CHAPTER 2

WCDMA NETWORK

2.1 INTRODUCTION

WCDMA is a third generation mobile communication system that uses CDMA technology over a wide frequency band to provide high-speed multimedia and efficient voice services. The WCDMA infrastructure is compatible with GSM mobile radio communication system. WCDMA provides for high-speed data and voice communication services. Installing or upgrading to WCDMA technology allows mobile service providers to offer their customers wireless broadband (high-speed Internet) services and to operate their systems more efficiently (more customers per cell site radio tower).

The WCDMA system is composed of mobile devices (wireless telephones and data communication devices called user equipment-UE), radio towers (cell sites called Node Bs), and a packet data interconnection system (switches and data routers). The WCDMA system uses two types of radio channels; FDD and TDD. The FDD radio channels are primarily used for wide area voice (audio) channels and data services. The TDD channels are typically used for systems that do not have the availability of dual frequency bands [47].

Figure 2.1 shows a simplified diagram of a WCDMA system. This diagram shows that the WCDMA system includes various types of mobile communication devices (called user equipment - UE) that communicate through base stations (node B) and a mobile switching center (MSC) or data routing networks to connect to other mobile telephones, public telephones, or to the Internet via a core network (CN). This diagram shows that the WCDMA system is compatible with both the 5 MHz wide WCDMA radio channel and the narrow 200 kHz GSM channels. This example also shows that the core network is essentially divided between voice systems (circuit switching) and packet data (packet switching).
2.2 SYSTEM ARCHITECTURE

The UMTS utilizes the same well-known architecture that has been used by all main second generation systems and even by some first generation systems. The reference list contains the related 3GPP specifications.

The UMTS system consists of a number of logical network elements that each has a defined functionality. In the standards, network elements are defined at the logical level, but this quite often results in a similar physical implementation, especially since there are a number of open interfaces (for an interface to be ‘open’, the requirement is that it has been defined to such a detailed level that the equipment at the endpoints can be from two different manufacturers). The network elements can be grouped based on similar functionality, or based on which sub-network they belong to.

Functionally the network elements are grouped into the Radio Access Network (RAN) that handles all radio-related functionality, and the Core Network, which is responsible for switching and routing calls and data connections to external networks. To complete the system, the User Equipment (UE) that interfaces with the user and the radio interface is defined.
From a specification and standardization point of view, both UE and UMTS Terrestrial Radio Access Network (UTRAN) consist of completely new protocols, the design of which is based on the needs of the new WCDMA radio technology. On the contrary, the definition of CN is adopted from GSM. This gives the system with new radio technology a global base of known and rugged CN technology that accelerates and facilitates its introduction, and enables such competitive advantages as global roaming.

Another way to group UMTS network elements is to divide them into sub-networks. The UMTS system is modular in the sense that it is possible to have several network elements of the same type. In principle, the minimum requirement for a fully featured and operational network is to have at least one logical network element of each type (note that some features and consequently some network elements are optional). The possibility of having several entities of the same type allows the division of the UMTS system into sub-networks that are operational either on their own or together with other sub-networks, and that are distinguished from each other with unique identities. Such a sub-network is called a UMTS Public Land Mobile Network (PLMN). Typically one PLMN is operated by a single operator, and is connected to other PLMNs as well as to other types of network, such as Integrated Services Digital Network (ISDN), PSTN, the Internet, and so on. Figure 2.2 shows elements in a PLMN and, in order to illustrate the connections, also external networks.

Figure 2.2 Network elements in a PLMN
The UTRAN architecture is presented and a short introduction to all the elements is given below.

The UE consists of two parts:

- The Mobile Equipment (ME) is the radio terminal used for radio communication over the Uu interface.
- The UMTS Subscriber Identity Module (USIM) is a smartcard that holds the subscriber identity, performs authentication algorithms, and stores authentication and encryption keys and some subscription information that is needed at the terminal.

UTRAN also consists of two distinct elements:

- The Node B converts the data flow between the Iub and Uu interfaces. It also participates in radio resource management.
- The Radio Network Controller (RNC) owns and controls the radio resources in its domain (the Node Bs connected to it). RNC is the service access point for all services UTRAN provides the CN, for example, management of connections to the UE.

The main elements of the GSM CN such as those used to provide IN services are as follows:

- Home Location Register (HLR) is a database located in the user’s home system that stores the master copy of the user’s service profile. The service profile consists of, for example, information on allowed services, forbidden roaming areas, and supplementary service information such as status of call forwarding and the call forwarding number. It is created when a new user subscribes to the system, and remains stored as long as the subscription is active. For the purpose of routing incoming transactions to the UE (e.g. calls or short messages), the HLR also stores the UE location on the level of Mobile Services Switching Centre/Visitor Location Register (MSC/VLR) and/or SGSN, i.e. on the level of the serving system.
MSC/VLR is the switch (MSC) and database (VLR) that serves the UE in its current location for Circuit Switched (CS) services. The MSC function is used to switch the CS transactions, and the VLR function holds a copy of the visiting user’s service profile, as well as more precise information on the UE’s location within the serving system. The part of the network that is accessed via the MSC/VLR is often referred to as the CS domain.

Gateway MSC (GMSC) is the switch at the point where UMTS PLMN is connected to external CS networks. All incoming and outgoing CS connections go through GMSC.

Serving GPRS (SGSN) Support Node functionality is similar to that of MSC/VLR but is typically used for Packet Switched (PS) services. The part of the network that is accessed via the SGSN is often referred to as the PS domain. Similar to MSC, SGSN support is needed for the early UE handling operation.

Gateway GPRS Support Node (GGSN) functionality is close to that of GMSC but is in relation to PS services.

The external networks can be divided into two groups:

- **CS networks.** These provide circuit-switched connections, like the existing telephony service. ISDN and PSTN are examples of CS networks.
- **PS networks.** These provide connections for packet data services. The Internet is one example of a PS network.

The UMTS standards are structured so that the internal functionality of the network elements is not specified in detail. Instead, the interfaces between the logical network elements have been defined. The following main open interfaces are specified:

- **Cu interface.** This is the electrical interface between the USIM smartcard and the ME. The interface follows a standard format for smartcards.
- **Uu interface.** This is the WCDMA radio interface, which is the subject of the main part of this book. The Uu is the interface through which the UE accesses the fixed part of the system, and is therefore probably the most
important open interface in UMTS. There are likely to be many more UE manufacturers than manufacturers of fixed network elements.

- **Iu interface.** This connects UTRAN to the CN. Similarly to the corresponding interfaces in GSM, A (Circuit Switched) and Gb (Packet Switched), the open Iu interface gives UMTS operators the possibility of acquiring UTRAN and CN from different manufacturers. The enabled competition in this area has been one of the success factors of GSM.

- **Iur interface.** The open Iur interface allows soft handover between RNCs from different manufacturers, and therefore complements the open Iu interface.

- **Iub interface.** The Iub connects a Node B and an RNC. UMTS is the first commercial mobile telephony system where the Controller–Base Station interface is standardized as a fully open interface. Like the other open interfaces, open Iub is expected to further motivate competition between manufacturers in this area. It is likely that new manufacturers concentrating exclusively on Node Bs will enter the market.

### 2.3 UTRAN ARCHITECTURE

UTRAN consists of one or more Radio Network Sub-systems (RNS). An RNS is a sub network within UTRAN and consists of one RNC and one or more Node Bs. RNCs may be connected to each other via an Iur interface. RNCs and Node Bs are connected with an Iub interface.
Before entering into a brief description of the UTRAN network elements (in this section) and a more extensive description of UTRAN interfaces (in the following sections), we present the main characteristics of UTRAN that have also been the main requirements for the design of the UTRAN architecture, functions and protocols. These can be summarized in the following points:

- Support of UMTS Terrestrial Radio Access (UTRA) and all the related functionality. In particular, the major impact on the design of UTRAN has been the requirement to support soft handover (one terminal connected to the network via two or more active cells) and the WCDMA-specific Radio Resource Management algorithms.
- Maximization of the commonalities in the handling of packet-switched and circuit switched data, with a unique air interface protocol stack and with the use of the same interface for the connection from UTRAN to both the PS and CS domains of the core network.
- Maximization of the commonalities with GSM, when possible.
- Use of the ATM transport as the main transport mechanism in UTRAN.
- Use of the IP-based transport as the alternative transport mechanism in UTRAN from Release 5 onwards.
2.4 PROTOCOL ARCHITECTURE

The protocol architecture is similar to the current ITU-R protocol architecture, ITU-R M.1035. The air interface is layered into three protocol layers:

- The physical layer (layer 1, L1);
- The data link layer (layer 2, L2);
- Network layer (layer 3, L3).

The physical layer [48] interfaces the medium access control (MAC) sub layer of layer 2 and the radio resource control (RRC) layer [49] of layer 3. The physical layer offers different transport channels to MAC. A transport channel is characterized by how the information is transferred over the radio interface. Transport channels are channel coded and then mapped to the physical channels specified in the physical layer. MAC offers different logical channels to the radio link control (RLC) sub layer of layer 2. A logical channel is characterized by the type of information transferred.

Layer 2 is split into following sub layers: MAC, RLC, packet data convergence protocol (PDCP) and broadcast/multicast control (BMC). Layer 3 and RLC are divided into control and user planes. PDCP and BMC exist in the user plane only. In the control plane, layer 3 is partitioned into sub layers where the lowest sub layer, denoted as RRC, interfaces with layer 2. The RLC sub layer provides Automatic repeat request (ARQ) functionality closely coupled with the radio transmission technique used.
<table>
<thead>
<tr>
<th>Specification</th>
<th>Name</th>
<th>Scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>TS 25.201</td>
<td>Physical layer – general description</td>
<td>Describes the contents of the layer 1 documents (TS 25.200 series); where to find information; a general description of layer 1</td>
</tr>
</tbody>
</table>
| TS 25.211     | Physical channels and mapping of transport channels onto physical channels (FDD) | Establishes the characteristics of the layer-1 transport channels and physical channels in the FDD mode, and specifies:  
• transport channels  
• physical channels and their structure  
• relative timing between different physical channels in the same link, and relative timing between uplink and downlink  
• mapping of transport channels onto the physical channels. |
| TS 25.212     | Multiplexing and channel coding (FDD) | Describes multiplexing, channel coding, and interleaving in the FDD mode and specifies:  
• coding and multiplexing of transport channels  
• channel coding alternatives  
• coding for layer 1 control information  
• different interleavers  
• rate matching  
• physical channel segmentation and mapping. |
| TS 25.213     | Spreading and modulation (FDD) | Establishes the characteristics of the spreading and modulation in the FDD mode, and specifies:  
• spreading  
• generation of channelization and scrambling codes  
• generation of random access preamble codes  
• generation of synchronization codes  
• modulation. |
| TS 25.214     | Physical layer procedures (FDD) | Establishes the characteristics of the physical layer procedures in the FDD mode, and specifies:  
• cell search procedures  
• power control procedures  
• random access procedure. |
| TS 25.215     | Physical layer measurements (FDD) | Establishes the characteristics of the physical layer measurements in the FDD mode, and specifies:  
• the measurements performed by layer 1  
• reporting of measurements to higher layers and network  
• handover measurements and idle-mode measurements. |
2.4.1 Logical channels

The MAC layer [50] provides data transfer services on logical channels. A set of logical channel types are defined for different kinds of data transfer services as offered by MAC. Each logical channel type is defined by the type of information that is transferred. Logical channel types are depicted in Figure 6.3. Logical channels are classified into two groups:

- Control channels for the transfer of control plane information (Table 2.2)
- Traffic channels for the transfer of user plane information (Table 2.3)

Table 2.2 Logical Control Channels

<table>
<thead>
<tr>
<th>Broadcast control channel (BCCH)</th>
<th>Downlink channel for broadcasting system control information.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paging control channel (PCCH)</td>
<td>Downlink channel that transfers paging information and is used when:</td>
</tr>
<tr>
<td></td>
<td>- Network does not know the location cell of the mobile station;</td>
</tr>
<tr>
<td></td>
<td>- The mobile station is in the cell connected state (utilizing sleep mode procedures)</td>
</tr>
<tr>
<td>Common control channel (CCCH)</td>
<td>Bidirectional channel that transfers control information between network and mobile stations. This channel is used:</td>
</tr>
<tr>
<td></td>
<td>- By the mobile stations having no RRC connection with the network;</td>
</tr>
<tr>
<td></td>
<td>- By the mobile stations using common transport channels when accessing a new cell after cell reselection</td>
</tr>
<tr>
<td>Dedicated control channel (DCCH)</td>
<td>Point-to-point bidirectional channel that transmits dedicated control information between a mobile station and the network. This channel is established through RRC connection setup procedure</td>
</tr>
<tr>
<td>ODMA common control channel (OCCCH)</td>
<td>Bidirectional channel for transmitting control information between mobile stations</td>
</tr>
<tr>
<td>ODMA dedicated control channel (ODCCH)</td>
<td>Point-to-point bidirectional channel that transmits dedicated control information between mobile stations. This channel is established through RRC connection setup procedure.</td>
</tr>
</tbody>
</table>
Table 2.3 Traffic Channels

<table>
<thead>
<tr>
<th>Dedicated traffic channel (DTCH)</th>
<th>Point-to-point channel, dedicated to one mobile station, for the transfer of user information. A DTCH can exist in both uplink and downlink.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ODMA dedicated traffic channel (ODTCH)</td>
<td>Point-to-point channel, dedicated to one mobile station, for the transfer of user information between mobile stations. An ODTCH exists in relay link. A point-to-multipoint unidirectional channel for transfer of dedicated user information for all or a group of specified mobile stations.</td>
</tr>
</tbody>
</table>

2.4.2 Transport channels

A transport channel is defined by how and with what characteristics data is transferred over the air interface [51]. There exist two types of transport channels:

- Dedicated channels
- Common channels, listed in Table 2.4.

There is one dedicated transport channel, the dedicated channel (DCH), which is a downlink or uplink transport channel. The DCH is transmitted over the entire cell or over only a part of the cell using beam-forming antennas. The DCH is characterized by the possibility of fast rate change (every 10 ms), the fast power control, and the inherent addressing of mobile stations.
Table 2.4 Traffic Channels

<table>
<thead>
<tr>
<th>Channel Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadcast channel (BCH)</td>
<td>Downlink transport channel that is used to broadcast system- and cell-specific information. The BCH is always transmitted over the entire cell with a low fixed bit rate.</td>
</tr>
<tr>
<td>Forward access channel (FACH)</td>
<td>Downlink transport channel. The FACH is transmitted over the entire cell or over only a part of the cell using beam-forming antennas. The FACH uses slow power control.</td>
</tr>
<tr>
<td>Paging channel (PCH)</td>
<td>Downlink transport channel. The PCH is always transmitted over the entire cell. The transmission of the PCH is associated with the transmission of a physical layer signal, the paging indicator, to support efficient sleep mode procedures.</td>
</tr>
<tr>
<td>Random access channel (RACH)</td>
<td>Uplink transport channel. The RACH is always received from the entire cell. The RACH is characterized by a limited size data field, a collision risk and by the use of open loop power control.</td>
</tr>
<tr>
<td>Common packet channel (CPCH)</td>
<td>Uplink transport channel. The CPCH is a contention-based random access channel used for transmission of bursty data traffic. CPCH is associated with a dedicated channel on the downlink, which provides power control for the uplink CPCH.</td>
</tr>
<tr>
<td>Downlink shared channel (DSCH)</td>
<td>Downlink transport channel shared by several mobile stations The DSCH is associated with a DCH.</td>
</tr>
</tbody>
</table>

2.5 PHYSICAL CHANNELS

The transport channels are channel coded and matched to the data rate offered by physical channels [52]. Thereafter, the transport channels are mapped on the physical channels. Physical channels consist of radio frames and time slots. The length of a radio frame is 10 ms and one frame consists of 15 time slots. A time slot is a unit, which consists of fields containing bits. The number of bits per time slot depends on the physical channel. Depending on the symbol rate of the physical channel, the configuration of radio frames or the time slots varies. The basic physical resource is the Code/frequency plane. In addition, on the uplink, different information streams may be transmitted on I and Q branch.
2.5.1 Downlink Physical Channel (DPCH)

There is one downlink dedicated physical channel, one shared and five common control channels:

- Downlink dedicated physical channel (DPCH)
- Physical downlink shared channel (DSCH)
- Primary and secondary common pilot channels (CPICH)
- Primary and secondary common control physical channels (CCPCH)
- Synchronization channel (SCH)

The DPCH carries both, user data and control information, in a time-multiplexed manner. The downlink DPCH can be interpreted as a time multiplex of a DPCCH and a DPCCH as shown in figure 2.4.

![Figure 2.4 Downlink DPCH Frame Structure](image)

The Dedicated Physical Data Channel (DPDCH) consists of two fields (Data1, Data2) for the transmission of the transport channels of Layer 2. The Dedicated Physical Control Channel (DPCCH) part of a DPCH slot has three fields, which are used for Transmission Power Control (TPC), Transport Format Combination Indicator (TFCI) and pilot bits. The TPC bits carry the power control command for the uplink power control. With the TFCI bits the receiver is informed
how the transport channels, which are mapped to the current transmitted downlink DPDCH, are combined. This field is optional and can be omitted, e.g. for fixed-rate services. The transmission of a TFCI field is determined by the UTRAN. The pilot bits are used for the channel estimation in the receiver.

The actually used fields and the exact number of bits per field is given by the slot format, which is signalled by higher layers. The possible spreading factors in the downlink range from 4 to 512, according to \( SF = 512/2^k \). The parameter \( k \) determines the total number of bits per downlink DPCH slot. Therefore, channel bit rates of 15 kbps up to 960 kbps are achievable in the downlink with a single code. Higher bit rates are possible with multicode transmission where several DPCH with the same spreading factor are transmitted in parallel. The used simulation environment offers eight different slot formats. Each of them corresponds to one spreading factor.

2.6 SPREADING

Spreading means increasing the bandwidth of the signal beyond the bandwidth normally required accommodating the information. The spreading process in UTRAN consists of two separate operations [53]: channelization and scrambling and are shown in figure 2.5.

![Figure 2.5 Spreading procedure](image_url)
2.6.1 Channelization Codes

The first operation is the channelization operation, which transforms every data symbol into a number of chips, thus increasing the bandwidth of the signal. The number of chips per data symbol is called the spreading factor (SF). Channelization codes are orthogonal codes, meaning that in an ideal environment they do not interfere each other. By channelization codes, the transmissions from a single source are separated i.e. dedicated physical channel in the uplink from one terminal and downlink connection within one sector.

The use of orthogonal variable spreading factor (OVSF) codes which allows the spreading factor to be changed and hence orthogonality among different kind of spreading codes having different lengths to be maintained. As illustrated in the figure 2.6, the codes are taken from the code tree. In case of connections uses variable spreading factor, the correct use of code tree also allows disspreading according to spreading factor. Hence it only requires that channelization code which is used from branch indicated by the code used for spreading factor [1].

![Channelization code trees](image)

Figure 2.6 Channelization code trees

For the transmission of single source, there are certain restrictions as to which of the channelization codes can be used. There is another physical channel which may use a certain code in the tree if no other physical channel to be
transmitted using the similar code tree is using a code that is on an underlying branch i.e. using a higher spreading factor which is generated from the intended spreading code to be used. Within each base station, the downlinks orthogonal are managed by the RNC in the network.

2.6.2 Scrambling

The second operation is the scrambling operation. Scrambling is used on top of spreading, so it does not change the signal bandwidth but only makes the signals from different sources separable from each other. As the chip rate is already achieved in channelization by the channelization codes, the chip rate is not affected by the scrambling [1].

It is required to separate terminals or base station from each other. Scrambling which is required on the top of spreading so it does not change the bandwidth of signal but only makes the signals separable from different sources. With scrambling, it does not matter if the actual spreading were performed for several transmitters with identical code. The relationship of the chip rate in channel to spreading and scrambling in UTRA is shown in the figure2.5. The already achieved the chip rate in spreading by the channelization code and the symbol rate is not affected by scrambling.

2.7 SUMMARY

This chapter provides a description of UMTS. The main parts of the UMTS system Architecture are summarized in the beginning furthermore the structure of the radio interface and multiple access method used in UMTS are presented. The chapter is dedicated to the physical layer of the radio interface protocol since the implementation of the simulation environment for this thesis is based on it.