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Digital Cellular Systems for Next Generation Wireless System

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ABSTRACT : Digital cellular systems such as the Global System for Mobile Communication (GSM) have experienced a tremendous acceptance in the population, and the power of this technology has changed the way of life in human society. This paper gives an overview of the presently existing digital cellular standards and their convergence towards the Universal Mobile Telephone System (UMTS), and their impact on semiconductor technology. The system requirements and their influences on highly integrated digital base band processors and RF transceivers are discussed. Also the various trends of progresses in technology and integration will be shown explaining the advantages of the concepts pursue.

Keywords: Cellular, Wireless system, Baseband Processing.

I. INTRODUCTION

The introduction of GSM a decade ago, the most successful second generation cellular system, has been followed by another ten years of heavy engineering and standardization work in the 80s. Since the introduction of GSM operation, while most of the resources have been working on integration and improvement of the voice services on mobile handsets, others have already been thinking of the third generation of wireless systems, known today as 3G or UMTS respectively.

Driving factor of the success was the continued integration and miniaturization path of the semiconductor technology, in particular the digital CMOS VLSI integ ration, and this shrin k path still continues.

As in the wired world, the digital data communication is the driving factor of the wireless world today. This increasing data traffic is a logical result of the rapidly increasing use of the Internet together with its new contents and new applications such as streaming audio and even video.

Current cellular communication terminals are mainly dedicated to voice communication. The data rates supported by the second generation systems are well below 100 kbps. Advanced applications, such as image and video processing or high-speed data transmission are either unattractive or simply not possible at such low data rates. The introduction of new services like WAP (Wireless Application Protocol) suffers from the limitations dictated by th e restricted system capabilities. General Packet Radio Service (GPRS) will provide continuous and instant access to the Internet which gives you - at least theoretically - "any information at any time at any place". In order to meet the demand for higher data rates, a new generation known as Enhanced Data Rates for Global Evolution (EDGE) will bring the necessary data transmission bandwidth for voice and image services. With its new modulation scheme for high spectral efficiency, EDGE will enable operators to roll out 3G services and performance on the basis of today's GSM network. Ultimately, Wideband Code Division Multiple Access (W-CDMA) together with multi mode mobile terminals will bring the total solution for the wireless Internet society, and the semiconductor industry will deliver the technology to facilitate the design of these multimedia and multi standard terminals.

II. EVOLUTION OF MOBILE NETWORKS

The migration path towards UMTS is rather different within the different regions of the industrialized world. Whereas Japan follows a straightforward strategy from first digital cellular systems towards UMTS or W- CDMA the legacy systems in the Americas and in Europe require a more evolutionary approach including backwards compatibility, Fig. 1.

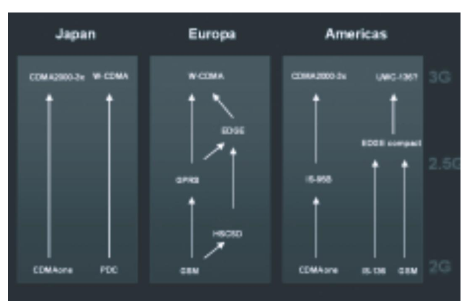

Fig. 1. Evolution of Networks.

The most important second generation system is European-based GSM, which has spread all over the globe and is now available in more than 135 countries. Other important 2G standards include US-based IS136 and CDMAone, and Japan-based PDC. The penetration rate exceeds 60% in some Asian or Scandinavian countries. The total number of mobile subscribers to 2G services today is larger than half a billion and is still rapidly growing. [3] Currently, these systems are being enhanced towards "2.5G" systems including the GSM based GPRS, packet enhanced PDC-P, and extensions of CDMAone. Japan is the country that requires the earliest deployment of 3G type services due to the spectrum bottlenecks and the success of 2G data services now in operation, such as *i*-mode.

3G systems, as they are currently driven by two 3G partnership projects, 3GPP and 3GPP2, are based on CDMA technologies and are evolutions of CDMAone (leading to multi-carrier CDMA, driven by 3GPP2) and GSM (leading to UMTS with its two modes, driven by 3GPP). EDGE (whose evolution is now within 3GPP) is sometimes also included in 3G, as well as the cordless DECT standard (to ease the integration of private branch exchanges). 3G systems will allow data rates of up to 2 Mbps in its later phases. First 3G systems will have peak rates of 384 kbps. For a vision on the evolution of mobile systems beyond 3G, [4].

III. APPLICATION AND MULTIMEDIA TERMINALS

The great increase of bandwidth transmitted over the air enables new data centric devices as opposed to classic voice centric devices. The Pocket PC, PDA and cellular phone worlds merge into combined devices. This makes new applications now possible such as on-line video, video conferencing, on-line banking etc. This requires additional computational power and security measures.

As such combined devices come with a variety of SW from companies not known to the mobile world so far and written by different specialized companies, an open platform is the key to success in this segment. Open platform means making SW integration as easy as possible. This can only be assured if the different suppliers of such platforms provide platforms looking almost equal to the software. This implies a shift of the mobile world towards a PC-like model.

Combined with the availability of higher data rates, operators will offer additional applications for mobile users. These applications are facilitated by operating systems useful for mobile terminals. Either terminals incorporate simple homemade operating systems or they deploy sophisticated third-party systems (e.g. PalmOS, Java, or Windows CE). Suitable processors in mobile devices are needed to support the operating system and applications taking into account to their special demands such as, e.g., a very low power consumption. Examples of applications include voice recognition, pen input, image processing, music rendering, and wireless Internet browsers. Furthermore, the demand for processing power can be unlimited considering applications like interactive games and video processing. The platform with the greatest chances right now appears to be based on standard operating systems like EPOC or WinCE and on an ARM-based HW-platform. There are very few applications where the performance requirements cannot be met by the ARM system on its own. For this, it is best to use HW accelerators rather than additional proprietary cores like programmable co- CPUs/DSPs as the SW providers will hardly manage to program a variety of proprietary cores in reasonably short time.

IV. BASEBAND PROCESSING

The increase in data rate also increases the demand on available signal processing power in terminals. Current implementations provide 20 to 80 Million Instructions Per Second (MIPS) for data processing. Depending on the user data rate terminals for new systems will require orders of magnitude more processing power. Advanced receiver algorithms such as iterative decoding, sophisticated channel estimation and equalization, or algo rithms for multiple-antenna systems additionally raise the need for powerful baseband processing [1].

The requirements of a future-proof implementation of 3G base band chips show the need to distinguish between signal processing algorithms supported by powerful DSPs on the one hand and real-time processes running on suitable micro-controllers on the other hand. Fig. 2 shows the architecture of Infineon's multi mode GSM/GPRS/EDGE/ UMTS FDD solution M-GOLD.

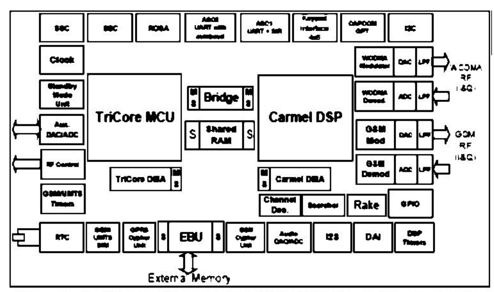

Figure 2. Block Diagram of M-GOLD, a Multi mode UMTS Base Band Chip

M-GOLD is a dual core chip with TriCore as controller, allowing fast context switching and extensive interrupt handling, and Carmel as high performing DSP, dedicated to physical layer and voice processing. The interface to customers is TriCore. Future M-GOLD releases will also offer ARM based solutions to allow for simple reuse of existing ARM-based SW.

V. SW-CONTROLLED RADIO

The standard family IMT-2000 shows with its five components for the terrestrial air interface the future development of mobile terminals. The support of various air interfaces will be necessary to allow end users to communicate anywhere at any time. Baseband chips for these terminals will integrate the functionality of different air interfaces and even of additional standards for short range connectivity, e.g. Bluetoo th. Competitive prices and manageable complexity suggest approaching this problem by software radio solutions [2]. A comparison between available DSP processing power and algorithm requirements given by the standards draws a different picture. The increasing demand of signal processing algorithms to fulfill the standard requirements does not allow for a completely DSP based solution for the baseband processing of future multi mode mobile terminals. DSP cores and 'configurable silicon' by means of data path solution have to be integrated in parallel. The software controlled radio will consist of known cores and datapaths which are switched on and off on demand or run the required set of functions after initial configuration. Infineon's base band processor M-GOLD deploys programmable data paths. Modification of the data paths and additional functionality will allow the support of further modes like IMT-2000 TDD and IMT-2000 Multi-Carrier.

VI. ANALOG AND MIXED SIGNAL INTEGRATION

As the demand for miniaturization and integration continues the monolithic integration of the analogue interface chip into the base band is a natural consequence as advanced CMOS circuit designs and analogue process capability allow to do so. A single chip Base band processor yields to smaller board area, less pins and less power consumption together with more degrees of freedom in the system architecture and circuit design.

Fortunately, fundamental limits of silicon technology are still quite far away from being reached [5] and Gordon Moore is also still on our side. It is expected that his famous extrapolation of the advances of semiconductor technology is still valid for at least another decade [6]. When developing the next generation circuits for multi mode systems, we still can rely on the evolution of microelectronics.

VII. RF-TRANSCEIVER INTEGRATION

In the GSM related systems the tendency to single-chip RF-Dual band handheld solutions using the Zero-IF receive concept is growing. In the transmit path mainly direct modulation and loop concepts are in use. Also the component count for the RF front end has reduced from some 500 components in the mid 1990s down to hundred with further potential for reduction. For power amplifier (PA) the discrete approach is more and more replaced by modules. The technology in use is shared by Si-LDMOS and GaAs-HBT.

The development of UMTS transceivers follows the integration roadmap GSM has shown. The receive signal path is very similar to most GSM solutions. Compared to GSM UMTS transceiver requires additional variable gain amplifiers in the TX path.

The development path to system on (single) chip is still ongoing. Limitations seen today will be solved and this will finally result in a highly integrated single chip RF and BB chip with advanced CMOS technologies in 0.13 μm and beyond.

VIII. EXAMPLE: INFINEON'S UMTS CHIP

Fig. 4 gives an inside into M-GOLD. The technology used for this IC is a 0.18μm process with five metal layers. Packaging for this IC is a 256 ball grid array. Both kernels together with their memory systems dominate the design with respect on area. The datapath for the UMTS FDD code division multiple access (CDMA) part shown as RAKE and searcher datapath process most of the chip based signal processing in order to relieve the CARMEL DSP. The analogue front end contains the functionality for the UMTS part as well as for GSM/GPRS and EDGE.

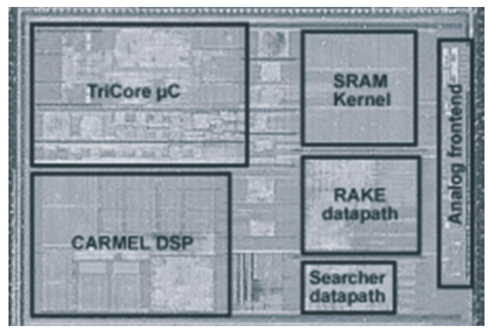

Fig. 3. Infineon's Chip M-GOLD 1

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