IP Transport | Miniaturization | Economization

Technology Reports

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

Base Station Supporting IP Transport

To reduce transmission line cost, we developed IP-BTS, a compact indoor base station and a high-density multi-band base station that accommodate IP transmission lines. We describe technology for decreasing the size and weight of the IP-BTS to allow more flexible construction of indoor service areas and technology for higher density in the multi-band BTS to reduce the space needed for base station installation.

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1. Introduction

In the midst of the rising demand for communication at even higher volume and speed to cope with music download and other such services via the FOMA service, there is also a need to reduce communication charges, such as through the introduction of flat rates. In the telecommunication industry, on the other hand, the reduction of network costs by introduction of highly general-purpose IP technology is proceeding rapidly as the Internet becomes more popular. While the conventional Asynchronous Transfer Mode (ATM)[*1] has been used for the transmission line between the Base Transceiver Station (BTS) and the Radio Network Controller (RNC)[*2], conversion of that link to IP is an effective way to economize on the operating cost of the transmission line.

In this article, we describe two units of equipment that adopt IP for the transmission lines, the IP-BTS, which allows flexible and economical expansion of FOMA indoor areas, and the high-density multi-band BTS, which handles multiple frequency bands (2 GHz, 1.7 GHz, and 800 MHz) for outdoor areas.

2. IP-BTS

The IP-BTS is a compact indoor BTS for the FOMA service (**Photo 1**). It was developed for flexible and economical construction of improved-quality FOMA service areas in buildings and underground facilities that are not easily reached by radio signals from outdoor base stations. Being capable of IP transport, it can also be used for corporate-use OFFICEED[*3] in-house communication service, opening up the possibility of tapping a new corporate market.

2.1 Equipment Overview

The basic specifications of the IP-BTS are shown in **Table 1**. This single-carrier 2-GHz band BTS is dedicated for indoor use. In an indoor environment, which differs from an outdoor environment, there is a sufficient space diversity[*4] effect even between two antennas that are not distant from each other, so this equipment is designed for receive diversity [1][2]. Furthermore, effective receiving signals that have a large delay time are not received in

Photo 1 IP-BTS (example)

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

*2 **RNC**: A device defined by the 3GPP for performing radio circuit control and mobility control in the FOMA network.

*3 **OFFICEED**: A flat-rate communication services among group of people pre-registered to an area within IMCS(see *9) -introduced buildings. This makes in-house communications possible with FOMA terminals.

*4 **Space diversity**: A technique for improving receive quality by receiving signals via different signal paths with multiple antennas.

Table 1 Basic specifications of the IP-BTS

Equipment name	IP-BTS	(reference) Conventional compact indoor BTS
Frequency band	2-GHz band	
Number of channels (in case of voice service)	48ch	40 ch (expandable up to 80 ch)
Size	W320 × D45 × H240 mm	W317 × D220 × H400 mm
Power consumption	100W or less	400W or less
Weight	Approx. 3 kg	Approx. 15 kg

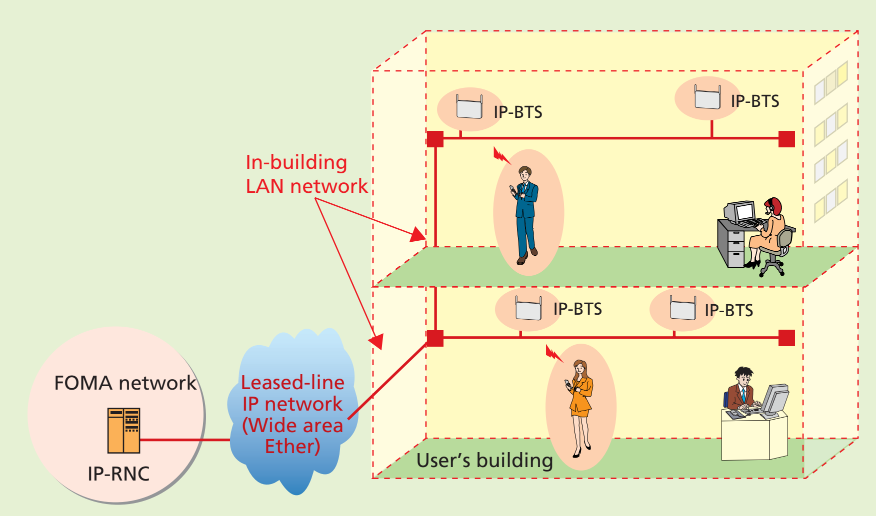


Figure 1 IP-BTS system configuration

an indoor environment, so we reduced the number of paths for Rake reception[*5] synthesis. Because the traffic volume is low, we optimized parameters such as the number of Random Access CHannel (RACH)[*6] Signatures[*7] and the number of simultaneous decoding processes[*8]. We also lowered the transmission output power because of the small service area radius (300 m). By optimizing the specifications of this equipment for an indoor environment, we achieved reductions in size (about 1/6) and weight (about 1/5) relative to the conventional equipment. We also reduced power consumption (about 1/4). These smaller and lighter units can be installed even above ceilings and other places where there are limits on weight, thus allowing more flexible expansion of FOMA indoor areas.

Conversion of the transmission lines to IP makes it possible to construct an In-building Mobile Communication System (IMCS)[*9] by Ethernet connection (LAN cable) in a LAN environment (**Figure 1**). Installation with existing optical fiber requires care because optical fiber is sensitive to stretching and bending, so using LAN cable facilitates installation. For small offices and a small number of users in a service area that includes multiple floors in a building, the signal from the antenna terminal of an IP-BTS can be distributed to multiple floors via coaxial cables. Construction with a Multi-drop Optical Feeder (MOF)[*10] is also possible in the same way as the conventional equipment, and existing facilities can be utilized for the OFFICEED service by replacing the existing BTS with the IP-BTS.

2.2 IP-BTS Technology

To reduce transmission line cost, we implemented new IP technology that differs from the BTS designed for the existing ATM transmission lines. The protocol stacks for between the IP-Radio Network Controller (IP-RNC) or the OPeration System (OPS)[*11] were changed and security measures as well as priority control were implemented.

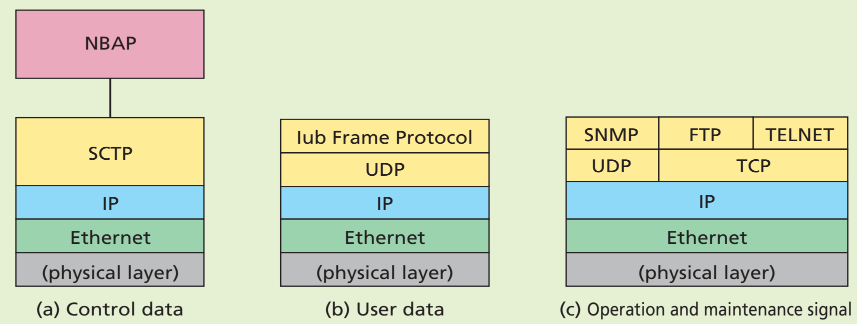
We adopted Stream Control Transmission Protocol (SCTP) for the inter-station control signal protocol and User Datagram Protocol (UDP) for user data. Signal reliability is essential for the control data, so SCTP that has excellent fault tolerance is adopted as a transport layer protocol. For user data, on the other hand, we adopted UDP (**Figure 2**) because the real-time property is more important than signal reliability. Concerning the operation and maintenance signals, equipment status reports and other such information are sent from BTS to OPS with the Simple Network Management Protocol (SNMP)[*12], which is above UDP, control data from OPS are sent by TELNET[*13] over Transmission Control Protocol (TCP), and file uploading and downloading are accom-

*5 **Rake reception**: A technique for improving receive quality by collecting and receiving signals that have different propagation delays and superimposing those signals.

*6 **RACH**: A common up-link channel that is used for transmitting control data and user data. It is shared by multiple users by each user independently and randomly transmitting a signal.

*7 **Signature**: In this article, a code for distinguishing signals from different users in the random access channel.

*8 **Number of simultaneous decoding processes**: The number of signals from users on the random access channel that can be decoded simultaneously.



NBAP: Node B Application Protocol

Figure 2 IP-BTS protocol stack

plished by File Transfer Protocol (FTP)[*14].

Because installation to the user building is assumed, security measures were implemented. As a security measure for the IP transport, IP Security (IPSec)[*15] functions were implemented to prevent eavesdropping and data tampering and to maintain privacy.

We adopted Differentiated Services (DiffServ)[*16] as the priority control function. DiffServ has a function for distinguishing traffic classes such as control data, traffic that requires the real-time property, and traffic that requires high quality, and a function for assigning DiffServ Code Point (DSCP)[*17]. In an IP network, the quality of the network itself is guaranteed by implementing the DSCP priority control function.

3. High-density Multi-band BTS

3.1 Equipment Overview

In response to the increasing number of FOMA service subscribers, we developed the high-density multi-band BTS (**Photo 2**) to succeed the 4-carrier 6-sector BTS[3]. In addition to handling multiple frequency bands (2 GHz, 1.7 GHz and 800 MHz), this BTS has increased device density for efficient use of installation space and realize economization through card integration and large-scale integration. It is also designed for supporting an IP transmission line. The basic specifications of the high-density multi-band BTS are shown in **Table 2**.

3.2 Line-up and Equipment Configuration

In this BTS, an optical interface is used for the connection between the Modulation and Demodulation Equipment (MDE) and the transmission power AMPlifier (AMP) or the Optical Feeder Transmitter and Receiver (OF-TRX)[*18]. The OF-TRX type is used mainly when there is outdoor installation space in the immediate proximity of the antenna; the AMP type is used otherwise. In the conventional BTS, the interface between the MDE and AMP is a coaxial interface. Changing the specifications to an optical interface allows processing by means of a common signal, whether the connected

(a) AMP type (b) OF-TRX type

Photo 2 High-density multi-band BTS (example)

Table 2 Basic specifications of the high-density multi-band BTS

	High-density multi-band BTS		(Reference) 4-carrier, 6-sector BTS	
	AMP type	OF-TRX type	AMP type	OF-TRX type
Carriers and sectors	8-carrier, 6-sector	16-carrier, 6-sector	4-carrier, 6-sector	
Channels (in case of voice service)	Up to 5,760 ch	Up to 11,520 ch	Up to 2,880 ch	
Weight	400 kg or less	300 kg or less	310 kg or less	200 kg or less
Power consumption	12 kW or less	10 kW or less	10 kW or less	5 kgW or less
Size	W795 X D600 X H1,800mm			W795 X D600 X H1,350mm
Transmission line type	<per MDE> 1.5 M, 6.3 M: Max. 4 lines each (ATM) ATM Megalink, MDN: Max. 2 lines each (ATM) 10Base-T/100Base-TX: Max. 2 lines (IP) 1000Base-SX: Max. 2 lines (IP)		1.5 M, 6.3 M: Max. 4 lines each (ATM) ATM Megalink, MDN: Max. 2 lines each (ATM)	
Equipment configuration per rack	AMP X 2 MDE X 2	MDE X 4 (MDE configuration has the same specs for outdoor and indoor)	AMP X 1 MDE X 2	MDE X 2

MDC: Mega Data Netz

*9 **IMCS**: NTT DoCoMo's system that allows communication in places such as high-rise buildings, underground areas and other locations where it is difficult or impossible for mobile terminals to make connections.

*10 **MOF**: A system that uses optical fiber to relay the RF signal of the BTS. It consists of a main unit and remote units.

*11 **OPS**: A system that performs operation and maintenance and control for infrastructure equipment in a FOMA network, such as the core network equipment and radio network equipment.

*12 **SNMP**: A protocol for the monitoring and control of communication devices (router or computer, terminals, etc) on a TCP/IP network.

*13 **TELNET**: Virtual terminal software that allows operation of a remote server from a local computer over a TCP/IP network, or a protocol that makes such operation possible.

equipment is AMP or OF-TRX. We achieve further commonality by adopting the standard Common Public Radio Interface (CPRI) specifications for the optical interface.

The BTS line-up is shown in **Figure 3**. The MDE comprises a MDE basic unit, to which up to four MDE expansion units can be connected. The basic unit comprises a common controller, a supervisory controller, and a call processing controller, while the expansion unit consists of a call processing controller. The ATM transmission line and IP transmission line can be selected freely in units of MDE according to the network configuration. In addition, when the IP transmission line is selected, the OFFICEED service can be provided, so it is suitable for installation in large buildings and other places that cannot be accommodated by several IP-BTSs.

The AMP type was developed for the 2GHz and 1.7GHz bands. Using an optical interface to connect the MDE and the AMP allows a distance of up to 20 km between them, which was not possible with the conventional equipment. That makes possible a centralized installation in a building with the MDE as the base point and only the AMP is installed directly below the antenna. It allows for efficient BTS installation even where there is little installation space.

The OF-TRX has an outdoor type and indoor type. For the outdoor type, we developed three types, for the 2GHz, 1.7GHz and 800MHz bands. The indoor type was developed for MOF connection.

3.3 Achieving Higher Density and Economization

The conventional 4-carrier 6-sector BTS can accommodate up to 2,880 channels in case of voice service, but the high-density multi-band BTS can handle up to twice that with the AMP type (5,760 channels) and four times as many with the OF-TRX type (11,520 channels). A single call processing controller cannot cope with the increased processing load of the call processing according to increased capacity, so this equipment adopts an architecture that distributes the call processing control in units of MDE. The Call Processing CoNTroller (CP-CNT), transmission line interface (HighWaY INTerface (HWY-INT)), Base Band signal processor (BB) and other such equipment is organized in units of MDE. The supervisory controller and the common controller, on the other hand, are centralized in the MDE basic unit to control multiple connected MDE expansion units at once, thus reducing the number of cards per MDE unit. Furthermore, by integrating functions that are implemented with multiple cards in the conventional equipment into a single card and by increasing the processing capability per BB card to reduce the number of cards, a single MDE (which occupies half the installation space of existing equipment) is made capable of accommodating 4-carriers 6-sectors, and 2,880 channels. Concerning the BB, the capacity per card was doubled through the use of the latest and most suitable Digital Signal Processors (DSP)[*19] and Large-Scale-Integrated circuit (LSI) chips. Power consumption was also reduced by about 40% per channel relative to the conventional 4-carrier 6-sector BTS by increasing amplifier efficiency, reducing the power consumption of the BB card, and integrating of the common cards.

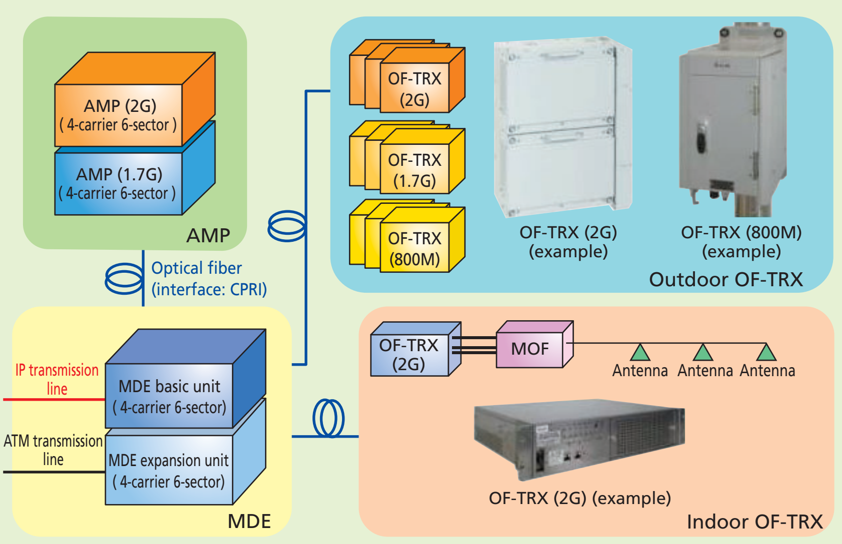


Figure 3 High-density multi-band BTS line-up

*14 **FTP**: A protocol that is generally used for transferring files over a TCP/IP network such as the Internet or an intranet.
*15 **IPSec**: A protocol for highly secure communication that involves encryption of IP packets and authentication.
*16 **DiffServ**: A technique for controlling the order of forwarding processing by assigning priority levels to IP packets.
*17 **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.
*18 **OF-TRX**: A device connected by an optical fiber to the MDE. It can be installed at up to about 20 km from the MDE.

3.4 Implementation of CPRI Technology

1) CPRI Overview

The CPRI used in the high-density multi-band BTS is a specification for the interface between the MDE and AMP or between MDE and OF-TRX which is described in Section 3.2. Both AMP and OF-TRX use CPRI. For the upper layer, which is not defined in the interface specifications, we added specifications such as operation and maintenance to adopt a common interface for the high-density multi-band BTS.

In the CPRI term, the MDE is defined as Radio Equipment Control (REC) and the AMP or OF-TRX is defined as Radio Equipment (RE). For the reason above, the notation REC and RE is used in the following explanation.

2) Equipment Configuration

Figure 4 shows a model of a CPRI. REC is connected to RE by optical fiber (CPRI link), and can be connected to either the AMP or the OF-TRX type, or both. Furthermore, interconnection of units from different vendors is possible. Such flexible configuration can be implemented because the CPRI link supports not only the Radio Frequency processing (RF processing) function, but also the operation and maintenance function.

3) CPRI Protocol Stack

The CPRI protocol stack is shown in **Figure 5**.

The CPRI definition for layer 1 applies either an electrical signal or an optical signal; however, an optical signal is adopted for the high-density multi-band BTS to make long-distance RE connections possible.

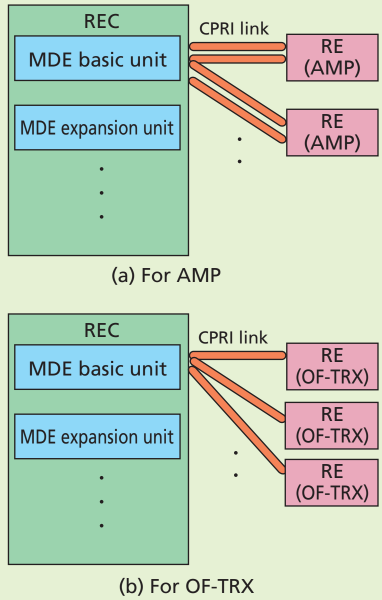


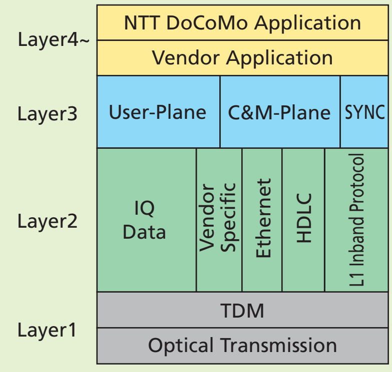
Figure 4 CPRI concept

Layer 2 is defined as follows.

- IQ[*20] Data: Data mapping of user data to digital IQ.
- L1 In-band Protocol: Basic CPRI link negotiation and Layer 1 operation and maintenance.
- Vendor Specific: Free area available to the user.
- High-level Data Link Control procedure (HDLC)[*21]: Used for operation and maintenance signals as the upper layer Control & Management-Plane (C&M-Plane)[*22].

In Layer 3 and Layer 4, the CPRI operation and maintenance functions and call processing functions are implemented by application programs supplied by the vendor or NTT DoCoMo.

4) Configuration of the Radio Transceiver



SYNC: SYNChronization

Figure 5 CPRI protocol stack

The configuration of the radio transceivers of the REC and RE in the W-CDMA Frequency Division Duplex (FDD)[*23] system is shown in **Figure 6**. The radio signals sent and received over the CPRI are transmitted as Time Division Multiplexing (TDM) digital IQ data in units of 1/3.84 MHz for each carrier branch[*24], with one CPRI link per sector. Concerning the functions related to the RF processing [4][5], there are no major differences from the conventional system; however, the design takes flexibility and expansibility in future into consideration with the functional modules of the REC and RE, as shown in Fig. 6. The specific special features are described below.

The transmission speed depends on the number of carrier branches supported by the RE and the bit rate of the IQ data per carrier branch. However, since the bit definition does not change, even for RE that have different numbers of carrier branches, the transmission speed of 1,228.4 Mbit/s is applied regardless of the RE type. Furthermore, because the RF processing functions are all centralized in

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

*20 **IQ**: In-phase and quadrature components of a complex digital signal.

*21 **HDLC**: A data transmission control procedure that provides control in units of bits. It is fast and highly efficient, and makes highly reliable data transmission possible.

*22 **C&M-Plane**: Control and management data between the REC and RE.

*23 **FDD**: A bidirectional transmit/receive system. Different frequency bands are allocated to the uplink and downlink to enable simultaneous transmission and reception.

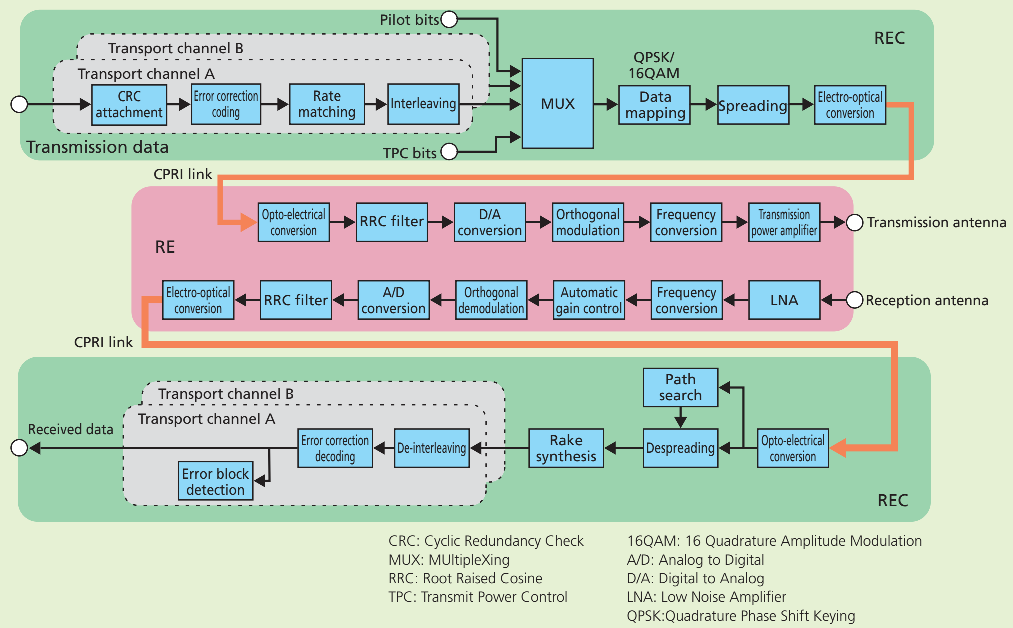

Figure 6 Radio transceiver configuration

the RE and all of the CPRI signals in the upper layer are common, it is possible to cope with any changes in the radio frequency, maximum transmission output power, number of carriers handled and other such factors by simply changing the RE RF processing function module.

4. Conclusion

Towards economizing the transmission line cost, we developed an IP-BTS and a high-density multi-band BTS as the BTS supporting IP transport.

We have described IP technology applied to the transmission line as well as technology for a smaller and lighter IP-BTS for flexible construction of an indoor service area, technology for a high-density multi-band BTS to reduce the space needed for base station installation, and technology for the adoption of CPRI in the interface between the MDE and AMP or OF-TRX. We intend to continue the pursuit of even a smaller, lighter and higher-density BTS using the newest technology for flexible FOMA area construction and economical expansion of system capacity in the future.

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*24 **Carrier branch**: Carrier indicates frequency; in FOMA, it represents frequency in units of 5 MHz bandwidth. Branch refers to the antenna.