IP Transport | High Performance | Economization

Technology Reports

Special Articles on IP-based RAN for Economical and Flexible Network Construction

IP Radio Network Controller

We developed a radio network controller that applies the IP technology to achieve economical application of IP transport to the FOMA radio access network and to cope flexibly with the future support of more advanced and higher-speed services.

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1. Introduction

The IP-Radio Network Controller (IP-RNC) was put into operation as a controller for the IP-based Radio Access Network (IP-based RAN) in April 2006. The pursuance of IP and other generic technology led to the economical introduction of IP-RNC. The system architecture took into consideration the future extensibility for more advanced and higher-speed services as well as adaptability to changing traffic.

We describe the purposes, the system architecture and the IP transport control technology of IP-RNC.

2. Background and Purposes of IP-RNC Development

1) Increasing Packet Service Traffic

Since the FOMA service started in 2001, both the volume and the proportion of packet communication traffic have increased along with the number of users. In 2004, NTT DoCoMo separated the Core Network into circuit-switched and packet-switched domains to cope with the increasing packet traffic. Furthermore, with the introduction of High Speed Downlink Packet Access (HSDPA)[*1] service in August 2006, the importance of economically supporting the increasing and faster traffic in the FOMA radio access network has risen. We developed the IP-RNC to apply IP transport that can realize economical support of wider bandwidth in the FOMA radio access network and to flexibly cope with the increasing traffic.

2) Economical Expansion of the FOMA Network

The number of FOMA service users had reached approximately 34 million by the end of February 2007, and it is expected to continue to increase with users changing over from the PDC system and the addition of new subscribers. The service area itself also has been expanding into large buildings and underground facilities where the radio signals from outdoor base stations do not reach and into areas in which there are relatively small numbers of users. IP-RNC was developed as a flexible system that can handle various forms of operation both by coping with future traffic increases economically and by accommodating a large number of relatively low-capacity Base Transceiver Stations (BTS), which are expected to increase in number.

3) Extensibility for Implementing New Services

The FOMA service is expected to expand to include even more advanced packet communication services. The extensibility to handle such services was another important aspect in the development of the IP-RNC. This system also makes it possible to provide new services such as the OFFICEED[*2] corporate on-premises communication service, which takes advantage of the flexible IP routing control. OFFICEED is one of the services targeted at businesses that are expected to grow.

*1 **HSDPA**: A high-speed downlink packet transmission system based on W-CDMA. Maximum downlink transmission speed under the 3GPP standard is approximately 14 Mbit/s. Optimizes the modulation method and coding rate according to the radio reception status of the mobile terminal.

*2 **OFFICEED**: A flat-rate communication services among group of people pre-registered to an area within IMCS-introduced buildings. This makes in-house communications possible with FOMA terminals.

3. System Architecture

3.1 Hardware Configuration and Features

To realize high performance and density, and economization of the system, with the reliability required for the infrastructure of the mobile communication system, we based the development of the IP-RNC hardware on the concept of using general-purpose products that adopt the latest device technology.

The features of this system are explained below.

1) Hardware Capabilities

The IP-RNC has about twice the processing capacity and the reliability (Mean Time Between Failure (MTBF)[*3]) of the existing system and about the same size factor of two 19-inch racks (**Photo 1**).

The processing capacity can be adjusted to the capacity and the number of accommodated BTSs by increasing or reducing the number of cards installed. It is also possible to flexibly cope with the future changes in traffic conditions by changing the number of controller cards or traffic processing cards, the ratio among those types of cards, or even by adding chassis and racks as needed.

2) Adoption of General Technical Specifications

We adopted the general-purpose blade servers of the advanced Telecom Computing Architecture (aTCA)[*4] communication platform defined by the PCI Industrial Computers Manufacturers Group (PICMG)[*5]. Making each type of card in the chassis conform to the aTCA specifications allows the use of commercially available blade servers and switches and the application of standard operation and maintenance functions, thus reducing costs and shortening the development period.

Future improvements in processing capacity are also possible by using products with higher-performance and conformity to the same specification.

3) Hardware Configuration

The IP-RNC hardware configuration is shown in **Figure 1**. Connections between the cards in the system and between chassis adopt Gigabit Ethernet (GbE)[*6]. The interface between cards in a chassis has full-mesh configuration to maintain isolation of the signal paths, thus minimizing the influence of card failures relative to a bus configuration. The interface also has adequate bandwidth to cope with faster services in the future.

To increase the capacity and the processing speed of the trunk module, which implements the multiplexing and separation of the common channel sending/receiving data, selection combining and splitting of dedicated channel sending/receiving data, Radio Link Control (RLC), and HSDPA channel frame processing functions defined by the 3rd Generation Partnership

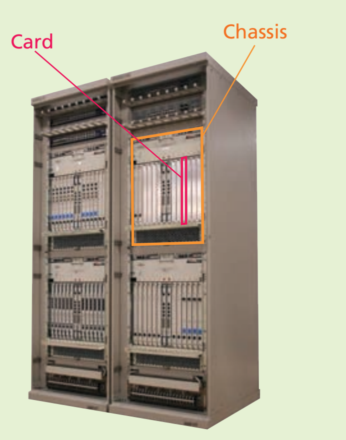

Photo1 External view of the IP-RNC

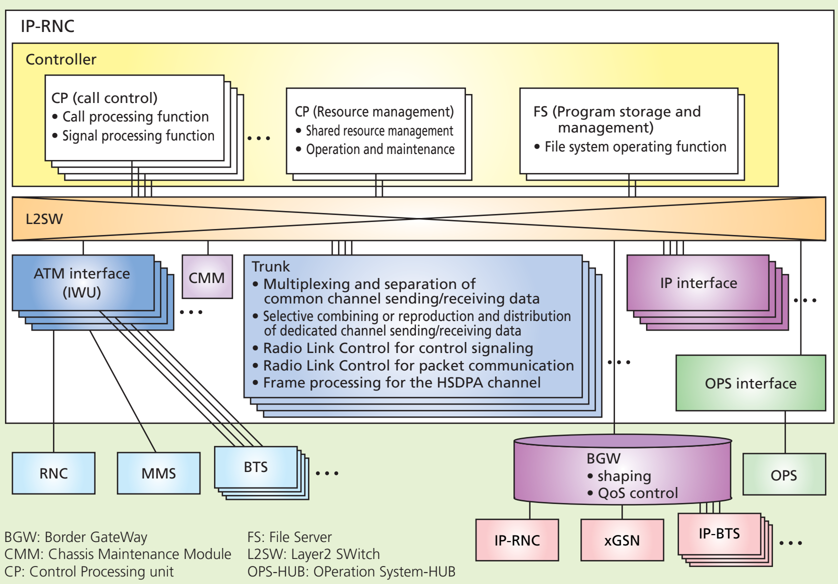

Figure 1 IP-RNC hardware configuration

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*3 **MTBF**: The average time from when a system is started or from when a system has failed to the next failure.

*4 **aTCA**: Industrial standard specifications for carrier-oriented next-generation communication equipment defined by the PICMG (see*5).

*5 **PICMG**: An organization that promotes the use of Peripheral Component Interconnect (PCI) plug-in circuit boards and related products for commercial use. Founded in October 1997.

*6 **GbE**: An Ethernet specification that provides communication speeds of up to 1 Gbit/s.

Project (3GPP), an IP-RNC specific card mounted with multiple Digital Signal Processors (DSPs)[*7] was developed to improve processing capacity with a higher degree of integration. That approach also provides extensibility to cope with the more advanced functions of the future. Furthermore, implementing various functions in firmware on a single common card (base card) rather than having a specialized card for each function, allows flexible response to a variety of traffic conditions by using different types of firmware rather than adding or removing hardware. This also decreases operation and maintenance costs by reducing the number of spare cards needed and shortening the time for firmware updating.

In addition, since the RLC function for packet communication, which was previously implemented in the Multimedia signal Processing Equipment (MPE), is incorporated in the newly developed card in IP-RNC, the system bears the potential to cope adequately with the future packet service advancements. Furthermore, it also contributes to the smaller connection and transfer delay for packet calls because signaling protocol and data transfer between systems are reduced.

This system also needs to have a interworking function with the Asynchronous Transfer Mode (ATM)[*8] to connect with the existing ATM-based systems that are already installed nationwide. For that purpose, we developed the Inter-Working Unit (IWU) card for the interworking between IP and ATM. Implementing the ATM-related functions and the interworking function as closed functions within the IWU makes it possible to design all the remaining hardware and software of IP-RNC on an IP basis. This configuration allows for unified control of the system regardless of the connection interface and the IWU can simply be removed without affecting other functions if ATM connection becomes unnecessary in the future.

3.2 Software Configuration and Features

1) Software Configuration

The IP-RNC software configuration is shown in **Figure 2**. For the Operating System (OS), we adopted Carrier Grade Linux (CGL)[*9], which is defined by the Open Source Development Lab (OSDL)[*10], to achieve the same high level of reliability and real-time quality as obtained with the previous infrastructure equipment. CGL is also adopted for other systems that have the aTCA platform, such as the serving/gateway General packet radio service Support Node (xGSN), and has already been used in commercial operation. Because CGL is open-source software, the cost of introduction is relatively low and the system can be customized to suit the equipment requirements by installing only the required functions.

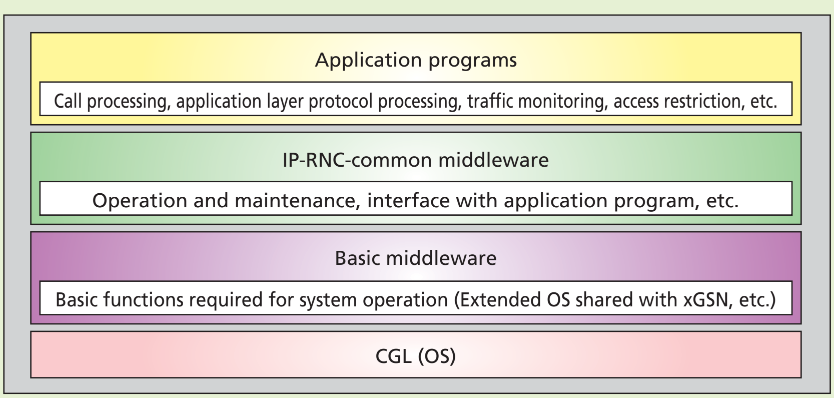

Figure 2 IP-RNC software configuration

The middleware is divided into the basic middleware that is common to other systems applying aTCA and CGL, such as xGSN, and the IP-RNC-common middleware that has been specialized for IP-RNC in general. The basic middleware possesses the basic functions that are required for the operation of the system; the IP-RNC-common middleware has a function for monitoring the cards in the system, including the IP-RNC-specific cards, and operation and maintenance functions for the control of self recovery from failures and card control from the network operation system.

The application programs possess the call control and call control protocol functions for the FOMA radio access network and the operation and maintenance functions required for the operation of the system such as traffic monitoring and control and access restriction control.

*7 **DSP**: A processor specialized for processing digital signals.

*8 **ATM**: A communication scheme in which fixed-length frames called cells are transferred successively.

*9 **CGL**: A highly-reliable version of the Linux, an Unix-style open source OS, defined by the Open Source Development Lab (OSDL) which is an organization that promotes business-use Linux. This can be used by telecommunication carriers.

2) Software Development

The basic concept of the software development was the maximal reuse of the existing RNC resources with the objectives of good quality software developed at low cost in a short time period. Especially, we succeeded in development maintaining quality of application programs in a short time period by using the existing RNC software assets with minimal modification for the adaptation to IP-RNC. We also made use of existing testing tools in the software testing process.

We will continue to use the existing software assets in the future development as well, effectively using the development environment, engineers and other such resources for more efficient development of software for both RNC and IP-RNC.

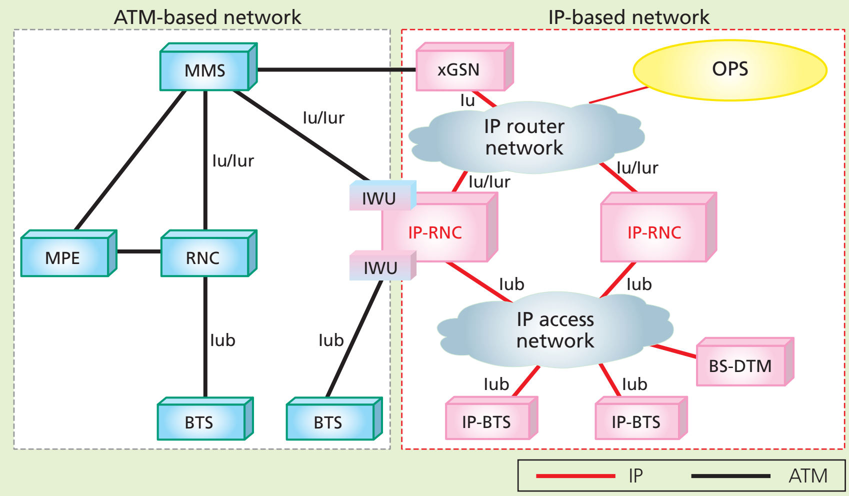

Figure 3 IP-RNC network connection configuration

4. IP Transport Control

4.1 Overview of the Network Configuration

An overview of the network connection configuration centered on the IP-RNC is shown in **Figure 3**. In addition to connecting to the ATM node via the IWU, the IP-RNC can connect to xGSN(Iu[*11]), IP-BTS (Iub[*12]), and to other IP-RNC (Iur[*13]) via the IP interface. The IP transport control function is provided for each interface.

In the design of the IP transport control function, maximal utilization of IP routing was the general principle. This approach allows, for example, direct routing when handover extends across nodes. With this approach, the user data transfer and its control load on nodes can be reduced and the increase in data traffic and user throughput can be handled by simply strengthening the IP transport network. Since the network is configured with generic routers and switches, this approach enables achieving a flexible, economical facilities design.

4.2 Protocol Stack

The User-Plane (U-Plane) protocol stack between IP-BTS, IP-RNC, and xGSN for packet communication is shown in **Figure 4**. The protocol stack for the Iur and Iub interfaces is shown in **Figure 5**. User Datagram Protocol (UDP)/IP is used for the transport protocol of each interface.

As for the Iu interface to xGSN, instead of applying the same configuration to the existing system, i.e. Iu to xGSN via Mobile Multimedia switching System (MMS), IP-RNC applied a direct connection through the IP interface. In addition, the Iur connection in the case of handover between RNCs utilizes direct transfer by IP instead of routing the data through MMS. This reduces the processing load on the MMS and the bandwidth bottleneck caused by the ATM transfer, thus also improving throughput. Furthermore, the control procedure described below allows transfer of user data without even passing through the Drift RNC[*14] when the Serving RNC[*15], the Drift RNC, and the BTS are all IP nodes.

4.3 Connection Procedures

Examples of the Iub section connection procedures are shown in **Figure 6** for connection between ATM nodes and in **Figure 7** for connection between IP nodes. Each system is logically divided into an Radio Network Layer (RNL)[*16] function and a Transport Network Layer (TNL)[*17] function. The RNL is as independent as possible of the difference in transport mode (ATM/IP), while TNL performs control specific to the transport,

*10 **OSDL**: An organization established in December 2000 to promote the use of Linux in businesses. Provides technical information and a testing environment to the Linux developer community.

*11 **Iu**: The name of a logical interface defined in the 3GPP standard specifications to serve as the interface between the RNC and the Mobile Switching Center (MSC) circuit-switching exchange and between the RNC and the Serving General packet radio service Support Node (SGSN) packet-switching exchange.

*12 **Iub**: The name of a logical interface defined in the 3GPP standard specifications to serve between the NodeB (base station) and the RNC.

*13 **Iur**: The name of a logical interface between RNCs defined in the 3GPP standard specifications.

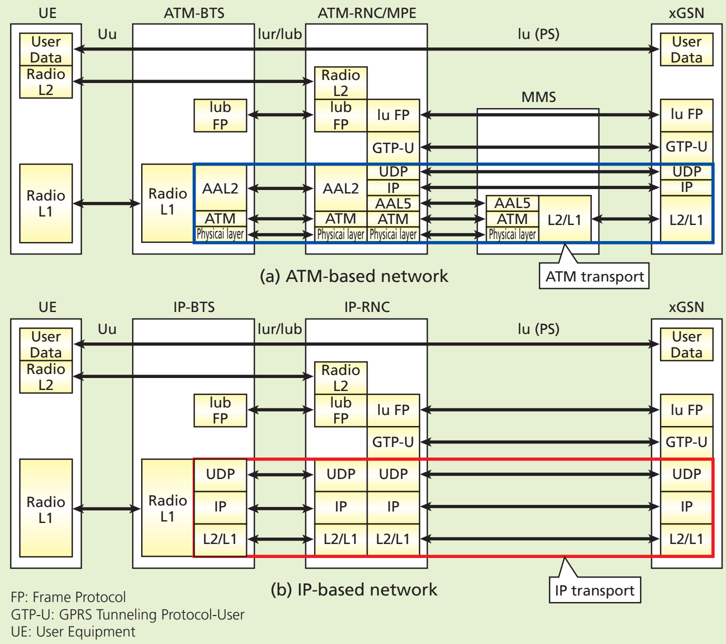

Figure 4 U-Plane protocol stack for packet communication

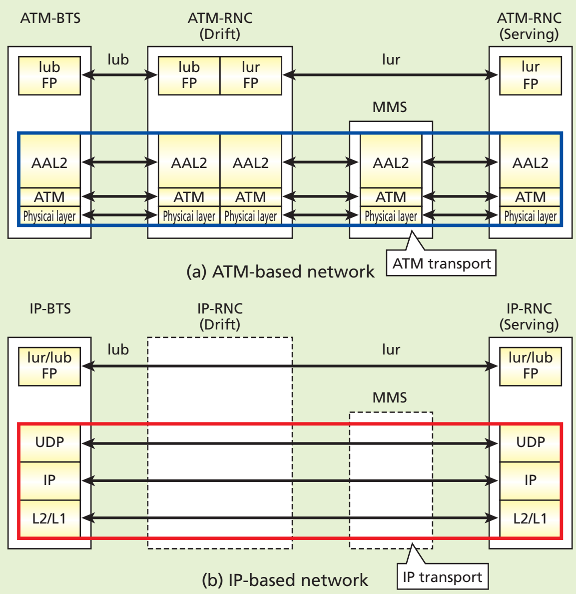

Figure 5 U-Plane protocol stack for the Iur/Iub sections

i.e. ATM or IP.

The connection procedures for connections between ATM nodes and connections between IP nodes are described below.

1) Between ATM Nodes

For connections between ATM nodes, the RNL radio link settings and the TNL connection settings are done independently, and the correspondence between the RNL and TNL is indicated by an identifier called the Binding ID (BID).

First, the RNL of the RNC sends a radio link setup request over Node B Application Part (NBAP)*18, which is the RNL signaling protocol (Fig. 6 (1)), and then the RNL of the BTS issues a BID and includes it in the response (Fig. 6 (2)). The RNL of the RNC then sends a connection setup request that contains the BID to the TNL (Fig. 6 (3)), which uses the ATM Adaptation Layer type 2 (AAL2)*19 signaling protocol to send a connection setup request that assigns a Channel IDentifier (CID) for distinguishing the AAL2 connection (Fig. 6(4)). Here, if there is an intermediate TNL circuit terminating equipment, an AAL2 connection setup request is sent for each section. The TNL of the BTS that receives the AAL2 connection setup request passes the BID that is contained in the message to the RNL (Fig. 6(5)). The RNL then uses that BID and the BID issued in Fig. 6(2) to identify the correspondence of the RNL radio link and the TNL AAL2 connection.

2) Between IP Nodes

For connections between IP nodes, the procedure of the AAL2 signaling protocol, which includes transport bearer setup and release, can be omitted. Because IP is a connectionless protocol, unlike ATM, the TNL connection setup can be accomplished by the simple exchange of end-to-end address information. The RNL signaling protocol (NBAP) is sufficient for that

*14 **Drift RNC**: Logical name for the RNC function that governs resource management. Cooperates with the Serving RNC to execute control during handover between RNCs.

*15 **Serving RNC**: Logical name for the RNC function that governs call control. Cooperates with the Drift RNC (see *14) to execute control during handover between RNCs.

*16 **RNL**: The radio network layer in the 3GPP standard layer structure.

*17 **TNL**: The transport network layer in the 3GPP standard layer structure.

*18 **NBAP**: The Iub signaling protocol.

*19 **AAL2**: One type of adaptation layer between the ATM layer and the layer above it.

purpose.

The RNL of the IP-RNC sends a connection setup request to the TNL (Fig. 7(1)) to obtain the IP address and UDP port number that will serve as the address information (Fig. 7(2)). It then sends that information to the IP-BTS in the radio link setup NBAP signal (Fig. 7(3)). The RNL of the IP-BTS sends a connection setup request to the TNL to provide the address information for the IP-RNC side (Fig. 7(4)) and to obtain the IP address and UDP port number address information from the TNL in the same way as was done in the IP-RNC (Fig. 7(5)). The RNL then sends the address information to the IP-RNC in the NBAP response signal (Fig. 7(6)). The RNL of the IP-RNC then sends the IP-BTS address information to the TNL (Fig. 7(7)) and the procedure is completed.

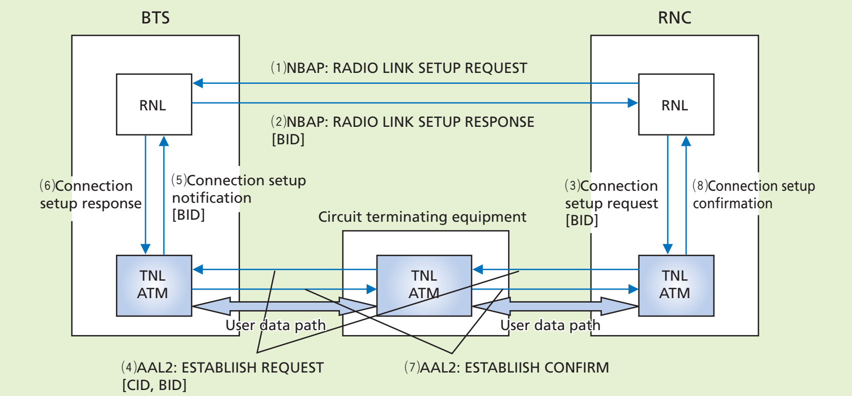

Figure 6 Example of lub section connection control between ATM nodes

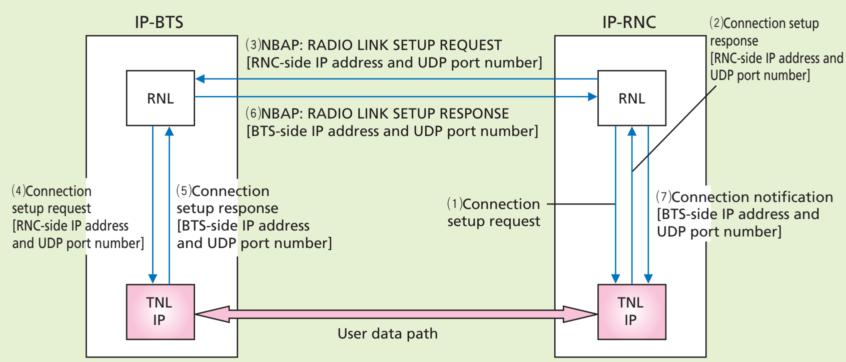

Figure 7 Example of lub section connection control between IP nodes

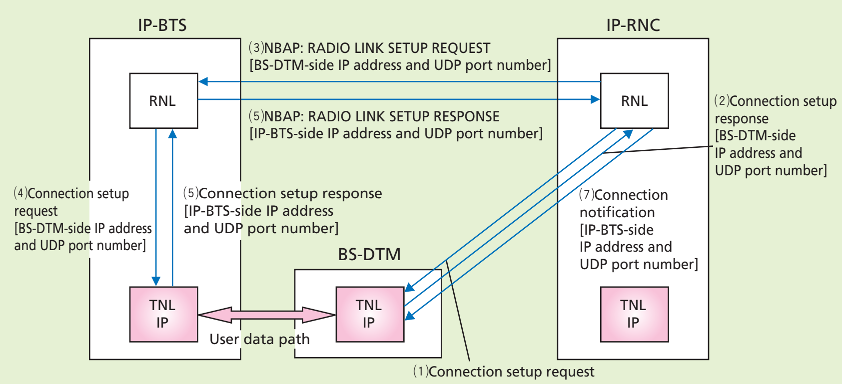

Figure 8 Example of connection control for U-Plane path fold-back by BS-DTM

4.4 Special Control Techniques

Upon the introduction of IP transport, we developed a connection control that makes use of the connectionless characteristic of IP. Two typical examples are described below.

1) Remote U-Plane Connection Setup by the BS-DTM

Separating the TNL function out from the IP-RNC as an independent BS-DTM system that is operated remotely from the IP-RNC allows a form of connection in which the U-Plane path for the communication between FOMA terminals is connected at the site of the base station. This approach lowers transport path cost and enables the provision of the OFFICEED service.

In the connection procedure, the RNL of the IP-RNC obtains the address information from the BS-DTM rather than from its own TNL and sends it to the IP-BTS. The RNL also sends the address information received from the IP-BTS to the BS-DTM (**Figure 8**). In this way, the IP-BTS connection setup from the BS-DTM can be completed without any

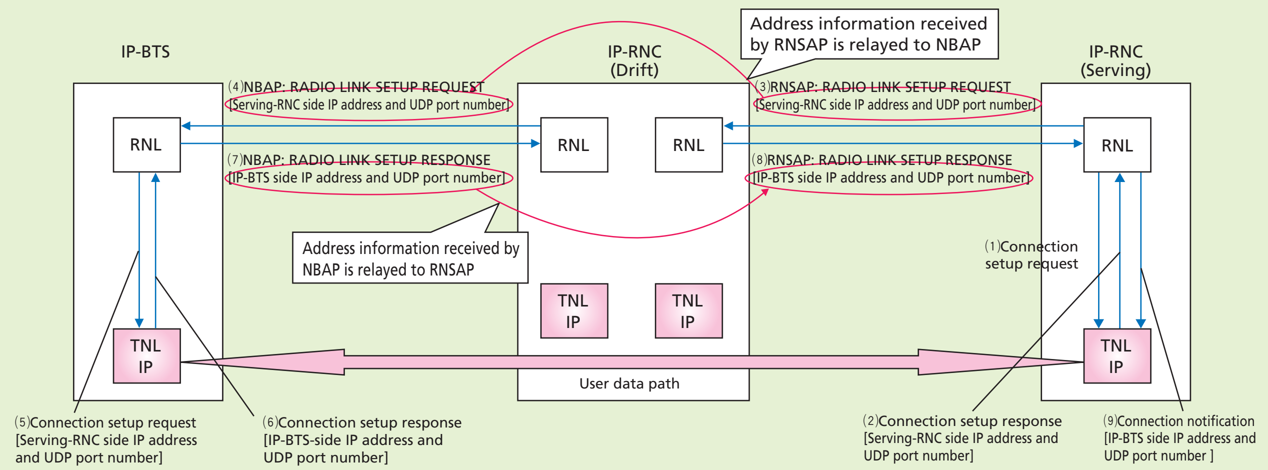

Figure 9 Example of Iub section connection control for direct transfer of Iur/Iub user data

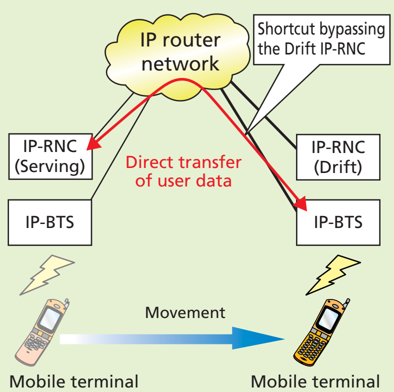

Figure 10 Direct U-Plane transfer on the Iur and Iub section

changes to the procedure between IP-RNC and IP-BTS.

2) User Data Direct Transfer of the Iur and Iub Sections

When the Serving RNC, the Drift RNC, and the BTS are all IP nodes, the address information received from the Serving IP-RNC via the Radio Network Subsystem Application Part (RNSAP)[*20] in the control procedure is relayed to NBAP in the Drift IP-RNC, and conversely, the address information received from the BTS via NBAP is relayed to RNSAP to accomplish connection control (**Figure 9**).

In this case, the user data does not pass through the Drift IP-RNC, but is transferred directly by IP between the Serving IP-RNC and the BTS (**Figure 10**). This contributes to reduction of the processing load and the bandwidth in the Drift IP-RNC.

5. Accommodation of IP-based RAN Systems in an IP Network

To allow IP network accommodation of the IP-based RAN systems, which includes IP-RNC, commercially available IP routers and switches are applied. The functions implemented in this system are described below.

1) QoS Control

Quality of Service (QoS)[*21] control is supported in the FOMA radio access network as an ATM function based on a priority assigned to each service. In the IP-based RAN, QoS control is supported by IP routers on the basis of different Diff-Serv Code Point (DSCP)[*22] values assigned for each service type by the IP-RNC, IP-BTS, BS-DTM, etc. The IP router performs bandwidth control according to the priority distinguished from the DSCP value given to each packet, thus achieving highly efficient data transfer while maintaining service quality.

2) Increasing Network Reliability

A function for minimizing the effects of the failure of an IP network device or other IP network failure is supported by the adoption of the Open Shortest Path First (OSPF)[*23] dynamic routing protocol, which rapidly selects an alternate path around the failure.

3) IPSec

For the systems that are installed on the user site, such as the IP-BTS and BS-DTM, IP Security (IPSec)[*24] is applied between them and the routers to maintain data integrity and confidentiality.

6. Conclusion

We have explained the purposes of introducing the IP-RNC for implementing control of the FOMA IP-based RAN. We

*20 **RNSAP**: The Iur signaling protocol.

*21 **QoS**: A level of quality on the network that can be set for each service. The amount of delay or packet loss is controlled by controlling the bandwidth that the service can use.

*22 **DSCP**: A code that determines the operation of routers, etc. to execute transmission processing that matches a service by distinguishing the types of packets that require the real-time property or high quality.

have also described the system architecture, the IP transport control technology, and the results of system development. The development of the IP-RNC allows reduction of system construction costs by making positive use of generic technology while considering the future functional extension. Introduction of the IP-RNC allows economical and flexible expansion of FOMA network capacity and service area, and also makes possible the construction of a foundation for the provision of new solutions such as OFFICEED and even more advanced future services.

References

[1] 3GPP TS25.401: "UTRAN overall description."

*23 **OSPF**: A routing protocol that selects routes on the basis of information called 'cost'.

*24 **IPSec**: A protocol for highly secure communication that involves encryption of IP packets and authentication.