and handover initiation latency of mobility management frameworks are compared. Furthermore, total handover latency time depending on D_{MN-SAR} is illustrated in Figure 5. In this Figure, it is assumed that $D_{SAR-TAR}$ is 20ms, D_{SAR-IS} is 40ms, and T_{L2} is 200ms. In result, it is verified that the proposed framework significantly enhances handover performance even though wireless link is excessively congested.

4.2 Network Simulation Analysis

We evaluate the performance of mobility management frameworks through network simulations using NS-2 release 2.29. In simulations, we design the simulation topology composed of IEEE 802.16 Wimax, IEEE 802.11b WLAN, and IPv6 core network as illustrated in Figure 6. Note that since the link layer configuration is outside the

Table 3. Comparison of handover latency of mobility management frameworks
표 3. 제안된 프레임워크와 기존 프레임워크들의 핸드오버 지연 시간 비교

Framework	Handover Preparation (MIH) Latency	Handover Initiation (FMIP) Latency
Legacy Framework	$6D_{MN-SAR} + 4D_{SAR-TAR} + 2D_{SAR-IS}$	$D_{Pr/Rd} + D_{FBU} + D_{FBack} + D_{HI} + D_{HAck}$
Framework in [7]	$6D_{MN-SAR} + 4D_{SAR-TAR} + 2D_{SAR-IS}$	$D_{FBU} + D_{FBack} + D_{HI} + D_{HAck}$
Proposed Framework	$2D_{MN-SAR} + 4D_{SAR-TAR} + 2D_{SAR-IS}$	$D_{FBack} + D_{HI} + D_{HAck}$

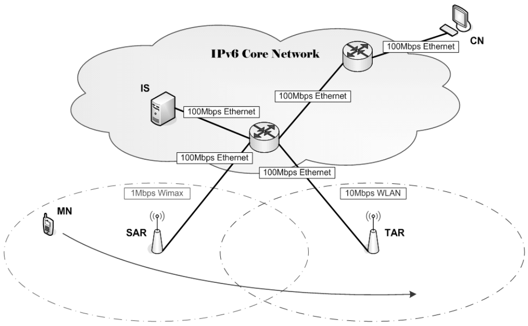

Figure 6. Simulation topology
그림 6. 시뮬레이션 구성

scope of this paper, the Wimax network is actually established by WLAN components. The simulations further employ the mobility package developed by NIST [13] to support MIH services and messages. In addition, we configure that the Correspondent Node(CN) generate TCP traffics with a packet size of 10Kbyte and a packet rate of 100 packets/sec. It is also set up that the radius of Wimax is 50m while which of WLAN is 25m, and the distance between them is 50m. We further assume that the average $D_{SAR-TAR}$ is 10ms, the average D_{SAR-IS} and D_{TAR-IS} are 20ms in simulations.

The simulation is performed in terms of handover latency, signaling overhead, and packet loss. Regard that the processing delay, such as CoA configuration and handover decision, and the T_{L2} are not concerned in simulations. In Figure 7, we compared the average handover latency vs. the MN velocity of the proposed framework with which of legacy framework. Consequently, it is verified that the proposed framework dramatically reduces handover latency. Especially, when MN moves with very high speed, e.g. MN in rapid-transit train, our proposed framework keeps very low latency while legacy one aggravates seriously. Figure 8 shows the average signaling overhead vs. Packet Error Rate (PER) in Wimax and WLAN networks. We evaluate both the overall and the wireless signaling overhead of both frameworks. In result, it is certain that the overall signaling overhead as well as the wireless one are significantly decreased by adopting the proposed framework. Particularly, our proposed framework

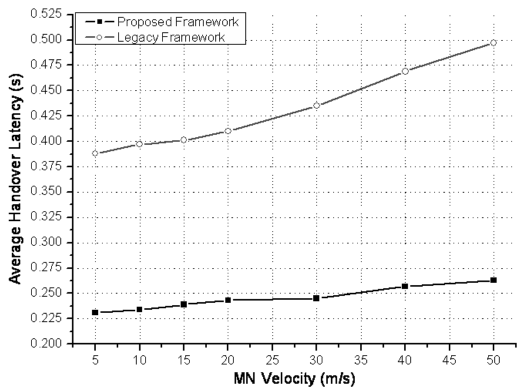

Figure 7. Comparison of average handover latency.
그림 7. 평균 핸드오버 지연 시간의 비교

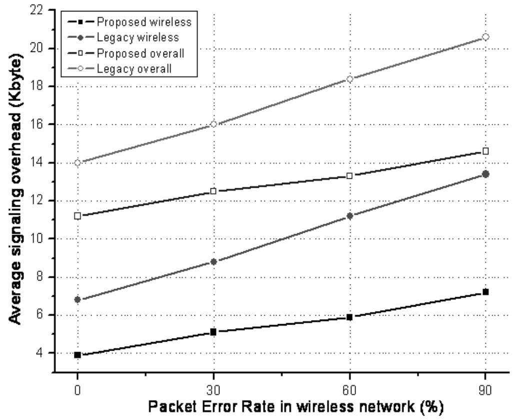

Figure 8. Comparison of average signaling overhead
그림 8. 평균 핸드오버 시그널링 오버헤드의 비교

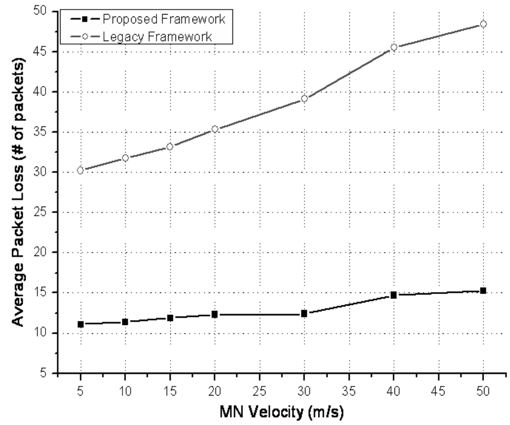

Figure 9. Comparison of average packet loss
그림 9. 평균 패킷 손실의 비교

maintains very low signaling overhead even though the PER in wireless networks is getting worse, because it minimizes the wireless signaling overhead. In addition, we compared the average packet loss vs. the MN velocity of the proposed framework with which of legacy framework as illustrated in Figure 9, and so confirmed that the our proposed framework reduces the packet loss significantly.

Ⅴ. Conclusions

In this paper, we have introduced the enhanced mobility management framework coordinating IEEE 802.21 MIH and IETF FMIPv6, suited for FGNs. Particularly, we have focused on both the calm service and the balance in order to facilitate the handover. Therefore, the novel signaling messages and local primitives are defined in order to provide vertical and seamless handover. They allow the MN to entrust both the configuration of new CoA and the decision of handover target network to the SAR in the proposed framework. They also enable the proposed framework to replace FBU, i.e. the remote message, by MIH_BindingUpdate, i.e. the local cross-layer primitive. Hence, a number of wireless signaling messages of legacy framework are eliminated in the proposed framework so that the handover latency and the packet loss are dramatically reduced. In addition, we have evaluated the proposed mobility management framework in terms of signaling overhead, handover latency, and packet loss. In result, it is verified that the proposed framework significantly reduces the signaling overhead, the handover latency, and the packet loss even though wireless network is excessively congested.

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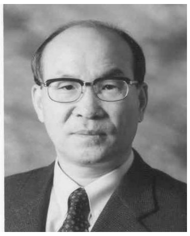

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