LTE-compliant Multi-Radio Access Technology (RAT) Baseband LSI

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In collaboration with NTT DOCOMO, INC., NEC Corporation, and Panasonic Mobile Communications, Fujitsu has developed a baseband LSI that provides multi-radio access technology (RAT) communication compatible with the Long Term Evolution (LTE) and High-Speed Packet Access Plus (HSPA+) technical standards. The demand for mobile communications to handle high-speed traffic is growing rapidly as a consequence of the spread of smartphones, and the speeding up of data transmission is continuing in many regions around the world. The transmission scheme adopted to handle this increase in transmission speed varies from country to country. Moreover, the scheme is often used concurrently with a conventional scheme. This means that the communication platform used in mobile devices and the baseband LSI that forms its core must support multiple communication schemes. In this report, the features and main technologies of a multi-RAT baseband LSI developed for handling multiple communication schemes are described, and future development directions for these technologies are discussed.

1. Introduction

With the continuing spread of smartphones, the volume of transmission traffic carried by mobile communications is rapidly increasing, and the boosting of both transmission speed and capacity is continuing. In Japan, NTT DOCOMO, INC. (hereafter, DOCOMO) has adopted the Long-Term Evolution–Frequency Division Duplex (LTE-FDD) technical standard, which enables high-speed data transmission (up to 100 Mb/s). A high-speed communication service providing a downlink line with a maximum speed of 75 Mb/s has been launched under the name "Xi" (pronounced "crossy").[note)]

Moreover, outside of Japan, the speeding up of data transmission using other communication schemes, such as LTE time division duplex (TDD), adopted by China Mobile, and High Speed Packet Access Plus (HSPA+), being adopted in Europe and America, is moving ahead. As this speeding up of mobile communications—using different transmission schemes in different regions around the world—continues, Fujitsu, in collaboration with DOCOMO, NEC Corporation, and Panasonic Mobile Communications, has developed a multi-radio-access technology (RAT) baseband LSI compatible with the LTE-FDD/TDD and HSPA+ technical standards and a communication platform. In this report, the features (namely, specifications and architecture) of the developed LSI are described, and future technical developments of this baseband technology are discussed.

note) "Xi" is a trademark or registered trademark of NTT DOCOMO, INC. in Japan and other countries.

2. Configuration of Multi-RAT communication platform

The hardware configuration of the developed multi-RAT communication platform—centered on the developed baseband LSI and composed primarily of an RF-LSI, synchronous dynamic random access memory (SDRAM), and power-supply circuits—is shown in **Figure 1**.

The LSI is composed of a CPU block for processing on layers 2 and/or 3 and of wireless access schemes such as radio link control (RLC), the Packet Data Convergence Protocol (PDCP), medium access control (MAC), a baseband (BB) block for layer-1 processing of

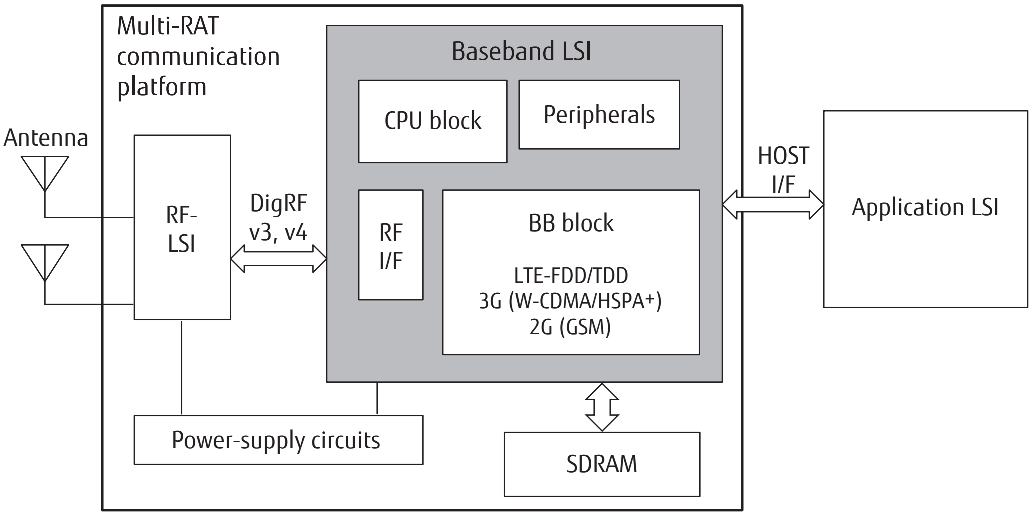

Figure 1
Hardware configuration of multi-RAT communication platform.

Table 1
Main specifications for baseband LSI.

Item	Specification
3GPP standard-support release	Release 8
Transmission scheme	LTE-FDD/TDD W-CDMA/HSPA+ GSM (EDGE/GPRS)
Maximum transmission rate	LTE: downstream: 100 Mb/s; upstream: 50 Mb/s HSPA+: downstream: 42 Mb/s; upstream: 11.5 Mb/s
HOST I/F	USB2.0, I2S, UART, general-purpose memory I/F
RF-I/F	MIPI DigRF v3, v4 compliant
Inter-RAT support	LTE⇔3G: Reselection/Redirection, packet-switched handover
	LTE⇔2G: Reselection/Redirection
	2G⇔3G: Reselection/Redirection, circuit-switched handover
Package	12 mm × 12 mm package-on-package

the wireless access schemes, an RF interface (I/F) for communication with the RF-LSI, and peripheral units for interfacing with application LSIs and PCs.

The BB block can handle all wireless-access schemes, namely, LTE-FDD/TDD, W-CDMA/HSPA+, and Global System for Mobile Communications (GSM) (EDGE/GPRS). The RF-LSI I/F uses the Mobile Industry Processor Interface (MIPI) Digital Radio Frequency (DigRF) standard (versions 3 and/or 4). It is thus possible to connect the baseband LSI with multiple RF-LSIs complying with the same standards. Fujitsu Semiconductor's MB86L10A RF-LSI transceiver is standard on the developed platform. Combining this single RF-LSI with the baseband LSI creates a multi-RAT communication platform for handling the LTE-FDD/TDD, W-CDMA/HSPA+, and GSM standards.

3. Multi-RAT baseband LSI

The main specifications for the developed baseband LSI are listed in **Table 1**. To handle multi-RAT communication, it incorporates schemes developed for improving transmission performance, reducing chip size and power consumption, and enabling flexible scalability. Its main features are described in the following sub-sections.

3.1 Transmission scheme

To enable high-speed data communication for devices (i.e., smartphones), the LSI provides transmission performance of 100 Mb/s (downlink) and 50 Mb/s (uplink) in accordance with Category-3 LTE and transmission performance of 42 Mb/s (downlink) and 11.5 Mb/s (uplink) in accordance with Category-20 HSPA+. For use during LTE communication, 2 × 2 and 4 × 2 multiple input multiple output (MIMO) technologies are implemented in the receiver unit as a means of improving receiver performance, and high performance is ensured by optimizing the MIMO processing algorithm. Moreover, a unique cell-detection algorithm for TDD communication (which differs from LTE-FDD communication during LTE-TDD communication) was developed and adopted, thereby ensuring cell detection during TDD communication. To prevent the synchronization channel (SCH) of W-CDMA having an interference wave and thereby degrading receiver performance during HSPA+ communication, an SCH-interference elimination algorithm was developed and implemented, thus ensuring good transmission performance. The main specifications for LTE and HSPA+ are listed in **Table 2** and **Table 3**, respectively.

3.2 Multi-RAT shared configuration

When multiple wireless-access schemes are to be handled, a circuit is set up for each scheme; consequently, the circuit scale, and thus chip size, increases. Since the increase in chip size is directly linked to the cost, decreasing chip size is a major issue. An architecture that maximizes the region in which all wireless-access schemes can be commonly used was thus adopted for the developed processor. For example, regarding the error-correction code and decryption processor for the transmitted and received data, the architecture unitizes the turbo codes used by HSPA+, LTE, etc. (namely, processing units and processing details such as calculations and bit interleaving common to convolutional encoding schemes) in specific functional processing units and commonly uses them during communication by the different schemes. Application of this method to modulation and demodulation, timing-control processing, and so on makes it possible to reduce the chip size by more than 20% in comparison to that possible with conventional methods.

3.3 Multi-processor configuration

For the CPU block for processing on layers 2 and 3 of wireless-access schemes like RLC, PDCP, and MAC, ARM system processors are used. For the BB block for layer-1 processing, a multi-processor configuration with multiple high-performance digital signal processors (DSPs) is used. In general, baseband processing for LTE and HSPA+ involves a huge amount of computation that cannot be handled by a standard

Table 2
Main specifications for LTE.

Item		Downstream line	Upstream line
Maximum transmission rate		100 Mb/s	50 Mb/s
Wireless-access method		OFDM	SC-FDMA
Modulation scheme		64QAM	16QAM
Duplex		FDD, TDD	
Category		3	
System bandwidth		1.4, 3, 5, 10, 15, 20 MHz	
No. of base-station transmission antennas		1, 2, 4	
No. of receiving antennas		1, 2	
MIMO		2 × 2, 4 × 2 SU-MIMO/MU-MIMO with precoding	
	Code words	1 or 2	
Receiver diversity		2-branch antenna diversity	
Transmitter diversity		Support for 2-antenna transmission/ 4-antenna transmission	

Table 3
Main specifications for HSPA+.

Item		Downstream line	Upstream line
Maximum transmission rate		42 Mb/s	11.5 Mb/s
Wireless-access method		DS-CDMA	SC-FDMA
Modulation scheme		64QAM	16QAM
Duplex		FDD	
Category		20	
System bandwidth		5 MHz	
No. of base-station transmission antennas		1, 2	
No. of receiving antennas		1, 2	
MIMO		2 × 2	
	Code words	1 or 2	
Receiver diversity		2-branch antenna diversity	
Transmitter diversity		2-antenna transmission	

DSP. Therefore, much of the operational processing is done on specialized hardware circuits. However, to enable flexible compliance with specification changes and function additions proposed by the 3rd Generation Partnership Project (3GPP) standardization organization, a DSP that can very efficiently perform typical computational operations in the baseband is used for the developed LSI chip. Moreover, an architecture that supports many functions and computational operations in the baseband is used. Configuring the DSP of the layer-1 function as a multi-processor reduces the operation frequency per DSP, resulting in reduced power consumption.

3.4 RF-LSI interface

The RF-LSI interface, using the MIPI DigRF interface standard (versions 3 or 4), can connect to DigRF-compliant RF-LSIs of various vendors. Configuring the RF interface and block so that they are highly independent in relation to the other functional blocks in the LSI enabled the creation of an architecture that has high extendibility—while minimizing the effect of those extensions on the baseband blocks—in terms of the frequency bands used by different countries and changes in RF component parts.

3.5 High-efficiency MAC layer processing

The MAC processing performed by the CPU block is one of the factors that increase power consumption; that is, the processing load increases with the transmission rate. Therefore, the required operating clock frequency of the CPU also increases, which increases power consumption. This increase in the CPU clock frequency was suppressed in the developed baseband LSI by developing and implementing a direct memory access controller (DMAC) that can "intelligently" control the MAC processor, resulting in highly efficient MAC processing in coordination with the CPU.

3.6 Low-power-consumption architecture

The baseband LSI (which supports LTE and HSPA+) has an increased consumption current because of its increased circuit scale and larger internal memory. Power is saved, however, by segmenting the LSI power-supply block and by finely controlling the LSI power consumption by turning off the power to non-operating blocks.

3.7 Inter-RAT handover processing

The 3G wave received during LTE communication is measured, and handover (inter-RAT) between transmission schemes (such as handover to a 3G system if the LTE wave degrades) is supported. Moreover, if the wireless scheme changes during inter-RAT handover, power saving is maximized by finely controlling the circuits in the baseband LSI and by segmenting the multi-RAT shared configuration and power-source block.

3.8 LSI packaging

The baseband LSI is mounted in a 12 × 12-mm ball grid array (BGA) package. The number of LSI terminals was reduced to 436 by multiplexing the terminal functions and optimizing the terminal positions of the power source and ground lines. To ensure that SDRAM can be freely combined with the LSI, a package-on-package configuration was adopted.

4. Future trends

The multi-RAT-compatible baseband LSI presented here provides a baseband function enabling high-speed transmission by LTE-FDD/TDD (category 3: downlink: 100 Mb/s; uplink: 50 Mb/s) and HSPA+ (category 20: downlink: 42 Mb/s; uplink: 11.5 Mb/s) on a single chip. Its basic architecture lowers power consumption by efficiently sharing hardware between transmission schemes (including W-CDMA and GSM). With the "LTE-Advanced system" (the next-generation LTE system now being standardized), ultra-high transmission speeds (up to 1 Gb/s) will be possible, so the baseband processor will have to provide even higher performance. To dramatically improve its performance to make it LTE-advanced compatible without changing its architecture, we plan to continue our technical investigations.

5. Conclusion

In this report, a multi-RAT communication platform and baseband LSI for handling multiple wireless-access schemes (like LTE-FDD/TDD and HSPA+) and providing high-speed data communication were described. We intend to utilize the findings presented here to develop communications platforms that provide compatibility with the LTE-Advanced standard for ultra-high-speed transmission.

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