DEVELOPMENT FIELD

Design of Multi-mode Mobile Terminal Chips

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Abstract:
Based on the analysis of B3G evolution, the base-band processing chips for mobile terminals are introduced. Key technologies for multi-mode mobile terminal base-band chips are discussed. Terminal technologies are thought to be the key of B3G, and terminal base-band chips are regarded as the core of terminal technologies. Therefore, a unified wireless development platform is required for the R&D of multi-mode mobile terminal base-band processing chips.

Mobile communication has become the most promising technology with the most extensive market perspective in the field of communication. 3G is the center of the spotlight in mobile communication. Due to the incompatibility of the 3G mobile communication standards, people start to call for a unified mobile communication standard, and expect to solve the problem of incompatibility through establishing B3G mobile communication standards. International Telecommunication Union (ITU) is trying to frame the B3G mobile communication standards and has reached the following consensus: integrating the mobile communication system with other systems such as Wireless Local Area Network (WLAN) and World Interoperability Microwave Access (WiMAX) system to form B3G technology; increasing the data rate to 100 Mb/s before the year 2010; and providing diversified services more effectively. Presently, the B3G mobile communication standards compatible with 3G mobile communication technologies are under gestation in the industry[1].

Comparing with 3G mobile communication systems, the B3G mobile communication system has qualitative improvement in both technology and applications. The B3G system is not only to increase the data rate and provide new air interfaces, but also to enable seamless roaming among several mobile networks and wireless networks globally.

One of the development tendencies of wireless communication is the merge of the mobile network and the wireless access network. B3G system should be an integration of the mobile network and the wireless access network. It should be able to implement seamless connection with the WLAN. The seamlessness of B3G is shown in the system, services and coverage. The seamless system means that subscribers can access both the WLAN and the cellular systems. The seamless services refer to seamless voice, data and image services, while the seamless coverage means that the B3G system can provide services globally. Therefore, B3G is a comprehensive system. Its cellular part should provide mobility in the wide area, while the WLAN provide high-speed services in hot areas. In addition, it has a Personal Area Network (PAN) for home and office.

1 Possible B3G Technology Evolution

The B3G mobile communication system will be based on open-type wireless structure to ensure a single terminal to access local high-speed wireless access systems automatically and seamlessly. While a B3G subscriber is in office, at home, at the airport or in a shop, his terminal can use the wireless local area networks (such as WLAN, broadband wireless access systems and the wireless local loop). Once he moves to a mobile district (such as highway, beaches and remote areas), the same terminal will automatically switch to the wireless mobile networks (such as GPRS, WCDMA, CDMA2000 and TD-SCDMA systems).

Based on open wireless structure, the future B3G mobile communication system will have the open base-band signal processor, open Radio Frequency (RF) transceiver, open wireless/mobile operating system and open terminals[2]. The B3G mobile communication system adopts Orthogonal Frequency Division Multiplex (OFDM) of Multi-Carrier Modulation (MCM) technology[3-5].

Seen from the definition made by ITU, communication systems in the era of B3G should be in multiple radio environments including satellite communications, cellular mobile communications (GSM/GPRS/WCDMA, IS-95/CDMA2000 EV-DO/CDMA2000 EV-DV, TD-SCDMA), WLAN, PAN (such as bluetooth and UWB), and WiMAX.

High-Speed Downlink Packet Access (HSDPA) and CDMA2000 EV-DO/EV-DV support global roaming. Based on IP, the application system and core network of WLAN and WiMAX system have inborn advantages. The WiMAX system will take up much market share in Metropolitan Area Network (MAN), while WLAN lead in area and

enterprise communications.

1.1 Merge of Wireless Technologies

HSDPA, CDMA2000 EV-DO/EV-DV, WiMAX, WLAN and B3G Testbeds adopt similar physical layer technologies such as OFDM, Orthogonal Frequency Division Multiplex Access (OFDMA), Multi-Input Multi-Output (MIMO), self-adapting link technologies (such as modulation, coding, and base band receiving algorithm), and H-ARQ technique. Adopting similar physical-layer technologies is the requirement of net grouping, multi-media, flexible service support capability and more.

In the aspect of network, WLAN/WCDMA is under standardization, and the merge of WLAN and CDMA2000 EV-DO has been implemented. In the uplink, Wide Area Network (WAN) is utilized to order programs, while the transmission of programs by satellites in the downlink is implemented. The merge of the 3 networks is going further step by step (such as mobile TV, mobile Internet, mobile private network and trunking network).

Considering the aspect of home gateway, 3C (communications, computer and consumer electronics) has integrated WLAN and Local Area Network (LAN).

The essence of the merge of WLAN, WiMAX and WCDMA is the merge of fixed and mobile networks. The merge of the IT industry and traditional telecommunication industry will construct new Information Communication Technology (ICT) network, new industrial chain and new business models.

1.2 Evolution of Wireless Transmission Technology

3GPP R5 was released in March 2002, as the first version of the all-IP network. IP Multimedia Subsystem (IMS) was introduced into the core network of R5. R5 has only realized the basic functions and services of IMS (referred as the first stage of IMS). An enhancement of R5 is the HSDPA technology used at the wireless interface. This technology can increase the data speed in the downlink up to 10 Mb/s.

3GPP R6 was released in March 2005. 3GPP R6 continued to improve the functions of IMS at the second stage, which include network interconnection and security. Meantime, 3GPP R6 carried out the study on several new wireless technologies (such as MIMO and OFDM), network sharing and integration of WLAN and mobile communication systems. Besides, R6 also created new services and functions.

The evolution of 3GPP Radio Transmission Technology (RTT) may follow the following routine: R'99 DS-CDMA (2 M) → HSDPA (10 M) → HSDPA+MIMO (40 M) → OFDM+ MIMO+HSUPA.

1.3 Focus of Research in Wireless Transmission Technology

The author of this article believes that GSM/GPRS/WCDMA will definitely be the mainstream standards in the 3G era because it has attracted the biggest capital investment, productivity and patent system in the world. As for the B3G evolution, we should give priority to the evolution based on the merge of WLAN, WiMAX and 3G (WCDMA or TD-SCDMA). This direction in evolution should be the mainstream, and the evolution based on the merge of WLAN, WiMAX and 3G (CDMA2000) might be the substream.

It has not been defined yet whether the B3G Radio Access Network (RAN) should develop new service capabilities based on the previous 3G/2G RAN service capabilities, or go for brand-new service capabilities.

Seen from the evolution routine from CDMA2000 to EV-DV and EV-DO and the routine from R'99 to HSDPA, RAN can go for new service capabilities only through revolutionary changes, rather than through evolution. The development from 1G to 2G, and from 2G to 3G has fulfilled new service capabilities of wireless voice, data and multimedia. However, B3G is unnecessarily to be an all-purpose system, therefore its provision of supplement services is more important than implementation of all-purpose service capabilities. Implementation of the merge at the service and terminal layers might be the more practical choice.

The reason why CDMA2000 develops faster than WCDMA in terminals is its partial legacy at the physical layer. Therefore, it is necessary to study the complexity and realizable possibility of B3G terminals in order to study B3G. In other words, B3G terminal technology is the focus of the B3G study, and the R&D of mobile terminal base-band processing chips is the focus of the B3G terminal technology study.

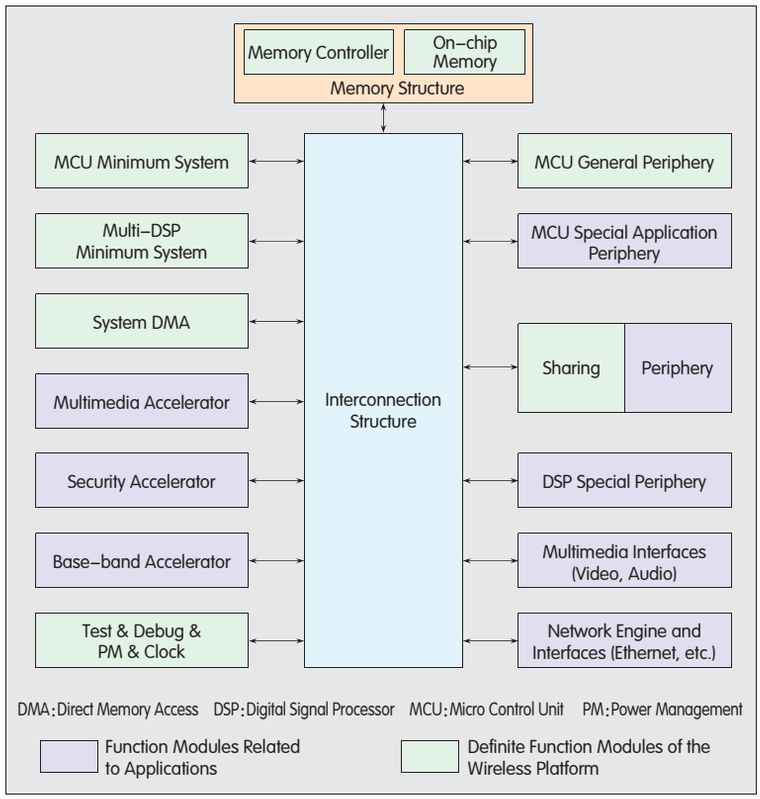
2 R&D of Mobile Terminal Base-band Processing Chips

The mobile communication system develops from 2G, 2.5G to 3G, and its base-band processing chips also develop with the system. The structure of the base-band processing chips of mobile phones will be analyzed in the following paragraphs.

2.1 2G/2.5G/3G Base-band Chips

In the middle of the development of 2G/2.5G mobile phones, the base-band digital processing functionality and basic periphery functions of mobile phones are integrated into System on a Chip (SoC), with a basic double-core structure of Micro Control Unit (MCU) + Digital Signal Processor (DSP). The DSP sub-system, supported by the accelerator and base-band special peripheral units, fulfills all the functions at the physical layer through software, while the MCU mainly runs control software at the physical layer, protocol stack software and application software.

The base-band chips of 3G mobile phones are under



▲Figure 1. General functional framework of the wireless platform.

development, and few vendors have released related solutions.

Comparing with 2G base-band chips, the base-band chip solutions for 3G mobile phones greatly improve the application processing capability of the mobile phones. The Open Multimedia Applications Platform (OMAP) released by TI is a typical example. The OMAP is a multi-structure platform integrating base-band processing and applications processing, adopting the solutions of the SoC application processor ARM + the base-band Modem (ARM+DSP), and the base-band processing chip+ double-chip application processor. At the same time, in the WCDMA solution released by Qualcomm, the base-band chip adopts the structure of the application processor + double DSP.

2G/2.5G/3G base-band chips have the following characteristics:

(1) The changes in the functionality and performance of base-band chips from 2G to 3G are as follows:

• Application functions are enhanced by improving the performance of the processor, or by embedding special application processor cores.

• The level of integration capability of base-band chips has always been raised, for instance, the analog base band and digital base band are in one, and more application interfaces are integrated (such as interfaces for camera, Universal Serial Bus (USB) etc.).

• The processing capabilities of MCU and DSP are enhanced. Even so, numerous accelerating modules and search engines are added into the WCDMA base-band chips with the consideration of such factors as the power consumption, real-time processing, performance and more.

• The power consumption of base-band chips is decreased by improving workmanship, or by the change of design.

• Multimode base-band chips have become the tendency, for instance, the available 3G base-band chips all support GSM/GPRS and WCDMA. Qualcomm has even planned to release the multi-mode base-band chip supporting CDMA2000, WCDMA and GPRS/GSM.

(2) The structure of the base-band chips is still based on double processor cores as MCU+DSP, but the processing capabilities of MCU and DSP are enhanced. Moreover, the data exchange between the MCU subsystem and DSP subsystem has changed from the mode of simple dual-port Random Access Memory (RAM) to multiple bus resources sharing. Some vendors adopt multi-level bus protocol from AMBA.

(3) Embedded large-capacity Static Random Access Memory (SRAM) in the chip, in favor of decreasing power consumption and system cost, is very popular now. Intel has embedded the large-capacity flash RAM into its chips. The extended memory in general supports Synchronous Dynamic Random Access Memory (SDRAM) and NAND flash RAM. In the structure of memory, MCU and DSP have cache or second-level cache in their sub-systems, and share on-chip SRAM and external memories.

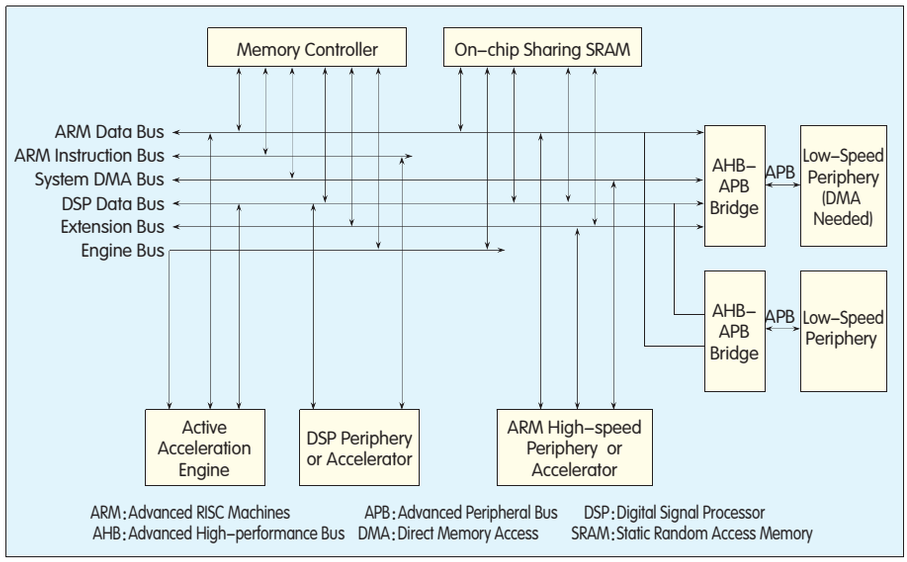
(4) In the peripheries, new functions such as USB and Multimedia Control (MMC) are added in addition to the traditional Serial Communication Unit (SCU), Multimedia Interface (MMI) and communication interfaces. As for the double-core system, many manufacturers treat the shared unit as a periphery. The base-band chip includes special communication interfaces with the analog base-band chip and Radio Frequency (RF) chip.

(5) The DSP subsystem is still the focus of base-band processing. It includes many hardware accelerators and related processing modules. In the 2G era, the physical layer of the base-band chips was generally fulfilled by DSP software, while in the WCDMA base-band chip many special hardware have been added.

2.2 Multi-mode Mobile Terminal Base-band Processing Chips

Seen form the development of 2G/2.5G/3G base-band chips, the R&D of base-band chips is based on ARM + DSP structure or ARM + double DSP structure. In the era of B3G, mobile terminals will be multi-mode ones to implement seamless roaming among several mobile networks and wireless networks globally. The multi-mode mobile terminal base-band processing chip proposed in this article is designed on the basis of a unified wireless platform, which is based on ARM + multiple DSP structure.

Figure 1 represents the general functional framework of the wireless platform, using different colors to emphasize the common function units and special product related function modules that are abstracted from the wireless platform.



▲Figure 2. Interconnection structure of the wireless platform.

The on-chip interconnection bus on the wireless platform follows the ABMA bus standard from ARM Company and adopts multi-layer Advanced High-performance Bus (AHB) by ABMA.

On the wireless platform, there are 4 basic AHB buses, and 4 AHB bus masters are the ARM data bus, ARM instruction bus, DSP data bus and system Direct Memory Access (DMA) bus. Besides, the low-speed peripheries of ARM are classified into the peripheries supporting DMA and those not supporting DMA, which respectively use the Advanced Peripheral Bus (APB) to implement connection through the AHB-APB bridge. The peripheries and accelerators of DSP are connected to the DSP AHB, or by adding an AHB-APB bridge if necessary. The high-speed peripheries and accelerators of ARM can be directly connected to the AHB, or connected through the channel controller when DMA visit is required.

The AHB master bus can be extended if required. The wireless platform interconnection structure is shown in Figure 2.

The interconnection structure of the wireless platform has the following characteristics:

(1) The interconnection structure is easy to extend because it is easy to be implemented to add more AHB Master buses or APB buses and to extend AHB peripheries or APB peripheries.

(2) Flexibility of the system is enhanced. For instance, both the DSP core and ARM core can visit all the system resources. Therefore, there are flexible choices for configuration when making system integration.

(3) Several high-speed AHB buses allow multi-master parallel data transmission to improve the whole system performance.

(4) Separating the low-speed equipment from high-throughput memory system is in favor of decreasing both power consumption and complexity of the peripheries module interfaces.

(5) Peripheries supporting and not supporting DMA adopt the AHB-APB bridge and APB bus connection respectively. This arrangement is not only favorable for the data transmission of peripheries with comparatively huge data flow, but also decrease the APB load.

(6) The APB can run at a frequency lower than the AHB clock to decrease the power consumption.

Software Defined Radio (SDR) technology will be applied to the B3G system. It makes the system flexible and adaptable, catering to different networks and air interfaces. It also supports multimode mobile phones and base stations using different air interfaces, and fulfills the variable requirements of QoS of applications. Moreover, it is favorable for integration of different standards and systems.

The possible applications of SDR technology in 4G include:

- Base stations adopting SDR can provide services to multiple networks at the same time.
- When a terminal roams, for instance, it moves to a mobile system using a different standard, it can automatically reconfigure itself according to the new system standard to acquire services in the new system.

The essence of software rebuilding of terminals is the download of software for air interfaces. With the enhancement of signal processing and the decreasing of processing cost, it becomes possible for mobile phones to rebuild base-band processing application. This results in the application of flexible air interfaces.

The flexible air interface means various parameters, such as the modulation type, carrier frequency and multiple address modes (TDMA, FDMA, OFDM etc.), need not to be defined before a communication connection takes place. The mobile terminal and the base station can dynamically define the appropriate physical parameters according to their relative capabilities and the connecting mode required for the service. For instance, the QoS of voice communication is apparently different from that of visual communications.

The application of software download and rebuilding technology will promote the development of B3G mobile terminals. The B3G mobile terminals will provide diversified air interface configurations, special application optimization, and more. Because of the rebuilding capability of downloading software, B3G terminals have been regarded as the "future indicator", which will provide multiple modes, multiple services and multiple standards.

Complete software rebuilding capability enables new base stations and new network platform structure to develop fast and dynamically to carter to different service requirements. In addition, it enables subscribers to maximize the utilization of the limited frequency and bandwidth resources. The structure of ARM + multiple DSP can implement SDR.

Moreover, some scholars have presented an Integrated Circuit (IC) solution to meet the requirements of 2.5G, 3G and B3G, which is new adaptive-computing processing technology. Its chip is a new-generation IC Adaptive Computing Machine

(ACM) adopting the adaptive computing technology to directly map the dynamic arithmetic to dynamic hardware (chip) resources[6]. This new IC is still under study without products for commercial use.

3 Conclusions

With 3G gradually being used in commercial fields, many governments and big communication companies have started the research of B3G/4G. China formally initiated its 4G mobile communication project based on Future Technologies for a Universal Radio Environments (FuTURE) in 2002. The project was included in the "863" research plan of China. It is significant for China, through heavy investment into the R&D of 4G mobile communication technologies, to make efforts to achieve breakthroughs in core technologies, and obtain a voice in the process of standard making. The unfavorable position for China to passively follow other's standards in the Intellectual Property Rights (IPR) negotiation, due to lacking of core technologies in 2G and 3G eras, is accordingly expected to be changed. The mobile terminals in B3G/4G will be the multimode terminals. To carry out research on the structure of the multimode mobile terminal chips and to develop chips with proprietary intellectual property rights is significant for the development of the mobile terminal business in China.

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Li Shuhong graduated from Xi'an Jiaotong University. He is an IC system engineer at Kangsun Research Institute of ZTE Corporation. From 2001 to 2002, he participated in the GPRS base-band chip R&D project, setting up the GPRS base-band chip system test platform. From 2002 to 2004, he took part in the SoC platform chip project as a system engineer.

Roundup

ZTE Bags China Telecom's Largest Metropolitan NGN Project

ZTE Corporation is to provide China Telecom, the country's largest fixed-line operator, with its largest metropolitan intelligent fixed-line NGN network.

The commercial trial network will be located in Shanghai, one of the most economically developed and densely populated Chinese cities, which has around 10 million fixed-line and PHS subscribers. It will mainly employ ZTE Fixed-line 3G@NGN solutions for provisioning enhanced calling services and data services.

The first phase of the intelligent network will be in operation by July 2006, provisioning an assortment of services including polyphonic ringtones, number portability, prepaid fixed lines, synchronous rings, etc..

"The large subscriber base makes any service deployment in Shanghai very complicated," said Mr Huang Dabin, Vice General Manager of ZTE Network Division. "We are proud of being chosen for the network updating and improvement, which will largely advance the network's intelligence, mobility and multimedia features."

The China Telecom agreement is just the latest NGN success for ZTE which was the first Chinese member of ISC (International Softswitch Consortium). Since embarking on a feasibility analysis of the technology in 1998, ZTE has constructed China's first commercial network based on Softswitch technology and installed around 200 NGN networks in countries including Indonesia, Pakistan and the Philippines.

In 2005, ZTE has notched up a series of global NGN wins. In July, ZTE was chosen to build Central Asia's first commercial NGN network following an agreement with Tajikistan's major fixed line operator, Tajiktelecom. In September the American telco Corisat selected ZTE to build a network enabled by ZTE NGN solutions to deliver enhanced calling services and wholesale VoIP services across America and Latin-America. In December, Emcali, one of Colombia's four major fixed-line operators, chose ZTE to provide the infrastructure for its upgraded Softswitch-based Next Generation Network.