Open Wireless Architecture (OWA) – Defining China's Fourth Generation Mobile Communications

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Abstract

The wireless industry is rapidly transitioning from proprietary architecture to more flexible, cost effective open wireless architecture (OWA) systems. This transition is creating interesting challenges for developers, manufacturers, integrators, operators and end-users as they wrestle with complexities of open wireless systems.

Fourth Generation (4G) Mobile Communications should not focus only on the data-rate increase and new air interface. 4G Mobile should instead converge the advanced wireless mobile communications and high-speed wireless access systems into an Open Wireless Architecture (OWA) platform which becomes the core of this emerging next generation mobile technology. Based on this OWA model, 4G mobile will deliver the best business cases to the wireless and mobile industries, i.e. cdma2000/ WLAN/ GPRS 3-in-1 product, TD-SCDMA/WIMAX/WLAN 3-in-1 product, etc.

Asia-Pacific is the most dynamic market of new generation mobile communications with over $100 Billion business in the next decade. The 4G mobile technology – convergence of wireless mobile and wireless access, will definitely drive this growth.

Any single-architecture wireless system, including single 3G, HSDPA, WiMax, etc., is a transitional solution only, and will be replaced by open wireless architecture (OWA) system very soon where various different wireless standards can be integrated and converged on this open platform.

Introduction

In the future wireless service provision will be characterized by global mobile access (terminal and personal mobility), high quality of services (full coverage, intelligible, no drop and no/lower call blocking and latency), and easy and simple access to multimedia services for voice, data, message, video, world-wide web, GPS, etc. via ONE user SINGLE terminal.

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 fourth generation mobile will mainly be characterized by a horizontal communication model, where different access technologies as cellular, cordless, WLAN type systems, short range wireless connectivity 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 “Converged Broadband Wireless Platform, or Open Wireless Architecture (OWA)”.

OWA defines the open interfaces in wireless networks and systems, including base-band signal processing parts, RF parts, networking parts, and OS and application parts, so that the system can support different 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 can be re-set or altered by software. Therefore, SDR is just one of the implemental modules of the OWA system.

OWA will eventually become the global industry leading solution to integrate various wireless air-interfaces into one wireless open terminal where the same end equipment can flexibly work in the wireless access domain as well as in the mobile cellular networks. As mobile terminal (rather than wireline phone) will become the most important communicator in future, this single equipment with single number and multiple air-interfaces (powered by OWA) will definitely dominate the wireless communication industries.

As stated in the newest OECD (Organization of Economy, Cooperation and Development) report in April 2005, "As too many wireless systems come out every day, the current closed architecture and proprietary systems do not bode well for its success", therefore open architecture platform will definitely drive the future wireless and mobile communications.

Fourth Generation (4G) mobile communication will basically focus on the Open Wireless Architecture (OWA), and Cost-effective and Spectrum-efficient High-speed wireless mobile transmission. The 3G system suffers tremendously worldwide because it did not fundamentally improve the wireless architecture, and making the architecture open is the final solution in the wireless industry.

In the recent 18th ITU WP8F meeting in Bangkok on future mobile communications beyond IMT-2000 (officially called "IMT-Advanced" by ITU), the delegates fully agreed that the IMT-Advanced (which is basically a 4G program by ITU) will be targeting converged common wireless and mobile communication platform which is technically in the primary scope of Open Wireless Architecture (OWA) initiatives.

Open Wireless Architecture (OWA)

The 4G Mobile communications will be based on the Open Wireless Architecture (OWA) to ensure the single terminal can seamlessly and automatically connect to the local high-speed wireless access systems when the users are in the offices, homes, airports or shopping centers where the wireless access networks (i.e. Wireless LAN, Broadband Wireless Access, Wireless Local Loop, HomeRF, Wireless ATM, etc) are available. When the users move to the mobile zone (i.e. Highway, Beach, Remote area, etc.), the same terminal can automatically switch to the wireless mobile networks (i.e. GPRS, W-CDMA, cdma2000, TD-SCDMA, etc.). This converged wireless communications can provide the following advantages:

- Greatly increase the spectrum efficiency
- Mostly ensure the highest data-rate to the wireless terminal
- Best share the network resources and channel utilization
- Provide the seamless networking among different wireless standards
- Optimally manage the service quality and multimedia applications

Figure 1 shows the wireless evolution to 4G mobile communications based on OWA platform, where 3G, Wireless LAN and other wireless access technologies will be converged into 4G mobile platform to deliver the best infrastructure of mobile communications with optimal spectrum efficiency and resource management. In fact, this OWA model had already been accepted by many wireless industries, for example, the W-CDMA/W-LAN/ WIMAX 3-in-1 terminal is being designed in many companies.

The global 4G Mobile R&D focuses on the following Open Wireless Architecture (OWA).

Adaptive Modulation and Coding (AMC)

The principle of AMC is to change the modulation and coding format (transport format) in accordance with instantaneous variations in the channel conditions, subject to system restrictions. AMC extends the systems ability to adapt to good channel conditions. Channel conditions should be estimated based on feedback from the receiver. For a system with AMC, users close to the cell site are typically assigned higher order modulation with higher code rates (e.g. 64 QAM with R=3/4 Turbo Codes). On the other hand, users close to the cell boundary, are assigned lower order modulation with lower code rates (e.g. QPSK with R=1/2 Turbo Codes).

AMC allows different data rates to be assigned to different users depending on their channel conditions. Since the channel conditions vary over time, the receiver collects a set of channel statistics which are used both by the transmitter and receiver to optimize system parameters such as modulation and coding, signal bandwidth, signal power, training period, channel estimation filters, automatic gain control, etc.

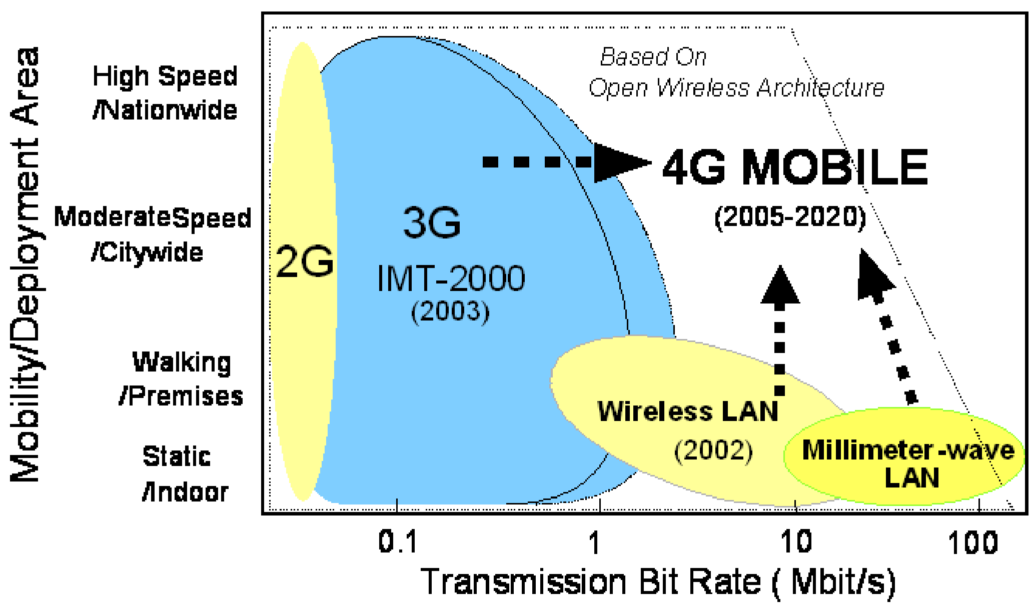

Figure 1: Wireless Evolution to 4G Mobile Based on Open Wireless Architecture (OWA)

Adaptive Hybrid ARQ

A successful broadband wireless system must have an efficient co-designed medium access control (MAC) layer for reliable link performance over the lossy wireless channel.

The corresponding MAC is designed so that the TCP/IP layers see a high quality link that it expects. This is achieved by an automatic retransmission and fragmentation mechanism (ARQ), wherein the transmitter breaks up packets received from higher layers into smaller sub-packets, which are transmitted sequentially. If a sub-packet is received incorrectly, the transmitter is requested to retransmit it. ARQ can be seen as a mechanism for introducing time-diversity into the system due to its capability to recover from noise, interference, and fades.

Adaptive hybrid ARQ shows significant gains over link adaptation alone through e.g. Chase combining. Hybrid ARQ self-optimizes and adjusts automatically to channel conditions without requiring frequent or highly accurate C/I measurements: 1) adds redundancy only when needed; 2) receiver saves failed transmission attempts to help future decoding; 3) every transmission helps to increase the packet success probability.

Generic MIMO and OFDM

Increasing demand for high performance 4G broadband wireless mobile calls for use of multiple antennas at both base station and subscriber ends. Multiple antenna technologies enable high capacities suited for Internet and multimedia services and also dramatically increase range and reliability. This design is motivated by the growing demand for broadband wireless Internet access. The challenge for wireless broadband access lies in providing a comparable quality of service for similar cost as competing wireline technologies. The target frequency band for this system is 2 to 5 GHz due to favorable propagation characteristics and low radio-frequency (RF) equipment cost. The broadband channel is typically non-LOS channel and includes impairments such as time-selective fading and frequency-selective fading. Multiple antennas at the transmitter and receiver provide diversity in a fading environment. By employing multiple antennas, multiple spatial channels are created and it is unlikely all the channels will fade simultaneously.

OFDM is chosen over a single carrier solution due to lower complexity of equalizers for high delay spread channels or high data rates. A broadband signal is broken down into multiple narrowband carriers (tones), where each carrier is more robust to multipath. In order to maintain orthogonality amongst tones, a cyclic prefix is added which has length greater than the expected delay spread. With proper coding and interleaving across frequencies, multipath turns into an OFDM system advantage by yielding frequency diversity. OFDM can be implemented efficiently by using FFT's at the transmitter and receiver. At the receiver, FFT reduces the channel response into a multiplicative constant on a tone-by-tone basis. With MIMO, the channel response becomes a matrix. Since each tone can be equalized independently, the complexity of space-time equalizers is avoided. Multipath remains an advantage for a MIMO-OFDM system since frequency selectivity caused by multipath improves the rank distribution of the channel matrices across frequency tones, thereby increasing capacity

Open Broadband Wireless Core

The open wireless platform requires:

- Area and power-efficient broadband signal processing for wideband wireless applications

- Highest industry channel density (MOPS pooling) in flexible new BTS (Base Transceiver System) signal processing architectures
- BTS solutions scalable to higher clock rates and higher network capacity
- Waveform-specific processors provides new architecture for platform reuse in terminals for multiservice capability
- Terminal solutions achieve highest computational efficiency for application with high flexibility
- Powerful layered software architecture using virtual machine programming concept

For example, the key features of open BTS modem include (but not limited to):

Multi-standard air-interfaces
- GSM, cdma2000, WCDMA, HDR, TD-SCDMA, WLAN, OFDM, WIMAX
- proprietary standards

Highest channel-density
- 3GPP channels, 3GPP2 channels
- OFDM channels, WiMax channels
- ability to support multiple sectors on one chip
- grow from sectors-on-a-chip to BTS-on-a-chip or System-in-Package

Scalable data-rates
- support from 8 kbps to 384 kbps to 2 Mbps to 10 Mbps or higher

Configurable to mix voice and data
- programmable allocation of channels

IP-ready
- interfaces directly via BTS IP back-haul

Over-the-network programmable
- remotely configurable from network operations center

The key features of open wireless terminal include:

Multi-standard Air Interface
- GSM, cdma2000, WCDMA, W-LAN, Bluetooth, OFDM, WIMAX, TD-SCDMA

Power Efficient
- 100 MOPS/mW and more

Scalable Architecture
- Breaks the 384 kbps, 2Mbps and 10Mbps plateau

High-level Modem VMI
- Simplifies programming for each standard
- Enhances reuse across standards

Integrates across many platforms
- No DSP and minimal microprocessor dependent code

SIP Cores (Silicon Intellectual Property)

- Initial engine optimized for B3G/4G applications, for example, TD-SCDMA/WiMax/WLAN 3-in-1 core platform for open service-oriented architecture.

Figure 2 shows the Multi-standard BTS Engine for this OWA Platform, where "HDR" means "Hardware Defined Radio"; "SDM" is "Software Defined Module".

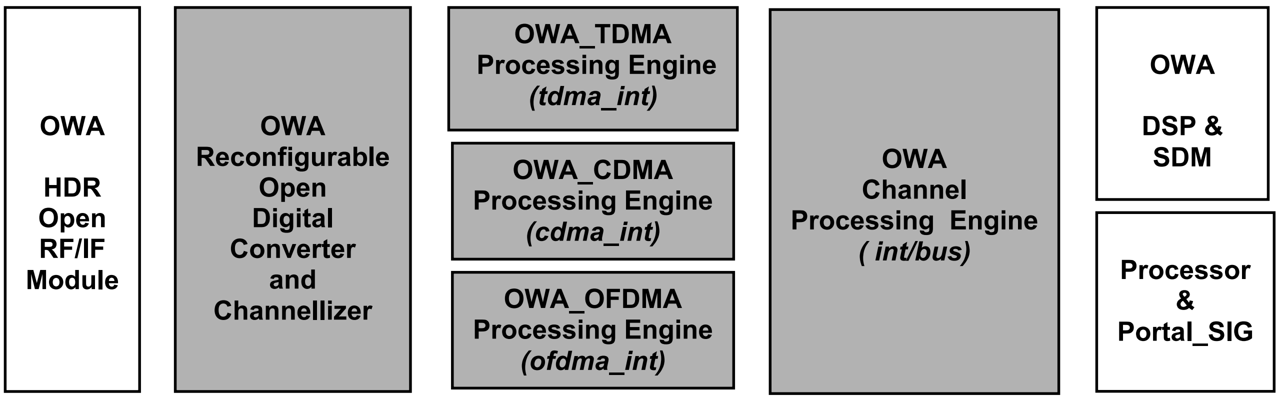

Figure 2: Multi-standards BTS Engine for the 4G OWA Platform

Open Base-band Processing Platform

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 (OWA) demands efficient baseband 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, TD-SCDMA, 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 3 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.

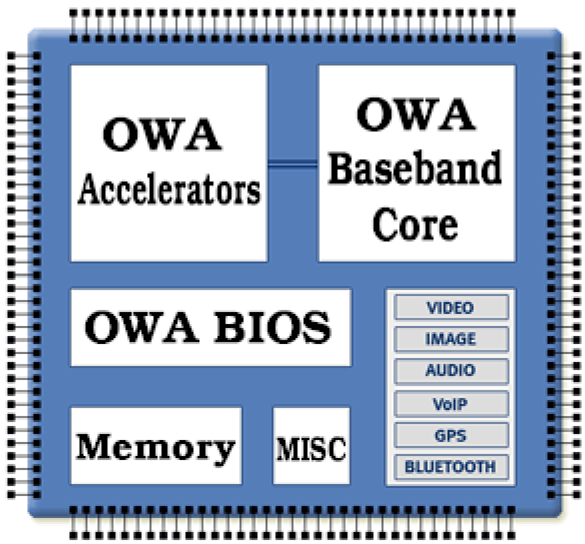

Figure 3: OWA Baseband Processing SoC Platform

Open Network Access Platform

In recent years, access aggregation technologies have been developed that allow a common access and transport network to bear the traffic of subscribers from multiple service providers. Separating access and transport from service accomplishes two points:

- It eliminates the burden of building out an access network, reducing the barrier to entry for new service providers and improving the growth potential for existing service providers.
- It promotes technical and business efficiencies for access and transport enterprises due to economies of scale and the ability to resell that access infrastructure to multiple service providers.

New systems provide end-to-end direct IP connections for users by extending access aggregation architectures to mobile broadband access. Network and service providers can leverage existing equipment, tool and content bases to support mobile broadband end users, while the end users experience the best of the wireless and wired worlds — the broadest range of applications and end-user devices, coupled with the freedom to move and high data rates.

Dynamic Spectrum Access and Capacity Enhancement

Wide-area wireless broadband systems' spectral efficiency can yield a system capacity that allows the services to be delivered simultaneously to many users in a cell, reducing the cost of service delivery for this mass-market broadband service. These systems are optimized to exploit the full potential of adaptive antenna signal processing, thereby providing robust, high-speed connections for mobile users with a minimum of radio infrastructure.

The spectral efficiency of a radio system — the quantity of billable services that can be delivered in a unit of spectrum — directly impacts network economics and service quality. Spectrally efficient systems have the following characteristics:

- Reduced spectrum requirements, minimizing up-front capital expenses related to spectrum
- Reduced infrastructure requirements, minimizing capital and operating costs associated with base station sites, translating into reduced costs per subscriber and per covered population element
- High capacity, maximizing the system throughput and end-user experience even under load

The acquisition of spectrum is a key component of the cost structure of wireless systems, and two key features of spectrum have great impact on that cost — the spectral efficiency of the wireless system and the type of spectrum required to implement the system. A fully capable and commercially viable mobile broadband system can operate in as little as 5 MHz of unpaired spectrum with a total of 20 Mbps throughput per cell in that amount of spectrum.

Spectral efficiency measures the ability of a wireless system to deliver information, "billable services," with a given amount of radio spectrum. In cellular radio systems, spectral efficiency is measured in bits/second/Hertz/cell (bps/Hz/cell). Many factors contribute to the spectral efficiency of a system, including the modulation formats, air interface "overhead" (signaling information other than user data), multiple access method, and usage model, among others. The quantities just mentioned all contribute to the bits/second/Hertz dimensions of the unit. The appearance of a "per cell" dimension may seem surprising, but the throughput of a particular cell's base station in a cellular network is almost always substantially less than that of a single cell in isolation. The reason is self-interference generated in the network, requiring the operator to allocate frequencies in blocks that are separated in space by one or more cells. This separation is represented by a reuse factor, where a lower number is representative of a more efficient system.

For example, mobile broadband systems' spectral efficiency of 4 bps/Hz/cell means that a mobile broadband radio network can support a given mobile customer base with far fewer sites and far less spectrum than would be required with other technologies — and, hence, with greatly reduced capital and operating costs. With 10 MHz of usable spectrum, for example, each mobile broadband base station would provide 40 Mbps of access capacity. In contrast, a 2G or 3G system with a spectral efficiency of 0.1 bps/Hz/cell, would provide only 1 Mbps of access capacity per cell in that same 10 MHz. In a capacity-limited rollout situation, a system with 2G- or 3G-like spectral efficiency would therefore require forty times (4/0.1) the number of base stations as a wireless broadband system and have a correspondingly higher cost of service delivery.

Actually, many countries' expectation of 3G technology is to increase its service capacity and spectrum efficiency rather than demanding higher data-rate transmission, which at this time, is not the killer application.

The rollout of 3G and 4G technologies will be stunted unless wireless spectral efficiency improves. Consumer and enterprise adoption will be dependent on new wireless technologies providing significant new capabilities inexpensively and seamlessly.

Open Service-Oriented Architecture and Open OS Platform

The success of future wireless communications rely mostly on the services provided and the applications the users require, rather than the underlying wireless transmission technologies. The users will dislike different boring names of various wireless standards, such as 802.11, 802.16 or cdma2000, etc, and therefore the service-oriented architecture (SOA) is extremely important for the system design and product development of future wireless communications.

To support this SOA platform, OWA is required to converge various radio transmission technologies onto an open system platform, including baseband processing platform, operating system platform, RF platform and infrastructure platform, to facilitate the future wireless terminal and base-station to handle different communications needs with same open equipment and same number – a truly unique and global personal communication identifier.

Figure 4 shows the future open services environment. The OWA layer sits under the SOA layer and the Service Oriented Infrastructure layer, and hence is transparent to the end users. This open environment is designed for the future wireless lifestyle of year 2010 and beyond.

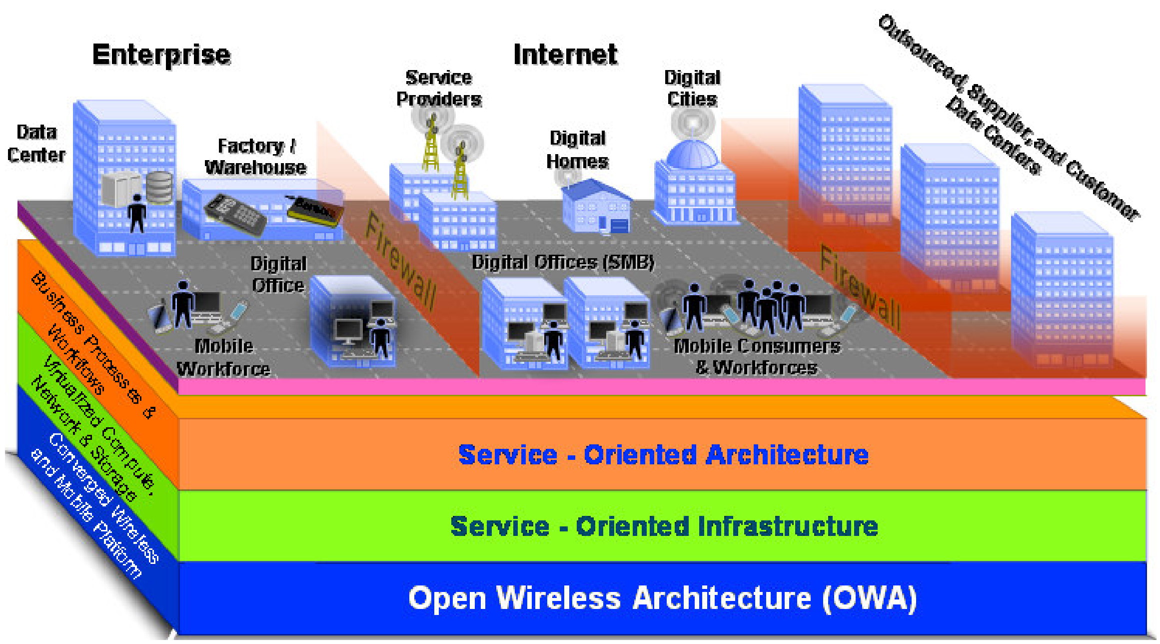

Figure 4: The Future Open Services Environment

Open Distributed Wireless Ad-Hoc Networks

Experts doubt that the current path to 3G will succeed. Current 3G migratory paths involve slowly enhancing voice-centric, high-power, hierarchical networks with IP-overlays. Air-interfaces may upgrade from GSM to WCDMA, or CDMA to HSDPA, but such RF adaptations do not address the underlying wireless network architecture issue. A concern is whether or not upgrading star networks will work any better in a wireless environment than it did in wireline.

However, low-powered, ad hoc mesh architected networks offer spectrally efficient high performance solutions to this dilemma. In such peer-to-peer networks, end-user wireless handsets act as both end terminals and secure wireless routers that are part of the overall network infrastructure. Upstream and downstream transmission “hop” through subscriber handsets and fixed wireless routers to reach network access points or other end terminals. Routing infrastructure, including handsets, utilize intelligent routing capabilities to determine “best path” for each transmission.

Routing for “best path” must be defined for “least power”. That is, network nodes must be able to calculate and update routing tables to send data packets through the paths with minimal power requirements. This is different than network nodes associating with the physically closest available infrastructure. Therefore, subscriber terminals do not “shout” at a centralized base station, but rather whisper to a near-by terminal that routes the transmission to its destination. Therefore subscriber terminals cooperate, instead of compete for spectrum. Spectrum reuse increases dramatically, while overall battery consumption and RF output within a community of subscribers is reduced. Simply put, additional users enhance rather than strain network capacity.

Thus, while the cellular handset can only maintain a 144kbs (for example) link to the base station, the ad hoc mesh device can maintain a multi-megabit link without undue interference.

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

Meanwhile, 4GMF®, FuTURE, WWRF, mITF, K4G, etc are working very hard to promote this emerging 4G mobile development on the worldwide basis. Due to the current economic situation, many experts predict that the 4G mobile may come much earlier than expected if 3G takes too long time to takeoff.

Challenges and Solutions

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.

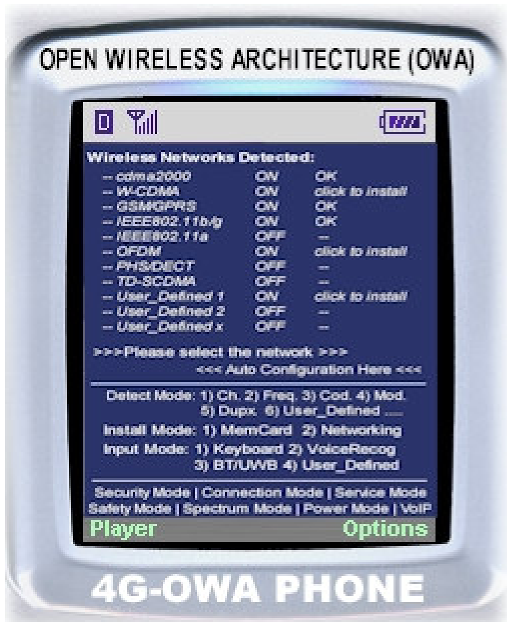

Figure 5: Future All-in-One 4G Terminal by OWA

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 6 shows an implemental OWA radio transceiver architecture 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

Open Wireless Architecture (OWA) technology is the solution for the Fourth Generation wireless and mobile communications (4G) on the worldwide basis. OWA refers to the open broadband wireless platform that can support diverse wireless and mobile standards, and can integrate multiple wireless networks. To achieve this flexibility, OWA focuses on all aspects of a communication system such as RF (radio frequency), baseband processing, networking and application segments. The flexibility and adaptability required for the converged open wireless platform can be achieved by defining the open interface parameters for the OWA systems and sub-systems.

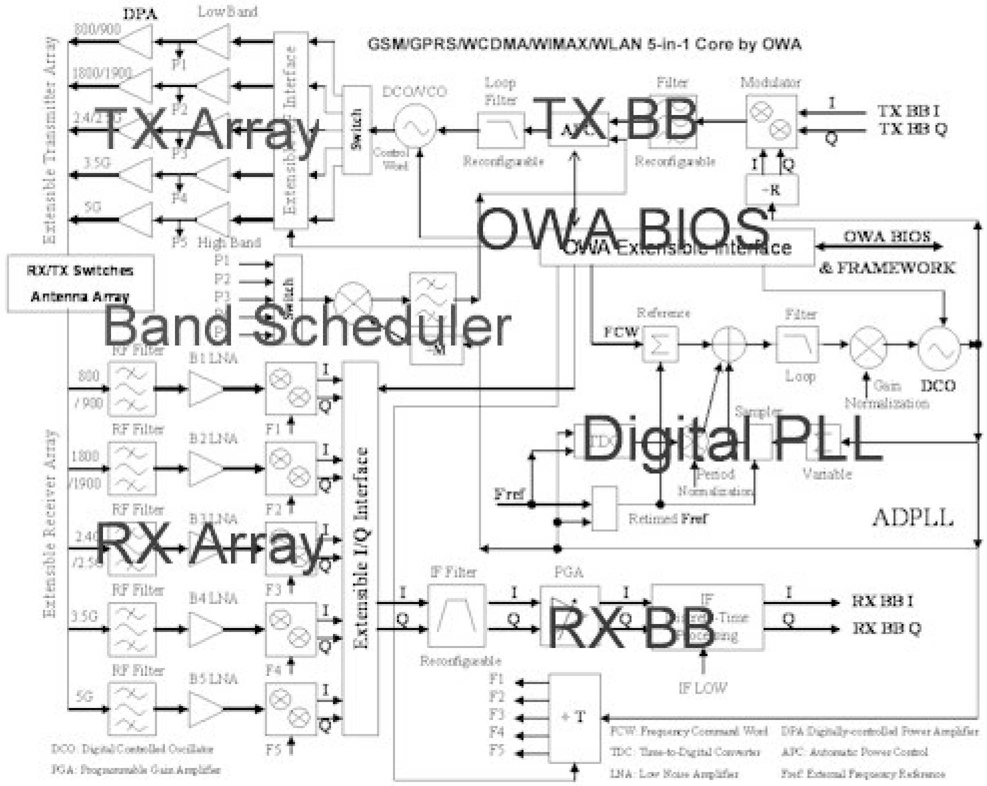

Figure 6: Architecture of Multi-Band OWA Transceiver

OWA helps in realizing global roaming facilities and seamless networking capabilities amongst different radio transmission technologies. It allows the network operators and subscribers to use third party solutions or user-defined solutions on their systems and to customize their systems according to their business models. Using OWA we can build systems which support multiple standards, multiple bands, multiple modes and offer diverse services to the customers.

OWA is different from SDR (software defined radio) because OWA basically maps various wireless standards into open interface parameters and maintain the system platform including RF, baseband, networks and applications an open architecture. Hence, in OWA systems, different modules (both hardware and software) can be from different vendors which are similar to the open computer architecture in personal computer system and open network architecture in packet router system. For more on OWA technologies, please visit: B3G.org.

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