white paper

**Basic Concepts of
WCDMA Radio Access Network**

ERICSSON

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1 Background

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 down loading 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. Ericsson has for a long time played a very active role in both ITU and 3GPP and is a major contributor to WCDMA and the fulfillment of the vision of a global mobile telecommunication system.

2 WCDMA a development from GSM and CDMA

Naturally there are a lot of differences between WCDMA and GSM systems, but there are many similarities as well.

GSM/WCDMA Architecture
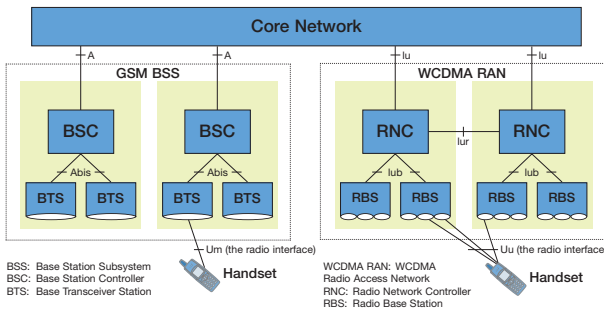
The GSM Base Station Subsystem (BSS) and the WCDMA Radio Access Network (RAN) are both connected to the GSM core network for providing a radio connection to the handset. Hence, the technologies can share the same core network.

Furthermore, both GSM BSS and WCDMA RAN systems are based on the principles of a cellular radio system. The GSM Base Station Controller (BSC) corresponds to the WCDMA Radio Network Controller (RNC). The GSM Radio Base Station (RBS) corresponds to the WCDMA RBS, and the A-interface of GSM was the basis of the development of the Iu-interface of WCDMA, which mainly differs in the inclusion of the new services offered by WCDMA.

The significant differences, apart from the lack of interface between the GSM BSCs and an insufficiently specified GSM Abis-interface to provide multi-vendor operability, are more of a systemic matter. The GSM system uses TDMA (Time Division Multiple Access) technology with a lot of radio functionality based on managing the timeslots. The WCDMA system on the other hand uses CDMA, as described below, which means that both the hardware and the control functions are different. Examples of WCDMA-specific functions are fast power control and soft handover.

2.1 Code Division Multiple Access and WCDMA

Code Division Multiple Access (CDMA) is a multiple access technology where the users are separated by unique codes, which means that all users can use the same frequency and transmit at the same time. With the fast development in signal processing, it has become feasible to use the technology for wireless communication, also referred to as WCDMA and CDMA2000.

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. Use of unique codes means 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.

3 Radio Network Functionality

For optimal operation of a complete wireless system i.e. from handset to radio access network (RAN) several functions are needed to control the radio network and the many handsets using it. All functions described in this section, except for Handover to GSM, are essential and therefore necessary for a WCDMA system.

3.1 Power control

The power control regulates the transmit power of the terminal and base station, which results in less interference and allows more users on the same carrier. Transmit power regulation thus provides more capacity in the network.

With a frequency re-use of 1, it is very important to have efficient power control in order to keep the interference at a minimum. For each subscriber service the aim is that the base station shall receive the same power level from all handsets in the cell regardless of distance from the base station. If the power level from one handset is higher than needed, the quality will be excessive, taking a disproportionate share of the resources and generating unnecessary interference with the other subscribers in the network. On the other hand, if power levels are too low this will result in poor quality. In order to keep the received power at a suitable level, WCDMA has a fast power control that updates power levels 1500 times every second. By doing that the rapid change in the radio channel is handled. To ensure good performance, power control is implemented in both the up-link and the down-link, which means that both the output powers of the handset and the base station are frequently updated.

Power control also gives rise to a phenomenon called "cell breathing". This is the trade-off between coverage and capacity, which means that the size of the cell varies depending on the traffic load. When the number of subscribers in the cell is low (low load), good quality can be achieved even at a long distance from the base station. On the other hand, when the number of users in the cell is high, the large number of subscribers generates a high interference level and subscribers have to get closer to the base station to achieve good quality.


High Loadcase

Low Loadcase
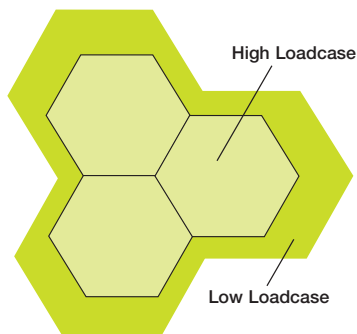
3.2 Soft and softer handover

With soft handover functionality the handset can communicate simultaneously with two or more cells in two or more base stations. This flexibility in keeping the connection open to more than one base station results in fewer lost calls, which is very important to the operator.

Cell A   Cell B
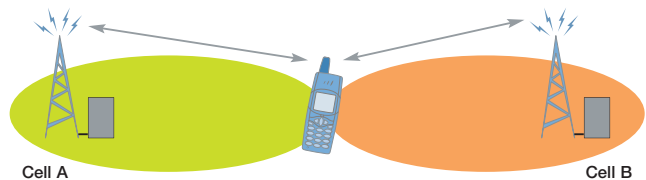
To achieve good system performance with a frequency re-use of 1 and power control, soft and softer handover is required. Soft and softer handover enables the handset to maintain the continuity and quality of the connection while moving from one cell to another. During soft or softer handover, the handset will momentarily adjust its power to the base station that requires the smallest amount of transmit power and the preferred cell may change very rapidly.

The difference between soft and softer handover is that during soft handover, the handset is connected to multiple cells at different base stations, while during softer handover, the handset is connected to multiple cells at the same base station. A drawback with soft handover is that it requires additional hardware resources on the network side, as the handset has multiple connections. In a well-designed radio network, 30–40 % of the users will be in soft or softer handover.

RNC

RBS   RBS   RBS

Softer   Soft
Handover   Handover
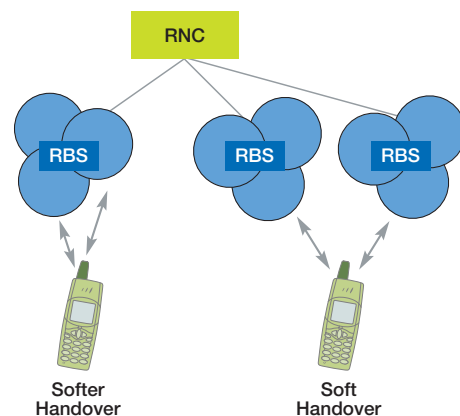
3.3 Handover to GSM (inter-system handover)

When WCDMA was standardized a key aspect was to ensure that existing investments could be re-used as much as possible. One example is handover between the new (WCDMA) network and the existing (GSM) network, which can be triggered by coverage, capacity or service requirements.

Handover from WCDMA to GSM, for coverage reasons, is initially expected to be very important since operators are expected to deploy WCDMA gradually within their existing GSM network. When a subscriber moves out of the WCDMA coverage area, a handover to GSM has to be conducted in order to keep the connection. Handover between GSM and WCDMA can also have a positive effect on capacity through the possibility of load sharing.

If for example the numbers of subscribers in the GSM network is close to the capacity limit in one area, handover of some subscribers to the WCDMA network can be performed.

First
Expansion

WCDMA

GSM/GPRS
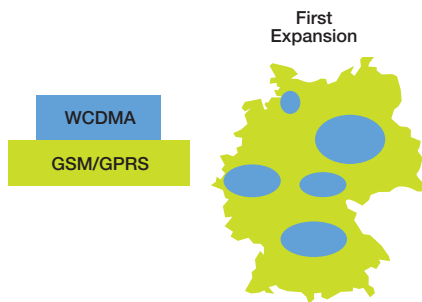
Another function that is related to inter-system handover is the compressed mode. When performing handover to GSM, measurements have to be made in order to identify the GSM cell to which the handover will be made. The compressed mode is used to create the measurement periods for the handset to make the required measurements. This is typically achieved by transmitting all the information during the first 5 milliseconds of the frame with the remaining 5 milliseconds being used for measurements on the other systems.

3.4 Inter-frequency handover (intra-system handover)

The need for inter-frequency handover occurs in high capacity areas where multiple 5 MHz WCDMA carriers are deployed. Inter-frequency handover, which is handover between WCDMA carriers on different frequencies, has many similarities with GSM handover, for example the compressed mode functionality.

3.5 Channel type switching

In WCDMA there are different types of channels that can be used to carry data in order to maximize the total traffic throughput. The two most basic ones are common channels and dedicated channels. Channel type switching functionality is used to move subscribers between the common and the dedicated channel, depending on how much information the subscriber needs to transmit.

The dedicated channel is used when there is much information to transmit, such as a voice conversation or downloading a web page. It utilizes the radio resources efficiently as it supports both power control and soft handover.

The common channel, on the other hand, is less spectrum efficient. One benefit is that the common channel reduces delays as many subscribers can share the same resource. Hence it is the preferred channel for the transfer of very limited information.

3.6 Admission control

As there is a very clear trade-off between coverage and capacity in WCDMA systems, the admission control functionality is used to avoid system overload and to provide the planned coverage. When a new subscriber seeks access to the network, admission control estimates the network load and based on the new expected load, the subscriber is either admitted or blocked out. By this the operator can maximize the network usage within a set of network quality levels, i.e. levels depending on what kind of service/information the subscriber wants to use.

3.7 Congestion control

Even though an efficient admission control is used, overload may still occur, which is mainly caused by subscribers moving from one area to another area. If overload occurs, four different actions can be taken. First, congestion control is activated and reduces the bit rate of non real-time applications, to resolve the overload. Second, if the reduced bit rate activity is not sufficient, the congestion control triggers the inter- or intra-frequency handover, which moves some sub-

scribers to less loaded frequencies. Third, handover of some subscribers to GSM and forth action is to discontinue connections, and thus protect the quality of the remaining connections.

3.8 Synchronization

One of the basic requirements when WCDMA was standardized was to avoid dependence on external systems for accurate synchronization of base stations. This has been achieved by a mechanism, where the handset, when needed, measures the synchronization offset between the cells and reports this to the network. In addition, there is also an option to use an external source, such as GPS, for synchronizing the nodes, i.e. to always provide the best solution both asynchronous and synchronous nodes are supported

4 Basic architecture concepts/System overview

In this section some fundamental views of the WCDMA Radio Access Network will be presented. This includes the WCDMA RAN architecture itself, the radio interface protocol architecture, the Radio Access Bearer concept and the role of the transport network in a WCDMA RAN.

4.1 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:

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.

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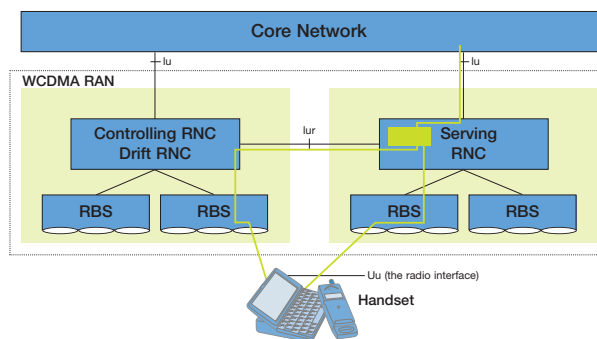
core network via the Iu interface. There are two distinct roles for the RNC, to serve and to control. The Serving RNC has overall control of the handset that is connected to WCDMA Radio Access Network. It controls the connection on the Iu interface for the handset and it terminates several protocols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

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 Iu 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.

4.2 Transport 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.

Transport network
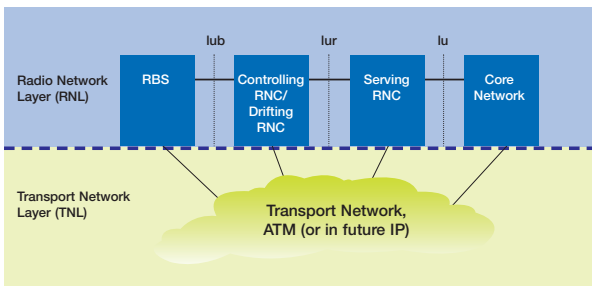

4.3 Radio Interface Overview

The protocol stack of the radio interface between WCDMA Radio Access Network and the handset consists of a number of protocol layers, each giving a specific service to the next layer above. The main purpose with each layer is as follows:

Layer 3: Signaling to control the connection to the handset.

Layer 2: If there is time for it, to retransmit packets which has been received in error.

Layer 1: To transmit and receive data over the radio, including basic protection against bit errors.

Radio interface Protocol Structure
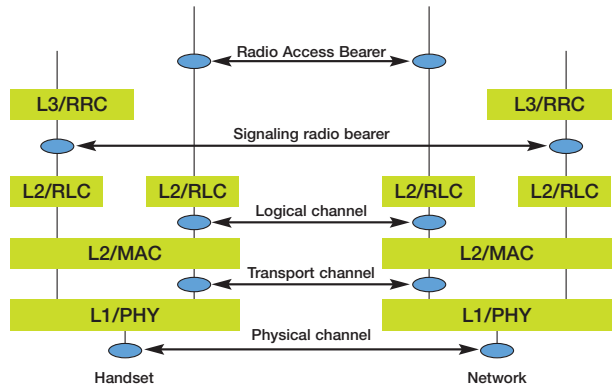
The **Physical Layer** (Layer 1) offers **Transport Channels** to the MAC layer. There are different types of transport channels with different characteristics of the transmission. Common transport channels can be shared by multiple handsets (e.g. FACH, RACH, DSCH, BCH, PCH). Dedicated transport channels (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.

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. This document does not describe the TDD 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, and thus include the Dedicated Control Channel (DCCH), Common Control Channel (CCCH), Dedicated Traffic Channel (DTCH), Common Traffic Channel (CTCH), Broadcast Control Channel (BCCH) and the Paging Control Channel (PCCH). The MAC layer performs scheduling and map-

ping of logical channel data onto the transport chan-
nels provided by the physical layer. Also, for common
transport channels, the MAC layer adds addressing
information to distinguish data flows intended for dif-
ferent 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, unac-
knowledged or acknowledged mode. It performs
segmentation/re-assembly functions and, in acknow-
ledged mode, provides an assured mode delivery ser-
vice 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.

5 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
		TDMA	Time Division Multiple Access
CDMA 2000	Code Division Multiple Access as specified in IS-2000	RNC	Radio Network Controller
		RAB	Radio Access Bearer
ITU	International Telecommunication Union	QoS	Quality of Service
3GPP	3rd Generation Partnership Project	FDD	Frequency Division Duplex
Mcps	Mega chips per second	TDD	Time Division Duplex
GSM	Global System for Mobile Communication	MAC	Medium Access Control
RBS	Radio Base Station	RLC	Radio Link Control
Node B	Radio Base Station	RRC	Radio Resource Control
RAN	Radio Access Network	IP	Internet Protocol

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