Overview of 3G and WiMAX Technology.

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ABSTRACT

Mobile telephony allowed us to talk on the move. The internet turned raw data into helpful services that people found easy to use. These two technologies are converging to create a third generation mobile services. 3G technologies were rolled out to provide an increase in capacity over Second Generation (2G) mobile networks, both for data and voice services. WiMAX is a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL. Mobile WiMAX technology enables the mobility features and attributes for the end user. This paper discusses the 3G and WiMAX technologies within the perspective of Mobile Technology.

(Keywords: telecommunications, wireless, information technology, telephony, mobile services)

INTRODUCTION

In today's competitive environment, where bandwidth requirements are critical, it is evident that wireless technology is aggressively dominating the information flow infrastructure. Though existing transport is primarily wire line-based, rapid advancement in the utilization of the spectrum space is allowing a large set of applications to be supported by wireless. However, it is expected that there is some inter-working between the wireless and the wired infrastructure. This assures that users get the benefit of obtaining bundled services, comprising of voice, video, and data. In this multi-vendor world, where people have a lot of choices for applications and have extensive demands for travel, they seek a simple technology usage that will give them maximum convenience.

Over the years, every conceptual shift in wireless technology has been characterized as a generational change. With a good dose of hindsight, the generations of radio and major radio systems in each category are classified as shown in Table 1.

Few first generation (or 1G) systems remain, except in the United States, where AMPS (Advanced Mobile Phone System) remains a background universal service. Most services are now second generation (or 2G) dominated by Global System for Mobile communications (GSM) but also with widespread development of code-division multiple access (CDMA). CDMA is a conceptual advance on the 2G systems typified by GSM and so is commonly classified as 2.5G. Third generation (or 3G) offers a significant increase in capacity and is the optimum system for broadband data access.

Third generation includes wideband mobile multimedia networks and broadband mixed wireless systems. This paper gives an overview of 3G technology and discuss the various aspects of WiMAX technology.

THIRD GENERATION 3G TECHNOLOGY

Third generation (3G) services combine high speed mobile access with Internet Protocol (IP)-based services. But this doesn't just mean fast mobile connection to the World Wide Web. Rather, whole new ways to communicate, access

Table 1: Major Mobile Communication Systems [7].

TABLE 1. Major mobile communication systems with year of first widespread use.

System	Year	Description
0G		Broadcast, no cells, few users, analog modulation
MTS	1946	Mobile Telephone Service, half duplex, operator assist to establish call, push-to-talk
AMTS	1965	Advanced Mobile Telephone System, Japan, full-duplex, 900 MHz
IMTS	1969	Improved Mobile Telephone Service, full duplex, up to 13 channels, 60–100 km (40–60 mile) radius, direct dial using DTMF (dual tone multi-frequency) keypad.
0.5G		FDMA, analog modulation
PALM	1971	(also Autotel) Public Automated Land Mobile radiotelephone service, used digital signaling for supervisory messages, technology link between IMTS and AMPS.
ARP	1971	AutoRadioPuhelin (Car Radio Phone), obsoleted in 2000, used cells (30 km radius) but not hand-off. 80 channels at 150 MHz, half-duplex and latter full duplex
1G		Analog modulation, FSK for signaling, cellular, FDMA
NMT	1981	Nordic Mobile Telephone, 12.5 kHz channel, 450 MHz, 900 MHz
AMPS	1983	Advanced Mobile Phone System, 30 kHz channel
TACS	1985	Total Access Communication Systems, 25 kHz channel, widely used up to 1990s, similar to AMPS
Hicap	1988	NTT's mobile radiotelephone service in Japan
Mobitex	1990	National public access wireless data network, first public access wireless data communication services including two-way paging network services, 12.5 kHz channel, GMSK
DataTac	1990	Point-to-point wireless data communications standard (like Mobitex), wireless wide area network, 25 kHz channels, max bandwidth 19.2 kb/s (used by the original BlackBerry device)
2G		Digital modulation
PHS	1990	Personal Handyphone System, originally a cordless phone, now functions as both a cordless phone and as a mobile phone
GSM	1991	Global System for Mobile Communications (formerly Groupe Spécial Mobile), TDMA, GMSK, constant envelope, 200 kHz channel, max. 13.4 kb per timeslot (at 1900 MHz), 2 billion customers in 210 countries
DAMPS	1991	Digital AMPS, narrowband, (formerly NADC for North American Digital Cellular and prior to that as USDC for U.S. Digital Cellular), *pi*/4DQPSK, 30 kHz channel
PDC	1992	Personal Digital Cellular, Japan, 25 kHz channel
cdmaOne	1995	Brand name of first CDMA system known as IS-95. spread spectrum, CDMA, 1.25 MHz channel, QPSK
CSD	1997	Circuit Switched Data, original data transmission format developed for GSM, max. bandwidth 9.6 kb/s, uses a single timeslot
2.5G		Higher data rates
WiDEN	1996	Wideband Integrated Dispatch Enhanced Network, combines four 25 kHz channels, max. bandwidth = 100 kb/s
GPRS	2000	General Packet Radio System, compatible with GSM network, used GSM time slot and higher-order modulation to send 60 kb per time slot, 200 kHz channel, max. bandwidth = 171.2 kb/s
HSCSD	2000	High-Speed Circuit-Switched Data, compatible with GSM network, max. bandwidth = 57.6 kb/s, based on CSD, higher quality of service than GPRS
2.75G		Medium bandwidth data—1 Mb/s
CDMA2000	2000	CDMA, upgraded cdmaOne, double data rate, 1.25 MHz channel
EDGE	2003	Enhanced Data rate for GSM Evolution, compatible with GSM network, 8PSK, TDMA, max. bandwidth = 384 kb/s, 200 kHz channel
3G		Spread spectrum
FOMA	2001	Freedom of Mobile Multimedia Access, first 3G service, NTT's implementation of WCDMA
UMTS		Universal Mobile Telephone Service, 5 MHz channel, data up to 2 Mb/s
• WCDMA	2004	Main 3G outside China
• OFDMA	2007	Evolution to 4G (downlink high bandwidth data)
1xEV-DO		(IS-856) Evolution of CDMA2000, max. downlink bandwidth 307 kb/s, max. uplink bandwidth 153 kb/s.
TD-SCDMA	2006	Time division synchronous CDMA, China. Uses the same band for transmit and receive, base stations and mobiles use different time slots to communicate, 1.6 MHz channel
GAN/UMA	2006	Generic access network, formerly known as unlicensed mobile access, provides GSM and GPRS mobile services over unlicensed spectrum technologies (e.g., Bluetooth and WiFi.)
3.5G		
HSDPA	2006	High-speed downlink packet access, high download speeds up to 14.4 Mb/s, incorporated in UMTS
3.75G		
HSUPA	2007	High-speed uplink packet access, high upload speeds up to 5.76 Mb/s, incorporated in UMTS
4G		Low latency (e.g., for VoIP) + MIMO + OFDM + wireless broadband (WBB, > 100 Mb/s) + software defined radio

information, conduct business, learn and be entertained – liberated from slow, cumbersome equipment and immovable points of access.

3G is designed to deliver:

- A wide range of market-focused applications
- Long-term market-driven creativity, an innovative value chain and real user benefits, driving genuine market demand
- Advanced, lightweight, easy-to-use terminals with intuitive interfaces and instant, real-time multimedia communications
- Global mobility and roaming
- A wide range of vendors and operators, offering choice, competition and affordability
- High-speed e-mail and Internet access.

3G technologies were rolled out to provide an increase in capacity over second generation (2G) mobile networks, both for data and voice services. Global System for Mobile communications (GSM) and Code Division Multiple Access (CDMA), the two main 2G technologies, have been extremely successful at expanding the use of cellular voice services and basic narrowband data services like Short Message Service (SMS). To carry the rapidly increasing cellular traffic, mobile operators needed additional spectrum allocations and technologies with higher spectral efficiency. As voice accounts for the largest share of overall traffic, and in almost all markets for over 80% of service revenues, an increase in voice capacity was the highest priority.

3G technologies were developed to address these requirements, at a time when the Internet and broadband connectivity were still in their early days. As a result, 3G technologies like Wideband CDMA (WCDMA) and CDMA 1xRTT were initially optimized to carry switched voice traffic. Although 3G data capacity is higher than in 2G networks, 3G was not designed primarily as a data technology to support heavy subscriber use of packet-based data applications, like VoIP or streaming, that require low latency or high throughput in a cost-effective way.

Despite expected improvements in performance, technologies like High Speed Packet Access (HSPA) and EV-DO Rev A and B are severely limited by the lack of a native IP core and by the use of CDMA multiplexing. Wireless data technologies are migrating to OFDMA: 3GPP and 3GPP2 have recognized the need to change direction and are developing a new generation of OFDMA and IP-based technologies that are optimized to carry packet data traffic.

Building on the strong performance of its predecessors, GSM and CDMA, the initial market expectations for 3G were very high, especially because 3G was the first mobile technology to support broadband applications like video calls, content streaming and mobile TV, in addition to high-speed Internet access.

The market reception of 3G data services, however, has been disappointing. The uptake among 3G laptop users has been very limited, as subscribers complain of high service prices and limited bandwidth. Vodafone, one of the operators that has most aggressively targeted the laptop market, had only 140,000 laptop subscribers at the beginning of 2006. The limited capacity of 3G networks has forced operators to be cautious in the services they promote and to tightly control the network resources to avoid congestion. Most operators do not allow certain applications, including VoIP and video streaming. Even when they charge a flat fee, they frequently add “fair usage limitations” which determine the amount of monthly traffic allowed, often set to 1 GB which can easily be reached by subscribers.

To further control traffic, mobile operators have developed applications they deliver exclusively through their portals, but these have only met with limited success. For instance, Multimedia Messaging Service (MMS) has never taken off and there are indications of decline in its use in countries like the UK, according to that country's regulator, Ofcom2.

Less bandwidth-intensive applications like SMS and instant messaging still generate more than half of data revenues in many markets. The increasing use of off-portal access, where allowed, suggests that subscribers want to have more choices in the applications available to them. Capacity limitations in 3G networks also impede the operators’ ability to provide affordable broadband data services that are attractive to a large consumer market. The cost of supporting high levels of broadband data traffic in 3G

networks is high and results in expensive data plans that only a small niche of business users can afford. This, in turn, makes it difficult for the operator to recoup the infrastructure costs met to roll out the service.

WIMAX TECHNOLOGY

WiMAX is a standards-based technology enabling the delivery of last mile wireless broadband access as an alternative to cable and DSL. Worldwide interoperability for Microwave Access (WiMAX) is the common name associated to the IEEE 802.16a/REVd/e standards. These standards are issued by the IEEE 802.16 subgroup that originally covered the Wireless Local Loop (WLL) technologies with radio spectrum from 10 to 66 GHz.

• In January 2003, the IEEE approved 802.16a as an amendment to IEEE 802.16- 2001, defining (Near) Line-Of- Sight capability.

• In July 2004, IEEE 802.16 REVd, introduces support for indoor CPE (NLOS) through additional radio capabilities such as antenna beam forming and OFDM sub-channeling. The applications associated with each of these standards are shown in Figure 1.

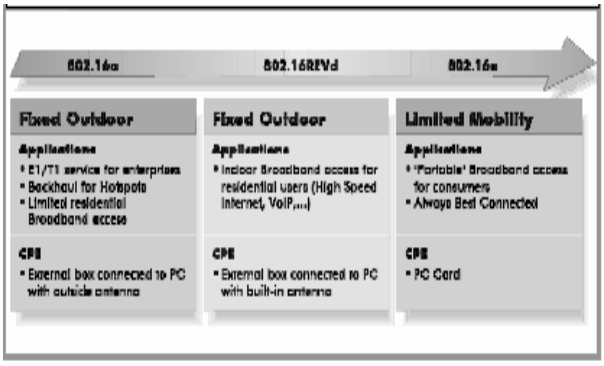

Figure 1: Different Flavors of WiMax [6].

Mobile WiMAX technology enables the mobility features and attributes for the end user. WiMAX technology will provide fixed, nomadic, portable and mobile wireless broadband connectivity without the need for direct line-of-sight with a base station. In a typical cell radius deployment of three to 10 kilometers, WiMAX systems can be expected to deliver capacity of up to 40 Mbps per channel, for fixed and portable access applications.

This is enough bandwidth to simultaneously support hundreds of businesses with T-1 speed connectivity and thousands of residences with DSL speed connectivity. Mobile network deployments are expected to provide up to 15 Mbps of capacity within a typical cell radius deployment of up to three kilometers. WiMAX chipsets can be incorporated into notebook computers, ultra mobile PCs, PDAs, and handsets, allowing for portable outdoor broadband wireless access for private and public sectors.

KEY ELEMENTS OF WIMAX TECHNOLOGY

One of the main elements of WiMAX technology is the interoperability of WiMAX equipment that results in mass volume and confidence by service providers in the interoperability of equipment from various companies.

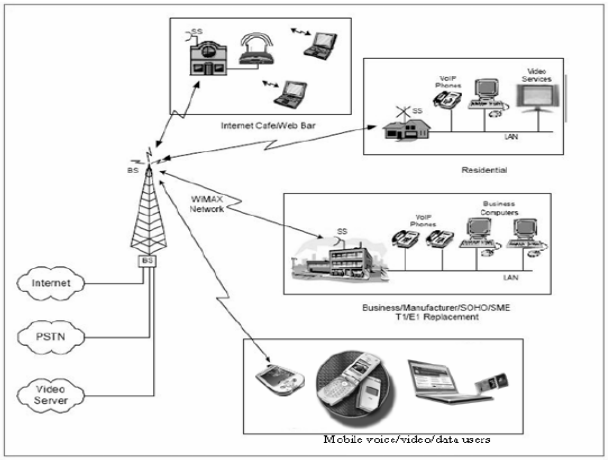

Figure 2: WiMax Architecture [3].

The WiMAX Forum *[2][3]* has brought together leaders in the communications and computing industries to drive a common platform for the global deployment of IP-based broadband wireless services.

The IEEE 802.16 Air Interface Specification contains options for a number of physical layers for different frequency bands and region-by-region frequency regulatory rules other key elements are cost of deployment, coverage,

capacity and standard for both fixed and mobile wireless access. A combination of following factors makes WiMAX technology as the best candidate for successful rollouts of mobile broadband services *[4][5].*

- **Advanced performance:** WiMAX high-capacity base stations offer high per-user throughput and low latency, and supports all of those applications supported by a wired broadband connection, including real-time and bandwidth-intensive applications.

- **A wide variety of devices:** Laptop add-in cards and modules will be the first WiMAX subscriber devices to be introduced in the market. A wide variety of form factors will soon follow including PDAs, phones, game consoles, ultra-mobile PCs, MP3 players, and custom devices for vertical market applications. Internet Protocol (IP) architecture offered through WiMAX technology makes it easier to integrate and support these new devices.

- **Cutting-edge technology:** WiMAX is a technology developed and optimized for packet-based data applications and offers some of the most advanced functionality and spectral efficiency among commercially available wireless data technologies. Its native IP core network and support of IP Multimedia Subsystem (IMS) and Multi-Media Domain (MMD) will make it easier and cheaper to roll out new data applications and to interwork with other IP-based technologies. The use of Orthogonal Frequency Division Multiple Access (OFDMA), the multiplexing mechanism that is at the core of most next-generation technologies, including Third Generation Partnership Project's (3GPP) Long Term Evolution (LTE), brings higher throughput and improved indoor coverage. Quality of Service (QoS) functionality enables mobile operators to offer advanced services and to prioritize traffic from different applications. Finally, advanced antenna techniques like Multiple Input Multiple Output (MIMO) and beam forming bring further enhancements in throughput and range.

- **Support for mobility:** WiMAX technology supports seamless handoffs at vehicular speeds that enable subscribers to maintain their connection as they move across areas covered by different base stations.

- **Cost effectiveness:** WiMAX technology features spectral efficiency that enables network operators to carry more traffic and to deploy a cost-effective infrastructure. Manufacturing economies of scale are expected to drive down product production costs and promote wide product availability. Operator cost savings can be passed on to subscribers, thus widening the appeal and adoption of mobile broadband services to the mass market.

- **Commercial availability:** Mobile WiMAX technology is based on the Institute of Electrical and Electronics Engineers (IEEE) 802.16e-2005 standard, approved in December 2005, and on European Telecommunications Standards Institute (ETSI) High Performance Radio Metropolitan Area Network (Hyper MAN). WiMAX Forum certification of Mobile WiMAX products will begin in mid-2007. Mobile WiMAX enjoys a two-to-four-year time advantage compared to cellular technologies like LTE and Evolution Data Optimized (EV-DO) Rev C at a time when the availability of affordable mobile broadband is not sufficient to meet demand for the service.

- **Worldwide availability:** Mobile WiMAX operates in three spectrum bands (2.3-2.4 GHz, 2.496-2.69 GHz, and 3.4-3.6 GHz) which have common allocations in most countries. It is a global technology that subscribers can use worldwide with a single device. The WiMAX Forum certification program tests equipment from different vendors for interoperability and standards conformance thus facilitating the use of the same equipment across markets. WiMAX fully supports roaming capabilities and the WiMAX Forum is already working towards a worldwide roaming framework.

Key critical technologies to WiMAX advanced performance are:

- **Orthogonal Frequency Division Multiple Access (OFDMA):** This is a multiplexing technique well suited to multi-path environments that gives network operators higher throughput and capacity, great flexibility in managing spectrum resources, and improved indoor coverage. OFDMA has emerged as the technology of choice for next-generation mobile networks. 3GPP has

incorporated OFDMA in its LTE specification and 3GPP2 is moving in the same direction.

- **Time Division Duplex (TDD) and Frequency Division Duplex (FDD)**: The IEEE 802.16e-2005 standard and ETSI Hiper MAN support both duplexing mechanisms. However, the initial WiMAX Forum certification profiles for Mobile WiMAX only support TDD as this is the duplexing mode that is best suited for data applications and advanced antenna technologies, and one that most network operators and vendors prefer.

- **Multiple Input Multiple Output (MIMO) and beamforming:** These advanced antenna technologies bring a substantial improvement in throughput and coverage.

- **Multiple handoff mechanisms**: WiMAX implementations support a variety of handoff mechanisms that allow subscriber devices to maintain a connection while traveling at vehicular speeds.

- **IP core network**: The use of a common IP platform simplifies inter-working with other wired and wireless technologies.

- **IP Multimedia Subsystem (IMS) and Multimedia Messaging Service (MMD):** Support for IMS and MMD further facilitates inter-working and removes existing redundancies in the core network. With IMS and MMD, network operators can develop applications independently of the access technology within a flexible, layered architecture in which application modules can easily be modified or reused. To foster integration with other technologies, the WiMAX Forum has established the Networking Working Group which closely collaborates with service providers, the IEEE, ETSI, 3GPP and 3GPP2 to assure a unified network architecture that facilitates inter-working, roaming and infrastructure sharing with current and emerging cellular and wired technologies.

- **Global roaming:** It allows subscribers to access different networks using the same device and a single, familiar interface. The WiMAX Forum is working towards a framework that will encourage the establishment of global roaming relationships among service providers.

WI-FI AND MOBILE

The initial data from 3G data services incorrectly suggests that the demand for mobile broadband is low and limited to business users [5]. The rapid growth of Wi-Fi suggests otherwise.

The success of Wi-Fi has taken the industry by surprise and was initially met with suspicion or rejection from mobile operators. The Wi-Fi model differs in significant ways from that of 3G.

Wi-Fi adoption was driven by end-users, who typically purchase the connection devices. Service providers do not need to subsidize the subscriber unit and economies of scale have led to a much faster reductions in prices are typically seen in the cellular industry.

Wi-Fi can be used in virtually every country worldwide. Despite being deployed in unlicensed bands that are shared by many technologies, a combination of market forces and superior performance has made Wi-Fi a truly global technology. Direct regulatory intervention (other than allowing the use of the technology in the 2.4 GHz band and in some cases relaxing previously defined constraints) was not needed. Increasingly, domestic and international roaming allows subscribers to use their service plan more extensively, in a way similar to that afforded by GSM.

Few restrictions are placed on the subscriber's ability to access content or applications, as capacity rarely becomes an issue.

Coverage areas are much more restricted than for cellular networks: Wi-Fi is well suited to high bandwidth services in limited hotspot areas and cannot compete with 3G or 2G technologies in providing wide-area coverage. However, laptop users are often willing to travel to the closest hotspot where they can download or send their email, or do some work at higher data rates.

Despite its more limited coverage, and the fragmentation of Wi-Fi service providers, Wi-Fi access through laptops is more widely used for public access than 3G in most markets.

Technology Roadmap for 3G and WiMAX is given below in Figure 3.

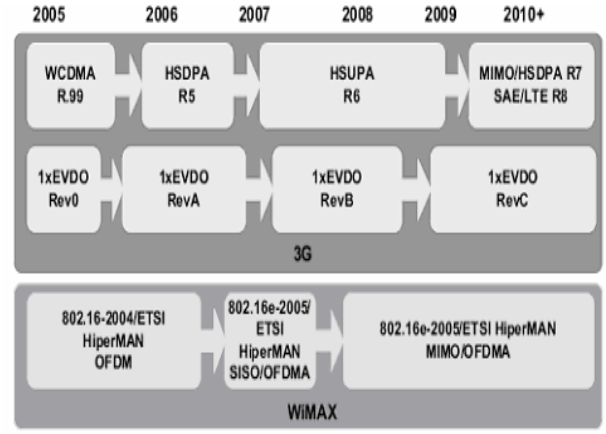

Figure 3: Technology Roadmap for 3G and WiMax [WiMax Forum].

CONCLUSION

The experience with initial mobile broadband services points to a few instructive learning points. 3G performs an essential role in providing wide mobile broadband coverage, but by itself it cannot meet the demand for affordable data plans that support extensive use of bandwidth-intensive (content streaming) or real-time (VoIP, gaming) applications. It is rapidly evolving to improve its performance, but its switched, voice-centric approach limits its ability to meet the demand of an increasingly sophisticated subscriber base.

New technologies like WiMAX and plans for technologies like LTE point towards alternative technologies that are optimized for IP data traffic and are better suited to provide the high-throughput, affordable data services that the market requires.

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