MMS Packet Processing Device for FOMA International Roaming

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To realize FOMA international roaming packet services, we have developed a conversion device that can be installed as part of the MMS, which is the FOMA switching system, to convert connection methods between DoCoMo's ATM-SVC networks and IP networks of packet roaming exchange carriers.

● Development Reports ●

1. Introduction

DoCoMo started to provide Freedom Of Mobile multimedia Access (FOMA) services which adopts Third-Generation (3G) mobile communications system, International Mobile Telecommunications-2000 (IMT-2000), in May 2001 and launched the services with the FOMA international roaming services (voice roaming only) in June 2003. A year later, in June 2004, the FOMA international roaming-in services (packet service) were launched.

With these services, FOMA users can now perform both voice and packet communication in overseas locations using the User Identity Module (UIM), FOMA cards, of the mobile terminals they use in Japan.

This article explains the connection methods of the FOMA international roaming packet service and provides an overview of the ConVerter (CV), which is a mode converting device used to connect DoCoMo's networks with the General packet radio service Roaming eXchange (GRX) networks that comprise the core of the roaming services.

2. Development Background

The Mobile Multimedia switching System (MMS), the FOMA switching system, handles connections of various transmission speeds, providing efficient transfer capabilities and high traffic management capabilities. This was made possible because it adopts the Asynchronous Transfer Mode-Switched Virtual Channel (ATM-SVC) connection method in order to transfer user data. In parallel with this, the Quality of Service (QoS) performance and security performance of Internet Protocol (IP) networks have improved according to the development of the IP technologies; therefore, some communication carriers have begun to adopt IP networks. In order to perform packet communication with overseas mobile communication carriers (hereinafter referred to as other carriers), the connection has to be made via IP-based GRX networks, which means that a protocol conversion between IP and ATM-SVC is required for the User-Plane (U-Plane), which is used for communicating user packets on both networks. Furthermore, on the Control-Plane (C-Plane), which is used for communicating control signals, the GRX adopts IP network routing, while DoCoMo adopts a method where signals are transferred via Signaling System No. 7 (SS7) on the Asynchronous Transfer Mode (hereinafter referred to as ATM-SS7). Thus, a C-Plane control method conversion between the ATM-SS7 routing and IP routing methods is required.

For these reasons, it has become necessary to develop a CV device that has such ATM/IP protocol conversion functionality.

3. International Roaming Packet Service Connection Method

3.1 Overview

In IMT-2000 system, when a mobile terminal performs packet communication with an Internet Service Provider (ISP) and treasure Casket of i-mode service, high Reliability platform for CUStomer (CiRCUS) etc., first a General packet radio service Tunneling Protocol (GTP) tunnel, which is used for transferring user packets between the Serving General packet radio service Support Node (SGSN) and Gateway General packet radio service Support Node (GGSN), is established by the C-Plane for each connection, and the user packets are then transmitted/received through the tunnels via a Radio Access Network (RAN).

As for data transfer between the SGSN and GGSN within the core network, the 3rd Generation Partnership Project (3GPP) prescribes the GTP from which user can be identified uniquely and the User Datagram Protocol for the Internet Protocol (UDP/IP) by means of which packets are transferred to the destination node, but does not prescribe any specific requirements below the lower data link layer. In the following, an overview of the packet communication connection method adopted in the DoCoMo network and problems when connecting the ATM network and IP network are given, using **Figure 1** for the explanation.

1) DoCoMo's Packet Communication Connection

Since DoCoMo applies the ATM-SVC protocol for the data link layer, ATM-SVC path A is established for each connection between the Local Mobile Multimedia switching System

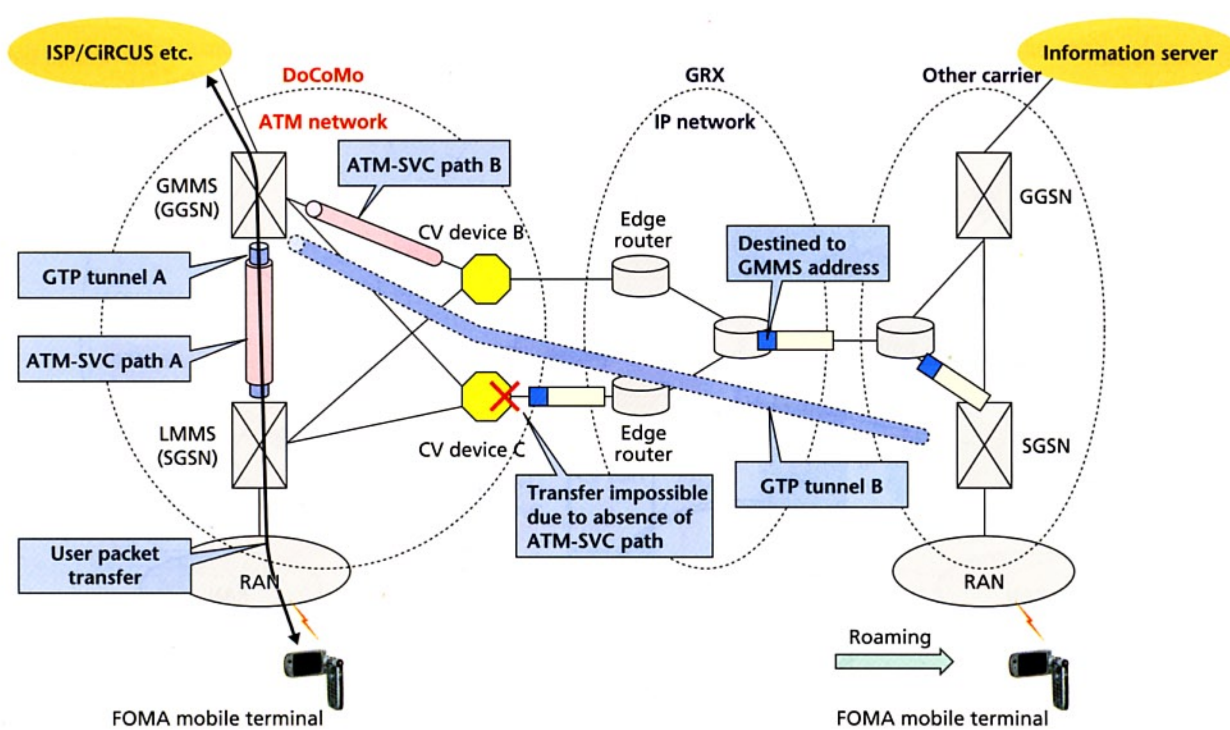

Figure 1 Issues when connecting between ATM-SVC and IP networks

(LMMS) of the SGSN and the Gateway Mobile Multimedia switching System (GMMS) of the GGSN, and GTP tunnel A is established along the ATM-SVC path A. Moreover, a Tunnel Endpoint IDentifier (TEID), a unique GTP tunnel identifier determined for each connection, is set in the GTP header of a packet. Routing is then performed based on a Virtual Channel Identifier (VCI), which is a connection identifier set as part of the ATM packet header, the user packet transfer route is fixed and the packet is delivered to the destination (this process is hereinafter referred to as ATM-SVC routing).

2) Issues when Connecting between ATM Networks and IP Networks

When using a FOMA mobile terminal with other carriers, a GTP tunnel is established between DoCoMo's GMMS and the other carrier's SGSN. Actually, the terminal is connected to the other carrier's network via a GRX network. Since the GRX network adopts IP routing, however, a CV device that performs protocol conversion of the data link layer and lower layers is required to connect an ATM network and IP network.

When communicating with the other carrier via the GRX network, after establishing GTP tunnel B between the SGSN and GMMS, the destination IP address is set in the packet's IP header, a TEID is set in the GTP header, and the user packet is transferred. At this point, it is effective to set up multiple CV devices at connection points between the networks in order to secure higher reliability.

Even if multiple CV devices are set up, it is possible to transfer packets to specific CV devices in the direction from the ATM network to the IP network, because ATM-SVC path B has been established between the MMS and the CV devices at call determination. However, in the direction from the IP network to the ATM network, it cannot be known by which route a packet is transferred due to the characteristics of the IP network. In other words, the destination IP address of a packet is the IP address of the GMMS designated as the end point of the GTP tunnel, and routing is carried out based on the destination IP address. For this reason, a packet may not be routed via the CV device through which ATM-SVC path B of the U-Plane has been established, and may thus not be transferred.

3.2 2-Tunneling Connection method

Figure 2 shows a possible solution method for the problems above. When establishing a GTP tunnel that connects a GMMS and SGSN via a CV device, GTP tunnel and a TEID used for each user is created separately by the ATM network and the IP network in question, and the each GTP tunnel is terminated at the CV device.

As shown in Fig.2, GTP tunnel B1 is established between the GMMS and CV device B and GTP tunnel B2 is established between CV device B and the SGSN. Since the GTP tunnel is terminated at CV device B, if a user packet is transferred from

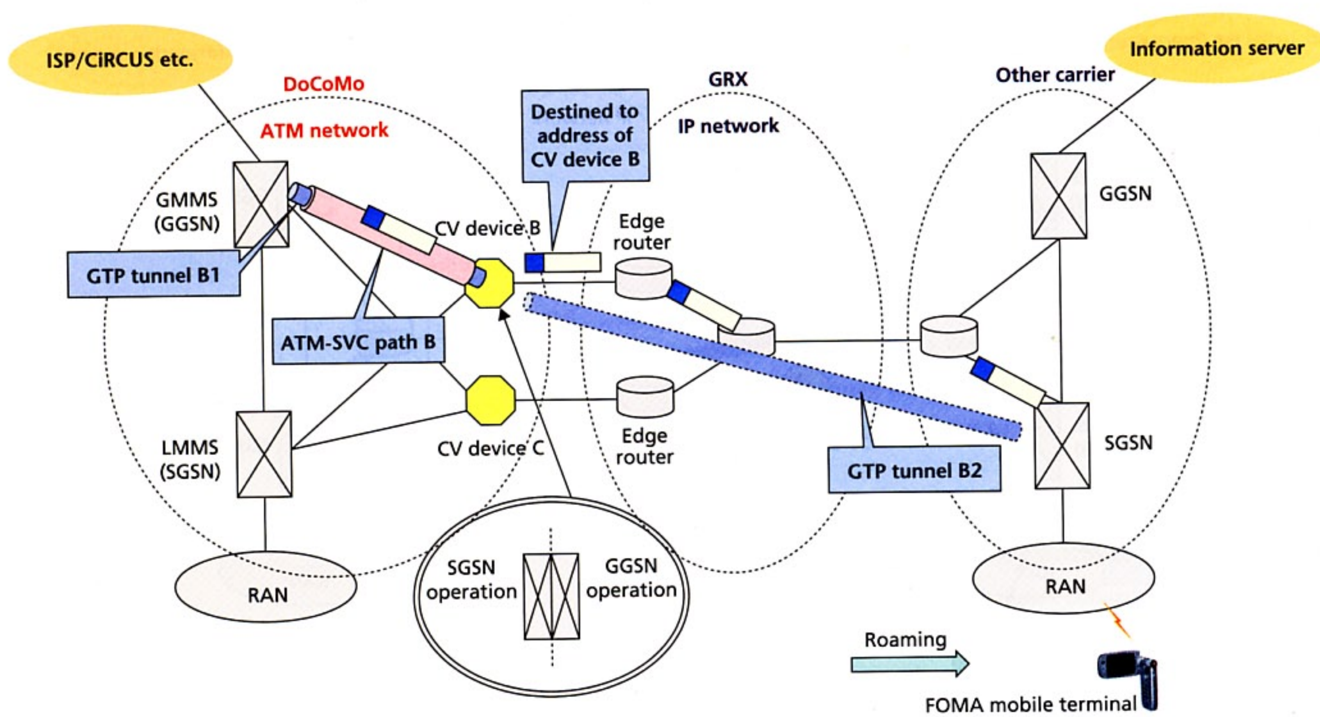

Figure 2 2-tunneling connection method

the SGSN of the IP network to the ATM network, the user packet is transferred to the IP address of CV device B determined at path determination. This means that the same CV device is used as a relay throughout the processing from the call determination to the call cut; user packets will never be transferred via another CV device such as C.

With this tunneling method, the GTP tunnels are terminated at CV devices, which means that a given CV device acts as an SGSN for the GMMS and as a GMMS for the SGSN on the opposite side.

The explanation above outlines the case when a FOMA mobile terminal attempts to connect via other carrier. When a mobile terminal of other carrier attempts to connect to the other carrier via DoCoMo, DoCoMo's LMMS and the other carrier's GGSN must be connected.

4. System Configuration

Figure 3 shows the system configuration for the international roaming packet services. To reduce development cost, a CV device performing connection method conversion between ATM and IP networks was developed to be installed as part of the MMS.

This device, the Border Gateway (BG) device, is a general-purpose device placed between the networks of DoCoMo and another carrier.

In order to implement the international roaming packet services in an economical manner, it is effective to connect to a GRX network node. DoCoMo will then be able to connect mutually with as many other carriers as possible by going though the GRX network.

A CV device is divided into a CV part and a Converter-SIGnaling processing unit (C-SIG) part; each part has different roles and functions. The CV part mainly deals with the U-Plane processing while the C-SIG part is in charge of the C-Plane processing. The functions of the CV device are explained in the following section.

5. Functions of CV Devices

5.1 CV Part

1) Division Function/U-Plane Processing Function

As shown in Fig.3, packets belonging to either the U-Plane or the C-Plane are transferred from the GRX side to the DoCoMo side. Such mixed-status packets are passed to the CV part, that judges whether each packet belongs to the C-Plane or U-Plane, and divides the packets accordingly.

If a packet belongs to the C-Plane, the CV part transfers the packet to the C-SIG part, which is equipped with the C-Plane processing functionality. The C-SIG part carries out the C-Plane processing explained in Section 5.2 and sends the packet to the target MMS on the DoCoMo side.

If a packet belongs to the U-Plane, it is processed by the U-Plane processing function of the CV part. **Figure 4** shows the protocol stack of the U-Plane. The U-Plane processing functionality of the CV part consists of functions for conversion between ATM-SVC and ATM-PVC, conversion between DoCoMo's ATM-SVC routing and the GRX side's IP routing methods, and processing of the U-Plane tunneling protocol, General packet radio service Tunneling Protocol-User (GTP-U).

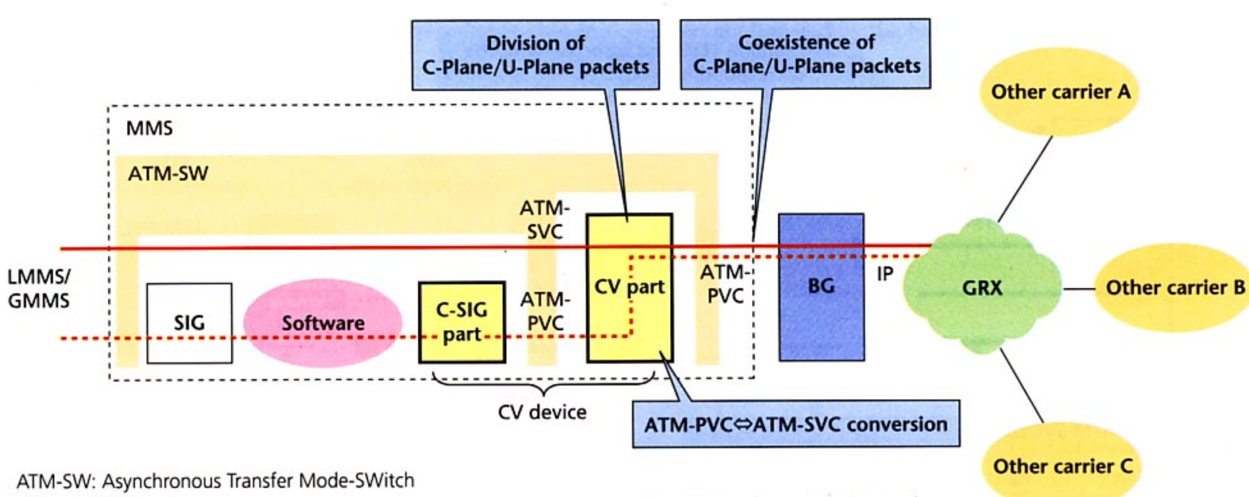

Figure 3 International roaming packet system configuration

This GTP-U processing handles correspondence between the "IP address handled on the DoCoMo side and the TEID identifier of GTP-U" and the "IP address and TEID handled by the other carrier," along with header conversion.

Via the routing method shown in **Figure 5**, whenever a packet is received from the GRX side, the call that it belongs to is identified by its TEID, and the packet is assigned to the corresponding ATM-SVC path. In addition, the GTP-U processing, which consists of rewriting the IP address and TEID of the packet, is also carried out and the packet is transferred to the DoCoMo side.

C-Plane and U-plane packets transferred from the DoCoMo side to the GRX side are multiplexed in the CV part and transferred to the GRX side. The U-Plane processing for a packet transferred from the DoCoMo side identifies the call by examining the packet's VCI and assigns the IP address and TEID corresponding to this call. The packet is then transferred to the GRX side through the connection to the BG via the Asynchronous Transfer Mode-Permanent Virtual Channel (ATM-PVC).

2) Fragment Reassembly Function

When an IP packet is transferred via a network, the packet length (datagram length) may exceed the Maximum Transmission Unit (MTU), which is the upper limit value of layer 2 (Ethernet, ATM, token ring etc.). In this case, it is necessary to fragment (divide) the packet according to the MTU. The fragmented packet is not reassembled in a node while being transferred, but it is reassembled at the destination of the IP packet.

The maximum GTP payload length specified by 3GPP is

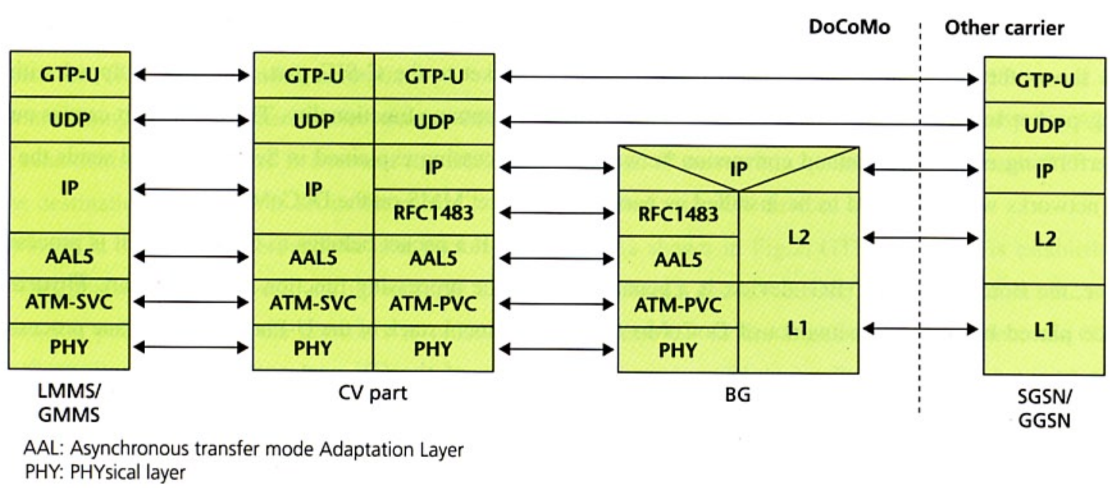

Figure 4 U-Plane processing protocol stack

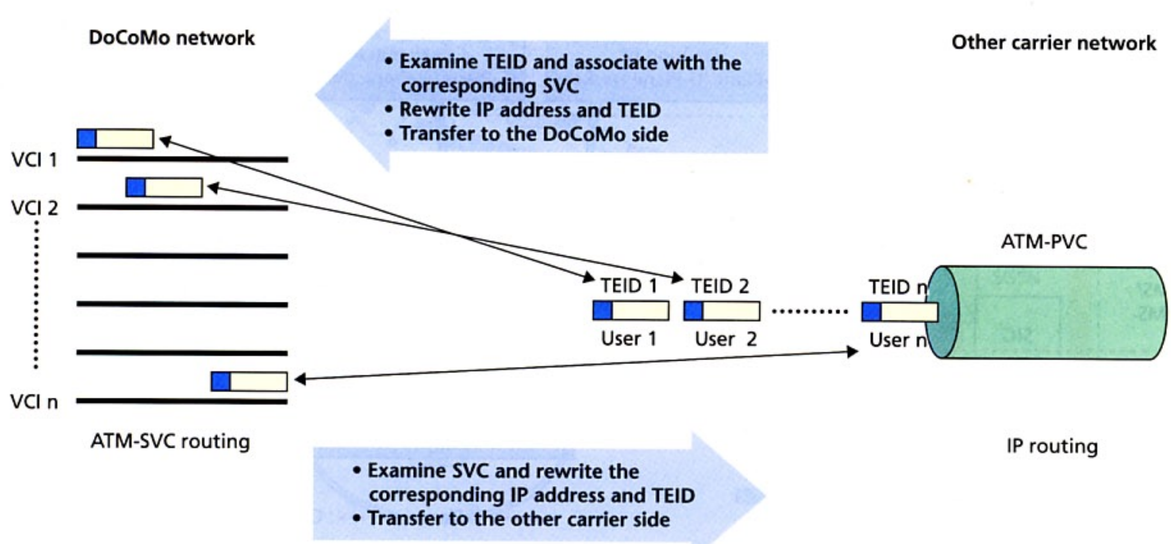

Figure 5 U-Plane processing

1500 bytes, and the length may exceed 1500 bytes if a header is attached.

DoCoMo adopts a network configuration using the ATM on the data link layer. This means that fragmentation at the GTP layer will not happen, because the MTU of the ATM layer is 9180 bytes.

On the other hand, GRX network and other carriers may be utilizing any type of data link layer to communicate. The MTU is 1500 bytes if Ethernet is used. In this case, packets transferred from other carriers are fragmented and delivered to the DoCoMo network as shown in **Figure 6**. The CV part judges whether or not a packet is fragmented and reassembles it if it is fragmented.

3) Other Functions

i) Packet Count Function

The CV part has a function that counts the number of packets, to charge users of the international roaming packet service for the amount of traffic.

ii) Traffic acquisition function

The CV part collects various kinds of traffic information of the CV device, such as the number of input/output packets, the number of bytes and the number of error packets. The information is utilized to keep track of usage conditions of the internal roaming packet service and as reference information for addition and improvement of devices.

iii) Sequence number processing function

Since DoCoMo transfers packets via the ATM, reversal of the order of packets never occurs on the receiving side. On the GRX side, where general IP network routing is used, however, reversal of packet order may occur. For this reason, the CV part is equipped with a function that is able to rearrange packets in the correct sequence according to the following procedure before transferring them to the DoCoMo side in case the order of packets transferred from other carriers is reversed.

The function checks the packets' sequence numbers, which are values assigned to each of the packets, incremented by 1 for each sent packet, to detect whether or not the order is reversed. If the sequence numbers are not in order, the CV part retains the packets for a fixed time.

- If the expected packets are received during this retention period, the CV part rearranges the order and transfers the packets.
- If packets are received when the retention buffer is full, the CV part flushes the retained packets and checks the order of the succeeding packets.
- The CV part flushes retained packets for which a fixed period has elapsed.
- When the sequence number reaches the maximum number, the value is reset to 0.

5.2 C-SIG Part Functions

Figure 7 shows the C-Plane protocol stack of the MMS when connecting to a DoCoMo network node. The MMS must identify the control signals of the C-Plane and determine U-Plane paths. The processing of the General packet radio service Tunneling Protocol-Control (GTP-C), which corresponds to the control signals of the C-Plane, and the processing of the Message Transfer Part-3b (MTP-3b) protocol or higher are handled by software. Protocols below the Service Specific Coordination Function-Network Node Interface (SSCF-NNI) layer are handled by the hardware of the existing device, i.e. the

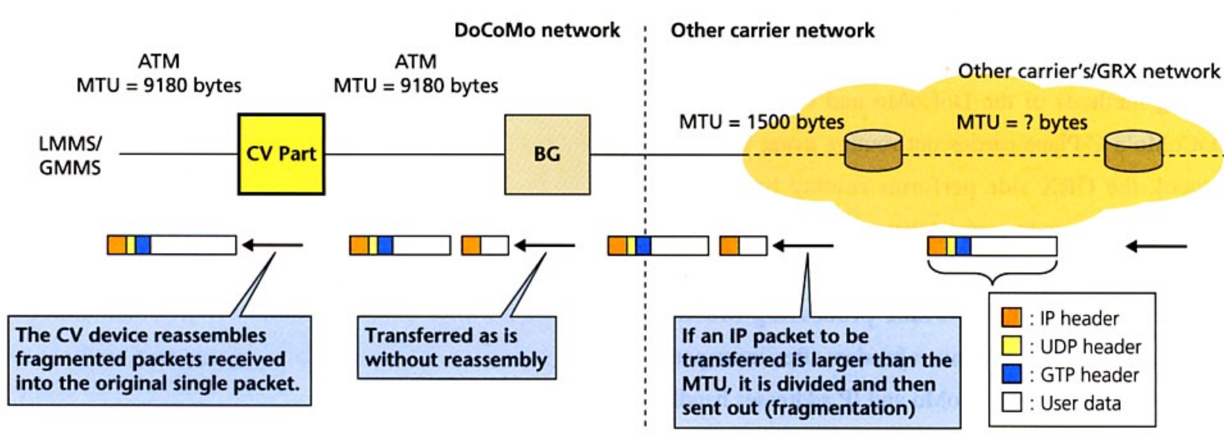

Figure 6 Fragment reassembly processing

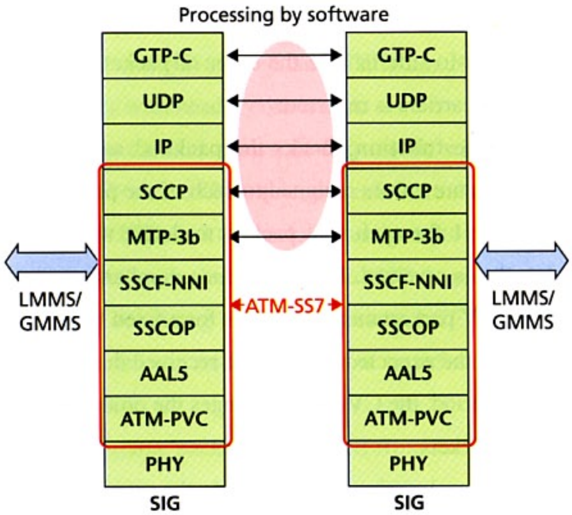

Figure 7 C-Plane processing within the DoCoMo network

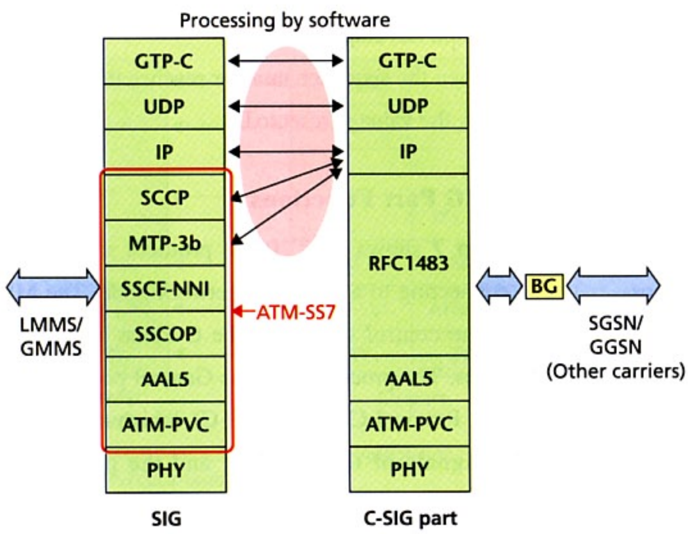

Figure 8 C-Plane processing protocol stack

SIGnaling processing unit (SIG) device, and packet communication is also handled by the SIG device.

Figure 8 shows the C-Plane's protocol stack. The C-Plane processing function of the C-SIG part converts between the C-Plane routing methods of the DoCoMo and GRX networks. While DoCoMo's C-Plane carries out routing using the ATM-SS7 protocol, the GRX side performs routing based on IP addresses. It is necessary to convert these different routing protocols.

Moreover, an additional C-Plane processing function becomes necessary, namely to convert headers after corresponding IP addresses handled by DoCoMo and IP addresses handled by the other carriers' side. This processing was implemented in software.

With the functions above, it is possible to perform processing of each protocol in a different device when converting between DoCoMo's ATM-SS7 routing and the GRX side's IP routing. Since DoCoMo already has the SIG device that handles the ATM-SS7 routing, it is only the C-SIG part, which processes protocols on the other carriers' side, that requires new development.

Implementation of the C-SIG part was achieved in the following manner: the processing of the Service Specific Connection Oriented Protocol (SSCOP)/SSCF-NNI of the SIG device was shifted to Multiprotocol Encapsulation over ATM Adaptation Layer 5 (RFC1483) in the Request For Comments (RFC) in order to convert between the ATM-SS7 routing and IP routing methods. This change was developed and implemented by hardware modification of the SIG device. Moreover, the protocol processing software on the other carriers' side was changed so that it does not process the Signaling Connection Control Part (SCCP) and MTP-3b in this development.

6. Conclusion

This article explained the connection method used for providing the international roaming packet services and provided an overview of the CV device that handles the necessary connection method conversion.

We believe that the continued improvement of the international roaming packet services reinforces FOMA's new global strategies and will lead to support of diffusion of IMT-2000 throughout the world. In the future, we plan to improve functions etc. to enhance the convenience of these services.

ABBREVIATIONS

3GPP: 3rd Generation Partnership Project
AAL: Asynchronous transfer mode Adaptation Layer
ATM: Asynchronous Transfer Mode
ATM-PVC: Asynchronous Transfer Mode-Permanent Virtual Channel
ATM-SVC: Asynchronous Transfer Mode-Switched Virtual Channel
ATM-SW: Asynchronous Transfer Mode-SWitch
BG: Border Gateway
CiRCUS: treasure Casket of i-mode service, high Reliability platform for CUStomer
C-Plane: Control-Plane
C-SIG: Converter-SIGnaling processing unit
CV: ConVerter
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
GTP-C: General packet radio service Tunneling Protocol-Control
GTP-U: General packet radio service Tunneling Protocol-User
IMT-2000: International Mobile Telecommunications-2000
IP: Internet Protocol
ISP: Internet Service Provider
LMMS: Local Mobile Multimedia switching System
MMS: Mobile Multimedia switching System
MTP-3b: Message Transfer Part-3b
MTU: Maximum Transmission Unit
PHY: PHYsical layer
QoS: Quality of Service
RAN: Radio Access Network
RFC: Request For Comments
SCCP: Signaling Connection Control Part
SGSN: Serving General packet radio service Support Node
SIG: SIGnaling processing unit
SSCF-NNI: Service Specific Coordination Function-Network Node Interface
SSCOP: Service Specific Connection Oriented Protocol
TEID: Tunnel Endpoint IDentifier
UDP: User Datagram Protocol
UIM: User Identity Module
U-Plane: User-Plane
VCI: Virtual Channel Identifier