# High-Capacity BDE Supports the Advancement of Mobile Communications

KONDO Seiji, IMAE Yuki, YOSHIDA Mitsutaka, TOKUNAGA Michita, ISHIKAWA Yasuaki, ITABA Naoto, SHIMOYAMA Yuji, IWASAKI Motoya

## Abstract

The increase in the capacity of mobile communications is being conducted by mixing the macro cells that cover wide areas while using multiple frequency bands with the small cells that cover local cells that support heavy traffic. In order to conduct efficient communications in such an environment, it is necessary to use the C-RAN architecture that can significantly increase the number of cells and the users covered by each base station and implements carrier aggregation with a high degree of freedom. To deal with this need, NEC has developed a high-capacity BDE (Base-station Digital-processing Equipment) and has improved its functionality in several steps. This paper introduces the architecture and the key technologies of high-capacity BDE.

Keywords

mobile communication, base station equipment, capacity increase, C-RAN, carrier aggregation

## 1. Introduction

NEC has developed high-capacity BDE (Base-station Digital-processing Equipment) compatible with the PREMIUM 4G™ service that was started by NTT DOCOMO, Inc. in March 2015.

High-capacity BDE adopts the advanced C-RAN (Centralized Radio Access Network) architecture that deploys the LTE-Advanced (LTE-A) system. This architecture has been proposed by NTT DOCOMO for the heterogeneous network environment, where macro cells covering wide areas and small cells covering local areas that have high population densities and heavy traffic coexist as shown in **Fig. 1**. The aim is for faster transmission and efficient use of wireless resources by advanced cell linkages via the use of carrier aggregation (CA).

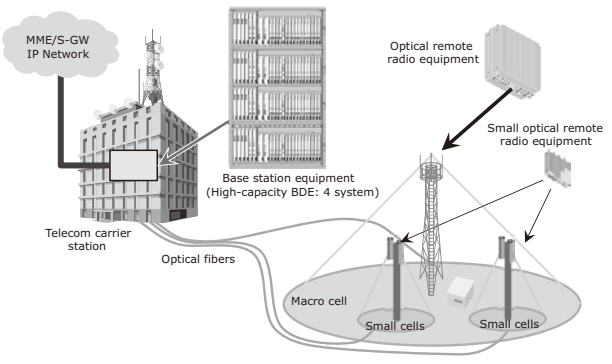


Fig. 1 Usage case.

At NEC, we are studying the application of BDE in public service networks. At present, the public service networks employ low bit rates that are focused on voice communications, while the need for the transmission of large capacity data such as videos is recently tending to increase. Due to this situation, attempts at applying the LTE system to public service networks are increasing. For this application, it is necessary to ensure "network stability" and "flexibility in responding to the production of deviated traffic". It is to meet these needs that we are examining the use of the high-capacity BDE featuring advanced C-RAN architecture.

Below, we outline the configuration of the newly developed high-capacity BDE and the characteristics of its function blocks.

Table 1 Specifications of the high-capacity BDE.

| Item | High-capacity BDE | Previous equipment |
|---|---|---|
| Communication system | 3G/LTE/LTE-A | LTE/LTE-A |
| Duplexing system | FDD/TDD | FDD |
| Accommodated cells | 48 | 6 |
| Accommodated users | 144,000 (3,000 UE/cell) | 5,040 (840 UE/cell) |
| Component carriers | 5CC/UE (100 MHz/UE) | 2CC/UE (25 MHz/UE) |
| U-Plane throughput | 9.8 Gbps | 1.2 Gbps |
| Transmission/reception antennae | Max. 8 | Max. 2 |

## 2. Main Specifications

**Table 1** displays the main specifications of the high-capacity BDE. Its main features include its large capacity for dealing with increased traffic by using a multi-processor system and the increased communication rate enabled by using the CA and MIMO (Multiple Input, Multiple Output). The communication capacity is as high as X8 in terms of the number of accommodated cells and about X30 in terms of the number of accommodated users compared to previous equipment. The number of CA component carriers is 3CC (Component Carriers) as of 2015 but it can be expanded to 5CC by the projected software updating. The number of transmission/reception antennae is up to 2 as of 2015 but may be expanded up to 8 by software updating.

## 3. Function Blocks

The high-capacity BDE is compatible with LTE and 3G communication systems. Its function blocks are roughly divisible into the following three groups.

**(1) Common function block group**

This is the group of function blocks required to implement the LTE and 3G functions. It consists of: HWY (Highway) control function block, RE (Radio Equipment) interface function block, signal repeater function block, timing generation function block, external equipment monitoring control function block and power supply function block.

**(2) LTE function block group**

This is the group of function blocks required to implement the LTE functions. It consists of: LTE-AP (Application Program) block, LTE-BB (Base Band) block, highway control function block, RE interface function block, maintenance/surveillance function block, file system function block, test function block, and equipment maintenance function block, etc.

**(3) 3G function block group**

This is the group of function blocks required to implement the 3G functions. It consists of: 3G-AP block, 3G-BB block, RE interface function block, maintenance/surveillance function block, file system function block, test function block, and equipment maintenance function block, etc.

This paper describes the characteristic function blocks of the high-capacity BDE, which are the LTE-AP, LTE-BB, HWY and RE interface function blocks.

### 3.1 LTE-AP Function Blocks

The LTE-AP is the software that executes the call processing via the processor on the Common Control card.

The call processing includes termination of the L3 protocols such as the RRC (Radio Resource Control), S1AP (Application Protocol) and X2AP, and RRM (Radio Resource Management) as well as the handover processing.

The LTE-AP of the previous equipment runs on a single processor. However, its processing performance is limited, as is the number of accommodated users. The high-capacity BDE adopts a multi-processor configuration to deal with these issues. In order to allow the multi-processor configuration to manifest its characteristics, the loads are distributed on several processors and the LTE-AP on each processor is run concurrently.

### 3.2 LTE-BB Function Blocks

#### 3.2.1 Function Allotment

The LTE-BB function block is composed of the following three layers.

- **PHY (Physical) layer**
  The functions of this layer include: error correction by means of error correction codes and hybrid ARQ (Automatic Repeat request), modulation/demodulation of physical channels and transmission/reception of MIMO.
- **MAC (Medium Access Control) layer**
  The functions of this layer include: the high-speed scheduling that allocates radio resources according to the radio quality and the priority between UE and between logical channels at every millisec., the SCell (Secondary Cell) status management, hybrid ARQ control, and UL reception timing control, etc.
- **RLC (Radio Link Control) layer**
  This layer features UM (Unacknowledged Mode) and AM (Acknowledged Mode). The UM does not execute the ARQ resend control and is applied to the services with real-time requirements such as voice

calls. The AM executes the ARQ resend control and is applied to services with specific data transmission requirements such as file transfers.

### 3.2.2 Characteristics of the LTE-BB Function Block

The BB card of the high-capacity BDE has the flexibility to enable the addition of functions such as a different communication system like the W-CDMA (Wideband Code Division Multiple Access), the CA up to 5CC and the CA using the two LTE systems of FDD (Frequency Division Duplex) and TDD (Time Division Duplex). It also has compatibility with proposed technologies such as high-speed communications with a maximum downstream user throughput of 1 Gbps, by simply replacing the software.

When the BB card is exchanged, the previously used equipment required momentary interruption of the services of the cells allotted to the exchanged BB card, but the high-capacity BDE features improved maintainability that enables maintenance without interrupting the services of the cells.

### 3.2.3 Architecture

With the previous equipment, the LTE-BB functions are provided by an integrated card accommodating PHY/MAC/RLC.

With the high-capacity BDE, the advanced C-RAN with which various usages can be assumed is implemented with optimum scalability. The configuration is separated into the L-BB cards (accommodating PHY) that depend on the number of accommodated cells and the H-BB cards (accommodating MAC/RLC) that depend on the number of accommodated subscribers (**Fig. 2**). In addition, all of the BB cards are connected in a star shape via the L2SW (Layer 2 Switches) so that they are able to communicate mutually (**Fig. 3**).

In order to provide high speed signal processing and advanced flexibility, the high-capacity BDE confidently adopts the latest multicore DSP, large-integration FPGA and programmable accelerator IP.

### 3.3 HWY Function Block

The HWY function block includes the following functions.

- **Highway interface**
  The functions of this interface include the IPsec protocol processing and QoS shaping for use in communications with the equipment on the core network side.

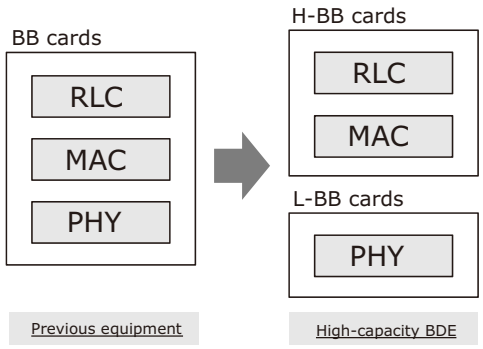


Fig. 2 Architecture of the LTE-BB function block.

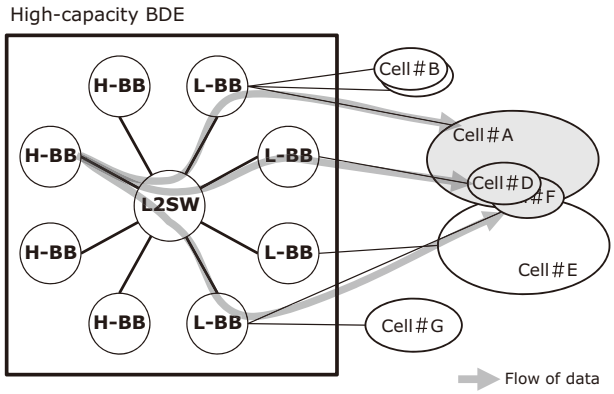


Fig. 3 Flow diagram of user data (CA at arbitrary cells).

- **GTP-U (GPRS-Tunneling Protocol User plane) layer**
  The functions of this layer include the establishment of a data communications path to the equipment on the core network side for each of the communications users.
- **PDCP (Packet Data Convergence Protocol) layer**
  The functions of this layer include data encryption and user packet header compression (ROHC: RObust Header Compression) for use in communications with the users.

Due to the use of CA and multilevel modulation the high-capacity BDE must provide a performance of about 10 Gbps. This need is caused by the increased number of accommodated cells and the increased throughput of cell/user traffic. To enable such a performance, the HWY function that was performed in a single CPU with the previous BDE is distributed to four CPUs. The distribution method of the main functions of the HWY function block in the multiple CPUs and how the control and user data packets are processed is as shown in Fig. 4. The control packets refer to the packets transmitted and re-

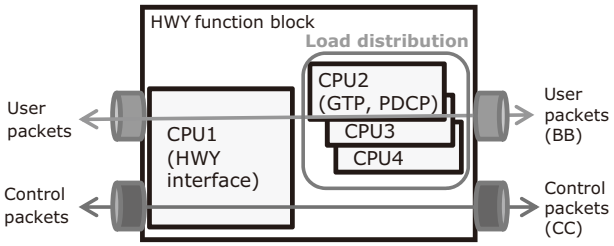


Fig. 4 Configuration of the HWY function block.

ceived with the MME and the user data packets refer to the packets transmitted and received with the S-GW.

As seen in **Fig. 4**, CPU1 executes the protocol processing of the highway interface. On the other hand, CPU2 to CPU4 are configured in parallel and execute the GTP-U protocol processing and the PDCP protocol processing respectively.

The increase in user numbers following the increase in the accommodated cells has exerted a considerable effect on the GTP-U and PDCP protocol processing operations that must be controlled per user. High-capacity BDE provides the HWY function block with the necessary performance by adopting a configuration capable of achieving a uniform distribution of loads per user to these function sites. This uniform distribution is realized by isolating the highway interface from the GTP protocol processing and PDCP protocol processing. It thereby distributes the per-user load uniformly to CPU2 to CPU4 independently the setting of the highway interface.

### 3.4 RE Interface

For interfacing with the RE the high-capacity BDE adopts the optical transmission highway of the base station standard, called the CPRI (Common Public Radio Interface). **Table 2** shows the main specifications of the RE interface. For the physical configuration, up to 48 optical transceiver modules called the SFPs (Small Form-factor Pluggables) can be mounted for each piece of equipment, and the modules are connected to the SFP modules on the RE via optical cables. As the SFP modules are capable of plug-in and plug-out midway through an operation, even when a hardware failure occurs in an SFP module, the service can be restored while continuing all of the services except for those for the cell in question.

High-capacity BDE is compatible with the CPRI line bit rates, not only with the 2.4576 Gbps used by the previous equipment but also with the 4.9152 Gbps and the 9.8304 Gbps, thereby enabling an increase in highway capacity. While the maximum optical transmission distance of the previous equipment is 20 km, it is extended to 30 km with the high-capacity BDE so that a more flexible area configuration than with the previous equipment becomes possible.

Table 2 Main specifications of the RE interface.

| Item | High-capacity BDE | Previous equipment |
|---|---|---|
| RE interfaces per equipment | Max. 48 ports | Max. 6 ports |
| Compatible CPRI line bit rates | Mixed presences of following possible.<br>・2.4576 Gbps<br>・4.9152 Gbps<br>・9.8304 Gbps | Fixed.<br>・2.4576Gbps |
| Unit of exchange in case of failure | Per card or SFP module | Per card (containing SFP module) |
| Optical transmission distance | Max. 30 km | Max. 20 km |
| Duplexing system | FDD/TDD, mixed presences possible. | FDD |
| Communication system | Mixed presences of following possible.<br>・LTE<br>・3G (inside high-capacity BDE)<br>・3G (shared with 3G-BTS) | Mixed presences possible.<br>・LTE<br>・3G (shared with 3G-BTS) |
| 3G BTS I/F ports per equipment | Max. 12 ports | Max. 6 ports |

The most significant feature of the RE interface is that various diversified operations are possible within the same piece of equipment. Besides the FDD/TDD operations, various diversified operations including those of CPRI line bit rates and of LTE/3G are currently permitted simultaneously. In particular, in the case of the communication systems, the 3G systems processed by the high-capacity BDE may be added to the currently diversified LTE/3G (shared with 3G-BTS) that is already available with the previous equipment.

## 4. Conclusion

In the above, we introduced the high-capacity BDE that enables an increase in the numbers of cells and users and implements carrier aggregation with a high degree of freedom. The aim is being to deal flexibly with increased capacity and with the advancement of mobile communications.

The new equipment has already been introduced and it has been run widely as the core equipment of mobile base stations of the Japanese telecom carriers.

As described in this paper, BDE is configured to have sufficient flexibility for dealing with future technologies. Even at present, it is achieving compatibility with the new standards. In the future functional extensions will be continued by aiming to acquire compatibility with the proposed next generation mobile communications.

* PREMIUM 4GTM is a trademark of NTT DOCOMO, Inc.
* LTE is a registered trademark of European Telecommunications Standards Institute(ETSI).

## Authors' Profiles

**KONDO Seiji**
Deputy General Manager
Mobile Radio Access Network Division

**IMAE Yuki**
Assistant Manager
Mobile Radio Access Network Division

**YOSHIDA Mitsutaka**
Assistant Manager
Mobile Radio Access Network Division

**TOKUNAGA Michita**
Assistant Manager
Mobile Radio Access Network Division

**ISHIKAWA Yasuaki**
Assistant Manager
Mobile Radio Access Network Division

**ITABA Naoto**
Assistant Manager
Mobile Radio Access Network Division

**SHIMOYAMA Yuji**
Assistant Manager
Mobile Radio Access Network Division

**IWASAKI Motoya**
Senior Manager
Mobile Radio Access Network Division

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