CDMA AND OFDM

The convergence of wireless mobile services

1. INTRODUCTION

Up until the end of the 20th century, there was a fairly clear division between the cellular industry and other telecommunication industries which offered basic telephone, television, radio, computer and Internet services. Most mobile operators used second generation (2G) digital wireless technologies to enable voice communications and limited data services, while most wireline, cable and satellite systems provided the bulk of the other telecommunication services. In spite of its initial limitations, cellular communications has been a tremendous success, surpassing fixed line connections worldwide in 2001,just 12 years after its market introduction. This has been especially evident in developing markets where, due to its lower deployment costs and greater network flexibility, wireless technologies have become the primary means of communication for millions of people, spurring the economic and social development of these markets.

Since the beginning of the 21st century, there has been a dramatic shift in the market dynamics of telecommunications services. With the introduction of third generation (3G) IMT-2000 technologies based on CDMA, wireless operators have been able to offer high-quality voice services as well as broadband Internet access and multimedia services, blurring the boundaries between the telecom industries. Service providers and regulators across both developed and developing markets have been quick to adopt and promote the technologies. As a result, a tremendous momentum has been built behind the deployment and adoption of the 3G CDMAservices. In the 7 years since its introduction in 2000, over 460 operators have launched CDMA2000 and WCDMA systems surpassing a half a billion users by September 2007. The adoption of 3G mobile broadband technologies, such as CDMA2000 1xEV-DO and HSPA, has also accelerated, reaching 270 commercial systems serving more than 100 million users in 165 countries.

Yet again, the wireless industry stands at the crossroads of selecting capabilities and services to take it well into the future. These new dimensions include: the proliferation of voice, video, television, broadband Internet and value-added data services; integration amongst wireless and fixed networks to enable the seamless delivery of these services over multiple networks; improved user experience and economics, and; convergence of industries such as telecommunications, information and broadcasting.

The next-generation of IMT systems based on CDMA and Orthogonal Frequency Division Multiple (OFDM) technologies, along with OFDM-based broadcast technologies such as DVB-H, FLO and ISDB-T, will be key enablers of this transition. In particular, CDMA2000 EV-DO Revision B (Rev. B), HSPA+, Ultra Mobile Broadband (UMB), Long

Term Evolution (LTE), and Mobile WiMAX (802.16m) are capable of providing the performance characteristics that will support multi-megabit-per-second data delivery to users, carrier-grade VoIP and other real-time and broadband intensive applications (Figure 1).

With significant market momentum and large economies of scale and scope, 3G CDMA technologies will continue to be the leading platform for mobile communications, including next-generation broadband services, well beyond the year 2020. Nevertheless, some incumbent operators and new service providers are considering the purchase of additional spectrum and deployment OFDM-based systems.

Regardless of the operator's approach and existing technology roadmap, it is becoming evident that a "one network fits all" strategy will not suffice in future competitive markets. Selecting alternate technologies will be very dependent upon an operator's unique set of circumstances, including market opportunities, assigned licenses, available spectrum, previous technology selections, vendor relationships and propensity for risk. In other words, service providers will choose the path and technologies that best meets their market and economic requirements.

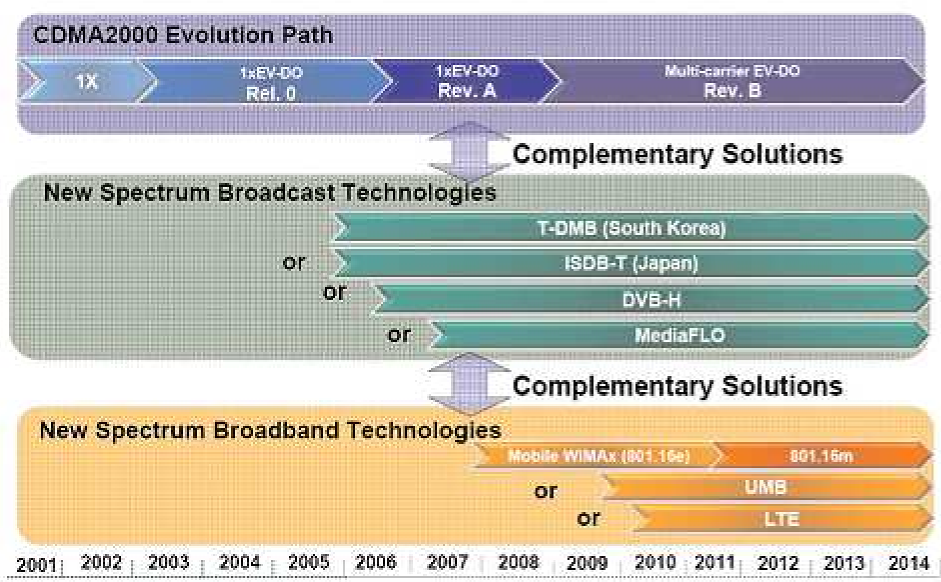


FIGURE 1
CDMA2000 Roadmap with Complementary Mobile Broadcast and Broadband Solutions

From its inception, the CDMA technology roadmap has provided operators with technology-leading performance capabilities and a time-to-market advantage. Thanks to CDMA's forward-and-backward compatible technology upgrades within the 1.25 MHz CDMA radio channel, CDMA operators have benefited from the favorable economics of an evolutionary "in-band" solution. As a result they have been able to deploy new technologies and value-added services throughout their entire network much faster than their competitors.

The CDMA2000 family of technologies is strongly positioned to remain a vital component of the convergence revolution. With the commercial availability of CDMA2000 1xEV-DO Revision A(Rev. A) in 2006 and multi-carrier EV-DO, or EV-DO Revision B (Rev. B) in 2008 to provide additional capacity via a simple software upgrade, CDMA2000 operators will be able to offer multi-megabit-per-second average data rates to individual users while leveraging the large economies of scale and scope that the CDMA2000 industry offers.

This white paper discusses the future role of CDMA2000 in an environment where new local as well as wide area networks and technologies are now being considered. In Section 3, the paper highlights the CDMA2000 migration, beginning with IS-95, through 1X, EV-DO and beyond. With this basis of understanding, the paper then examines the importance (and advantages) of multi-carrier EV-DO Rev. B, as well as why there is interest and some advantages in considering OFDM technologies, a non-CDMA standard.

Convergence will also have a major role to play in next-generation wireless networks. Section 4 examines convergence at the device and network layer and how it will allow wireless service providers to pick and choose the most appropriate network technology for the given application. The paper concludes with an analysis of the potential deployment scenarios for OFDM-based next generation mobile broadband solutions, including opportunities with legacy CDMA2000 operators as well as with new entrants.

2. NEXT-GENERATION MOBILE BROADBAND TECHNOLOGIES

Existing 3G cellular technologies, including CDMA2000 1X/EV-DO, WCDMA/HSPA, and TD-SCDMA, utilize CDMA as the core radio access technology. Since their first market introduction, they have evolved to deliver higher capacities, through-puts and efficiencies to support the growing usage of increasingly bandwidth-intensive data services. In narrow bandwidth allocations (up to 5 MHz), Rev. A and Rev. B, HSPA and HSPA+ can achieve some of the highest data throughputs possible in a given amount of spectrum. With wider radio channels (more than 10 MHz), OFDM-based technologies such as UMB, LTE and Mobile WiMAX have emerged as viable options to deliver wider-bandwidth mobile broadband services. For specific bandwidth-intensive applications such as multicasting and broadcasting, OFDM-based technologies such as DVB-H, FLO, ISDB-T, S-DMB and T-DBM have been commercialized since 2006.

Both 3G CDMAand OFDM-based technologies provide the spectral efficiencies, network capacities and latencies necessary to support mobile television and rich broadband services of the future. Yet, depending upon the market scenario they can either complement or compete against each other. Each technology has its own technical merits.

Comparison of Mobile Broadband Technologies

CDMA and OFDM-based technologies use different air interfaces and antenna techniques to achieve their respective performance characteristics. Depending upon the technical standard and its field implementation, their performance results will vary. They can offer different capabilities, whether it's for fixed backhaul connectivity, broadcast transmissions or high-bandwidth mobile broadband services.

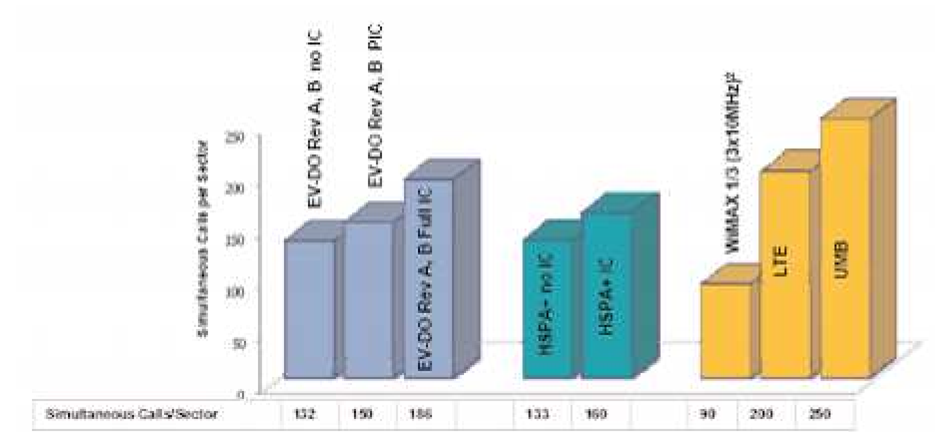
This section provides a comparison of the performance characteristics of each of the existing and future mobile broadband technology standards based on a common set of assumptions and parameters. The comparisons were made within a full-mobility environment in the 1.9 to 2 GHz frequency band, with bandwidths normalized at 10 MHz (2 x 5 MHz FDD or 10 MHz TDD 2:1), with the exception of the VoIP capacity comparison whereby Mobile WiMAX was assigned 30 MHz of bandwidth.

For existing technologies, the performance is based on empirical measurements from commercially available systems including CDMA2000 1X, 1xEV-DO Rel. 0, 1xEV-DO Rev. A, GPRS, EDGE, WCDMA, HSDPA and HSPA. For technologies under development, the latency performance is based on laboratory test results and spectral efficiencies / sector throughputs are based on computer simulations that take into consideration expected implementation margins, reasonable coverage and a variety of mobility conditions. 3GPPand 3GPP2 'mixed channel model' simulation methodologies were used to most closely estimate the 'actual' system performance that operators should expect to get in the field - values the vendors are willing to "Guarantee."

VoIP Capacity

One of the key performance criteria of any wireless technology is its capacity to support carrier-grade voice communications. Thus, the number of simultaneous VoIP calls per sector was compared in a full-mobility environment. The service quality of these calls was normalized such that each call supported a voice quality equivalent to that of existing circuit-switched wireless systems. For 3GPP2 systems, an EVRC codec is assumed and for other systems, an AMR 7.95k codec is assumed.

The amount of spectrum allocated for Mobile WiMAX in the VoIPcapacity comparison below was increased from 10 MHz to 3x10 MHz TDD based to accommodate a re-use factor of 3:1.



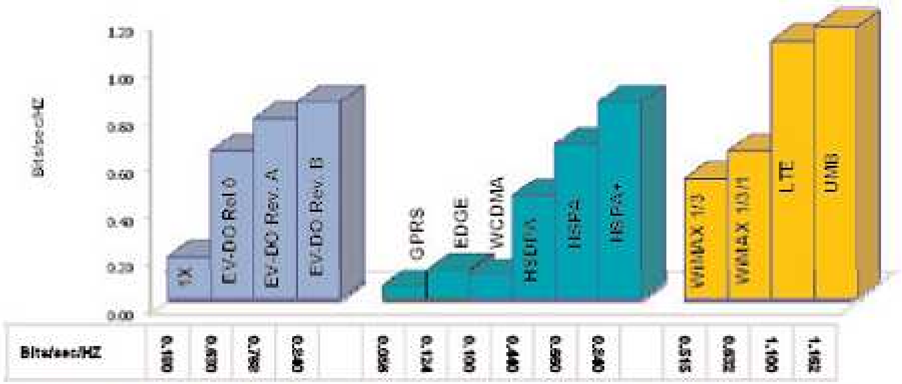
1 Channel Capacities reflect the effects of frequency reuse and overhead structure.
2 A bandwidth of 30 MHz is necessary to assign a separate 10 MHz frequency assignment for each sector

Carrier grade VoIP assumes handsets with a quality comparable to that in the existing wireless systems under mobility environment
CDMA2000: 3GPP2 Assumptions, EV-DO Rev A and B 3 carriers in 5 MHz FDD with no Interference Cancellation (no IC), Pilot Interference Cancellation (PIC) and Full Interference Cancellation (IC)
3GPP Assumptions, 5 MHz, FDD • WiMAX Forum, 3x10 MHz TDD DL:UL=2:1 with 1/3 reuse
Source: CDMA Development Group, December 2007

FIGURE 2
VoIP Capacity Comparison
(Simultaneous VoIP Users Per Sector)
(2x5 MHz FDD for CDMAand 3x10 MHz TDD for WiMAX)

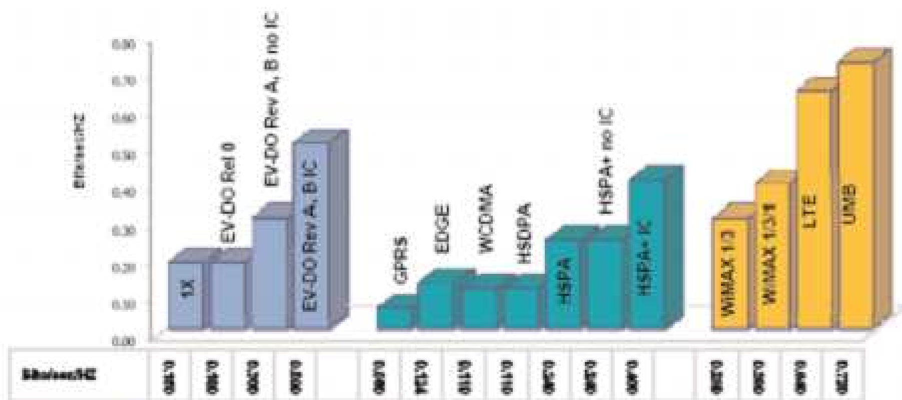
Spectral Efficiency

The spectral efficiency of any wireless technology depends upon its modulation and coding schemes, control and signaling mechanisms, radio resource management, interference cancellation techniques and antenna configuration. The spectral efficiencies for commercial systems were field verified. The spectral efficiencies of future systems included proper implementation margins and RF environment.



1 Efficiencies for existing systems are field verified. Efficiencies for future systems include proper implementation margins and RF environment.
3GPP2 Assumptions, 5 MHz FDD, 1X and EV-DO assume 3 carriers. EV-DO assumes 1x2 SIMO. Rev. B includes Hardware Upgrade and UMB 2x2 MIMO
3GPP Assumptions, 5 MHz FDD, WCDMA assumes no DSCH. HSDPA assumes 1x1 SISO, HSPA assumes 1x2 SIMO; HSPA+ includes 1x2 SIMO and
equalizer; LTE includes 2x2 MIMO
WiMAX Forum Assumptions, D:L = 2:1, 2x2 MIMO; Reuse = 1/3 in 3x3.33 MHz TDD carriers; Reuse = 1/3/1 FFR within 10 MHz TDD channel
Source: CDMA Development Group, December 2007

FIGURE 3
Downlink Spectral Efficiency Comparison
(2x5 MHz FDD or 10 MHz TDD 2:1)

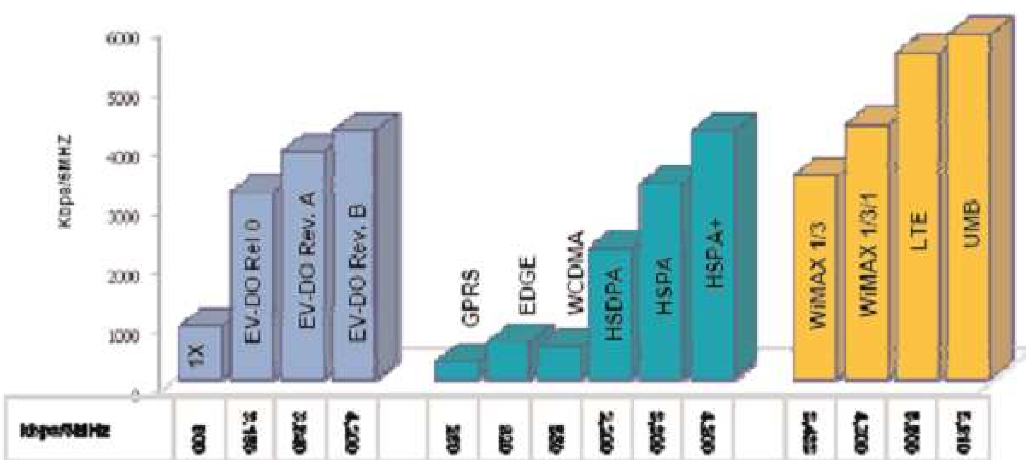


1 Efficiencies for existing systems are field verified. Efficiencies for future systems include proper implementation margins and RF environment.
3GPP2 Assumptions, 5 MHz FDD, 1X and EV-DO assume 3 carriers. Rev. A and Rev. B includes no Interference Cancellation (no IC) and interference cancellation (IC); Rev. B includes hardware upgrade and UMB 1x2 SIMO
3GPP Assumptions, 5 MHz FDD, HSPA+ and LTE includes 1x2 SIMO. HSPA+ includes no IC and IC, HSPA = Rel. 6, HSPA+ = Rel. 7
WiMAX Forum Assumptions, D:L = 2:1; Reuse = 1/3 in 3x3.33 MHz TDD carriers 2x2 MIMO; Reuse = 1/3/1 FFR within 10 MHz TDD channel 1x2 SIMO
Source: CDMA Development Group, December 2007

FIGURE 4
Uplink Spectral Efficiency Comparison
(2x5 MHz FDD or 10 MHz TDD 2:1)

Aggregate Sector Throughputs

The average aggregate data throughput per sector for each technology is another comparison characteristic that is widely considered by the industry. Among other factors, it is dependent upon the number of users per sector, the distance these users are from the transceiver and how fast they are moving. To measure the data throughputs, the user traffic expected in the field was simulated using industry accepted channel simulation models. For 3GPP, the simulation methodology assumes a 2.8 km site-to-site distance and a channel model mix of users where 50% are handset pedestrians (PA3) moving at 3 km/h, another 25% are data device pedestrians (PB3) moving at 3 km/h and 25% are vehicular users (VA30) traveling at 30 km/h. The 3GPP2 simulation methodology assumes a 2 km site-to-site distance and a channel model mix of users, where 30% are handset pedestrians (pedA) moving at 3 km/h, 30% are data device pedestrians (pedB) moving at 10 km/h, 20% are vehicular users (vehA) traveling at 30 km/h, 10% are pedestrians (pedA) moving at 120 km/hr and 10% of the remaining radio signal is cancelled due to Rician fading. Asecond set of uplink data throughput values are shown for EV-DO Rev. A, Rev. B and HSPA+ to consider the enhancements enabled by interference cancellation (IC). Using interference cancellation techniques in the uplink enables existing 3G CDMA technologies to deliver aggregated data throughput levels closer to those of OFDM-based next generation broadband technologies.



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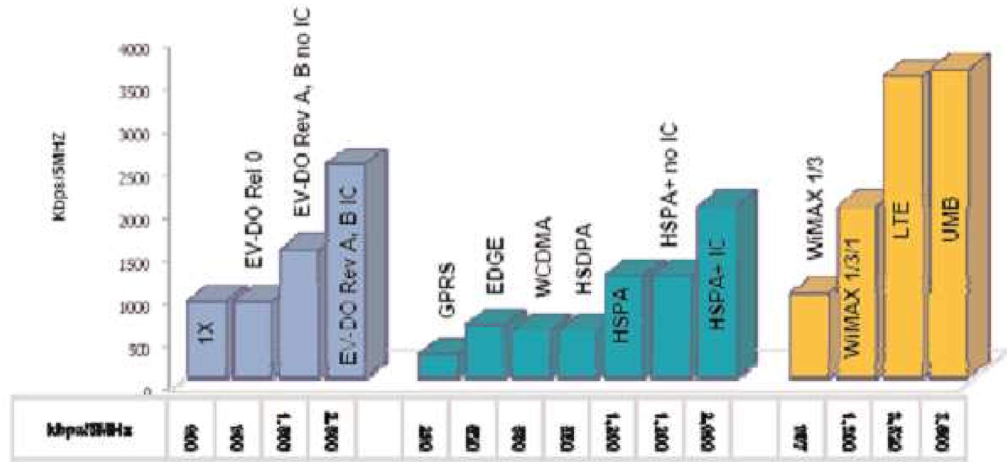
Source: CDMA Development Group, December 2007

FIGURE 5
Aggregated Downlink Data Throughput Comparison
(2x5 MHz FDD or 10 MHz TDD 2:1)



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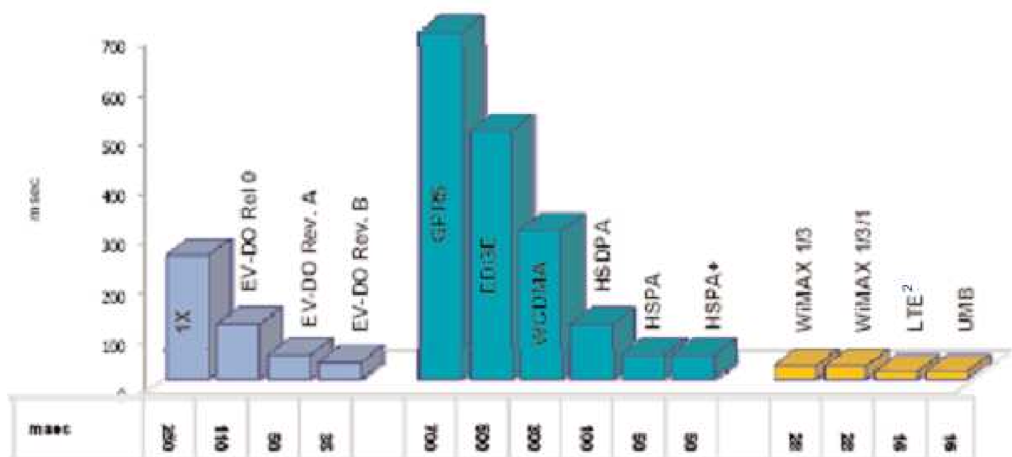
Source: CDMA Development Group, December 2007

FIGURE 6
Aggregated Uplink Data Throughput Comparison
(2x5 MHz FDD or 10 MHz TDD 2:1)

Average Latency
The average latency of each technology standard was compared by measuring the Round Trip Time (RTT) of a 32-byte ping, assuming a minimum network and backhaul delay in a laboratory environment.



The round trip time (RTT) latency of existing systems is based on laboratory measurements using 32 Byte ping.
1 The RTT latency of future systems is based on air interface specification under laboratory environment and reasonable backhaul and network delays.
2 LTE RTT latency is expected to be comparable to that of UMB, pending the completion of the standard.
Source: CDMA Development Group, December 2007

FIGURE 7
Average Latency Comparison
(Average round trip time between network nodes)

CDMA2000 will continue to evolve to deliver increasingly higher spectral efficiencies and improved performance to meet the growing demand for rich mobile data applications. High aggregate data throughputs enable CDMA2000 operators to send large files in both directions and offer robust bandwidth intensive applications, such as rich multimedia messaging, push-to-multimedia, see what I see (SWIS), data casting and remote video monitoring. CDMA2000 also offers lower average latencies to enable delay-sensitive services such as video telephony, push-to-talk and other VoIP-based applications. CDMA2000 will be first to support carrier-grade VoIPin 2008.

3. THE CDMA2000 MIGRATION PATH OPTIMIZES PERFORMANCE TO DELIVER NEXT-GENERATION SERVICES WHILE LEVERAGING LEGACY SYSTEMS

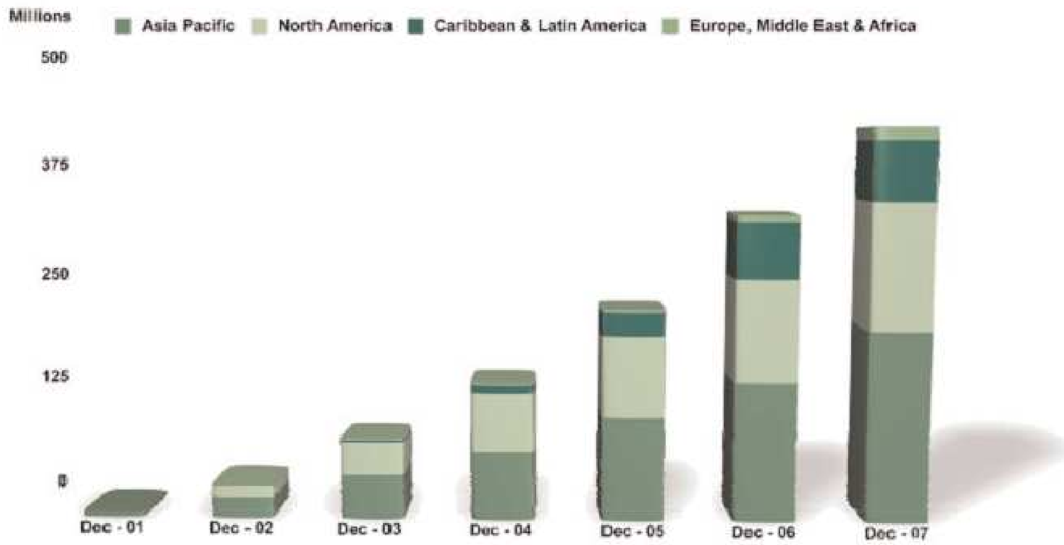
Since its inception, the CDMA2000 migration path has sought to maximize performance and minimize costs, by sustaining an evolutionary path that eliminates the need for expensive "forklift" upgrades. This commitment has resulted in a faster time-to-market, lower capital and operating expenditures, and a higher degree of backwards compatibility between new and legacy technologies within a CDMA2000 network.

CDMA2000's In-Band Evolution Towards Advanced Broadband Capabilities
When IS-95 (known by the trade name cdmaOne™) was first commercialized in 1995, it utilized a 1.25 MHz radio channel. By using a narrow radio channel, CDMAoperators benefited from greater flexibility in deploying services in existing 'in-band' frequency allocations, as compared to wider-bandwidth 10 MHz radio channel solutions.

Over the years, CDMA technology has matured with the introduction of a number of new technology advancements that have enabled increased capabilities, an enhanced user experience and improved economics, including new speech vocoders, advanced antenna techniques, interference cancellation and the aggregation of radio channels. These advancements became available through the publication and commercialization of new global standards, such as CDMA2000 1X and CDMA2000 1xEV-DO.

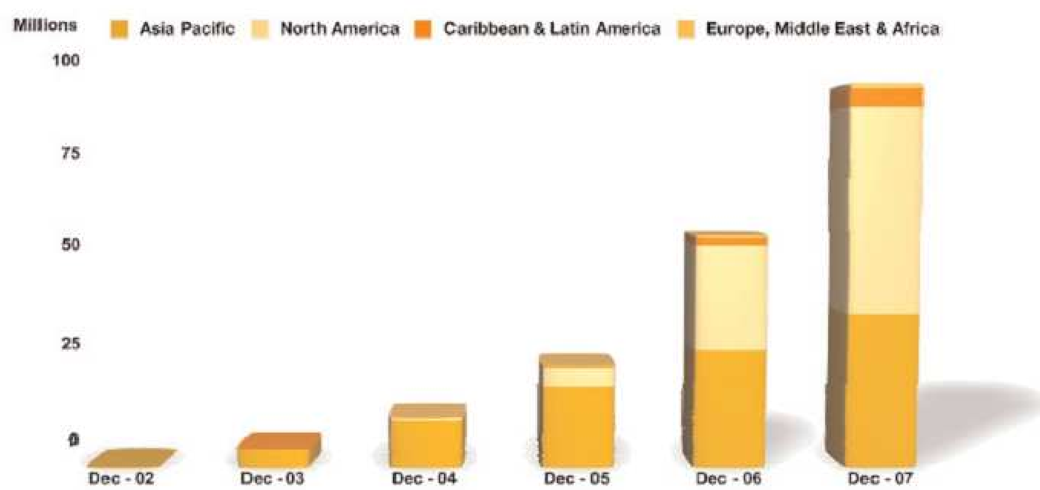
CDMA2000 1X, 1xEV-DO Rel. 0 and 1xEV-DO Rev. A(all ITU-approved IMT-2000 3G technologies) are designed to operate in a single 1.25 MHz channel and allow operators a smooth upgrade to deliver higher performing and more affordable services. All three technologies have been commercially deployed: 1X was introduced in 2000, Rel. 0 was launched in 2002, and Rev. A was commercialized in late 2006.

Rev. A maximizes spectral efficiency to deliver a peak data rate of 3.1 Mbps in the downlink and 1.8 Mbps in the uplink, plus lower latency and advanced QoS mechanisms to support carrier-grade VoIP and other delay-sensitive applications. The use of a 1.25 MHz radio channel, however, limits the maximum data rate that any one user can achieve. Therefore, for CDMA2000 operators looking to deliver additional bandwidth and multi-megabit-per-second data rates economically to their subscribers by preserving their previous infrastructure investments, an upgrade to multi-carrier Rev. B is the optimum solution. Rev. B is also a viable solution for Greenfield deployments.



Source: CDMA Development Group, December 2007

FIGURE 8
CDMA2000 Market Maturity



Source: CDMA Development Group, December 2007

FIGURE 9
EV-DO Subscriber Growth

Multi-Carrier EV-DO Rev. B Builds Upon the Spectral Efficiencies of EV-DO and Aggregates Spectrum to Offer Advanced Wireless Broadband

EV-DO Rev. B, also an approved IMT-2000 standard, is a multi-carrier implementation of Rev. Athat allows operators to combine several discrete 1.25 MHz carriers through a software upgrade without any degradation of spectral efficiency. For example, using three 1.25 MHz carriers (within 5 MHz of spectrum) and a software upgrade to Rev. B, the user peak data rate jumps to 9.3 Mbps in the downlink and 5.4 Mbps in the uplink. With an additional channel card hardware upgrade, the peak data rates will increase further to 14.7 Mbps in the downlink. The additional carrier assignments also increase the capacity for VoIP communications.

The average data rates advertised for commercial Rev. Anetworks range from 600 kbps to 1.4 Mbps in the downlink and 500 to 800 kbps in the uplink. With a three carrier Rev. B software upgrade implementation, a user should experience average data rates that are three-times higher, up to 4.2 Mbps in the downlink and 2.4 Mbps in the uplink, and even higher with the hardware upgrade.

Since upgrading to Rev. B simply requires new software to aggregate multiple Rev. A hardware channels, CDMA2000 operators can roll-out additional bandwidth quickly throughout their entire network and still support Rev. A devices. From the subscriber's perspective, the performance of Rev. B will deliver a much better user experience, including quicker network connections and faster downlink and uplink data rates. Rev. A subscribers will also benefit since less network capacity will be consumed by the faster Rev. B devices, freeing up unused network resources for Rev. A devices.

For the operator that has deployed multiple Rev. A channels, these enhanced capabilities will only require a modest capital investment since a software upgrade to the Rev. A infrastructure is generally all that is required along with new communications modems in the handsets. The operator may also choose to add new Rev. B channel cards for higher performance improvements.

4. CONVERGENCE AND THE ROLE OF 3G AND OFDM SYSTEMS

Network convergence defines the seamless integration of multiple access technologies through a common core network. Device convergence, enabled by Moore's Law, defines the ability for one device to support multiple radio technologies. The combination of network and device convergence allows service providers to deliver a larger selection of revenue-generating services across different types of networks, including concurrent voice and data services, seamlessly and with greater flexibility.

Network and Service Convergence

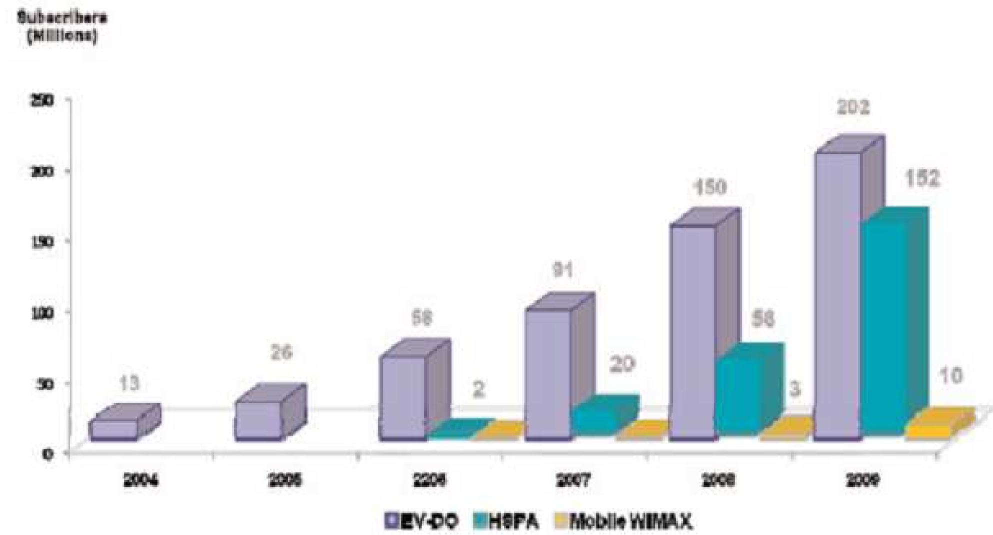
Network and service convergence is facilitated by IP Multimedia Subsystems (IMS), a set of standardized technologies which are being adopted by mobile operators and fixed wireline operators to enable IP-based core network solutions. IMS defines and separates an operator's network into access, control and application layers, thus allowing an operator to more quickly introduce applications and services, migrate from a circuit-switched network to an all-IP packet-switched data network, and provide a seamless user experience to its subscribers, regardless of the access network being used.

As there is no single network technology that is a perfect fit for all user situations, services and environments, IMS will enable operators to interconnect their various wireless and fixed network systems to improve the delivery and economics of convergent services. Here are a few examples to help illustrate the point:

- **The convergence of networks**: In addition to 3G networks, in most developed countries there is an abundance of Wi-Fi access points in residential homes, coffee shops, campuses and enterprises. In all instances, Wi-Fi is used to provide a short range wireless extension of a broadband wireline connection, such as xDSL, to a small group of people who are within range of the signal. There is also a growing availability of wide area broadcast networks dedicated to delivery of television, rich multimedia multicasting and data casting services to mobile devices. A large number of 3G CDMA operators are using OFDM-based Wi-Fi and forward link only broadcast networks such as DVB-H, FLO, T-DMB, and ISDB-T to complement their existing portfolio of services, provide extra broadband capacity and off load traffic from their wide area networks in home, campus and office environments. This allows 3G operators to leverage their existing mobile communications networks to become ubiquitous Internet Service Providers (ISPs) and broadcasters.
- **The extension of coverage**: To reach more subscribers and provide advanced services to where they work and live, pico and femtocell solutions are being deployed for seamless universal access to 3G voice and broadband services. Extending coverage serves two purposes: it expands access to services; and increases the service provider's network capacity by offloading user traffic from its wide area network (WAN) radio channel and using a separate backhaul.
- **The convergence of services**: The introduction of a wide selection of services defines the competitiveness of a service provider. A single operator's ability to deliver voice, video, broadband Internet access, position location and a plethora of mobile data services maximizes their revenue opportunity across a diverse subscriber base (where each user has unique needs) and leverages existing capital expenditures. These services are used to supplement and extend services across multiple industries including entertainment, education, transportation, banking, advertising, broadcasting, and information technology. To even the casual industry follower, it is evident that no single telecommunications delivery mechanism is currently capable of fulfilling all of these multi-varied requirements. Instead, operators typically use an IMS implementation to provide the subscribers with a seamless user experience by assigning the most appropriate access technology (3G CDMA, Bluetooth, 802.11, NFC, OFDM, etc.) to deliver the requested service.

OFDM-based Technologies Offer Operators an Opportunity to Complement 3G Solutions in Delivering Converged Services

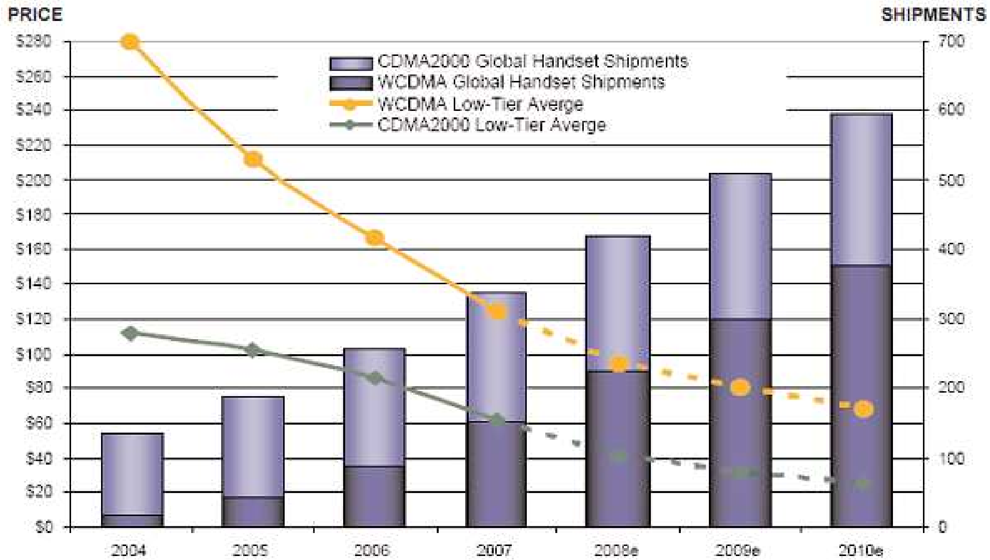
Due its huge economies of scale, 3G CDMA will retain a significant cost advantage over OFDM-based technologies when it comes to delivering mobile telephone and broadband services, a cost advantage exemplified by the availability of very affordable 3G CDMA2000 handsets. Almost 100 very low-end (less than $50 USD wholesale) CDMA2000 handsets from nineteen different suppliers are currently available in high-growth emerging markets around the world. In 2008, more than 50 million very-low-end (VLE) CDMA2000 handsets are expected to be shipped.



Sources: Strategy Analytics, Worldwide Cellular User Forecast, July 2007, and Mobile Broadband Subscriptions Forecast, November 2006, Wireless Intelligence World Cellular Subscriber Forecast, October 2007, Yankee Group, Global Mobile Forecast, October 2007, In-Stat/MDR, April 2007, Informa, Future Mobile Broadband: HSPA, EV-DO, WiMAX & LTE, 2007, Yankee Group, Modest WiMAX Grows Despite Uncertainty, January 2007

FIGURE 10
Cumulative Global Mobile Broadband Subscribers

Analysts forecast that by 2010, there will be 548 million mobile broadband users worldwide, and 94 percent of them will be using iterations of existing technologies, such as EV-DO and HSPA, which will eclipse all alternative broadband technologies. Economies of scale is the single biggest contributor toward achieving more attractive device prices, since it drives down manufacturing costs and distributes development costs across a large number of devices.



Sources
ABI (Q4 2007), IDC (July 2007), Strategy Analytics (July 2007) and Yankee Group (October 2007) handset shipment forecasts
Yankee Group, CDMA2000 and WCDMA ASP trends, January 2008

FIGURE 11
3G CDMALowest Handset Pricing and Global Handset Shipment Volume

The harmonization of the higher-bandwidth spectrum for OFDM-based solutions will be necessary to build economies of scale. Considering WCDMA as an example of how long it takes to roll-out a new technology, it will take OFDM-based solutions at least a decade to offer ubiquitous coverage, global roaming and competitively priced handsets.

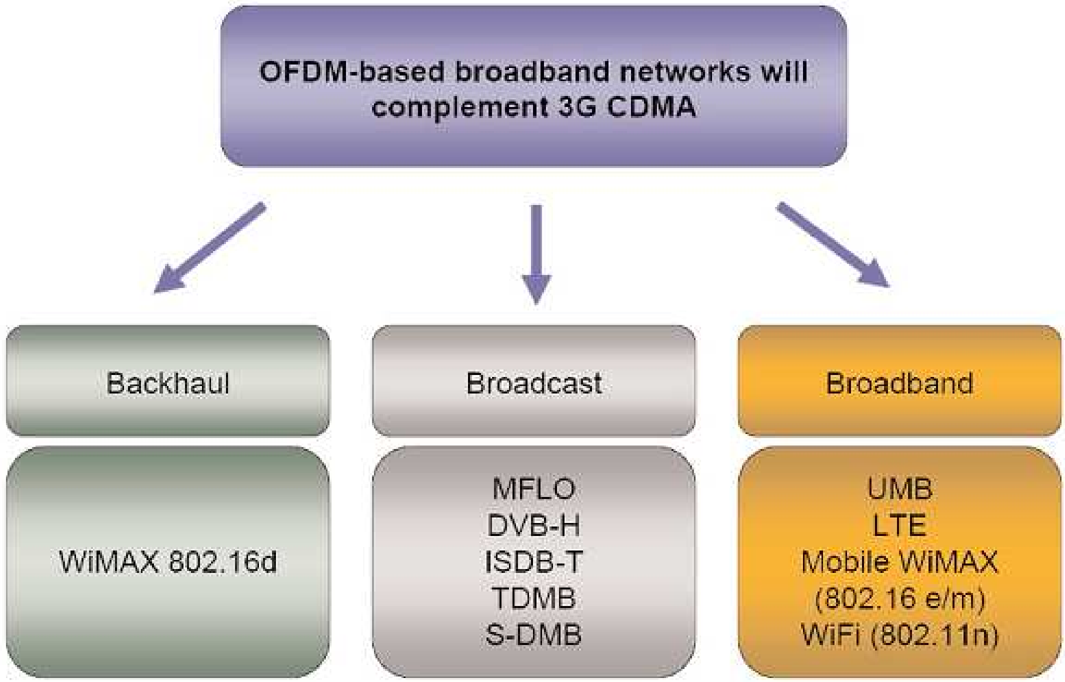


FIGURE 12
CDMA and OFDM Complementary Coexistence

While CDMA-based technologies offer compelling performance and economic advantages that will support service providers well into the next decade, there are situations and applications where OFDM-based technologies may be more attractive to operators.

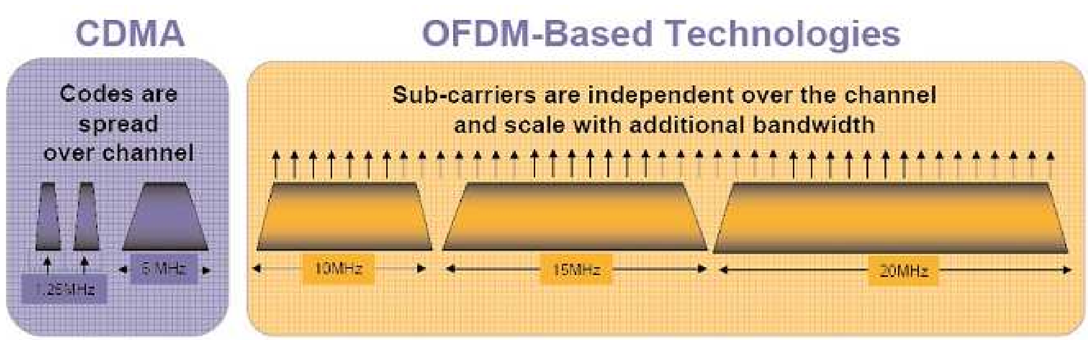


FIGURE 13
Optimal Bandwidth Assignments For CDMA and OFDM-based Technologies

For service providers who want to offer mobile broadcast or multicasting services, OFDM-based technologies such as DMB, DVB-H or Media FLO are better suited to simultaneously deliver rich multimedia content from one base station transceiver to many people in a single sector. In this case, the supplementary OFDM-based broadcast network will overlay the 2G/3G mobile network to deliver premium video content and television-like services. For service providers with existing or a limited amount of spectrum, CDMA-based technologies are the best option since they are more spectrally efficient in bandwidths up to 5 MHz. For a service provider that has access to a large amount of bandwidth (e.g., more than 10 MHz of spectrum), OFDM-based technologies may be a suitable option to introduce new bandwidth-intensive broadband services or complement existing 2G or 3G solutions with additional broadband capacity in densely-populated metro-zones, also referred to as "hot-zones." This is because wider radio channels support higher data throughputs in capacity constrained areas such as busy or dense data traffic areas. As bandwidth scales (increases) beyond 2x5 MHz FDD or 10 MHz TDD, OFDM-based technologies offer a simpler implementation than CDMA technologies. Outside of high traffic metro areas, OFDM-based systems are not economical since the spectrum and network will most likely remain under utilized.

IMS can be used to combine the economic advantages of the ubiquitous 3G network with a complementary wider-bandwidth OFDM broadband network in high-traffic areas or "hot-zones" within the network. In this overlay scenario, an operator would retain the 3G network for wide area broadband coverage while the consumer will need to own a dual-mode (CDMA + OFDM) handheld device to access the higher bandwidth broadband services inside and outside of the OFDM coverage zones.

Fixed, line-of-sight, OFDM-based technologies such as WiMAX are also well suited to provide backhaul connectivity to 2G/3G mobile broadband networks. Several CDMA2000 networks use WiMAX (IEEE 802.16d) for their backhaul.

To some extent, the relationship between 2G/3G and mobile OFDM networks is very similar to the relationship between 2G/3G and Wi-Fi. Just as Wi-Fi complements 3G, mobile OFDM technologies will complement the services, features and network capacity provided by 3G.

The role and deployment of OFDM systems will be ultimately determined by a business case, which in turn will depend on the availability of revenue-generating applications and affordable devices, the market demand for bandwidth-intensive applications and the economic benefits they offer to the operator. The industry is yet to develop a clear business model for these services, and as the experience with 3G demonstrates, it will take time for a sustainable business model to evolve. Thus, the mass market adoption timing of wider-bandwidth OFDM-based solutions is uncertain.

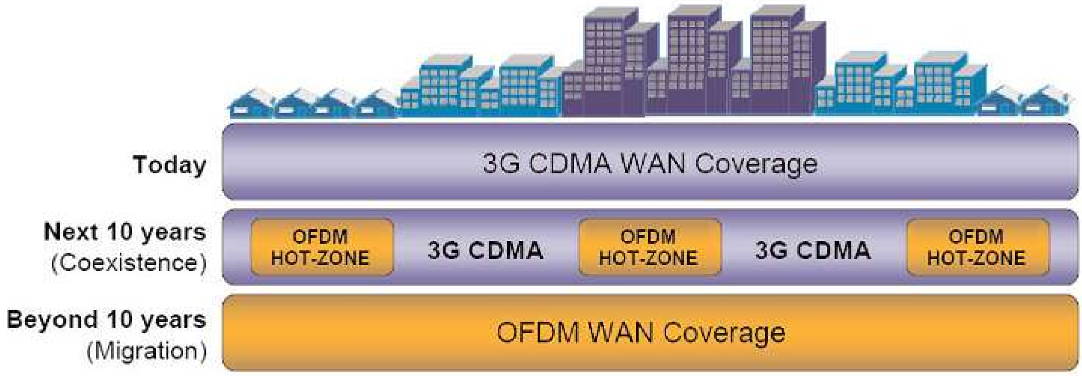


FIGURE 14
OFDM Broadband Overlay Timeline

OFDM-based solutions will be built-out over time as the demand for high-capacity broadband services grows and wider bandwidth spectrum becomes available. Meanwhile, 3G CDMA solutions will coexist with these higher-bandwidth OFDM-based solutions until OFDM-based technologies are fully capable of delivering an equivalent or better value proposition to the end user, including ubiquitous coverage, compelling broadband services, carrier-grade VoIP replacing circuit-switched voice services, affordable devices, global roaming and an improved profitability for operators.

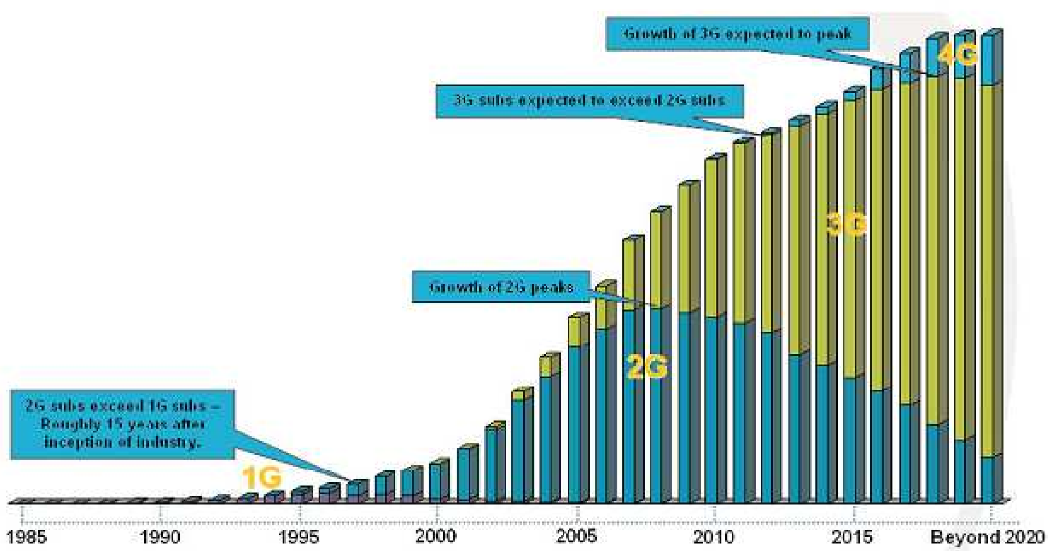


FIGURE 15
Migration Timeline

It is expected that the coexistence of CDMA and OFDM-based solutions will persist well beyond 2020. Until then, 3G CDMA-based solutions will remain the core business for hundreds of operators. Once the adoption criteria are met, the more than 3-4 billion wireless subscribers in the world will begin migrating to the newer generation of wireless technologies. With an ever increasing subscriber base, the migration process is lengthening.

FIGURE 16
Multimode Multiband WorldMode Configurations

Device Convergence Integrates Multiple Access Technologies Onto One Platform for a Seamless User Experience

As more capabilities and features are introduced into handheld devices, Moore's Law is enabling more wireless technologies to be incorporated within them. Presently, these wireless technologies include analog, IS-95, GSM, GPRS, EDGE, CDMA2000 1X, WCDMA, CDMA2000 1xEV-DO and HSPA for wide area network access, Wi-Fi for the local area network, GPS for location-based services, near field communications (NFC) for mobile commerce, and Bluetooth for personal area network connectivity. By the end of 2009, some multimode WorldMode devices will include UMB, LTE and Mobile WiMAX.

As consumers become accustomed to the presence of multiple access technologies, they will expect their handheld device to support the technologies that they use the most wherever they go. Carrying a separate device for each access technology isn't considered practical. 3G CDMA handsets that support multiple radio technologies already exist (there are 48 WorldMode devices that support both CDMA2000 and GSM technologies). In the coming years, CDMA2000 devices will include support for WCDMA/HSPA, WiMAX, UMB and LTE. Bluetooth is becoming very common due to consumer interest in wireless headsets and various government regulations which strictly limit holding a cell phone while driving. NFC-enabled handsets are being used for transportation and mobile commerce solutions. Likewise, Wi-Fi is integrated into a number of CDMA handsets to provide high-speed access to the Internet/VPN in the home, campus or office.

Most consumers will not purchase a single-mode OFDM-based device that only works within limited areas. OFDM-based devices, therefore, will have to support multiple technologies and a range of bands to retain the existing wide and local area connectivity provided by 3G and other widely used technologies, not to mention the valuable revenue produced by their voice and broadband data services.

5. CONCLUSIONS

The "one technology fits all" approach will not suffice in the future competitive telecommunications market. Instead, operators will leverage the most appropriate technology for a particular application or service. Bluetooth will support the personal area network, NFC will enable mobile commerce, Wi-Fi will satisfy local area network connectivity, GPS will enable presence and location-based services, 2G and 3G cellular technologies will provide ubiquitous voice and broadband data services, and OFDM-based technologies will provide large amounts of bandwidth for backhaul, broadcast and broadband applications in "hot-zones."

For most operators, 3G CDMA-based technologies will be more than sufficient for their voice and broadband data requirements for the at least a decade. For those operators that require higher amounts of bandwidth especially in high-traffic areas, OFDM-based technologies offer certain economic benefits and will enable them to complement their services, features and coverage. In most instances, however, 3G CDMA will remain the leading and most economical platform for the delivery of mobile broadband services.

OFDM-based solutions will be built-out over time as the demand for broadband services grows and spectrum becomes available. Mass adoption of these wide-bandwidth OFDM-based solutions will take years, as coverage is expanded and economies of scale are built. Meanwhile, CDMA2000 will continue to be the core business for hundreds of operators for well over a decade and play a key role in the future of the wireless industry.

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