Development Reports

# Packet-Based International Roaming Communication by xGSN

*Yuuichi Suwa, Tokiharu Moriyama,*
*Karin Sugiyama and Tomoki Shibahara*

*This article describes a method for implementing packet-based international roaming communication services focusing on the xGSN packet processing node, which constitutes the backbone of DoCoMo's new packet network linked to IP-based networks.*

## 1. Introduction

The core network of Freedom Of Mobile multimedia Access (FOMA) utilizes the serving/gateway GPRS Support Node (xGSN), which has been developed to execute packet switching processing via separate networks for circuit and packet switching calls in order to accommodate future increases in the demand for flexible packet-based communication service [1]. Thus far, packet-based international roaming communication services have been provided using the Mobile Multimedia switching System-ConVerter (MMS-CV); the essential requirements to such a system is that it can address the expected increase in the number of carriers joining the roaming services and the needs of customers in a rapid and flexible manner.

This article describes how to implement packet-based international roaming communication by utilizing the xGSN nodes of the core network; more specifically, it presents a comparison with the conventional connection method, new technologies related to the signal processing involved in roaming communication, a method of roaming connection with overseas carriers, and a method for switching from existing DoCoMo networks to the new packet-based communication.

## 2. Development Background of International Roaming Functions

### 2.1 Communication Method with Overseas Mobile Communication Carriers

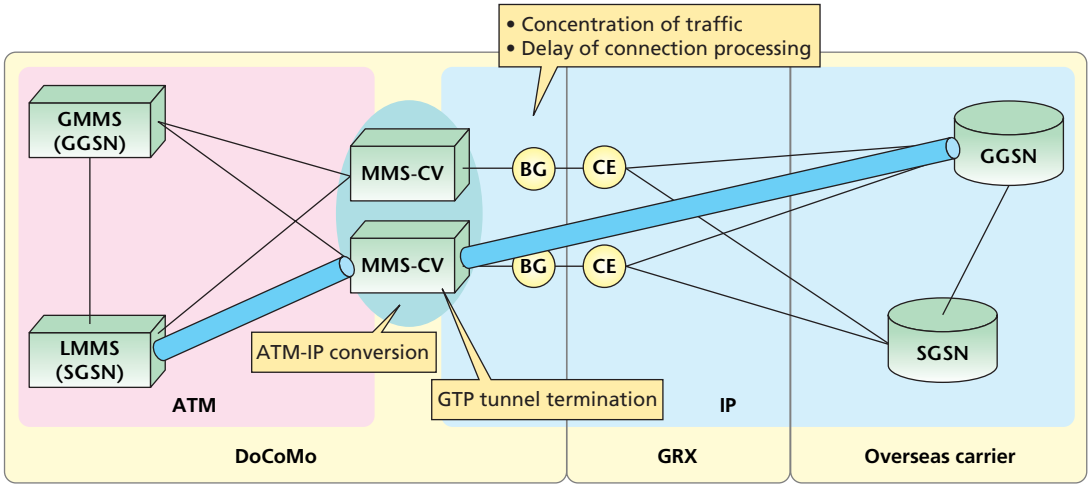
When the FOMA services were first started, the Asynchronous Transfer Mode-Switched Virtual Channel (ATM-SVC) method using the Mobile Multimedia switching System (MMS), which is an integrated switch capable of handling both circuit and packet communication, was adopted as the switch/transmission method of the core network. This method is characterized by high network efficiency due to the packet switched network superimposed on the circuit switching network, as well as high reliability of the Asynchronous Transfer Mode (ATM)-based transmission network (hereinafter referred to as ATM-based networks). Overseas mobile communication carriers (hereinafter referred to as overseas carriers) and General packet radio service Roaming eXchange (GRX) carriers, on the other hand, adopt Internet Protocol (IP)-based packet networks. In order to implement packet-based international roaming communications with overseas carriers, a device that is able to relay and connect to both DoCoMo's ATM-based networks and GRX carriers' IP-based networks was needed. MMS-CV was thus developed for this reason, and services have so far been provided via MMS-CV.

Using roaming-in as an example, packet-based roaming with overseas carriers can be described based on the outline shown in **Figure 1**. First, General packet radio service Tunneling Protocol (GTP) logical sessions (hereinafter referred to as GTP tunnels), i.e., GTP tunnels between an MMS-CV and a Serving General packet radio service Support Node (SGSN) and between the MMS-CV and a Gateway General packet radio service Support Node (GGSN) on the overseas carrier side via a GRX node, are established for the call units, and these are then connected. This connection form is called the 2-tunneling method (Fig. 1) [2]. The MMS-CV thus acts as a gateway that connects DoCoMo and overseas carriers, and all roaming calls are going back and forth between DoCoMo and overseas carriers' networks via MMS-CV nodes.

On the other hand, a form where DoCoMo's SGSN (or GGSN) and an overseas carrier's GGSN (or SGSN) are directly connected with a single GTP tunnel without relaying via an MMS-CV is shown in **Figure 2**, called the 1-tunneling method. DoCoMo has been promoting a shift to networks based on IP technologies that allow easy capacity increase, and the packet transmission is being transformed from ATM technology base to IP technology base. As a consequence of the shift to IP-based core networks, the relay of roaming packet connections via MMS-CV nodes described above will no longer be mandatory, so this motivated us to undertake a re-evaluation of the packet roaming connection forms as the packet functions implemented in the xGSNs are gradually becoming available for practical use.

### 2.2 Result of Comparison between Tunneling Methods

As discussed in Section 2.1, all packet-based roaming calls




CE: Customer Edge router
GMMS: Gateway Mobile Multimedia switching System
LMMS: Local Mobile Multimedia switching System

**Figure 1 Packet-based international roaming connection method of the GTP2 tunneling model**

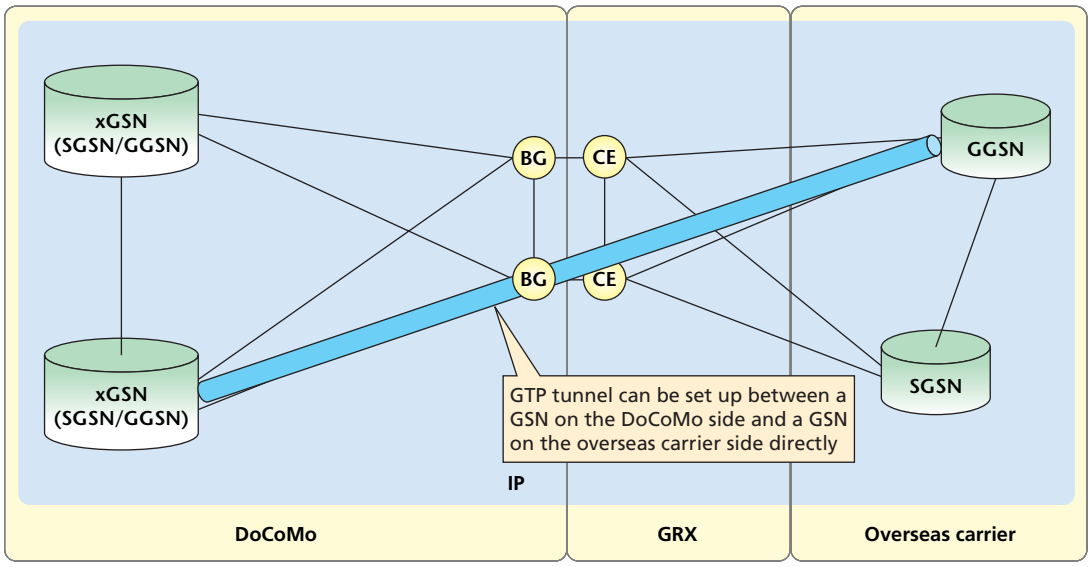



**Figure 2 Packet-based international roaming connection method of the GTP1 tunneling model**

are relayed by an MMS-CV node in case of the conventional 2-tunneling method. Roaming calls are terminated once at the MMS-CV node before being relayed/transmitted, allowing integration of billing functions for roaming calls, traffic information collection functions and other necessary functions in the MMS-CV nodes. This method implies that DoCoMo's SGSN and GGSN nodes that can be recognized and linked to by overseas carriers are limited to the MMS-CV nodes; thus such information as the connection configuration, changes to the Access Point Name (APN) assignment in the DoCoMo network is hidden to overseas carriers, which is an advantage in terms of security. On the other hand, all roaming traffic is concentrated at the MMS-CV nodes in the end, and it is thus difficult to address increases in the roaming call traffic in a flexible manner. Moreover, the connection form involving relaying via MMS-CV nodes is unique to DoCoMo, and function development related to such things as protocol conversion processing may be required in the future as well. This may represent a factor that inhibits smooth accommodation of new standards, improvement of economical efficiency and reductions in development periods, which are important issues in the development of packet-based roaming connection technologies.

The 1-tunneling method conforms to the standard inter-SGSN/GGSN communication method supported by the 3rd Generation Partnership Project (3GPP). In other words, this will eliminate the need to consider the unique connection form using the 2-tunneling method and allows distributing roaming traffic within DoCoMo networks in a flexible manner rather than concentrating the traffic at MMS-CV nodes, thus making it relatively easy to address increased traffic demands in the future. In the 1-tunneling method, the relay processing is omitted and the call setting and packet transmission processing are thus simplified; the connection time is shortened and the throughput is improved as a result. It needs to be noted that, since MMS-CV is an MMS-based device, if it remains as a packet processing device, it is still necessary to develop packet functions for MMS. This is not an effective method in terms of improvement of development efficiency and economical efficiency. In conclusion, the 1-tunneling method has the best future prospects overall and is more advantageous.

## 3. Considerations in Development of the 1-tunneling Method

### 3.1 System Configuration and Mandatory Conversion Function

Packet-based international roaming communication is a mechanism that allows connecting DoCoMo networks with overseas carriers via GRX networks. A system configuration is adopted, where a DoCoMo network node and GRX networks are connected via a general-purpose Border Gateway (BG) node (**Figure 3**). The GRX network assumes that the destination IP address is specified using a global IP address, in the same way as for Internet communication. For this reason, it is necessary to perform the IP address conversion outlined below in DoCoMo's xGSNs to assign private IP addresses when executing the packet-based international roaming communication.

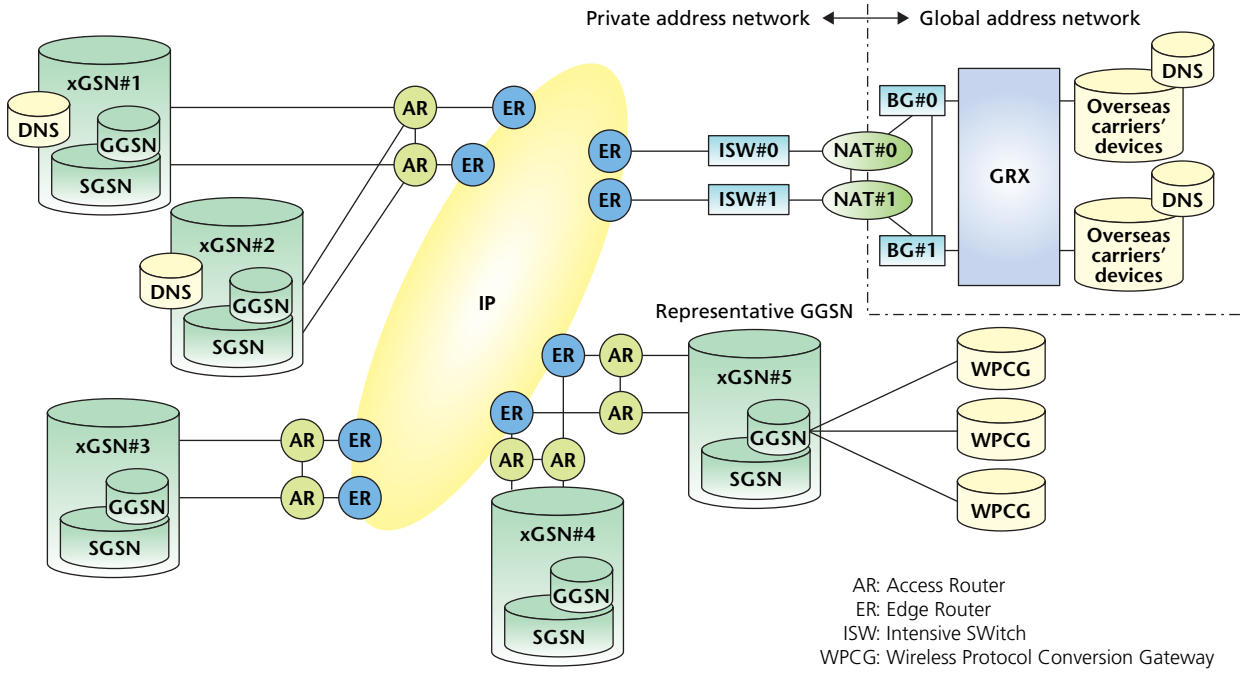



**Figure 3 Packet-based international roaming connection configuration**

1) When sending a packet to a node of an overseas carrier, the private IP address of the sender is converted to a global IP address before sending it to a GRX node.
2) When receiving a packet from a node of an overseas carrier, the global IP address of the sender is converted to a private IP address before the packet is sent to the DoCoMo network.

For the IP address conversion of the IP header, it was to use a general function, the Network Address Translation (NAT) function, but because the NAT function is not originally implemented in general-purpose BG nodes, and there is no prospect for it to be implemented in the future either, a dedicated NAT device was constructed. Note that this NAT device is set up in the nearest location of a BG node that does not go through domestic communication routing in order to keep the facility costs and the number of assigned global IP addresses as low as possible.

### 3.2 Routing Method

If more xGSNs are added, the routing setting must be changed; a mechanism that keeps the changes at a minimum is adopted for the domestic communication. In case of the packet-based international roaming communication, however, the destination IP addresses are not uniform and depend on the destination, it becomes necessary to update the routing settings for the entire DoCoMo network as the number of the destinations increases. In order to reduce the amount of work and lower the frequency of setting mistakes involved in the updating procedures, a method is adopted which notifies a default route from the NAT devices to all xGSNs and calls involving non-domestic communication are automatically routed to the NAT devices.

As described above, the IP address conversion function is implemented in NAT devices; however, there are also situations where IP addresses are required in various information elements, for instance in packet call control messages such as GTP and Mobile Application Protocol (MAP) messages used for position registration control. Furthermore, in roaming, xGSNs maintain their own global IP addresses as system data since it is necessary to set global IP addresses for these elements as well.

A roaming-in connection control is as follows. When an SGSN receives a call request from a mobile terminal and judges it to be a call from a roaming-in user, the SGSN transmits, a packet connection request to the GGSN of the overseas carrier, via a GTP message. In order to specify IP addresses for the Control Plane (C-Plane) and for the User Plane (U-Plane) of the SGSN as information elements in the GTP message, an xGSN reads out and sets its own global IP address, the Service General packet radio service Support Node-Control Plane (SGSN-C) global IP address and the Service General packet radio service Support Node-User Plane (SGSN-U) global IP address from the system data.

Similarly, when a roaming-out DoCoMo user in an overseas

carrier's zone wants to connect to one of DoCoMo servers, an xGSN sets the GGSN-C global IP address and GGSN-U global IP address which it maintains as system data for the C-Plane and U-Plane IP addresses, respectively, of the GGSN and sets them in the response to a packet connection request from an SGSN of the overseas carrier.

### 3.3 Gateway Connection Method

A connection with a roaming-in user involves a connection between an xGSN (SGSN) on the DoCoMo side and a GGSN of an overseas carrier via the Gn[*1] interface; a GTP tunneling is formed and packet communication is performed. Also when connecting with a roaming-out user, a GTP tunneling is formed via the Gn interface between an SGSN of an overseas carrier and an xGSN (GGSN) on the DoCoMo side, and packet communication is performed. Currently, in contractual territory-based communication such as i-mode, the Address Resolution Function (ARF), which handles the address resolution of each packet sent from an SGSN, may return different address resolution results (GGSN addresses) even if the Service Provider Number (SPN) is the same, depending on the local operator based on the received SPN and the local operator code within the DoCoMo network. This allows distributing GGSNs within the Gn range; routing across multiple local operators are not necessary in the following Gi[*2] range (routing between GGSNs and Public Data Networks (PDN)). In case of contractual territory-based connection from a roaming-out user in the 1-tunneling connection, on the other hand, distributing GGSNs within the Gn range cannot be achieved because it is not possible for an SGSN of an overseas carrier to identify local operators by address resolution. Thus, in order to realize contractual territory-based communication, it was determined that GGSNs to which SGSNs of overseas carriers can connect should maintain the Gi connection routing information for all local operators. Upon receiving a packet connection request from an SGSN of an overseas carrier, an xGSN (GGSN) sends an address resolution request to the ARF, obtains the address resolution result for each local operator to which it can be connected via the Gi interface, and establishes the connection. In other words, connections via either the Gn or Gi interface are possible for domestic connections, while the Gi interface is used in case of roaming-out home access.

*1 Gn: An interface used when two GSNs are located in the same Public Land Mobile Network (PLMN). It indicates an interface between an SGSN and a GGSN or between two SGSNs.

*2 Gi: Connection interface between an International Mobile Telecommunications-2000 (IMT-2000) and public and private packet networks such as the Internet and Intranet.

### 3.4 Conversion of Node IP Addresses

In the 2-tunneling method, DoCoMo has been using MMS-CV nodes so far to interface with GSNs of overseas carriers. For this reason, when an address resolution request to connect to one of DoCoMo's APNs (roaming-out home access) is received from an SGSN of an overseas carrier, the MMS-CV address is always returned in response, regardless of the connection destination APN. In the 1-tunneling method, on the other hand, an appropriate xGSN (GGSN) in DoCoMo network must be selected according to the connection destination APN in the address resolution response to be sent to the SGSN of the overseas carrier.

In order to realize this address resolution, DoCoMo networks provide Domain Name System (DNS) servers for roaming services. **Figure 4** shows a DNS reference route from an overseas carrier. The address resolution function and data for address resolution in DoCoMo networks are collectively controlled by the ARF function. As a result of considering the data exchange between the ARF and DNS server functions, it is defined that the DNS server function is deployed as a logical node within each xGSN in the same way as the ARF function, and the functions are efficiently implemented by linking these functions within the xGSN.

The DNS client function is also implemented in the xGSN, since it is necessary for the xGSN to make an address resolution query directly to an overseas carrier's DNS server when requesting a connection from a DoCoMo network node to an overseas carrier APN (in case of roaming-in home access), which is the opposite of the above.

### 3.5 Billing Function

As described in Section 3.1, the MMS-CV nodes that handle the relay function in the 2-tunneling method incorporate the billing function used in packet-based roaming. However, in the 1-tunneling method, which does not involve MMS-CVs, a corresponding billing function targeting packet-based roaming communication with overseas carriers must be implemented in xGSNs. **Figure 5** shows the billing method in case of the 1-tunneling method. The billing process in DoCoMo networks creates detailed bills for the amount of downlink data (hereinafter referred to as downlink detail bills) in SGSNs and detailed bills for the amount of uplink data (hereinafter referred to as uplink

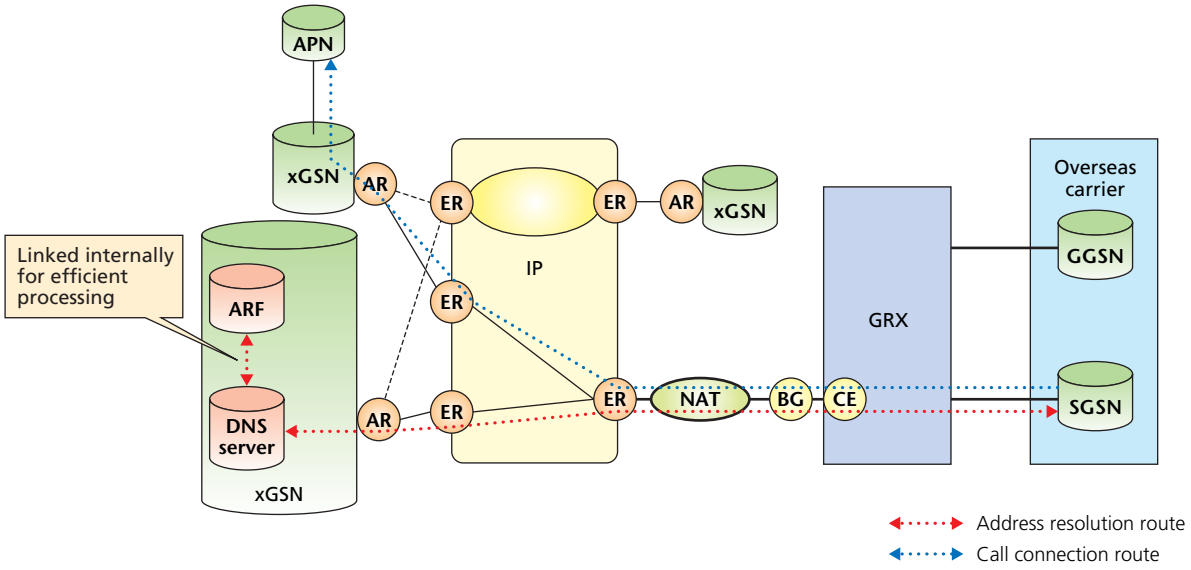



**Figure 4 DNS reference route from overseas carriers**

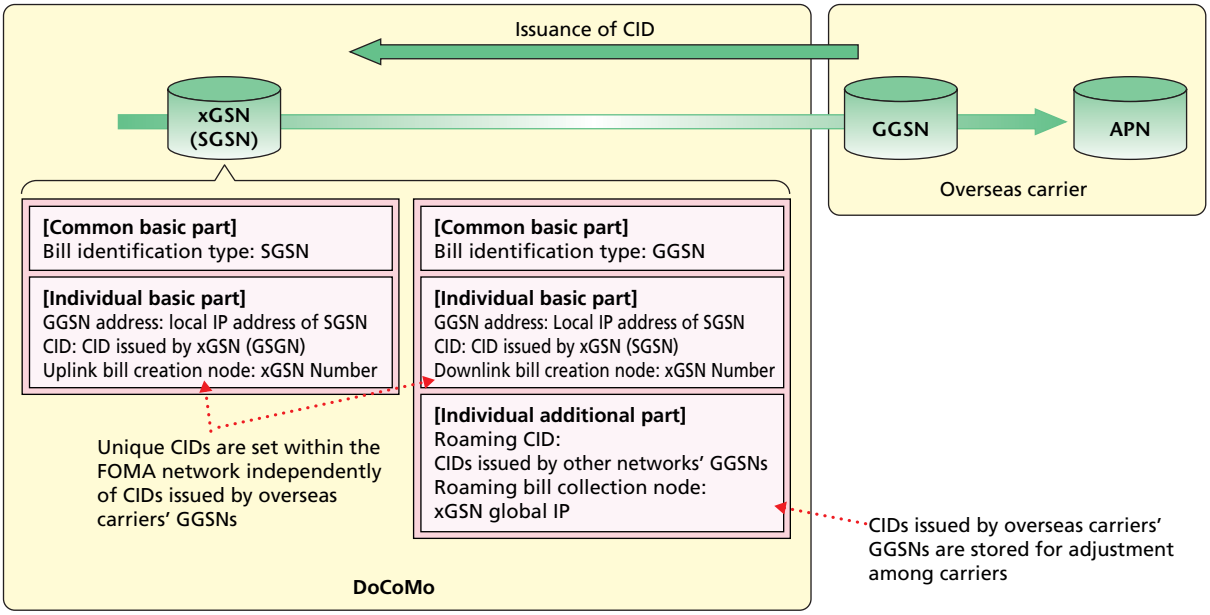



**Figure 5 CIDs setting method for billing information for packet-based international roaming communication**

detail bills) in GGSNs, respectively. In case of packet-based roaming communication, where the SGSN or the GGSN is a GSN of an overseas carrier, functions for creating detail bills related to roaming-in connections not only for downlink but also for uplink in SGSNs and creating detail bills related to roaming-out connections not only for uplink but also for downlink in GGSNs, were added. Moreover, in order to be able to crosscheck the billing information at detail bill centers, a Charging ID (CID) is attached to each detail bill. This CID is important for billing accurately and strictly controlled so as to guarantee no overlap for a certain period of time. According to 3GPP, it is standardized that the GGSN issues a CID for each call, which means that CIDs are issued by overseas carriers' GGSNs in roaming-in communication. However, issuing unique CIDs for DoCoMo networks from xGSN and crosschecking detail bills by CIDs for DoCoMo networks enable us to guarantee the reliability of DoCoMo's billing information.

## 4. Replacement Method

### 4.1 Replacement Procedure

The procedure to replace from the 2-tunneling method via MMS-CV to the 1-tunneling method is performed in three steps:

replacement of roaming-in connections, replacement of roaming-out connections, and replacement of the DNS servers.

1) Replacing Roaming-in Connections

Roaming-in calls are replaced by changing the routing destination from an MMS-CV to an NAT device. Before replacing, communication is performed by turning off the IP address conversion function explained in Section 3.2 (communication via private IP addresses), but after replacing, the communication is performed with the IP address conversion turned on (communication via global addresses). The replacement is performed by turning on the service switch in each unit in order. Since the IP address conversion function is not added to MMS nodes for the reason of development cost, this step can only be performed when all packet switching calls are processed in xGSNs.

2) Replacing Roaming-out Connections

Roaming-out calls are replaced by changing the IP addresses of MMS-CV nodes for DNS resolution notification to IP addresses of GGSNs (representative GGSNs) that process international roaming calls. When changing the routing information in the DNS servers, the MMS-CV routing information must also be maintained until it is certain that the cache is cleared, because there is a possibility that DNS clients of overseas carriers cache IP addresses before it's changed. Because the 1-tunneling method is used in the representative GGSNs as well, it is essential to turn on the IP address conversion function in these GGSNs before executing the replacement task.

3) Replacing DNS

Currently, the operating DNS servers for international roaming are equipped in MMS-CV nodes. Because the purposes of separating Packet Switching (PS) are to reduce the PS call processing functions that have to be implemented in MMS nodes and to reduce the development cost, it is necessary to transfer the DNS servers to xGSNs as well. Since there are two DNS systems at the moment, the easiest way to handle this is to stop one DNS system and transfer the DNS function to the xGSNs. Then, the address of the DNS can be changed in the NAT device to eliminate the necessity to change the IP address of the currently used DNS. After one system is transferred, the other system can be transferred with the same procedure as well; thereby, replacing of the DNS function from MMS-CV nodes to xGSNs is completed.

### 4.2 Inter-working Roaming Expert Group Test

The Inter-working Roaming Expert Group (IREG) of GSM prescribes tests for confirming functions required for international roaming communication. xGSNs incorporate both the IREG tests via MMS-CV nodes and functions for implementing the IREG tests without going through MMS-CV nodes.

xGSN has a service switch for shifting roaming-in calls to the 1-tunneling connection that does not go through MMS-CV nodes as described above, but even if this switch is turned off, xGSN provides a switch for IREG tests that allows to select whether or not to use MMS-CV nodes, limiting the tests to target calls related to roaming-in call tests. If this IREG test switch is turned on (not via MMS-CV) and the service switch is turned off, connection tests in the 1-turnneling method without going through MMS-CV nodes are made possible for tests targeting calls for roaming-in call only. Other calls are connected with the 2-tunneling method that goes through MMS-CV nodes.

The IREG tests of roaming-out call, on the other hand, are implemented by registering the International Mobile Subscriber Identity (IMSI) of a test target terminal to the New Mobile Service Control Point (NMSCP) in advance and calling from the registered mobile terminal, in both the case where MMS-CV nodes are involved and the case where they are not involved. Since it can be selected whether or not to go through MMS-CV nodes by changing the DNS response to other networks, it becomes possible to perform connection tests in the 1-tunneling method without going through MMS-CV nodes for test calls only and connect other calls in the 2-tunneling method that involves going through MMS-CV nodes, by preparing a separate APN for tests and returning only the DNS response to this APN to the representative GGSN rather than to the MMS-CV node.

## 5. Conclusion

This article described the method for implementing packet-based international roaming communication services using xGSNs, which handle packet-based switching processing of FOMA, and outlined the connection method of packet-based international roaming communication services by the 1-tunneling method, the connection method using the NAT function, which hides the differences between the IP addresses of overseas carriers and the addresses used within DoCoMo networks, the call processing functions such as gateway connection, DNS reference and billing processing, as well as the replacing procedure and method of implementing the IREG tests.

The number of subscribers to the packet-based international

roaming services is expected to increase, and various other new services can be assumed to appear in the future. We intend to consider upgrading functions related to roaming in the future as well, so that services can be provided promptly in response to the growing needs of the customers.

## REFERENCES

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[2] R. Satrusajang, et al.: "MMS Packet Processing Device for FOMA International Roaming," NTT DoCoMo Technical Journal, Vol. 6, No. 2, pp.54–61, Sep. 2004.

## ABBREVIATIONS

3GPP: 3rd Generation Partnership Project
APN: Access Point Name
AR: Access Router
ARF: Address Resolution Function
ATM: Asynchronous Transfer Mode
ATM-SVC: Asynchronous Transfer Mode-Switched Virtual Channel
BG: Border Gateway
CE: Customer Edge router
CID: Charging ID
C-Plane: Control Plane
DNS: Domain Name System
ER: Edge Router
FOMA: Freedom Of Mobile multimedia Access
GGSN: Gateway General packet radio service Support Node
GMMS: Gateway Mobile Multimedia switching System
GRX: General packet radio service Roaming eXchange
GTP: General packet radio service Tunneling Protocol
IMSI: International Mobile Subscriber Identity
IMT-2000: International Mobile Telecommunications-2000
IP: Internet Protocol
IREG: Inter-working Roaming Expert Group
ISW: Intensive SWitch
LMMS: Local Mobile Multimedia switching System
MAP: Mobile Application Protocol
MMS: Mobile Multimedia switching System
MMS-CV: Mobile Multimedia switching System-ConVerter
NAT: Network Address Translation
NMSCP: New Mobile Service Control Point
PDN: Public Data Network
PLMN: Public Land Mobile Network
PS: Packet Switching
SGSN: Serving General packet radio service Support Node
SGSN-C: Service General packet radio service Support Node-Control Plane
SGSN-U: Service General packet radio service Support Node-User Plane
SPN: Service Provide Number
U-Plane: User Plane
WPCG: Wireless Protocol Conversion Gateway
xGSN: serving/gateway GPRS Support Node