Standardization on Mobility Management Architectures and Protocols for All-IP Mobile Networks

Hee Young Jung · Seok Joo Koh

This paper gives an overview of standardization activities on mobility management (MM) architectures and protocols for the next-generation all-IP mobile networks, which have so far been made in the ITU-T, 3GPP, IEEE 802, and IETF. The MM functionality for all-IP mobile networks includes the location and handover management, and the MM types can be classified into intra-access network, inter-access network, and inter-operator MM issues. In this paper, we discuss a lot of standardization works on MM architectures and protocols, based on the MM functionality and types. In the future, the effective cooperation between standardization bodies is needed to identify the unified architectures and protocols for MM in all-IP mobile networks.

Keywords: All-IP Networks, Mobility Management, Architecture, Protocol, Standardization

I. INTRODUCTION

Mobility Management (MM) is one of the challenging issues for the next-generation mobile networks. In particular, the Internet Protocol (IP) has been recognized as a key technology for the all-IP mobile networks along with the explosively increasing need for IP-based multimedia services. Accordingly, the technical challenges to the next-generation all-IP mobile networks include "how to effectively provide the mobility management for supporting seamless multimedia traffic in the IP-based mobile networks that consist of a wide variety of heterogeneous wireless access networks."[1]

It is noted that the next-generation mobile network will consist of an IP-based core network and a wide variety of heterogeneous access networks. In the network, the mobile users will move around within or across a variety of heterogeneous access networks. In the meantime, seamless multimedia services should be supported regardless of locations of the users. As such, the mobility management to support the seamless services will be essentially required for the next-generation all-IP mobile networks.

In general, the MM issues can be divided into the IP-based network layer mobility and radio/access-specific mobility. We will focus on the IP-based network layer MM, which will ensure that the MM schemes could be commonly applied to a variety of heterogeneous access networks/systems, independently of the underlying radio/wired link-layer technologies. The radio/access-specific MM issue (e.g., link-layer handover) is usually addressed by its own access technology.

From the network point of view, the MM issues for future all-IP mobile networks will include:

- MM framework to provide seamless mobility in all-IP mobile networks;
- Vertical mobility support across heterogeneous access

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networks; and
- Seamless mobility support in IP-based access networks.

To address these issues, a variety of standardization bodies are now developing many MM-related standards with their own scope and direction on standardization. This paper describes an overview of the recently progressed standardization activities on the MM architectures and protocols for the all-IP mobile networks, which have so far been made in the ITU-T, 3GPP, IEEE 802, and IETF. For this purpose, we will first discuss the MM functionality such as location and handover management, and then classify the types of MM into intra-access network MM, inter-access network MM, and inter-operator MM. With the MM functionality and types identified, we analyze and compare a variety of standardization works on the architectures and protocols for all-IP mobile networks.

This paper is organized as follows. Section II identifies the functionality and types of MM for all-IP mobile networks. In Section III, we review and compare a variety of standardization works on the MM architectures and protocols. Section IV concludes this paper with further issue.

II. FUNCTIONALITY AND TYPE OF MOBILITY MANAGEMENT

In this section, we describe the MM functionality and types as a basis to classify the standard MM architecture and protocols for all-IP mobile networks.

1. MM Functionality

The MM functionality can be divided into location management and handover management.

1.1. Location Management

Location management (LM) is a primary functionality required for MM. The LM is responsible for managing the location information of a moving user in the network and for locating the user so as to deliver the data traffic. That is, the LM is used to support the prospective 'upcoming' session (or call) to the mobile user. LM functionality includes the following specific function: location registration/update and location query for user data transport.

The location registration and update functions are used to keep track of the current location of a user. When a user is attached to the network, it will register its current location information (e.g., IP address) with the LM functional entity (with a suitable location database). When the user moves further into another network, it will update its current location.

The location query function is used for a corresponding user to locate the mobile user. When the corresponding user asks an LM functional entity about the current location of the mobile user, the LM functional entity will inform the corresponding user about the current location of the user (locator) by using a suitable location query/response scheme.

1.2. Handover Management

Handover management (HM) is a key functionality required to provide the seamless services and mobility. The HM is responsible for providing 'session continuity' for the 'on-going' sessions (calls) of the moving user. To provide the session continuity, the HM scheme needs to minimize user data losses and handover latency during the handover period.

An HM scheme will operate together with an appropriate handover signaling between the user terminal and network entities concerned with handover. This handover signaling will be triggered with movement detection (e. g., using the IEEE 802.21 Media Independent Handover). Depending on how to detect the movement of a user terminal and how to perform the handover signaling in the network, a different handover scheme can be devised. The handover schemes can also be differently designed for the vertical handover (between heterogeneous access networks) and the horizontal handover (within a homogeneous access network)

2. Applicability of MM Functionality by Services Models

This section examines applicability of MM functionality by application services model. For this purpose, we consider the two conventional services models: Client-Server (C-S) services model and Peer-to-Peer (P-P) services model.

In the C-S services model, the client (mobile user) will request an application service to a well-known fixed server. Typically, the client will be a subscriber to a service provider, whereas the server will be located in the fixed network of the service provider. The client initiates an application session with the fixed server. In this context, the C-S services may not require the location

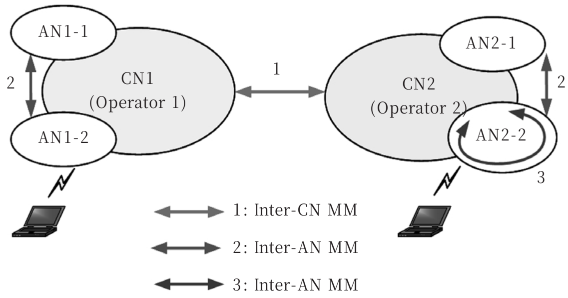

Figure 1. Types of MM for all-IP mobile networks

Table 1. Applicability of MM functionality by services model

Services Model	Feature of Session	Location Management	Handover Management
Client-Server	Short-lived	Not Required	Not Required
	Long-lived(non-real time)	Not Required	Required(loss-sensitive)
	Long-lived(real time)	Not Required	Required(delay-sensitive)
Peer-to-Peer	Short-lived	Required	NotRequired
	Long-lived(non-real time)	Required	Required(loss-sensitive)
	Long-lived(real time)	Required	Required(delay-sensitive)

management functionality. In the P-P services model, the two end users communicate each other. This model requires the location management for an endpoint to locate the corresponding endpoint for communication.

The application sessions can also be categorized into: short-lived sessions (e.g., Short Message Services), long-lived sessions for non-real time services (e.g., Multimedia Message Services), and long-lived sessions for real-time services (e.g., Voice over IP). Short-lived sessions will usually be implemented in the request-response fashion between two end users. This kind of services might not require the handover management, since the session will be completed in the short time interval. Long-lived sessions will require handover management. The long-lived sessions can be classified into non-real time services and real-time services. The long-lived non-real time sessions are loss-sensitive rather than delay-sensitive. On the other hand, the long-lived real-time sessions are much sensitive to handover latency, as seen in the VoIP applications.

Table 1 summarizes the applicability of MM functionality by services model in all-IP mobile networks.

3. Types of Mobility Management

The next-generation mobile network is characterized by a wide variety of heterogeneous access networks (ANs) that are connected each other via Core Network (CN). In this paper, the MM types are classified into three categories: Inter-CN MM between different operators (denoted by MM1), Inter-AN MM between different ANs (MM2) under the same operator, and Intra-AN MM within an AN (MM3), as illustrated in Figure 1.

As shown in the figure, the MM3 (Intra-AN) will support the mobile users that move around within an AN under the same operator's domain, whereas the MM2 (Inter-AN) considers the users who may move into the other AN using different access technology in the same operator's network. On the other hand, the MM1 (Inter-CN) will support the mobility between different operators.

It is noted that each type of mobility will have different MM requirements and characteristics, and hence the different mobility schemes need to be designed as per the type of MM. For example, MM1 may need a roaming agreement between two different network operators, whereas MM2 and MM3 will be supported within an operator's domain. MM2 should consider the mobility concerning different access technologies, whereas the MM3 will deal with the mobility within a single homogeneous AN.

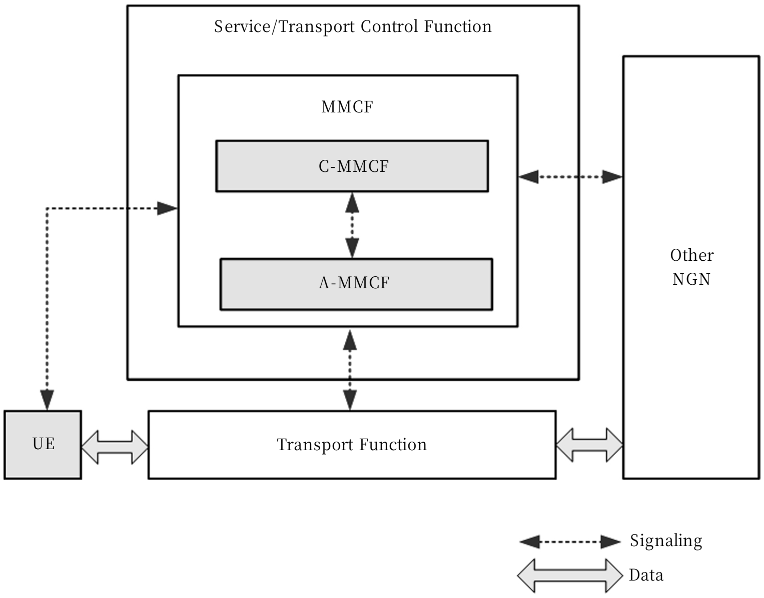

Figure 2. Functional architecture for MM in NGN[3]

III. STANDARDIZATION OVERVIEW

The mobility management is a key technology for realization of all-IP mobile networks, which has been considered as a main work item in a lot of standardization bodies.

1. ITU-T/MMF

The NGN-GSI (Next Generation Networks-Global Standards Initiative) is a joint group made to encourage the joint activities among the NGN-related Study Groups (SGs) and Questions in the ITU-T. In particular, the MM is regarded as an important issue for realization of the NGN, since the seamless mobility across a variety of heterogeneous access systems is one of the primary goals for NGN.

In this respect, the NGN-GSI MM group activity was initiated as a joint activity of Question 6 of SG13 and Question 2 of SG19 to develop the MM-related standards for NGN. As a related work, the MM requirements for NGN were identified in the ITU-T Recommendation Q.1706 [2]. At present, the framework and architecture of MM are being developed in the draft Recommendation Q.MMF [3], which contains the functional architecture for location and handover management in NGN.

Figure 2 shows the functional architecture of the MM Control Functions (MMCFs) in NGN, which is specified in MMF. This architecture is based on the NGN architecture that consists of the service and transport stratum.

As shown in the figure, the MMCFs could be provisioned with the service and/or transport control functions in the NGN architecture. The MMCFs can be divided into Central-MMCF (C-MMCF) and Access-MMCF (A-MMCF). In the core network, the C-MMCF is responsible for the overall mobility management functions for location and user profile management. The A-MMCF performs the MM functions at the access level of the user to the network, which includes the IP address management, location registration/update, and handover support.

Each MMCF can contain the two specific functions: Location Management Function (LMF) and Handover Control Function (HCF). The LMF is used to perform the location management such as location update and location query, whereas the HCF will support the seamless handover of the user terminals. Furthermore, the LMF can be classified into C-LMF and A-LMF, and the HCF is categorized into C-HCF and A-HCF.

The MM functionality is realized using the signaling operations between User Equipment (UE) and MMCFs, or between different MMCFs. These signaling operations depend on the specific MM scheme and protocols used for MM, such as Mobile IP (MIP) and Proxy MIP (PMIP).

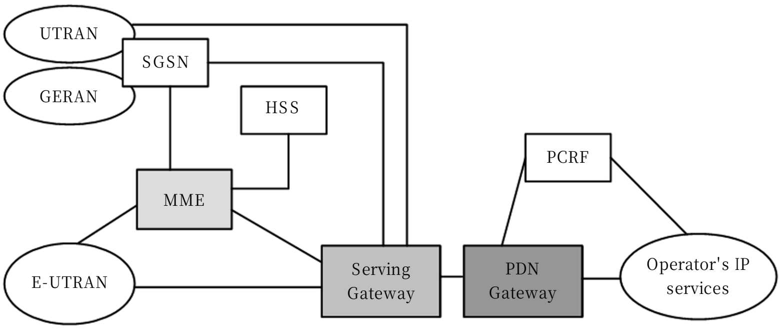

Figure 3. SAE architecture in 3GPP in the non-roaming case[4]

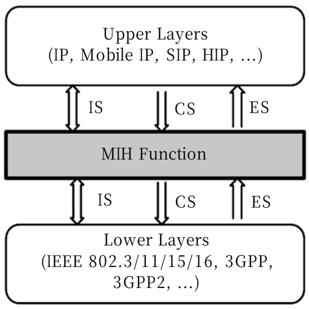

Figure 4. Conceptual model of MIH

To support the roaming between different operators, which corresponds to the inter-CN MM (MM1), the associated two C-LMF (home C-LMF and visited C-LMF) will interwork each other. On the other hand, the inter-AN (MM2) and intra-AN (MM3) issues will be addressed through the MM signaling operations between C-MMCF (C-LMF and A-LMF) and A-MMCF (C-HCF and A-HCF).

2. 3GPP/SAE

The 3rd Generation Partnership Project (3GPP) is actively driving the standardization on '3G evolution.' The System Architecture Evolution (SAE) architecture is proposed as a way toward the 3G evolution in the system aspect [4].

The 3GPP/SAE is being developed with the following goals: optimization of IP based services, IP based network evolution, support of heterogeneous access networks, and mobility support between different access networks. The SAE is trying to provide the mobility between 3GPP access systems [5] and non-3GPP access systems [6] as well as the mobility within 3GPP access systems. Accordingly, the SAE can be regarded to deal with the three types of MM; MM3 within the evolved Radio Access Network (eRAN), MM2 between eRAN and 2G/3G RAN, and MM1 between 3GPP operator and non-3GPP operator.

Figure 3 shows the SAE architecture in the non-roaming case.

As shown in the figure, the three entities are used to support mobility: Mobility Management Entity (MME), Serving Gateway, and PDN Gateway. The MME supports the mobility within an E-UTRAN. The MME is responsible for MM signaling such as paging, whereas the two Gateways are used for termination and switching of user data. In particular, the Serving Gateway supports the mobility between E-UTRAN and 2G/3G 3GPP RANs, whereas the PDN Gateway is used to support the mobility between 3GPP and non-3GPP access networks. The SAE also specifies the MM issues in the roaming case between Home PLMN and Visited PLMN.

3. IEEE 802.21/MIH

The IEEE 802 Committees are developing the PHY/MAC standards for wired/wireless access such as IEEE 802.3, 802.11, 802.16, and so on. In particular, the IEEE 802.21 is working on the Media Independent Handover (MIH) [7] to support handover between heterogeneous ANs. Note that the MIH can be used to support the handover between the IEEE family AN and non-IEEE (3GPP or 3GPP2) AN, which corresponds to the inter-AN mobility (MM2).

Figure 4 shows a conceptual model of MIH.

It is generally assumed that the MIH function is located between link layer and IP layer, and basically adopts the cross-layer design concept to achieve effective vertical mobility. In other words, MIH function plays a role as an inter-mediator between lower layers (e.g. link layer) and upper layers (e.g., IP layer).

The MIH provides the three types of services: Event Service (ES), Command Service (CS), and Information Service (IS). ES is used to inform the upper layer about the events of the lower layer. Typical examples of the events include *link-up/down*, *link-going-up/down*, and *link parameter changes*. CS is used when the upper layer wants to command something to the low layer. The examples of these commands include *get-status, link-switch, configure, scan*, etc. IS can be used to provide the useful information to achieve effective handover such as a list of neighboring entities, and the number of distinct operators for available link types. In the MIH model, the events and commands are classified into the two types: local and remote. The 'local' events/commands are used for information exchange within a local entity. On the other hand, the 'remote' events/commands will be used for communication between two different MIH entities.

In summary, the MIH protocol is used for handover management, especially to effectively support the IP handover for inter-AN mobility (MM2).

4. IETF/MM Protocols

The IETF is responsible for standardization of the IP-based MM protocols that can be used for location and handover management. In the IETF, a lot of Working Groups are involved in the standardization works, which include MIP4 (Mobile IPv4) [8], MIP6 (Mobile IPv6) [9], MIPSHOP (MIP Signaling and Handover Optimization) [10], DNA (Detecting Network Attachment) [11], MOBIKE (IKEv2 Mobility and multihoming) [12], HIP (Host Identity Protocol) [13], NEMO (Network Mobility) [14], and NETLMM (Network-based Localized MM) [15] Working Groups.

First of all, the MIP is one of the well-known protocols for MM. The MIP is divided into MIPv4 and MIPv6, as per the associated IP version. The MIP protocol can be used to support the location management for the MM types of MM1 and MM2. With the evolution trend toward all IP-based networks, the MIP is being considered in the 3G cellular networks to support the mobility for packet data service. Recently, the MIP is being evolved to enhance the protocol functionality, which results in the Hierarchical MIP (HMIP) [16], Fast Handover for MIP (FMIP) [17], and Proxy MIP (PMIP) [15].

The HMIP is proposed to reduce the MIP registration latency and the signaling overhead, which is based on the localized MM approach. For this purpose, the HMIP introduces the Mobile Anchor Point (MAP) to the MIPv6 that is used to locally manage the mobility of mobile nodes within a MAP domain. The MM within the domain will be controlled by the MAP, rather than the MIP Home Agent (HA). Accordingly, the registration latency and signaling overhead could be considerably reduced when the MN moves around within a MAP domain.

The FMIP is another enhancement of MIP, which is used to reduce the handover latency of Mobile IP. For this purpose, the link layer triggers will be used in the FMIP protocol. Note that this approach is based on the cross-layer design concept, described in the IEEE 802.21 MIH. In the cross-layer optimization scheme, the link layer information will be delivered to the upper layer, which ensures that the IP handover operations can be initiated much earlier (i.e., before the link layer handover is completed).

The PMIP can be regarded as a radical change for enhancement of MIP, which is based on the 'network-based' MM scheme, differently from the 'host-based' MM of the legacy MIP. In the network-based scheme, the 'network' will perform the overall control of the location and handover management for the mobile nodes. Note in the MIP that a mobile node is involved in the mobility control in the end-to-end fashion. This network-based MM approach will be preferred by the network operators in that the mobile nodes do not need to care the MM control operations and thus the MM-related signaling overhead can be significantly reduced in the wireless access link in which the bandwidth is usually scarce. At present, the IETF NETLMM WG is working in progress for development of the PMIP protocol.

The other noticeable MM-related Working Groups in the IETF include the DNA, MOBIKE, NEMO and HIP.

Table 2. Standardization works on MM for all-IP mobile networks

SDO	Reference	Associated MM Type	MM Functionality	Description
	MMF (Architecture)	MM1/2/3	LM and HM	• Define the MM types (MM1/2/3) and functionality (LM & HM) • Two-level MM functional architecture based on NGN architecture(C-MMCF, A-MMCF) • MMCF consists of LMF(LM) and HCF(HM)
	SAE (Architecture)	MM1/2/3	LM and HM	• Architecture based on 3GPP system • Separation of control/user-plane functions MME and Gateways) • MM1(roaming and non-roaming case), MM2 (between eRAN and 2G/3G RAN, between 3GPP and non-3GPP systems), MM3 (intra E-UTRAN)
	MIH (Protocol)	MM2	HM	• Platform for vertical handover (MM2) between IEEE ANs, and between IEEE and non-IEEE ANs • Three kinds of services: CS, ES, and IS • Provide protocol for communication between MIH entities
	MIP (Protocol)	MM1/2	LM	• Global IP mobility support • Mainly for location management • Adopted in the 3GPP2 packet data system
	FMIP (Protocol)	MM3	HM	• MIP extension to support the fast handover • Use the link layer triggers
	HMIP (Protocol)	MM3	LM and HM	• MIP extension to support the localized MM • Provide the scalability by reducing the signaling latency and overhead
	PMIP (Protocol)	MM2/3	LM	• Network-based Mobile IP; mobile nodes are not involved in the MM signaling operations • Working in progress in the NETLMM WG

First, the DNA provides a fast and efficient mechanism to detect attachment in the IPv6 networks. MONIKE is an enhanced protocol of IKEv2 to support roaming, mobility and multihoming. NEMO WG is developing protocols for support network mobility in bus, train, ship or airplane. On the other hand, the HIP WG deals with a sort of paradigm shift of the Internet. In the Internet, TCP basically distinguishes a connection based on an IP address, and thus the MIP is needed to keep service continuity for a moving terminal that changes its IP address in time. In HIP, however, a connection is identified by a persistent Host ID rather than an IP address, so that the mobility support can be more easily achieved.

5. Summary and Comparison

We have so far discussed the standardization works made in a variety of Standards Developing Organizations (SDOs). Some of them are focusing on the design of the framework and architecture for MM, and the others are making the protocols/scheme for location management (LM) and/or handover management (HM) for the MM types such as MM1, MM2, and MM3.

Table 2 gives the brief summary and comparison on those standardization works.

The ITU-T is working on the design of MM framework in the NGN perspective. In the MM framework, the MM types are defined and the functional architecture is described for supporting seamless mobility. It is noted that the MM works in the ITU-T are purposed to provide overall directions on MM in the NGN, which are based on a lot of works that are being made in the other SDOs such as 3GPP, IEEE, and IETF.

The 3GPP is dealing with the MM issues in the perspective of the 3GPP-specific radio access networks. In this respect, a new architecture is proposed to enhance the 3G wireless systems and services. It is noted that in the ITU-T NGN that the 3G wireless systems may be considered as one of the candidate access networks.

The IEEE 802.21 is working on the MIH used for vertical handover across heterogeneous access networks. The MIH is a key component technology for seamless handover to achieve MM in the ITU-T and 3GPP. That is, a variety of the MIH services such as CS, ES, and IS could be used by the MM mechanisms defined in the ITU-T and 3GPP.

The IETF WGs are developing a lot of protocols for MM such as MIP, FMIP, HMIP, and PMIP. Those protocols can be viewed as 'component protocols' that can be used for MM in the ITU-T NGN and 3GPP SAE systems. In particular, the MIP and PMIP protocols are now being considered as core protocols that can be used to provide the location management and handover management in the ITU-T and 3GPP.

In summary, ITU-T and 3GPP are focusing on the 'system' and 'architecture' aspects of MM, whereas the IEEE and IETF are working on the specific component protocols that can be used to support the seamless MM in the ITU-T and 3GPP systems. In the system perspective, 3GPP deals with the 3G-specific wireless access networks, whereas ITU-T addresses overall MM issues in the NGN, in which the 3G wireless system can be considered as one of the candidate access networks of NGN.

IV. CONCLUSION AND FURTHER ISSUE

In this paper we have identified the MM functionality and types for all-IP mobile networks. The types of MM for all-IP mobile networks can be classified into Inter-CN (MM1), Inter-AN (MM2), and Intra-AN (MM3). Based on those types, we have examined a variety of the on-going standardization activities which are being done in the ITU-T, 3GPP, IEEE, and IETF.

In the ITU-T, a high-level functional architecture for MM is designed in the NGN network environment. The 3GPP/SAE describes the evolutional architecture of the 3GPP systems, which deals with how to integrate the new emerging radio access networks effectively into the existing 3GPP systems in the MM point of view. The IETF has developed a lot of MM protocols that are based on IP, whereas the IEEE 802.21 is dealing with the MIH to support the vertical handover across heterogeneous ANs using the link layer information.

From these standardization works, we can see that each SDO has a common objective to provide the seamless mobility for all-IP mobile network with its own scope and background of standardization. It is noted that the next-generation all-IP mobile networks will be evolved into a convergence network that will be based on a variety of heterogeneous access technologies (such as 3GPP, 3GPP2, IEEE 802, etc), and the relevant MM issues are being developed in many SDOs such as the MM architectures in the ITU-T and 3GPP, and a lot of MM protocols in the IETF, 3GPP and IEEE 802.21. The MM technologies of each SDO have their own unique characteristics and these features need to be unified and integrated to a common and general framework to provide the seamless MM in the future wireless mobile networks.

From the recently made works, the 3GPP leads the standardization in the mobile communication area. In particular, the SAE is considered as the strongest candidate architecture for future IP-based mobile networks. With this trend, the mobile WiMAX (i.e., Wibro) and 3GPP2-specific access systems may be integrated into the SAE architecture in the future. Accordingly, it may be a very practical way to develop or adopt more proper MM protocols based on the SAE architecture in future IP-based mobile networks.

However, even in this case, SAE still needs to be made in the collaboratively manner with the other SDOs. For example, the Mobile IP and PMIP shall be incorporated into the SAE to support seamless mobility. In addition, the works on the MM requirements and framework in the ITU-T need to be considered as the long-term vision of the SAE. The IEEE MIH can also be considered for seamless handover in the SAE. It will be a challenging issue how to effectively harmonize these MM works among a lot of relevant SDOs in the future.

Acknowledgement

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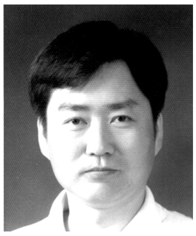
[REFERENCES]

[1] *ITU-T Recommendation Q.1702*, Long-term Vision of Network Aspects for Systems beyond IMT-2000, Mar. 2002.

[2] *ITU-T Recommendation Q.1706/Y.2801*, Mobility Management Requirements for Next Generation

Networks, Nov. 2006.
[3] *ITU-T Draft Recommendation Q.1707/Y.2804*, Generic Framework of Mobility Management for Next Generation Networks, Mar. 2008.
[4] *3GPP TR 23.882*, 3GPP System Architecture Evolution: Report on Technical Options and Conclusions (Release 7), V1.14.2, Jan. 2008.
[5] *3GPP TS 23.401*, General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access (Release 8), V8.0.0, Dec. 2007.
[6] *3GPP TS 23.402*, Architecture Enhancements for Non-3GPP Accesses (Release 8), V8.0.0, Dec. 2007.
[7] *IEEE P802.21*, Media Independent Handover Services, D04.00, Feb. 2007.
[8] *IETF MIP4 WG*, http://www.ietf.org/html.charters/mip4-charter.html.
[9] *IETF MIP6 WG*, http://www.ietf.org/html.charters/mip6-charter.html.
[10] *IETF MIPSHOP WG*, http://www.ietf.org/html.charters/mipshop-charter.html.
[11] *IETF DNA WG*, http://www.ietf.org/html.charters/dna-charter.html.
[12] *IETF RFC 4555*, IKEv2 Mobility and Multihoming Protocol (MOBIKE), Jun. 2006
[13] *IETF HIP WG*, http://www.ietf.org/html.charters/hip-charter.html.
[14] *IETF NEMO WG*, http://www.ietf.org/html.charters/nemo-charter.html
[15] *IETF NETLMM WG*, http://www.ietf.org/html.charters/netlmm-charter.html.
[16] *IETF RFC 4140*, Hierarchical Mobile IPv6 Mobility Management (HMIPv6), Aug. 2005.
[17] *IETF RFC 4068*, Fast Handovers for Mobile IPv6, Jul. 2005.



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