LTE | Mobile Terminal Platform | Licensing

Technology Reports

Special Articles on "Xi" (Crossy) LTE Service—Toward Smart Innovation—

LTE Mobile Terminal Platform for Expansion into Global Markets

The provision of high-speed, large-capacity and low-delay LTE services is expanding throughout the world to meet the demand for higher transmission speeds and greater capacity in mobile communications. NTT DOCOMO has developed an LTE-based mobile terminal platform in collaboration with three leading mobile-terminal manufacturers in Japan. With this platform, NTT DOCOMO aims to provide users with attractive and up-to-date LTE-compatible mobile terminals and to enter into licensing agreements in both domestic and overseas markets.

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1. Introduction

Data traffic and content capacity have been increasing rapidly in recent years, and the need for higher transmission speeds and greater capacities has been urgently felt. In response to this need, the provision of high-speed, large-capacity and low-delay LTE[*1] services has been expanding throughout the world first in Europe and then in the United States, China and elsewhere. NTT DOCOMO has also been active in LTE development, launching its LTE "Xi" (Crossy)[*2] Service for data terminals in December 2010 and working on the commercialization of smartphones and other high-function mobile terminals supporting LTE. The performance required of mobile terminals is rising on a yearly basis, and to meet this demand, the development process must be made more efficient and quality must be improved. Although gains have been made in this regard by the development of a common mobile terminal platform [1][2], the need for providing users with attractive and up-to-date LTE mobile terminals has led to the joint development of an LTE-based mobile terminal platform[*3] (hereinafter referred to as "LTE-PF") by NTT DOCOMO and three domestic mobile-terminal manufacturers (NEC CASIO Mobile Communications, Ltd., Panasonic Mobile Communications Co., Ltd. and Fujitsu Limited).

NTT DOCOMO has demonstrated the quality and global potential of LTE-PF by performing Interoperability Testing (IOT) with overseas network equipment vendors, and it seeks to license LTE-PF technology in both Japan and overseas markets.

This article describes the development of LTE-PF and NTT DOCOMO's IOT and licensing activities.

2. Development Background and Effects

In an attempt to increase transmission speed and data capacity in mobile communications systems, the development period of the communications modem section in mobile terminals has become longer and development

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*1 **LTE**: Extended standard fot the 3G mobile communication system studied by 3GPP. Achieves faster speeds and lower delay than HSPA (see*18).

*2 **"Xi" (Crossy)**: The generic name for NTT DOCOMO's high-speed, large-capacity and low-delay mobile communications service launched in December 2010. Based on LTE communications technology, it provides a downlink peak rate of 37.5 Mbit/s and an uplink peak rate of 12.5 Mbit/s outdoors and a downlink peak rate of 75 Mbit/s and an uplink peak rate of 25 Mbit/s in some indoor areas. "Xi" (read "Crossy") and its logo are trademarks of NTT DOCOMO.

expenses have been increasing generating a big load on the development process. The same can be said for LTE services where the need for advanced functions to support a new radio system means a larger circuit scale and more software-related man-hours that simply increase the development load. Thus, while the communications modem section has become a major development load for mobile terminal manufacturers, it is not a section with which a manufacturer can differentiate its products or make a profit worthy of its development expenses. For these reasons, the development of LTE-PF was undertaken aiming for the following three effects.

1) Extensive Lineup of Mobile Terminals

The adoption of a common mobile terminal platform by mobile-terminal manufacturers means that a company can reduce its development and testing man-hours for the communications modem section. This frees up the company to concentrate its development efforts and demonstrate its originality in areas like application software where it can differentiate itself from other companies.

2) Economies of Scale by Inducing Mobile-terminal Manufacturers to Enter Foreign Markets

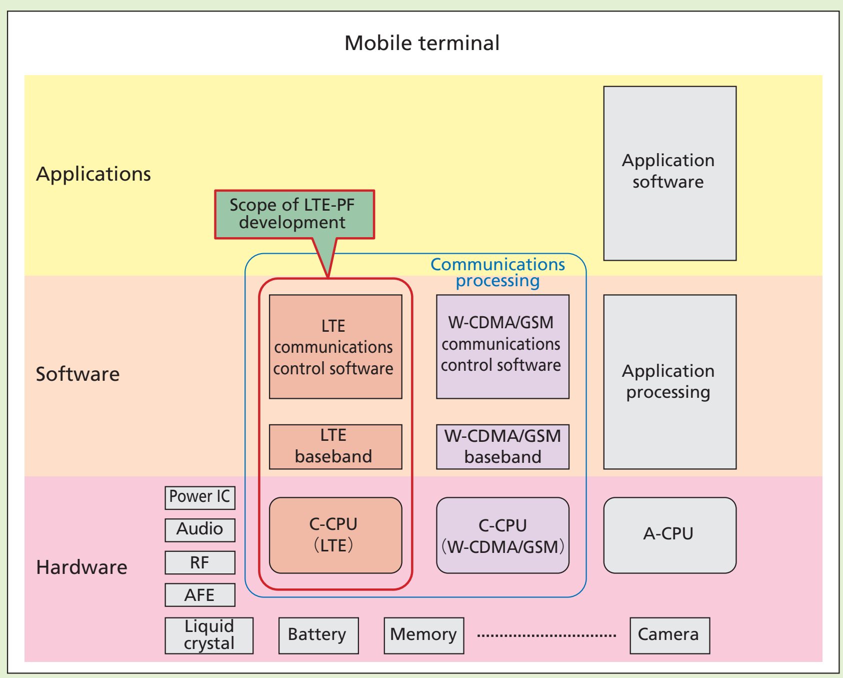
LTE-PF supports the LTE system defined by international standards as well as multimode designs to accommodate Wideband Code Division Multiple Access (W-CDMA) and GSM systems now used throughout the world. In addition, IOT with overseas network equipment vendors is demonstrating the interoperability and quality of LTE-PF thereby enhancing its competitiveness in technology licensing. This is helping to spread the use of LTE-PF on a global scale and making it easier for mobile-terminal manufacturers that adopt LTE-PF to enter foreign markets. In short, LTE-PF is expected to drive the price of mobile terminals down through economies of scale.

3) Construction of a Development Eco System through Technology Licensing Revenues

LTE-PF development provides of Intellectual Property (IP)[*4] that can be licensed. The revenues obtained through such technology licensing can be applied to functional extensions and the development of mobile terminals that are even more appealing to users.

3. Overview of LTE-PF

LTE-PF is the result of a joint-development project between NTT DOCOMO and NEC CASIO Mobile Communications, Panasonic Mobile Communications, and Fujitsu making use of technologies so far cultivated in the development of mobile terminals. The scope of this LTE-PF development covers LTE baseband[*5] section (hereinafter referred to as "LTE baseband") and LTE communications control software (**Figure 1**).



A-CPU : Generic name of the CPU in charge of application processing in a mobile terminal.
C-CPU : Generic name of the CPU in charge of communications and call-control processing in a mobile terminal.
AFE : Analog Front End

Figure 1 Scope of LTE-PF development

*3 **Mobile terminal platform**: The basic system for achieving communications consisting, for example, of baseband (see *5) processing software to provide the mobile terminal with the communications functions it requires.

*4 **IP**: Intellectual property consisting here of design data and simulation models for implementing technology like LTE in semiconductor devices.

*5 **Baseband**: The signal before modulation and after demodulation.

The LTE system is specified as 3GPP Release 8. The main LTE specifications supported by LTE-PF are Shown in **Table 1**. At 3GPP, mobile-terminal performance is divided into five LTE User Equipment (UE) categories [3]. These UE categories are listed in **Table 2**.

The maximum number of receive bits in the downlink is expressed as the maximum number of bits transmitted per Transmission Time Interval (TTI) in the Physical Downlink Shared Channel (PDSCH) [4], and the maximum buffer size for use by the Hybrid-Automatic Repeat reQuest (H-ARQ)*6 scheme is expressed as the maximum receive buffer size in bits when synthesizing and demodulating the pre-retransmission signal and the retransmitted signal. In addition, UE categories 2 to 4 must support up to two Multiple Input Multiple Output (MIMO)*7 layers while UE category 5 must support up to four layers. In the uplink, no MIMO support has yet been specified, and UE category 5 must support 64 Quadrature Amplitude Modulation (64QAM)*8. Maximum throughput in UE categories 1 to 5 in the downlink/uplink are 10/5, 50/25, 100/50, 150/50 and 300/75 Mbit/s, respectively.

As shown in Table 2, supporting a higher category means enlarging the H-ARQ maximum buffer size, increasing the maximum number of MIMO layers, and improving the maximum throughput. But increasing memory size and processing load are factors in raising the price and current consumption of the mobile terminal. Moreover, increas-

Table 1 Main LTE specifications supported by LTE-PF

Item	Uplink	Downlink
Maximum transmission speed (LTE mobile terminal capability)	50 Mbit/s (Category 3)	100 Mbit/s (Category 3)
Radio access system	SC-FDMA	OFDMA
Duplex	FDD	
System bandwidth	1.4/3/5/10/15/20 MHz	
CP length	Normal, Extended	
Subcarrier frequency interval	15 kHz	
Resource block bandwidth	180 kHz	
Radio frame length	10 ms	
Sub-frame length	1 ms	
Slot length	0.5 ms	
OFDM symbol length per slot	7 (Normal Cyclic Prefix), 6 (Extended Cyclic Prefix)	
Modulation scheme	BPSK, QPSK, 16QAM	BPSK, QPSK, 16QAM, 64QAM
Channel coding	Convolutional code, Turbo code	
Number of transmit/receive antennas	1	2
3GPP version supported	Release 8	

BPSK : Binary Phase Shift Keying
FDD : Frequency Division Duplex
OFDMA : Orthogonal Frequency Division Multiple Access
SC-FDMA : Single Carrier-Frequency Division Multiple Access

Table 2 UE categories of LTE mobile terminals

UE Category	Downlink					Uplink		
	Maximum number of receive bits /TTI	Maximum number of receive bits/TBS/TTI	Maximum H-ARQ buffer size (bit)	Maximum number of MIMO layers	Maximum throughput (Mbit/s)	Maximum number of send bits /TTI	64QAM support	Maximum throughput (Mbit/s)
Category 1	10,296	10,296	250,368	1	10	5,160	No	5
Category 2	51,024	51,024	1,237,248	2	50	25,456	No	25
Category 3	102,048	75,376	1,237,248	2	100	51,024	No	50
Category 4	150,752	75,376	1,827,072	2	150	51,024	No	50
Category 5	299,552	149,776	3,667,200	4	300	75,376	Yes	75

*6 **H-ARQ**: Technology combining ARQ and error correction codes to increase error correction capacity during repeats and reduce the number of repeats.

*7 **MIMO**: Wireless communications technology for expanding transmission capacity by using multiple transmit/receive antennas.

*8 **64QAM**: A digital modulation method used in wireless communication. Data is transmitted using 64 different phase and amplitude costellations. Can transmit more data at a time (6 bits) than either Quadrature Phase Shift Keying (QPSK) or 16 QAM.

ing the maximum number of MIMO layers, that is, increasing the number of antennas on the mobile terminal, restricts the shape of the terminal. For LTE-PF, UE category 3 having a maximum throughput of 100/50 Mbit/s in the downlink/uplink has been adopted considering standardization trends, the platform specifications of competing companies, market needs, commercial schedules, etc. From the viewpoint of maximum throughput, LTE-PF is a mobile terminal platform than can support an extensive lineup of mobile terminals, from dedicated data terminals and mobile routers to smartphones.

LTE-PF is combined with a platform supporting the W-CDMA and GSM/General Packet Radio Service (GPRS)[*9] systems so that seamless communications can be provided among LTE, W-CDMA and GSM/GPRS service areas (Fig. 1). Specifically, LTE-PF provides for Packet Switched (PS) handover[*10] during packet communications to prevent call interruptions and also supports Circuit Switched (CS) Fallback[*11] that gives the mobile terminal access to voice services on the W-CDMA system. LTE-PF also adopts general-purpose interfaces to facilitate connection with an existing mobile terminal platform like W-CDMA or GSM.

A key feature of LTE-PF development is that it incorporates the development of IP for technology licensing. As a design independent of any specific chipset vendor's technology, LTE-PF can be widely licensed to mobile terminal manufacturers and chipset vendors themselves.

4. Development of the LTE Baseband

The LTE baseband performs processing associated with Layer 1[*12] (physical layer), Layer 2[*13] (Medium Access Control (MAC)[*14]), Radio Link Control (RLC)[*15] and the Packet Data Convergence Protocol (PDCP)[*16] layer as specified by the 3GPP TS 36.21x and 32x series of specifications. An engineering sample of the LSI for this LTE baseband and its block diagram is shown in **Figure 2**. The LTE baseband provides Layer 1 functions and the LTE U-Plane Processor (UPP) performs processing on the User Plane (U-Plane)[*17].

Issues that come up in the development of the baseband are the processing of large amounts of data in a short period of time and achieving a flexible architecture that can deal with changes in specifications as standards progress. To achieve low-delay transmission of large amounts of data in accordance with LTE features, the terminal must respond to the reception of 1TTI (1 ms) worth of data within 3 ms, which calls for high-speed processing beyond what is capable by the existing High Speed Packet Access (HSPA)[*18] system. It is also necessary that the latest 3GPP specifications be observed to maintain interoperability, which calls for architecture that can easily incorporate changes in specifications.

To address these issues, the LTE baseband adopts an architecture featuring dedicated hardware and a firmware processing section consisting of a Digital Signal Processor (DSP)[*19] and a general-purpose processor such as a CPU.

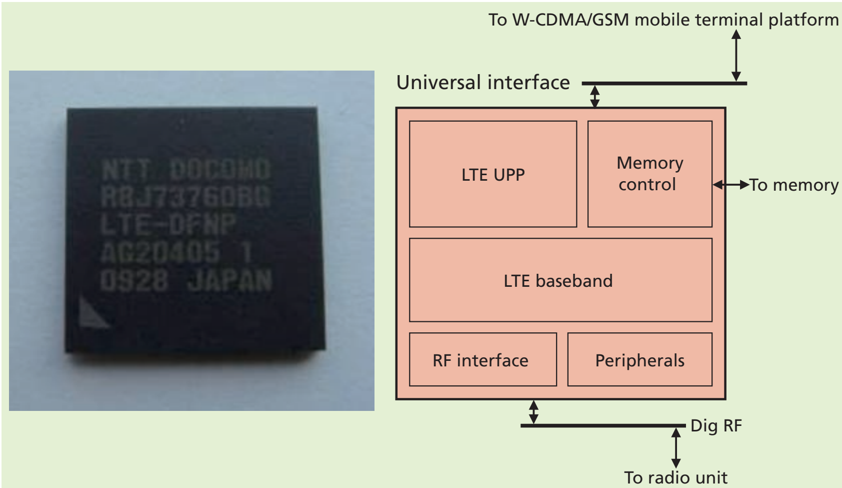


Figure 2 LSI sample and block diagram

*9 **GPRS**: A packet switching service available on GSM network.

*10 **PS handover**: A process for continuing communications between different systems or cells during packet exchange without interrupting communications.

*11 **CS Fallback**: A function for providing voice services in the circuit-switched domain by switching to a W-CDMA or GSM system when making or receiving a call in an LTE area.

*12 **Layer 1**: The first layer (physical layer) in the OSI reference model.

*13 **Layer 2**: The second layer (data link layer) in the OSI reference model.

*14 **MAC**: A protocol in LTE that performs logic-channel and transport-channel mapping, random access control, and standby control.

*15 **RLC**: The data-link-layer protocol in LTE performing retransmission control and other functions.

*16 **PDCP**: A sublayer of layer 2. A protocol for ciphering, validation, ordering and header compression, etc.

The dedicated hardware raises processing performance and shortens processing time but suffers from a long development time and inflexibility to changes in specifications. It is also a factor in increasing the size of the LSI and is not advantageous in terms of costs. In contrast, firmware processing by a general-purpose processor, while having low processing performance, is highly flexible to changes in specifications. With the above in mind, LTE-PF adopts an architecture that combines the best features of dedicated hardware and firmware processing.

Here, Layer 1 processing is achieved by dedicated hardware and DSP firmware processing. While functions such as MIMO that require general and high-speed processing independent of LTE specifications are achieved by dedicated hardware, functions that require flexibility to changes in LTE specifications such as those for the control channel are achieved by DSP firmware processing. The dedicated hardware is also implemented with algorithms designed to raise performance and reduce the size of the LSI as much as possible. For example, high-speed data communications can be achieved by applying MIMO, but performance here depends of the MIMO signal processing system. The Minimum Mean Square Error (MMSE)[*20] and Maximum Likelihood Detection (MLD) methods[*21] are typically used as MIMO signal processing systems. The MLD method theoretically offers the best performance but has high computational complexity. LTE-PF applies the complexity-reduced MLD with QR decomposition and M-algorithm (QRM)-MLD method[*22] [5] having similar performance to MLD while significantly reducing computational complexity thereby raising performance and reducing LSI size at the same time. The QRM-MLD method achieves the same throughput as the MMSE method with a low Signal to Noise Ratio (SNR) and provides large-capacity data communications over a broader range.

The Layer 2 processing system consists of dedicated hardware for security processing and a general-purpose CPU core processor. The LTE system specifies the SNOW3G[*23] and Advanced Encryption Standard (AES)[*24] security algorithms, both of which are supported by dedicated hardware. Layer 2 functions other than those for security are achieved by firmware processing on the CPU.

In addition to the above, the use of general-purpose interfaces to the application section and Radio Frequency (RF) section helps to make LTE-PF more flexible as well as more competitive. The RF interface used here conforms to Dig RF[*25].

5. Development of the LTE Communications Control Software Section

After having developed Protocol Stack Software (PSS) for controlling communications with the network in the W-CDMA/GSM system [6], NTT DOCOMO has now added LTE functions based on that PSS. On adding these functions, it was decided that the components (modularized software) making up each system would be somewhat loosely interconnected and have heavily independent designs to preserve the connectivity and performance of legacy W-CDMA/GSM and to ensure that each system can be independently maintained and ported (to enable only the LTE system to be licensed, for example) (**Figure 3**). To achieve loose interconnections between these components, a system is adopted by which functions other than Operation and Administration Management (OAM) functions and Protocol Stack Super Visor (PSSV)[*26] functions common to LTE/W-CDMA/GSM, that is, LTE-protocol and W-CDMA/GSM-protocol functions, can make exchanges indirectly via a terminal adapter without the use of an interface. In addition, access to the Universal Subscriber Identity Module (USIM)[*27] from LTE protocol is achieved via W-CDMA/GSM protocol to avoid duplicate input.

*17 **U-plane:** The protocol for transmitting user data.

*18 **HSPA**: Standard that enables the high speed packet data transmission in W-CDMA; collective term for High Speed Downlink Packet Access (HSDPA) that speeds up the downlink (from base station to mobile terminal) and High Speed Uplink Packet Access (HSUPA) that speeds up uplink (from mobile terminal to base station).

*19 **DSP**: A general term for a microprocessor that is specialized for processing specific digital signals such as audio or video.

*20 **MMSE**: A method for suppressing interference from other signals by multiplying the received signal with calculated weights.

*21 **MLD method**: A method that compares received signals with all signal sequences that could possibly be received to estimate received signals.

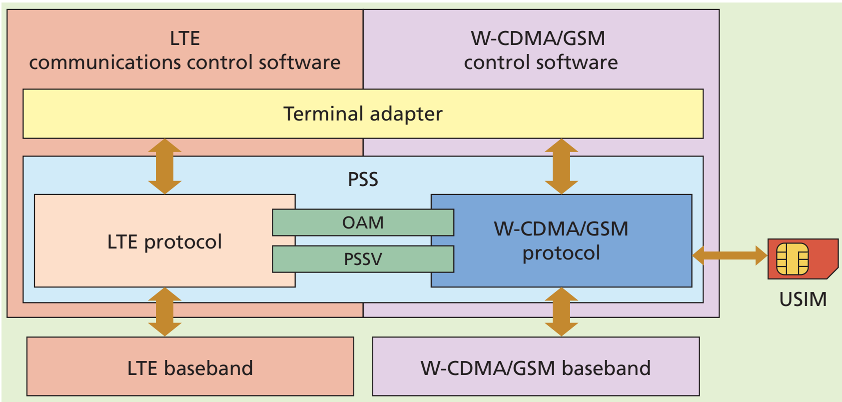


Figure 3 Configuration of PSS

6. IOT Activities

Interoperability of the LTE-PF system with overseas networks is extremely important considering that LTE-PF is offered as a system that conforms to international standards and that is suitable for global expansion. From the end-user's point of view, it is essential that interoperability be confirmed by performing actual tests on site. However, LTE networks are still in an early stage of deployment, and in terms of a mobile terminal platform, it is more realistic to check interoperability by laboratory tests with network equipment vendors. During the LTE-PF development period, NTT DOCOMO confirmed LTE interoperability in collaboration with three major overseas network equipment vendors that supply overseas mobile operators in Asia, Europe, and North America and that had the capability to perform such function-verification tests. Interoperability was also confirmed with regard to interworking[*28] between systems in the multimode function with W-CDMA and GSM/GPRS. In short, it has been shown in the above ways that LTE-PF presents no problems in terms of standard conformance and interoperability.

7. LTE-PF Licensing

As described above, LTE-PF is a mobile terminal platform that not only conforms to the international LTE standard but that also satisfies interoperability requirements with global networks as demonstrated by IOT with overseas network equipment vendors. Thus, by receiving a license for LTE-PF whose global connectivity has already been verified, mobile terminal manufacturers and chipset vendors would have no need to develop basic LTE functions, which means that they could enjoy shorter development times and reduced development costs. With this in mind, NTT DOCOMO investigated the licensing business in parallel with LTE-PF development, and as a result of this study, it set up a licensing scheme (**Figure 4**) and business format to offer LTE-PF to the chipset and platform markets and to build relationships in which both the licensor and licensees could benefit. Chipsets equipped with LTE-PF should therefore be able to expand globally, which should help Japanese mobile terminal manufacturers enter overseas markets and overseas manufacturers enter the Japanese market. To give an example of such LTE-PF licensing, NTT DOCOMO announced on July 27, 2010 that it had signed a licensing agreement with MediaTek Inc, a Taiwanese firm that has extensive sales experience in global chipset markets. The signing of this agreement bodes well for the global expansion of LTE-PF and for the use of licensing as an additional source of revenue. NTT DOCOMO plans to continue negotiations toward licensing in a variety of markets throughout the world.

8. Conclusion

This article has described an LTE-supporting mobile terminal platform called LTE-PF that has been developed to provide users with up-to-date LTE mobile terminals amid rising market demand and to enable the global licensing of NTT DOCOMO LTE platform technology. With the aim of integrating LTE-PF with W-CDMA and

*22 **QRM-MLD method**: This method selects the most likely combination of signal points from among all possible signal-point candidates of each transmit antenna branch. The application of QR decomposition and M-algorithm significantly reduces computational complexity.

*23 **SNOW3G**: One type of security algorithm

*24 **AES**: One type of security algorithm.

*25 **Dig RF**: An interface standard between a communications platform and Radio Frequency Integrated Circuit (RFIC) specified by Mobile Industry Processor Interface (MIPI), a non-profit organization preparing standards and specifications for mobile terminals.

*26 **PSSV**: A PSS common management function for managing tasks, managing access to non-volatile memory, etc.

*27 **USIM**: An IC card used to store information such as the phone number from the subscribed mobile operator. The module used to identify W-CDMA/LTE mobile communications subscribers under the 3GPP is called a USIM.

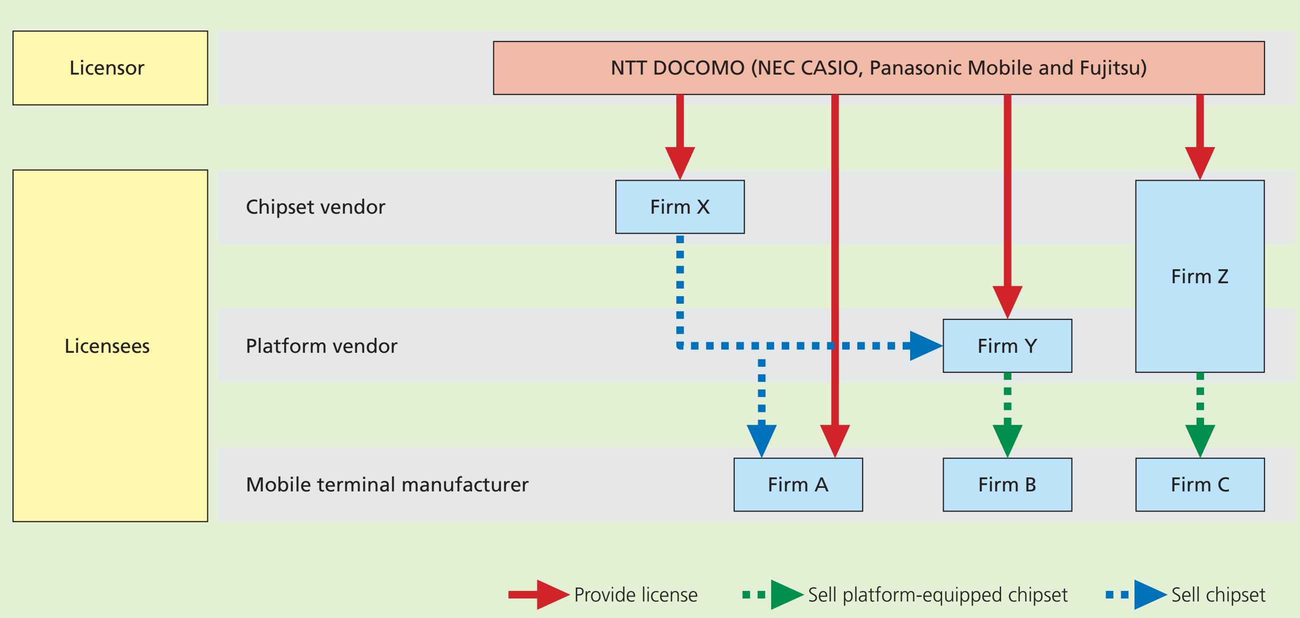


Figure 4 Licensing scheme

GSM/GPRS technologies and to further globalize LTE-PF, NTT DOCOMO plans to study architectures on supporting HSPA+*29, LTE Time Division Duplex (TDD)*30 and LTE-Advanced*31 (an LTE-enhancing standard).

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*28 **Interworking**: Interfacing between different systems; here, the exchange of communications-related information among the LTE, W-CDMA and GSM systems.

*29 **HSPA+**: Generic name for a communications standard that applies 64QAM and MIMO technologies to the HSDPA and HSUPA W-CDMA extensions.

*30 **TDD**: A bidirectional transmit/receive system. It achieves bidirectional communication by allocating different time slots to uplink and downlink transmissions that use the same frequency band.

*31 **LTE-Advanced**: A radio interface enhancing LTE to be standardized as 3GPP Release 10.