FOMA Core Network xGSN Packet Processing Nodes

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We have developed a new type of packet processing nodes to strengthen the packet communication capacity of the DoCoMo network and at the same time achieving significant reductions of communication network construction costs. This article introduces the development background, and describes various new technologies, such as location registration and signal processing, as well as the connection configuration for each service node, which are made available by linking with an IP router network.

Development Reports

1. Introduction

In the core network of FOMA (Freedom Of Mobile multimedia Access), switching is handled by the Mobile Multimedia switching System (MMS), which can process voice and packet calls in an integrated manner, and traffic is transferred between them via Asynchronous Transfer Mode (ATM) networks. Considering the fact that flat rate services such as “Pake Hodai (send as many packets as you want)” are being introduced, the number of FOMA subscribers is expected to increase and the packet-based traffic, in particular, will grow significantly. For this reason, it is essential to reduce the costs for expanding packet-based networks, and it is important that the network must be more efficient and enhanced.

This article provides an overview of the serving/gateway General packet radio service Support Node (xGSN), which is a new type of node integrating the functions of the Serving General packet radio service Support Node (SGSN) and the Gateway General packet radio service Support Node (GGSN), developed to provide enhanced FOMA packet communication services.

2. Background

2.1 Background and Purposes of PS Separation

The unique technologies that have been successfully developed for DoCoMo's FOMA network so far include the capability to construct equipment efficiently due to integration of call processing of both Packet Switching (PS) calls and Circuit Switching (CS) calls, and its ATM networks which can provide Quality of Service (QoS) guarantees. To exploit these advantages further, DoCoMo developed a node type based on ATM-SWitching (ATM-SW), MMS, and expanded the ATM network equipments. The features of the MMS nodes are as follows.

- It can perform call processing of PS calls and CS calls in the same physical node.
- It can improve the circuit usage efficiency and thus reduce the communication costs by processing transmission and data reception of various call types, including voice, data and video, using the same circuit.
- In spite of being based on packet communication, it allows high-speed switching by dedicated hardware.

These features are particularly effective in reducing node and transmission costs, and have significantly contributed to reduction of equipment construction costs compared to equipment of the Personal Digital Cellular (PDC) system.

However, due to the expansion of packet traffic demands caused by the rapid increase of the number of FOMA subscribers in recent years, the volume of PS call traffic is expected to increase faster than CS calls. A dramatic shift in the demand pattern from voice services to packet data services can already be observed, the most typical example being the success of i-mode. Together with the global development of Internet Protocol (IP) technology, this shift has the potential of improving the equipment efficiency due to the availability of new design philosophies, compared to conventional node cost and transmission cost design methods.

In short, in existing DoCoMo ATM networks, the packet switching services were implemented based on the basic call processing technology for circuit switching services, and PS calls and CS calls were handled with the same ATM circuit setting method by carrying over the existing switching procedures. For this reason, if, for example, a PS call were to be connected to an Access Point Name (APN) accommodating carriers of other regions, there was no other choice but to choose a route via the Transit Mobile Multimedia switching System (TMMS) altogether (**Figure 1** (1)), causing the amount of equipment (nodes and transmission lines) that would have to be involved in the relay steps to increase compared to general IP routing. Moreover, this difference in the amount of equipment can be expected to increase proportionally to the number of PS calls. However, these issues can be solved by the following measures:

- Divide the existing CS/PS integrated network into a PS network and a CS network, thus allowing optimal network design according to the IP routing network configuration for the PS calls, thus suppressing the network equipment costs.
- The transmission channel costs can be suppressed by changing the transmission channels from existing ATM networks to IP router networks, which allows cutting general equipment construction costs.
- The same level of QoS as obtained by existing ATM networks can be guaranteed in IP router networks as well.

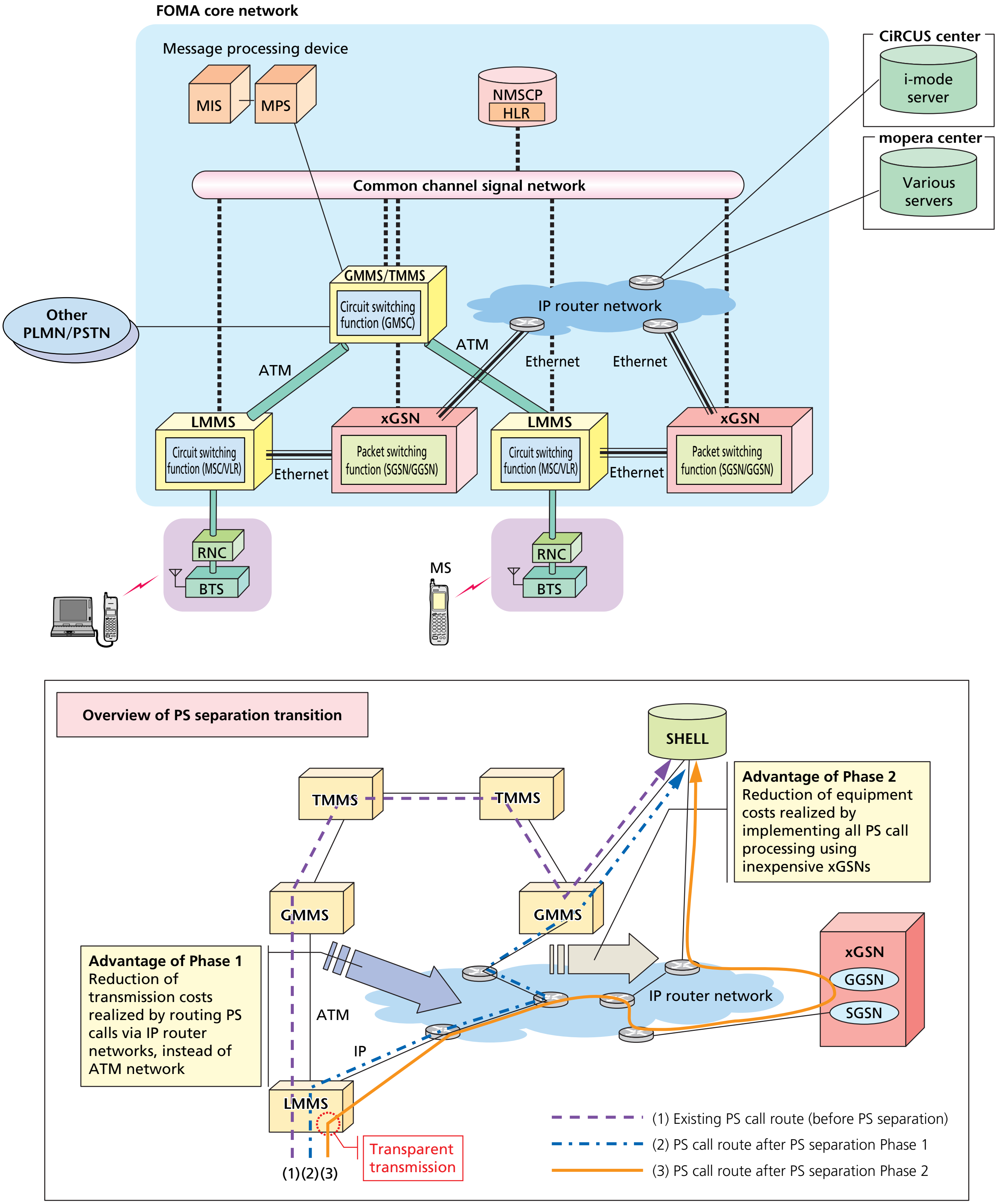
We thus attempted to separate the PS network from the CS/PS integrated network.

In the following, the outline of the transition to PS separation (implementation of xGSN) and the flow of PS calls during the transition are explained.

The transition to PS separation consists of two processes (Phase 1 and Phase 2). In Phase 1, the packet switching call from the Local Mobile Multimedia switching System (LMMS) to the Gateway Mobile Multimedia switching System (GMMS) is changed to take place via the IP router network. It is necessary to allow relocation control between the existing MMS nodes and the newly introduced xGSNs during the transition to the PS separation as well (Fig. 1 (2)). In Phase 2, all packet switching functions are separated from the MMS nodes and incorporated in the xGSNs, which means that the PS traffic is entirely separated (Fig. 1 (3)).

2.2 Advantages

While examining the implementation of the new node type, we aimed to improve the throughput capacity and reduce the equipment costs significantly compared to existing nodes. For this reason, we examined the advantages of using a newly established IP router network to achieve reduction of PS call transmission costs when separating the PS calls from the relay steps of the CS calls and perform IP routing via a separate network in



BTS: Base Transceiver Station
CiRCUS: treasure Casket of i-mode service, high Reliability platform for CUStomer
MIS: Mobile Information Storage system
mopera: Mobile OPEration Radio Assistant
MS: Mobile Station
PLMN: Public Land Mobile Network
PSTN: Public Switched Telephone Network

Figure 1 FOMA network configuration and overview of PS separation transition

order to connect to nodes belonging to SHELL[*1] systems, such as Wireless Protocol Conversion Gateway (WPCG) nodes. As a result, we decided to develop xGSN (SGSN/GGSN functions integration server) based on the following considerations.

- General-purpose server products and open source software can be adopted to achieve equipment cost reductions and throughput capacity improvements in a straightforward manner.
- It is possible to reduce the development costs and shorten the development time by implementing general-purpose software products, and tools and environments required for the development can easily be obtained.
- Since the server part is IP-based, it is straightforward to connect with IP router networks, and doing so does not require any special development compared to packet switching specialization of existing MMS nodes.
- IP systems are widely used in the market, which makes the acquisition of technologies and procurement of engineers easier.

Moreover, estimating the total costs for development, commercial equipment and maintenance involved in the xGSN implementation shows that it is possible to increase the equipment cost efficiency by approximately 20% compared to existing MMS nodes.

3. Evaluation of xGSN System Structure

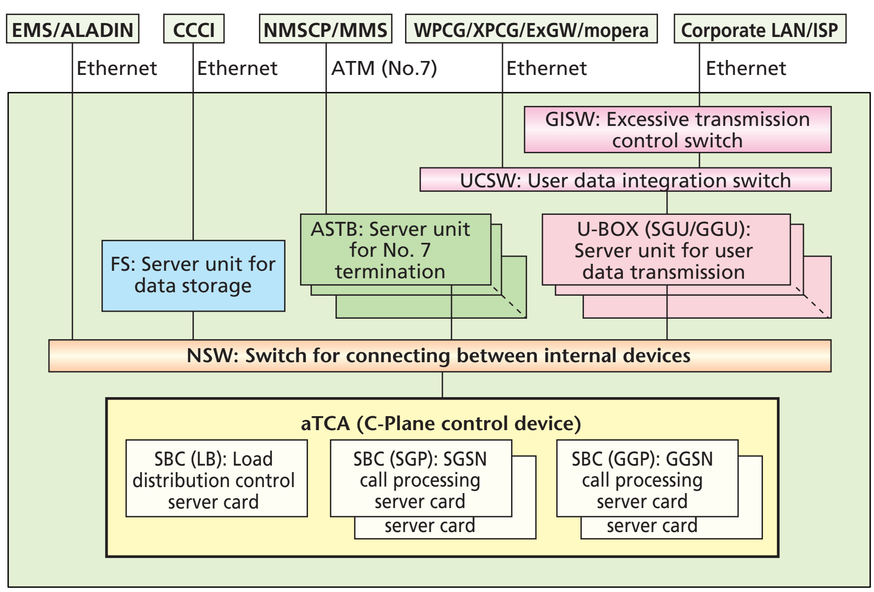
3.1 Hardware Configuration and Features

Figure 2 shows the hardware configuration of an xGSN.

The hardware structure is divided into a signal control part (Control-Plane (C-Plane)) and a user data processing part (User-Plane (U-Plane)). This allows for flexible equipment designs where the throughput and circuit capacity can be designed independently of one another, according to equipment requirements matching the station conditions (for example, areas with few base stations but large numbers of subscribers versus areas with many base stations but small numbers of subscribers etc.).

The basic structure of the hardware is configured with a group of servers and Layer2 SWitches (L2SWs) that connect between the servers. The C-Plane server group adopts a general-purpose blade server[*2] conforming to the advanced Telecom Computing Architecture (aTCA) standard. aTCA is an open

*1 SHELL: This refers to nodes outside the core network (i.e., outer SHELL).
*2 Blade server: A compact card-type server that can be installed on a special rack.



ALADIN: ALl Around DoCoMo INformation systems
ASTB: ATM Signaling Termination Box
CCCI: Calling rate Change Center-IMT
EMS: Element Management System
FS: File Server
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GISW: Gi Interface connect layer2 SWitch
ISP: Internet Service Provider
LB: Load Balancer
NSW: Node inside SWitch
SBC: Single Board Computer
SGP: SGSN C-Plane Processor
SGU: SGSN U-Plane box
U-BOX: U-Plane BOX
UCSW: U-Plane box Connect SWitch

Figure 2 Hardware structure

standard for industry devices and advanced next generation communication platforms standardized by the Peripheral component interconnect Industrial Computers Manufacturers Group (PICMG), an industry organization that manages engineering specifications. In the future, server devices conforming to this standard are expected to be used in a wide range of industrial products and, thus, the prices are considered to be kept low by the effects of mass-production. Moreover, as one of the advantages of conforming to open standards, it can be expected that various vendors will successively provide blade servers with built-in high-performance Central Processing Units (CPUs), which become faster and faster every year, on the market. It is thus possible to improve the throughput capacity of xGSN-based systems by upgrading to the blade servers that provide the most excellent performance and cost available at any given time. Another advantage of products conforming to open standards is that the lifetime of the system can be extended beyond the lifetime of a specific server, which depends on a specific vendor. Moreover, the specifications facilitate compact and highly integrated products, and can thus easily accommodate future C-Plane expansion requirements by allowing for reduced mounting space and power consumption. Commercially available servers and switches are used in many of the other functional parts as well; they can be expected to be able to satisfy various requirements such as improvement of individual hardware functions as components, in a flexible manner.

The U-Plane servers are implemented using devices designed specifically for xGSN, but the price is suppressed by using commercially available products for the motherboards.

This hardware structure, consisting of a small number of compact and simple components, not only shortens the time required for installation work and incidental tests dramatically, but it can also be performed by general server and router engineers, which provides various fringe benefits together with the ease of securing sufficient installation space.

3.2 Software Configuration and Features

Figure 3 shows the software structure of an xGSN, which consists of an Operating System (OS), middleware (extended OS) and applications.

CG-Linux (Carrier Grade Linux) is adopted for the OS. CG-Linux is a Linux version that has been proven to provide as high performance and reliability as conventional switching equipment used for telecommunication carriers by the Open Source Development Lab (OSDL), an industry organization in which several well known manufacturers participate. It is open source software, which means that not only can the implementation costs be reduced, but it also allows breaking away from the vendor lock-in inherent in systems adopting conventional vendor-dependent platforms. Use of CG-Linux makes it possible to achieve the high reliability required by telecommunication carriers as well as to reduce development costs and shorten development time by adopting a general-purpose product. The middleware (extended OS) is in charge of device control tasks, such as file update and fault handling, system configuration control and general-purpose database processing, and achieves high

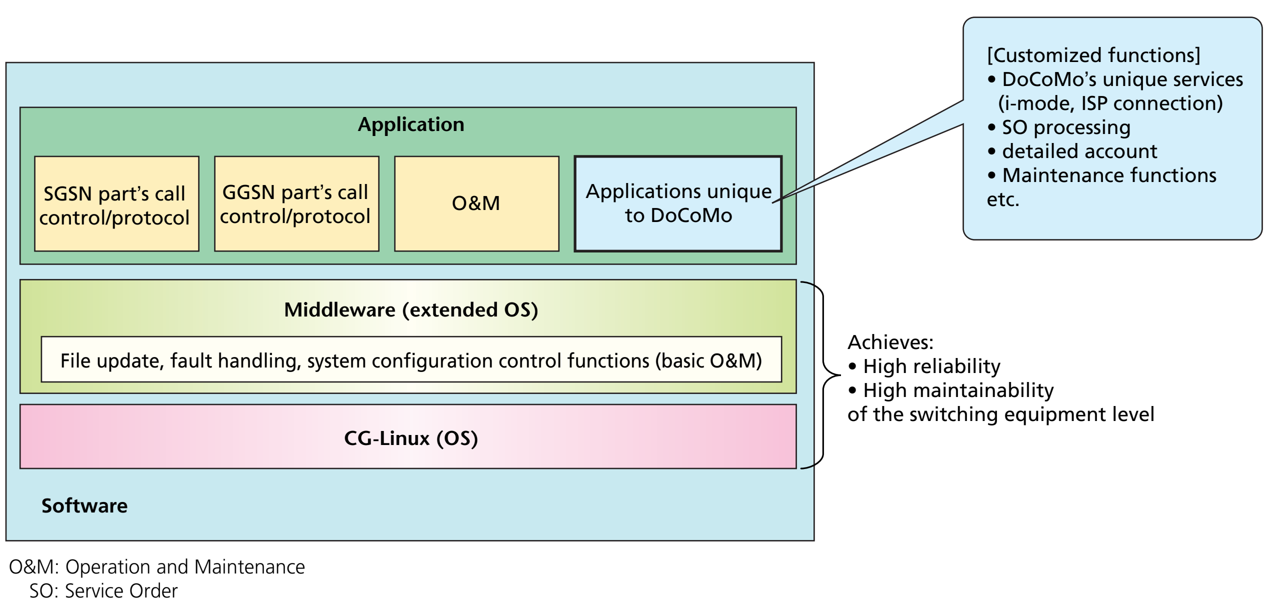


Figure 3 Software structure

reliability and high maintainability together with CG-Linux. Finally, the applications (general-purpose function part) implement all service functions required to conform to the general-purpose SGSN/GGSN standard.

DoCoMo's own service functions are entirely managed by the uniquely customized applications. It is these customized applications that implement the NetWork Management Protocol (NWMP), which is one of DoCoMo's unique protocols, DoCoMo's unique services such as combined network location registration, which is described later, i-mode and dual-network services, and various maintenance functions.

4. Designs and Highlights in xGSN Development

The requirements to the development of xGSN included inheritance of existing MMS functions, along with proper function distribution by separation of physical nodes and the definition of a new interface utilizing IP. So, we made various designs in addition to simple function distribution and implementation of IP for the interface. This chapter explains some of these designs, focusing on a few representative examples.

4.1 Improvement of Location Registration Method

In order for xGSN to inherit the PS functions of the existing MMS nodes, a throughput capacity of 360,000 Busy Hour Call Attempts (BHCAs) or higher was required. In order to achieve this capacity, it was necessary to introduce a multi-processor configuration using high-performance CPUs as well as eliminating redundant parts of the software processing and lower the load to increase the throughput capacity. It was also necessary to minimize the impact on existing systems and observing the standards by the 3rd Generation Partnership Project (3GPP) when implementing xGSNs in the FOMA network; we therefore reviewed the location registration processing, which accounted for a significant part of the processing load in the existing mobile communication networks.

In the existing MMS nodes, which are equipped with both CS and PS functions, an combined network location registration method is adopted, taking the network resource utilization efficiency into consideration (**Figure 4** (1)). The combined network location registration method is most efficiently applied with a node configuration ratio between Mobile Switching Centers/Visitor Location Registers (MSCs/VLRs) and SGSNs of 1:1; this means that, in the existing MMS networks, the circuit switching location registration area (Location Area (LA)) and packet switching location registration area (Routing Area (RA)) have the same configuration.

Given the throughput capacity configuration ratio between xGSN and MMS nodes, a network configuration where several xGSNs are connected to one MMS is desirable after the PS separation. Moreover, in the location registration system of the 3GPP standard (Fig. 4 (2)), an increase of the number of signals and the volume of profile processing for Home Location Registers (HLRs) affects the processing load of HLRs more seriously than in the network combined location registration method; we thus realized that there was a risk that the equipment cost for the current large capacity mobile communication service control devices (New Mobile Service Control Point (NMSCP)) would increase. For this reason, we decided to implement a new location registration method.

The location registration method implemented in xGSNs (Fig. 4 (3)) is a combined network location registration method based on the 3GPP standard location registration method, and can be applied regardless of the physical node configuration while keeping the number of signals in the common channel signaling network low.

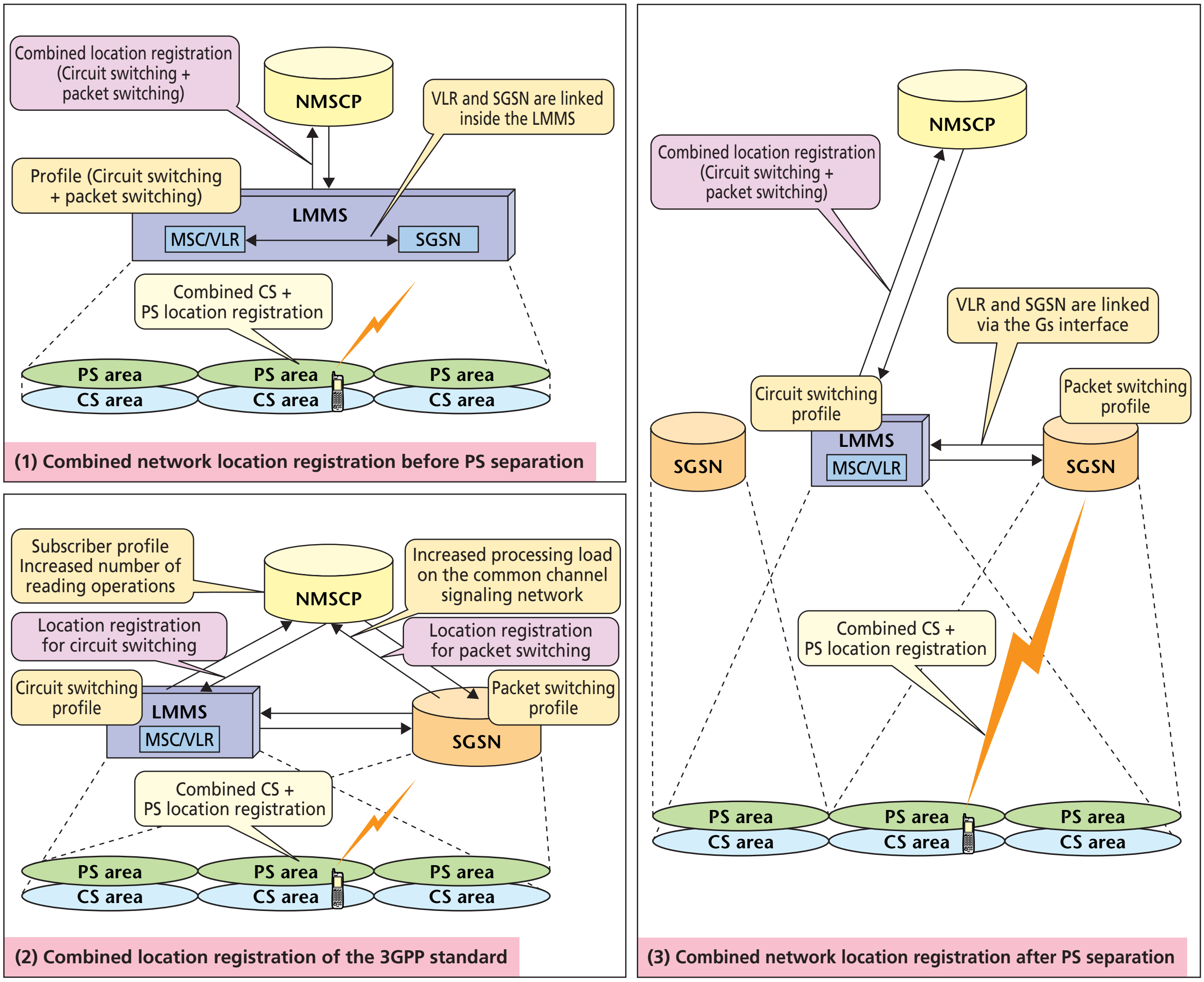
Moreover, an internal interface was used to link between the MSC/VLR and SGSN parts of the existing MMS nodes, but in the new design it became necessary to define a new Gs interface since a separate node is used to provide the SGSN functionality. The Base Station System Application Part+ (BSSAP+) protocol of the 3GPP standard is used for the Gs interface in order to link between the MSC/VLR and SGSN in a smooth manner.

4.2 Review of Signal Procedure for Basic Calls

We reused the existing functions as many as possible in xGSN designs to shorten the development and reduce the costs, but various basic call processing procedures needed to be reviewed due to changes in the network configuration. During the review, we aimed at achieving an efficient system with shortened processing time and low load, while minimizing the impact on the existing network configuration. The main signal procedures reviewed this time are as follows.

1) Packet Switched Call Origination/Termination

For the Iu connection between a Radio Network Controller (RNC) and an SGSN, a method to connect through multiple IP-based Asynchronous Transfer Mode-Switched Virtual Channels (ATM-SVCs) via an LMMS is adopted. This was determined



Note: The configuration ratios between PS and CS areas are given as examples.

Figure 4 Conceptual diagrams of location registration processing

by taking the influence on the throughput of existing systems, the total development scale including other nodes and reduction of capital investment costs by utilizing existing equipment into account. By implementing the Iu packet routing function in the LMMS, ATM-SVC-based connection control between the RNC and LMMS and IP address-based routing between the LMMS and xGSN can be achieved. This was obtained as a result of carrying over the current equipment; IP is expected to be adopted for the Iu interface in the future.

2) Circuit Switched Call Termination

At circuit switched termination, paging is performed from SGSN by using Gs interface according to the 3GPP standard operation, if combined location registration is implemented by the relevant subscriber and the collaboration between MSC/VLR-SGSN is being carried out.

The SGSN, upon receiving a termination request from the LMMS, checks the status of the packet switched communication when the SGSN performs paging to the radio side. If the subscriber is communicating, the SGSN terminates only to a unique RNC.

If the subscriber is not communicating, the SGSN performs paging to all the RNCs included in LA that is set by termination request received from LMMS.

3) Short Message Service Origination/Termination

In the Short Message Service (SMS) based on the packet switched communication, the SGSN executes transfer to the mobile terminal as well as to the Message Processing System (MPS). The SMS is transferred using the ATM network as the Gs interface between the SGSN and LMMS and by superimposing it on the existing ATM route between the LMMS, GMMS and TMMS (Inter Working MSC (IWMSC) or Gateway Mobile Switching Center (GMSC)).

4.3 Operation and Maintenance

Although xGSN is a new device, it reuses the maintenance concepts and commands of the existing MMS as much as possible; special care was applied so that current maintenance person can accept it easily. In the development, we conducted a detailed comparison survey between the capabilities of the general-purpose functions of xGSN and DoCoMo's maintenance concepts and commands, identified parts to be developed anew and changed them carefully to lower the development costs. Moreover, we paid special attention to complementing the redundancy capacity of the base products to maintain the quality of the existing networks and nodes in the commercial DoCoMo networks.

4.4 Connection Configuration with Other Nodes

As discussed above, the newly developed nodes adopted IP routing for PS calls; it was necessary to actively change the method of connection with other nodes to a configuration that can utilize the IP router network efficiently.

When examining the connection specification, we focused on determining the optimal interface that can provide IP router network for each service, on the preconditions of carrying out the existing specifications and minimizing the impact on other nodes in the network.

It was also necessary to design a system that would allow changing to a new configuration while incorporating the actual equipment conditions, without any adverse impact on the customers. For example, xGSNs are not designed to be installed in the same buildings as the MMS nodes. It was thus essential to define connection specifications that allow shifting without changing the installation location with respect to the connection with the interface point device (child router), with the other node installed in the same building as the MMS.

First of all, one of the basic points to examine was to revise the ATM-based MMS connection specification to fit the Ethernet-based IP router network connection specification of xGSN. This could be achieved by changing only the low-layer interface specifications. Specifically, we changed the specification where an APN was assigned for each Permanent Virtual Channel (PVC) to the inter-Virtual Local Area Networks (VLANs) communication of Ethernet using IEEE802.1Q [2] of the standardized specification by the Institute of Electrical and Electronics Engineers (IEEE). **Figure 5** shows the connection configuration for each APN.

We also examined the following two points.

1) Connection Configuration of i-mode Calls

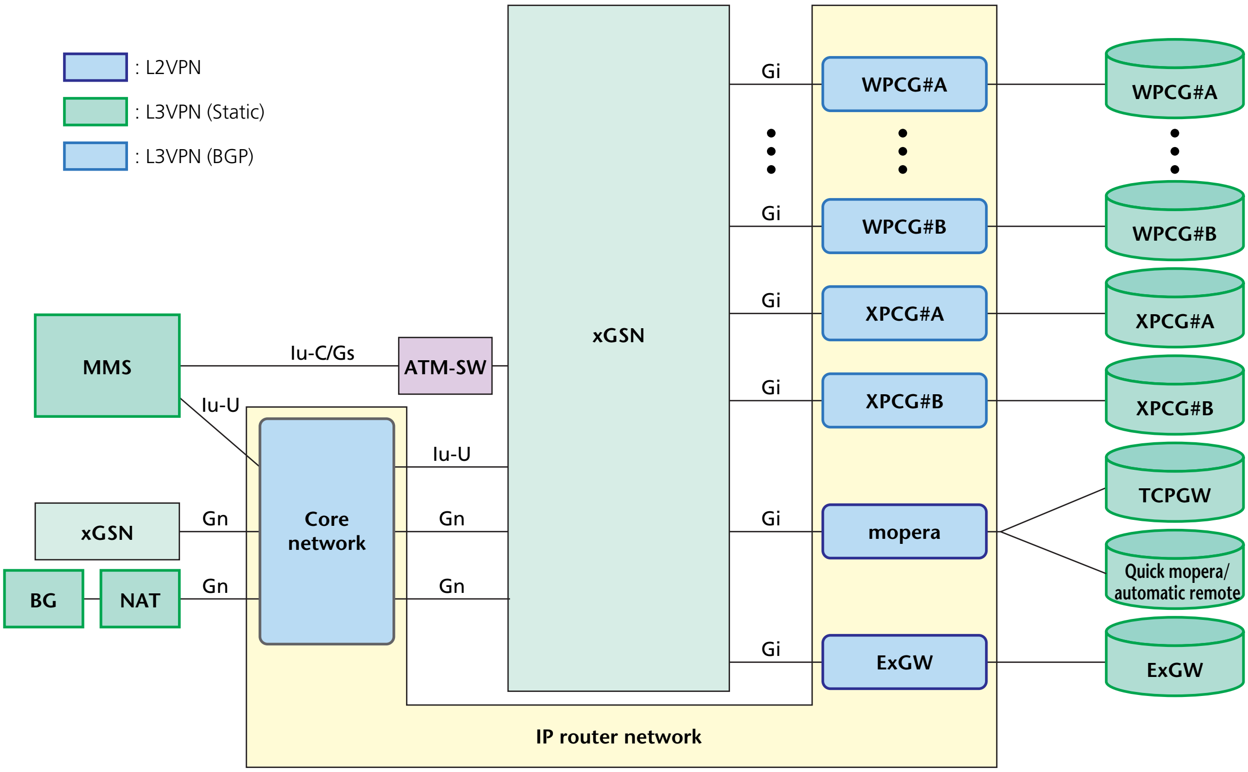
We examined the connection between xGSNs and WPCG/eXtended wireless Protocol Conversion Gateway (XPCG), aiming to change to an n:m connection configuration taking transmission channel costs and equipment costs into consideration. The connection conditions included that xGSN needed to communicate with multiple WPCGs and a WPCG needed to communicate with multiple xGSNs. For this reason, the Layer3 Virtual Private Network (L3VPN) connection configuration, which allows such communication configurations, was adopted. L3VPN allows routing within the VPN using IP addresses and is the communication method most suited to full-mesh connection configurations such as n:m. When configuring it within one VPN, however, overlapped IP addresses are not allowed under W/XPCG units due to the L3VPN operations; it was found that the configuration is difficult due to the IP address system assigned to mobile terminals. For this reason, we adopted an n:1 specification instead, where the L3VPN is set up in units of W/XPCGs, which may cause an increase in the number of VPNs, but without any adverse effects on the communication as each unit is connected to each xGSN, thereby solving the problem.

2) Connection Configuration for Non-i-mode Calls

For non-i-mode calls, it was not possible to adopt connection specifications using the L3VPN in the IP router network because it was necessary not to change the device settings of the existing other nodes and connection must be established using the existing address system. We solved this problem by adopting the L2-based VPN service, rather than the IP routing called the Layer2 Virtual Private Network (L2VPN). This method had the shortcoming that the equipment costs and the number of VPNs in the IP router network may increase, but this problem was avoided by overlapping VLANs according to the IEEE802.1Q standard within the L2VPN for child routers on the xGSN node side installed in the same building.

5. Conclusion

This article provided an overview of the background of xGSN implementation, which was developed in preparation for the coming DoCoMo networks to All-IP, as well as its system configuration, new technologies and network configuration. Regarding switching nodes using general-purpose servers conforming to open standards and using open-source software such



* Gi interfaces are distributed among xGSNs for each service (i-mode is deployed in all xGSNs.).

BG: Border Gateway
BGP: Border Gateway Protocol
ExGW: packet Exchange GateWay
IMT-2000: International Mobile Telecommunications-2000
NAT: the ip Network Address Translator
TCPGW: TCP GateWay

Iu: Interface between RNC and core network
Iu-C: Indicates the C-Plane part of Iu
Iu-U: Indicates the U-Plane part of Iu
Gs: Interface between MSC/VLR and SGSN
Gn: Interfaces used when two GSNs are positioned within the same PLMN; indicates interfaces between SGSN and GGSN, as well as SGSN and SGSN
Gi: Connection interface between IMT-2000 network and public or private packet network such as Internet or Intranet

Figure 5 Connection configuration for each APN

as aTCA and CG-Linux, in particular, we are the first telecommunication carrier in the world to make efforts toward the development of xGSN. We intend to improve the xGSN software and hardware that will serve as the foundation for a single common platform that can be applied to new nodes introduced in the future IP adaptation in the DoCoMo networks.

References

[1] Yatsu, Shibahara, Yokoyama, and Morikawa: "Generalization of Load Reduction Method in Location Registration Process," Institute of Electronics, Information and Communication Engineers (IEICE), Proceedings of 2004 General Meeting.

[2] http://standards.ieee.org/reading/ieee/std/lanman

Abbreviations

3GPP: 3rd Generation Partnership Project
ALADIN: ALl Around DoCoMo INformation systems
APN: Access Point Name
ASTB: ATM Signaling Termination Box
aTCA: advanced Telecom Computing Architecture
ATM: Asynchronous Transfer Mode
ATM-SVC: Asynchronous Transfer Mode-Switched Virtual Channel
ATM-SW: ATM-SWitch
BG: Border Gateway
BGP: Border Gateway Protocol
BHCA: Busy Hour Call Attempt
BSSAP+: Base Station System Application Part+
BTS: Base Transceiver Station
C-Plane: Control-Plane
CCCI: Calling rate Change Center-IMT
CG-Linux: Carrier Grade Linux
CiRCUS: treasure Casket of i-mode service, high Reliability platform for CUStomer
CPU: Central Processing Unit
CS: Circuit Switching
EMS: Element Management System
ExGW: packet Exchange GateWay
FOMA: Freedom Of Mobile multimedia Access
FS: File Server
GGP: GGSN C-Plane Processor
GGSN: Gateway General packet radio service Support Node
GGU: GGSN U-Plane box
GISW: Gi Interface connect layer2 SWitch
GMMS: Gateway Mobile Multimedia switching System
GMSC: Gateway Mobile Switching Center
HLR: Home Location Register
IEEE: Institute of Electrical and Electronics Engineers
IMT-2000: International Mobile Telecommunications-2000
IP: Internet Protocol
ISP: Internet Service Provider
IWMSC: Inter Working Mobile Switching Center
L2SW: Layer2 SWitch
L2VPN: Layer2 Virtual Private Network
L3VPN: Layer3 Virtual Private Network
LA: Location Area
LB: Load Balancer
LMMS: Local Mobile Multimedia switching System
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O&M: Operation and Maintenance
OS: Operating System
OSDL: Open Source Development Lab
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QoS: Quality of Service
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TMMS: Transit Mobile Multimedia switching System
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U-Plane: User-Plane
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