Special Article on IMT-2000 Services (2)
– Launch of FOMA, the Pioneer of the New Mobile Age –

Core Network Technologies

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This article describes a technology overview for the IMT-2000 core network, with reference to the network configuration and control systems.

1. Introduction

International Mobile Telecommunications-2000 (IMT-2000) is an international standard of third-generation mobile communications systems, which enables mobile phones to offer high-speed and high-quality multimedia services.

This article reviews the characteristics of the IMT-2000 core network adopted by NTT DoCoMo, the physical network configuration, the basic control system, and the functions of devices.

2. Overview and Characteristics of Core Network Technologies

IMT-2000 has various characteristics that are different from the core network of Personal Digital Cellular (PDC), which is the existing second-generation mobile phone system. Its main characteristics are as described below.

(1) International Standards

One of the most noteworthy characteristics of IMT-2000 is that it is a system compliant with international standards. PDC, the second-generation system, was based on Japanese standards inapplicable to other countries, which meant that terminals used in Japan could not be used overseas. In contrast, IMT-2000 is a system in compliance with international standards, meaning that locally-used terminals can be used in areas outside the scope of NTT DoCoMo as long as they are based on the same standards (global roaming).

(2) Integrated Circuit Switching and Packet Switching System

The Core Network (CN) of IMT-2000 is an evolved version

of the second-generation system, which progressed from circuit switching to packet switching. Enhancements have been made to achieve new functions and capabilities. In the recommendation issued by the International Telecommunication Union-Telecommunication standardization sector (ITU-T), as network components, the Circuit Switched (CS) domain and the Packet Switched (PS) domain are defined separately from each other [1]. These represent a group of logical function units, which may correspond installed physical devices and nodes at discretion. NTT DoCoMo has built an integrated system that exchanges and transmits various types of media, ranging from speech traffic to large-volume data traffic, by fulfilling CS and PS functions with a single node.

(3) ATM Technology

IMT-2000 adopts Asynchronous Transfer Mode (ATM) as its transmission and switching technology [2].

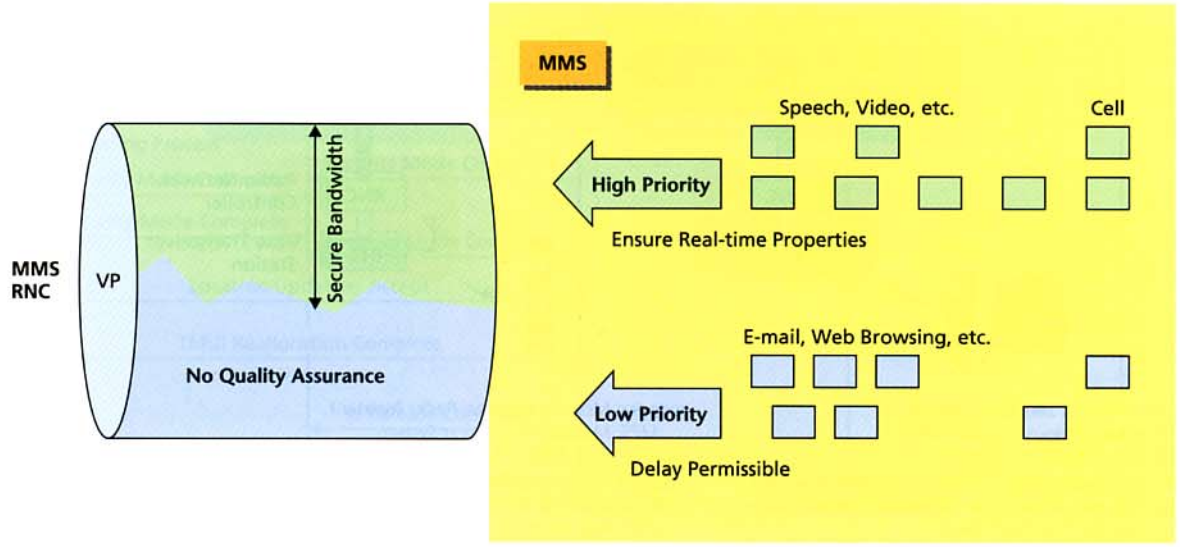
ATM is a technology that divides information into fixed-length, 53-byte frames for transmission and switching. CN in IMT-2000 must handle circuit switching data such as speech, audiovisual and unrestricted digital information, as well as packet switching data subject to Internet Protocol (IP) connection. ATM technology makes it possible to transmit these data in an integral manner.

CN in IMT-2000 provides ATM-Switched Virtual Channels (ATM-SVCs) for both circuit switched and packet switched services. ATM Adaptation Layer (AAL) type 1 is applied to circuit switching data, AAL type 5 to packet switching data, and AAL type 2 to forwarding of circuit switched services in CN and information including packet switched services between Radio Network Controllers (RNC) when the subscriber line is extended upon handover.

ATM has high traffic management capabilities compared to existing IP networks, and under IMT-2000, it guarantees Quality of Service (QoS) by using ATM traffic control. For speech and video communications with high real-time requirements, ATM's signaling information is used to secure a certain bandwidth upon establishing connection. **Figure 1** illustrates QoS control through ATM. By applying ATM's QoS control function to packet switched domain, it is possible to achieve packet communication with various QoS types [3] [4].

(4) IN Service

The advanced Intelligent Network (IN) separates and stratifies the switching control function and the service control function (which used to be accommodated in one switching system) into Service Switching Function (SSF) and Service Control Function (SCF). This makes the addition and modification to services more flexible and prompt [1]. The advanced IN applies CAMEL Application Part (CAP) signals to the interface between SSF and SCF so that new services can be provided simply by manipulating the SCF side. It should be noted that CAP was standardized under the 3rd Generation Partnership Project (3GPP) based on the IN Application Protocol (INAP), the standard interface recommended by ITU-T. Advanced IN services achieved in NTT DoCoMo networks include voice



MMS: Mobile Multimedia switching System
RNC: Radio Network Controller
VP: Virtual Path

Figure 1 QoS Control by MMS

mail services and incoming call forwarding services.

3. Network Configuration and Control Procedures

3.1 Network Configuration

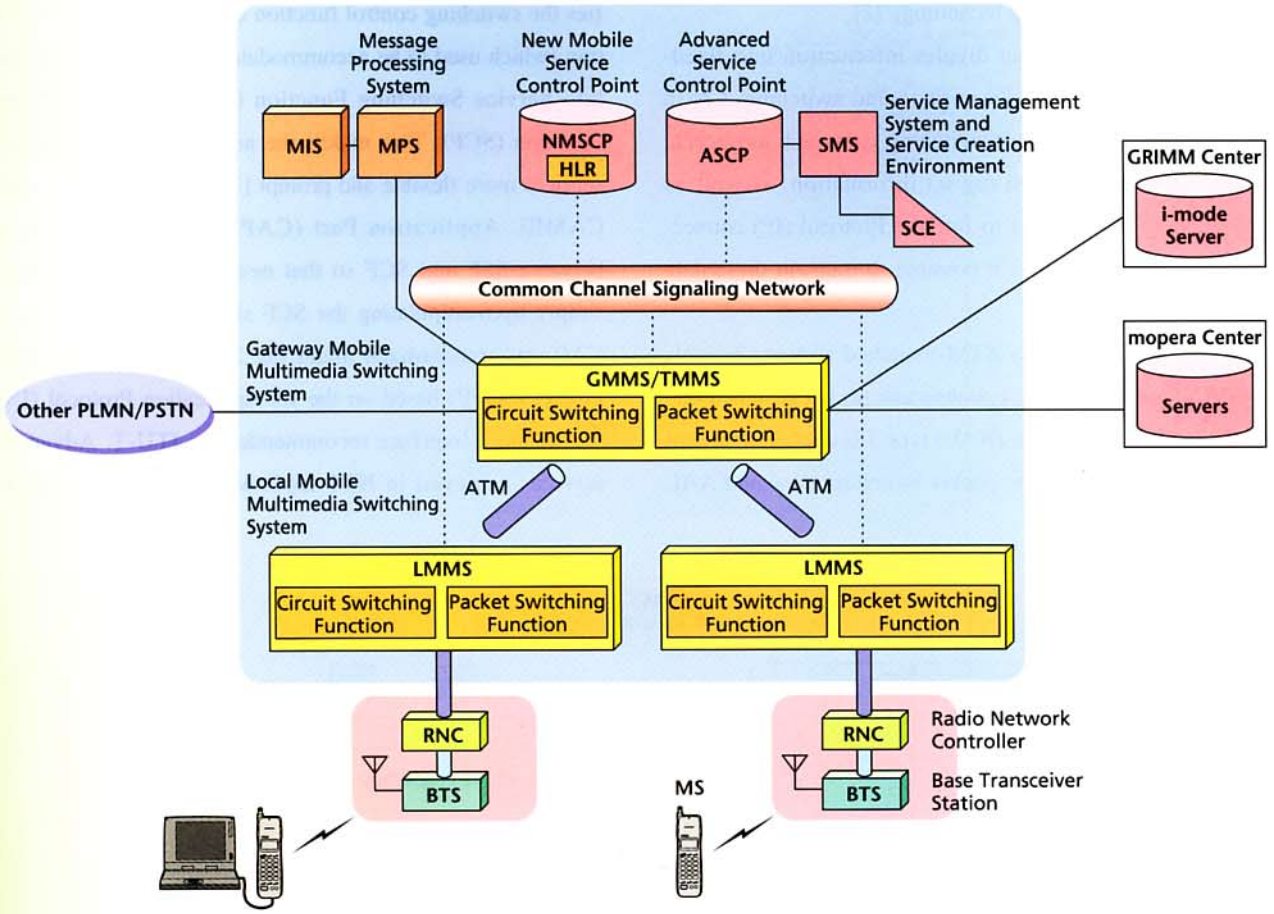
Figure 2 shows the configuration of NTT DoCoMo's IMT-2000 core network. CN consists of the Local Mobile Multimedia switching System (LMMS), the Toll Mobile Multimedia switching System (TMMS) and the Gateway Mobile Multimedia switching System (GMMS), which are switches that execute call connection processes for circuit switching and packet switching; the New Mobile Service Control Point (NMSCP), which serves as a high-capacity mobile communication service controller that registers subscribers' profiles and in-range location information; the Advanced Service Control Point (ASCP) and the Service Management System (SMS), which are nodes for controlling advanced IN services; and the Message Processing System (MPS), which is a short message center. Further information on these devices will be explained in Chapter 4.

3.2 Control Procedures

The basic process in IMT-2000 networks (location registration, call origination/termination) and process associated with typical optional services (IN service process, short message origination/termination process) are as follows.

(1) Location Registration Process (**Figure 3**)

Unlike the PDC networks, IMT-2000 networks adopt the



ASCP: Advanced Service Control Point
ATM: Asynchronous Transfer Mode
BTS: Base Transceiver Station
GMMS: Gateway Mobile Multimedia switching System
GRIMM: Gateway service Representative Internet Market Mobile access exchange
HLR: Home Location Register
LMMS: Local Mobile Multimedia switching System
MIS: Mobile Information Storages System
mopera: Mobile OPEration Radio Assistant
MPS: Message Processing System
NMSCP: New Mobile Service Control Point
PLMN: Public Land Mobile Network
PSTN: Public Switched Telephone Network
RNC: Radio Network Controller
SCE: Service Creation Environment
SMS: Service Management System
TMMS: Toll Mobile Multimedia switching System

Figure 2 NTT DoCoMo's IMT-2000 Core Network

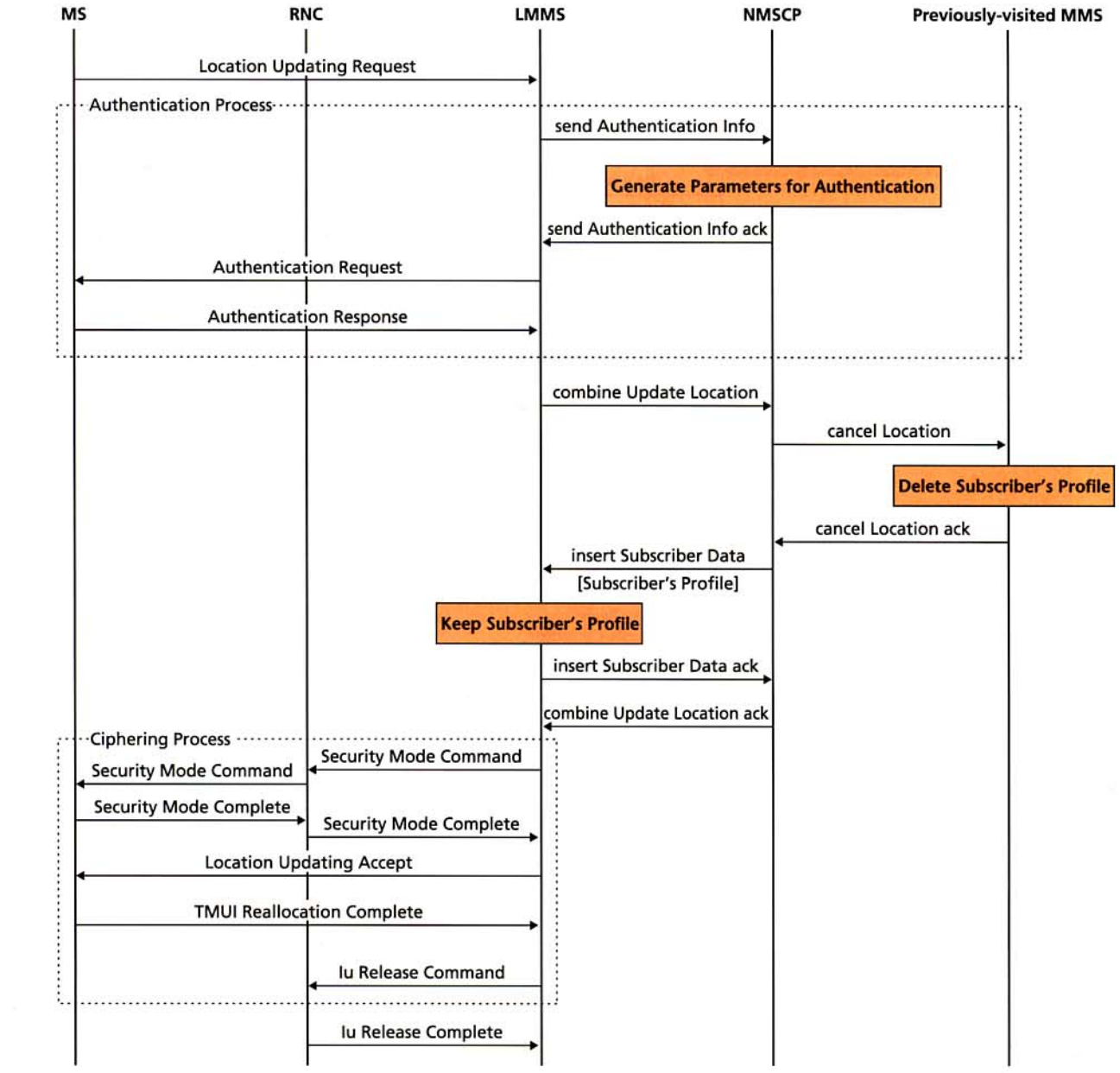
Visitor Location Register (VLR) system, which downloads the subscriber's profile from NMSCP to the Mobile Multimedia switching System (MMS) at the time of processing location registration, and uses subscriber's profile over VLR at the time of origination/termination processing.

NTT DoCoMo's networks manage to carry out the circuit switching process and the packet switching process in the same switching system (MMS). Accordingly, the location registration process for circuit switching and packet switching are integrated, for the purpose of using network resources in an efficient manner.

(2) Call Origination/Termination Procedures in Circuit Switching

Figure 4 shows the call origination process in circuit switching. As the call origination process involves the use of the subscriber's profile over VLR to execute the originated call translation process, the process is carried out exclusively inside MMS.

Figure 5 shows the call termination process in circuit switching. NTT DoCoMo's networks apply the Pre-Paging process to the Paging process in association with the call termi-



LMMS: Local Mobile Multimedia switching System
MS: Mobile Station
NMSCP: New Mobile Service Control Point
RNC: Radio Network Controller
TMUI: Temporary Mobile User Identity

Figure 3 Location Registration Sequence

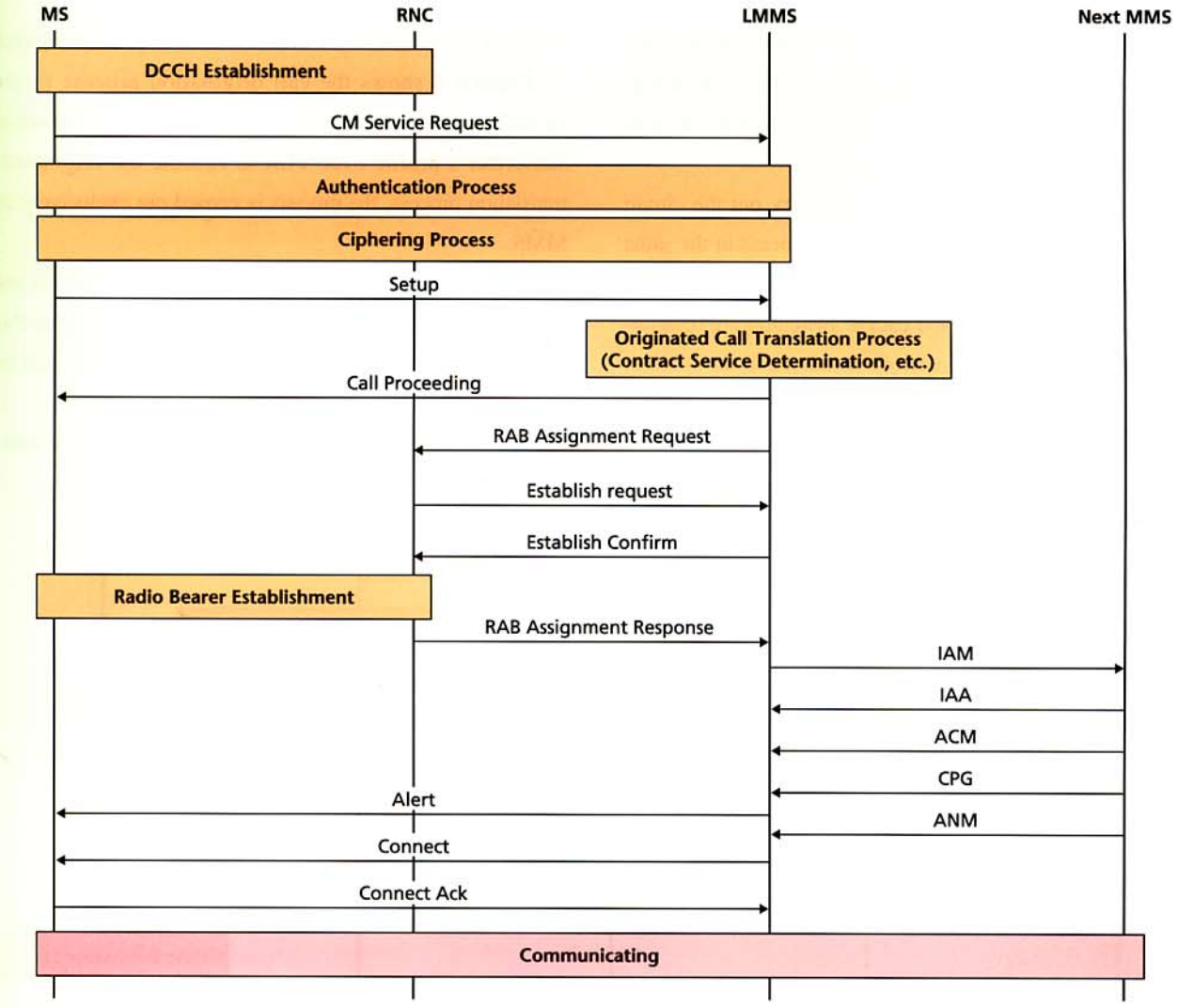


Figure 4 CS Call-Origination Sequence (Mobile Phone →Other Network)

nation process. Pre-Paging process executes the Paging process before establishing the circuit up to the switching system in the receiver's range, so that the receiver determines whether it is in or out of range. When it is out of range, the out-of-range process can be carried out without tracing the circuit up to the in-range switching system.

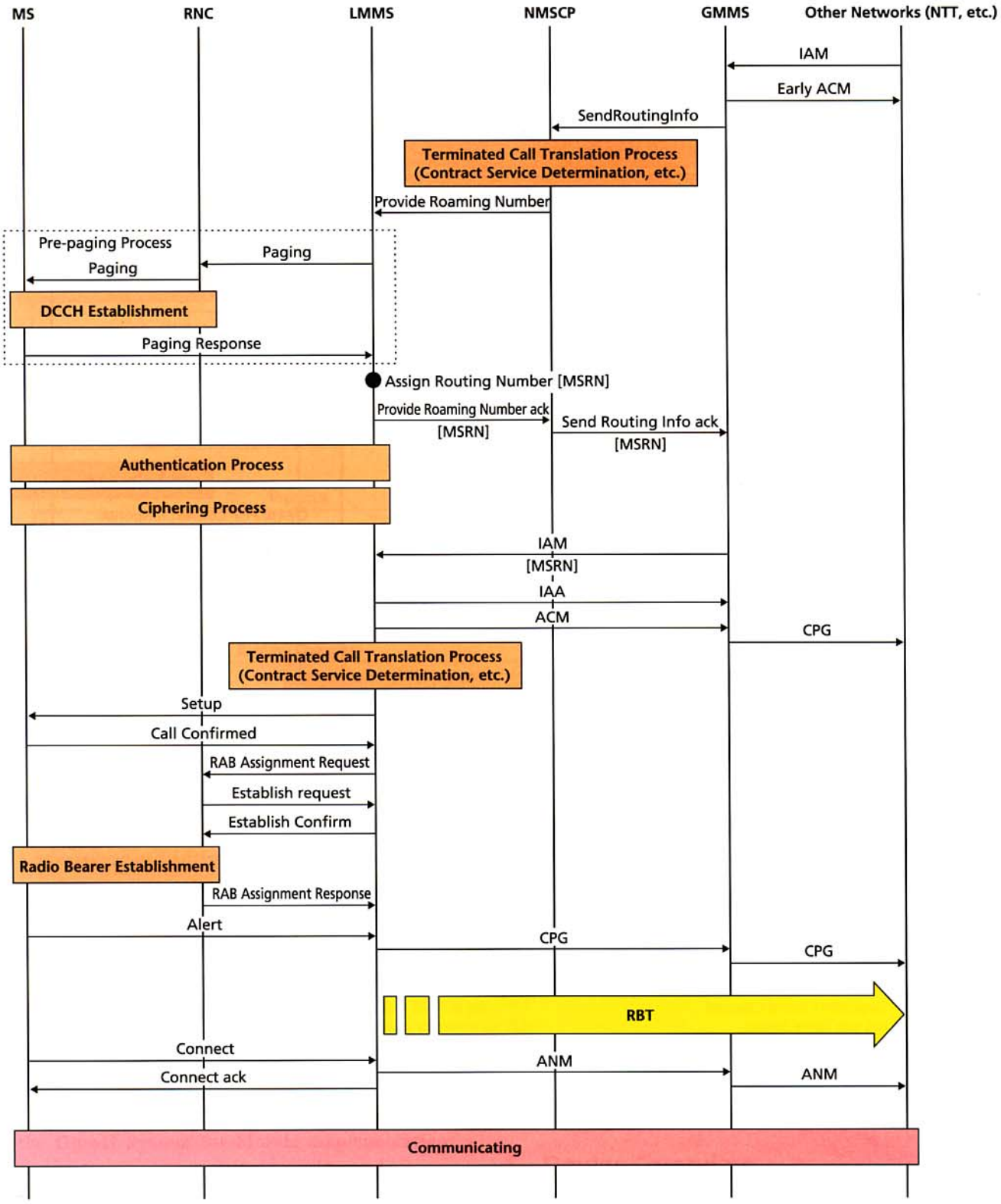
In an IMT-2000 network, the Mobile Station Roaming Number (MSRN) is assigned to the switching station in the receiver's range. MSRN makes it possible for the station to route calls in the receiver's range and identify the receiver at such station.

(3) Packet Switching Process

Figure 6 shows the call origination process in packet switching. When the Mobile Station (MS) originates a call in packet switching, the Access Point Name (APN) is set as the destination of connection by MS. MMS carries out an address resolution process to specify the GMMS requiring connection in association with the received APN. With the aim to achieve a wide range of QoS in packet communications, ATM-SVC is set for each call to forward user packets as in the case of circuit switching.

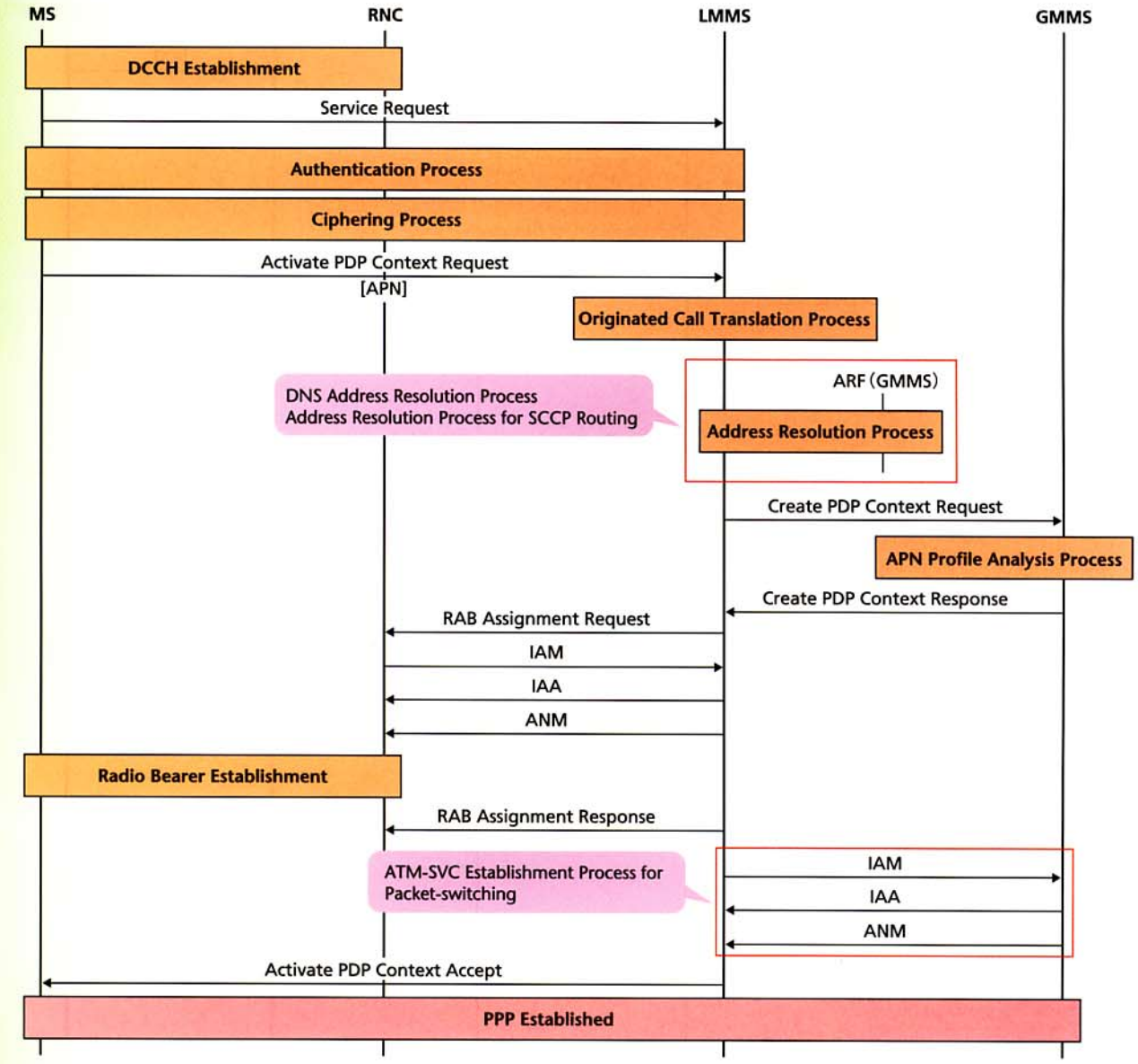
(4) IN Service Control Procedures

Figure 7 shows an example of IN service control procedures upon call origination. The information used by MMS for determining whether to execute IN (CAMEL (Customized Application for Mobile network Enhanced Logic)) service is



ACM: Address Complete Message
ANM: ANswer Message
CPG: Call ProGress
DCCH: Dedicated Control CHannel
GMMS: Gateway Mobile Multimedia switching System
IAA: IAM Acknowledgment message
IAM: Initial Address Message
LMMS: Local Mobile Multimedia switching System
MS: Mobile Station
MSRN: Mobile Station Roaming Number
NMSCP: New Mobile Service Control Point
RAB: Radio Access Bearer
RBT: Ring Back Tone
RNC: Radio Network Controller

Figure 5 CS Call-Termination Sequence (Other Network →Mobile Phone)



ANM: ANswer Message
APN: Access Point Name
ARF: Access link Relay Function
ATM-SVC: ATM-Switched Virtual Channel
DCCH: Dedicated Control CHannel
DNS: Domain Name System
GMMS: Gateway Mobile Multimedia switching System
IAA: IAM Acknowlegment message
IAM: Initial Address Message
LMMS: Local Mobile Multimedia switching System
MS: Mobile Station
PDP: Packet Data Protocol
PPP: Point to Point Protocol
RAB: Radio Access Bearer
RNC: Radio Network Controller
SCCP: Signalling Connection Control Part

Figure 6 PS Call-Origination Sequence (PPP Connection)

CAMEL Subscription Information (CSI). CSI may depend on subscription conditions (Dialed Service CSI (D-CSI) and Terminating CSI (T-CSI)) or on network conditions (Network service CSI (N-CSI)). CSI based on subscription conditions refers to the CSI assigned when a user subscribes to the service, whereas CSI based on network conditions is applicable to services that may be received when the user is in the range of the network. The former is used for controlling the voice mail service and other optional subscriber services. CSI used for determining the service status upon call origination (D-CSI) is kept at MMS as the subscriber's profile. The latter is applied to quick dialing service, etc., which is set as MMS station data.

(5) Short Message Transmission/Reception Procedures

Figures 8 and **9** shows the short-message origination process and the short-message termination process, respectively. The Mobile Application Part (MAP) is the method of for-

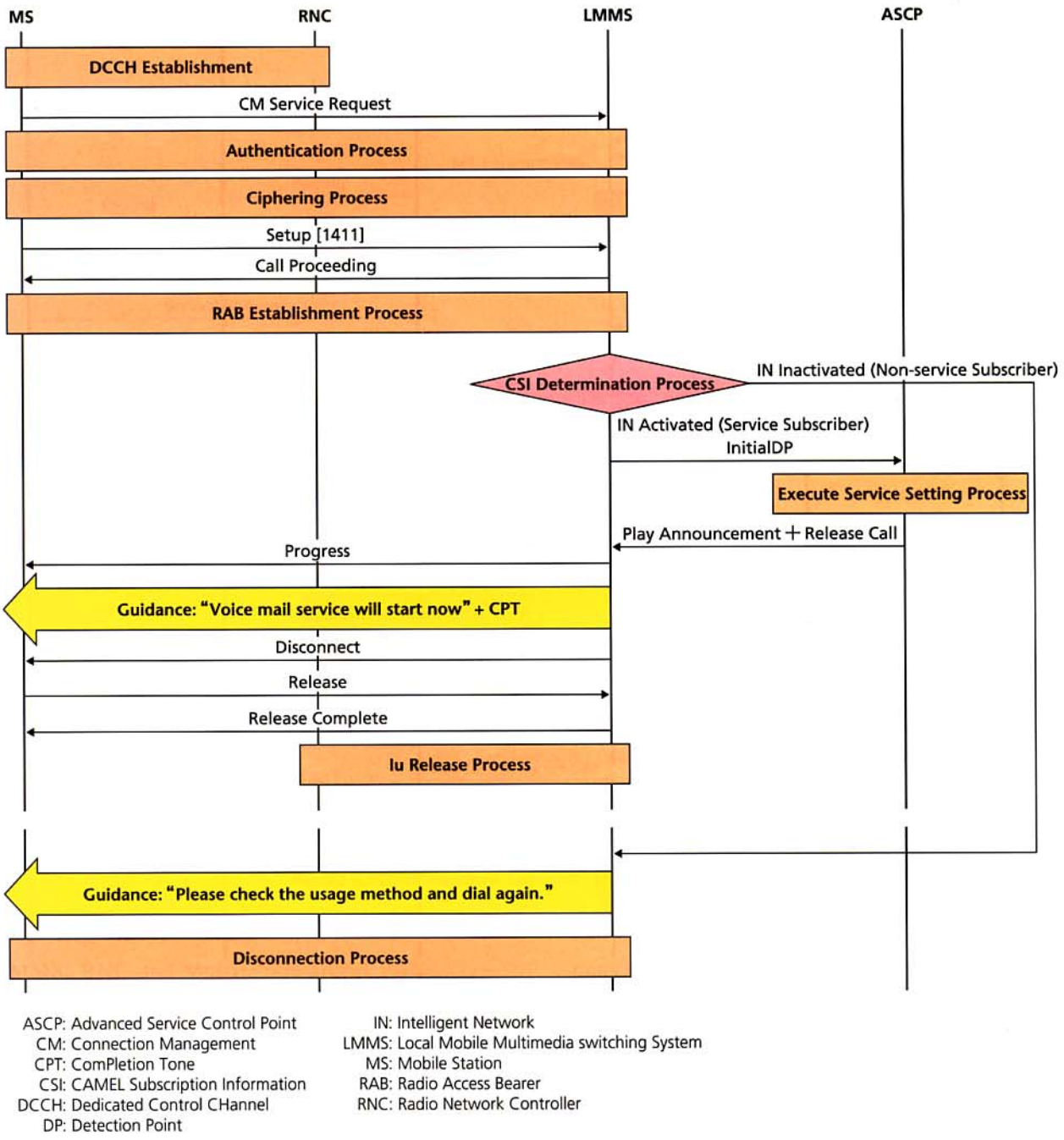


Figure 7 IN Call-Origination Service Sequence (e.g. Setting for launching voice mail service: 1411)

warding short messages between stations (switching systems) under the Global System for Mobile communications (GSM)/3GPP standard. Rather than forwarding short-message MAP via a common channel signaling network, NTT DoCoMo overlays and forwards such MAP over ATM lines from MMS to MMS, in consideration of the processing load incurred by the common channel signaling network. Further, the receiver determination process is executed between NMSCP and TMMS to make sure that users do not receive short messages addressed to PDC users, as the control procedures are different from PDC short mail.

4. Device Overview

The hardware configuration, software configuration, functions and characteristics of devices constituting CN under IMT-2000 are as follows.

4.1 MMS

MMS is a switching system in charge of basic call control, which forms the core of CN under IMT-2000. MMS has a large

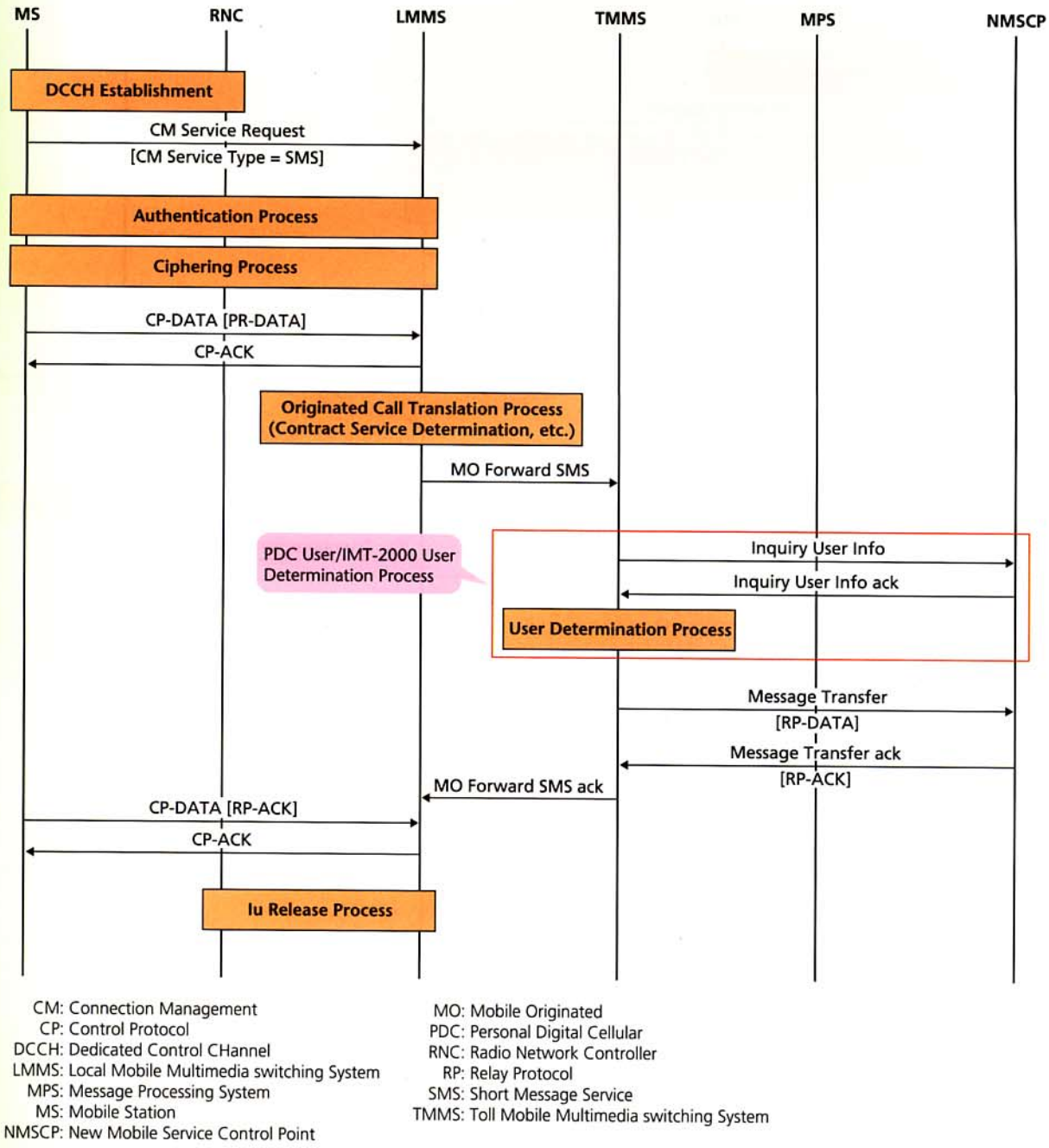


Figure 8 Short Message Origination (CS) Sequence

capacity to perform multimedia switching in a highly efficient, economic manner by adopting ATM technology.

The hardware and software configurations of MMS are as follows.

(1) Hardware Configuration

Figure 10 shows the logical hardware configuration of MMS (Local Switch (LS) and Gateway Switch (GS)).

① CS/PS-shared Parts

- Processors consist of loosely-coupled, functionally-dispersed processors (Operation and Maintenance Processor (OMP), Resource Management Processor (RMP), CaLl control Processor (CLP) and Common channel Signaling Processor (CSP)) and load-dispersed processors. Multiprocessor configuration is designed to flexibly deal with various service ratios and scales. Also, processors have been accelerated with ATM technology in order to cope with larger capacity. The Processor HUB (PHUB) can accommodate dozens of processors.
- The SIGnaling trunk (SIG) which terminates the common channel signaling link includes those designed for the exist-

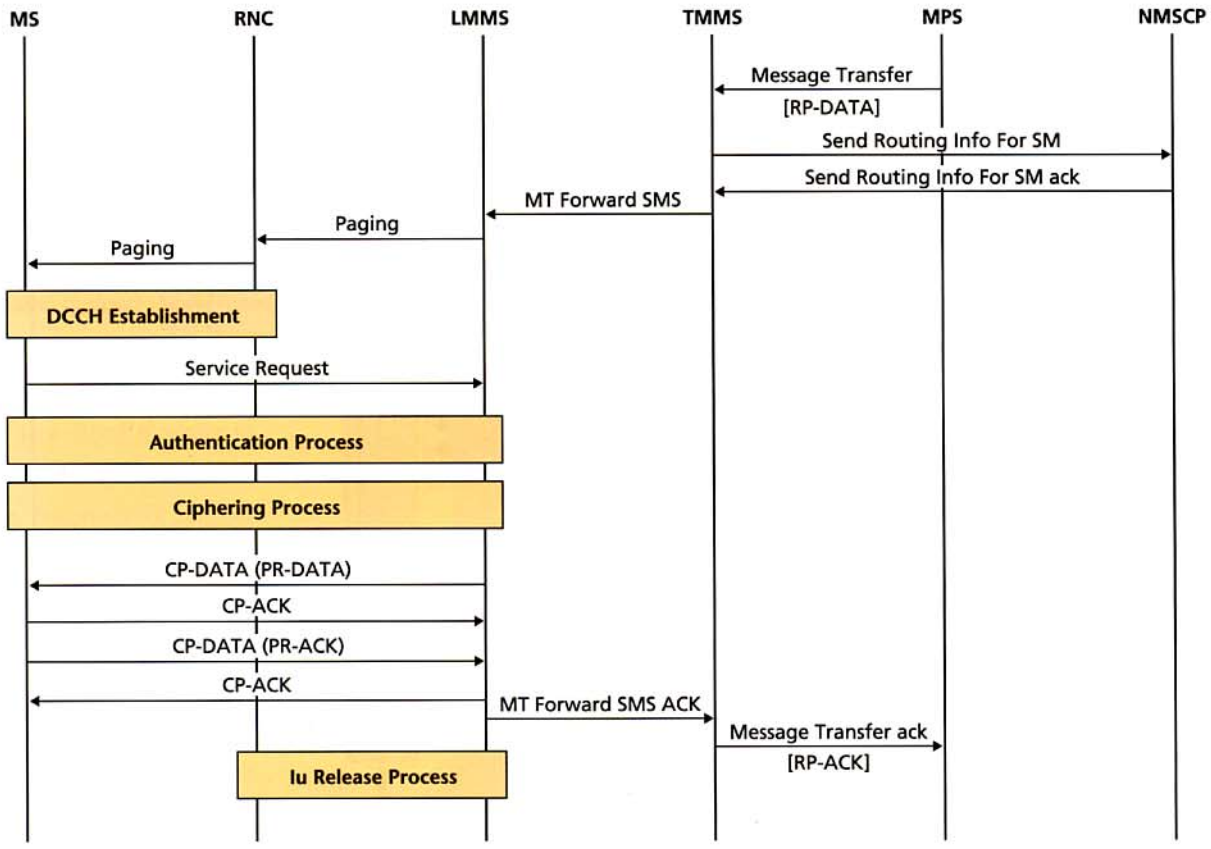


Figure 9 Short Message Termination (CS) Sequence

ing Signaling Transfer Point (STP), in addition to those for MMS, RNC and Multimedia signal Processing Equipment (MPE). Each SIG is able to transmit signals at up to 1.5Mbit/s, and achieves even greater transmission efficiency based on ATM technology, aimed at coping with increased traffic volume associated with additions to services in the future.

- Call channel devices center around a large ATM SWitch (ATM-SW), and are configured in such a manner that CS-specific parts and PS-specific parts can be installed or removed as required depending on variations in the traffic ratio of CS calls and PS calls. CMPosit trunk (CMP) is used to efficiently transmit and switch compressed speech (Adaptive Multi Rate (AMR)), etc. and has transmission and reception control functions at the ATM cell level to offer QoS, in addition to the ATM-InterFace (ATM-IF).

② CS-specific Parts

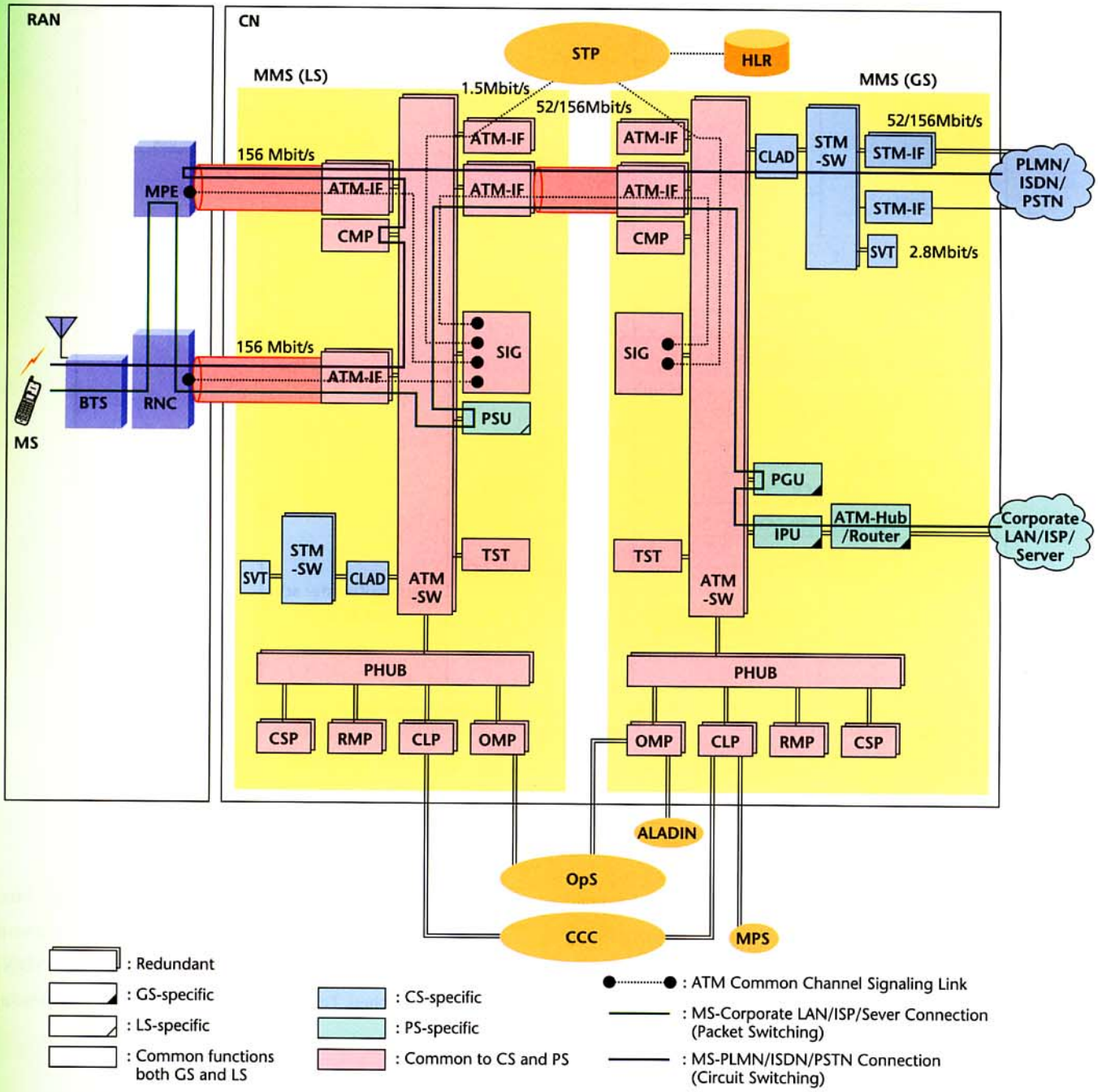
- The ATM/STM (Synchronous Transfer Mode) conversion function (CeLl Assembly/Disassembly (CLAD)) has functions to inter-work with Public Land Mobile Network (PLMN), Integrated Services Digital Network (ISDN), Public Switched Telephone Network (PSTN) and existing STM-based SerVice Trunk (SVT).

③ PS-specific Parts

- Between RNC and LS, and between LS and GS, a tunneling protocol called GTP is applied to enable IP packet forwarding. The Packet Subscriber Unit (PSU) and the Packet Gateway Unit (PGU) of LS and GS have the function to forward user IP packets, as well as a counting function for billing and traffic gathering. The IP mux Unit (IPU) of GS has the function to transfer user IP packets to an ATM-SVC link in CN.

(2) Software Configuration

Software characteristics of MMS include the integrated circuit-switching/packet-switching process, the multi-vendor support function, and the VLR function.



ALADIN: ALI Around Docomo INformation systems
ATM : Asynchronous Transfer Mode
ATM-IF: ATM-InterFace
ATM-SW: ATM-SWitch
BTS: Base Transceiver Station
CCC: Customer Call record Collector
CLAD: CeLl Assembly/Disassembly
CLP: CaLl control Processor
CMP: CMPosit trunk
CN: Core Network
CSP: Common channel Signaling Processor
GS: Gateway Switch
HLR: Home Location Register
IPU: IP mux Unit
ISDN: Integrated Services Digital Network
LAN: Local Area Network
LS: Local Switch
MMS: Mobile Multimedia switching System
MPE: Multimedia signaling Processing Equipment
MPS: Message Processing System
MS: Mobile Station
OMP: Operation and Maintenance Processor
OpS: Operation System
PGU: Packet Gateway Unit
PHUB: Processor HUB
PLMN: Public Land Mobile Network
PSTN: Public Switched Telephone Network
PSU: Packet Subscriber Unit
RAN: Radio Access Network
RMP: Resource Management Processor
RNC: Radio Network Controller
SIG: SIGnaling trunk
STP: Signaling Transfer Point
SVT: SerVice Trunk
TST: TeSt Trunk

Figure 10 Logical Hardware Configuration of MMS (LS and GS)

① Integrated Circuit-switching/Packet-switching Process (**Figure 11**)

Common applications can broadly be divided into 4 functions: CS-specific function, PS-specific function, CS/PS-shared function, and operation and maintenance function. This configuration minimizes the software size and makes it easier to add functions.

② Multi-vendor Support Function

An APplication Interface (API) is defined in order to adopt a multi-vendor architecture. Functions for applications common to all vendors and applications unique to particular vendors are separated from each other. The Extended Operating System (EOS) is specified for each vendor machine in order to absorb the differences among vendors under the Operating System (OS).

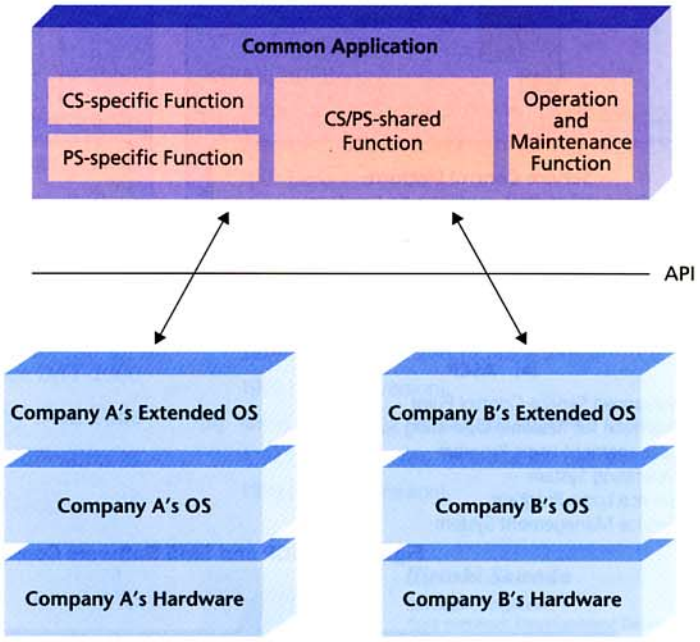
③ VLR Function

In order to achieve the VLR function, subscribers' profiles are dispersed and stored in different CLPs. Administrative information whether the CLP stores the subscriber's profile or not is kept in RMP. Which CLP would store the subscriber's profile is not decided statically by the subscriber's number, instead, the profiles are allocated evenly to CLPs. As call processing is executed by the CLP which is storing the subscriber's profile, no interprocessor communication with the RMP occurs except upon downloading the profile from the Home Location Register (HLR) or upon reading out the CLP which stores the profile.

4.2 NMSCP

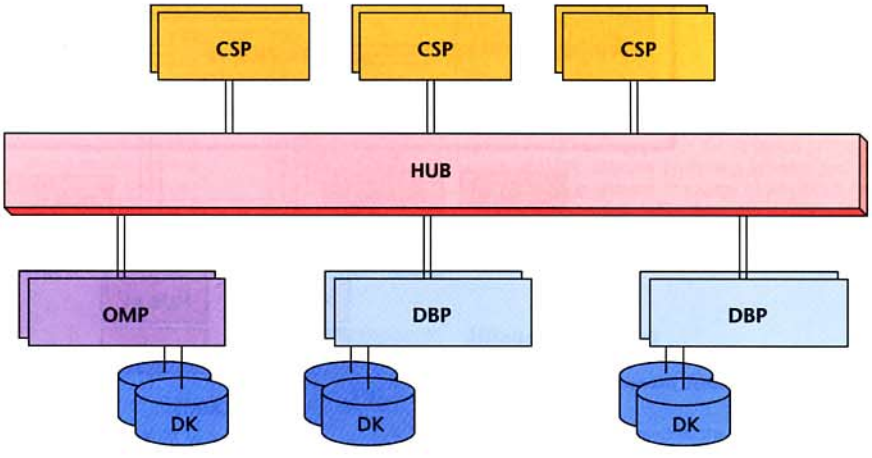
NMSCP is a node with the HLR function, which belongs to both the PDC network and the IMT-2000 network to enable numbers to be transferred from PDC to IMT-2000 without any change.

The device (**Figure 12**) consists of multiple Data Base Processors (DBP), multiple CSPs and one OMP. It stores the



API: APplication Interface
OS: Operating System

Figure 11 Concept of Software Configuration of MMS



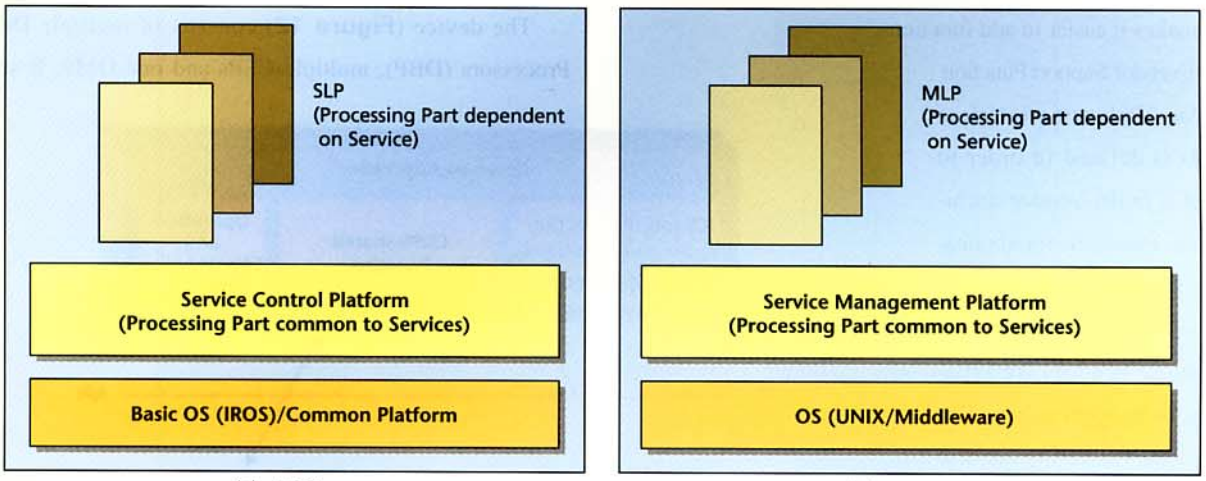
CSP: Common channel Signaling Processor
DBP: Data Base Processor
DK: DisK
OMP: Operation and Maintenance Processor

Figure 12 NMSCP Device Configuration

subscriber data in the DBPs to process calls and administer the database. DBP is fully in charge of call processing for PDC, PDC mobile Packet data communication system (PDC-P) and IMT-2000, and is able to carry out process according to the request from each network.

4.3 ASCP and SMS

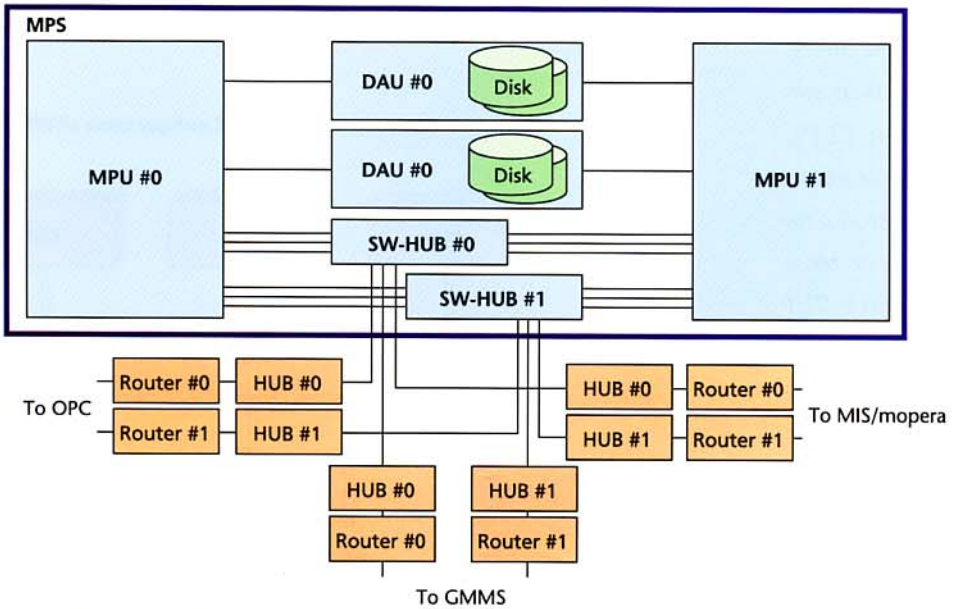
ASCP and SMS are nodes which constitute the advanced IN. ASCP has SCF, which is an optional IMT-2000 service. SMS has the Service Management Function (SMF), which includes the administration of contract information and the distribution of information required for service control to ASCP.



(a) ASCP (b) SMS

ASCP: Advanced Service Control Point
IROS: Interface for Realtime Operating Systems
MLP: Management Logic Program
OS: Operating System
SLP: Service Logic Program
SMS: Service Management System

Figure 13 ASCP and SMS Software Configuration



DAU: Disk Array Unit
GMMS: Gateway Mobile Multimedia switching System
MIS: Mobile Information Storages System
mopera: Mobile OPEration Radio Assistant
MPS: Message Processing System
MPU: Message Processing Unit
OPC: OPeration Center

Figure 14 MPS System Configuration

ASCP and SMS localize the impact of additions and modifications to services, etc. by dividing the software configuration into processing parts common to services (platform) and processing parts dependent on the service, which makes it possible to reduce the number of man-hours required for service development and promptly provide services (**Figure 13**). Service-dependent processing parts of ASCP and SMS are referred to as the Service Logic Program (SLP) and the Management Logic Program (MLP), respectively.

4.4 MPS

MPS is a system that serves as a service center for short message service. MPS has the function to receive short messages sent from mobile phones and other Short Message Entities (SME), and distribute the message to the specified destination SME. It also has the function to temporarily store messages that could not be distributed to retransmit them later.

Services available in association with the use of short messages include the forwarding of short messages from IMT-2000 mobile phones, the forwarding of short messages by Dual Tone Multi Frequency (DTMF) signal entry, and the notification of the number of messages in the voice mail service.

Figure 14 shows the system configuration of MPS.

5. Conclusion

This article reviewed the configuration of CN in NTT DoCoMo's IMT-2000 service launched ahead of the world, and overviewed the technologies for its implementation. As IMT-2000 is destined to penetrate the market worldwide, improvements in user convenience and technological progress in IMT-2000 are expected, including the implementation of global roaming and the rolling out of worldwide multimedia services.

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GLOSSARY

3GPP: 3rd Generation Partnership Project
AAL: ATM Adaptation Layer
ACM: Address Complete Message
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AMR: Adaptive Multi Rate
ANM: ANswer Message
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DK: DisK
DNS: Domain Name System
DP: Detection Point
DTMF: Dual Tone Multi Frequency
GMMS: Gateway Mobile Multimedia switching System
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GSM: Global System for Mobile communications
GTP: GPRS Tunneling Protocol
HLR: Home Location Register
IAA: IAM Acknowledgment message
IAM: Initial Address Message
IMT-2000: International Mobile Telecommunications-2000
IN: Intelligent Network
INAP: IN Application Protocol
IP: Internet Protocol
IPU: IP mux Unit
IROS: Interface for Realtime Operating Systems
ISDN: Integrated Services Digital Network
ITU-T: International Telecommunication Union-Telecommunication standardization sector
LAN: Local Area Network
LMMS: Local Mobile Multimedia switching System
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SMF: Service Management Function
SMS: Service Management System
SMS: Short Message Service
SSF: Service Switching Function
STM: Synchronous Transfer Mode
STP: Signaling Transfer Point
SVT: SerVice Trunk
T-CSI: Terminating CSI
TMMS: Toll Mobile Multimedia switching System
TMUI: Temporary Mobile User Identity
TST: TeSt Trunk
VLR: Visitor Location Register
VP: Virtual Path