Radio Network Control System

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Our radio network control system based on the W-CDMA global standard specifications of the 3GPP (3rd Generation Partnership Project) can provide multimedia services such as voice, TV telephone, packet, and multi-call at a higher quality and higher rate than those of the 2nd generation mobile telecommunication system.
Our radio network control system has a highly flexible and scalable structure. This has been achieved by dividing various functionalities such as diversity handover, common transport channel related transaction, user data transaction with protocol conversion, and bandwidth control based on ATM and other technologies into several transaction units. These transaction units use high-speed RISC processors and closely interact with each other under the control of the application part to achieve various high-performance functionalities. This paper describes the architectures, functionalities, and technologies of our radio network control system.

1. Introduction

These days, mobile telecommunication systems are in widespread use and a large number of people are using a variety of handy mobile terminals in various situations. Multimedia services such as audio and visual services as well as traditional voice services have become very important for the future growth of the market. The large variety of services that will become available in the future will be achieved by adding more functions, capacity, and bandwidth to the network. Also, a new global standard for the 3rd generation mobile system is needed. Such a standard is being prepared by the 3GPP.

Based on the 3GPP specifications, Fujitsu has developed several radio network control systems, including an RNC (Radio Network Controller) and MPE (Multimedia signal Processing Equipment).[1] The RNC and MPE consist of several types of transaction units, and each unit has unique software and hardware structures for achieving the required functionalities, for example, diversity handover. In this paper, we describe the features and functionalities of the new equipment and the transaction units.

2. Standard specification

The RNC and MPE have the necessary functions specified by the 3GPP and ITU-T to conform to the global standard. **Table 1** shows the main standard specifications of the RNC and MPE.

3. System overview

3.1 System architecture

Figure 1 shows the UTRAN (Universal Terrestrial Radio Access Network) architecture. UTRAN is a conceptual term for the part of the network that contains RNCs and Node Bs between Iu and Uu interfaces.

The RNC is responsible for all radio resources and controls call processing such as connection establishment and diversity handover.

Table 1
Main standard specifications of RNC and MPE.

Category	Function	Organization	Specification
Application layer	RRC	3GPP	TS25.331
	RANAP	3GPP	TS25.413
	RNSAP	3GPP	TS25.423
	NBAP	3GPP	TS25.433
	B-ISUP	ITU-T	Q.2763
	ALCAP	ITU-T	Q.2150.3, Q.2630.1
Transport layer	GTP-U	3GPP	TS29.060
	RLC	3GPP	TS25.322
	MAC	3GPP	TS25.321
	Iu FP	3GPP	TS25.415
	Iub/Iur FP	3GPP	TS25.425, TS25.427, TS25.435
	AAL Type1/2/5	ITU-T	I.363.1, I.363.2, I.363.5
	ATM	ITU-T	I.361
Voice	μ-law PCM	ITU-T	ITU-T G.711
	GSM-AMR	3GPP	TS26.071
Encription	Cipher/ Authentication	3GPP	TS33.102

The MPE is logically located in the UTRAN as a packet data transaction unit and also in the CN (Core Network) as a vocoder.

3.2 RNC structure

To realize a structure that can flexibly adapt to changes in function and capacity, we adopted an architecture in which each function block is separately connected through an ATM (Asynchronous Transfer Mode) switch (**Figure 2**).

RNS has seven function blocks: the CONT (controller), SIG (signalling block), MAC-C (MAC-c/sh transaction block), SCT (splitting and combining trunk), BWC (bandwidth controller), EIF-L (low-speed external interface), and EIF-H (high-speed external interface).

Each function block is connected to the SW (switch) via the HWY (highway), which is commonly used by all function blocks for cost reduction. Details of these function blocks are given below.

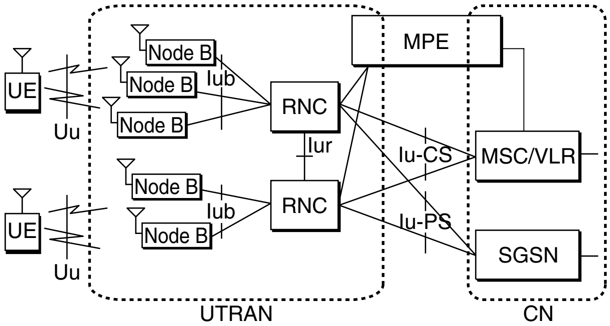


Figure 1
UTRAN architecture.

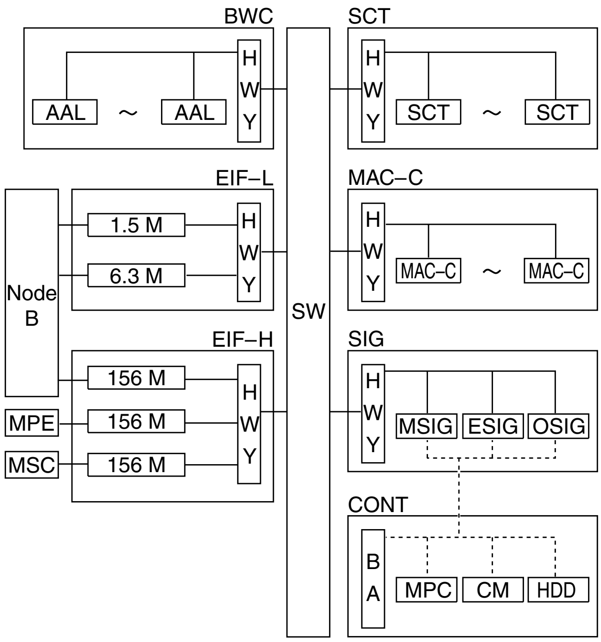


Figure 2
RNC structure.

3.3 MPE structure

To achieve the high flexibility mentioned above, our MPE has basically the same structure as an RNC (**Figure 3**). Also, except for the PCVT (protocol converter), our MPE uses the same function blocks as an RNC. This enables common development and therefore leads to cost reductions and easier maintenance. The PCVT is functionally identical to the MPE and performs protocol conversion between the CN and UTRAN for voice, packet, and N-ISDN services. Details of the PCVT are given below.

3.4 Specifications

The specifications of the RNC and MPE are shown in **Table 2** and **Table 3**, respectively.

3.5 Appearance

Figure 4 shows photographs of the RNC and MPE. The units basically consist of two racks, but the MPE has an additional transaction rack for future capacity expansions.

4. Technologies

4.1 Software

The main feature of our RNC software is that it has a hierarchical structure to enable stable and efficient call processing and O&M (Operation & Maintenance) functions. The structure consists of the application part, middleware, and signalling block (SIG) (**Figure 5**).

The RNC application part deals with the application protocols specified by the 3GPP (e.g., RRC, NBAP, RANAP, and RNSAP) and those that are specified by the ITU-T (e.g., B-ISUP and ALCAP) which are controlled by the APC (Application Protocol Controller).

A Fujitsu-created middleware is built into the application system to provide an API between a common application and our own equipment. This middleware also autonomously supervises the function blocks in the equipment.

The hierarchical structures of these applications enables stable and efficient call processing and O&M functions.

These applications transmit and receive signalling messages to and from other nodes through the SIG (signalling block) in the RNC. The SIG consists of an MSIG, ESIG, and OSIG. The MSIG contains an RLC and implements a ciphering function to achieve reliable transport of RRC signalling messages between RNC applications and the UE (User Equipment). The ESIG deals with all other signalling messages between the RNC and other network nodes such as other RNCs (RNSAP), Node Bs (NBAP), CNs (RANAP/B-ISUP), and MPEs. The ESIG also deals with control/supervision messages between the RNC applications and each function block in the RNC. The OSIG transmits and receives control signals between the main controller and the operation equipment via Ethernet in order to exchange various O&M

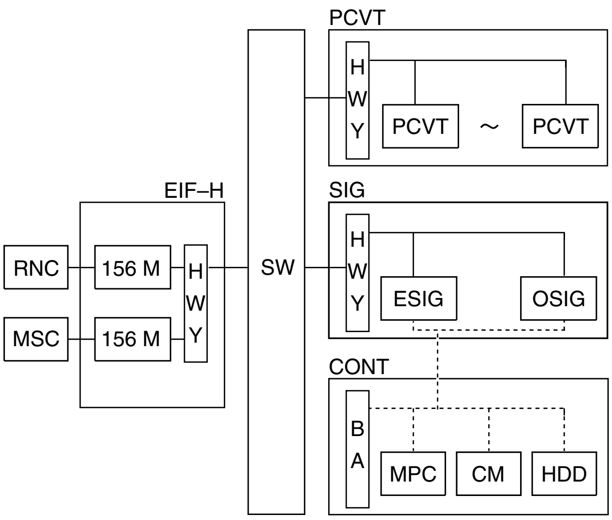


Figure 3
MPE structure.

Table 2
RNC specifications.

Category	Sub-category	Specification
Line interface	Node B IF	1.5 Mb/s (TTC JT- I431-a, ITU-T G804) 6.3 Mb/s (TTC JT-G703-a, ITU-T G.804) 155 Mb/s (TTC JTG-957, 707)
	Iu IF	155 Mb/s (TTC JTG-703, 707)
	MPE IF	155 Mb/s (TTC JTG-703, 707)
	Operation system IF	100Base-TX
Maintenance interface	PCMCIA TYPEII/III	Flash memory
	Debug interface	100Base-TX RS-232C
	Storage medium	Hard disk

Table 3
MPE specifications.

Category	Sub-category	Specification
Line interface	RNC/Iu IF	155 Mb/s (TTC JTG-703, 707)
	Operation system IF	100Base-TX
Maintenance interface	PCMCIA TYPEII/III	Flash memory
	Debug interface	100Base-TX RS-232C
	Storage medium	Hard disk

information.

The MPE has a Fujitsu-created application and communicates with the RNC or MSC (Mobile Switching Center) through the ESIG in the SIG and with the operation equipment through the OSIG. This communication mechanism and the control/supervision function of each function block in the MPE are similar to those of the RNC.

4.2 Diversity handover

In this system, a UE can communicate with multiple Node Bs simultaneously during handover. The RNC transmits the same data on multiple channels (established in different sectors and cells) to a single UE and combines the data received from the UE on these multiple channels. This diversity handover provides high-quality communication and improves the system capacity. A SCT (Splitting Combining Trunk) unit in the RNC processes this function (**Figure 6**).

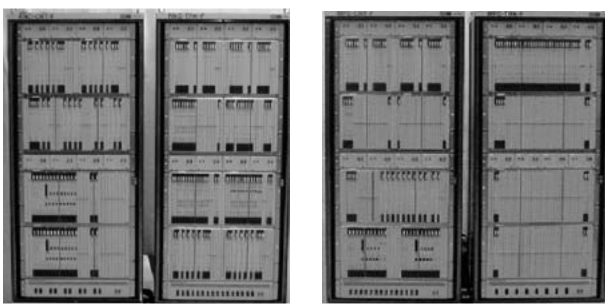
In uplink data streams, data from a UE is received on multiple channels through multiple Node Bs and transferred to the SCT. The data, after being selected in the SCT, is delivered to a function block according to its type. In downlink data streams, data from other function blocks is split into multiple channels.

Selection in the SCT is processed based on the quality of each channel. The quality is determined by the bit error rate, uplink interference, and frame number, which indicates the reception timing. This quality information is continuously measured in the SCT and reported to the application part that uses this information for power control (called outer loop power control) and other purposes to maintain good quality in each channel. When the SCT detects that the measured quality is too poor to continue communicating with the UE, it reports the detection result to the application part and the application part starts error recovery.

Splitting in the SCT is realized by duplicating transmission data and by transmitting the data to multiple channels at an appropriate timing so that several duplicate copies reach the UE simultaneously.

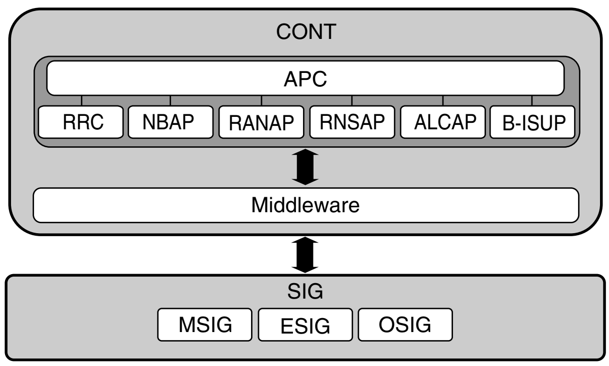
In addition to the handover procedure, the SCT also deals with Iu/Iub/Iur frame protocols by terminating the DCH (Dedicated Channel) transport channel for all services. Furthermore, the SCT ensures that AMR voice communication is reliable by using a cipher/decipher function.

Figure 7 shows the SCT hardware structure. We adopted a hardware-oriented structure in order to realize high-speed data processing. In the SCT, the necessary information is configured onto hardware by software. Then, the hardware con-



(a) RNC (b) MPE

Figure 4
The RNC (a) and MPE (b).



APC: Application protocol controller
RRC: Radio resource controller
NBPA: Node B application part
RANAP: Radio access network application part
RNSAP: Radio network subsystem application part
ALCAP: Access link control application protocol
B-ISUP: Broadband ISDN user part

Figure 5
Software and signalling architecture of RNC.

veys the data, for example, to and from other nodes (Node Bs or UEs) or ciphering transactions, according to the information.

4.3 Common transport channel control and transport channel type switching

In the 3GPP WCDMA standard specification, there are two types of transport channels: common transport channels (e.g., PCHs and FACHs) and dedicated transport channels (e.g., DCHs). Also, many types of logical channels are defined in the 3GPP (e.g., PCCHs, CCCHs, DCCHs, and DTCHs). Logical channels for different kinds of data transfer services are mapped to transport channels. The function for this mapping is provided in an L2 layer called the MAC (Medium Access Control) Protocol, and the mapping function between the logical channels and the common transport channels is provided by the MAC-c/sh (MAC sub-layer), which is implemented in function block MAC-C in the RNC.

The MAC-C mainly provides four functions in cooperation with the MSIG and SW. These functions are scheduling/priority handling, TFC selection, paging, and transport channel type switching (**Figure 8**).

Scheduling/priority handling is a mapping that is done according to channel priority. One or several types of logical channels are mapped onto the same transport channel. Each logical channel has a different priority indicated by a higher layer. The MAC-C multiplexes logical channels into a transport channel according to the priority.

TFC selection is used for Iub communication with Node B. Each transport channel has a transport format set (TFS). The TFS is defined as a set of transport formats associated with a transport channel. The transport format defines the format of data exchanged between the MAC and L1 (Iub interface). When one or several common transport channels are multiplexed into one physical channel, for example, when a PCH and multiple FACHs are multiplexed into a S-CCPCH, the application creates a list of allowable combinations of transport format sets for each physical channel (TFC: Transport Format Combination). The application then sends the list to the MAC-C, which selects the appropriate TFC for each Iub communication.

DCCHs and DTCHs can be mapped to a dedicated transport channel or a common transport channel. The MAC-C can switch the mapping of

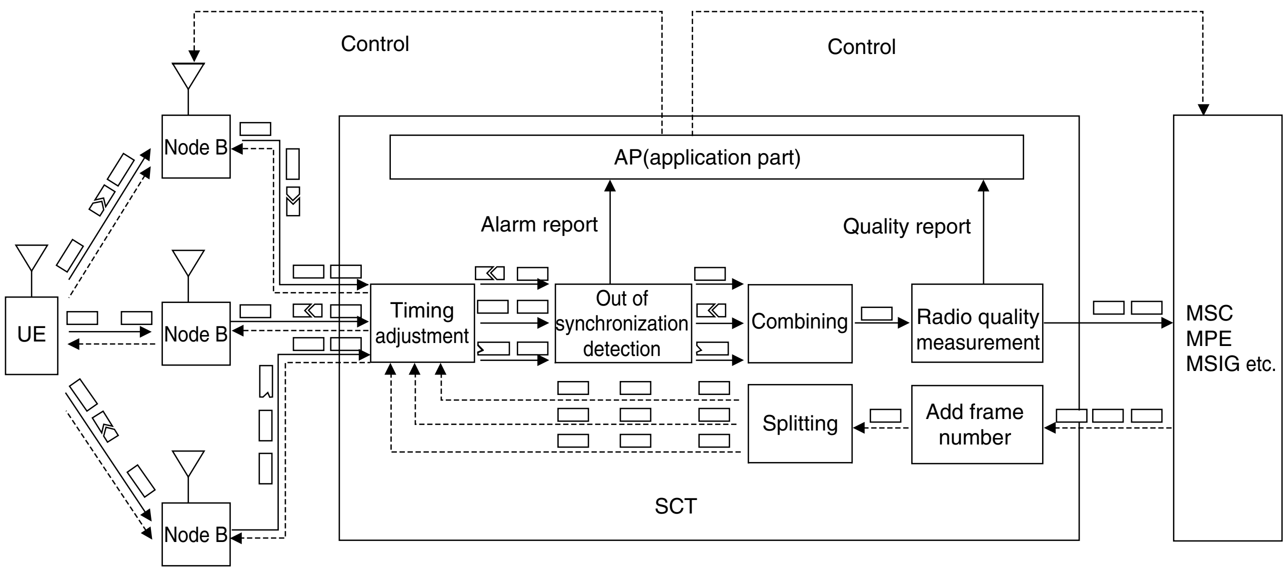


Figure 6
SCT data processing.

a designated logical channel to a dedicated transport channel or a common transport channel if requested by a higher layer (this is called transport channel type switching).

The MAC-C hardware structure is shown in **Figure 9**. The MAC-C mainly consists of the CPU part and the DSP part. The DSP part has most of the functions required in the MAC-C described above, which makes it possible to easily follow the 3GPP's specification changes by updating only the software. The CPU part communicates with a higher layer and transmits/receives the parameters needed for the DSP part.

4.4 U-Plane transaction

In the radio network control system, multimedia data transaction functions are integrated into the PCVT of the MPE to flexibly provide various types of services. The PCVT converts the protocols of the core network into those of the radio access network and vice versa for voice, packet, and N-ISDN services.

For a packet service, the PCVT can provide a ciphering function as well as the protocol conversion. Furthermore, the PCVT continuously measures the amount of downlink transmit data sent to each UE and reports it to the MPE appli-

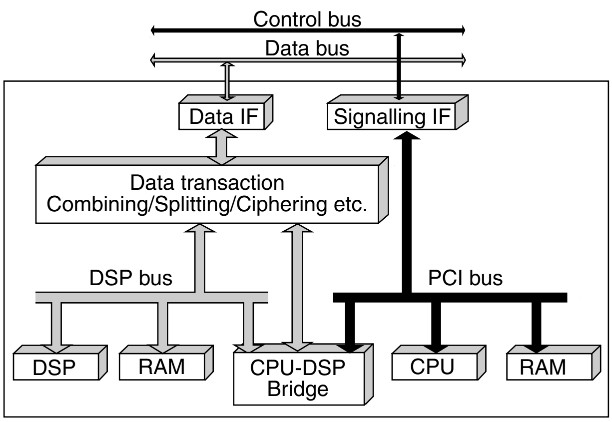


Figure 7
SCT hardware structure.

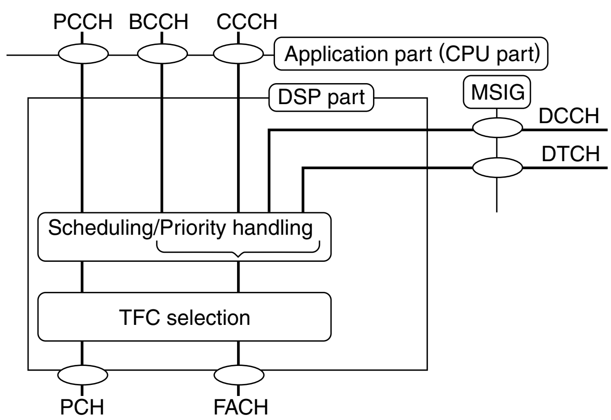


Figure 8
MAC-C related functions.

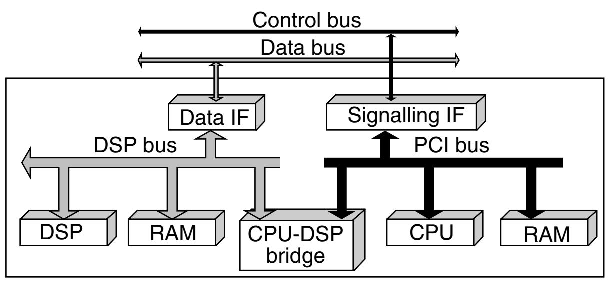


Figure 9
MAC-C hardware structure.

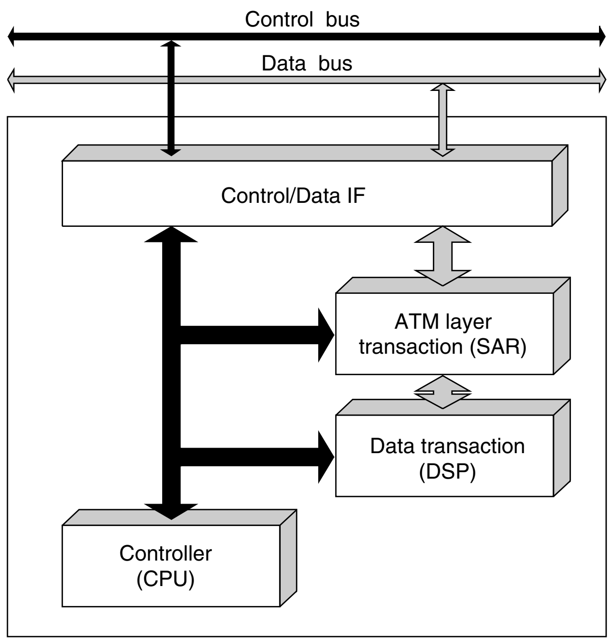


Figure 10
Structure of PCVT.

cation when requested.

The structure of the PCVT and a data transaction in the PCVT are shown in **Figure 10** and **Figure 11**, respectively.

When the PCVT is configured, it can support a service by using selectable software ("Service-dependent" in Figure 11) that processes protocol transactions corresponding to the service and by hardware common to all services ("Service-independent" in Figure 11). This makes it easier to add new services and adjust to different conditions.

In addition, 3GPP-specific functions are realized by the CPU, DSP, and FPGA so that specification changes can be flexibly accommodated.

4.5 Bandwidth control

Signalling data and user data are both transferred by ATM in each interface (e.g., Iub, Iur, and Iu). In ATM, the data packet length is identical (53 bytes) and easy to control in terms of QoS (Quality of Service). ATM is therefore appropriate for transferring data traffic mixed with various services and is advantageous when used in multimedia communication. Especially, AAL2 (ITU-T I.363.2) is used as the user data bearer, which enables efficient use of transport bearer resources by the statistical multiplexing effect. The bandwidth control mentioned below is achieved in the BWC (Bandwidth Controller) unit.

The guaranteed QoS depends on the type of service and must be controlled separately for each service. In our RNC, QoS control is achieved by allocating a different buffer to each QoS class (**Figure 12**). These buffers have two shaping functions. One can control multiplexing of an AAL2 PDU into a virtual channel, and the other can control multiplexing of one or several virtual channels into a single connection. In this way, we can guarantee the QoS class, for example, the cell loss probability and delay, necessary for each type of service.

As shown in **Figure 13 (a)**, if the same bandwidth is independently allocated at every virtual connection with the same QoS class, a data stream that exceeds the allocated bandwidth will cause some of the data in the stream to be discarded,

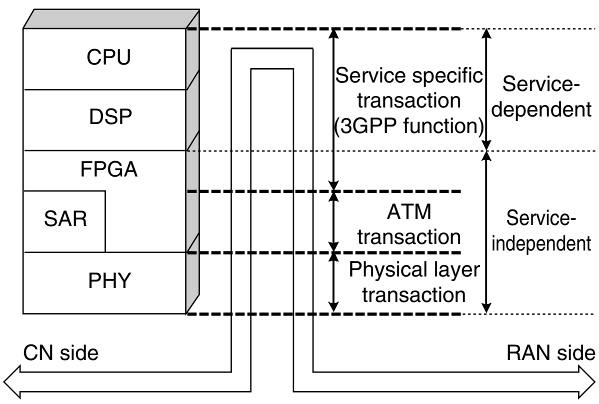


Figure 11
Data transaction in PCVT.

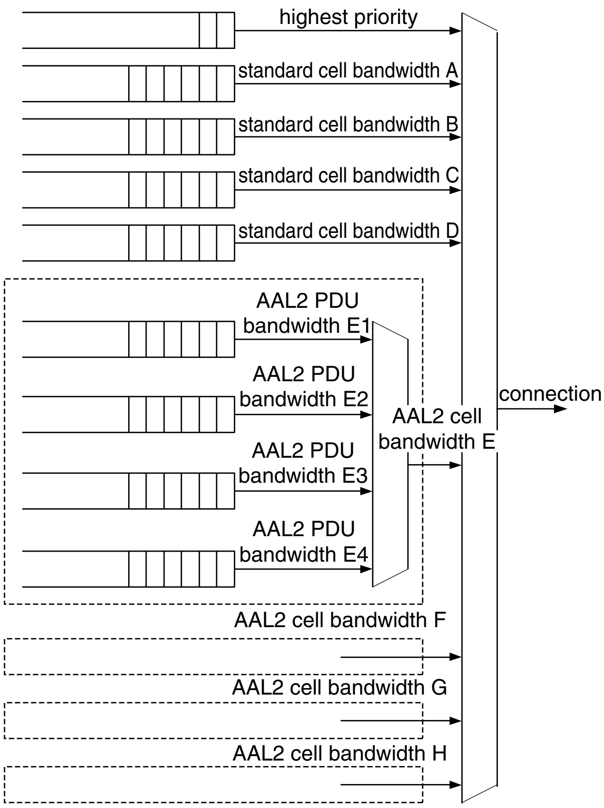


Figure 12
Shaping of different QoS classes.

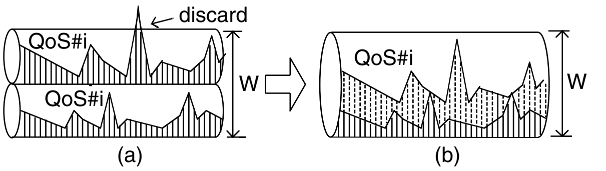


Figure 13
Effect of sharing virtual path by connections with the same QoS.

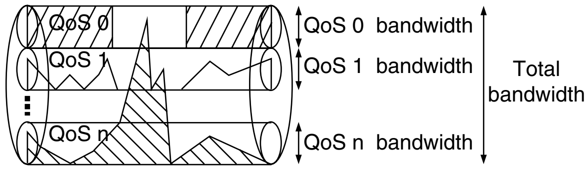


Figure 14
Override method.

even though other connections have low-volume traffic.

Therefore, for efficient use of virtual path resources, bandwidth should be shared by one or several connections with the same QoS class as shown in **Figure 13 (b)**. In other words, bandwidth and traffic should be controlled based not on connection class but on QoS class.

In addition to the bandwidth control mentioned above, our RNC has an override function. In the override method, each connection is configured by specific QoSs and those connections are multiplexed into another connection whose bandwidth is larger than the total bandwidth of those multiplexed connections. When there is no data to transmit in a connection with a certain QoS class, the unused bandwidth can be used by other connections having a best effort QoS class, which enables effective utilization of connection bandwidth (**Figure 14**). This method is based on the fact that, in a best-effort service, although the MCR (Minimum Cell Rate) and PCR (Peak Cell Rate) are not guaranteed, data can be transmitted as long as some bandwidth is available.

5. Conclusion

This paper described the features of the radio network control system and its software and hardware technologies. Our RNC and MPE consist of various function units for realizing high scalability. Furthermore, each function unit in our RNC and MPE has a unique structure for achieving the required functionality so that all transactions are processed effectively and various high-quality services can be provided.

Commercial service using IMT-2000 technology has already started, and the demands for services at much higher bit-rates and lower cost will only increase in the future. The 3GPP is now specifying a new high-speed data communication technology called HSDPA (High Speed Data Packet Access) that will make it possible to transport downlink packet data at about 10 Mb/s in a specific channel shared by several users. In addition, the 3GPP is also investigating the introduction of IP technology into UTRAN with the aim of reducing network costs. The new systems that could come from these efforts would be effective for future mobile communication systems, but they will require more advanced technology. Fujitsu will gradually introduce this technology into its own radio network control systems to provide various services with high quality and reliability and at lower cost.

Reference

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