AN OPEN BASEBAND PROCESSING ARCHITECTURE FOR FUTURE MOBILE TERMINAL DESIGN

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ABSTRACT

This paper introduces an open wireless architecture (OWA) terminal design, focusing on the open baseband processing platform to support different existing and future wireless communication standards through the multi-dimensional open baseband processing modules with open interface parameters and baseband management systems. The paper describes multi-layer open system architecture to maximize the system flexibility and minimize the terminal power consumption, so as to provide an integrated and converged next generation wireless and mobile communication terminal system.

INTRODUCTION

Second-generation (2G) mobile systems were very successful in the previous decade. Their success prompted the development of third-generation (3G) mobile systems. While 2G systems such as GSM, IS-95, and cdmaOne were designed to carry speech and low-bit-rate data, 3G systems were designed to provide higher-data-rate services. During the evolution from 2G to 3G, a range of wireless systems, including GPRS, IMT-2000, Bluetooth, WLAN, and HiperLAN, have been developed. All these systems were designed independently, targeting different service types, data rates, and users. As these systems all have their own merits and shortcomings, there is no single system that is good enough to replace all the other technologies. Instead of putting efforts into developing new radio interfaces and technologies for 4G (fourth generation) mobile systems, which some researchers are doing, we believe establishing 4G systems that integrate existing and newly developed wireless systems into one open platform is a more feasible option.

Researchers, from all over the world, are currently developing frameworks for future 4G mobile networks. Different research programs, such as Mobile VCE, MIRAI, and DoCoMo, have their own visions on 4G features and implementations. Some key features (mainly from the users' point of view) of 4G mobile networks are stated as follows:

- High usability: anytime, anywhere, and with any technology
- Support for multimedia services at low transmission cost
- Personalization
- Integrated services

Next generation wireless and mobile networks (meaning 4G mobile networks and beyond) are all-IP based heterogeneous networks that allow users to use any system at any time and anywhere. Users carrying an integrated open terminal can use a wide range of applications provided by multiple wireless networks, and access to various air interface standards. Second, next generation mobile systems provide not only telecommunications services, but also data and multimedia services. To support multimedia services, high-data-rate services with good system reliability will be provided. At the same time, a low per-bit transmission cost will be maintained. Third, personalized service will be provided by this new-generation network. It is expected that in future, users in widely different locations, occupations, and economic classes will use the services. In order to meet the demands of these diverse users, service providers should design personal and customized services for them. Finally, next generation mobile systems also provide facilities for integrated services. Users can use multiple services from any service provider at the same time based on the open services architecture.

This vision from the user perspective can be implemented by integration of these different evolving and emerging wireless access technologies in a common flexible and expandable platform to provide a multiplicity of possibilities for current and future services and applications to users in a single terminal. Systems of future mobile networks will mainly be characterized by a horizontal communication model, where different access technologies as cellular, cordless, WLAN type systems, short range wireless connectivity, broadband wireless access systems and wired systems will be combined on a common platform to complement each other in an optimum way for different service requirements and radio environments which is technically called "Open Wireless Architecture (OWA)", the core technology for the 4G mobile wireless communications.

In order to use the large variety of services and wireless networks in next generation wireless and mobile systems, open user terminals are essential as they can adapt to different wireless networks by reconfiguring themselves. This eliminates the need to use multiple terminals (or multiple hardware components in a terminal). The most promising and optimal way of implementing such multimode and multi-standard user terminals is to adopt the open wireless architecture (OWA) approach.

OWA defines the open interfaces in wireless networks and systems, including baseband signal processing system, RF system, networking, and service and application, so that the system can support different wireless industrial standards and integrate the various wireless networks into an open broadband platform. For comparison, Software Defined Radio (SDR) is only a radio in which the preset operating parameters including *inter alia* frequency range, modulation type, and/or output power limitations, etc can be reset or altered by software. Therefore, SDR is just coupling different wireless systems into a reconfigurable radio without defining an open interface within the converged wireless platform. SDR consumes much more power when the number of supported wireless standards increase, especially in the RF system and baseband processing systems.

Like open computer architecture (OCA) in the computer systems, the OWA shares all the open system resources including hardware and software by mapping different wireless standards to the open interface parameters of baseband, RF and networks. Each OWA system module is an open module, rather than any standard-specific module, and can be easily reconfigured to maximize the system performance, and minimize the power consumption.

To migrate current systems to such an advanced open wireless system with the features mentioned above, we have to face a number of technical challenges in the open baseband processing:

- Terminal design is much hard than base station design due to its limitation of power consumption, chip area, and processing capability,
- Open architecture requires full flexibility in baseband processing which normally can be handled by general-purpose processors and digital signal processors (DSP). However, these processors consume more power with less efficiency in system performance.
- Application-specific integrated circuits (ASIC) is a very efficient processor and consumes low power compared to genera-purpose processors and DSPs, but without flexibility in supporting different wireless standards, because ASIC is normally a standard-specific implementation solution.
- Open Wireless Architecture (OWA) demands efficient baseband processing management system to optimize the open processing modules and system performance.

Such an open baseband processing architecture of the OWA mobile terminal design provides an optimal solution to manage the baseband processing tasks for the next generation mobile communication terminals integrating and converging different wireless standards based on the open wireless architecture technologies.

SUMMARY OF THE OWA BASEBAND PROCESSING PLATFORM

This paper introduces an open baseband processing architecture for next generation wireless and mobile communication terminal design which provides an optimal open baseband processing platform supporting different existing and future defined wireless radio transmission technologies (or air interfaces) including, W-CDMA (code division multiple access), cdma2000, GSM, GPRS, OFDMA (orthogonal frequency division multiple access), WLAN (wireless local area network), WPAN (wireless personal access network) and BWA (broadband wireless access system), either in the simultaneous connection mode, or in the selective connection mode of various wireless standards in the user's service geographic region, where different radio standards are mapped into the open interface parameters as inputs to the open processing modules scheduled and administrated by the Baseband Management system for the optimization of the system performance and resource of the wireless mobile terminal.

The OWA baseband processing architecture incorporates a multi-dimensional open processing architecture including the general-purpose processors and digital signal processors (DSP) to handle the main flow of the baseband algorithms and protocols, and the special processing accelerators to focus on the computationally intensive repetitive operations of specific communication-oriented algorithms, such as, space-time transceiver processing, adaptive modulation, channel coding and equalization. The processing accelerators are very important open processing subsystems in the mobile terminal design because they utilize the distributed open modular flexible architecture to achieve the ASIC-like efficiency and performance. The processing accelerators include two different open accelerators: OCM (Open Computing Machines) Accelerator and Open-Kernels Accelerator. The OCM Accelerator is a very efficient and powerful processing engine for complex repetitive communication-oriented algorithms, including, adaptive modulation and space-time processing. The Open-Kernels Accelerator handles independent or dependent communication protocol cores, algorithm cores, and service and application processing cores, including, open service architecture processing and service convergence processing. The multi-dimensional open processing architecture also includes the multi-tasked SIMD (single-instruction stream, multiple-data stream) processing cores to deal with the small scale wireless convergence and integration solution, for example, W-CDMA/GSM/WLAN 3-in-1 integrated terminal, and CDMA/OFDM 2-in-1 integrated terminal. In this case, the SIMD Cores can handle all the communication algorithms and protocols, and the accelerators can be turned off in order to save terminal power and minimize the power consumption.

The OWA baseband processing architecture utilizes an efficient baseband management method based on the open processing tree. The open processing tree includes, but can be reconfigured, a) processing root utilized by the system main processor, handling general system operations and maintenances; b) processing trunk utilized by the general-purpose processors and DSPs or the SIMD cores, handling the main flow of the baseband algorithms and protocols, and controlling the accelerators; c) processing branches utilized by the OCM Accelerators and the Open Kernels Accelerators, handling the complex communication-oriented algorithms and protocols; d) processing leafs utilized by the Open Kernels Accelerators or the general-purpose processors and DSPs of the SIMD Cores, handling general processing of Open Services Architecture (OSA). The open tree architecture is a proven efficient tasks scheduler for open baseband processing of the future mobile terminal, where users can reconfigure the processing tree to optimize the system performance. If the tree is small enough, for example of simple wireless convergence of 2-in-1 or 3-in-1 integrated terminal, the SIMD cores are capable of handling all the baseband processing tasks of the system, and therefore the system power consumption can be minimized.

The OWA baseband processing architecture has the capability to support Open Services Architecture (OSA) including, open application program interface (OAPI), service convergence, open mobile operating systems, quality of service (QoS), session controls, mobility management, security, media conversion and user defined services. The open services architecture is a very important open service platform supporting different services and applications (both existing and future defined) of different wireless standards by various service providers so that the same open terminal can simultaneously or selectively access to different wireless networks in the user's service geographic region.

This OWA processing platform also has the capabilities to allocate some baseband processing modules to the external processors, controllers and DSPs defined as the Software Defined Modules (SDM) containing, algorithms, parameters, instructions, tasks and service-related cores. The SDM can also be the data module to be stored in the internal or external memory, or transferred to/from the Internet. The software defined module is a very useful portable baseband module for the future mobile applications, for example, a mobile handset can share with a mobile car-terminal on system resources where the car-terminal can help process some modules for the mobile handset based on the open wireless architecture (OWA) technology definitions.

The OWA baseband processing platform guarantees that all the processing modules are open modules instead of standard-specific modules which are used by the existing mobile communications. These open modules based on Open Wireless Architecture (OWA) technology with Open Interface Parameters (OIP) are the shared processing engines for the different wireless standards to maximize the system processing efficiency. Meanwhile, many of the open modules are the independent modules which can be easily turned off/on based on the system requirement and resource management to minimize the terminal power consumption. The open interface parameters map between the various wireless standards and the open processing modules, and incorporate capabilities to define new radio transmission technology for the future wireless mobile communications.

This OWA platform also possesses capabilities to support the open RF (radio frequency) module through the open RF interfaces. As different wireless standards may work in different radio frequency bands, a portable radio header with the open RF interface is necessary for next generation mobile communications. The open wireless architecture (OWA) is optimized with the shared spectrum allocation strategy, and RF direct conversion method, though it works quite well with the existing RF solutions of the converged wireless terminal.

Other features of the OWA baseband processing architecture comprise the physical layer transmission convergence including, adaptive modulation, adaptive channel coding, digital filtering, etc., and medium access controls, including, flexible access control, dynamic channel allocation and resource management. In addition to the above, the OWA baseband processing platform also include the multi-layer system and configuration bus, and the bus bridge which defines the I/O (input/output) bandwidth to access to/from the system bus.

DETAILS OF THE OWA TERMINAL BASEBAND DESIGN

This paper introduces an open baseband processing architecture for next generation wireless and mobile communication terminal design wherein the baseband architecture is based on the Open Wireless Architecture (OWA) technology platform.

The OWA technology will be driven by human-oriented communication services in the future. In addition, efforts to develop various new services are being made in five categories: the Internet, location information, information distribution, remote sensing/control, and settlement. The next generation wireless communications will be based on this OWA platform by constructing and operating a system that integrates broadband mobile networks, fixed wireless access networks, wireless LAN, and so forth.

The key to providing future mobile services is not limited to the concept of each and every subscriber having his or her own terminal to communicate. Another key issue is to build a ubiquitous information environment surrounding humans at home, in the office, or at hot spots so that information can be obtained in various forms according to individual needs.

In the future networking, the key will be to provide an IP network with sufficient reliability, and construct a flexible open network configuration that enables seamless connections with the use of various accessing methods, the number of which will increase further in the future. FIG.1 shows a next-generation open mobile network architecture. "IP over everything" is believed to make progress, in which IP packets are processed based on various transport technologies. In the next-generation IP network, the control and packet forwarding functions will evolve independent of each other, and the functional configuration of the IP transport network and middleware will be separated logically. The middleware will consist of two platforms in this paper: Open network control platform (ONCP) and Open service support platform (OSSP). The ONCP and OSSP functions include open mobility management, session management, QoS (Quality of Service) management, authentication and admission, security, and open transmission resource management required for wireless and mobile communications operations. The OWA core is a revolutionary new architecture for open mobility management that does not depend on one radio system, so services can be sustained seamlessly across different types of access systems. The OSSP also consists of open service function groups exemplified by content conversion/distribution, service convergence, user defined service, etc. The OSSP functions include the provision of services unique to wireless mobile communications, such as location services support and converged common air interfaces.

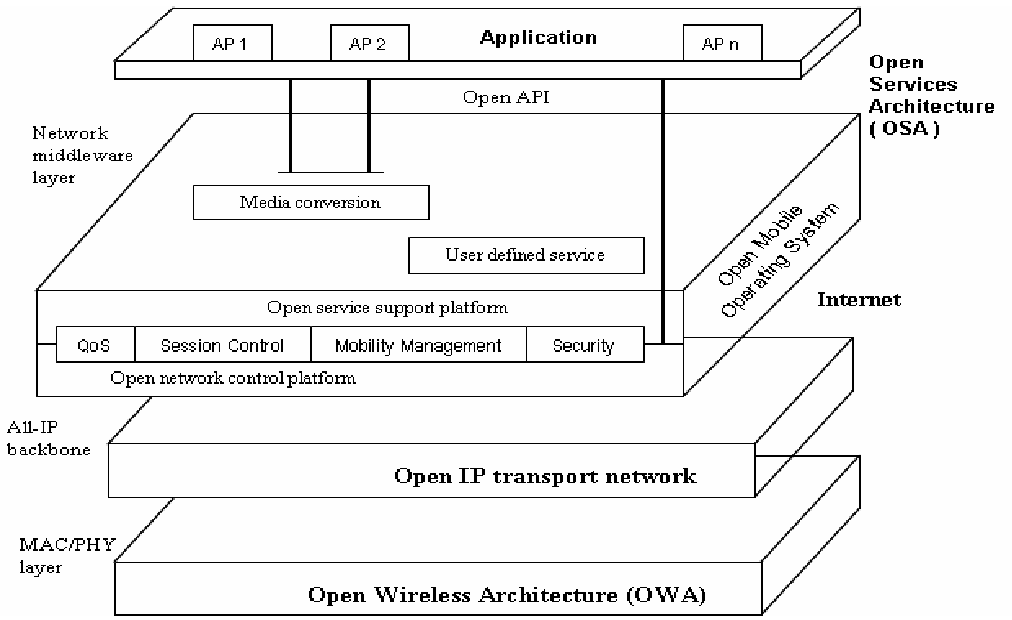

FIG.1 Next Generation Open Mobile Network Architecture

The application layer, the above OSSP and part of ONCP construct the Open Services Architecture (OSA) which will drive the future applications for next generation mobile networks. This OSA includes open mobile operating systems, bandwidth-on-demand and service convergence as well. The OSA is a very important open service platform supporting different services and applications of different wireless standards by various service providers so that the same open terminal can simultaneously or selectively access to different wireless networks in the user's service geographic region.

As for future open terminals, limited-functionality chiptype terminals (so small that they can not provide any services by themselves) are expected to emerge and form a ubiquitous environment, in addition to the generic all-in-one mobile terminals serving as the evolved version of existing terminals. Furthermore, connections between future open terminals are expected to be based primarily on local networks, such as ad hoc networks. In this manner, an extremely broad range of access and networking capabilities will be supported in the OWA systems platform.

Open Wireless Architecture (OWA) helps expand the future service areas and implement services flexibly at low cost, just by changing the open radio interface parameters using the radio frequency, frequency bandwidth, radio frame composition, and so on as the common air interfaces, based on the open baseband processing platform.

Increasing user demands for flexibility, scalability, configurability, and multifunctional communication equipment has motivated the need for important open wireless architecture (OWA) user terminal systems. It is envisaged that this OWA as a technology will help bring together the different forms of communications through the open interfaces. The incorporation of mobile communications, broadband wireless access systems, broadcast receivers, location services, Internet, multimedia, dedicated point-to-point communications, personal computing and digital convergence would all be possible with the help of a mature and reliable OWA core technology. This would eventually lead to the realization of open radio systems and networks that consist of self-organizing, self-evolutionary intelligent open wireless system infrastructure and user terminals for ubiquitous information interaction.

This OWA baseband is open and adaptive because of its ability to reconfigure itself, upgrade itself and adapt itself. The software architecture of this Open Base-Band (OBB) processing subsystem, as shown in FIG.2, is based on object-oriented methodology. Each element of the baseband transceiver module is open and reconfigurable by instantiation of an appropriate class and/or reinitialization of sub-module(s) with new attributes.

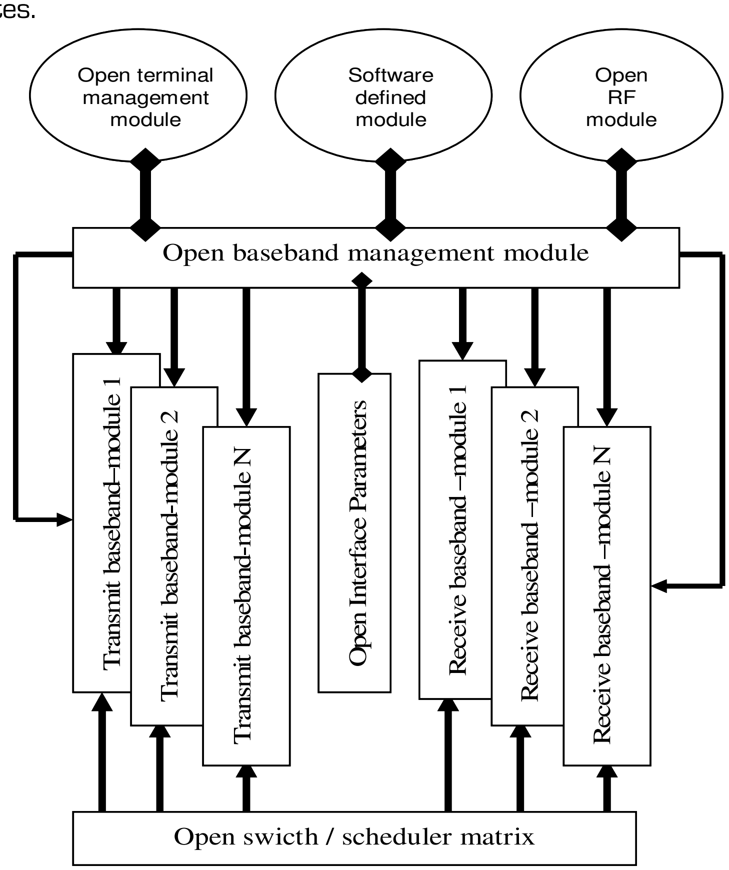

FIG.2 Open Baseband Software Architecture

The OBB software architecture consists of the following key components:

- Open baseband software management module – The overall authority of the OBB processing subsystem. It is responsible for negotiating reconfiguration, creating active and shadow transceiver modules, and controlling the runtime behavior of each module and its element. It also controls the open RF subsystems (with shared spectrum management, for example) through appropriate signaling, and schedules the various software defined modules (SDM) for support of different wireless air-interfaces and optimization of system performance. In addition, it manages the open interface parameters (OIP) for mapping between wireless air interfaces and open parameters of the open terminal system.
- Transceiver baseband modules – the incumbent and target baseband transceiver modules.
- Open interface parameters – baseband parameters defined in the OWA core to support various wireless air-interfaces.
- Software defined modules – a portable processing and/or data module supporting different air-interfaces and performance optimization. It can be downloaded from Internet or loaded from a memory card. This module can be processed by the external processors or DSPs. It also can carry its own processor or DSP. In addition, it may also contain the configuration map of the transceiver baseband modules, which is the overall definition of the baseband processing subsystem, and is important when a new standard is to be implemented.
- Open terminal management module – A module for definition of the terminals with parameterized interfaces to the transceiver baseband modules, and configuration of the open terminals supporting various air-interfaces.
- Open switch/scheduler matrix – It controls and schedules the transceiver baseband modules in different working modes – active, shadow or others.

To design the future open wireless terminal, the baseband processing architecture should be open and flexible in supporting various common air interfaces. However, in the real system design and implementation, terminal power saving and power consumption become the most crucial issue in the OWA system. Meanwhile, the silicon area is the second concern for the mobile handset design.

An open radio requires the radio to have real-time reconfiguration capability to interface and communicate with open networks and open wireless air-interfaces as the user moves over different geographic regions with different wireless networks, requests different services or if the radio has to adapt to varying channel conditions. Such a multimode open operation with limited resources (especially for mobile terminals) demands efficient implementation of open systems on a common hardware platform. The terminal baseband processing architecture, which is being defined by the Open Wireless Architecture (OWA) is based on an open systems platform that facilitates efficient common modular processing of systems and algorithms within the open radio through the managed Open Interface Parameters (OIP) as mentioned above.

General-purpose processors (GPP) and Digital Signal Processors (DSP) can provide maximum flexibility in baseband processing, but they consumes too much power and not efficient for intensive repetitive algorithms processing. Application-specific integrated circuits (ASIC) provide the most efficient hardware implementation of an algorithm, but without flexibility in dealing with different wireless standards in the same hardware system.

Special processing Accelerators are thus typically used with the GPP and DSP where the GPP/DSPs handle the main flow of the baseband algorithms and protocols, and control the accelerators that handle computationally intensive repetitive operations of specific algorithms, such as, space-time transceiver processing, adaptive modulation, channel coding and equalization, etc. An optimal OWA solution should be able to configure its hardware to the needs of the current system, thereby minimizing power and silicon area to achieve best performance similar to or approaching to an ASIC implementation.

FIG.3 shows an Open Baseband Processing Platform, associated with the OWA baseband processing architecture, wherein the system baseband processing tasks are handled by both Multi-Tasked SIMD (single-instruction stream, multiple-data stream) Cores and special processing Accelerators. The SIMD cores include general-purpose controllers / processors / DSPs, and several Processing Elements (PEs). These SIMD cores are in stream processing architecture, and generally deal with common air-interfaces of the most popular standards. Therefore, the SIMD cores are capable to support simple converged wireless platform, such as, W-CDMA/GSM/WLAN 3-in-1 converged terminal.

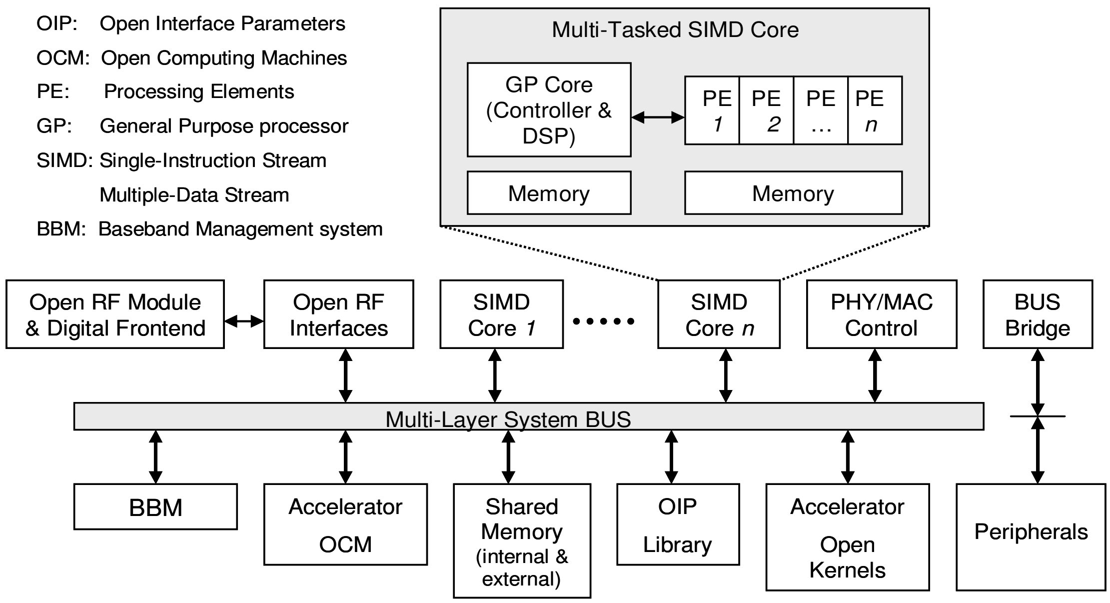

FIG.3 Open Baseband Processing Platform Powered by OWA

The OWA system requires open interfaces platform in support of various air interfaces. Hence, accelerators are needed to focus on the complex algorithms processing, in addition to the SIMD processing cores, to optimize the system performance and minimize the terminal power consumption. The OCM (Open Computing Machines) Accelerator is a very efficient co-processing subsystem to allow designers to achieve flexibility in hardware. The OCM accelerators have open hardware for frequently used cores, such as, filtering, equalization, turbo coding, or other communications-oriented algorithm cores, which result in efficient open radio designs. OCM accelerators also give the system the option to selectively speedup algorithms by developing specialized cores for future wireless terminal design.

The Open Kernels Accelerators help the system to handle special functional protocols processing, algorithms processing and application-oriented cores processing, etc. Based on the Open Interface Parameters (OIP), defined in the OWA system, each open kernel of the open kernels accelerators can run independent processing tasks, as well as be configured to handle joint baseband processing through multi-layer configuration bus.

Baseband Management system (BBM) is a very important system level administrator to manage the processing resources of the system, wherein the key functions include:

- Manage the whole system baseband processing modules and minimize the baseband processing power consumption,
- Optimize the baseband processing tree structure, defined by the OWA system,
- Schedule the processing tasks to meet the OWA requirements and open interface parameters,
- Turn on/off the processing modules to optimize the system performance

In some applications, the BBM can also allocate certain processing modules to the external hardware and software subsystems, in the form of software defined modules, or SIM (smart integrated memory) card modules, to minimize the terminal power consumption and maximize the terminal system performance.

The Open Interface Parameters (OIP) Library contains the mappings of the common air interfaces' standards and the baseband processing parameters defined in the open wireless architecture (OWA) system core. As more wireless and mobile communication standards come out, this OIP library will be updated frequently. In addition, users can define new radio transmission technology (RTT) which generates related open interface parameters to reconfigure specific baseband processing algorithms, for example, a new wireless system with OFDM (orthogonal frequency division multiplex) in the downlink transmission, and CDMA (code division multiple access) in the uplink transmission.

The Physical Layer and Medium Access Control (PHY/MAC) control module, associated with the OWA baseband processing architecture, is responsible for the following functions:

- Wireless transmission convergence controls, including adaptive modulation, adaptive channel coding, equalization, space-time coding, antenna control, etc.
- Transmission channels control and flexible access control,
- Radio resource management and dynamic channels allocation

The PHY/MAC control module works with the SIMD cores and accelerators through the multi-layer system bus.

One of the very important OWA system blocks is the Open RF module which supports different RF transceivers working in different frequency bands. Shared spectrum allocation will become the mission-critical spectrum management strategy in the future wireless and mobile communications, and the OWA is the best system solution for its implementation. Open RF Interface connects the baseband systems to the Open RF module as well as the digital frontend. As radio Direct Conversion (DC) will be evolving as one of the leading conversion solutions in next generation mobile communications, digital baseband processing becomes increasingly important for future wireless terminal design. In fact, the OWA system can be optimized by direct conversion and/or low intermediate frequency principle with digital channel filtering, etc which provides the transceiver with openness and flexibility for the multi-standard air-interfaces. The OWA solution fully supports the convergence of various existing and future wireless standards.

Bus Bridge defines the I/O (input/output) bandwidth for the multi-layer system bus, and control the access to/from this bus.

System memory includes processing memory and shared memory (both internal and external).

Open Computing Machines (OCM) in next generation mobile handset is ideal for complex open physical layer signal processing algorithms supporting various wireless air-interfaces. This OCM can be designed as standalone hardware or as accelerators to general-purpose processors (GPs). OCM accelerators can be either programmable external accelerators or embedded into a GP or DSP.

The OCM, based on the open wireless architecture (OWA), provides an approach in which similarities and differences between the waveform radio standards are identified and parameterized into the Open Interface Parameters (OIP). Therefore, the OWA radio uses as little standard-specific hardware as possible and maximizes parameterized open modules that can implement various wireless waveforms for different standards.

FIG.4 shows an independent OCM accelerator, associated with the OWA baseband processing architecture, that can be used by the general – purpose processor or DSP. The goal is to allow the GP or DSP to perform complex high-speed processing on the OCM accelerator. The OCM accelerator itself may consist of one or more processing elements (PEs). Each PE can be designed for a particular class of algorithms, such as, adaptive modulation algorithm, channel coding algorithm, or equalization algorithm. The system can contain one or more PEs of a similar kind (e.g., adaptive modulation) based on the needs of the open system. The OCM accelerator and DSP share a common and multi-layer system bus which may also interface with other RAM and I/O modules.

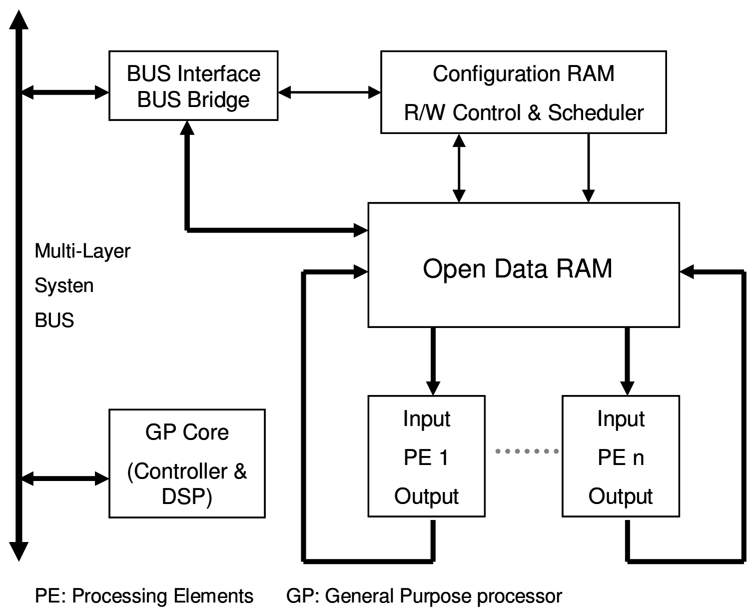

FIG.4 Baseband Open Computing Machines (OCM) Accelerator Architecture

Depending on the algorithm of the PE, multiple sweeps on the PE might be required. The intermediate processing results are stored in the Data RAM, also called as the shadow memory. The configuration RAM provides the Read/Write control for the data RAM to the PEs, as well as configuration scheduler for the PEs. The OCM accelerator can be used to implement subroutines or loops that can run without interruption from the main processor. Once processing is completed, the OCM interrupts the main processor, and data is transferred through bus interface and/or bus bridge.

The use of memory for transfer of data between the PEs and the processor alleviates the I/O bottleneck frequently seen in the terminal baseband design.

The OCM accelerator provides an improved open architecture along with a QoS (quality of service) - driven open operating system for future low-power mobile multimedia systems. It demonstrates that open hardware with the PEs can be used as an optimal solution for future multi-standards handsets. A software control system based on this open model has been utilized for mapping and dynamic reconfiguration, including, mapping air interfaces into open interface parameters, and mapping applications onto open hardware platform. The OCM accelerator can also be designed as a stream-based architecture to allow algorithms to be efficiently paged in and out of the baseband chip which greatly simplifies the implementation of multi-module open systems.

The OCM accelerator is very important for open wireless architecture terminals. Since the speed of reconfiguration of the open wireless interfaces is critical to the OCMs, the system itself has to minimize the reconfiguration time as well as the execution time.

Low-power implementations still remain a challenge in baseband design for mobile terminals. With this OCM technology, the system remains the competitive low power consumption to meet the power requirements of the future handsets.

The OCM accelerators are regarded as extremely powerful processing engines which can also be rapidly reconfigured for open air-interfaces . However, they are not ideally suited for control operations since they lack a microprocessor-like architecture with flexible event-driven operations. Since control operations can be efficiently programmed on a general-purpose processor or DSP, the OCMs will be most beneficial as accelerators or co-processors rather than standalone general processors. A GP or DSP can be responsible for downloading specific processing blocks (like an equalization, Turbo decoder, demodulation, etc) on to the OCM accelerator and also allow the programmer to initiate such operations in the high-level or assembly languages used to program the DSP. Processed data can be collected by the DSP by polling the OCM accelerator, or through interrupts. Data transfer can be accomplished through shared memory depending on the applications and air interfaces. For block processing operations, requiring many OCM cycles an interrupt-driven setup might be more favorable while polling by a DSP might be more suitable for continuous real-time processing such as multimedia applications over the future mobile terminal.

High-speed open signal processing usually entails large volumes of raw and processed data that have to be moved in and out of the OCM accelerators. An OCM accelerator designed as a separate chip that interfaces to a GP or DSP requires careful design of the I/O bandwidth. Hence, bus bridge together with the OCM accelerator memory, is employed to solve this problem.

The OCM accelerator is evolved from traditional computing machines, so parameterized cores (with open interface parameters) can be built as a common denominator for different wireless standards. Furthermore, the OCM accelerator supports more general cores. Such generalized cores will allow easier implementation of new algorithms (such as, new air-interface standards) without modifying the hardware chip.

An OWA terminal is required to support various air-interfaces and waveforms while adapting to varying channel conditions and signal strengths. As modifications are made to the algorithms, for instance, the error correction codes, the modulation techniques, or space-time codes, efficient spatial as well as temporal partitioning of the algorithms on hardware is important to minimize specific cost functions such as, latency, chip area, and terminal power.

The OWA handsets require extremely flexible and efficient low power hardware, as well as limitation on the hardware implementation size. While general-purpose processors and DSPs can provide reconfigurable alternatives for complex high-speed processing, the use of OCM cores can greatly enhance the performance and reducing the power consumption by optimizing the hardware for the applications and the different air-interfaces.

The open wireless architecture (OWA) platform requires open processing architecture in the baseband design including, channel processing, space-time transceiver processing and protocol processing. Therefore, co-processors and kernels' architecture is critical for an efficient system design, especially for future mobile terminal.

FIG.5 shows an open baseband processing kernel architecture, associated with the OWA baseband processing architecture, wherein each processing unit is an open kernel, and connected each other through an open flexible interconnect and management unit. Based on the system processing requirement, the number of processing kernels can be determined and allocated dynamically. These kernels are carefully managed to optimize the system performance, and minimize the processing power consumption for mobile terminal design.

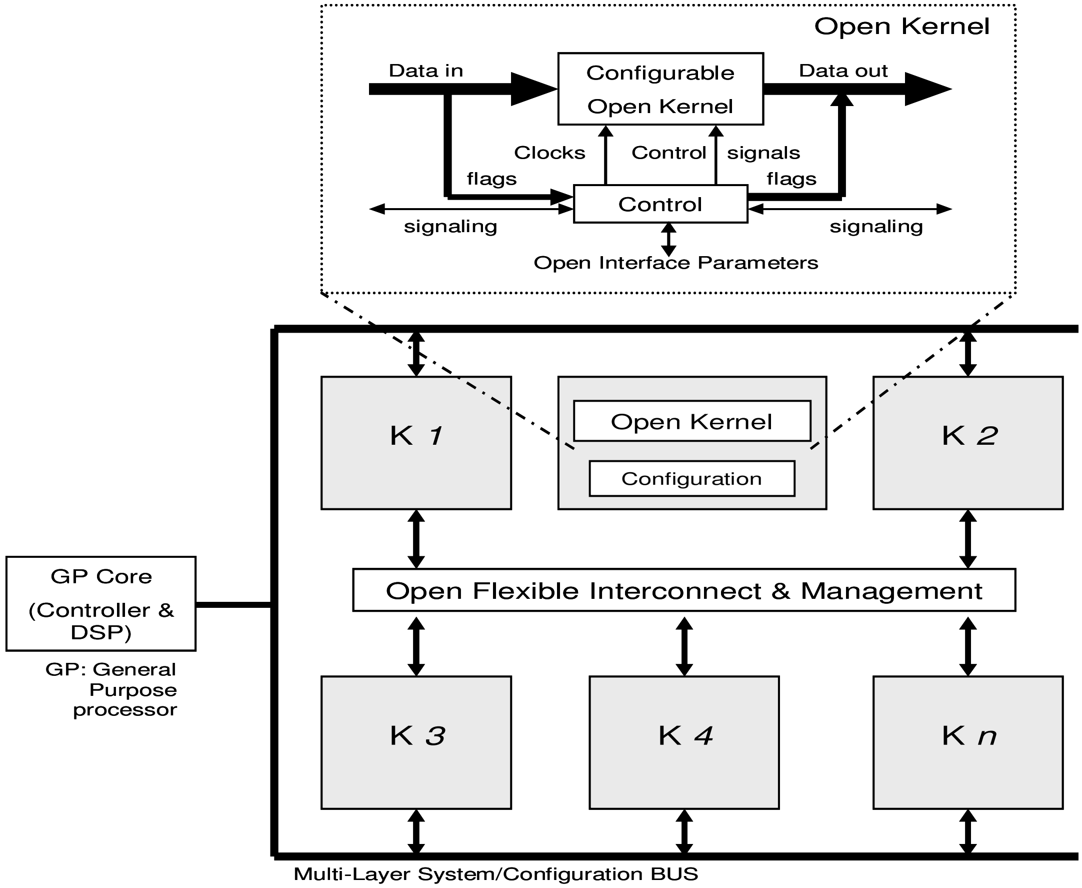

FIG.5 Open Baseband Processing Kernel Architecture

Each open kernel module includes a configurable open kernel core, and the control sub-module. Based on the various open interface parameters defined in the OWA system, the open kernel will initiate different processing jobs based on different clocks, parameters and signals, etc. The open kernel can also process different communication protocols as scheduled by the general baseband management system of the terminal device.

These open kernels connect to the general-purpose processors and DSPs through multi-layer system and configuration bus.

THE OWA MOBILE TERMINAL DEVELOPMENT

Same as open computer architecture in the computer system, the OWA shares all the open system resources including hardware and software by mapping different wireless standards to the open interface parameters of baseband, RF and networks. Each OWA system module is an open module, rather than any standard-specific module, and can be easily reconfigured to maximize the system performance, and minimize the power consumption.

To migrate current wireless and mobile systems to such an advanced open wireless system with the features mentioned above, we have to face a number of technical challenges in the open baseband processing of such OWA system:

- Terminal design is much hard than base station design due to its limitation of power consumption, chip area, and processing capability.
- Open architecture requires fully extensible and upgradeable in baseband processing which traditionally can be handled by general-purpose processors and digital signal processors. However, these processors consume more power with less efficiency in system performance.
- Application-specific integrated circuits (ASIC) is a very efficient processor and consumes low power compared to genera-purpose processors and DSPs, but without flexibility in supporting different wireless standards, because ASIC is normally a standard-specific implementation solution.
- Open Wireless Architecture demands efficient baseband processing management system to optimize the open processing modules and system performance.

OWA provides an optimal open baseband processing platform supporting different existing and future defined wireless radio transmission technologies (or air interfaces) including, but not limited to, W-CDMA, cdma2000, GSM, GPRS, OFDMA, WLAN, WPAN and BWA (broadband wireless access system), either in the simultaneous connection mode, or in the selective connection mode of various wireless standards in the user's service geographic region, where different radio standards are mapped into the open interface parameters as inputs to the open processing modules scheduled and administrated by the baseband management system for the optimization of the system performance and resource of the wireless mobile terminal. Figure 6 shows an OWA based Baseband Processing System-on-Chip platform for 4G mobile phone where OWA accelerators include baseband open computing machines (OCM) accelerator and open processing kernel accelerator. OWA BIOS is a wireless basic input/output system defined by open interface parameters (OIP) of OWA technology. This OWA Baseband SoC is designed for GSM/ cdma2000/ TD-SCDMA/ WiMax/ WLAN 5-in-1 compact mobile phone terminal.

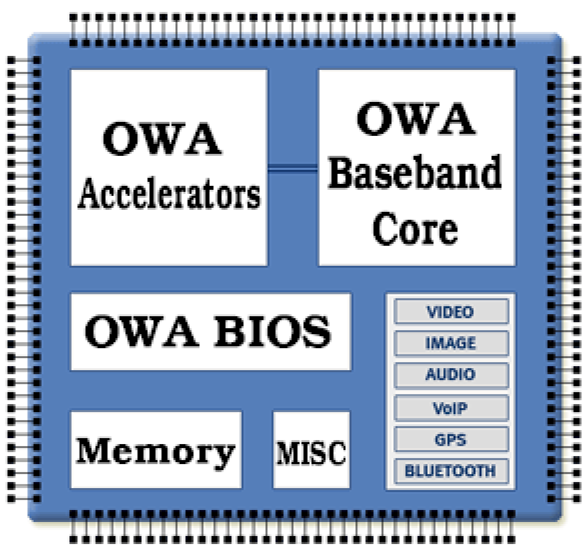

Figure 6: OWA Baseband Processing SoC Platform

THE OWA STANDARDS WILL PREVAIL IN NEXT DECADE

With the strong economy growth in East Asia including Korea, China and Japan, and the neighboring countries, the 4G mobile system based on Open Wireless Architecture (OWA) will become the next wave in wireless communications. It is well predicted that Asia-Pacific (AP) will be the major global hub of this 4G mobile in the coming years, and over 70% of world's 4G R&D are based in this region which reflects huge business opportunities and industrial potentials in future wireless communications. The

OWA standards will definitely drive this new storm in the region's information and communication technology industry, especially in China and US.

Some technical challenges are being studied in the USCWC ® for this emerging 4G-OWA systems, including definitions of open interface parameters (OIP) developed in the OWA core; sharing studies in the common frequent bands between IMT-2000 (3G) and fixed broadband wireless access (BWA like WiMax for example) systems including nomadic applications in the same geographical area; spectrum sharing for IMT-Advanced (the 4G program by ITU) and the principles to prioritize some candidate bands for this OWA converged systems; dynamic bandwidth allocation, radio resource management and adaptive network optimization, etc.

Figure 7: All-in-One 4G Mobile Phone powered by OWA

Since an internationally unified standard becomes unfeasible and impossible, there will be many different standards and frequency bands co-existing in the ITU IMT-Advanced era. The OWA platform provides an optimal solution to converge these different radio transmission technologies into a common and shared wireless communications infrastructure, supporting the future service-oriented open architecture. As a practical solution for the initial development of the 4G-OWA system, we focus on the exampled GSM/ TD-SCDMA/ cdma2000/ WiMax/ WLAN 5-in-1 open platform targeting for short-term strategy towards the year 2010 in some emerging markets including North America and East Asia regions. Figure 7 shows an implemental OWA All-in-One mobile phone supporting multi-bands of 800/900, 1800/1900, 2.4G/2.5G, 3.5G and 5G. This 5-in-1 OWA core platform is being developed by USCWC® for the emerging China mobile communication markets.

CONCLUSION

This paper proposes an open baseband processing architecture for next generation wireless and mobile communication terminal system supporting full integration and convergence of existing and future wireless standards based on Open Wireless Architecture (OWA) technology platform to optimize the terminal system performance and network resource management. This OWA baseband technology has been developed in the U.S. Center for Wireless Communications ® (USCWC®) in California to be delivered in USA, China and the Asia-Pacific regions for the fourth generation mobile communications.

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