

# A COMPARATIVE STUDY OF CDMA2000 AND W-CDMA

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**Abstract** – Third generation wireless systems promise to provide advanced and enhanced services requiring very high data rates compared to 2<sup>nd</sup> generation wireless systems. Two key Radio Transmission Technology (RTT) proposals to meet the desired data rates and other requirements are cdma2000 by Telecommunications Industry Association (TIA) of USA and W-CDMA by European Telecommunication Standards Institute (ETSI) of Europe. In this paper, a functional level comparison is carried out between these two technologies. These two technologies are compared and analyzed based on a number of factors. Some of these factors are chip rate, modulation and encoding techniques, power control, handoffs, spreading and channelisation codes and others. We present as part of our analysis, the impact of chosen options on system design, deployment, backward compatibility and future network evolution. We discuss harmonization of these two proposals and factors influencing that effort.

## I. INTRODUCTION

Second generation mobile systems have been widely deployed around the world since the beginning of 90s. Significant improvements have been made in 2<sup>nd</sup> generation (2G) mobile systems compared to first generation mobile systems. In 2G systems, analog radio interfaces have been converted to digital air interfaces. Network interfaces (IS-41 and GSM-MAP) have been standardized to provide roaming capabilities. Enhanced services are provided in addition to improved voice service. However, 2G systems still suffer from some drawbacks. The data rates are limited to less than 64kbps due to limitations of the defined air interface radio technologies. Therefore, services requiring high data rates such as Internet access and multimedia services cannot be provided. Global roaming cannot be achieved due to the multitude of radio interfaces (IS-136, IS-95, GSM) and network standards (IS-41 and GSM-MAP). The cost of wireless service –although decreasing every year – is still not affordable for most of the people in the world. These issues have become key driving forces for 3<sup>rd</sup> generation (3G) systems.

International Telecommunication Union (ITU) is a global telecom body responsible for requirements and standards development. ITU formed International Mobile Telecommunication —2000 (IMT-2000) forum for development of requirements and specifications for 3G systems. Under this forum, regional standards bodies, service providers, equipment manufacturers, regulators and administrators collaborate to develop standards for 3G systems. IMT-2000 has published a set of requirements for 3G radio interfaces and criteria for evaluating candidate radio interfaces against these requirements. Standard bodies from different countries and regions have submitted sixteen proposals to IMT-2000 forum as of June 30, 1998 for consideration[6]. These proposals cover both terrestrial and satellite networks. TIA's cdma2000 and ETSI's W-CDMA are two Code Division Multiple Access (CDMA) based terrestrial radio proposals that have widespread support. These two proposals may become the dominant 3G standards.

One of the goals of IMT-2000 effort is to develop a single radio interface standard for the 3G wireless system. A single standard is desirable to achieve goals of global roaming, service portability, seamless roaming and enhanced services. As a result, there is an effort within IMT-2000 and in various regional standard bodies to harmonize these two proposals. In this paper, we will analyze the key similarities and differences between these two proposals. This will provide an understanding of the issues related to harmonization of these proposals and achieve a unified standard for 3G systems.

The rest of the paper is organized as follows: First, cdma2000 is introduced and its major features are presented. Following this, W-CDMA and its major features are presented. Next, we analyze the similarities and differences between cdma2000 and W-CDMA radio technologies. Finally, our conclusions are presented where we discuss the road to harmonization and the factors influencing that decision.

## II. CDMA2000

cdma2000 is a 3G Radio Transmission Technology (RTT) proposal submitted by TIA[1]. TR45.5 subcommittee of TIA developed the cdma2000 proposal. 2G CDMA standards i.e. IS-95 family of standards is also developed and maintained by the same group. The latest version of IS-95 is IS-95B. IS-95 based systems have been developed and deployed in the USA and around the world except for the European countries.

cdma2000 is designed to be backward compatible with IS-95B. This ensures reuse of most of IS-95 and related standards, graceful evolution to third generation systems from 2G systems and protection of investments of 2G systems operators. cdma2000 builds on top of the IS-95 channel structure. cdma2000 provides two deployment options. One of them is Multi-Carrier configuration where available bandwidth is divided into  $N$  1.2288 MHz carriers. The user data is demultiplexed and spread on to  $N$  separate channels. This allows IS-95 and cdma2000 systems to co-exist in overlay/underlay configuration. Multi-Carrier option is supported only in the forward direction. The other deployment configuration is Direct Spreading (DS) option where the user data is spread over the entire bandwidth.

There are several new features in cdma2000 compared to IS-95B. cdma2000 enhances supplemental channel to support high data rate requirements (up to 2 Mbps) of IMT-2000. It introduces dedicated and common control channels to provide efficient packet data service. Variable length walsh codes (from 4 bits to 1024 bits in length) are used for spreading on supplemental channel to support various information rates. In addition to fast reverse link closed loop power control, cdma2000 provides fast forward link closed loop power control. Dedicated and common auxiliary pilot channels are introduced to take advantage of smart antennas. Smart antennas have the ability to provide coverage directed at specific geographical areas or mobile stations.

## III. W-CDMA

W-CDMA is an RTT proposal submitted by ETSI[2]. It is developed by SMG2 working group of ETSI. It is a radio interface of choice for Universal Mobile Telecommunication System (UMTS). UMTS is a forum under which ETSI, and European companies are developing specifications for 3G systems. UMTS is the successor to the 2G GSM systems. SMG2 is also responsible for development of Global System for Mobile communication (GSM) radio interface for 2G systems. GSM systems are deployed in Europe and around the world with a small presence in the USA.

The 2G GSM radio interface is based on TDMA technology. W-CDMA represents a significant change in 3G systems. W-CDMA is not designed to be backward compatible with GSM air interface. However, handoffs between UMTS and GSM systems are supported.

There are several new features in W-CDMA. W-CDMA supports high data rate requirements of IMT-2000. Orthogonal Variable Spreading Factor (OVSF) codes are supported to provide variable data rates. W-CDMA supports asynchronous mode of operation where reception and transmission timings of different cell sites are not synchronized. It supports fast cell acquisition when a mobile initially powers up. It also supports forward and reverse fast closed loop power control operation.

## IV. COMPARISON BETWEEN CDMA2000 AND W-CDMA

In this section, we will analyze the similarities and differences between the two RTT proposals. Our analysis is presented based on the following categories:

**Table –1 Categories for analysis**

| <i>Category</i>                             | <i>Details</i>                                                                                                                                              |
|---------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Bandwidth and data rates                    | Channel bandwidths, data rates, spreading rates,                                                                                                            |
| Deployment configurations                   | Deployment configurations in forward and reverse direction                                                                                                  |
| Pilot channel and system acquisition        | Code-based and Time multiplexed pilot channels, continuous vs. discontinuous pilots, common, dedicated and auxiliary pilots, system acquisition differences |
| Synchronous/Asynchronous mode of operations | Inter-cell synchronization requirements, impact on handoffs, timing issues                                                                                  |
| Channel and frame structures                | Logical and physical channels, frame sizes and content structures                                                                                           |
| Cell and user identification codes          | PN, walsh, OVFSF, cell-specific scrambling, preamble and gold codes                                                                                         |
| Power control and handoffs                  | Open loop, closed loop power control schemes, hard, soft and softer handoff comparison, inter-technology and inter-generation (2G and 3G) handoffs          |
| Data services support                       | Packet and circuit data, multimedia support, MAC                                                                                                            |

| <i>Category</i>            | <i>Details</i>                                                                    |
|----------------------------|-----------------------------------------------------------------------------------|
|                            | control states, LAC layer support, QoS mechanisms                                 |
| Smart antenna applications | Beam forming, adaptive steering applications, dedicated and auxiliary pilots      |
| Other areas                | Diversity mechanisms – Orthogonal Transmit and Multi-carrier transmit diversity . |

In the following sections, these categories will be analyzed in detail..

### Bandwidth and Data rates

The bandwidths and spreading rates for cdma2000 are given in table 2. The supported bandwidths are 1.25 MHz, 3.75 MHz, 7.5 MHz, 11.25 MHz and 15 MHz. cdma2000 uses a base spreading rate of 1.2288 MHz. The spreading rates are  $1.2288 * N$  Mcps. The value on N can be 1, 3, 7, 9 and 11. The spreading rates

| <i>Bandwidth<br/>(MHz)</i> | <i>Spreading Rates<br/>(Mcps)</i> |
|----------------------------|-----------------------------------|
| <b>1.25</b>                | <b>1.2288</b>                     |
| <b>3.75</b>                | <b>3.6864</b>                     |
| <b>7.5</b>                 | <b>7.3278</b>                     |
| <b>11.5</b>                | <b>11.0952</b>                    |
| <b>15</b>                  | <b>14.7456</b>                    |

**Table –2 cdma2000 spreading rates**

are defined as multiple of 1.2288 Mcps to ensure backward compatibility with IS-95B.

The bandwidths and spreading rates for W-CDMA are given in table 3. The supported bandwidths are 5, 10 and 20 MHz. W-CDMA uses a base spreading rate of 4.096 MHz. The spreading rates are in multiples of

| <i>Bandwidth</i> | <i>Spreading Rates</i> |
|------------------|------------------------|
| <b>5</b>         | <b>4.096</b>           |
| <b>10</b>        | <b>8.192</b>           |
| <b>20</b>        | <b>16.384</b>          |

**Table – 3 W-CDMA spreading rates**

4.096 Mcps. Unlike cdma2000, W-CDMA is not burdened by requirements of backward compatibility with a 2G CDMA technology

### Deployment Configurations

Cdma2000 RTT supports two different deployment configurations; one configuration is a Multi-Carrier (MC) based approach and the other one is the Direct Spread (DS) approach. In the forward link, i.e. in the direction of transmission from the base station to mobile stations, both the MC and DS configurations are defined and supported by cdma2000. However, in the reverse direction i.e. transmission from the mobile stations to the base station only DS is defined and supported

In Multi-Carrier (MC) configurations, the available bandwidth is divided into multiple carriers of 1.25 MHz each to carry data over the air. Each carrier supports a chip rate of 1.2288 Mcps to transport data over the air. MC configuration has been designed in the cdma2000 to provide a graceful evolution from IS-95B 2G systems to cdma2000 3G systems. In that case, backward compatibility with IS-95B systems is required. For example, Multi-carrier systems may be used to deploy as an overlay configuration. In this configuration, we can set up systems to provide IS-95B and cdma2000 services simultaneously to mobile stations. This means that we can deploy cdma2000 services without needing a clear spectrum for deployment. Both IS-95B and cdma2000 subscribers are supported over the same frequency channel. Moreover, an overlay configuration allows IS-95B system may share its pilot channel with a cdma2000 system. It is also possible to share paging channels and provide service in a cooperative manner between the IS-95B and cdma2000 systems.

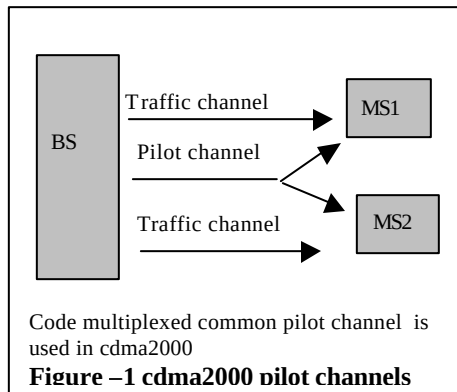
cdma2000 supports Direct Spread (DS) configuration in both the forward and reverse links. The chip rates supported are at  $1.2288N$  where  $N = 1, 3, 6, 9, 12$ . In DS configuration, transmission is done using a single carrier with appropriate bandwidth to carry the spread signal at the rate of  $1.2288N$  Mcps. Note that for both the MC and DS configurations, a guard band of 1.25/2MHz (0.625MHz) is provided on both sides. In the forward link, cdma2000 DS configuration may be used in environments where there are no constraints of backward compatibility and clear spectrum for the bandwidth desired is available.

W-CDMA supports only Direct Spread (DS) configuration in both the forward and reverse links. Again, this is because W-CDMA does not have any backward compatibility constraints

## Pilot channels

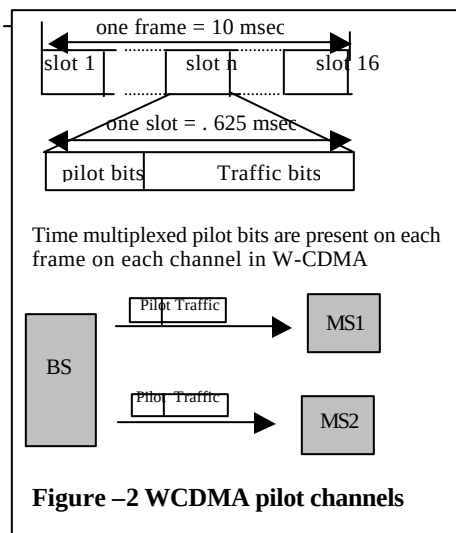
Pilot channels, in general, are used to provide a reference signal to receivers. Receivers derive timing and phase information from pilot signal, which helps in coherent demodulation of user signals.

cdma2000 employs a common pilot channel in forward



direction that is shared by all mobiles as shown in the figure below. . This cdma2000 pilot channel is a code-multiplexed channel using Walsh codes for orthogonal spreading. Common pilot channel provides all the mobiles with a reference signal for channel estimation and a timing reference. The pilot channel is also used for system acquisition. In the reverse direction cdma2000, uses time multiplexed pilot signals which are dedicated to each user.

In WCDMA, pilots are time multiplexed signals that



are part of traffic and overhead channels in both directions. Therefore, W-CDMA pilots are dedicated

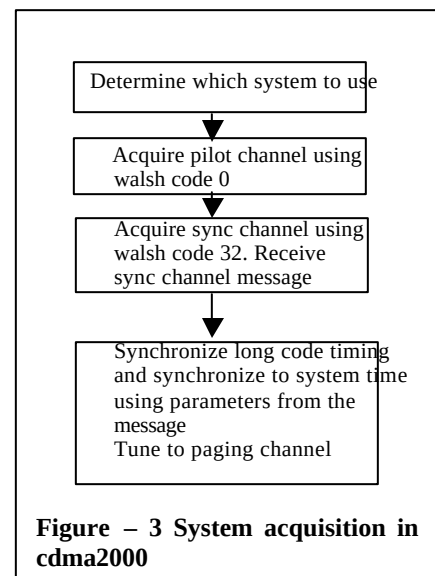
channels. As shown in the figure below, each traffic frame contains certain number of pilot bits.

Unlike cdma2000, Pilots are discontinuous waveform signals in WCDMA. W-CDMA uses pilot channel for channel estimation and coherent demodulation in both directions. Since, pilots are dedicated, they cannot be used for system acquisition. The system acquisition in W-CDMA is performed using synchronization channel.

## System acquisition

System acquisition in cdma2000 is performed using pilot and sync channel. It is shown in figure-3

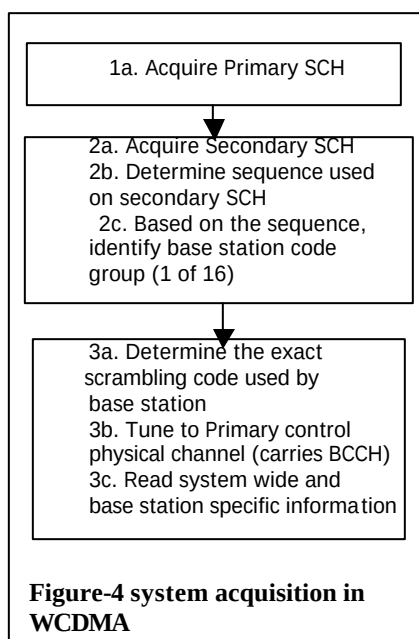
All cdma2000 base stations transmit the pilot contents over the air using QPSK modulation. First, QPSK modulation is applied to the pilot sequence of 0's. The QPSK components, the In-phase and Quadrature components, are separately spread using Walsh code 0. The resulting sequence (which is again a sequence of 0's) is then complex PN spread using two PN sequences. The two PN sequences are the same ones used in IS-95B and have a period of 26.66 msec i.e.



32768 or  $2^{15}$  chips.

Mobile stations acquire a base station by searching for forward common pilot channels. One way to search is to locally guess or generate the short PN sequence and correlate it with received signal. Mobile chooses the signal with the highest correlation value, i.e. the base station with the strongest signal. When a match is found, mobile continues the PN sequence generation and continually verifies it. When mobile concludes that it has acquired a base station, it only means that the mobile station has found a pilot of a base station. No other information could be deduced at this point.

Sync channel demodulation follows system acquisition. Sync channel uses Walsh code 32 for orthogonal spreading. Sync channel parameters message contains information about system time, PN offset used and the long code state value to be used. Mobile station sets the long code state to the received long code state value. Mobile station then aligns its time with the base station. Mobile is now ready to demodulate the paging channel.



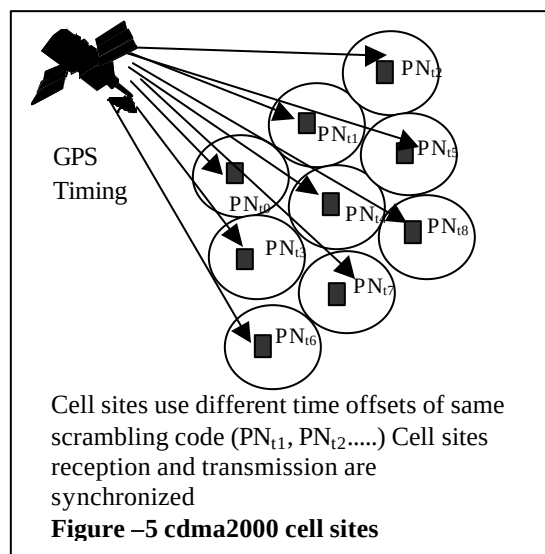
System acquisition in WCDMA is performed using synchronization channel and primary common control physical channel which carries Broadcast Control Channel (BCCH). The BCCH carries system and base station related configuration information. It is shown in figure-4

WCDMA mobile stations acquire the system using the following procedure:

1. Mobile station searches for the base station to which it has the least path loss. This is done by looking for the primary SCH code which is the same for all base stations. Mobile station has now acquired slot synchronization
2. Next the mobile station looks for the secondary synchronization channel sequence used by monitoring the secondary SCH and matching it to the 32 possible sequences. This identifies which of 32 scrambling code groups are used
3. Mobile station does symbol-by-symbol correlation to determine the exact scrambling code used by the cell. Now the mobile station has acquired the system and is ready to receive system information on the primary common control channel.

## Synchronous vs. Asynchronous cells

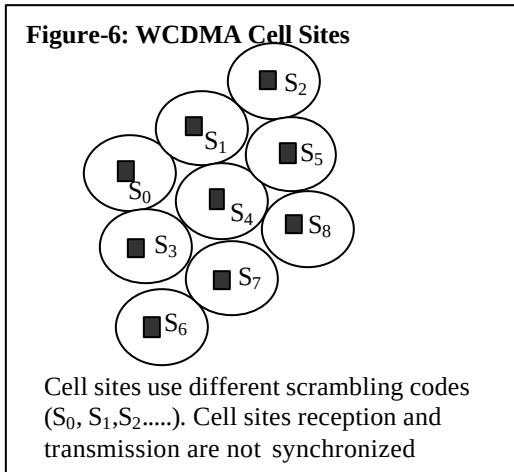
cdma2000 employs synchronous mode of operation as shown in figure 5. The synchronous operation means



the transmission and reception timings of cell sites are synchronized. All cdma2000 cell sites use single common timing source such as Global Positioning System (GPS). All cell sites transmit a Pseudo Random (PN) sequence of length  $2^{15}-1$  chips with a period of 26.67 milliseconds. The transmission of this sequence in different cell sites is offset in multiples of 64 chips. These timing offsets, known as pilot PN offsets, distinguish one cell site from another. Tight synchronization between different cell sites assists in soft handoff. The mobile can measure the timing and signal strength differences between its current reference cell and candidate cells in terms of 64 chips. This measurement is reported to the network to assist in making decisions on whether to add cells into soft handoff.

However, dependence on common source for synchronization can result in a single point of failure. The loss of that source may make entire system unavailable for service.

W-CDMA employs asynchronous mode of operation as shown in figure 6. In other words, transmission and reception timings of different cell sites need not be synchronized. Each cell site transmits cell-specific scrambling code sequence. This is different from cdma2000 where same scrambling code is transmitted in all cells with different time offsets. Scrambling code uniquely identifies a cell site. The scrambling codes are 40,960 chips in length. They are transmitted with a



period of 10msec. The asynchronous mode of operation avoids having a single point of failure.

### Channel Structure

The cdma2000 channel structure is derived from IS-95B. Additional channels are provided to support high rate data and multimedia services..

cdma2000 channels can be divided into common and dedicated channels. Common channels are point to multipoint channels between base station and multiple mobile stations used in shared access mode. The pilot, sync, paging and access channels are common channels derived from IS-95B. The functionality of pilot and sync channels is described in system acquisition section. The paging channel is used in forward direction (from base station to mobile station) to carry system wide and mobile specific information when mobile is not in a call. For example, system wide information such as number of paging channels is sent on paging channel. Mobile specific messages such as the paging message required to initiate a mobile terminated call is also sent on paging channel. Access channels correspond to paging channels in the reverse direction. Access channels are uncoordinated, shared channels used by the mobile stations to communicate with the base station while not on a call. Access channels are typically used to originate call requests or respond to page messages received from base stations. In addition to these channels, cdma2000 defines common control channel. Common control channel has been introduced for data services. It carries short user bursts, MAC signaling for packet and other data services.

Dedicated channels are point to point channels between base station and a single mobile station carrying information dedicated to single user. cdma2000 defines fundamental and supplemental channels to carry information related to user services.

The fundamental and supplemental channels are derived from IS-95B. However, different coding and modulation techniques are used in cdma2000. The fundamental channel is transmitted at variable rate as in IS-95B and requires blind detection at the receiver. Therefore it suited for voice services. It is also used for low rate data services. The data rates on fundamental channel is limited to 14.4 kbps. Fundamental channel supports rate set 1 (9.6, 4.8, 2.4 and 1.2 kbps) and rate set 2 (14.4, 7.2, 3.6 and 1.8 kbps). Different rates are used based on voice activity. Fundamental channel supports 5 and 20 msec frame sizes. The fundamental channels use fixed walsh code length.

Supplemental channels in both directions are similar to IS-95B supplemental channels. Supplemental channels support data rates from 1.2kbps to more than 2Mbps. cdma2000 specifies supplemental channel as a way of meeting IMT-2000 high rate data rate services requirements. Supplemental channel can be operated in two modes. In the first mode, supplemental channel supports Rate Set 1 and Rate Set 2. in variable rate mode. It can carry voice and low rate data in this mode. In the second mode, supplemental channel supports data rates higher than 14.4 kbps. The data rates can go upto 2 Mbps. However, in the second mode, supplemental channel does not operate in variable rate mode and does not require blind detection at the receiver. The data rate must be explicitly negotiated between base station and mobile station and any change must be renegotiated. In both modes, supplemental channels support only 20msec frames. The supplemental channel supports different walsh code lengths. This is required to support various rates as specified in IMT-2000.

In addition to these channels, cdma2000 defines dedicated control channel. It carries upper layer signaling, MAC signaling and short user bursts. Dedicated control channel has several purposes. It can carry short user bursts for data services. It can be used in association with fundamental channel carrying signaling and power control information. Thus fundamental channel carries only voice information providing high quality voice services. Dedicated control channel can also be used in association with supplemental channel carrying power control and link continuity information. This is useful for high rate data services configuration and eliminates the need for fundamental channel.

W-CDMA channel structure is very simple one. As with cdma2000, channels can be classified as common and dedicated channels.

There are four common channels in W-CDMA. They are Broadcast control channel (BCCH), Paging Channel (PCH), Forward Access Channel (FACH) and reverse Random Access Channel (RACH). The BCCH is

defined in forward direction. It carries system wide and cell specific information. After mobile powers up and synchronizes with the system, it tunes to BCCH to obtain system configuration. The paging channel is used to carry control information to a mobile station when the base station does not know the location of mobile in the cell. The forward access channel is used in forward direction. It carries control information and short user packets when base station knows the location of the mobile in the cell. It may be used for directed coverage by smart antenna beam-forming applications. The reverse random access channel is similar to access channel in cdma2000. As in cdma2000, it is accessed by multiple mobile stations in un-coordinated shared access mode. It is typically used to carry control information. All the common channels in W-CDMA use frame size of 10 msec.

W-CDMA defines only one dedicated channel. It is known as Dedicated Channel (DCH). W-CDMA specifies DCH as a way of meeting IMT-2000 high rate data rate requirements. It supports data rate of upto 2 Mb/s. Unlike fundamental channel or supplemental channel, the DCH does not operate in variable rate mode and does not require any blind detection at the receiver. The data rates must be explicitly negotiated and any changes must be renegotiated. The DCH supports variable rate OVFSF codes which are described in next section. This is required to support different data rates required by IMT-2000.

## Frame Sizes

Layer 3 signaling and user traffic is carried in 20 msec frames in cdma2000. In addition, cdma2000 employs 5 msec frames to carry MAC signaling. Longer frame sizes improve time diversity as interleaving and sequence repetition is done over the entire frame span. This improves the error performance. Thus, longer 20 msec frames are used for voice and data services. Shorter frame length reduces the total delay which is required for voice and MAC signaling. One of the applications of MAC signaling is faster reassignment of traffic channels. This is typically used in packet data services. Packet data services are characterized by discontinuous traffic with short bursts of high activity interleaved with periods of idle time. Since idle times are usually high compared to burst times, radio channel usage can be inefficient. Traffic channels are deallocated during idle periods. When user has traffic to send, fast assignment of traffic channel is done using MAC signaling.

. On the other hand, W-CDMA uses a frame size of 10 msec for Layer 3 signaling, user traffic and MAC signaling. The choice of one frame size allows for simplicity and ease of implementation. It is a

compromise between better error performance requirements of voice and data services and low delay requirements of voice and MAC signaling.

## Channelization codes

Channelization codes are required to distinguish channels (discussed in previous section) in both directions.

cdma2000 uses Walsh codes to differentiate between channels in the forward link. Walsh codes are orthogonal codes. Channels are spread using appropriate length codes based on the data rate supported on the channel. All the forward link channels within a cell/sector are separated using Walsh codes. Walsh codes are unique not just within channels of same user, but across different users in the same cell. The network controls Walsh code allocation for forward link channels.

On reverse link also, cdma2000 uses Walsh codes to differentiate between channels. However, unlike in forward link, Walsh codes only distinguish channels from same user. In other words, channels from different users may use the same Walsh code. User separation on reverse link is achieved by user specific PN codes as discussed in the next section.

W-CDMA uses Orthogonal Variable Spreading Factor (OVFSF) codes for channel separation in the forward link. OVFSF codes are similar to Walsh codes and the length of code used for a channel is dependent upon the channel's data rate. The network controls OVFSF allocation for forward link channels.

On reverse link also, WCDMA uses OVFSF codes to differentiate between channels. Similar to cdma2000, OVFSF codes only distinguish channels from same user. User separation on reverse link is achieved by user specific scrambling codes as discussed in the next section.

## Cell and User separation codes

Cell separation codes are required to identify transmission from different cells in forward direction.

In cdma2000, cell separation is performed by two PN sequences of length  $2^{15} - 1$  chips, one for I channel and another for Q channel. These sequences have a duration of 26.67 msec. Same sequences are used in all cells. However, transmission of these sequences in different cells is offset in multiples of 64 chips. These offsets are called PN offsets. Each cell uses a unique PN offset to distinguish its transmission from its neighboring cells. In W-CDMA, cell separation is achieved by Gold sequences (called as scrambling codes). Unlike cdma2000, each cell uses a different Gold sequence to

identify its transmission uniquely. These sequences have a length of 40,960 chips and a duration of 10 msec.

User separation codes are required to identify transmission from different users in the reverse link.

In cdma2000 long PN code of length  $2^{42}-1$  are used to distinguish different users in the reverse direction. Again, the same long code is used by all the users in all cells. However, the transmission from different users is offset by different number of bits. This offset is achieved by using Electronic Serial Number (ESN) which is unique to each user.

In WCDMA, either short or long scrambling codes are used to distinguish users in reverse direction. Short codes are very large kasami codes of length 256 while long codes are gold sequences of length  $2^{42}$ .

## Power Control

Both cdma2000 and W-CDMA use reverse open loop power control and bi-directional closed loop power control. In open loop power control, the mobile estimates transmit power based on received power in forward direction. This is based on the assumption that the path loss is equal in both forward and reverse direction. Open loop power control is used when mobile is initially accessing the system.

The closed loop power control is based on feed back scheme. The receiver instructs to the sender either to increase or decrease transmit power based on received power. The sender then adjusts the transmit power. The instructions are one bit up/down commands. These are called power control commands. Both, cdma2000 and W-CDMA employs closed loop power control in forward and reverse direction. However, the difference is in the rate of power control commands. In cdma2000, power control commands are sent at the rate of 800 bits/second whereas in W-CDMA power control commands are sent at the rate of 1,600 bits/second.

## Handoff

cdma2000 supports both soft and softer handoffs. In soft handoff, mobile measures the pilot strength from candidate base stations. The measurements are reported to network through current source base station. Please note the cdma2000 uses synchronous cells in which case the transmissions from different base stations is time offset in multiples of 64 chips. Therefore, mobile can measure signal strength once every 64 chip time period or multiple of 64 chip time period. Thus, the measurement becomes simpler. The measurements are associated with timing offsets in multiples of 64 chips

from the current source base station. The network can infer base station identity from the timing offsets. It uses measurements to add or delete base stations to soft handoff. Once base stations are added to soft handoff, they begin to transmit towards mobile. The transmissions from different base stations arrive at mobile stations at different time offsets which is again in multiple of 64 chips. The mobile coherently combines signals from different base stations. In the reverse direction the transmission from the mobile is received by all base stations involved in soft handoff. After demodulation, the base stations send frames to a centralized location in the network. Among these frames, the best frame is selected and used.

W-CDMA also supports soft and softer handoff. The soft handoff mechanism has many similarities to soft handoff mechanisms in cdma2000. However, there are many differences. As in cdma2000, the mobile measures signal strength from different base stations. But W-CDMA uses asynchronous cells where transmissions from different base stations are not coordinated. The mobile must estimate the timing offset between current base station and the target base station. It reports the estimated timing offset for candidate base stations to network through the current base station. The network adds the target base station to the soft handoff and informs it off the timing offset. The target base station uses the timing offset to adjust the transmission on downlink. The adjustment is done in steps of 256 chips to maintain orthogonality. Thus, mobile receives transmissions from different base stations at approximately same time instant. This is different from cdma2000 where the transmissions from different base stations are time offset in multiples of 64 chips. The mobile uses maximal ratio combining to combine signals from different base stations. In reverse direction, the transmission from mobile station is received.

In addition, both cdma2000 and W-CDMA support inter-frequency handoffs. cdma2000 also supports handoffs from cdma2000 system to IS-95B system and vice versa. The W-CDMA supports handoffs from W-CDMA system to GSM system and vice versa.

## Smart antenna applications

Smart antenna applications provide for beam forming covering portions of cells/sectors or adaptive beams directed at a single mobile station. Such applications provide for enhanced coverage in hot spots such as sports arenas and high propagation loss areas or increase the data rate for high speed terminals.

As discussed earlier, cdma2000 uses common pilot channel applied to entire cell. However, beam forming

is applied to cover a smaller portion of a cell. Therefore, the receivers would require an additional dedicated pilot for reliable channel estimation for beam forming application. Channel estimations will not be accurate if the reference pilot traverses a different path compared to the data signal. Thus, cdma2000 supports additional auxiliary pilots dedicated to one or group of mobiles in an area. Auxiliary pilots use a different Walsh code for spreading to differentiate it from common pilot. In order to conserve number of Walsh codes, cdma2000 uses expanded Walsh codes on auxiliary pilot channels.

In W-CDMA, pilots are time multiplexed and dedicated to each mobile station. Therefore, in order to support adaptive beam steering applications, no additional pilots are necessary. However, W-CDMA does not have a way to support common pilot for hot spot areas like cdma2000.

## V. CONCLUSIONS

This article compares and analyzes similarities and differences between cdma2000 and WCDMA which are two dominant candidates for IMT-2000 radio interfaces. Due to many factors discussed in this article, harmonization between these two proposals is necessary. Two important factors are global roaming and service portability. These factors represent serious limitations of current generation of networks.

Efforts are underway to harmonize these two proposals. However, there are many contentious issues. The base spreading rate is one of the stumbling blocks on the road to harmonization. cdma2000 uses a base chip rate of 3.6864 Mcps in 5 MHz band whereas WCDMA uses a base chip rate of 4.096 Mcps in 5 MHz band. cdma2000 claims backward compatibility as the reason whereas WCDMA claims better performance as the reason for the chosen spread rate. Synchronous vs. asynchronous cell sites, frame sizes, variable rate coding are some of the issues in harmonization debate.

ITU in the coming months will choose radio technology for IMT-2000 networks. Some have argued the need for more than one radio technology given the market realities. Therefore, the family of systems concept where both cdma2000 and WCDMA can coexist has been floated. Even then, harmonization among these proposals is necessary to ensure interoperability, simplified mobile terminal design and deployment of services such as global roaming.

## VI. REFERENCES

(1) TR45.5.4 committee "The cdma2000 ITU-R RTT candidate submission" TTA/EIA, 1998

- (2) SMG 2 committee "The ETSI UMTS Terrestrial Radio Access (UTRA) ITU-R RTT candidate submission" ETSI, 1998
- (3) Dahlman, Erik et al "UMTS/IMT-2000 based on Wideband CDMA" September 1998, IEEE Communications Magazine
- (4) Prasad, Ramjee, et al "An overview of CDMA evolution toward Wideband CDMA" Fourth quarter 1998, IEEE communicate surveys
- (5) IMT-2000 study committee "Japan's proposal for candidate RTT on IMT-2000:W-CDMA" ARIB, 1998
- (6) IMT-2000 Web site "www.itu.int/imt"