

WCDMA - TECHNOLOGY FOR 3G CELLULAR SYSTEMS

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ABSTRACT

W-CDMA (Wideband Code-Division Multiple Access), an ITU standard derived from Code Division Multiple Access, is officially known as IMT-2000 direct spread. W-CDMA is a third-generation mobile wireless technology that promises much higher data speeds to mobile and portable wireless devices than commonly offered in today's market. The present seminar discusses the applicability of WCDMA system with respect to 3G mobile system. The reason for the popularity of spread spectrum technique is addressed and the evolution of WCDMA over CDMA is also pointed out. The protocol architecture of WCDMA, WCDMA network architecture and the compatibility of existing GSM system with WCDMA system are also discussed in brief.

Keywords: Code Division Multiple Access, Wideband Code Division Multiple Access, Protocol architecture, Radio Access Network, Global System Mobile

1 Introduction

There has been a tremendous growth in wireless communication technology over the past decade. The significant increase in subscribers and traffic, new bandwidth consuming applications such as gaming, music downloading and video streaming will place new demands on capacity. The answer to the capacity demand is the provision of new spectrum and the development of a new technology – Wideband CDMA or hereinafter referred to as WCDMA.

WCDMA was developed in order to create a global standard for real time multimedia services that ensured international roaming. With the support of ITU (International Telecommunication Union) a specific spectrum was allocated – 2GHz for 3G telecom systems. The work was later taken over by the 3GPP (3rd Generation Partnership Project), which is now the WCDMA specification body with delegates from all over the world.

2 What is 3G System

UMTS (Universal Mobile Telecommunications System) is a so-called "third-generation (3G)," broadband, packet-based transmission of text, digitized voice, video, and multimedia at data rates up to and possibly higher than 2 megabits per second (Mbps), offering a consistent set of services to mobile computer and phone users no matter where they are located in the world. Based on the GSM communication standard, UMTS, endorsed by major standards bodies and manufacturers, is the planned standard for

mobile users around the world by 2002. Once UMTS is fully implemented, computer and phone users can be constantly attached to the Internet as they travel and, as they roaming service, have the same set of capabilities no matter where they travel to. Users will have access through a combination of terrestrial wireless and satellite transmissions. Until UMTS is fully implemented, users can have multi-mode devices that switch to the currently available technology where UMTS is not yet available.

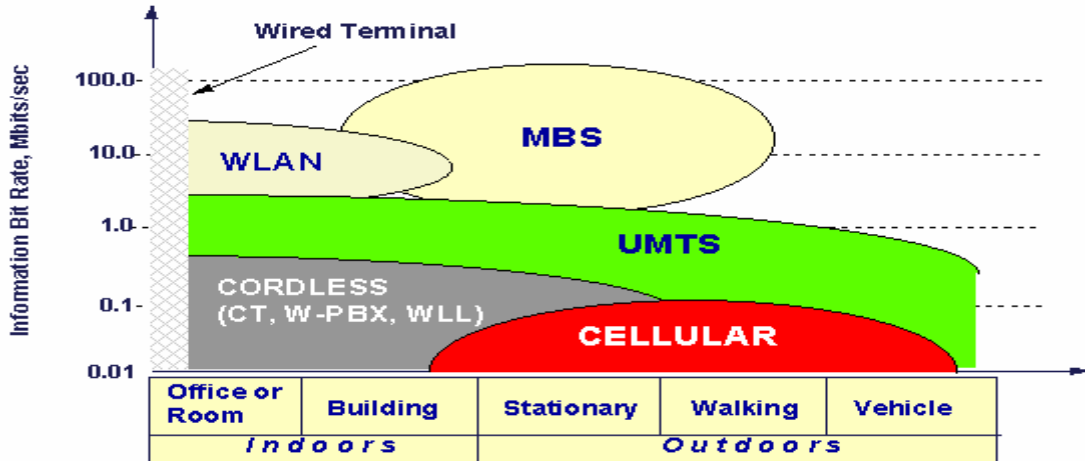


Fig 1. 3G System Overview

Today's cellular telephone systems are mainly circuit-switched, with connections always dependent on circuit availability. Packet-switched connection, using the Internet Protocol (Internet Protocol), means that a virtual connection is always available to any other end point in the network. It will also make it possible to provide new services, such as alternative billing methods (pay-per-bit, pay-per-session, flat rate, asymmetric bandwidth, and others). The higher bandwidth of UMTS also promises new services, such as video conferencing. UMTS promises to realize the Virtual Home Environment in which a roaming user can have the same services to which the user is accustomed when at home or in the office, through a combination of transparent terrestrial and satellite connections. **UMTS** is a network consisting of two main elements connected over a standard interface, called Iu. These two elements are:

UTRAN (UMTS Terrestrial Radio Access Network). This is composed of Node B which is equivalent to the GSM BTS and the Radio Network Controller (RNC) which is equivalent to the GSM BSC. A novelty with the UTRAN concept is the existence of a new modulation scheme: the Frequency Division Duplex (FDD) and W-CDMA. This mode offers the highest efficiency within a single system whatever the conditions—wide area, urban, indoor coverage from outdoor, indoor, and so on. One carrier use 5 Mhz.

The Core Network. This is the equivalent of the GSM NSS. There are two options for the implementation of 3G and the evolution of the GSM Core Network:

ATM based architecture: this R'99 architecture may reuses in some cases the two-domain architecture of GSM/GPRS, with:

Iu-PS (Packet Switched) interface instead of Gb on the packet domain.

Iu-CS (Circuit Switched) interface instead of A on the circuit domain.

Transport Independent and multimedia architecture: this R'00 architecture is in line with

the Next Generation Networks architecture and introduces separation of control and user planes. It also integrates multimedia capabilities.

3 Spread Spectrum System

- It is a kind of modulation system in which the modulated (spread spectrum) signal bandwidth is much greater than the message signal bandwidth
- The spectral spreading is performed by a code that is independent of the message signal. The same code is used at receiver to despread the received signal and to recover the message signal.

3.1 Benefits of Spread Spectrum System

- It is very secure, without knowing the chip code it is nearly impossible to intercept.
- A large number of codes can support a large number of users
- As a large bandwidth is used the system is less prone to distortion
- Since the power is distributed in a large bandwidth so the power spectral density goes below to noise level so it is resistant to jamming and remain invisible to unintended users.
- It provides asynchronous multiple access

3.2 Different Spread Spectrum Systems

3.2.1 Direct Sequence Spread Spectrum

In direct sequence spread spectrum, the stream of information to be transmitted is divided into small pieces, each of which is allocated across to a frequency channel across the spectrum. A data signal at the point of transmission is combined with a higher data-rate bit sequence (also known as a *chipping code*) that divides the data according to a spreading ratio. The redundant chipping code helps the signal resist interference and also enables the original data to be recovered if data bits are damaged during transmission.

3.2.2. Frequency Hopping

In an FH-CDMA system, a transmitter "hops" between available frequencies according to a specified algorithm, which can be either random or preplanned. The transmitter operates in synchronization with a receiver, which remains tuned to the same center

frequency as the transmitter. A short burst of data is transmitted on a narrowband. Then, the transmitter tunes to another frequency and transmits again. The receiver thus is capable of hopping its frequency over a given bandwidth several times a second, transmitting on one frequency for a certain period of time, then hopping to another frequency and transmitting again. Frequency hopping requires a much wider bandwidth than is needed to transmit the same information using only one carrier frequency. The Near-Far problem of DS/SS is avoided here. FH-CDMA devices use less power and are generally cheaper, but the performance of DS-CDMA systems is usually better and more reliable. The biggest advantage of frequency hopping lies in the coexistence of several access points in the same area, something not possible with direct sequence.

3.2.3 Hybrid System: DS/(F)FH

The DS/FFH Spread Spectrum technique is a combination of direct-sequence and frequency-hopping. One data bit is divided over a number of (let N_{FH}) frequency-hop channel (carrier frequencies). In each frequency-hop channel one complete PN-code of length N is added to the data signal (in figure, N_{FH} is taken to be 5).

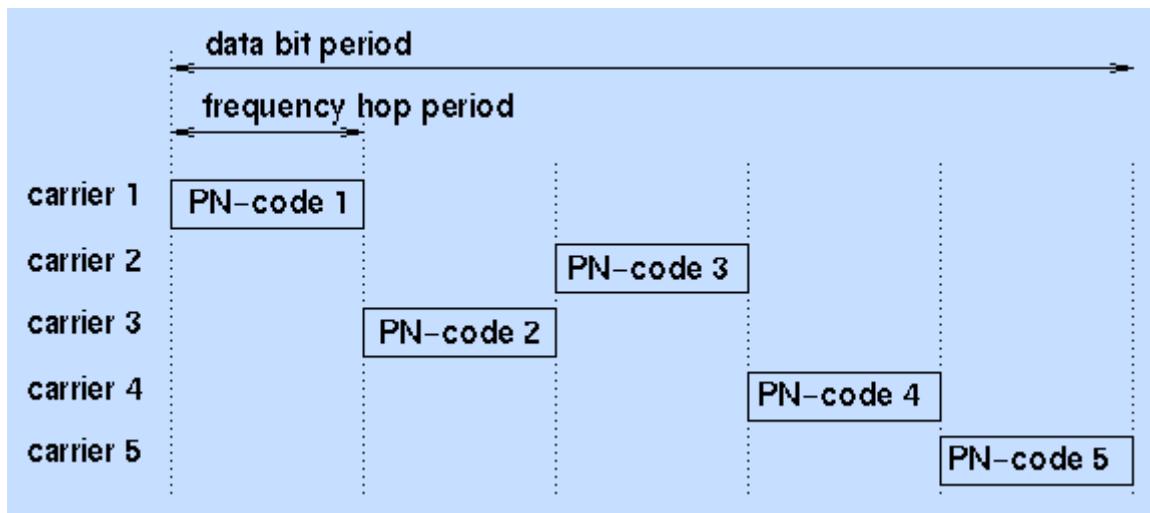


Fig 2. Example of DS/(F)FH System

As the FH-sequence and the PN-codes are coupled, an address is a combination of an FH-sequence and N_{FH} PN-codes. To bound the hit-chance (the chance that two users share the same frequency channel in the same time) the frequency-hop sequences are chosen in such a way that two transmitters with different FH-sequences share at most two frequencies at the same time (timeshift is random).

4 Code Division Multiple Access

CDMA is a form of multiplexing, which allows numerous signals to occupy a single transmission channel, optimizing the use of available bandwidth. The technology is used in ultra-high-frequency (UHF) cellular telephone systems in the 800-MHz and 1.9-GHz bands.

CDMA employs analog-to-digital conversion (ADC) in combination with spread spectrum technology. Audio input is first digitized into binary elements. The frequency of the transmitted signal is then made to vary according to a defined pattern (code), so it can be intercepted only by a receiver whose frequency response is programmed with the same code, so it follows exactly along with the transmitter frequency. There are trillions of possible frequency-sequencing codes; this enhances privacy and makes cloning difficult.

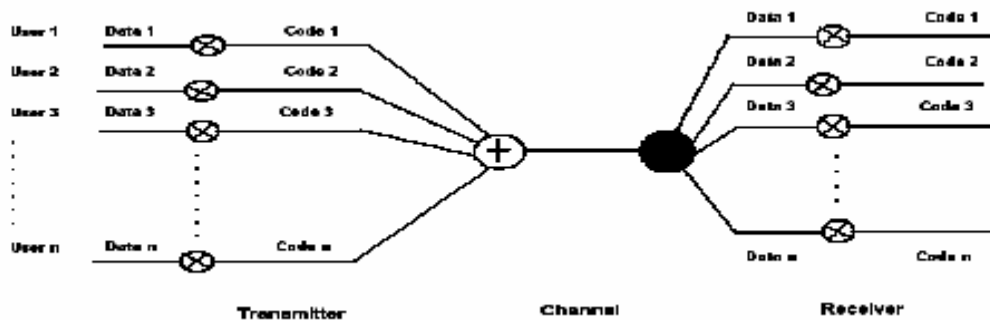


Fig 3. CDMA Procedure

5 WCDMA

The original CDMA standard, also known as CDMA One and still common in cellular telephones in the U.S., offers a transmission speed of only up to 14.4 Kbps in its single channel form and up to 115 Kbps in an eight-channel form. The next version of CDMA, CDMA2000, also known as IMT-CDMA Multi-Carrier or 1xRTT, can support mobile data communications at speeds ranging from 144 Kbps to 2 Mbps.

In CDMAOne and CDMA2000, a 1.25 MHz wide radio signal is multiplied by a spreading signal (which is a pseudo-noise code sequence) with a higher rate than the data rate of the message. The resultant signal appears as seemingly random, but if the intended recipient has the right code, this process is reversed and the original signal is extracted. Uses of unique codes mean that the same frequency is repeated in all cells, which is commonly referred to as a frequency re-use of 1.

WCDMA is a step further in the CDMA technology. It uses a 5 MHz wide radio signal and a chip rate of

3.84 Mcps, which is about three times higher than the chip rate of CDMA2000 (1.22 Mcps).

The main benefits of a wideband carrier with a higher chiprate are:

- Support for higher bit rates
- Higher spectrum efficiency thanks to improved trunking efficiency (i.e. a better statistical averaging)
- Higher QoS

Further, experience from second-generation systems like GSM and cdmaOne has enabled improvements to be incorporated in WCDMA. Focus has also been put on ensuring that as much as possible of WCDMA operators’ investments in GSM equipment can be re-used. Examples are the re-use and evolution of the core network, the focus on co-siting and the support of GSM handover. In order to use GSM handover the subscribers need dual mode handsets.

6 WCDMA Protocol Architecture

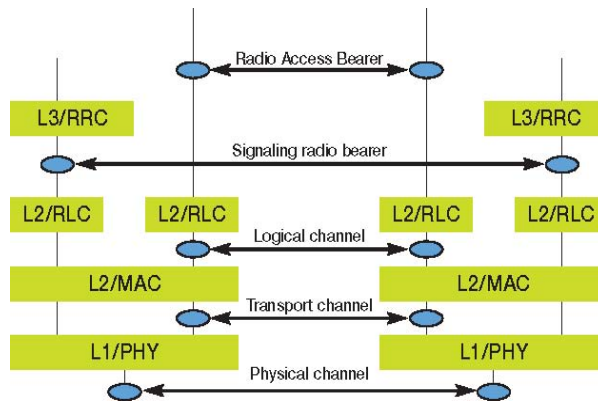


Fig 4. WCDMA Protocol Architecture

The **Physical Layer** (Layer 1) offers **Transport Channels** to the MAC layer. There are different types of transport channels with different characteristics of the transmission. Common transport channels can be shared by multiple handsets (e.g. FACH, RACH, DSCH, BCH, PCH). Dedicated transport channels (DCH) are assigned to only one handset at a time. The transmission functions of the physical layer include channel coding and interleaving, multiplexing of transport channels, mapping to physical channels, spreading, modulation and power amplification, with corresponding functions for reception. The following is the physical layer frame structure of WCDMA.

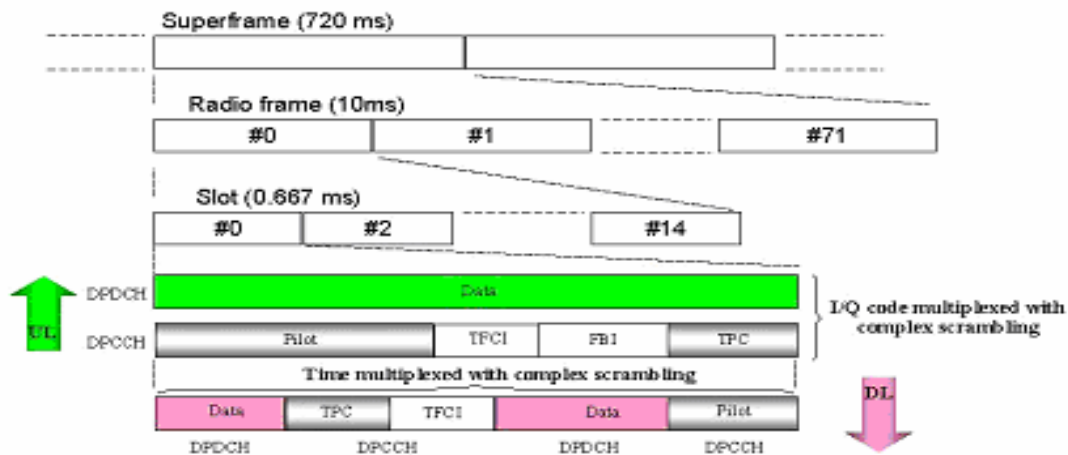


Fig 5. WCDMA Frame Structure

A frequency and a code characterize a physical channel. The specifications include two modes: the FDD mode (Frequency Division Duplex) and the TDD mode (Time Division Duplex). The FDD mode is the mainstream mode that operators are now deploying in WCDMA. The TDD mode may eventually be deployed as well, as a complement to the FDD mode.

The *Medium Access Control (MAC)* protocol (Layer 2) offers logical channels to the layers above. The logical channels are distinguished by the different type of information they carry. The main two types are,

- a. **Dedicated channel** –reserved for a single user only.
Support fast power control and soft handover.
- b. **Common channel** – can be used by any user at any time.
Don't support soft handover but some support fast power control.

Here is a complete mapping of different transport channels to physical channels.

Transport Channel	Physical Channel
(UL/DL) Dedicated channel DCH	Dedicated physical data channel DPDCH Dedicated physical control channel DPCCH
(UL) Random access channel RACH	Physical random access channel PRACH
(UL) Common packet channel CPCH	Physical common packet channel PCPCH
(DL) Broadcast channel BCH	Primary common control physical channel P-CCPCH
(DL) Forward access channel FACH (DL) Paging channel PCH	Secondary common control physical channel S-CCPCH
(DL) Downlink shared channel DSCH	Physical downlink shared channel PDSCH
Signaling physical channels	Synchronisation channel SCH
	Common pilot channel CPICH
	Acquisition indication channel AICH
	Paging indication channel PICH
	CPCH Status indication channel CSICH
	Collision detection/Channel assignment indicator channel CD/CA-ICH

Table 1. Mapping from Transport to Physical Channels

The MAC layer performs scheduling and mapping of logical channel data onto the transport channels provided by the physical layer. Also, for common transport channels, the MAC layer adds addressing information to distinguish data flows intended for different handsets. One major difference to GSM is the possibility to dynamically switch one logical channel (data flow) onto different transport channel types, e.g. based on the activity of the subscriber. This is called channel type switching.

The **Radio Link Control (RLC) protocol** (Layer 2) operates in one of three modes: transparent, unacknowledged or acknowledged mode. It performs segmentation/re-assembly functions and, in acknowledged mode, provides an assured mode delivery service by use of retransmission. RLC provides a service both for the RRC signaling (the **Signaling Radio Bearer**) and for the user data transfer (the **Radio Access Bearer**). The **Radio Resource Control (RRC) protocol** (Layer 3) provides control of the handset from the RNC. It includes functions to control radio bearers, physical channels, mapping of the different channel types, handover, measurement and other mobility procedures. Because of the flexibility of the WCDMA radio interface, this is a fairly complex protocol.

7 WCDMA System Overview

7.1 Radio Access Network (RAN) Architecture

The main purpose of the WCDMA Radio Access Network is to provide a connection between the handset and the core network and to isolate all the radio issues from the core network. The advantage is one core network supporting multiple access technologies. The WCDMA Radio Access Network consists of two types of nodes:

a. Radio Base Station (Node B)

The Radio Base Station handles the radio transmission and reception to/from the handset over the radio interface (Uu). It is controlled from the Radio Network Controller via the Iub interface. One Radio Base Station can handle one or more cells.

b. Radio Network Controller (RNC)

The Radio Network Controller is the node that controls all WCDMA Radio Access Network functions. It connects the WCDMA Radio Access Network to the

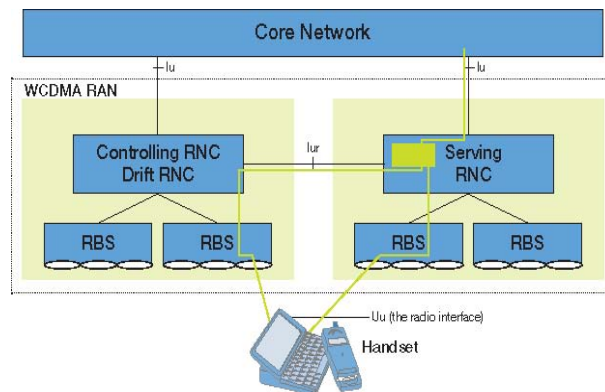


Fig 6. Transport network

core network via the Iu interface. There are two distinct roles for the RNC, to serve and to control. The Serving RNC has overall control of the handset that is connected to WCDMA Radio Access Network. It controls the connection on the Iu interface for the handset and it terminates several protocols in the contact between the handset and the WCDMA Radio Access Network.

The Controlling RNC has the overall control of a particular set of cells, and their associated base stations. When a handset must use resources in a cell not controlled by its Serving RNC, the Serving RNC must ask the Controlling RNC for those resources. This request is made via the Iur interface, which connects the RNCs with each other. In this case, the Controlling RNC is also said to be a Drift RNC for this particular handset. This

kind of operation is primarily needed to be able to provide soft handover throughout the network.

7.1.1 Radio Access Bearers

The main service offered by WCDMA RAN is the Radio Access Bearer (RAB). To establish a call connection between the handset and the base station a RAB is needed. Its characteristics are different depending on what kind of service/information to be transported.

The RAB carries the subscriber data between the handset and the core network. It is composed of one or more Radio Access Bearers between the handset and the Serving RNC, and one lu bearer between the Serving RNC and the core network. 3GPP has defined four different quality classes of Radio Access Bearers:

- Conversational (used for e.g. voice telephony)
 - low delay, strict ordering
- Streaming (used for e.g. watching a video clip)
 - moderate delay, strict ordering
- Interactive (used for e.g. web surfing)
 - moderate delay
- Background (used for e.g. file transfer)
 - no delay requirement

Both the Conversational and Streaming RABs require a certain reservation of resources in the network, and are primarily meant for real-time services. They differ mainly in that the Streaming RAB tolerates a higher delay, appropriate for one-way real-time services. The Interactive and Background RABs are so called 'best effort', i.e. no resources are reserved and the throughput depends on the load in the cell. The only difference is that the Interactive RAB provides a priority mechanism.

The RAB is characterized by certain Quality of Service (QoS) parameters, such as bit rate and delay. The core network will select a RAB with appropriate QoS based on the service request from the subscriber, and ask the RNC to provide such a RAB.

7.2. *Transports in WCDMA Radio Access Network*

The WCDMA Radio Access Network nodes communicate with each other over a transport network. The 3GPP specification provides a very clear split between radio related (WCDMA) functionality and the transport technology, meaning that there is no particular bias to any technology. The transport network is initially based on ATM, but IP will soon be included as an option.

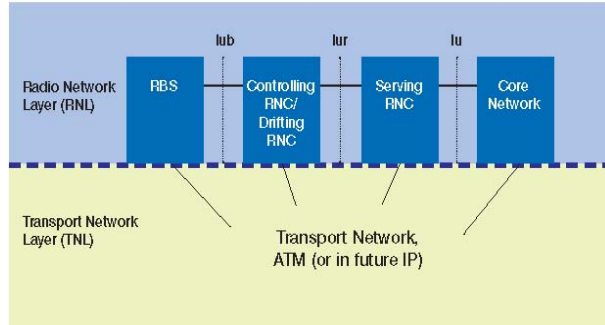


Fig 7. Transport network

8 Hand-Over between WCDMA and GSM system

9 Abbreviations

CDMA	Code Division Multiple Access	GSM BSS	GSM Base Station Subsystem
WCDMA	Wideband Code Division Multiple Access	GSM BSC	GSM Base Station Controller
cdmaOne	Code Division Multiple Access as specified in IS-95	GSM BTS	GSM Base Transceiver Station
CDMA 2000	Code Division Multiple Access as specified in IS-2000	TDMA	Time Division Multiple Access
ITU	International Telecommunication Union	RNC	Radio Network Controller
3GPP	3rd Generation Partnership Project	RAB	Radio Access Bearer
Mcps	Mega chips per second	QoS	Quality of Service
GSM	Global System for Mobile Communication	FDD	Frequency Division Duplex
RBS	Radio Base Station	TDD	Time Division Duplex
Node B	Radio Base Station	MAC	Medium Access Control
RAN	Radio Access Network	RLC	Radio Link Control
		RRC	Radio Resource Control
		IP	Internet Protocol