Design of Network Architecture and Signaling Procedure for Interoperability of IRIDIUM and CDMA-based Cellular Networks

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IRIDIUM 망과 CDMA 기반 이동통신망의 연동을 위한 망 구조 및 시그날링 절차 설계

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Abstract

In order to provide a global roaming service across networks, it is necessary to develop mechanisms for integration of and inter-working between different mobile/satellite communication networks. In this paper, a network architecture has been designed for the integration of domestic CDMA-based cellular network and IRIDIUM network which is going to provide a global satellite communication service. Specifically, we have designed a Clearing House which could perform the conversion of signaling protocols and messages, and parameter mapping functions between CDMA-based cellular network and IRIDIUM network. New signaling procedures for location registration and call setup in the integrated network are also proposed.

요 약

전세계적인 서비스지역의 확보를 위한 망간의 효율적인 로밍 (roaming)서비스를 지원하기 위해 이동통신 망간의 통합 및 연동 방안을 개발하는 것이 필요하다. 본 논문에서는 전세계를 대상으로 서비스를 제공할 수 있는 IRIDIUM 망과 현재 국내에서 서비스중인 CDMA 기반의 셀룰러 망간의 통합을 위한 망 구조를 설계하였다. 구체적으로, 시그날링 메시지와 프로토콜의 변환 및 관련 매개변수의 매핑 기능을 수행하는 Clearing House를 설계하였다. 또한 통합망에서 호설정과 위치등록을 위한 신호 절차를 설계하였다. 본 연구 결과는 지상 및 이동통신망들의 연동을 통한 광역 통신 서비스 제공을 위한 망 구성 및 신호절차 설계에 활용 될 수 있다

I. Introduction

There have world-widely been strong interests for the development of wireless personal communication systems to provide the global communication service to any one, at any time, and at any place. Currently, the capacity of analog mobile communications has already been saturated, and digital mobile cellular networks which can use the radio channels more efficiently than analog systems has been developed. Digital mobile cellular networks can also interwork more effectively with broadband integrated services digital network (B-ISDN) to provide various multimedia services. There have been active researches to develop a global personal communication system that could provide a full roaming service with worldwide coverage to the subscribers. For example, mobile satellite system (MSS) has been being developed to provide global telecommunication services under several large `projects including IRIDIUM [1], GLOBALSTAR, and INMARSAT-P. These MSSs may provide the subscribers with location independence because it could directly use satellite beam to provide the service at any place in the world. MSS tends to be less impervious to earthquakes, floods, hurricanes, and other natural disasters. In addition, MSS will not be affected by weather and damage of local telephone systems and power lines, making it an important asset to disaster-relief network operations [2]. With the reliability and expansiveness of MSS's services, MSS is frequently recommended as a compensatory network for the terrestrial one.

In order to provide subscribers with global mobile communication services, cellular network operators need to develop inter-system roaming technologies. An integration of terrestrial cellular system and satellite mobile communication system is one of these technologies that are used by current mobile communication service providers [3-6]. Since architecture, interfaces and other standards of terrestrial cellular network and MSS are quite different, there are problems to be solved for an efficient integration, which may include those associated with mobile application part (MAP) protocol interoperability, numbering, addressing, charging, access method, network management, and call routing. The interoperability of different MAP protocols is specifically related to the achievement of an intersystem global roaming service in an integrated network.

There are several regional standards for digital mobile cellular systems each of which has its own MAP protocol: GSM MAP [7-13], IS-41 MAP [14], PDC MAP [15]. There are basically two approaches to resolve the differences between these MAP protocols for providing intersystem roaming service. The first approach is to use call forwarding method, which is known to be relatively simple to implement. The drawback of this approach is that it may take much time to do call routing and can't support intersystem handover. The second approach is to use a gateway system with translation mechanism that could interpret and generate the signaling message required in each constituent system. A gateway system can provide an intersystem roaming service between terrestrial mobile cellular networks that have different MAP protocols. This approach doesn't require the modification of constituent mobile cellular systems. Additionally, a gateway can be interconnected to many terrestrial mobile cellular systems. However, the time required to perform call setup and location registration is closely dependent on the processing capacity and performance of a gateway in this approach. Uchiyama, et al., [16] designed nodes to provide roaming services between GSM and Personal Digital Cellular System (PDC) which is a digital cellular system developed in Japan. In the nodes that consists of interworking location register (ILR) and interworking mobile switching center (IMSC), they convert MAP protocol of PDC into that of GSM. Additionally, they designed signaling procedures to provide intersystem roaming service using a gateway. Yamaguchi, et al., [17] designed a interworking function block which mainly deals with PDC MAP / GSM MAP protocol conversion to provide terminal mobility to subscriber with subscriber identification card (SIM) between PDC and GSM networks. Jorgen [18] proposed interworking nodes similar to nodes designed by Uchiyama. This gateway approach can also be extended to provide a global roaming service through an integration of terrestrial cellular systems and a mobile satellite communication system [19, 20]. Practically, literature [21] presents the integration scenarios of INMARSAT-P mobile satellite communication system and terrestrial mobile cellular system. INMARSAT-P uses GSM compatible MAP protocol. Thus, Clearing House is proposed as a gateway to integrate INMARSAT-P and GSM non-compatible mobile cellular system. Clearing House performs the conversion of MAP protocols.

In this paper, a network architecture has been designed for the integration of Domestic CDMA-based cellular network and IRIDIUM network that is going to provide a global satellite communication service. MAP protocol signaling messages carrying subscriber's information are transferred across boundaries of networks for handling call processing, inter-network handover, and location registration for roaming subscribers. Domestic CDMA-based cellular network uses common channel signaling No.7 (CCS No.) [22] as signaling transfer protocol and IS-41 MAP (Mobile Application Part) as MAP protocol. On the other hand, IRIDIUM uses CCS No.7 as transfer protocol and GSM MAP as mobile application part protocol. Thus, we choose the gateway approach to integrate IRIDIUM network and domestic CDMA-based cellular network. The gateway which could perform this translation function is named as a Clearing House. We design the architecture and interfaces of the Clearing House that consists of CCS No.7, conversion processor, message conversion mapping table, and database for roaming subscriber. Specifically, we design, in Clearing House, the functions associated with the conversion of signaling protocols and messages, and parameter mapping between CDMA-based cellular network and IRIDIUM network. In addition to these functions, we propose new signaling procedures for location registration and call setup in the network that is integrated by using the Clearing House.

II. An Integration Architecture for IRIDIUM System and CDMA-based Cellular System

1. IRIDIUM Mobile Satellite Communication System

The IRIDIUM system is a global communication system and has unique constellation of 66 low-earth-orbit (LEO) satellites. These satellites are arranged in six polar orbital planes 780 kilometers above the planet, each containing 11 satellites. This configuration is suggested to offer low path delays and global coverage. The constellations of satellites of the IRIDIUM system comprise the L-band cell sites through which subscribers receive mobile telecommunication service. Through its intersatellite links, the system will cover the vast portions of the world where telecommunications networks cannot be economically justified, and will serve polar and ocean areas. However, several ground components are involved to work as a complete personal communications system, as shown in Fig. 1.

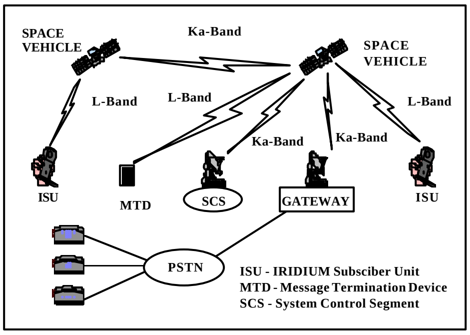
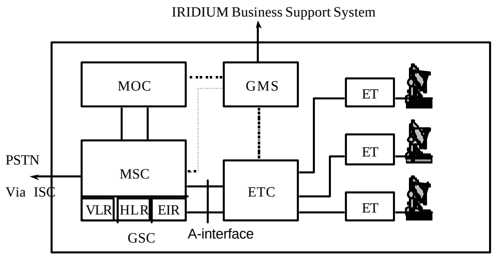


Fig. 1. IRIDIUM system configuration

A number of GSM system features are utilized to implement the ground system of IRIDIUM. However, IRIDIUM-specific modifications to GSM system features were made in order to control the dynamic nature of the satellite constellation. Fig. 2 shows a block diagram of an IRIDIUM gateway. MSC operating as the switch in GSM system has two interfaces. One is a land interface which connects to the telephone network, and the other is a mobile interface which connects across an “A” interface to an earth terminal controller (ETC). The ETC is similar to the base site subsystem (BSS) of a terrestrial GSM system. It controls a set of earth terminals (ETs) which communicate with the constellation using K-band radio links. Information for subscribers is kept in both VLR and HLR. Information for physical subscriber equipment is kept in the equipment identification register (EIR).



MSC - Mobile Switching Center
GMS - Gateway Management System
ET - Earth Terminal
VLR - Visited Location Register
ISC - International Switching Center

Fig. 2. Gateway block diagram

2.2 An Integration Architecture of IRIDIUM System and CDMA-based Cellular System

The integration of IRIDIUM system and CDMA-based cellular system can be done at both terminal level and network level. Terminal level integration requires the use of call forwarding capability. In this integration, dual-mode terminal must have an IRIDIUM directory number as well as CDMA directory number. Every incoming call is forwarded to the IRIDIUM by CDMA’s HLR, in either when dual-mode terminal is registered in the IRIDIUM, or when the terminal cannot be reached via CDMA paging. This integration method has, as drawback, a long routing time and require dual number assignment. But the implementation is easy. This integration may be valuable only for terminals with very infrequent requirements for inter-network roaming. At network level integration, both networks require interaction for call routing and authentication between location registers and switching centers of each network. This interaction is closely related to the signaling protocol, numbering, and addressing used in each network. If MAP protocols used in each network are the same, integration is very easy. Just one directory number can be used and additional equipment may not be required. However, MAP protocols used in IRIDIUM system and CDMA-based cellular system is not the same. Therefore, the conversion of MAP protocols is required for integration of IRIDIUM and CDMA system. The conversion of MAP protocols can be performed at a gateway.

IRIDIUM system is connected to the terrestrial network through PSTN's international switching center (ISC). CDMA-based cellular system is connected to PSTN's toll switch (TS). Therefore, PSTN plays a role of an intermediate network for the integration of IRIDIUM system and CDMA-based cellular system. Fig. 3 shows integrated network architecture. We assume that dual-mode terminal may have only a CDMA system directory number assigned through terrestrial subscription. Since dual-mode terminal has only mobile identification number (MIN), its subscriber is registered in the CDMA’ s HLR and not in the IRIDIUM’ s HLR. When dual-mode terminal cannot access broadcast channel of CDMA in CDMA service area or is internationally roaming in other country where CDMA service is not available, dual-mode terminal may be registered at the IRIDIUM’ s VLR and may access IRIDIUM service as an expansion of terrestrial services.

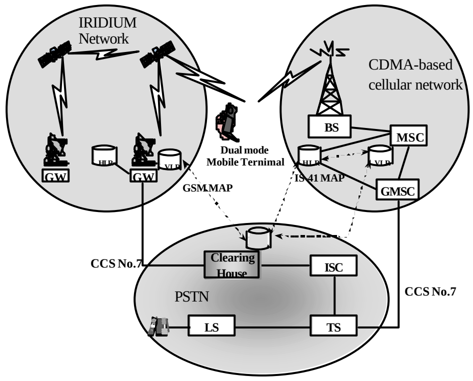


Fig. 3. Architecture of integrated IRIDIUM and

CDMA networks

Network interworking will occur principally through MAP protocol signaling across D-interface, which allows the IRIDIUM's VLR to communicate with the CDMA's HLR of a visiting dual-mode terminal. Since the dual-mode terminal belongs to a CDMA home system, the terminal will always be a visitor in the IRIDIUM. Seamless roaming will require interaction mainly between the IRIDIUM's VLR and the CDMA's HLR. With its CDMA system directory number, all calls to the mobile will be first routed to the CDMA's HLR. Rerouting to IRIDIUM will be performed after the last mobile location registration has been done in IRIDUM service area.

However, some problems may occur when MAP messages are interchanged across network's boundaries. CDMA system uses IS-41 MAP as mobile application part protocol. On the other hand, IRIDIUM uses GSM MAP as mobile application part protocol. Because of the significant differences between the intersystem MAP signaling protocols, transparent interworking can only be provided through a translation mechanism that has the capability to interpret and generate the signaling message required in each system. The Clearing House is a gateway that could perform these functions. The Clearing House can be implemented in the IRIDIUM Gateway or between IRIDIUM Gateway and ISC.

3. A Design of Clearing House

3.1 Clearing House Architecture

We have designed an architecture of Clearing House shown in Fig. 4, which is composed of MTP-1, MTP-2, MTP-3, SCCP, and TCAP. Fig. 4 also shows message conversion part made up of conversion processor and mapping table, and database for roaming subscriber in the IRIDIUM system.

3.1.1 Message Transfer Part (MTP)

MTP consists of three levels: level 1 corresponds to the electrical transmission of bits from one signaling point to another. The signaling point nodes are connected by signaling links that could be land-line wires, fiber optic cable, or satellite communication links. MTP level 2 attempts to provide reliable signaling unit transfer between two directly connected signaling points. MTP level 3 is intended to provide reliable signaling unit transfer between any two signaling points in the network.

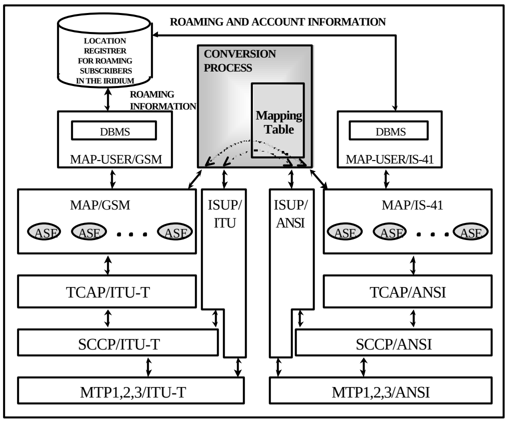


Fig. 4. Architecture of Clearing House

3.1.2 Service Connection Control Part (SCCP)

SCCP supports user-to-user communication with enhanced addressing functions such as symbolic names for a destination, that SCCP translates into a physical address. The SCCP also provides both connectionless and connection-oriented communications.

3.1.3 Transaction Capabilities Application Part (TCAP)

TCAP provides a set of tools in a connectionless environment that can be used by an application at one node to invoke an execution of a procedure at another node and exchange the results of such invocation. It includes protocols and services to perform remote operations. The primary use of TCAP is for invoking remote procedures in support of IN services such as 800-number services (freephone).

3.1.4 Mobile Application Part (MAP)

MAP is an application layer protocol using the SS7 TCAP services. To use TCAP, MAP has defined operation codes, parameter identifiers, and error codes for identifying MAP messages. MAP messages could be routed to the destination using SCCP global title translation (GTT) capabilities. A MAP dialogue is defined as an exchange of information between two MAP users to perform a common task. A MAP dialogue will consist of one or several MAP services.

3.1.5 Message Conversion Processor

Interpretation and generation of the signaling messages required in each system are performed in this functional block. Message Conversion Processor includes mapping table that contains matching pairs of messages and parameters. This block can also control error codes occurred in both MAP protocols.

3.1.6 Location Register for Subscriber Roaming in the IRIDIUM Network

This functional block is responsible for storing, maintaining, updating the information of subscriber roaming in the IRIDIUM system. When a subscriber is in the IRIDIUM system, that subscriber's information is stored in this block. When the subscriber moves from IRIDUM to CDMA system, his or her information is removed. Location information may be changed due to the movement of subscriber in the IRIDIUM system. This changed information is not stored in the CDMA's HLR but only in this location register.

3.2 Design of Interfaces and Protocol for the Clearing House

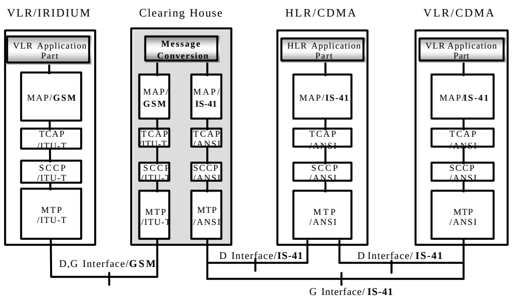


Fig. 5. D and G-interfaces and Clearing House in an integrated network

As we have mentioned before, the service provisioning in the integrated network requires subscriber's information to be exchanged between mobile satellite telecommunication network and terrestrial one. D and G interfaces have been defined at the boundaries for the purposes as shown in Fig. 5. Intersystem MAP messages must be transmitted between networks through the Clearing House, which translates IS-41 MAP message into GSM MAP message, and vice versa.

MAP messages are transmitted through CCS No.7 network that provides out of band channel signaling and has signaling message transfer protocol made up of MTP1,2,3 and SCCP. The call to the roaming subscriber is routed to its destination through a real space network of the satellite interconnected by inter-satellite links (ISLs).

3.3 Functions of Clearing House

Clearing House has three functions as a gateway system for integration of IRIDIUM and CDMA system. The first is MAP protocol conversion. Clearing House must interpret and generate the signaling messages required in each system taking into account of numbering plan, addressing, routing mechanism, and access method to acquire subscriber information. The second is mobility management for subscribers roaming in the IRIDIUM system. When a subscriber is in the IRIDIUM system, subscriber's information is stored in the IRIDIUM's VLR and in the location register of Clearing House. Terminating call of the subscriber roaming in the IRIDIUM system will be primarily routed to Clearing House, and then rerouted to the subscriber registered in the area where IRIDIUM service is provided. Clearing House manages the location information of roaming subscriber in the IRIDIUM system. In other words, Clearing House plays role of the HLR for the roaming subscribers in the IRIDIUM system. The third is account management of subscriber roaming in the IRIDIUM system. Clearing House collects account information for the roaming subscribers and stores in the location register of Clearing House. When CDMA system operator requests the account information, Clearing House provides that stored in the location register.

4. Message Conversion, Parameter Mapping, and Signaling Procedures

4.1 Message Conversion

Signaling messages are transferred across Clearing House when the intersystem signaling is performed for mobility management, authentication, call setup, and so forth. As previously described, IS-41 MAP message format and handling procedures differ from those of GSM MAP. We must match one MAP message to the other or generate new MAP message for the completion of intersystem signaling across boundary of IRIDIUM and CDMA system. Fig. 6 shows the message conversion for location registration between IRIDIUM and CDMA system. Practical signaling procedures are described in more detail in the following subsection 3.

4.2 Parameter Mapping

Parameters must be taken into account to convert messages. Parameters are closely related to numbering plan and addressing. Call setup is performed by using directory number (MIN; Mobile Identification Number, IMSI; International Mobile Station Identification). So this number must be able to be translated in each system for call setup and signaling. Subscriber number is supposed to be unified after time-T in which ISDN numbering plan [23] is put into operation. Addressing must be taken into account for the transmission of messages between both systems. CDMA system uses mobile switching center identification (MSCID) to differentiate MSCs. However, IRIDIUM uses MSC address represented in ISDN number. Clearing House plays role of MSC and VLR of an extended cell in the CDMA system and does as Gateway and HLR in the IRIDIUM. Therefore, the Clearing House must have both MSCID and MSC addresses for routing of call setup and signaling. It must also have IRIDIUM's HLR addresses. These addresses or IDs are recognized by both MAP users of the Clearing House. However, there are some parameters defined in the CDMA system and not in the IRIDIUM system, and vice versa. In this case, default values may be assigned to these parameters through network operators' negotiation.

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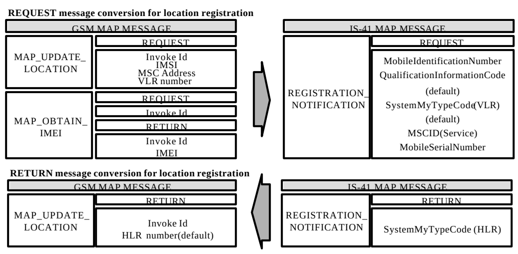

Fig. 6. Message conversion for location registration between IRIDIUM and CDMA systems

4.3 Signaling Procedures

Location update procedure updates the location information held in the network, and is invoked when subscriber power on his terminal or when subscriber moves to other service area with terminal of the idle state. This information is used for routing of incoming calls, short messages and unstructured supplementary service data to the roaming subscriber.

4.3.1 Move from CDMA System to IRIDIUM

When a subscriber with dual-mode terminal moves from the service area of the CDMA system to that of the IRIDIUM system, location registration signaling procedures are performed as depicted in Fig. 7.

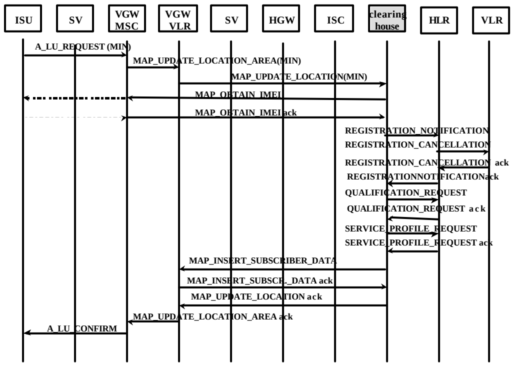

Fig. 7. Location registration signaling message flow (Move from CDMA system to IRIDIUM)

The detailed location registration procedures are described below.

Step a) Dual-mode terminal tries to register to the current serving VLR of the IRIDIUM system.

Step b) The IRIDIUM's VLR sends message requesting location registration to the CDMA's HLR by using the CDMA system directory number of the terminal

Step c) After the Clearing House receives the request message from the IRIDIUM's VLR, it acquires international mobile equipment identification (IMEI) from the terminal and converts GSM MAP message into IS-41 MAP message containing IMEI as MobileSerialNumber. Then, the converted message is transmitted to the CDMA's HLR of the terminal.

Step d) The CDMA's HLR requested location registration sends message requesting location cancellation to the previous serving the CDMA's VLR for the first time, and then receives the request acknowledge message. HLR updates its database and sends acknowledge message to the Clearing House.

Step e) Clearing House requests subscriber information to the CDMA's HLR and receives that. Then it stores the information in the LR of the Clearing House. It also sends the information to the IRIDIUM's VLR.

Step f) The IRIDIUM's VLR updates its database with the information received from the Clearing House.

4.3.2 Move from IRIDIUM to CDMA System

When a subscriber with dual-mode terminal moves from the service area of the IRIDIUM system to that of the CDMA system, location registration signaling procedures are performed as depicted in Fig. 8. In this case, Clearing House converts only cancellation message.

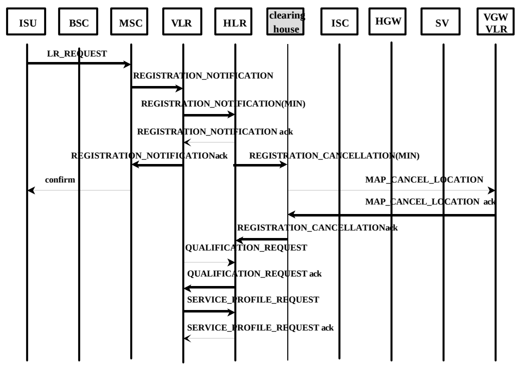

Fig. 8. Location registration signaling message flow (Move from IRIDIUM to AMPS)

The detailed location registration procedures are described below.

Step a) Dual-mode terminal tries to register to the current serving VLR of the CDMA system.

Step b) CDMA's VLR sends message requesting location registration to the CDMA's HLR by using the CDMA directory number of the terminal

Step c) CDMA's HLR requested location registration sends message requesting location cancellation to the previous serving IRIDIUM's VLR for the first time, and then receives the request acknowledge message. HLR updates its database and sends acknowledge message to the CDMA's VLR.

Step d) The CDMA's VLR requests the subscriber information to the CDMA's HLR and receives that.

Step e) CDMA's VLR updates its database with the information received from the CDMA's HLR.

4.3.2 Call Setup

Clearing House performs call setup to the subscriber roaming in the IRIDIUM system. Clearing House has two addresses and two IDs. The MSCID of the Clearing House is used for routing call with MSISDN of the subscriber roaming in the IRIDIUM system. Location information stored in the location register of the Clearing House is also used to acquire MSRN (Mobile Station Roaming Number).

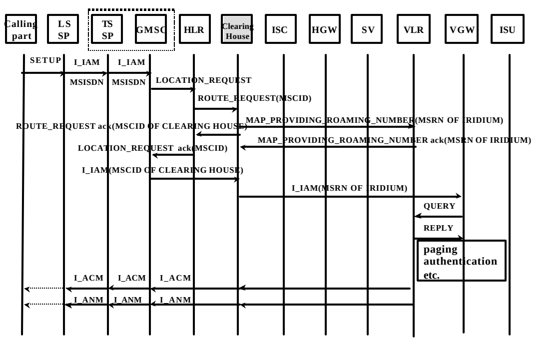

Fig. 9. Terminating call setup procedure for the roaming subscriber in the IRIDIUM system

Fig. 9 shows the detailed signaling procedures which are described below.

Step a) When the CDMA's GMSC (Gateway MSC) receives terminating call from PSTN subscriber to the CDMA's subscriber roaming in the IRIDIUM system, the CDMA's GMSC requests subscriber location information (MSCID) of the CDMA system directory number to the CDMA's HLR and receives the MSCID (the Clearing House's MSCID)

Step b) The CDMA's GMSC reroutes the call to the Clearing House with MSCID received from the CDMA's HLR.

Step c) The Clearing House requests the MSRN of the subscriber who should be called with the CDMA system directory number to the current serving the IRIDIUM's VLR and receives that number.

Step d) The Clearing House reroutes the terminating call to the corresponding subscriber.

Fig.10 describes the three phased routing procedure of terminating call to the CDMA's subscriber roaming in the IRIDIUM

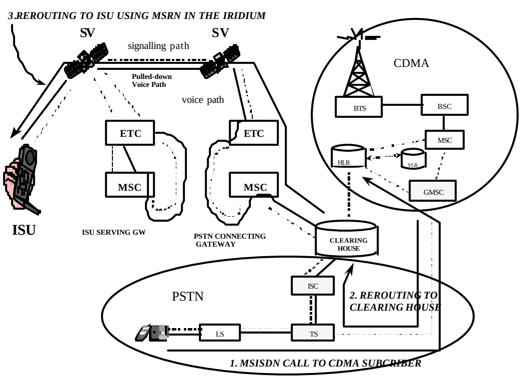

Fig. 10. Routing to dual-mode-terminal roaming in the IRIDIUM system

5. Conclusion

In this paper, we have designed an architecture for the integration of IRIDIUM system and domestic CDMA-based cellular system, and have defined network interfaces at the boundaries where signaling messages containing subscriber's information are exchanged. In particular, we have designed an architecture of Clearing House that consists of SCCP and MTP of CCS No.7, message conversion mapping table, conversion processor that is responsible to convert MAP/GSM and MAP/IS-41. We have also specified the functions of Clearing House. Finally, we suggest new signaling procedures for location registration and call setup. Since IRIDIUM service will be provided after time-T when ISDN numbering plan is in operation, the conversion of parameters related to numbering is achieved by using the current ISDN numbering plan.

Satellite mobile telecommunication systems may interwork terrestrial mobile telecommunication systems to provide the global communication service to anyone, at any time, and at any place. For this interworking, terminal level or network level integrating of satellite and terrestrial mobile network are needed. Korea has selected CDMA-based cellular system for digital mobile telecommunication system. Our work can be used to design of architecture and signaling procedure for providing the intersystem roaming services between mobile communication networks including global mobile personal communication system (GMPCS). It can also be used to realize the third-generation mobile telecommunication system, where IRIDIUM system may efficiently interwork with CDMA-based cellular system.

For further research work, we are going to perform performance evaluation such as the time delay of call setup and handover through Clearing House in the integrated IRIDIUM and CDMA-based cellular system, as network configuration and other key parameters necessary for evaluation are set. Another feasible research area may include an efficient handover technology in the integrated network, and an applying intelligent network technology for integration of diverse terrestrial and/or satellite mobile cellular networks.

Reference

[1] Jonathan Hutcheson and Mata Laurin, "Network Flexibility of the IRIDIUM Global Mobile Satellite System", *Proceeding of International Mobile Satellite Conference*, Ottawa, pp. 503-507, 1995.

[2] Fulvio Ananasso and Francesco Delli Priscoli, "The Role of Satellite in Personal Communication Services", *IEEE Journal on Selected Areas in Communications*, Vol. 13, No. 2, pp. 180-196, February 1995.

[3] Enrico Del Re, "A Coordinated European Effort for the Definition of a Satellite Integrated Environment for Future Mobile Communications", *IEEE Communications Magazine*, pp. 98-104, February 1996.

[4] R. Matyas, P. Kelleher, P. Moller, and T. Jones, "Interworking Evolution of Mobile Satellite and Terrestrial Networks", *Proceeding of International Mobile Satellite Conference*, Pasadena California, pp.125-130, June 1993.

[5] E. H. Drucker, "Integration of Mobile Satellite and Cellular Systems", *Proceeding of International Mobile Satellite Conference*, Pasadena California, pp.119-124, June 1993.

[6] E. Del Re, F. Delli Priscoli, P. Iannucci, R. Menolascino, and F. Settimo, "Architectures and Protocols for an Integrated Satellite-Terrestrial Mobile System", *Proceeding of International Mobile Satellite Conference*, Pasadena California, pp. 137-142, June 1993.

[7] M. Mouly and Marrie B. Pautet, *The GSM system for mobile communications*, 1992.

[8] GSM recommendations 03.03, *Network archi-*

tecture, Phase two, ETSI/GSM, September 1994.

[9] GSM recommendations 03.04, *Signaling requirements relating to routing of calls to mobile subscribers*, Phase two, ETSI/GSM, September 1994.

[10] GSM recommendations 03.07, *Restoration procedure*, Phase two, ETSI/GSM, September 1994.

[11] GSM recommendations 03.12, *Location registration procedures*, Phase two, ETSI/GSM, September 1994.

[12] GSM recommendations 09.01, *General network interworking scenarios*, Phase two, ETSI/GSM, September 1994.

[13] GSM recommendations 09.02, *Mobile application part (MAP) specification*, Phase two, ETSI/GSM, September 1994.

[14] TIA/EIA IS-41, *Cellular Radiotelecommunications Intersystem Operation*, Revision C, September 1994.

[15] TTC JJ-70.10, *MAP signalling system of digital mobile communications network internode interface for PDC*, TTC, 1994.

[16] Yasuyui Uchiyama, Hiroshi Nakamura, and Masami Yabusaki, "Network Functions and Signalling for Personal Roaming between Digital Cellular Standards", *Proceeding of IEEE International Conference on Universal Personal Communications*, pp. 447-451, November 1995.

[17] Toshinori Suzuki, Fumio Watanabe, and Toshio Mizuno, "Interoperability of PDC with GSM", *Proceeding of IEEE International Conference on Universal Personal Communications*, pp. 452-456, November 1995.

[18] Jorgen Lantto, "Towards a global cellular service", *Proceeding of IEEE International Conference on Universal Personal Communications*, pp. 457-461, November 1995.

[19] Dong-Hee Lee, Jong-Tae Park, and Jae-Young Ahn, "A network Architecture for Integration of IRIDIUM and AMPS System", *Proceeding of Multi-Dimensional Mobile Communications*, pp. 424-429, June 1996.

[20] Dong-Hee Lee, Jong-Tae Park, and Jae-Young Ahn, "A Network Architecture for Integration of IRIDIUM and CDMA Systems", *Proceeding of IEEE International Conference on Communications*, Montreal, pp. 1221-1225, June 1997.

[21] Inmarsat-P: Terrestrial Network Specification, draft version 0.2, November 1995.

[22] Abdi R. Modarressi and Ronald A. Skoog, "Signaling System No.7: A Tutorial", *IEEE Communications Magazine*, pp. 19-35, July 1990.

[23] ITU-R Recommendation E.164, *Numbering Plan for the ISDN Era*.