High Performance Digital Signal Processing System for Wideband Mobile Communications

Yumi Takizawa, Saki Yatano, and Atushi Fukasawa

***Abstract*—** This paper describes a higher performance numerical operation system for next generation mobile communications. This system is featured as an efficient embedded system composed with MPU, FPGA, and a high resolution display. Basic functions and the specifications of the system are mainly defined by amount of data and data rate.

Total quantity of processing is shared by MPU and FPGA in practical design. MPU bears functions of control and management operations. FPGA bears functions of high data rate signal processing. Other types of processors are attached depending on individual features to enhance capability of processing.

New configuration was proved to provide sufficient capability for high quality still and moving pictures processing with a prototype signal processing system.

***Keywords*—** Digital signal processing, Embedded system, Mobile communications, MPU, Prototype model, JPEG, MPEG.

I. Introduction

Mobile communication is now one of the most popular and useful systems for public communications. Computer is another one of the most essential tool for business and human activities. Together of public communication and computer network services are fundamental systems of information fed to daily life of citizens. These systems are providing much quantity of information under less cooperation.

If these systems are merged and integrated, new services will be expected with transmission of higher order data and high quality picture. Real time data processing of large amount of data is needed to communications. Communication processing contains parallel processing for synchronization, coding and decoding, packetizing and de-packetizing, modulation and demodulation, data reception and transmission, channel control, and so on.

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Digital signal processing systems are integrated with real-time operation, small power consumption, and compact configuration.

A prototype system was implemented and confirmed of high quality pictures transmission.

II. Digital Signal Processing with Embedded System

A. Advanced Mobile Communication

Static and motion pictures transmission services have been introduced in mobile personal communications services (PCS). Low data rate transmission limits quality and size of pictures and display.

An expected communication service should provide potential users with sufficient quality with enough amounts of pixels for practical applications of business, medical, security, and the other variety of applications.

Advanced mobile communication system is studied for services after the present Personal Commutations Services (PCS)[1][2]. Services of communication, information, broadcasting, and consumer electronics (electronic game machines) will be unified toward new service.

The above concept and practical systems, will be realized by successful achievement of technologies of wideband mobile radio channels and sophisticated data processing and control with compact and low power consumption. Newly composed system of next mobile communications is assigned for a pair of technologies described above.

B. Digital signal processing with an embedded system

Embedded systems are concerned in many areas as a efficient technology for real-time digital signal processing with reduced power consumption, cost, and size. The embedded system is taken up in this paper especially being targeted to advanced mobile communications at the next generation[3].

III. System Configuration

A. Strategic Configuration of Software and Hardware

In the newly composed system, the target data and signals together with operational components are categorized and related with each other.

In order to implement a target algorithm and control protocol, categorization is done as the following steps;

(a) Software

Unspecified contents of processing and control, which is assumed as documentation, spread sheet software, and so on are first assigned for processing by software, which are done by offline processing.

e-mailing, browsing, and scheduling are then assigned to software, which are done by online processing.

As the third area, flexible or adaptively decided procedure of processing, operation management, and

(b) Hardware

Number of operational components is chosen 4 kinds as MPU, DPS, FPGA and custom LSI. Based on the above categorization, the target data and signals are categorized into 4 groups evaluated by necessary processing time length.

MPU bears processing defined by software said in the first part of above (a). This plays a role of flexible and a limited amount of operations.

DSP bears processing also defined by software in the second part of above (a). This plays a role of constant part of processing relating to filtering, correlation calculation, amplitude /phase equalization, etc. These operations are featured by repetition of multiplication and accumulation.

FPGA bears processing controlled by software designed and fixed at development. This plays especially important role to process high quality pictures and related large amount of data.

Custom LSI gives central part of a system at later time of development. Most part of processing is implemented by this component to realize high processing speed with reduced power consumption, size, and cost.

Table 1 shows a strategy of hardware configuration.

	devices	Sharing of processing
Defined by Software	**MPU**	**Management, Communication & protocol control, User-programming**
	DSP	**Multiply and Accumulation (MAC) for communication processing**
Defined by Hardware	**PLD / FPGA**	**High speed parallel data processing**
	Custom IC	**High capability with low power consumption**

Table 1 Strategy of configuration of task and hardware.
MPU: micro processing unit, DSP: digital signal processor,
PLD: programmable logic device,
FPGA: field programmable gate array.

B. Expected Function of Embedded System

Comparisons of system concepts of embedded operation systems are:

The proposed digital signal processing system is given with an embedded system as follows;

1) Language system is provided for specified and unspecified users to use their own programs.

2) Communication protocols are embedded in OS kernel as standard functions.

3) Multi-process/thread/task are supported based on memory protections with priority control function. Real time processing is especially actualized be applied for public communications.

4) Security are enhanced and less-compatibility brought by unique OS.

Concepts of existing embedded system[4] are;

1) No language system is prepared.

2) A few protocols are supported.

3) Multi-process are restricted.

4) The operation system is based on open OS. Therefore systems developments are easy, but security protections are needed.

IV. Prototype System

A. Prototype System Design

A basic configuration was designed and its hardware was implemented by using commercial use devices relating to mobile communication, navigation, and video games.

(a) Micro processor unit (MPU)

Commercial MPU was chosen in this prototype system. MPU chip is produced CMOS technology with 720Mips at clock frequency 400MHz.

(b) Digital signal processor (DSP)

Parametric operations of filtering, mathematical calculation of numeral and data are assigned to DSP.

(c) Field Programmable Gate Array (FPGA)

Commercial supply of FPGA is chosen. FPGA was introduced effectively used main part of communication signal processing in this development.

(d) Customized LSI circuit

In this study, grater part of hardware could be changed into customized LSI circuit to reduce hardware size power consumption. This is planed for future study.

B. Configuration of prototype system

Complex, large scale and high-speed data processing are needed for next generation mobile communications to provide high quality picture and high data rate services. Efficient classification and limitation of task must be done first based on a strategy shown in Table.1. A practical configuration is shown in Fig.1, which shows a prototype model of embedded system for next generation mobile communication

Management and control is done by a MPU with less volume and power consumption to reduce total volume and power as an embedded system. Flash memory with 512MB is installed in the MPU board. Graphic processing must be a custom IC in future to achieve minimum volume, power and cost. However FPGA is used in place of custom IC for prototype model of hardware. In this study the content of processing is provided by the prototype radio system FT04, which has been developed by the authors.

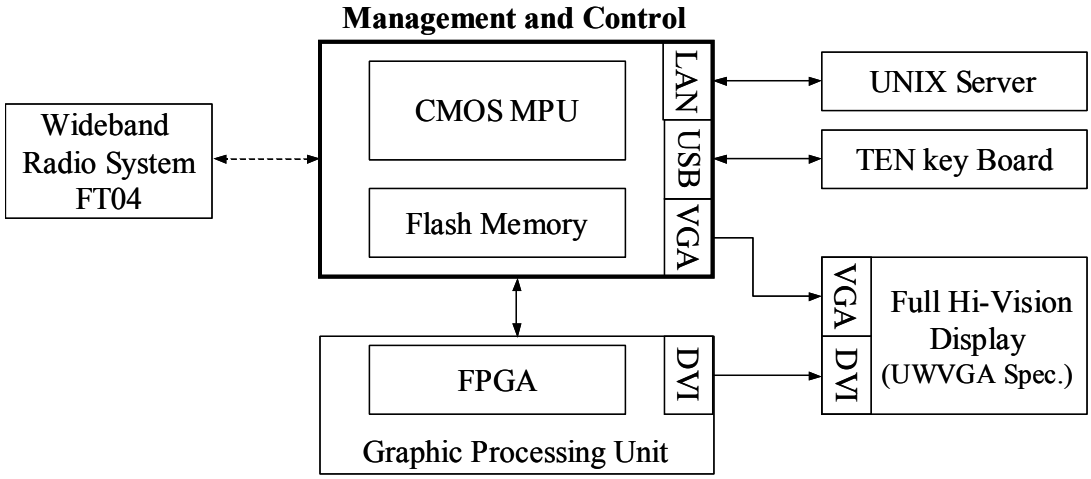

Fig.1 Configuration of a prototype embedded system.
VGA: video graphics array, DVI: digital visual interface,
UWVGA: ultra-wide-VGA,
CMOS MPU: Complementary MOS MPU, RENESAS SH-4a.

Fig. 2 Photograph of a prototype system for advanced mobile communication included display and speakers (left) and developed embedded system (right).

C. Validation with prototype hardware

The prototype system model was applied to data processing and communication control for the transmission of the following data. The radio bandwidth and transmission data rate are 40 MHz at 3.5 GHz band, 0.256 to 32 Mbit/sec maximum. The data was produced of still pictures defined by JPEG and moving picture was simulated by continuous transmission of JPEG. It was found that the picture quality was enough for practical application including broadcasting reception, printing for business use and so on. Without suitable standard of evaluation for moving and still picture qualities, the detail data of quality evaluation of pictures shall be the future research.

Quality of pictures was found equivalent to wired transmission system and to meet to quality of public services. A photograph of the prototype system is shown in Fig. 2.

D. Subjects and issues in future

Still and moving pictures with low resolution and limited size are transmitted by present mobile radio communications. Wideband radio technologies are studied under the environment of multi-path propagation. The maximum data rate was 32 Mbit/s through 40 MHz radio bandwidth at 3.5 GHz microwave band in this study. Maximum data rate related to microwave band and bandwidth are future issues.

On the viewpoint of signal processing capability in small handy terminal, transmission of high quality pictures are studied. An embedded system has been taken up to provide high performance signal processing of high quality pictures. Strategy of configuration of task and hardware was first analyzed for efficient embedded system with compact and low power consumption. Packet transmission technologies are applied for Sound and video transmission. Validation of the proposed scheme has been done by a prototype hardware developed with commercially available components including MPU and FPGA.

Suitable standard and its evaluation methods for the quality of moving and still pictures are the future issues.

V. Conclusion

It was found that sufficient and enough quality of pictures can be transmitted by a wideband CDMA radio systems with 40 MHz bandwidth at 3.5 GHz band. It was also proved that relatively small size and power consumption were achieved by a proposed configuration with CMOS MPU. It is expected that practical values of size and power consumption based on custom LSI at the next in near future.

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