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Evolution of CDMA one and Development of CDMA 2000 Convergence and Harmonization

Rezaul Hoque Khan [1]A.H.M. Razibul Islam Md. Rakibuddin
Department of Electrical and Electronics Engineering Chittagong
University of Engineering and technology, Chittagong-4349, Bangladesh.
[1]Department of Electrical and Electronics Engineering
Islamic University of Technology, Gazipur-1704, Bangladesh

Abstract: The objective of this study is to present our views on key topics with respect to third generation (3G) and address some of the more technical aspects of the CDMA 2000 3G proposal. This study also documents the ongoing activities through out the world that are taking place toward CDMA One ™ evolution and 3G standards.

Key words: CDMA 2000, CDMA One, WCDMA, UMTS, 3G, Chip rate.

INTRODUCTION

Code Division Multiple Access, a cellular technology originally known as IS-95[1] competes with GSM technology for dominance in the cellular world. There are now different variations, but the original CDMA is now known as CDMA One. CDMA One has clearly demonstrated its superiority in the second-generation wireless marketplace. In September 1998, only three years after the first commercial deployment, there were 16 million subscribers on CDMA One systems worldwide. Over 35 countries have either commercial or trial activity ongoing. The CDG(CDMA Development group's) has over 100 members of whom 40% are companies based outside of North America, testimony to the truly international reach of CDMA. The CDG established the Advanced Systems Initiative to provide a growth path for CDMA One to next generation systems. Primary goals of the initiative include development of a worldwide standard that meets IMT-2000 requirements and other services identified as critical to operator members, and graceful evolution to next generation CDMA One systems[2].

The Advanced Systems Initiative is a means for CDG members to define the requirements and priorities for CDMA One and to collaborate with regional and international standards organizations to meet industry objectives. CDG members have been involved with IMT-2000 since its inception.

In addition to the work of the Advanced Systems Initiative, the CDG leadership is actively engaged in industry-wide efforts on 3G. The CDG is ensuring the rapid evolution of CDMA One and the development of CDMA 2000 to meet the needs of operators worldwide, enabling the availability of 3G products and services beginning in 1999.

We now have CDMA 2000 and its variants like 1X EV, 1XEV-DO and MC 3X. The refer to variants of usage of a 1.25Mhz channel. 3X uses a 5 Mhz channel. Wideband CDMA that forms the basis of UMTS(Universal Mobile Telephony System) 3G networks, developed originally by Qualcomm, CDMA is characterized by high capacity and small cell radius, employing spread-spectrum technology and a special coding scheme. CDMA was adopted by the Telecommunications Industry Association (TIA) in 1993. May 2001 there were 35 million subscribers on CDMA One systems worldwide[3]. Over 35 countries have either commercial or trial activity ongoing. There are already 43 Wireless Local Loop (WLL) systems in 22 countries using CDMA One technology. Enhancing today's data capabilities is the 1XRTT CDMA standard - this next evolutionary step for CDMA One operators will provide data rates up to 300 kbps, significant capacity increases as well as extended battery life for handsets. Worldwide resources are being devoted to roll out third-generation CDMA technology, including Multi-Carrier (CDMA 2000 1xMC and HDR in 1.25 MHz bandwidth), and 3xMC in 5 MHz bandwidth) and Direct Spread (WCDMA in 5 MHz bandwidth)[4].

This first phase of CDMA 2000- variously called 1XRTT, 3G1X, or just plain 1X - is designed to double current voice capacity and support always-on data transmission speeds 10 times faster than typically available today, some 153.6 kbps on both the forward and reverse links[5].

Corresponding Author: Rezaul Hoque Khan,Department of Electrical & Electronics Engineering Chittagong University of Engineering & technology, Chittagong-4349, Bangladesh.

CDMA aficionados are rigorously promoting a technically benign upgrade of existing CDMA One (IS-95) CDMA networks to faster CDMA 2000 technology, a CDMA 3G standards that they say can provide the same level of 3G service claimed by W-CDMA/UMTS promoters [4]. There are various types of CDMA 2000 types, explained below.

CDMA20001X: The 1xEV specification was developed by the Third Generation Partnership Project 2 (3GPP2), a partnership consisting of five telecommunications standards bodies: CWTS in China, ARIB and TTC in Japan, TTA in Korea and TIA in North America. It is also known as High Rate Packet Data Air Interface Specification. It delivers 3G-like services up to 140 kbps peak rate while occupying a very small amount of spectrum (1.25 MHz per carrier), protecting this precious resource for operators.

CDMA2000-1X-EV-DO: 1X EV-DO, also called 1X-EV Phase One, is an enhancement that puts voice and data on separate channels in order to provide data delivery at 2.4Mbit/s. It was developed by the Third Generation Partnership Project 2 (3GPP2), a partnership consisting of five telecommunications standards bodies, also known as High Rate Packet Data Air Interface.

CDMA2000-1X-EV-DV: EV-DV, or 1X-EV Phase Two with promises of data speeds ranging from 3Mbps to 5Mbps. As many as eight proposals have been submitted to standards committee 3GPP2 for the design of EV-DV.

CDMA200-3X: CDMA 2000 3x is an ITU(International Telecommunication Union)-approved, IMT-2000 (3G) standard. It is part of what the ITU has termed IMT-2000 CDMA MC. It uses 5 Mhz spectrum (3x 1.25 MHz channels) to give speeds of around 2-4 Mbps[6].

Handset standby times also increase by up to 50%. Users will also be able to benefit from enterprise and consumer applications requiring more bandwidth, including personal information management, telemetry, corporate intranet access, video conferencing, gaming and music on demand. The increase in voice and data capacity stems inter alia from advances in modulation algorithms, new IP backbones, and new chipsets that support up to 32 simultaneous users on a single chip, a four-fold increase over the previous generation.While the CDMA 2000 specification allows for an evolutionary migration to later advances in CDMA 2000 that use core IP networks and voice-over-IP, the current 1X migration requires relatively modest hardware and software upgrades to existing CDMA one infrastructure. Even then, operators can upgrade to 1X without having to implement it throughout their entire CDMA one network, which means they can upgrade certain hotspots that require voice capacity enhancements or higher data speeds[7]. The strategy also aims to reduce technological risks by phased enhancements of networks with medium rate data services, and then later evolve to higher rate data services so as to avoid uncertainties of ROI that currently cloud the UMTS 3G vision.CDMA 2000 can be deployed in existing spectrums such as 1900MHz along with an existing CDMA one system, overlaying its new feature set and increased capacity on the existing CDMA one networks. Most importantly, it uses existing (and paid for) 1.25 MHz spectrum. Handsets using CDMA 2000 technology will also be backward compatible to the existing CDMA one networks, so current handsets and features will operate over next generation networks providing continued access both at home and while roaming. Operators who deploy 3G with 1X will still have roaming with worldwide CDMA operators on their CDMA one networks. Dual mode handsets that allow TDMA (Time Division Multiple Access)/CDMA 2000 interoperability may also augment the business case for a move by TDMA operators to CDMA 2000[8]. The flexible migration from CDMA one provides a series of upgrades leading to CDMA2000's increased voice capacity and Megabit 3G data rates, allowing each operator to upgrade when its individual market requirements dictate without significantly upgrading infrastructure or purchasing new spectrum. QUALCOMM owns a substantial portfolio of CDMA patents, including many essential patents that are necessary for the deployment of any proposed 3G CDMA system, such as Multi-Carrier, Direct Spread, and another system referred to as TD-SCDMA. QUALCOMM has now granted royalty-bearing licenses to more than 75 manufacturers for CDMA and, as part of these licenses, has transferred technology and know-how in assisting these companies to develop and deploy CDMA products.

A significant number of these companies' licenses cover third-generation applications, including WCDMA, 1x and High Data Rate (HDR). Under terms of QUALCOMM's existing 3G licensing agreements, a licensee will pay the same royalty to QUALCOMM for 3G systems, including WCDMA, TD-SCDMA and 1x, as that licensee pays QUALCOMM for today's CDMA infrastructure, phones and test equipment.

TECHNICAL INFORMATION

CDMA is characterized by high capacity and small cell radius, employing spread-spectrum technology and a special coding scheme. Capabilities of CDMA one

evolution have already been defined in standards. IS-95B provides ISDN rates up to 64 kbps.

The next phase of CDMA one is a standard knows as 1XRTT and enables 144 kbps packet data in a mobile environment.

Other features available are a two-fold increase in both standby time and voice capacity. All of these capabilities will be available in an existing CDMA one 1.25 MHz channel.

The next phase of CDMA one evolution will incorporate the capabilities of 1XRTT, support all channel sizes (5 MHz, 10 MHz, etc.), provide circuit and packet data rates up to 2 Mbps, incorporate advanced multimedia capabilities, and include a framework for advanced 3G voice services and vocoders, including voice over packet and circuit data. This phase of the standard will be complete by 4Q99.

Table 1:Current flavors of CDMA:

Composite CDMA/TDMA	Wireless technology that uses both CDMA and TDMA. For large-cell licensed band and small-cell unlicensed band applications. Uses CDMA between cells and TDMA within cells. Based on Omni point technology.
CDMA	In addition to the original Qualcomm-invented N-CDMA (originally just ' CDMA', also known in the US as IS-95. See N-CDMA below). Latest variations are B-CDMA, W-CDMA and composite CDMA/TDMA. Developed originallyby Qualcomm, CDMA is characterized by high capacity and small cell radius, employing spread- spectrum technology and a special coding scheme. It was adopted by the Telecommunications Industry Association (TIA) in 1993. The first CDMA-based networks are now operational. B-CDMA is the basis for 3G UMTS (see below)
CDMA one	First Generation Narrowband CDMA (IS-95). See above.
CDMA2000	The new second-generation CDMA MoU spec for inclusion in UMTS.

EVOLUTION OF CDMA ONE AND DEVELOPMENT OF CDMA 2000

The path to 3G: A great deal of attention has been focused on 3G harmonization and convergence. While the CDG believes in the ITU's vision of a global standard, they are quickly building on the technical foundation of CDMA one to deliver many advanced services in the near future in a way that allows operators the flexibility to offer these services as the market demands. The CDG efforts are focused around an evolution strategy so that capabilities can be introduced in phases during the next few years, based on and leading to the complete capabilities of CDMA2000. The bottom line: The CDG is working aggressively to enable fast-track development of the CDMA 2000 standard. CDMA one is the only technology with a clear evolution to 3G because it builds on the design and framework of today's CDMA one system. Looking at 3G from an operator's perspective, preservation of investments made in infrastructure and spectrum are significant issues in defining requirements for technology migration. Services designated as "3G"will be available with CDMA one in existing as well as new spectrum bands. This point is important in considering the position of established operators who may not choose, or be able, to get new spectrum. This point is also vitally important in developing regions considering the allocation of PCS spectrum for 2G [1]. With CDMAOne, operators and subscribers in these regions can reap the benefits of today's advanced digital technology while assured their investments are protected. Evolution from technologies such as GSM to WCDMA, however, will require significant change out of equipment and costly upgrades.

Capabilities of CDMA one evolution have already been defined in standards. IS-95B provides ISDN rates up to 64 kbps. The next phase of CDMA one is a standard knows as 1XRTT and enables 144 kbps packet data in a mobile environment. Other features available when the standard is published in 1Q99 are a two-fold increase in both standby time and voice capacity. All of these capabilities will be available in an existing CDMA one 1.25 MHz channel.

The next phase of CDMA one evolution will incorporate the capabilities of 1XRTT, support all channel sizes (5 MHz, 10 MHz, etc.), provide circuit and packet data rates up to 2 Mbps, incorporate advanced multimedia capabilities, and include a framework for advanced 3G voice services and vocoders, including voice over packet and circuit data. This phase of the standard will be complete by 4Q99.

In addition to the capabilities of the CDMA one air interface, evolution of the ANSI-41 core network will enable subscribers to continue to benefit from advanced services offered by the CDMA one platform [15]. Investment in costly infrastructure and network upgrades are not necessary.

The myths and the facts about chip rate: The debate about CDMA 2000 and WCDMA convergence has been based on the fact that these CDMA-based proposals have certain parameter definitions that present an opportunity for compromise. The most discussed and

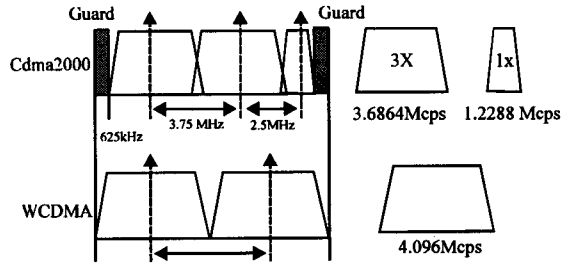

Fig. 1: Deployment scenario for CDMA 2000 and WCDMA in a 2x 10 MHz operation

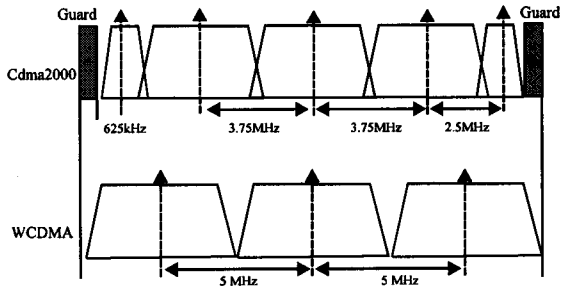

Fig. 2: Deployment scenario for CDMA 2000 and WCDMA in a 2x 15 MHz operation

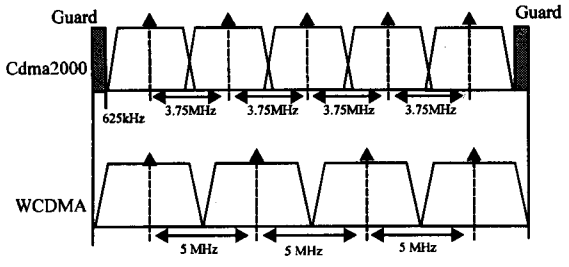

Fig. 3: Deployment scenario for CDMA 2000 and WCDMA in a 2x 20 MHz operation

debated parameter is the system chip rate. WCDMA uses a chip rate value of 4.096 Mbps. CDMA200 uses 3.6864 Mbps. WCDMA proponents liken the higher rate to more horse and claim the lower CDMA 2000 rate degrades performance. This falsity requires clarification.

Deployment scenarios in various bands: First, WCDMA proponents claim that the WCDMA chip rate provides as much as a 10% capacity improvement over that of CDMA2000. This should be examined under a realistic scenario of how the technology will be deployed, and must include all factors affecting system performance. While some operators will deploy 3G in as little as 5 MHz of spectrum many will use allocations of 10, 15, or 20 MHz. This is important since it is the usable spectrum, in conjunction with chip rate, which affects capacity. Figures 1-3 illustrate the deployment scenarios for CDMA 2000 and WCDMA in 10, 15, and 20 MHz bands respectively. Even with the required guard bands as verified in today's operational CDMA one systems, greater overall capacity is achieved with a mixture of CDMA 2000 1X and 3X channels as compared with using WCDMA channels. With that configuration it can be shown that up to 13% capacity improvement is achievable in a 20 MHz deployment.

Examining chip rate in context with other characteristics: Second, chip rate alone does not determine overall system capacity. To build on the automobile analogy referenced earlier, assuming chip rate is the only factor affecting capacity is like assuming tire pressure is the only thing affecting gas mileage. One of the main parameters in determining the capacity of a CDMA system is the ratio of energy per information bit to noise power spectrum density (Eb/No) required to achieve certain QoS (Quality of Service) requirements such as frame or bit error rate. The required Eb/No value depends on frame structure, coding and modulation characteristics, diversity techniques and channel model. The small difference in chip rate between 3.6864 Mcps and 4.096 Mcps has negligible impact on the Eb/No requirement. Instead, other system designs such as channel structure (including pilot structure), power control mechanisms, diversity techniques, handoff efficiency, and base station synchronization have a much greater impact on system capacity [9]. The impact of system design on capacity is illustrated in Table I, where the normalized spectrum efficiency in Erlangs/MHz/cell for voice services in a vehicular environment is shown, taken from the CDMA 2000 and the UTRA (WCDMA) RTT. Table I also contains the simulation results from the RTT evaluation report submitted by the Chinese evaluation group. We can see that a larger chip rate does NOT translate into higher spectrum efficiency.

Consideration of power emissions: Finally, what proponents of the WCDMA chip rate often overlook are the negative effects on spectrum use and power emissions by using the higher value chip rate. The CDMA air interface signal of IMT-2000 needs to fit into a 5 MHz spectrum to comply with different frequency plans around the world. For example, if deployed in a 5 MHz spectrum such as in the D, E, F North American PCS blocks, the WCDMA system as specified currently cannot meet the FCC out-of-band emission requirements[4]. All major wireless technologies use guard bands to separate their signal spectra from those of services in adjacent bands.

It is unreasonable to assume that WCDMA can operate without such guard band protection. For instance, the guard band used to separate IS-95 CDMA from TDMA/AMPS is 270 KHz on each side; the guard band used to separate DECT from adjacent service bands is 2.396 MHz to the lower band, and 1.052 MHz to the upper band. This issue is particularly significant for the PDC systems in Japan, as well as anywhere there is another service operating in the band adjacent to the IMT-2000 band.

Advocates propose using more complex filters to address this. While in theory such an approach can be conceived, the required filter is hard to realize within a 5 MHz bandwidth. Essentially, the purported 10% capacity gain is not realizable in practical deployments that in many markets need to consider adjacent channel interference or FCC power emission requirements – not a realistic solution for operators.

In summary, chip rate is not a simple issue with a direct cause and effect relationship. More is not necessarily better. CDMA 2000 enables 3G services without the deployment risks and cost of WCDMA.

CONVERGENCES AND HARMONIZATION

The CDG has been actively trying to achieve the ITU's goal of a global standard for IMT-2000. To that extent, the CDG and its members have been active on CDMA2000/WCDMA harmonization in regional standards bodies (ARIB, ETSI, TIA, TTA, T1P1), discussions with worldwide operators, and meetings with government entities. Convergence can enable a number of benefits for consumers, operators, and manufacturers. ARIB (Japan) recognized this early on and has been instrumental in reducing the number of differences between CDMA 2000 and WCDMA to a handful. However, some WCDMA proponents have not been receptive to these efforts. The CDG believes in the benefits of convergence, but will not be able to achieve it alone. In any case, CDMA one evolution proceeds on a fast track, ensuring that operators can deliver 3G services as the market demands

CONCLUSIONS

The growth of CDMA one technology is certain. Whether new capabilities are labeled 3G or not is not of material importance since the real challenge is having advanced services ready for market when customers demand them, and delivering these services cost effectively. Whatever results from the 3G standards process, CDMA one operators will have standard solutions that enable 3G services with a clear growth path from today's systems.

Table 1: Spectrum efficiency for voice in a vehicular environment: CDMA 2000 & WCDMA

		Spectrum Efficiency for forward link/reverse link (erlangs /MHz / omni cell)	
System	Chip rate (Meps)	Self evaluation	Chinese evaluatuion
CDMA 2000 ULTRA	3.6864	36.7/29	26.4/27.2
WCDMA	4.096	17.8/22.4	18.4/22

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