cdma2000 Mobile Radio Access for IMT 2000

Y.S. Rao and Anil Kripalani
Qualcomm Incorporated
6455 Lusk Blvd., San Diego, CA 92121
Phone: (619) 651-4241, Fax: (619) 658-2115
E-mail: ysrao@qualcomm.com and akripalani@qualcomm.com

Abstract

This article presents key design characteristics of the cdma2000 RTT in terms of the proposed forward and reverse link structure. cdma2000 demonstrates that it can fully support IMT-2000 requirements and additional future services while providing backward compatibility to existing TIA/EIA-95-A/B cdmaOne networks. Major differences between the cdma2000 and WCDMA RTT proposals, in the areas of chip rate selection, pilot structure, base station synchronization, and frame length are highlighted in this article. Based on theoretical analyses, computer simulation results, and several years of experience with CDMA networks, it is concluded that cdma2000 provides several competitive and economical advantages to operators and end users.

1. Introduction of cdma2000 RTT

The **cdma2000** Radio Transmission Technology (RTT) is a wideband, spread spectrum radio interface that uses Code Division Multiple Access (CDMA) technology to meet the needs of the next generation of wireless communication systems. This RTT meets or exceeds all requirements specified in the ITU circular letter and the corresponding documents of the IMT-2000[1]. The service requirements are satisfied for the Indoor Office, Indoor to Outdoor/Pedestrian, and Vehicular environments. In addition, the RTT, while meeting all of the requirements for the next generation, is also backward compatible with the current TIA/EIA-95-A/B or cdmaOne family of standards.

The key design characteristics of cdma2000 are:

- Backward compatibility with IS-95A/B
  - Overlay upgrade in N=1 and N=3 Multi-Carrier (MC)
  - Support of IS-95A/B signaling
  - Support of IS-95A/B services as well as new services
  - Spreading bandwidths compatible with IS-95A/B deployments
- Fully supports handoff to and from existing systems
- Support of different RF channel bandwidths of the form N x 1.2288 MHz where N = 1, 3, 6, 9, 12
  - 1.2288 Mcps
  - 3.6864 Mcps
  - 7.3728 Mcps
  - 11.0592 Mcps
  - 14.7456 Mcps
- Includes an advanced Medium Access Control (MAC) layer
- Supports different quality of service (QoS) characteristics
- Has FDD and TDD modes of operation

0-7803-4912-1/99/$10.00©1999 IEEE

The main parameters of the cdma2000 radio link are shown in Table 1.

Table 1: cdma2000 Radio Link Parameters

Bandwidth (MHz)	1, 25, 5, 10, 15, 20
FL Structure	Direct spread or Multicarrier
Chip rate (Mcps) Direct spread	1.2288/3.6864/7.3728 11.0593/14.7456
Multicarrier	Nx1.2288 for N=1, 3, 6, 9, 12
Spreading code	Walsh code Pseudo noise code
Modulation	QPSK (FL) QPSK/(Pi/2)BPSK (RL)
Coherent detection	Pilot time multiplexed PC (RL), Common continous pilot channel and auxiliary pilot (FL)
Channel coding	Convolutional Code (R=1/2, 1/3, 1/4, k=9) Turbo code (R-1/2, 1/3, 1/4, k=4) for high rate
Diversity	multi-carrier transmit diversity, orthogonal transmit diversity
Power control	open loop and fast close loop (800 Hz)

2. cdma2000 Design Overview

2.1 Forward Link Structure

The forward channel consists of dedicated channels and common channels, where the common channels carry information from the base station to a set of mobile stations in a point to multi-point manner, while dedicated channels carry information from the base station to a single mobile station.

Forward common channels:
Forward Pilot Channel (F-PICH),
Forward Common Auxiliary Pilot Channel (F-CAPICH),
Sync Channel (F-SYCH),
Paging Channel (F-PCH),
Forward Common Control Channels (F-CCCH)
Broadcast Channel (F-BCH), and
Quick Paging Channel (F-QPCH)

Forward dedicated channels:
Dedicated Auxiliary Pilot Channels (F-DAPICH),
Forward Fundamental Channel (F-FCH),
Forward Supplemental Channel (F-SCH), and
Forward Dedicated Common Control Channels (F-DCCCH).

The main functions of the forward link channels are briefly described below:

Forward Pilot Channel (F-PICH): The channel is continuously broadcast throughout the cell in order to provide timing and phase information. All mobiles in the cell share the pilot, and use the pilot to obtain fast acquisition of new multipath and channel estimation.

Forward Common Auxiliary Pilot (F-CAPICH): The channel is used with antenna beam-forming applications to generate spot beams. Spot beams can be used to increase coverage in a particular geographical area or to increase capacity towards hot spots. The Common Auxiliary Pilot can be shared among multiple mobile stations in the same spot beam.

Forward Sync Channel (F-SYNCH): The Sync Channel is used by mobile stations operating within the coverage area of the base station to acquire initial time synchronization.

Forward Paging Channel (F-PCH): A cdma2000 system can have multiple Paging Channels per base station. A Paging Channel is used to send control information and paging messages from the base station to the Mobile Stations (MS) and operates at a data rate of 9600 bps or 4800 bps.

Forward Common Control Channel (F-CCCH): The Forward Common Control Channel (F-CCCH) is a common channel used for communication of Layer 3 and MAC messages from the base station to the mobile station. Possible frame sizes for F-CCCH are 5ms, 10ms, and 20ms depending upon the operating environment.

Broadcast Channel (F-BCH) and Quick Paging Channel (F-QPCH) have been added.

Forward Dedicated Auxiliary Pilot (F-DAPICH): An optional Auxiliary Pilot can be generated for a particular mobile station. The Dedicated Auxiliary Pilot is used with antenna beam-forming application and beam steering techniques to increase the coverage or data rate towards a particular mobile station.

Forward Fundamental Channel (F-FCH): The channel is transmitted at a variable rate as in TIA/EIA-95-B and consequently requires rate detection at the receiver. Each F-FCH is transmitted on a different orthogonal code channel.

Forward Supplemental Channel (F-SCH): The Supplemental Channel (F-SCH) can be operated in two distinct modes. The first mode is used for data rates not exceeding 14.4 kbps and uses blind rate detection (no scheduling or rate information provided). In the second mode the rate information is explicitly provided to the base station (no blind rate detection is performed). There may be more than one F-SCHs in use at a given time. The individual F-SCH target FERs may be set independently with respect to the F-FCH and other F-SCHs, since the optimal FER set point for data is in general different than for voice. For classes of data services that have less stringent delay requirements, the FER may also be managed by retransmissions.

Forward Dedicated Control Channel (F-DCCH): The F-DCCH supports 5 and 20 ms frames at a 9.6 kbps encoder input rate. 16 CRC bits are added to the information bits for 5 ms frames or 12 CRC bits for 20 ms frames followed by the addition of 8 tail bits, convolutional encoding, interleaving, and scrambling.

The characteristics of the forward link are described as following:

- Channels are orthogonalized by Walsh functions
- QPSK data modulation
- Forward Error Correction
  - Convolutional codes (K=9) are used for voice and data
  - Turbo Codes are used for high data rates on Supplemental Channels
- Supports Non-Orthogonal Forward Link Channelization
  - Used when running out of orthogonal space (insufficient number of Walsh codes)
  - Quasi-orthogonal functions generated by masking existing Walsh functions
- Synchronous forward link
- Forward link transmit diversity
- Fast Forward Power Control
  - 800 Hz update rate
- Supplemental Channel Active Set subset of Fundamental Channel Active Set.
- Frame Lengths
  - 20ms frames are used for signaling and user information
  - 5 ms frames are used for control information

2.2 Reverse Link Structure

The reverse channel is composed of reverse common channels and reverse dedicated channels.
Reverse common channels:
- Reverse Common Control Channels (R-CCCH)
- Reverse Access Channel (R-ACH)

Reverse dedicated channels:
- Reverse Dedicated Control Channels (R-DCCH)
- Reverse Pilot Channel (R-PICH)
- Reverse Fundamental Channel (R-FCH)
- Supplemental Channels (R-SCH)

The Reverse Access Channel (R-ACH) and the Reverse Common Control Channel (R-CCCH) are common channels used for communication of Layer 3 and MAC messages from the mobile station to the base station. The characteristics described in this section apply to both the R-ACH and the R-CCCH. The R-CCCH differs from the R-ACH in that the R-CCCH offers extended capabilities beyond the Reverse Access Channel (R-ACH). For example, the R-CCCH supports lower latency access procedures required for efficient operation of the Packet Data Suspended State. The R-ACH and R-CCCH are multiple access channels as mobile stations transmit without explicit authorization by the base station. The Reverse Access Channel and Reverse Common Control Channel use a slotted Aloha type of mechanisms with higher capture probabilities due to the CDMA properties of the channel (simultaneous transmission of multiple users). There can be one or more access channels per frequency assignment. Different access channels are distinguished by different long codes.

Reverse Dedicated Channels consist of up to several physical channels, where a Reverse Pilot Channel is always used.

Reverse Dedicated Channels: The R-DCCH, R-FCH, R-SCH may or may not be used depending on the service scenario. Each physical channel is spread with a Walsh code sequence to provide orthogonal channelization among these physical channels. The spread Pilot and R- DCCH are mapped to the in-phase (I) data channel. The spread R-FCH and R-SCH are mapped to the quadrature (Q) data channel. Then, the I and Q data channels are spread using a complex-multiply PN spreading approach.

Reverse Pilot Channel(R-PICH): The Pilot Channel for the Reverse Dedicated Channels consists of a fixed reference value and multiplexed forward Power-Control (PC) information. It is used for initial acquisition, time tracking, Rake-receiver coherent reference recovery, and power-control measurements.

Reverse Fundamental Channel (R-FCH): the Reverse Fundamental Channel (R- FCH) supports 5 and 20 ms frames. The 20 ms frame structures provide rates derived from the TIA/EIA-95-B Rate Set 1 or Rate Set 2 rate sets. The 5 ms frames provide 24 information bits per frame with a 16-bit CRC. Within each 20 ms frame interval, either one 20 ms R-FCH structure, up to four 5 ms R-FCH structure(s), or nothing can be transmitted. In addition, when the 5 ms R-FCH structure is used, it can be "on" or "off" in each of the four 5 ms segments of a 20 ms frame interval.

Reverse Supplemental Channel (R-SCH): The Supplemental Channel (R-SCH) can be operated in two distinct modes. The first mode is used for data rates not exceeding 14.4 kbps and uses blind rate detection (no scheduling or rate information provided). In the second mode, the rate information is explicitly known by the base station (no blind rate detection is performed).

The characteristics of the reverse link are described as following:

- Channels are primarily code multiplexed
- Separate channels are used for different QoS and physical layer characteristics
- Transmission is continuous to avoid EMI issues
- Channels are orthogonalized by Walsh functions and I/Q split so that performance is equivalent to BPSK
- Hybrid Combination of QPSK and Pi/2 BPSK
- By restricting alternate phase changes of the complex scrambling sequence, power peaking is reduced and side lobes are narrowed
- Forward Error Correction
  - Convolutional codes (K=9) are used for voice and data
  - Parallel Turbo Codes (K=4) are used for high data rates on Supplemental Channel
- Fast Reverse Power Control
  - 800 Hz update rate
- Frame Lengths
  - 20 ms are used for signaling and user information
  - 5 ms frames are used for control information

3. Multi-Carrier Approach

One of the key design characteristics of cdma2000 is backward compatibility to IS-95A/B deployment in the 1.25 MHz bandwidth. In cdma2000, the proposed multi-carrier technique uses multiple 1.25 MHz CDMA carriers and multi-antenna configuration in forward link transmission. The multi-carrier approach, while providing frequency diversity, can enhance forward link capacity.

The main characteristics of the Multi-carrier approach are described as follows:

- Coded information symbols are demultiplexed among multiple 1.25 MHz CDMA carriers

- Frequency diversity is equivalent to spreading the signal over the entire bandwidth allocation

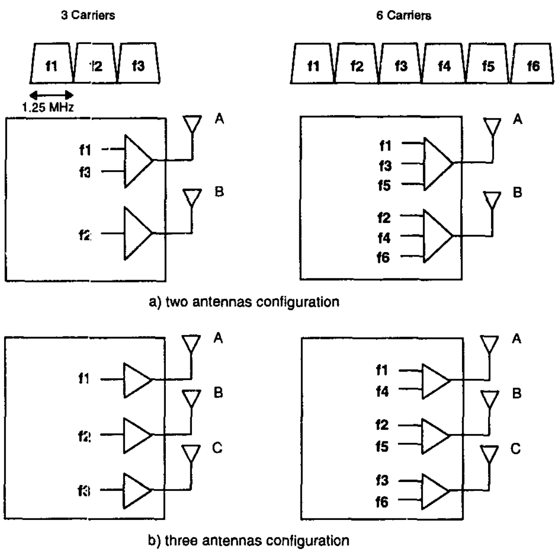
- Both time and frequency diversity are captured by the convolution coder/symbol repetition and interleaver
- Rake receiver captures signal energy from all bands

- Each forward link channel may be allocated an identical Walsh code on all carriers

- Fast power control

Figure 1 illustrates an example of 3x1.25 MHz multi-carrier transmitter.

Figure 1: 3x 1.25 MHz Multi-carrier Transmitter



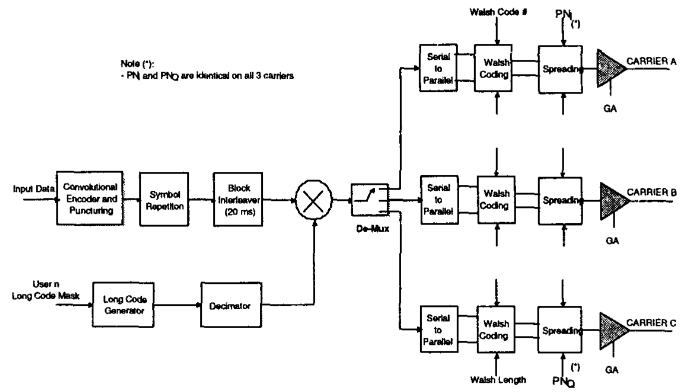
In 3x1.25 MHz Multi-carrier transmitter, one serial coded information symbols are divided into three parallel data streams, and each data stream is spread with a Walsh code and a long PN sequence at a rate of 1.2288 Mcps. At the output of the transmitter, there are three carriers, A, B and C.

3.1 Multi-carrier Transmit Diversity

After processing the serial coded information symbols with parallel carriers, the multi-carrier will be transmitted by multi-antenna, which is called Multi-carrier Transmit Diversity (MCTD). In MCTD, the total carriers are divided into subsets, then each subset of the carriers is transmitted on each antenna, where frequency filtering provides near perfect orthogonality between antennas. This provides improved frequency diversity and hence increases forward link capacity.

Figure 2 shows multi-carrier transmission in a two-antenna configuration and in a three-antenna configuration.

Figure 2: Multi-carrier Transmit Scheme



In addition, antenna schemes can provide substantially good spatial diversity.

3.2 Orthogonal Transmit Diversity

Orthogonal Transmit Diversity (OTD) could also be used to improve transmit diversity for the direct spread case. The implementation of OTD is as follows. Coded bits are split into two data streams and are transmitted via separated antennas. A different orthogonal code is used per antenna for spreading. This maintains the orthogonality between the two output streams, and hence self-interference is eliminated in flat fading. Note that by splitting the coded data into two separated data streams, the effective number of spreading codes per user is the same as the case without OTD. An Auxiliary Pilot is introduced for the additional antenna.

4. Comparison of cdma2000 and WCDMA

A comparison between the cdma2000 and WCDMA proposals is presented. Both are oriented towards a much wider set of services than existing cellular systems and include new performance improvements. There are many similarities between the two systems, *because both employ key design concepts of IS-95.*

Similarities in both systems include:

- Coherent forward and reverse link
- Fast power control on forward link as well as reverse link.
- Variable length orthogonal Walsh sequences used for forward link channelization
- Complex QPSK spreading on both forward and reverse link
- Convolutional codes used as baseline (identical polynomials)
- Parallel Turbo codes for higher data rates
- Orthogonal Walsh functions separating the users parallel code channels on the reverse link
- Variable spreading factor to achieve higher data rates
- Non orthogonal reverse link based on PN scrambling codes
- Mobile assisted inter-frequency hard handoff procedures
- Variable rate operation with blind rate estimation for simple services (e.g. voice)
- Continuous reverse link operation

It should be noted that while the concepts are similar, the details of the physical layer are different. This is mainly due to separate standardization efforts, although often claimed to be based on different requirements. However, since many of the underlying physical layer concepts are identical, many of the details can be converged without impacting the system performance or integrity.

The following items in Table 2 are major differences in parameters being addressed for future convergence of the two CDMA-based systems. There are many other differences in the details of the physical layer parameters and procedures.

Table 2: Major Differences between cdma2000 and WCDMA

	cdma2000	**WCDMA**
Chip Rate	3.6864.Mcps	4.096 Mcps
Forward link pilot for channel estimation	CDM common pilot	TDM dedicated pilot
Antenna beam forming and spot beams	Auxiliary pilot	TDM dedicated pilot
Base station synchronization	Synchronous	Asynchronous
Base station acquisition and detection	Synchronization through time shifted PN correlation	3 step parallel code search for base station detection and slot/frame
Network Signalling Support	IS-41 GSM-MAP	GSM-MAP

Before we address the items in Table 2, it is useful to discuss the impact of:

4.1 Out of Band Emissions

In a 5 x 2 MHz licensed band (similar to the US PCS D/E/F bands and also referenced in the UMTS requirements), a 4.096 Mcps system with realistic PA power (50 dBm for BS[1], 30 dBm for MS) would violate out-of-band emission limits in some regions, including US, Figure 3 shows the power spectral density of a 50 dBm base station assuming a 97-tap root raised cosine FIR filter.

[1] Estimated PA (power amplifier) size is 47 to 50 dBm, or 50 to 100 W per sector. This accounts for a bandwidth that's 4 times the current Is-95 1.25 MHz.
We ideally use 20 W PA in 1.25 MHz. To support 4 times the traffic load requires 4 times the power or an 80 W PA. The improvement in the modem efficiency is somewhat offset by the lack of statistical averaging in high rate data transmission. That is, if the BS is transmitting to a few data users at high rate, it would not experience the stable power requirement by a large pool of voice users who are transitioning between full and 1/8 rate frames.

Results from Figure 3 are further compared with Part 24 of the Code of Federal Regulations in Figure 4. This code specifies a limit of –13 dBm in a resolution bandwidth that is at least 1% of the signal bandwidth. As such, the 4.096 Mcps system has an out of band limit of –13 dBm/40.96 kHz. Figure 4 plots the power spectral density using a resolution bandwidth of 50 kHz (per FCC part 24) within a band of 2.5 MHz.

Figure 3: BS Tx Power (4.096 Mcps) and FCC Part 24 Emissions Limits

j

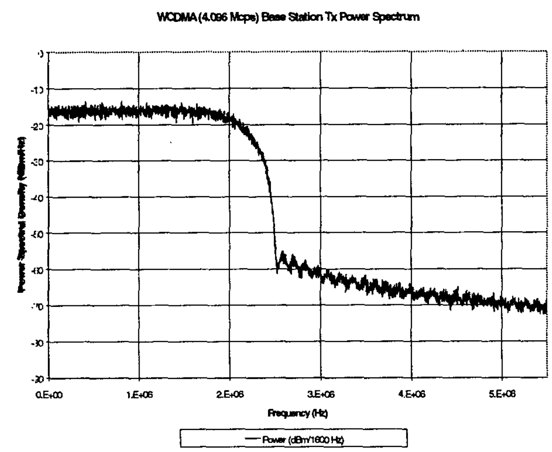
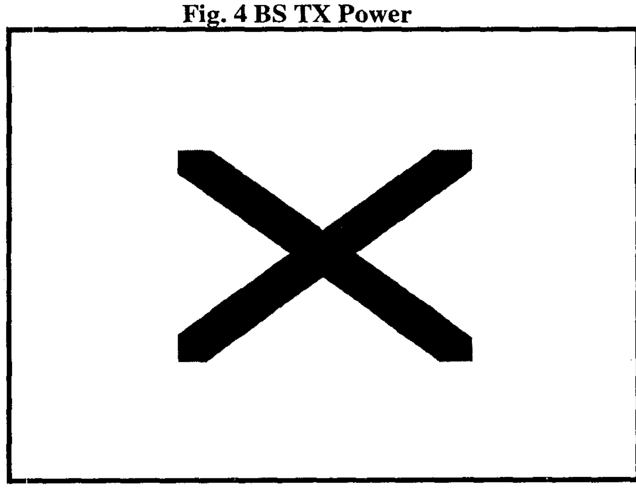


Fig. 4 BS TX Power



As can be seen on Figure 4, the out of band emissions violates the FCC limit by as much as 3.5 dB.

Two comments regarding this conclusion:

1. The FCC requirements referenced here are U.S. requirements. However, out of band spurious emission limits are more stringent in many other countries. Hence, it is desirable to meet as many of the known requirements as possible, and the discussion under 4.2, in any case, shows potential problems with the chip rate in 5MHz.
2. WCDMA RTT specifications do not meet the requirements, it is conceivable to specify another filter that might have better spectral characteristics (e.g., by increasing the number of taps to an extremely large number). In such a case, it would be necessary to also demonstrate the practicality of such implementation, including additional complexity and cost.

4.2 Chip Rate Selection

Considerations for chip rate selection include the following: migration from existing technologies, numerology, capacity and out of band emissions.

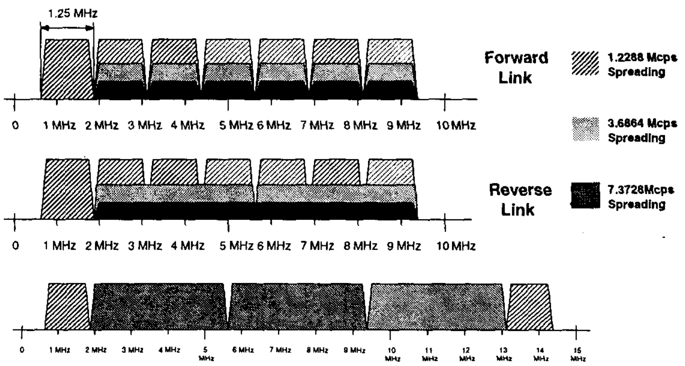
The overall capacity of a CDMA system is the minimum between the forward and reverse link capacities.

The reverse link is generally interference limited. Table 3 shows reverse link capacities for different packing of the available spectrum. It is shown that a 3.6864 Mcps combined with a 1.2288 Mcps chip rate as illustrated in Table 3 and the associated Figure 3, provides better system capacity in 10, 15, and 20 MHz deployments. In a 5 MHz deployment, a 4.096 Mcps system claims higher capacity but is forward link capacity limited due to out of band emissions constraints on total forward link power (discussed below). In 20 MHz band allocations, five distinct 3.6864 carrier waveforms can be accommodated (with guardband) whereas only four 4.096 waveforms can be made to fit, thus providing higher capacity with the 3.6864 approach. In 15 MHz band allocations, a flexible mix of 1.2288 and 3.6864 carrier waveforms can also yield higher capacity systems. Thus, for various band plans, 3.6864 Mcps chip rate provides superior overall system capacity compared to 4.096 Mcps.

Table 3: Band Packing and Capacity

Alloc. Block	3x Carrier Deployment cdma2000	3x Carrier Deployment WCDMA
5 MHz	1 x 3.75 Carrier + Guard Band	1 x 4.096 with no Guard Band
10 MHz	2 x 3.75 Carrier + 1 x 1.25 Carrier + Guard Band	2 x 4.096 + Guard Band
15 MHz	3 x 3.75 Carrier + 2 x 1.25 Carrier + Guard Band	3 x 4.096 + Guard Band
20 MHz	4 x 3.75 Carrier + 3 x 1.25 Carrier + Guard Band or 5 x 3.75 Carrier + Guard Band	4 x 4.096 + Guard Band

Figure 3:



5. Forward Link Pilot Structure

In a CDMA system using coherent modulation, a phase reference must be provided to the receiver. On the forward link, the common pilot provides a phase reference to each mobile station.

There are two independent factors affecting the selection of a pilot:

- It can be shared among all users
- It can be time multiplexed or code multiplexed with other information sent by the base station

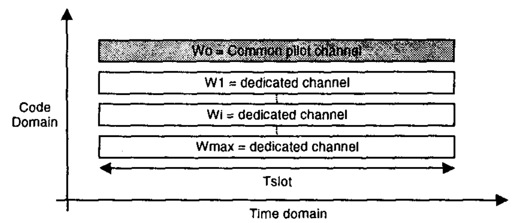
In addition, the forward link must provide a beacon channel for initial acquisition, timing information, and neighboring base station detection. This function is independent from the forward link pilot but can play an important rule when considering forward link pilot structure, as will be explained later on.

5.1 Basic Fundamental Approaches

As shown in Table 3, cdma2000 and WCDMA use two radically different approaches to deliver a forward link pilot as primary mode.

5.1.1 Common Code Multiplexed Pilot (CCMP)

Figure 5.3:



In the CCMP approach (Figure 5.3) one code channel is dedicated to pilot broadcasting. No pilot symbols are multiplexed with dedicated channels. All the users despread both the pilot symbols and the modulated information symbols in parallel. Similarly they demodulate the information symbols using the channel estimate. Note that additional pilot channel(s), the auxiliary pilot(s), can be dedicated to a subset of users as described later in the document.

When users are in Discontinuous Transmit (DTX) mode, as in the case of TM Pilot, the transmitted power is peaking when transmitting the pilot symbols and is lower when transmitting the data symbols to the active users. In the current WCDMA description this situation is only a special case, as different users can have different frame offsets, for example, to ensure synchronization in soft handoff situations. However, even with different offsets, there will be significant stochastic fluctuation of the combined pilot power transmitted at any given time. This increased peak/average ratio will make it necessary to increase the PA headroom (reducing the maximum capacity) in order to safely contain those variations.

5.1.2 Dedicated Time Multiplexed Pilot (DTMP)

In the DTMP approach, separate pilot symbols are time multiplexed on each dedicated traffic channel. Each user sequentially despreads the pilot symbols and information symbols and performs data demodulation using the channel estimate.

5.2 Advantages of CCMP over DTMP

Finally, the benefits of using a common pilot will be less total pilot overhead and hence increased forward link capacity, while ensuring reliable and fast estimation by MS.

Code multiplexed pilots will also result in lesser forward link peak to average power ratio.

6. Synchronized Base Stations

Synchronized base stations with time-shifted common pilots permit fast one-step correlation, resulting in quick acquisition and neighbor detection. In this case, there is no need to adjust the timing of each individual mobile in soft handoff. The mobile also does not need to decode any signal from the new base station prior to handing off. Complexity in the mobile station is kept to a minimum. Experience with current commercial CDMA networks has shown that synchronized networks are reliable and efficient. In contrast, WCDMA utilizes asynchronous BS operation, but also requires highly stable timing references in the infrastructure for timing alignment. WCDMA uses a 3-step acquisition scheme with multiple parallel correlations in each step. This has yet to be proven in high density fold systems.

Synchronized base stations permit the operation of common overhead and signaling channels (such as common control and paging channels) into soft-handoff. Paging and control channels can be broadcast synchronously over a specific partition of the network and combined coherently by mobile stations. Such procedures significantly increase the common channel reliability and the overall forward link capacity by reducing the common channel required transmit power. Those techniques can not be used in asynchronous networks without the expense of additional complexity and reduced performance that outweigh any benefits.

MS terminal battery saving techniques such as the Quick Paging channel work best with synchronized base stations. With asynchronous base stations, different cells are not time-aligned and the MS must wake up multiple times and for longer periods to monitor the different base stations. This reduces the attractiveness of battery saving techniques and severely impacts the battery life of mobile devices.

While GPS is the primary means for base station synchronization due to its ubiquitous nature and reliability, synchronization can be achieved by several means other than GPS, such as self-synchronizing mobiles. And there are several techniques available through which synchronization can be implemented and maintained for indoor networks, and also as fallback options for outdoor networks.

There are still several performance issues to be resolved regarding asynchronous operation. Hard, inter-frequency hand-off is one example. With asynchronous cells in WCDMA, it turns out that prior to handing off to the new frequency the mobile has to shift to the new frequency channel for 40 ms and decode its broadcast channel. This delay is long and will degrade performance.

All of the above points indicate that synchronous mode operation provides superior system capacity as well as battery life for the MS. It is often claimed that an asynchronous system can be operated in synchronous mode and benefit from the superior performance of synchronous operation while it can operate asynchronously when timing reference is not available. However, an asynchronous system operating in synchronous mode will still have:

- Higher mobile complexity primarily due to the need for increased searcher capability
- Reduced capacity due to non-orthogonal acquisition channels
- Large signaling overhead to support the two modes of operation (resulting in further reduced capacity)
- Increased hardware and software complexity for managing two modes of operation
- Increased design cycle

There is thus yet no specification for synchronous mode of operation in WCDMA.

7. Frame Length

The WCDMA RTT assumes a 10 ms frame length and 10 ms-based vocoder. After further clarifications during the Ad-Hoc meetings, it appears that WCDMA proponents are also considering other frame lengths, including 20 ms for channel interleaving and vocoder services. While 5 and 10 ms frame lengths can be appropriate for certain type of control messages and low-delay data applications, it is believed that a 20 ms based frame length should be considered as the basis for voice and data applications. Some of the reasons are outlined below.

A common objective is to reduce the end to end delay. The ITU originally set a target of less than 40 ms end to end delay. When 20 ms frame length is used, the end to end delay, based on EVRC estimation is of the order of 70 ms. This delay could be reduced with a 10 ms frame length but that would still not meet the above ITU target. An echo canceller is required for voice for both the 10 ms and 20 ms frame lengths. The ITU requirement has been relaxed, and thus, there is no constraint on using 20 ms frame length.

It has been demonstrated that 10 ms frame reduces time diversity and increases Eb/No requirements. At 30 km/h, up to 2dB additional Eb/No may be required, based on simulation results on RL, 800 bps PC, and two antennas per one path per antenna.

With 20 ms frames, the overhead percentage (convolutional tail bits, CRC, etc.) is reduced. With a 20 ms frame length, the overhead is 11% for 8.6 kbps voice services (per cdma2000 numerology). With a 10 ms frame length, the overhead is 20% for 8 kbps voice services (per WCDMA/NA numerology). Existing vocoders are widely deployed based on a 20 ms frame (EVRC, IS-733, and GSM).

In summary, a 20 ms frame length best fits the requirements of flexibility and performance for IMT-2000 purposes. A 20 ms frame length has been found to offer the best tradeoff between vocoder delay and interleaver depth. Shorter frame lengths (5 ms, 10 ms) could also be accommodated as requirements. Larger interleaving blocks (40 ms, 80 ms) could be accommodated as options, if they are shown to be viable, and do not impair performance or increase complexity.

8. Conclusion

This paper introduced a summary of the design concepts of cdma2000 RTT as proposed to the ITU for IMT-2000. The simulation results are provided as an annex to the ITU proposal as per IMT-2000 requirements of evaluation. They are available on the Web and hence are not presented here. While this paper is being written, convergence efforts are ongoing between the two dominant CDMA proposals for 3G. If the convergence efforts succeed, both operators and users will benefit from a single global CDMA standard.

8.1 Acknowledgements:

This paper draws extensively from the cdma2000 ITU-R RTT submission (0.18) and hence acknowledgements are due to TR 45.5 .4 .

We also acknowledge the fine work done by the proponents of cdma2000 RTT which includes many individuals from different companies.

We acknowledge the detailed information provided by Qualcomm personnel, including Ed Tiedemann, Olivier Glauser and Jack Holtzman.

References:

1. ITU-R Recommendations IMT-2000, Vol 1997 M Series-Part 2.

2. The cdma2000 ITU-R RTT Candidate Submission (0.18), TR45.5.4.

3. WCDMA and cdma2000 Comparison, Qualcomm Internal Memorandum, Olivier Glauser, Jack Holtzman.

4. Wideband CDMA for Third Generation Mobile Communications, Artech House, 1998, Ojanpera and Prasad.