System and Reference Design Kits for Mobile WiMAX Terminals

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We have developed a system design kit (SDK) and reference design kit (RDK) for Fujitsu's Mobile WiMAX chipset. These kits will be useful and effective for customers evaluating the chipset and developing products with it. This paper outlines the hardware and software of the SDK and RDK and introduces their performance in development fields and the market.

1. Introduction

Fujitsu has pursued a Mobile WiMAX (IEEE Std 802.16e)[1)-3)] chipset comprising a baseband system-on-a-chip (SoC) and a radio-frequency LSI since 2005 by drawing on its expertise in technologies such as radio, baseband signal processing, hardware, and firmware. In the development of wireless communications devices, it is necessary to prepare support tools that can be used for developing and evaluating the signal processing firmware effectively in parallel with device development. Moreover, because the WiMAX telecommunications system will be applied to a public wireless communications system, it is indispensable to guarantee interoperability between terminals and the base station (BS). Therefore, we need to prepare a mobile terminal for interoperability testing that has functions for connecting to the BS and monitoring and analyzing the connection conditions.

For customers developing wireless communications devices, it is important that chipsets are easy to evaluate and that products based on them can be developed easily and efficiently so that they can be brought to market quickly. Therefore, we must offer customers hardware and software tools that have the necessary functions for evaluating the chipset. We must also provide them with reference data for their design information and provide a platform for them to develop their applications.

Fujitsu has developed two tools for efficient development of WiMAX mobile terminals and their applications. The system design kit (SDK) has many effective and useful functions such as monitoring system operations and installing applications being developed onto a terminal. The reference design kit (RDK) enables a user to monitor the main system operations and installed applications from a personal computer (PC). Its designs let customers make products quickly.

In the remainder of this paper, Section 2 outlines the SDK and RDK, Sections 3 and 4 describe the hardware and software structures of the SDK and RDK, respectively, and Section 5 describes their performances.

2. Outline of SDK/RDK

The SDK and RDK have been developed to enable customers to easily develop various WiMAX terminals that use Fujitsu's MB86K21 WiMAX SoC. Their main specifications are shown in **Tables 1** and **2**, respectively, and their functions are compared in **Table 3**. Taking into

Table 1
SDK main specifications.
SoC board

Item	Specifications
Baseband chip	Fujitsu WiMAX SoC
Host interface	PC CardBUS I/F, USB 2.0 I/F
Transmission rate	DL: 20 Mb/s (max.), UL: 8 Mb/s (max.)
RF card interface	IQ analog I/F (TYPE-II PC card form factor)
ARM946 processor debugging interface	ICE port, ETM port, UART port
Maintenance port	BER measurement port Constellation measurement port
Size (W × D × H)	240 mm × 240 mm × 30 mm

RF card

Item	Specifications
RF LSI	Maxim RF LSI
PA LSI	Micromobio PA LSI
Radio frequency band	2.3/2.5 GHz
Band width	3.5/5/7/10/20 MHz
Transmission rate	DL: 24 Mb/s (max.), UL: 4 Mb/s (max.)
Max. RF output power	Power class 1 (max. +23 dBm QPSK)
SoC board interface	IQ analog I/F (TYPE-II PC card form factor)
RF interface	SMB connector
Size (W × D × H)	60 mm × 139 mm × 15.5 mm

DL: Downlink
UL: Uplink

Table 2
RDK main specifications.

Item	Specifications
Baseband chip	Fujitsu WiMAX SoC
RF LSI	Maxim RF LSI
PA LSI	Micromobio PA LSI
Host interface	PC CardBUS I/F
ARM946 processor debugging interface	ICE port, UART port
Radio frequency band	2.3/2.5 GHz
Bandwidth	3.5/5/7/10/20 MHz
Transmission rate	DL: 24 Mb/s (max.), UL: 4 Mb/s (max.)
Max. RF output power	Power class 1 (max. +23 dBm QPSK)
RF interface	SMB connector
Size (W × D × H)	60 mm × 139 mm × 15.5 mm

Table 3
SDK and RDK functions.

Category	Function	SDK	RDK
Host I/F			
	CardBUS I/F	○	○
	USB2.0 I/F	○	–
Debugging I/F			
ARM	ICE	○	○
	UART	○	○
	ETM	○	–
Maintenance I/F			
	Constellation measurement	○	–
	BER measurement	○	–

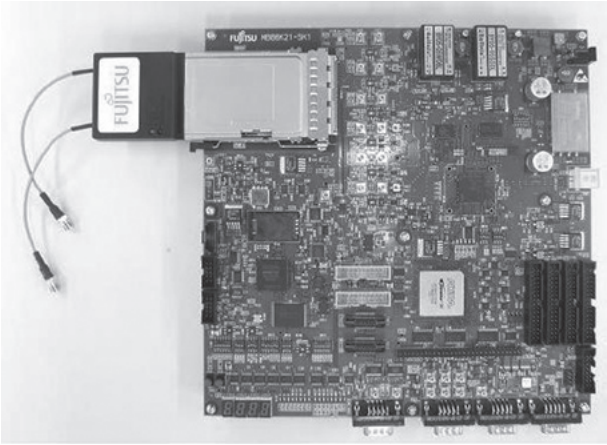
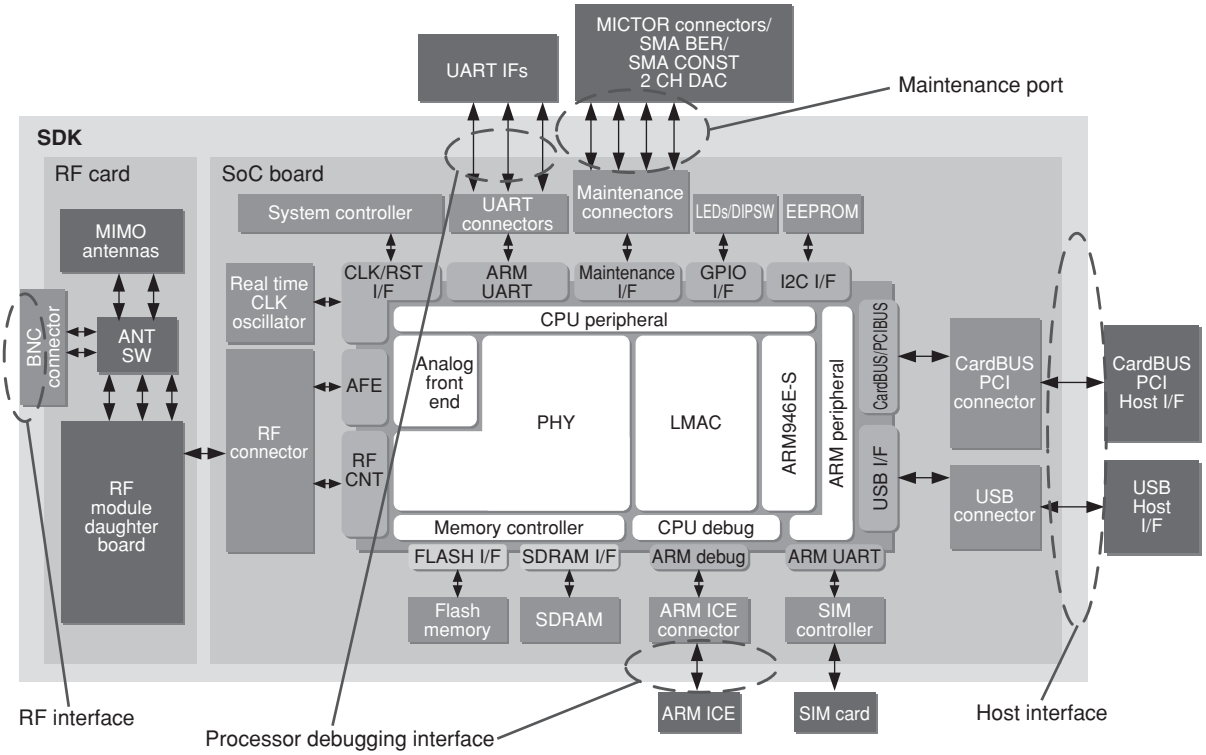


Figure 1
Photograph of SDK.

consideration the needs of equipment and module developers, we decided that the SDK/RDK should include the functions and software required to mount an SoC in equipment.

3. SDK

The SDK is a board designed for function/performance evaluation and system evaluation for various WiMAX terminals and software applications being developed by a customer. A photograph of it is shown in **Figure 1**. Its hardware and software architectures are shown in **Figures 2** and **3**, respectively.



2 CH DAC: 2-channel digital-to-analog converter
ANT SW: Antenna switch
GPIO: General-purpose input/output
LMAC: Lower media access control block
MIMO: Multiple-input multiple-output
PHY: Physical layer block
SIM: Subscribe identity module

Figure 2
SDK hardware architecture.

3.1 Hardware architecture

The SDK consists of an SoC board and an RF card. The SoC board has an interface for monitoring and controlling various essential system operation functions of Fujitsu's MB86K21 WiMAX SoC. The RF card has RF front circuits, such as a power amplifier and an RF-LSI, on the substrate. When the SoC board and RF card are connected, they operate as an SDK for WiMAX. The main interfaces of the SDK are roughly classified into the host interface, RF interface, processor debugging interface, and maintenance port. These are described below.

1) Host interface

Interfaces for USB 2.0 and CardBUS that conform to the respective standards are mounted on the board as host interfaces. They can be used to connect a PC via the connector on the board.

2) RF interface

The RF card has two subminiature version B (SMB) connector ports. One of them connects multiplexed transmit and receive signals to the first line of the RF interface. The other connects the receive signal to the second line of the RF interface. Customers can evaluate the performance of the air interface signal by connecting measurement equipment to these SMB connectors.

3) Processor debugging interface

The interface for debugging the processors in the WiMAX SoC consists of an in-circuit emulator (ICE) port, a universal asynchronous

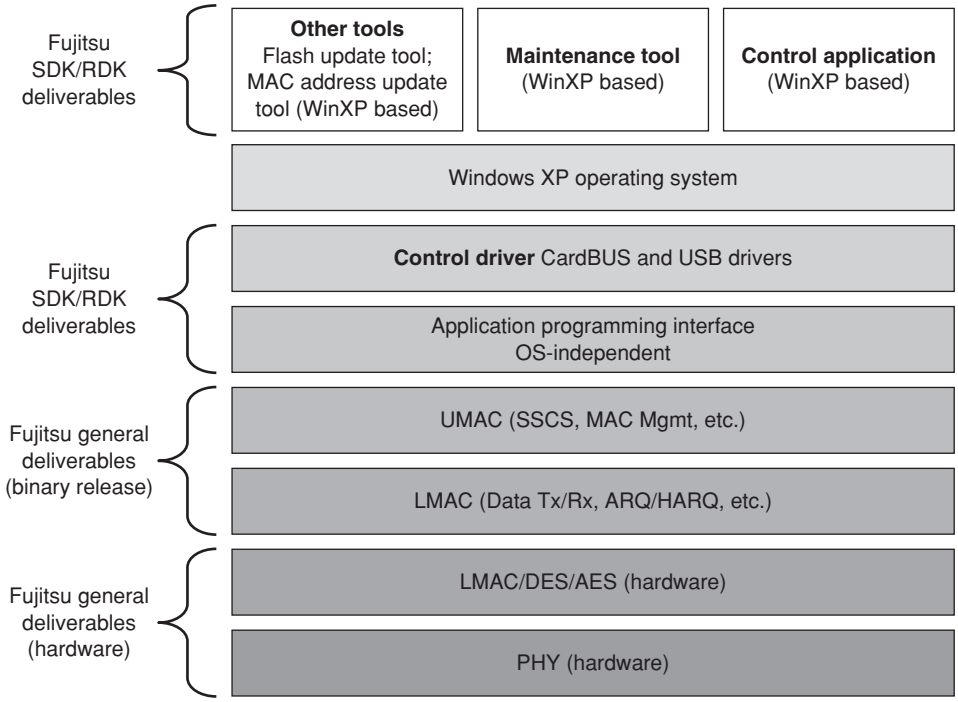


Figure 3
SDK software architecture.

receive/transmit (UART) port, and an ETM9™ note) port, which are mounted on the board. The SDK can be used to debug the basic firmware of the SoC.

4) Maintenance port

To support performance evaluations, maintenance, and troubleshooting for failures in the field, the SDK has various debugging ports. These ports can also be used to change system parameters. The mobile terminal functions are controlled by the values of system parameters whose values are stored in an electrically erasable programmable read only memory (EEPROM). Therefore, customers can control the mobile terminal functions by updating the values in the EEPROM. Some examples of system parameters are the media access control (MAC) address of the terminal and various limitation values such as timer, retry count, and RF output power.

note) ETM9 is the trademark of ARM Limited.

3.2 Software architecture

The SDK offers four kinds of software tools that operate on a PC running Windows XP or Vista: a control driver, control application, maintenance tool, and other tools. The control driver can also be used with Linux.

1) Control driver

A sample driver is provided for the USB 2.0 and CardBUS interfaces of a PC.

2) Control application

The SDK provides sample programs that are helpful when a customer develops application software. These programs are based on the application programming interface that extracts and displays various pieces of information for a terminal. These sample programs let customers concentrate on developing their applications.

3) Maintenance tool

Since the SDK has maintenance software for evaluating the functions and performance of the chipset, a customer can easily evaluate the radio characteristics and the protocol of Fujitsu's

Figure 4
Photograph of RDK.

WiMAX products.

4) Other tools

Four other tools are provided as software tools to enable a customer to easily customize the system: Flash maintenance tool, Flash update tool, MAC address writing tool, and system parameter writing tool. These software tools can shorten the time required for customers to install firmware during mass production in a factory and during firmware upgrading after shipment from the factory.

4. RDK

A photograph of the RDK is shown in **Figure 4**. Fujitsu provides the design data and the Gerber data of the RDK for reference to customers planning to manufacture a PC card for the WiMAX mobile terminal system. It enables a customer to make an equivalent PC card through easy customization. By using this data, a customer should be able to complete product development in a short time.

4.1 Hardware architecture

The RDK has a PC card architecture like the SDK but without the USB2.0 interface and ETM debugging port. The hardware composition of the RDK is shown in **Figure 5**.

4.2 Key development points of RDK

Fujitsu has applied advanced design methodology to the RDK to avoid the RF performance degradation that can be caused by various noise sources. To reduce the influence of noise entering the analog circuit via the digital circuit, we thoroughly separated the power supply lines for analog and digital circuits and carefully designed the circuits and mounting. Furthermore, to obtain impedance matching for the RF circuit, we carefully considered the design of the printed circuit board, such as the line thicknesses and widths. As a result, we were able to avoid any influence on the functions and characteristics introduced by noise and attained the expected performance.

4.3 Software architecture

The RDK has software equivalent to the SDK. For example, the same functional evaluation as performed by the SDK can be performed by operating the maintenance tool on a notebook PC with the RDK inserted into it.

5. Application results

5.1 Hardware

For technology like WiMAX, where development and standardization are carried out simultaneously, it is important to supply customers with information about the confirmation of interoperability and about developed products. For interoperability confirmation, we participate in the PlugFest of the WiMAX Forum[4),5)] and we have also aggressively carried out private interoperability testing together with major BS manufacturers on an individual basis. For good development information disclosure, we give timely exhibitions, presentations, and individual demonstrations for our major customers. As for dynamic exhibitions, we demonstrate videophones using the transmission of high-definition images and the voice over Internet protocol (VoIP) function. Fujitsu has demonstrated a transmission capability of 24 Mb/s ahead of any other company and has also presented the possibility of WiMAX applications and the superiority of its WiMAX SoC, so we hold a dominant position for Mobile WiMAX products. For confirmation

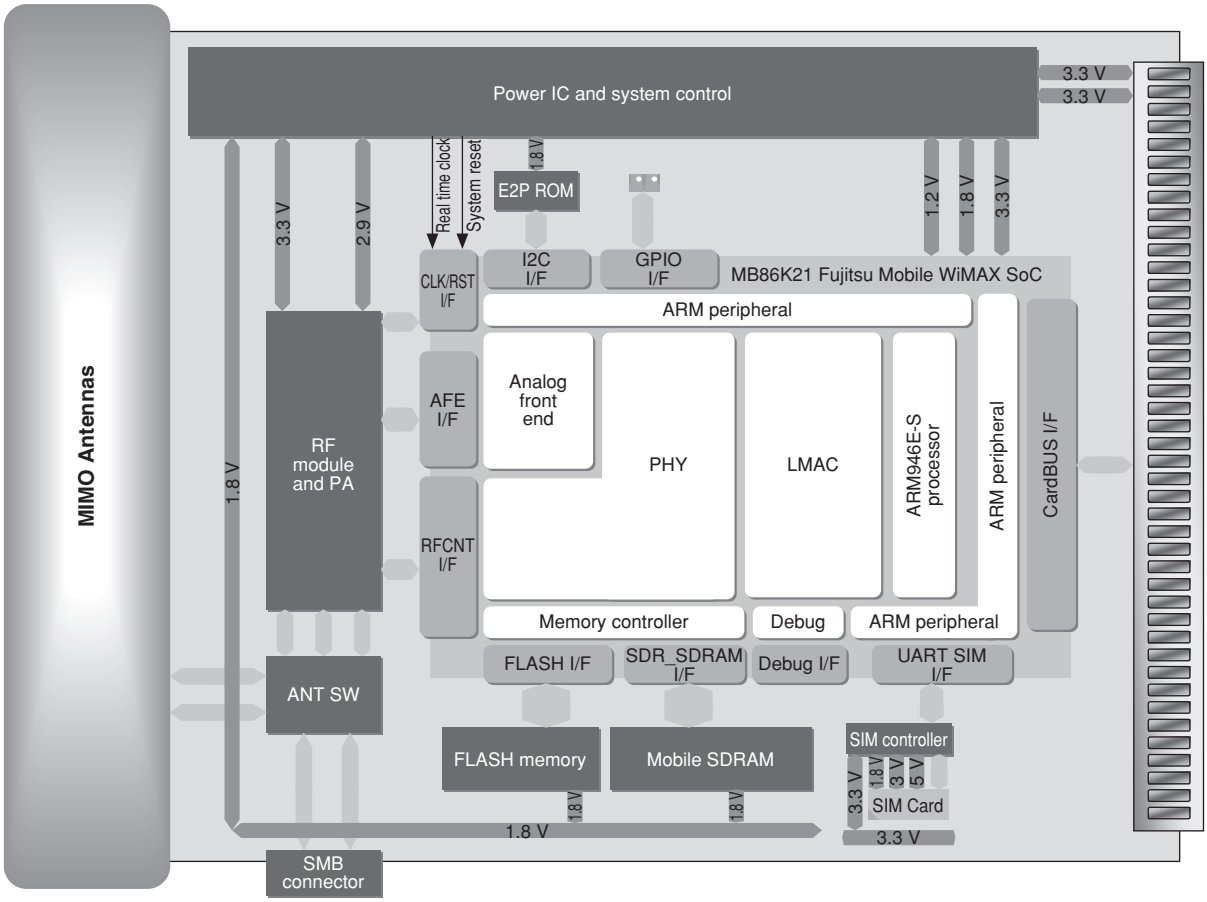


Figure 5
RDK hardware architecture.

of connections with BSs, the maintenance tool is effective for operations analysis of a connection test.

Fujitsu continues to demonstrate the SDK and RDK and perform BS connection checks. The many successful connections achieved with the BSs of numerous other companies show the validity of Fujitsu's chipset.

5.2 Software

Software development for mobile communication terminals is increasing in scale and complexity, and the burden on customers for software development is also becoming massive. In contrast to WiFi, software development for a carrier's mobile terminal, especially a WiMAX solution, which needs complex protocol procedures for various services, differs among individual telecommunications carriers, so the amount of software development required to meet all of their requests is increasing exponentially.

Fujitsu has accumulated experience with mobile solution technology for carriers through the development of cellular-phone terminals and BSs. By taking advantage of this experience, we can provide the software tools required by customers and sample programs that serve as references for WiMAX mobile terminal development. The referencing of such software is a huge contribution to enabling easy development of WiMAX mobile terminals.

6. Conclusions

In this paper, we outlined the SDK/RDK as

tools for efficiently developing WiMAX mobile terminals. Since these kits provide the hardware environment and software tools that customers require for evaluating and developing WiMAX mobile terminals, they enable customers to develop products quickly.

Standardization of the WiMAX system is still advancing today, with new proposals being actively published. Furthermore, the mobile communication market demand is shifted according to customer requirements. In accordance with these trends, we will tackle the upgrading of the SoC features and target further miniaturization and reductions in power consumption. Furthermore, according to the market requirements, we will further develop our SDK/RDK. To take one out of many possible examples, RDKs for USB-dongles and EXP cards are scheduled to be provided to the market consecutively to further accelerate WiMAX solutions development. By offering these reference designs, we will contribute to the expansion of WiMAX solutions and provide even greater convenience based on predicted market trends.

References

1) IEEE Std 802.16-2004: IEEE Standard for Local and Metropolitan Area Networks, Part 16: Air Interface for Fixed Broadband Wireless Access Systems. Oct. 2004.
2) IEEE Std 802.16e-2005 and IEEE Std 802.16-2004/Cor 1-2005: IEEE Standard for Local and Metropolitan Area Networks, Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems Amendment 2: Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands and Corrigendum 1. Feb. 2006.
3) IEEE P802.16-Rev2/D2: Draft Standard for Local and Metropolitan Area Networks, Part 16: Air Interface for Broadband Wireless Access Systems. Dec. 2007.
4) WiMAX Forum Mobile System Profile, Release 1.0: Approved Specification (Revision 1.5.0). Nov. 2007.
5) WiMAX Forum Mobile Radio Conformance Tests (MRCT) Release 1.0: Approved Specification (Revision 2.0.0). December, 2007.

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