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The Role of Digital Signal Processors for 3 Generation Mobile Communication Systems

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Abstract: Digital Signal Processors are microprocessors specifically designed to handle complex Digital Signal Processing tasks. These devices have seen tremendous growth in the last decade, finding use in everything from cellular telephones to advanced scientific instruments. The hardware engineers use "DSP" to mean Digital Signal Processor, just as algorithm developers use "DSP" to mean Digital Signal Processing. DSP has become a key component in many consumers, communications, medical, and industrial products. This paper will give the idea of role of Digital Signal Processors (DSP) for third generation mobile systems.. Many solutions for base station or mobile station have been implemented over the years, and each solution required a combination of two components, ASICs (Application Specific Integrated Circuits), and DSPs (Digital Signal Processors). The next generation of mobile computing requirements will increase due to higher data rates, increased complexity algorithms, and greater computation diversity but the power requirements will be just as stringent to ensure reasonable battery lifetimes. The design of the next generation of mobile platforms must address three critical challenges: efficiency, programmability, and adaptivity.This paper illustrates the role of Digital Signal Processors for Third generation (3G) mobile systems and DSP architectures for 4G wireless communication**.**

Keywords : Digital Signal Processors, 3G Mobile Communications Systems

I. INTRODUCTION

The first-generation (1G) cellular wireless mobile systems were analog and were based on frequency-division-multiple access (FDMA) technology. The second boost for the cellular industry came from the introduction of the second-generation (2G) digital technology standards, including Global System for Mobile (GSM), IS-136 (Time Division Multiple Access, TDMA), and Personal Digital Cellular (PDC) [1]. In the transition from 1G to 2G in mobile communications, new standards are deployed which are digital in nature. So, due to the need to operate on larger data streams, more MAC (complex multiply and accumulate) and ACS (Accumulate compare and select) operations are required. It is here that DSP plays a role in wireless communication. Signal processing has always played a critical role in the research and development of wireless communication systems. As the demand for high capacity and high reliability systemsincreases, signal processing has an even more important role to play. Today's programmable DSPs are universal in the wireless handset market for digital cellular telephony.

II. MOTIVATION

A. Achieving a competitive advantage

The communications market is very dynamic and has a high growth rate. Hence DSPs for communications must evolve to continue being a platform for achieving and sustaining a competitive standing. How can this be achieved?

The performance of DSPs is evolving further by advances in semiconductor technology. This leads *e.g.*, to higher clock frequencies as well as a reduced power consumption per MIPS. Additional performance improvements can be gained by the development of new DSP architectures, where performance is measurable by a reduced MIPS requirement per algorithm (improved efficiency), reduced power consumption, or allowable higher clock frequency. Riding on advances in semiconductor technology alone for achieving a competitive advantage can be extremely dangerous. Therefore, architecture technology is a key.

B. How to get a hold of DSP technology ?

Typical money maker ICs have gained a competitive advantage by sustaining a technical and/or marketing advantage. A technical advantage as :

(*i*) Power consumption
(*ii*) die size/cost
(*iii*) performance
(*iv*) package, I/O, chip-set integration

is achieved by combined architecture-application optimization.

C. What kind of DSPs are needed ?

There has been discussion on DSPs versus microprocessors. This was mainly based on general purpose floating-point DSPs. Actually, DSPs cover a very wide range of architectural customizing for applications. We can divide DSPs into three general classes, *i.e.*

, (*i*) Application specific DSP (AS-DSP)

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(*ii*) Domain specific DSP (DS-DSP)

(*iii*) General purpose DSP (GP-DSP).

AS-DSPs are typically customized to an application to serve high-end application performance requirements, or to minimize die size/cost. Generally the market volume must allow for a custom solution to be developed, and customizing is carried out to gain market advantages. However, time-to-market constraints must allow for a long design cycle. Examples of AS-DSP can be found e.g. for speech coding. Application customizing can be found in the data path, address generation, bus architecture, memory, and Input output.

DS-DSPs are designed to a wider application domains, as cellular modems. They can be applied to a variety of applications. Due to special instructions and additional hardware they can run domain specific algorithms efficiently e.g. Viterbi algorithm and equalizers. A DS-DSP is designed for a market with a volume high enough to allow specialized solutions. Its specific advantage over an AS-DSP is its fast availability.

GP-DSPs have evolved from the classic FFT/filtering multiply-accumulate design model. Examples are TIC50, Lucent 16xx, Motorola 563xx, ADI 21xxx and DSP-Semi's Oak/Pine. GP-DSPs are freely available, are extensively applicable, and have a large software base. They lack in performance as compared to more customized solutions for specific applications.

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III. THE THIRD GENERATION OF MOBILE

SYSTEMS REQUIREMENTS

Most applications require audio, video and communications processing capabilities, the requirements placed on processors used in base station and mobile stations have become more computationally and bandwidth intensive. Both RISC microcontrollers (MCU) and DSPs have served these applications. While RISC processors are architected to enable efficient asynchronous control flow, DSPs are architected to perform well for synchronous, constant-rate data flow. Since both control and media processing are required in many embedded applications. DSPs and MCUs are typically used together either at the board level or in system-on-chip (SoC) integration. The RISC processors and DSPs unite as the perfect processing engine for a wide variety of multimedia applications and products, such as cellular telephones, digital cameras, portable networked audio/video devices.

Key base-station areas that require high-performance DSPs will include:

- Antenna Arrays with Adaptive Digital Beam-Forming (in BS- Base Station)
- Power Control (in both BS and MS – Base and Mobile Stations)
- Voice Processing (in BSC: Base-Station Control)
- Base Band Modem (in BTS: Base Transceiver Station)

Digital signal processor are required both in BS and MS . Nowadays, there are some emerging technologies for example:- DSP– based Internet telephony which link between PSTN and packet network (VoIP gateway); the DSP advancements in processing power, smaller footprint, and reductions in power dissipation have extended number of channels carried on VoIP gateways.

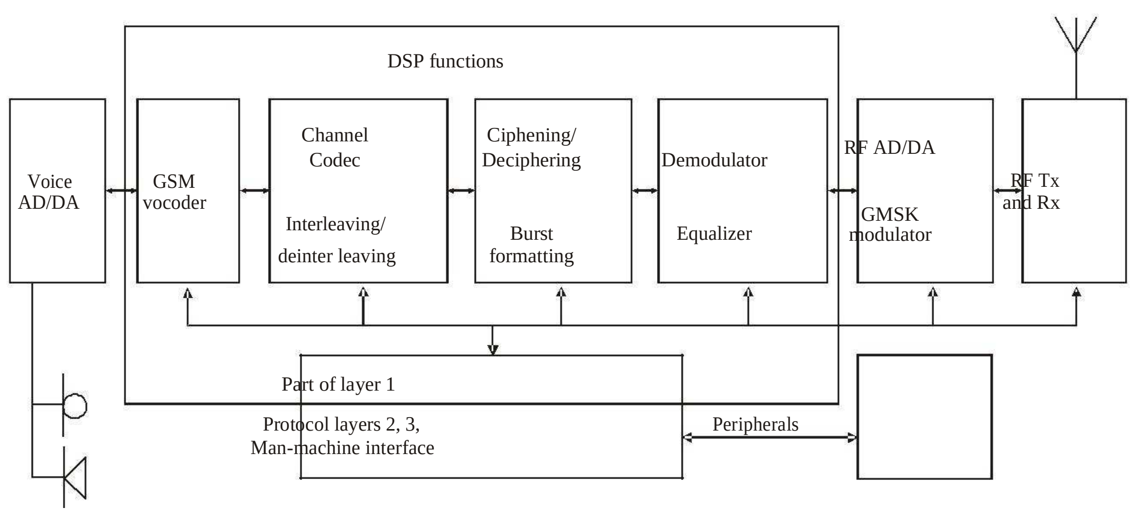

Fig.1. The GSM mobile station.

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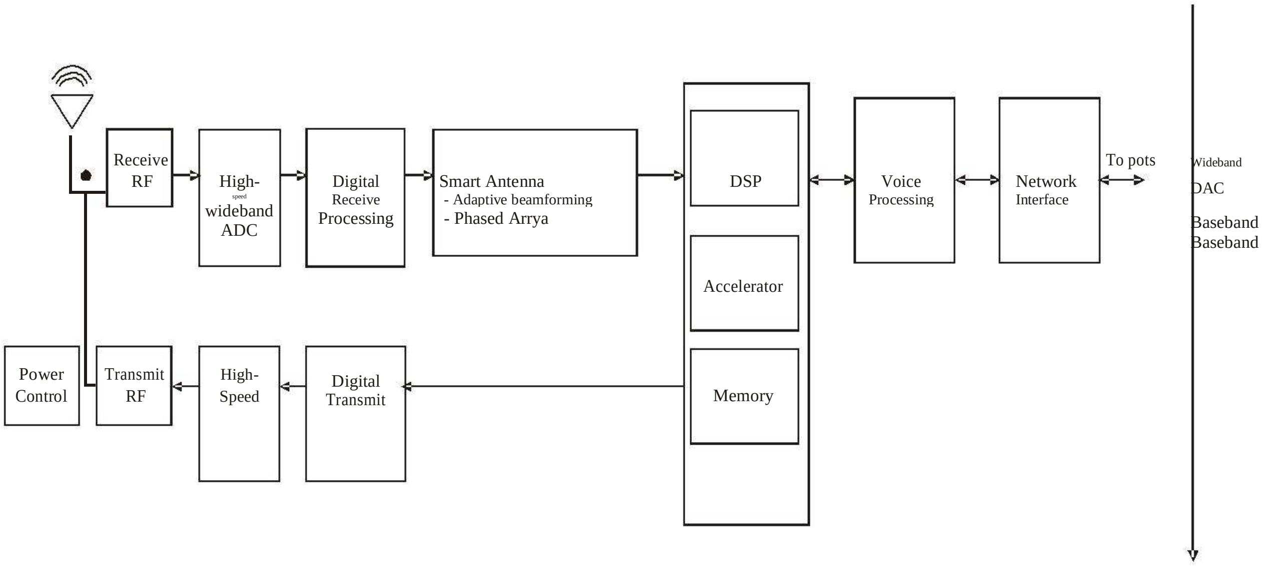

Fig.2. The base station.

(*i*) DSP – based Internet telephony which bridge between PSTN and packet network (VoIP gateway); the DSP advancements in processing power, smaller footprint, and reductions in power dissipation have expanded number of channels carried on VoIP gateways.

(*ii*) ADSL market (*iii*)

Software radio

(*iv*) Space-time processing

A. Smart antennas

Digital beam-forming algorithms are designed to target source locations in a noisy environment. They rapidly compare responses of several spatially deployed antennas; the result of the computation is a signal that is believed to have originated from the target direction. Basically, they compute a correlation function that compares the signals and gives a measure of how close the desired and received signals are. Due to the many factors involved in the algorithm, and their wide dynamic range, floating point multiply accumulate operations are used almost exclusively to minimize roundoff errors. The target is mobile, and could be moving at a significant speed, this adds another dimension of complexity to the computation.

B. Power control

In the code-division multiple-access (CDMA) systems proposed for 3G, base-station-initiated power control of remote-unit transmitters (uplink) is critical to compensate for fast fading, peaks in transmission power, and to avoid near-far problems. This is necessary to reduce inter-cell interference. The computations required for power control are multiply-accumulate intensive, requiring high performance digital signal processing to meet delay time requirement in 3G systems.

C. Voice processing

DSPs [3] are the traditional choice for speech processing within the cellular system. The phone user's opinion of the quality of the system is directly dependent on the performance of the speech coder, and this has a strong influence on the channel density. Several speech coders are in use today in current 2G systems and must be supported in 3G systems. Although lower codec bit rates increase equipment capacity, they worsen the speech quality. The critical DSP characteristics for high-quality voice processing combine large on-chip RAM and high processing capacity to support fast context switching and high channel density.

D. Base band modem

The 3G standard is expected to be an essential factor that enables applications involving the transmission of wideband signals. Accordingly, the base band modem (BTS) must be designed and implemented with the ability to intermix high bandwidth applications and low bandwidth voice and paging. In the downlink, the base transceiver station packages parallel transport-block streams into physical channels; and in the uplink, it recreates the transport blocks from the base band signal.

Designers of 3G base stations will make use of the DSPs in order to achieve the high performance and flexibility needed for tomorrow's voice and data applications. Speech coding is an essential application of digital signal processing in modern day telephony and mobile communications, which employ high data compression ratios. Effective embodiment of these design principles will fulfill the promise of 3G to provide the foundations of the kind of wireless infrastructure necessary for tomorrow's applications.

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A. DSP processors for 4G

3G supports multimedia Internet-type services at better speeds and quality compared to 2G. The W-CDMA based air-interface has been designed to provide improved high-capacity coverage for medium bit rates (384kbit/s) and limited coverage at up to 2 Mbit/s (in indoor environments). Statistical multiplexing on the air also improves the efficiency of packet mode transmission. There are certain limitations [12] with 3G as follows:

Higher data rate is difficult with CDMA due to excessive interference between services. It is difficult to provide a full range of multi-rate services,

4G is highly dynamic in terms of support for: the user's traffic, air interfaces and terminal types, radio environments, quality-of-service types and mobility patterns.

4G, puts more demand with adjustable and built-in intelligence. Thus a software system rather than a hard-and-fixed physical system is required. A 4G system [13] is required to provide a comprehensive and secure all-IP based mobile broadband solution to laptop ,computer, wireless modems, smartphones, and other mobile devices. Facilities such as ultra-broadband Internetaccess, IP telephony, gaming facilities, may possibly be provided to manipulators. In modern DSP's, architecture can be extended by duplicating the processor cores. Enhanced DSP's utilizes SIMD operations, while multiple-issue DSP's may implement either VLIW or superscalar architectures

System on Chip (SoC) based architectures Mobile device processor architecture became simple with SOC designs. Real time responsiveness in mobile devices can be managed by using an improved DSP hybrid chip. dropping the voltage of the chip enables low power operation in mobile devices. Martin at el [14] proposed reconfigurable processor architecture for mobile phones. Dynamically Configurable System on Chip (CSoC) architecture has been enhanced for mobile communications. CSoC's are modified for a specific application. Its architecture consists of processor core, memory, ASIC cores, and on-chip reconfigurable hardware units. Most of the smart phones are single or dual-core SoC's. For mobile applications, faster dual-core CPU provides better performance than quad-core SoC's. Future SoC's for mobile will become more sophisticated.

VI. PROGRAMMABLE DIGITAL SIGNAL PROCESSORS FOR 4G MOBILE

ARM Processors for Mobiles ARM based processors are the most widely used in modern Smart phones. ARM is a32-bit instruction set architecture based on RISC architecture . ARM processors are specially used in Smart phones because of its low power consumption and great performance. Different ARM architectures used in Smartphone are ARMv5 used in low-end devices, and ARMv6, ARMv7 used in high performance devices. ARMv7 has a hardware floating-point unit (FPU) providing improved speed. The 32-bit ARM architecture, such as ARMv7-A, is the most extensively used architecture in mobile devices. ARM architecture is the main hardware architecture for many of the operating systems of mobile devices such as iOS, Android, Windows Phone, Windows RT, Bada, Blackberry OS/Blackberry10, MeeGo, Firefox OS, Tizen, Ubuntu Touch, Sailfish and Igelle OS.

ARM Cortex Processors ARM Cortex processors cores are categorized into the following variants: Cortex-A Processors (ARM Application Processors)
Cortex-R Processors (ARM Embedded Real-time Processors)
Qualcomm Snapdragon Processors Snapdragon is a family of mobile system on a chip (SoC) processor architecture provided by Qualcomm. In the year 2013, Qualcomm Snapdragon 800 processor with Krait 400 CPU cores providing 2.3 GHz clock speed outperformed all other processors in the mobile segment.

NvidiaTegra Processors Tegra is a SoC series for mobile devices developed by Nvidia. It assimilates ARM architecture CPU, graphics processing unit (GPU), memory controllers, etc. on a single package. High performance and low power consumption for audio/ video applications is provided. It was found that Nvidia'sTegra 4 SoCis better than Qualcomm Snapdragon processor in terms of performance. Nvidiahas launched next generation mobile processor, Tegra K1. It is a mobile processor with 192 graphics cores for mobile gaming applications. Nvidia K1 was launched with a support for two versions: traditional 32-bit "4+1" ARM cores like Tegra 4, and dual core 64-bit version. Tegra K1 is assumed to be more powerful than either the Xbox 360.

B. A Variable point FFT processor for 4G Standards:

IMT-Advanced varieties of the exceeding binary ethics are developing. In all suggestions for 4G, the CDMA spread spectrumwireless technology cast-off in 3G systems and IS-95 is replaced by OFDMA and formerfrequency-domain equalization. This is combined with MIMO (Multiple In Multiple Out), e.g., multipleantennas, dynamic channel allocation and channe ldependent scheduling. Orthogonal Frequency Division Multiple Access (OFDMA) is a cellular air interface used in 4G communications networks such as WiMAX.

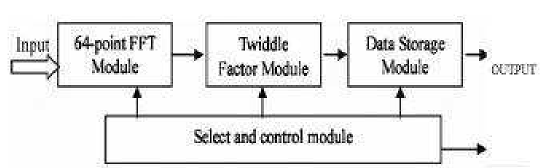

Figure 3: Block diagram of design of FFT Processor

OFDMA has several benefits ranging from increasedflexibility to improved throughput and robustness[16] By assigning sub-channels to specific subscribers, transmissions from several subscribers can occur simultaneously without interfering, thus minimizing aneffect known as Multiple Access Interference (MAI).Furthermore, sub channelization enables the concentrationof transmit power over a reduced number of subcarriers.

Another technique to cope with multipath disappearing is spaced carrier OFDMA [17]. It is OFDMA with code division multiplexing (CDM) such that the robustness increases. A variable point FFT processor [18] may be designed using FPGA in which OFDMA Technology is applied. The FFT processor uses Verilog HDL language to describe the circuit, Quartus II 7.2 software to build the model, and ModelSim SE 6.2b software is used to verify the timing function. This design completes the main computing modules in the OFDMA system, when applied to real-time signal processing system,

V. CONCLUSION

Designers of 3G base stations will make use of the DSPs in order to achieve the high performance and flexibility needed for tomorrow's voice and data applications. Speech coding is an essential application of digital signal processing in modern day telephony and mobile communications, which employ high data compression ratios. Effective embodiment of these design principles will fulfill the promise of 3G to provide the foundations of the kind of wireless infrastructure necessary for tomorrow's applications.

TigerSHARC DSP provides all the processing capacity to enable a single high speed 3G data channel.TMS320C6x series tries to reduce cost and increase execution speed by reducing hardware complexity. Figure 3 shows the TigerSHARC and Blackfin architectures. We have discussed advanced functionality in mobile devices from the major manufacturers, and with fourth generation (4G) wireless broadband. For 4G various DSP processors available are System on Chip (SoC) based architectures, ARMv-5ARMv-6 ARMv-7, Cortex-A, Cortex-R, Cortex-M Processors, Qualcomm Snapdragon Processors, NvidiaTegra Processors and Variable point FFT processor. Figure 3 shows the block diagram of FFT Processor.

VI . FUTURE TRENDS

A dominant embedded and mobile devices operating system has still to emerge, for the new generation of mobile devices. Future mobile processors will incorporate more parallelism in superscalar designs. VLIW and SIMD architectures will become more popular, because they allow to reduce the frequency and voltage of the processor chips without losing performance. In the future all these trends will lead to more efficient and powerful embedded and mobile devices. The big challenge is to still keep the power usage at a low level. One possibility is to embed many small processors in office and city environment, which can assist the mobile devices and reduce their power needs.

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BIOGRAPHY

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