Mobility Management Requirements and Framework for Systems Beyond IMT-2000

Hee Young Jung and Seok Joo Koh

Abstract: **This paper addresses mobility management (MM) requirements and framework for systems beyond IMT-2000 (SBI2K), based on the standardization works that has so far been done in ITU-T study group 19. We first identify the requirements for MM in SBI2K. Based on the identified MM requirements, we describe the MM framework for location management and handover management for SBI2K. We then review and analyze some of the existing IP-based MM protocols. From the analysis and comparison, we see that the existing MM schemes cannot meet all of the MM requirements for SBI2K. It is naturally concluded that further work is needed to enhance the available MM schemes SBI2K.**

Index Terms: **IMT-2000, mobility management, SBI2K.**

I. INTRODUCTION

Mobility management (MM) has so far been one of the challenging issues in next-generation wireless mobile communications networks, also known as 'systems beyond IMT-2000 (SBI2K).' In particular, with the so-called 'all-IP' trends, the Internet protocol (IP) has been recognized as a key technology for SBI2K along with the explosively increasing need for IP-based multimedia services. Accordingly, the technical challenges to SBI2K include "how to effectively provide MM for supporting IP multimedia traffic across heterogeneous wireless access networks." To this end, this paper addresses the MM requirements and framework for SBI2K, based on the research work that has so far been done in ITU-T study group 19 [1], [2].

The rationale behind SBI2K is the convergence of fixed and wireless networks, and ultimately the migration to interoperable and harmonized network architectures. This trend is becoming a crucial requirement to provide communication services transparently to users across different arrangement of heterogeneous access networks. This paper therefore asks: "What new MM protocols or enhancements to existing MM protocols are needed to support global and seamless mobility and services in SBI2K?"

In this context, we identify the MM requirements for SBI2K, based on recent done in ITU [3]–[5]. According to the identified MM requirements, we describe the MM framework for SBI2K that includes location management and handover management. We then review and analyze some existing IP-based MM protocols that might be used for MM in SBI2K.

This paper is organized as follows. Section II describes the generic features and issues related to MM in SBI2K. In Section III, we characterize the scope of MM for SBI2K, and discuss a set of requirements for MM protocols in SBI2K. In Section IV, we discuss a promising framework of MM for SBI2K, based on the identified MM requirements. Section V reviews and analyzes some existing MM protocols for SBI2K. Finally, Section VI concludes this paper.

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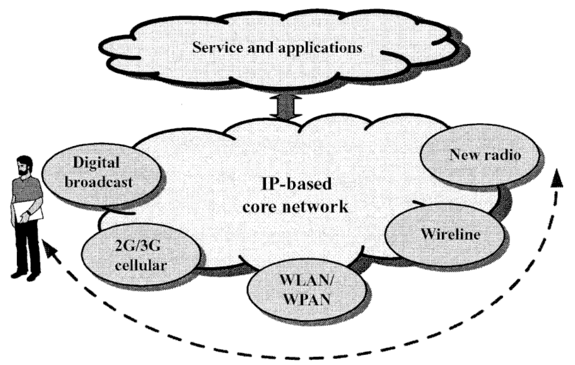

Fig. 1. Network environments in SBI2K.

II. CONSIDERATIONS OF MM FOR SBI2K

The ability of mobile users to communicate anytime and from anywhere is a key inherent feature of SBI2K. This is facilitated through the use of MM protocols to keep track of mobile users' locations at all times.

In SBI2K, a network generally consists of a core network and a variety of access networks, as shown in Fig. 1. In the SBI2K environments, a user will benefit from the seamless services across heterogeneous access networks, and the MM schemes for SBI2K need to support this seamless mobility.

Over the years, some sophisticated MM techniques have been developed and deployed in mobile systems to effectively manage the registration, authentication, and movement of mobile users. These techniques, however, have been specific to each system deployed, and manage the movement of users within similar cooperating mobile systems (e.g., an IMT-2000 family member). Therefore, the provision of seamless mobility across heterogeneous systems has been problematic due to the following factors:

- With the massive growth in the number of mobile users and the continuing deployment of heterogeneous systems (i.e., IMT-2000 family members, wireless LANs, IEEE 802.16, and IEEE 802.20), the demand to provide seamless service to mobile users gets stronger with time, which presents new challenges and requirements for new types of MM.

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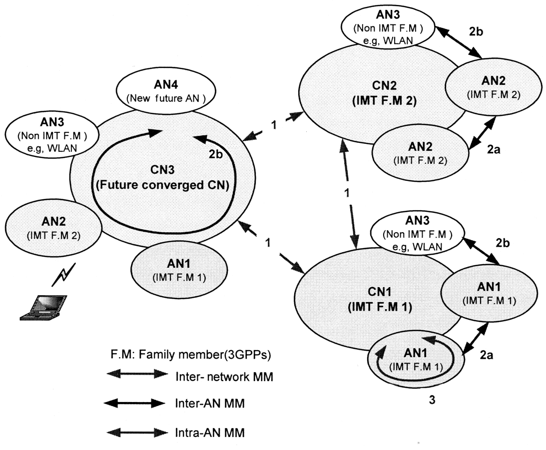

Fig. 2. Classification of MM for SBI2K.

- Moreover, future wireless mobile networks are envisioned to have an IP-based core, as noted in ITU-T Rec. Q.1702 [3], [4] and ITU-R Rec. M.1645 [5], where the long-term visions for future mobile systems are described from the network and radio aspects, respectively. Hence, the future thrust includes mobile and Internet convergence. In order to achieve this convergence, new interoperable MM techniques are required.

A promising solution for MM for SBI2K should take into account the long-term trends for future networks, the need for a smooth evolution of the existing infrastructure, and also the issue of backward compatibility with the existing networks. The MM architecture for SBI2K must also support a variety of user and terminal mobility scenarios across heterogeneous networks, including global roaming with seamless mobility. Moreover, MM protocols are required to be interoperable across heterogeneous networks and are also required to provide seamless mobility for new IP-based access networks.

III. MM REQUIREMENTS FOR SBI2K

To describe MM for SBI2K, we first need to define and classify the scope of MM, which will be helpful to identify MM requirements

A. MM Classification

MM requirements may be different according to the type of networks associated with SBI2K. Fig. 2 illustrates the classification of MM, along with the possible mobility patterns of a user in SBI2K.

As shown in the figure, a network consists of a core network (CN) and one or more access networks (ANs). An AN could be interworking with another AN via the CN.

- Core network (CN): Core network is an architectural term associated with a SBI2K, which is independent of the access technologies.
- Access network (AN): Access network is an entity or a set of entities between a user and the CN, which will be dependent on a particular access technology. Examples of access technologies include 2G, 3G (cdma2000, W-CDMA), WLAN, and IEEE 802.16, etc.

Considering the possible movement patterns of the user terminals in the network, the issues on MM for SBI2K are classified into 'inter-network' MM and 'intra-network' MM. The intra-network MM can be further divided into 'intra-AN' MM and 'inter-AN' MM.

A.1 Inter-Network MM

Inter-network MM addresses the issues on MM between different networks or operators. Inter-network MM will naturally accompany the MM between two ANs, i.e., inter-AN MM. In addition, the inter-network MM will also handle MM between different CNs, such as user authorization and service level agreement (SLA) negotiation. In Fig. 2, for example, MM between CN1 and CN3 corresponds to inter-Network MM, marked as '1' in the figure.

A.2 Intra-Network MM

Intra-network MM addresses the issues on MM within a network or operator. It can be subdivided into inter-AN MM and intra-AN MM.

(a) Inter-AN MM: Inter-AN MM addresses MM issues between different ANs within a single CN. Inter-AN MM can be further classified into the following two types of MM:
  - MM between the same type of ANs (e.g., MM between two AN1's within the CN1, as marked as '2a' in Fig. 2).
  - MM between different types of ANs (e.g., MM between AN1 and AN3 within CN1, as marked as '2b' in Fig. 2).

(b) Intra-AN MM: Intra-AN MM addresses MM within an AN. In Fig. 2, MM within AN1 of CN1 corresponds to intra-AN MM, marked as '3' in the figure.

B. MM Protocol Requirements

As described in the previous section, MM requirements for SBI2K may be different according to the movement pattern of a mobile user. However, we can identify a set of requirements for MM protocols, which are generally applicable to the MM for SBI2K.

1. Independence from the underlying access technology: First of all, it is required that the MM for SBI2K should be independent of the underlying network access technologies, since SBI2K is expected to support a variety of heterogeneous access networks that may use different access technologies, as shown in Fig. 1. Moreover, the MM should provide mobility across heterogeneous networks that possibly belong to the different operators.
2. Harmonization with the IP-based networks: In SBI2K, future converged networks are envisioned to be IP-based. Accordingly, MM protocols for SBI2K should also be IP-based so that they are well harmonized with the overall IP-based environment. It is also recommended to re-use existing MM schemes, to the extent possible, in the design of MM protocols for SBI2K.
3. Separation of control and transport functions: The transport plane should be separated from the control plane for effective mobility management and scalability. Such separation

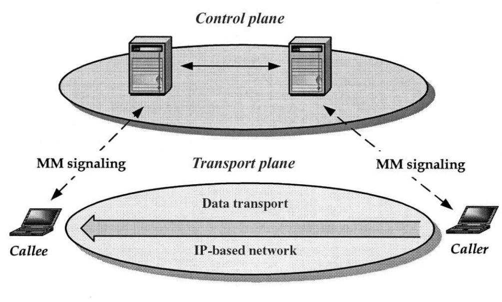

Fig. 3. Generic model of MM framwork.

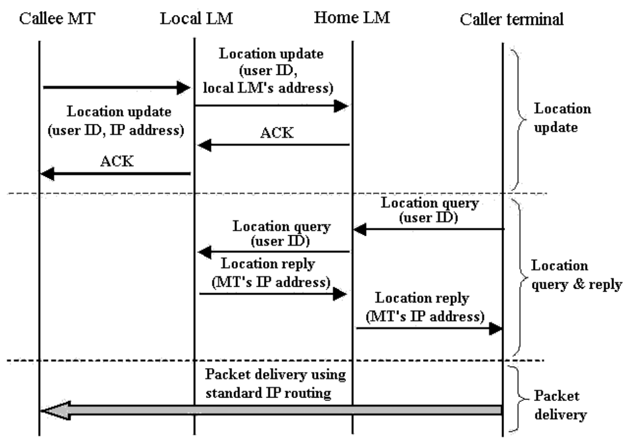

Fig. 4. Location update and query.

of control and transport planes will also provide the architectural flexibility that facilitates the introduction of new technologies and services. In this context, it may be a requirement to provide an open interface between the control and transport planes.

4. Location management function: It is essential to provide a location management function by which the locations of mobile users or terminals are registered and tracked. In IP-based networks, location management should also be IP-based.
5. Handover management function: MM should provide the handover management so as to support session continuity enabled by seamless handover with the movement of a mobile terminal across access network boundaries. The handover management function may be implemented along with an appropriate context transfer mechanism.
6. Identification of users/terminals: MM protocols for SBI2K need to interwork with the existing mechanisms used to identify the users/terminals in the networks. This identification functionality is the first step to be taken in the mobility management.
7. Support of both IPV4 and IPV6: The Internet is being evolved to IPv6. Therefore MM protocols for SBI2K need to support IPv6 as well as IPv4. In particular, it will be preferred to use a MM scheme that could be used in both IPv4 and IPv6 networks without any modification.

IV. MM FRAMEWORK FOR SBI2K

This section discusses the MM framework for SBI2K, based on the MM requirements described in the previous section.

A. MM Framework for SBI2K

Fig. 3 illustrates a generic model of the MM framework for SBI2K.

It is noted that the MM framework is designed based on the following principles:

1. Separation of control plane from data transport plane: This separation is required to ensure the independence of the MM control function from the user data transport function. The MM scheme will govern the overall control operations for mobility management of the users/terminals, whereas the data transport will be performed simply using conventional IP routing principles, with the help of the MM signaling. This separation could facilitate easy introduction of a new MM scheme and/or modification of the existing MM schemes, which is a very desirable feature from the viewpoint that SBI2K will be gradually evolved and migrated from the existing systems with time in many cases. (There will also be situations where there is no existing infrastructure to evolve and migrate from.)
2. Separation of local MM from home MM: This separation is required to enhance the scalability of deployed MM protocols. With this separation, the location management for a mobile terminal (MT) will be performed by a local MM entity and a home MM entity in a localized manner. It is noted that a localized MM scheme provides some advantages over a centralized one, since the frequency (signaling traffic) of the location updates with the home MM may be reduced, if the movement of the MT is restricted within the area covered by the local MM.

In the MM framework, the MM functionality may be classified into location management and handover management. Location management is used to support the location registration, update, tracking, and so on. On the other hand, the handover management is mainly used to provide session continuity for seamless mobility with a possible change of IP addresses for the MT. In the subsequent sections, we describe the location and handover management schemes, based on the MM framework for SBI2K.

B. Location Management

The procedures of location management include the location registration and tracking, and so on. With the help of the location management, an MT may register its current location with location manager (LM), whenever it moves into a new coverage area. The current location will typically be represented as an IP address.

For scalable location management, the location manager (LM) is divided into 'home LM' and 'local LM.' These two LMs interwork each other for location management. Fig. 4 shows the procedures for location update and location query/reply for an MT.

In the location update procedures, if an MT changes its subnet, it registers its new IP address and user ID with local LM. The user ID might be a SIP URI, E.164 number, or home address of the MT. Local LM maintains the information on the IP address and user ID of the MT in its database. It will then forward the location information of the MT (user ID and IP address of the local LM) to the home LM. This location update with the home LM will be repeated whenever the MT changes its associated local LM. However, if the MT moves within the network that is covered by the same local LM, then it performs the registration only with the local LM, not with the home LM.

In the location query and reply procedures, if an external terminal (caller) wants to communicate with the MT, the caller should first know the current location of the callee MT. Therefore, the caller will contact the home LM of the called MT (by using the user ID of the MT), so as to obtain the current IP address of the called MT. It is noted that the home LM already knows the location of the local LM that manages the called MT at present. In turn, the home LM sends the location query message to the corresponding local LM. The local LM will respond with the IP address of the called MT to the home LM, which will then be provided to the caller.

With the location query and reply procedures, the caller is informed about the current IP address of the called MT. Therefore, the caller can now deliver the data packets directly to the called MT using the standard IP routing scheme.

C. Handover Management

Handover management is mainly used to provide session continuity and seamless handover for an MT. For this purpose, handover manager (HM) may be located within the local network rather than the home network so as to reduce the latency of the handover signaling. In other words, HM could be used to minimize the impact of data transport plane latency for the handover of the MT so as to effectively support real-time services according to their quality of service requirements. Such a HM may be implemented within the routers.

In particular, HM functionality might be implemented using edge routers or crossover routers, which can be seen in the example MM protocols such as the fast mobile IP, which will be described in the next section.

Another approach for handover management is to perform the handover functionality in the transport layer, as we can see in the stream control transmission protocol (SCTP). The multi-homing feature of SCTP could be used to support the soft handover for the MT, which will also be described in the next section.

It is noted that adifferent handover scheme could be employed as per the characteristics of the concerned applications or network situations.

V. ANALYSIS OF EXISTING MM PROTOCOLS

In this section, we review and analyze some of the existing IP-based MM protocols that have so far been developed. It is noted that the IP-based MM for SBI2K could be implemented in the different layers such as the network, transport and application layers.

In this paper, we analyze and compare the following popular MM protocols by different layer:

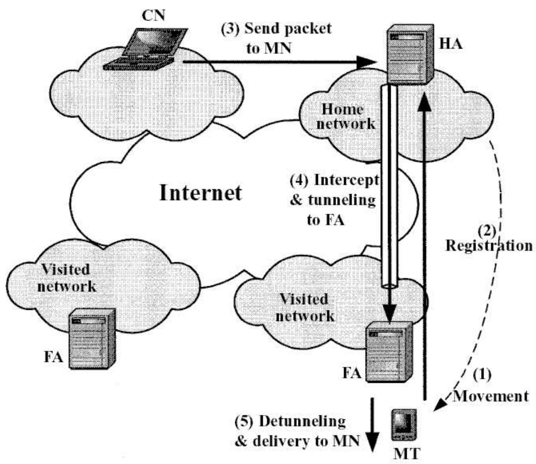

Fig. 5. Basic operation of MIPv4.

1. Mobile IP as a network layer scheme.
2. SCTP (Stream Control Transmission Protocol) as a transport layer scheme.
3. SIP (Session Initiation Protocol) as an application layer scheme.

The readers may wish to refer to some more example MM protocols described in ITU-T Q.sup52 [1].

A. Mobile IP

Mobile IP (MIP) is a protocol used to support IP mobility, which was standardized in the IETF. MIP may be classified into MIPv4 [6] and MIPv6 [7]. In this section, we focus on MIPv4. MIPv4 specifies the protocol operations between the following entities: Mobile terminal (MT), home agent (HA), foreign agent (FA), and correspondent node (CN). Fig. 5 shows the basic protocol operations of MIPv4.

As shown in the figure, when an MT moves into a new subnet (Step 1), it registers its care of address (CoA) with the HA (Step 2). The CoA could be the IP address of the FA (or the co-located CoA of the MT may be used instead). If the HA receives data packets destined for the MT from the CN (Step 3), the HA will intercept these packets, encapsulate them and forward them to the MT by using the mobile IP tunneling (Step 4). The FA will remove the encapsulation from the received packets and deliver the original packets to the MT (Step 5).

The basic specification of MIP cannot support the fast handover needed for time-critical and loss-sensitive applications. To address this problem, some extensions of MIP are being developed in the IETF, such as fast handover for MIP [8], [9] and Hierarchical MIP [10], [11]. It is expected that MIP together with its extensions will become a promising candidate solution for MM in SBI2K.

B. Stream Control Transmission Protocol

The stream control transmission protocol (SCTP) defined in IETF RFC 2960 [12] is an end-to-end, connection-oriented transport layer protocol, next to TCP and UDP. It is noted that the multi-homing feature of the SCTP can support IP mobility.

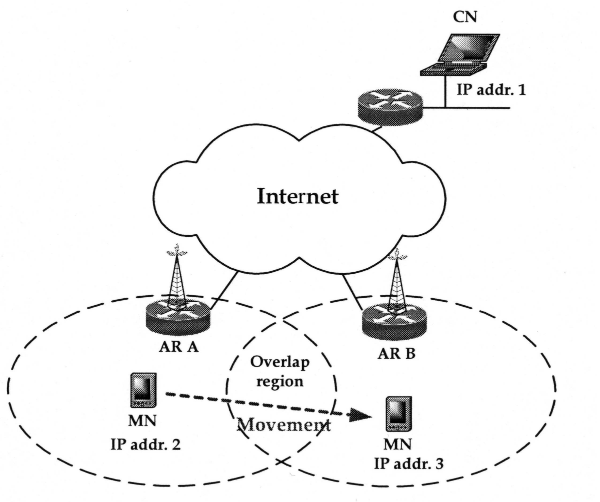

Fig. 6. mSCTP handover.

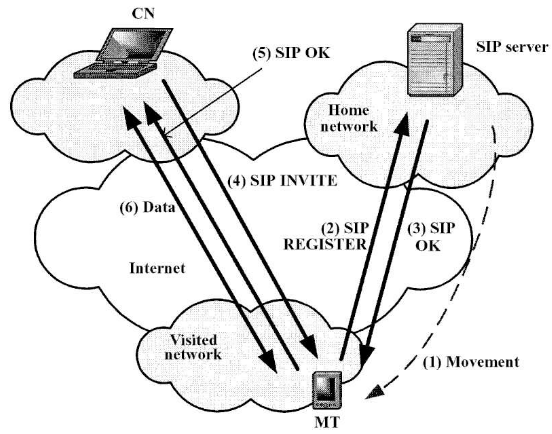

Fig. 7. SIP operations for MM.

Specifically, the SCTP with an extension of dynamic address reconfiguration can be used to provide soft handover for mobile terminals [13], [14]. This is called 'mobile SCTP (mSCTP)' in this paper, and is applicable to both IPv4 and IPv6. The mSCTP may be a promising scheme for handover. Unlike the mobile IP protocol that uses network agents, the mSCTP provides handover at the transport layer without additional help from the network layer routers. Fig. 6 shows the handover operations of mSCTP. In the figure, a mobile terminal (MT) initiates an SCTP association with a correspondent node (CN).

As shown in the figure, the mSCTP handover can be done as follows:

1. When a MT moves from access router (AR) A towards AR B in the overlapping region, it obtains a new IP address 3 from AR B by using any address configuration scheme such as DHCP. The newly obtained IP address 3 will be signaled to the CN in the transport layer.
2. The MT is now in a dual homing state. The old IP address (IP address 2) is still used as the primary address, until the new IP address 3 is set to be the "primary address" by the MT. As the MT further continues to move towards AR B, it will change to the new IP address as its primary IP address. Once the primary address is changed, the CN sends data packets to the MT's new IP address (IP address 3).
3. As the MT continues to move towards AR B, the old IP address (IP address 2) becomes inactive and the MT will delete it from the address list.

The procedural steps described above will be repeated whenever the MT moves to a new location. It is noted that mSCTP does not support location management. Accordingly, the mSCTP needs to be used together with another protocol to support location management.

C. Session Initiation Protocol

Session initiation protocol (SIP) has been defined in the IETF to support signaling for IP-based multimedia sessions [15]. SIP is an application-layer control protocol that can establish, modify, and terminate multimedia sessions. SIP could also be used to provide the location management for MM [16], [17].

Fig. 7 shows the SIP operations for MM. As shown in the figure, when an MT moves into a new network (Step 1), it will register its current location by sending a REGISTER message to the SIP Registrar server (Step 2). The server updates the location information (Step 3). When the MT moves into a new network, this SIP registration procedure will be repeated.

When a CN wants to communicate with the MT, it will connect to the MT by sending the SIP INVITE message, which will be delivered to the MT with the help of the SIP proxy servers (Step 4). When the MT receives the INVITE message, it will respond with the SIP OK message to the CN (Step 5). Now the MT can directly communicate with the CN (Step 6).

It is noted that SIP cannot provide seamless handover, since the on-going session will be terminated when the MT changes its IP address.

D. Comparison of the Existing MM Protocols

Table 1 compares the existing MM protocols that have so far been reviewed: MIP, SCTP, and SIP. We may also refer to [18] and [19] for more detailed descriptions of MIP, SCTP, and SIP.

First of all, MIP is an IP-based network layer protocol. It is independent of the underlying radio access technology. MIP provides location management and limited handover management functions with the help of the mobility agents such as HA, FA, etc. MIP binding update (BU) messages are used for location update and also possibly for route optimization. For fast and seamless handover, MIP needs an extension such as FMIP or HMIP.

On the other hand, the control and data transport functions of MIP are performed at the same time in that the first user data packet of MIP (flowing from the CN to MT) should be intercepted and tunneled by the HA. It may be preferred that the CN could transport the data packets directly to the MT, not by way of the HA. Accordingly, we may state that MIP does not meet the requirement '3' for MM.

We also note that MIP could be used in both IPv4 and IPv6 networks, but it has two different versions: MIPv4 and MIPv6.

Table 1. Comparison of existing MM protocols.

	MIP	SCTP	SIP
Layer	Network layer	Transport layer	Application layer
Location management	Provided	Not provided (may be used with SIP or MIP for location management)	Provided
User ID	IP address (home address)	IP address	SIP URI
Mobility agents	HA, FA (MIPv4)	No need of network agent	SIP servers (e.g. Registrar)
Messages used for location update	MIP binding update	SCTP ASCONF chunks	SIP RE-INVITE
Route optimization support	Need the route optimization extension	Intrinsically provided	Intrinsically provided
Handover support	Limited handover capability by MIP (FMIP, HMIP as extensions for seamless handover)	Provided at the transport layer	Not provided (may be used with MIP or SCTP for handover)
MM Requirements (of Section III-B)	Meets the requirements 1, 2, 4, 5, and 6	Meets the requirements 1, 2, 3, 5, 6, and 7	Meets the requirements 1, 2, 3, 4, 6, and 7

That is, interworking between MIPv4 and MIPv6 is another challenging issue to be addressed. Accordingly, we may state that the MIP does not meet requirement ‘7’ for MM.

Secondly, SCTP can be used to provide the handover at the transport layer. It does not support location management (MM Requirement ‘4’). For the purpose of location management, the SCTP may be used along with the SIP or MIP. On the other hand, SCTP does not require any additional mobility agents. It intrinsically provides the route optimization feature in the transport layer.

Finally, SIP is an application layer control protocol. SIP provides the location management function. It is noted that SBI2K considers SIP as a primary signaling protocol for IP-based multimedia services, as shown in the IP multimedia subsystem (IMS). SIP could operate independently of the underlying access technologies. SIP is independent of IP versions since it is an application layer protocol. However, SIP can not support seamless handover management (MM Requirement ‘5’). Therefore it will need an additional scheme to support handover.

VI. CONCLUDNG REMARKS

In this paper, we have identified the requirements and framework of MM for SBI2K. Based on those requirements and framework, we have reviewed and analyzed some of the existing MM protocols. From the analysis and comparison, it is shown that the existing MM schemes cannot meet all of the MM requirements for SBI2K. It implies that in the future we need to make some enhancements of the conventional MM schemes in a harmonized manner, or to develop a new MM scheme for SBI2K.

On the other hand, this paper has focused only on the basic MM functionality for SBI2K rather than the issues related to the performance of the MM schemes. We also did not consider the issues on the IP paging, context transfer, security, and QoS. Those items are for further study.

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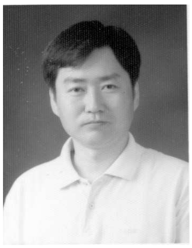

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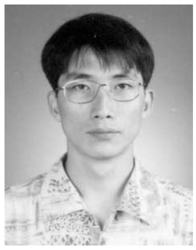

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