

# Evolved Node B on LTE System for NTT DOCOMO

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**Fujitsu has developed an evolved Node B (eNodeB) for the Long Term Evolution (LTE) mobile communication system of NTT DOCOMO in Japan. LTE provides at least 100 Mb/s of transmission throughput per piece of user equipment, which is a protocol for 3.9G mobile communication. The eNodeB was developed while taking into consideration its miniaturization, improved maintainability, and easy functional extension in addition to the effective utilization of existing facilities. As a result, Fujitsu has miniaturized the eNodeB by aggregating and optimizing functions, given it a configuration that can be shared with 3G systems and enhanced it by conducting only a software upgrade. This paper outlines the functions of this eNodeB, and the features of the installed hardware and software technologies.**

## 1. Introduction

Fujitsu has developed wireless base station equipment evolved Node B (eNodeB), which provides major infrastructure equipment for the Long Term Evolution (LTE) service called “Xi” (Crossy)<sup>note)</sup> started by NTT DOCOMO in December 2010 in Japan.<sup>1)–3)</sup>

In the development of eNodeB, it was designed based on a concept of miniaturization and improved maintainability by aggregating functions to be incorporated, effective utilization of existing facilities (3G base station facilities) and flexibility to allow easy functional extension.

This paper outlines the LTE wireless system and presents the configuration and features of eNodeB based on the concept described above.

## 2. Outline of LTE wireless systems

LTE uses the following wireless systems for greater frequency utilization efficiency and realization of a high throughput.

- 1) Wireless access system robust in multi-path environment

In mobile communication systems in general, multiple signal paths with varying signal arrival times exist due to signal reflection and diffraction caused by obstacles in wireless transmission paths. This is known to cause a deterioration of communication quality resulting from mutual interference with direct waves. A condition in which multiple wireless signal paths exist is called a multi-path environment.

As wireless access systems, LTE uses orthogonal frequency division multiple access (OFDMA) for downlinks from eNodeB to user equipment (UE) and single carrier-frequency division multiple access (SC-FDMA) for uplinks from UE to eNodeB. OFDMA is capable of mitigating the influence of frequency selective fading by transmitting multiple narrow-band carriers called subcarriers in parallel. It can also effectively suppress intersymbol interference by prefixing a signal symbol with a guard interval called cyclic prefix (CP). For this reason, it characteristically provides robust transmission

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note) “Xi” (Crossy) and its logo are trademarks or registered trademarks of NTT DOCOMO.

in a multi-path environment as compared with a single-carrier system.

For uplinks, SC-FDMA is used because it can minimize the peak-to-average power ratio (PAPR), which is high and poses a problem with OFDMA, and is effective for reducing the power consumption of UE.

## 2) Adoption of adaptive modulation and coding

For modulation, LTE uses three schemes: quadrature phase shift keying (QPSK), 16 quadrature amplitude modulation (16QAM) and 64 quadrature amplitude modulation (64QAM). In addition, adaptive modulation and coding (AMC) technology is used, which allows dynamic switching between these modulation schemes according to the communication quality between eNodeB and UE. With this technology, each piece of UE can obtain services with the optimum transmission capacity and communication quality according to the physical location, state of movement and surrounding environment at a given time.

## 3) MIMO technology

Multiple input multiple output (MIMO) is a multiple-input and multiple-output system that uses array antennas for both transmission and reception to transmit information. The present eNodeB developed uses  $2 \times 2$  MIMO technology for downlinks to achieve a downlink transmission throughput of at least 100 Mb/s per piece of UE in the 20 MHz band by combining multilevel modulation technology.

# 3. Configuration and features of eNodeB

The following subsections describe the configuration and features of the eNodeB that has been developed.

## 3.1 Equipment configuration

The eNodeB is composed of base station digital processing equipment (BDE), which includes an equipment controller (CNT) card that performs call control and monitoring control, a

baseband (BB) card for baseband processing and CPRI demultiplexer (CMUX) card that performs common public radio interface (CPRI) demultiplexing, and radio processing equipment (RE).

A simple architecture that realizes miniaturization and easy maintenance of the equipment has been adopted. This was made possible by functional aggregation to significantly reduce the types of cards mounted as compared with the existing Fujitsu equipment.

For connecting between the BDE and RE, a base station standard optical interface called CPRI interface is used.<sup>4)</sup>

The configuration of eNodeB is shown in **Figure 1**, its appearance in **Figure 2** and its specifications in **Table 1**.

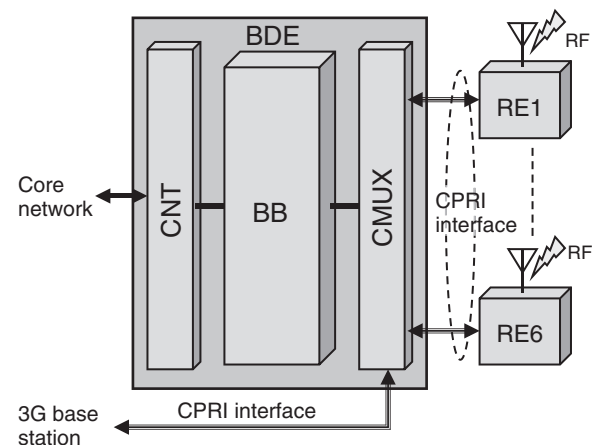


Figure 1  
Block diagram of eNodeB.

Table 1  
eNodeB specifications.

Item	Specifications
No. of sectors/carriers	1 carrier $\times$ 6 sectors
System bandwidth	5, 10, 15, 20 MHz/carrier
Modulation scheme	QPSK, 16QAM, 64QAM
No. of RRC connected users (UE)	840 users/sector
Maximum transmission throughput	Transmission: 150 Mb/s ( $2 \times 2$ MIMO) Reception: 50 Mb/s
Equipment size	600 $\times$ 600 $\times$ 1135 mm

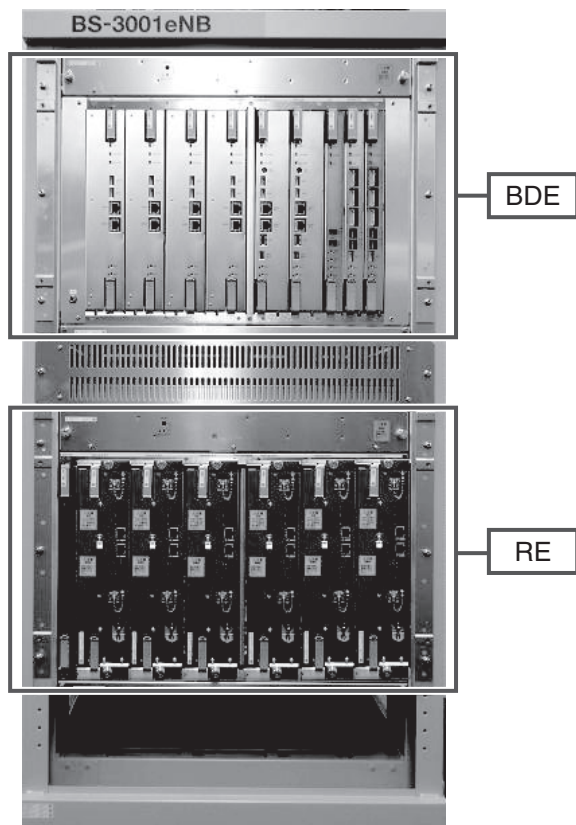


Figure 2  
Appearance of eNodeB.

### 3.2 Configuration for shared use with 3G services

As shown in Figure 1, the CMUX card, which is connected with third-generation (3G) wireless base station equipment (base transceiver station: BTS) via a CPRI interface, demultiplexes 3G IQ signals (W-CDMA signals) and eNodeB IQ signals (OFDMA/SC-FDMA signals) in the CMUX card to transmit to the RE. The RE collectively performs distortion compensation, A-D conversion and amplification of the 3G/LTE signals received. Shared processing of 3G/LTE signals in the RE allows 3G/LTE overlay service in the same cell area using the same antenna to be realized with minimum facility changes.

For details of the features of the RE, see “High-Efficiency Power Amplifier for LTE/W-CDMA System” contained in this magazine.

The following sections describe the features of the major functional parts of the BDE.

## 4. Baseband processing functions (BB)

### 4.1 Baseband functions

A BB card that realizes baseband functions is equipped with processing functions for the following four layers.

- 1) Physical layer (AMC, multilevel modulation, MIMO, etc.)

In the physical layer, the most suitable modulation and coding schemes and antenna multiplexing are performed according to the scheduling information from the medium access control (MAC) layer. As transmission/reception methods, single-antenna transmission, diversity transmission and reception and closed-loop and open-loop MIMO transmission are supported.

- 2) MAC layer

In the MAC layer, mapping is performed between logical channels, where the types are classified according to the content of the information transmitted/received, and transport channels, where the types are classified according to the transmission scheme in the wireless interface. In addition, based on the information including the downlink reception quality and the number of users connected, user allocation to wireless resources and priority are determined for the optimum resource assignment. In an environment with poor wireless conditions, transmission with the quality maintained is realized by retransmission/reception combining processing using hybrid automatic repeat request (HARQ).

- 3) Radio link control (RLC) layer

In the RLC layer, data transfer is conducted between the UE and eNodeB after conversion into the most suitable format according to the service. Three modes including the acknowledged mode (AM) provided with the retransmission function by ARQ, the unacknowledged mode (UM), which does not have the retransmission function and is characterized by small delay, and the transparent mode (TM) without overhead are used.

- 4) Packet data convergence protocol (PDCP)

layer

In the PDCP layer, IP packet headers are compressed and decompressed for efficient use of wireless resources. In addition, secrecy processing by data encryption and decryption is performed to ensure security in wireless sections.

#### 4.2 Adoption of digital signal processors (DSPs)

For baseband processing, DSPs, which excel in signal processing, are generally used. In the physical layer, however, dedicated LSIs were conventionally used. For this reason, specification changes or addition of functions in line with the standardization trends require hardware changes.

To avoid this situation, the latest multicore DSPs have been used for all baseband functions in the present development, thereby realizing software-defined radio (SDR).

The benefits of using high-performance multicore DSPs include:

- 1) Easy distribution of cores to run for each function or process.
- 2) Capability of processing division resulting from changes of bands and the number of sectors to accommodate.
- 3) Availability of resources from sectors with reserve capacity: In a situation in which resources are concentrated on a specific sector, the total number accommodated can be improved by distributing resources from other sectors.
- 4) Realization of a configuration allowing resource sharing: This is ideal for processing of scheduling, which, of the baseband processing, may have an especially large variation of throughput depending on the load.

#### 4.3 Hardware configuration

One feature of the hardware configuration is that all DSPs are connected using high-speed interfaces of 10 Gb/s via switching devices.

By adopting this configuration, all DSPs can communicate with each other. This allows addition and reduction of DSPs according to the size of the system required and any accompanying change of functional layout.

### 5. Equipment control processing functions (CNT)

The major functions of a CNT card include:

- Call connection function

This performs outgoing/incoming connection control and call ending control between the eNodeB and UE

- Equipment monitoring control function

This monitors the state of equipment for any abnormality and controls the state.

- Transmission path interface function

This is intended for IP protocol termination processing and security processing for communication secrecy in inter-station transmission paths.

In the conventional equipment, the functions described above were separately implemented in five cards. With the present CNT card we have developed, these functions are aggregated in one card for miniaturization and improved maintainability of the equipment.

To aggregate functions in a CNT card, software processing must satisfy the performance requirements and the number of mounted parts must be reduced. To meet these requirements, the present CNT card has adopted high-performance multicore processors, which has allowed parallel execution of various functions of the software and achieved high processing performance. In addition, the conventional hardware processing can now be performed by software, which has successfully minimized the number of mounted parts.

For main signals, a high-speed serial transmission scheme is used. Functional aggregation results in an increased number of signals. However, use of this scheme allows the number of signal lines to be reduced to

about 1/4 of the conventional system and high-density mounting in the card and a configuration integrating multiple interfaces between cards into one card have been realized.

## 6. Software structure

The software installed in the CNT card performs call processing and monitoring control processing as eNodeB and has an execution environment that allows programs of various hardware control functions and protocol control functions to be run in real time.

The software structure is composed of some application programming software (APL) to control the main functions of eNodeB (such as communication and monitoring processing), a platform (PF) to control the functional parts based on control requests from the APL, an operating system (OS) and drivers (**Figure 3**).

The APL and PF are connected via application programming interfaces (APIs). By using the APIs, the PF receives and internally processes control instructions from the APL and controls the hardware through the OS and drivers according to the control content, thereby realizing the functions of eNodeB. The PF software developed has a structure that ensures stable operation, accommodates functional enhancement expected in the future, and improves adaptability and versatility to support equipment lineup expansion.

As the OS, Carrier Grade Linux (CG Linux) is used. This is because it allows easy accommodation of various functional protocols in view of speeding up service development and provision, and future functional enhancement and high reliability is strongly required of communication equipment that supports social infrastructure.

The PF layer is roughly divided into the call processing and monitoring control functions and has a functional part configuration capable of parallel processing of control instructions from the APL. This has allowed the required

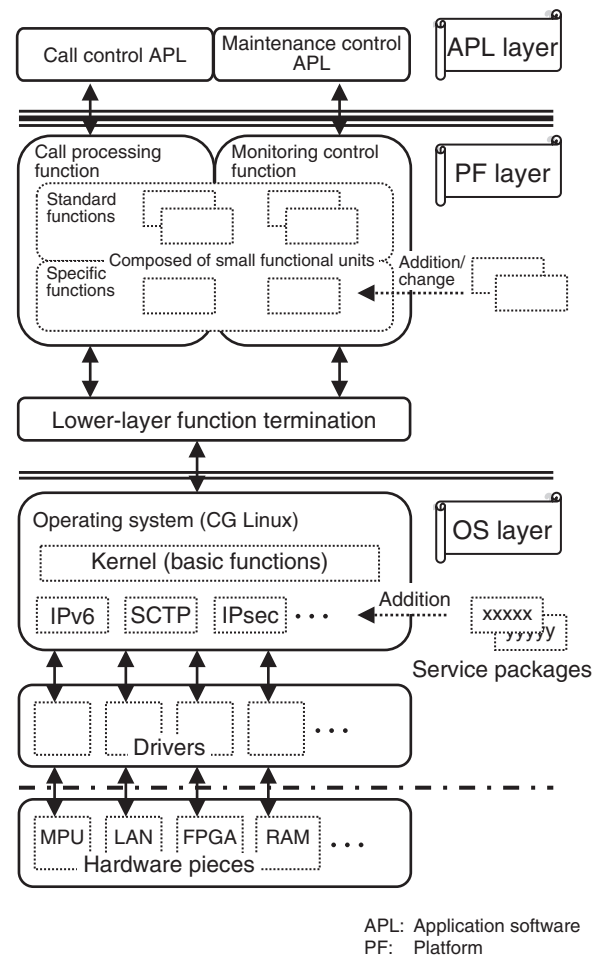


Figure 3  
eNodeB software structure.

call processing capacity and maintenance functions to be realized with high performance. The functional parts of the PF are divided into standard and specific functions, which are further divided into the minimum functional units. In this way, functional parts can be flexibly added or changed and their influence on the related functional parts can be minimized. This has realized a PF structure capable of flexibly accommodating future changes of hardware implementation conditions. In addition, a lower-layer function termination is set up between the PF and OS layers to provide an adapter layer with drivers in charge of controlling the OS and hardware. This has realized a structure where the upper PF and APL layers are unaffected by any change to the hardware/driver or OS.



## 7. Conclusion

This paper has presented the basic structure and technical features of the developed eNodeB.

The eNodeB has positively incorporated current technologies including high-density mounting, SDR implementation of baseband functions using high-performance DSPs and multicore processing of equipment controller. It has thus achieved significant miniaturization and improved the maintainability of the equipment by reducing the types and number of cards mounted. It has also realized an equipment configuration that allows the baseband and communications protocol functions, which are likely to undergo functional enhancement in the future, to be enhanced simply by changing the software.

Furthermore, a CPRI demultiplexing function has been implemented to provide shareability with 3G systems, thereby allowing changes to be made to 3G/LTE frequency carrier allocation by programming when both the existing 3G facilities and eNodeB are installed.

In this way, seamless transition from 3G to LTE services has been made possible.

Fujitsu intends to hand down and evolve the implementation technologies nurtured through the present eNodeB development. In this way, it will provide in a timely fashion a wide lineup of products according to the application ranging from femtocells (for very small mobile phone coverage areas of about several dozen meters in radius) to high-capacity equipment with multiband support. Fujitsu will thus contribute to the future diffusion and development of LTE systems.

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