Open Wireless Architecture – The Core to 4G Mobile Communications

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Abstract

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. TD-SCDMA/WLAN/GPRS 3-in-1 product, WCDMA/OFDM/WLAN 3-in-1 product, etc.

Asia is the most dynamic market of new generation mobile communications with over $50 Billion investment in the next five years. The 4G mobile technology – convergence of wireless mobile and wireless access, will definitely drive this growth.

Open Wireless Architecture

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
- 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 most wireless industries, for example, the W-CDMA/WLAN/Bluetooth 3-in-1 terminal is being designed in many companies.

The global 4G Mobile R&D focuses on the following Open Wireless Architecture:

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.
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 sees 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 FFTs 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 signal processing architectures
- BTS solutions scalable to higher clock rates and higher network capacity
- Waveform-specific processors provide 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:

Multi-standard air-interfaces
- GSM, IS-95, cdma2000, WCDMA, HDR, WLAN, OFDM
- Proprietary standards

Highest channel-density
- 3GPP channels, cdma2000 channels
- OFDM channels
- Ability to support multiple sectors on one chip
- Grow from sectors-on-a-chip to BTS-on-a-chip

Scalable data-rates
- Support from 8 kbps to 384 kbps to 2 Mbps to 10 Mbps

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, IS-95, cdma2000, WCDMA, W-LAN, Bluetooth, OFDM

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

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

Open Backbone 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, tools 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.

Shared Spectrum and Capacity Enhancement

Wide-area wireless broadband systems' spectral efficiency can yield a system capacity that allows that experience 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 bps/Hz/cell 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 (410.1) 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 Distributed 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 1XRTT, but such RF adaptations do not address the underlying wireless network architecture issue. At 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 architectured 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.

**Conclusion**

With the strong economy growth in China and the neighboring countries, the 4G mobile system based on Open Wireless Architecture will become the next wave in wireless communications. China, Japan, Korea, Singapore as well as other Asian countries are investing huge funds on this emerging 4G mobile core technology. It is well predicted that Asia will be the global hub of this 4G mobile in the coming years, and over 50 major wireless industries have moved their key R&D centers to the East Asia to reflect the importance of this region.

Meanwhile, 4GMF (www.4gmf.org), WWRF, mITF, K4G, etc are working very hard to promote this emerging 4G mobile development on the worldwide basis. In China, 4GMF will take the leadership in the next several years to make the region as a worldwide base on this 4G mobile mission. Due to the current economic situation, some experts predict that the 4G mobile may come much earlier than expected if 3G takes too long time to takeoff.

**Reference**


