



FACULTY OF TECHNOLOGY

Information Technology

Information Technology and Communications

BACHELOR'S THESIS

**NETWORK LAYER PROTOCOL ACTIVATION FOR PACKET DATA ACCESS IN UMTS
WCDMA LABORATORY NETWORK**

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PREFACE

This study was made for Helsinki Metropolia University of Applied Sciences. I would like to thank my supervisor Seppo Lehtimäki for his guidance and encouragement. I am also thankful to my language inspector Jonita Martelius who helped me with the language correction of the study and gave me good structural advices. Last but not least, I want to thank my wife for supporting me throughout this study.

Helsinki 6.6.2011

Erkka Lakkisto

TIIVISTELMÄ

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<p>Tämän insinöörityön tavoitteena oli saattaa käyttökuntoon Helsinki Metropolia Ammatti- korkeakoulun laboratoriossa sijaitseva UMTS WCDMA –tukiasema ja tutkia pakettidatayh- teyden avauksessa tapahtuvia protokollia.</p> <p>3G-verkon kehitys on ollut erittäin nopeaa ympäri maailman ja tällä hetkellä se on yksi langattoman tietoliikenteen pääverkko teknologioista. Metropolian laboratoriossa sijaitse- van kolmannen sukupolven matkapuhelinverkon toteutus mahdollistaa nykypäivän mo- dernin verkkoteknologian opetuksen ja tutkimisen.</p> <p>Laboratoriossa käytetty verkko rakennettiin käyttäen Nokian valmistamaa Flexi WCDMA – tukiasemaa, Nethawkin RNC/lub simulaattoria ja Nokian N73 3G matkapuhelinta. Labora- torioverkko on osittain simuloitu, koska Nethawk RNC/lub simulaattori on tietokonepohjai- nen ohjelmisto/työkalu. Pakettidatayhteyttä tutkittiin TEMS Investigation 6.1 tietokoneoh- jelmalla.</p> <p>Verkon konfiguraatio ja ylösajo suoritettiin onnistuneesti. Pakettidatayhteyden protokollien tutkiminen ja mittaustulokset saatiin onnistuneesti tehtyä TEMS analysaattorilla. PDP Context aktivointi sekä RRC yhteyden muodostus saatiin todennettua onnistuneesti ja yhteyden laatu todettiin soveltuvaksi datayhteyden käyttöön.</p>	
Avainsanat: UMTS, 3G, WCDMA, RNC, RRC, PDP Context	

ABSTRACT

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<p>The purpose of this Bachelor's Thesis was to set up the UMTS WCDMA network in the laboratory environment of Helsinki Metropolia University of Applied Sciences and to study the network layer protocol activation for packet data access.</p> <p>The development of 3G technology has been very rapid and it can be considered as one of the main technologies in telecommunication. Implementing the laboratory network in Metropolia enables teaching and researching of the modern network technology.</p> <p>Laboratory network was built using the Nokia Flexi WCDMA Base Station, Nethawk RNC/Iub simulator and Nokia N73 3G mobile phone. The network was partly simulated due to Nethawk RNC/Iub simulator, a computer based tool. Packet data access was analysed with computer based TEMS Investigation 6.1 software.</p> <p>The setup and the configuration process of the laboratory network were successful. The measurements and the analysis of the packet data access protocols with TEMS analyzer were successfully accomplished. PDP Context activation and RRC Connection were successfully established and the quality of the network was verified to be suitable for packet data connection.</p>	
Keywords: UMTS, 3G, WCDMA, RNC, RRC, PDP Context	

PREFACE

TIIVISTELMÄ

ABSTRACT

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ABBREVIATIONS

ALCAP	Access Link Control Application Part
ATM	Asynchronous Transfer Mode
AAL2	ATM Adaptation Layer 2
BS	Base Station
CC	Call Control
CS	Circuit Switched
CS-MGW	Circuit Switched Media Gateway
CDMA	Code Division Multiple Access
CN	Core Network
EDGE	Enhanced Data rates for GSM
FACH	Forward Access Channel
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
GGSN	Gateway GPRS Support Node
GMSC	Gateway MSC
GPRS	General Packet Radio System
GSM	Global System for Mobile communications
GERAN	GSM EDGE Radio Access Network
HSDPA	High Speed Downlink Packet Access
HS-DSCH	High Speed Downlink Shared Channels
HLR	Home Location Register
ISDN	Integrated Services Digital Network
IF	Intermediate Frequency
IMT-DS	International Mobile Telecommunications - Direct Spread
IMT-MC	International Mobile Telecommunications - Multi-Carrier
IMT-TC	International Mobile Telecommunications - Time Code
IMT-2000	International Mobile Telecommunications 2000

ITU	International Telecommunication Union
IP	Internet Protocol
IMS	IP Multimedia Subsystem
L1	Layer 1, Physical layer
L2	Layer 2, Data link layer
L3	Layer 3, Network layer
MAC	Medium Access Control
MS	Mobile Station
MSC	Mobile Switching Centre
MM	Mobility Management
NBAP	Node B Application Part
PDP	Packet Data Protocol
PS	Packet Switched
PCH	Paging Channel
P2P	Peer-to-Peer
PSTN	Public Switched Telephony Network
QAM	Quadrature Amplitude Modulation
RAN	Radio Access Network
RANAP	Radio Access Network Application Protocol
RF	Radio Frequency
RLC	Radio Link Control
RNC	Radio Network Controller
RNS	Radio Network Sub-system
RRC	Radio Resource Control
RACH	Random Access Channel
SGSN	Serving GPRS Support Node
SIM	Subscriber Identity Module
STM	Synchronous Transfer Mode

3G	Third Generation
3GPP	Third Generation Partnership Project
TDMA	Time Division Multiple Access
UMTS	Universal Mobile Telecommunications System
UTRA	Universal Terrestrial Radio Access
UTRAN	Universal Terrestrial Radio Access Network
UE	User Equipment
USIM	User Services Identity Module
WCDMA	Wideband Code Division Multiple Access
VLR	Visitor Location Register
VoIP	Voice over Internet Protocol

1 INTRODUCTION

This study was made for Helsinki Metropolia University of Applied Sciences. The purpose of this Bachelor's Thesis was to setup the UMTS WCDMA network in the laboratory of Metropolia and to analyse network layer protocol activation for packet data access.

The main purpose of Third Generation network development has basically been an intension to offer faster packet data access in mobile network. The research process of the 3G technology offers tremendously new information in order to improve current voice and data services. New frequencies have also been adopted to efficiently cover sparsely populated boarder areas.

UMTS WDCMA network differs from its predecessor, Second Generation GSM network, by its functions. Connections between user equipment and Base Station are not separated by frequencies or timeslots in UMTS WCDMA network. All the traffic is transmitted on the same 5 MHz bandwidth and users and Base Stations are separated with scrambling codes from each other. 5MHz wide bandwidth also enables low transmission power.

The beginning of the study introduces the reader to the primary concept of Third Generation technology and provides the reader with the essential knowledge for understanding the following parts of the study. The later chapters describe the network structure, used equipment and network layer protocol activation in packet data access.

2 NETWORK ARCHITECTURE

In this chapter the basic concept of UMTS Network architecture is clarified and the essential information for understanding the study is presented.

The UMTS (Universal Mobile Telecommunications System) network architecture is required to provide a greater level of performance to the original GSM network. However, as many networks had migrated through the use of GPRS and EDGE, they already had the ability to carry data. Accordingly, many of the elements required for the WCDMA / UMTS network architecture were seen as a migration. This considerably reduced the cost of implementing the UMTS network as many elements were in place or simply needed upgrading.

With one of the major aims of UMTS being to be able to carry data, the UMTS network architecture was designed to enable a considerable improvement in data performance over that provided for GSM. [1, 2 p.64]

2.1 3G Architectures

When third-generation (3G) systems were initially considered, the goal was to enable a single global communication standard that could fulfill the needs of anywhere and anytime communication. An international organization called ITU (International Telecommunication Union) was established to create recommendations to achieve standardized radio and telecommunication network. ITU's vision was to support multiple radio environments (cellular, satellite, cordless, and local area networks) [3, p.20-21]

IMT-2000

IMT-2000 (International Mobile Telecommunications 2000) was introduced to begin the standardization of undefined third generation systems. The purpose of the project was to compose recommendations, which would lead to worldwide compatible network coverage by using different cell sizes from "in building" picocells to global satellite cells. Through this project five radio transmission technologies were approved as potential technologies for third generation network, as shown in Figure 1. [7, p.18-19]

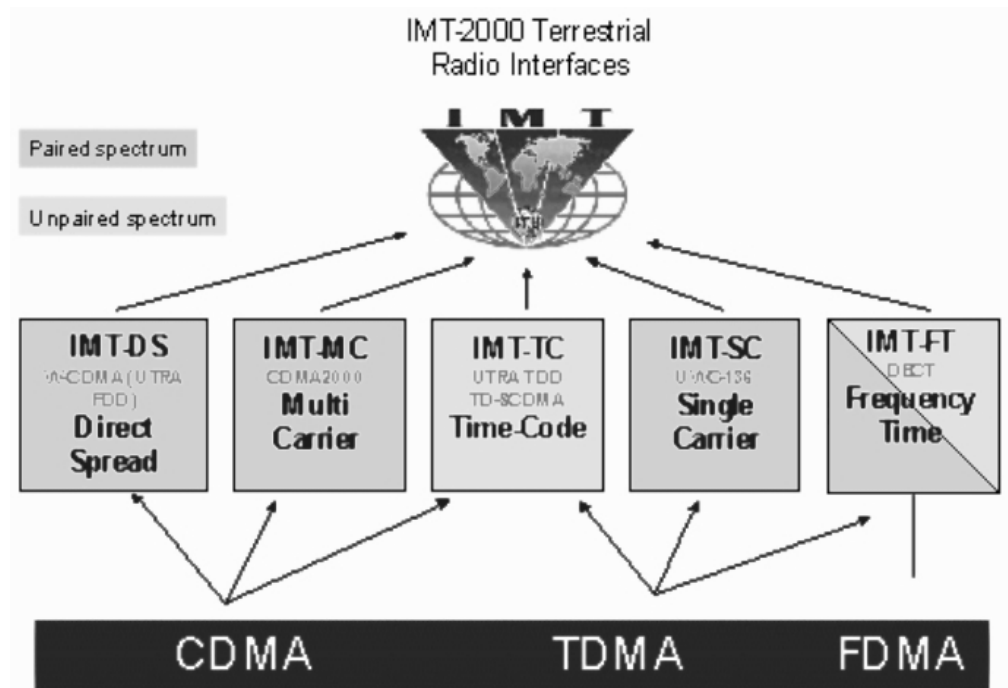


Figure 1, IMT-2000 Terrestrial Radio Interfaces [6]

Figure 1 presents five possible radio interfaces based on three different access technologies: CDMA (Code Division Multiple Access), TDMA (Time Division Multiple Access) and FDMA (Frequency Division Multiple Access). These technologies are illustrated in Figure 2.

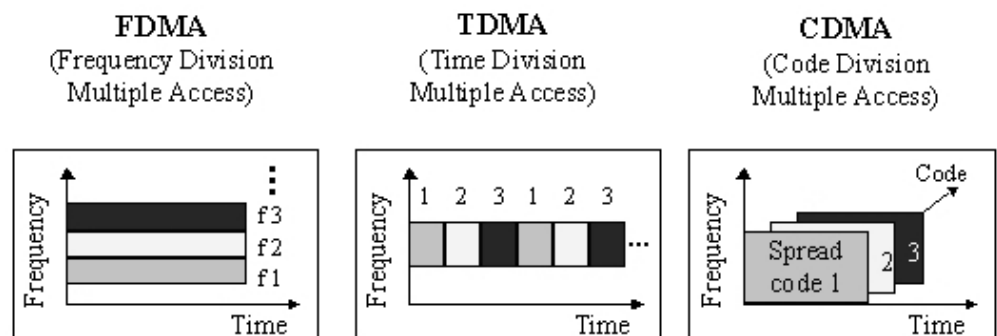


Figure 2, Network Access Technologies [6]

Figure 2 presents how multiple time and frequency slots are used in different access methods.

FDMA

FDMA is a technique whereby spectrum is divided up into frequencies and then assigned to users. With FDMA, only one subscriber at any given time is assigned to a channel. The channel therefore is closed to other conversations until the initial call is finished, or until it is handed-off to a different channel. A “full-duplex” FDMA transmission requires two channels, one for transmitting and the other for receiving.

TDMA

TDMA improves spectrum capacity by splitting each frequency into time slots. TDMA allows each user to access the entire radio frequency channel for the short period of a call. Other users share this same frequency channel at different time slots.

CDMA

CDMA is based on “spread” spectrum technology. It increases spectrum capacity by allowing all users to occupy all channels at the same time. Transmissions are spread over the whole radio band, and each voice or data call are assigned a unique code to differentiate from the other calls carried over the same spectrum. The dominant radio interface for IMT-2000, will be a wideband version of CDMA with three modes (IMT-DS, IMT-MC and IMT-TC) [6]

2.2 Early Steps of 3GPP Specifications

In the following, the gradual development of 3GPP specifications is explained in chronological order.

2.2.1 Release '99

The Release '99 core network has two domains: Circuit Switched (CS) and Packet Switched (PS), to cover the need for different traffic types. The division comes from the different requirements for the data, depending on whether it is real time (circuit switched) or non-real time (packet data). For example a voice call requires real time transmission and on the other hand web browsing can be handled as a non-real time action.

Figure 3 illustrates the Release '99 based core network where both CS and PS domains are shown. The Figure also contains registers, as well as the Service Control Point (SCP), to indicate the link for providing a particular service to the end user.

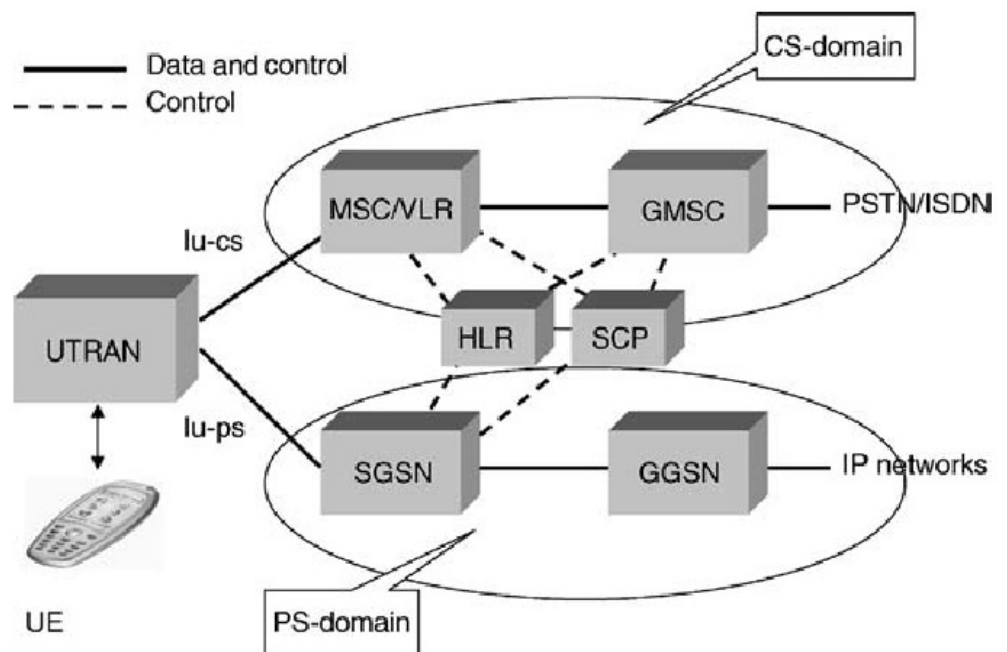


Figure 3, Release '99 UMTS core network structure [5, p.96]

The CS domain has the following elements:

- Mobile Switching Centre (MSC), including Visitor Location Register
- Gateway MSC (GMSC) connects CS core network to Public Switched Telephone Network (PSTN) and Integrated Services Digital Network (ISDN)

The PS domain has the following elements:

- Serving GPRS Support Node (SGSN), which covers similar functions as the MSC for the packet data, including VLR type functionality
- Gateway GPRS Support Node (GGSN) connects PS core network to other networks, for example to internet [5, p.95]

Figure 4 presents how GERAN and UTRAN are connected to PS and CS core networks.

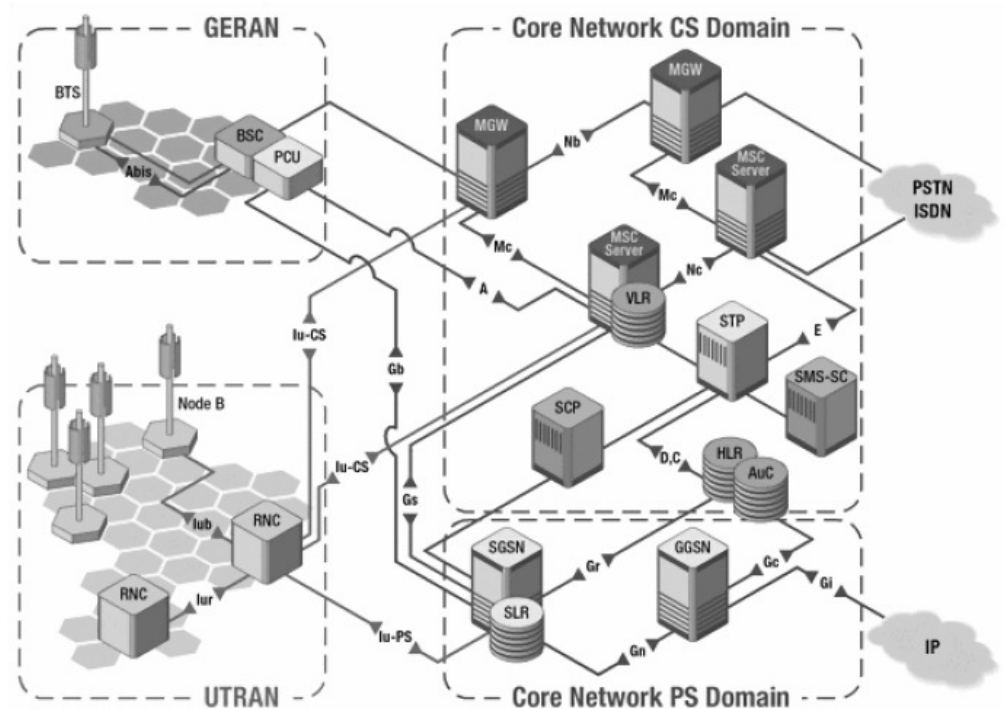


Figure 4, UTRAN, GERAN and Core Network

First phase core network must include definitions from GSM Release '99 so that the functions of the core network are equal to current GSM network. In addition, it is required to support at least 64 kbps data rate in Circuit Switched and 2 Mbps data rate in Packet Switched domain. Also, the user equipment must be able to create multiple simultaneous connections in the network.

This first phase Packet Switched data service is based on GPRS. Both UTRAN and GERAN networks connect through their own interfaces (UTRAN via Iu-PS and GERAN via Gb, Figure 4) to SGSN in Core Network PS Domain. [8, p.306]

2.2.2 Release 4

3GPP Release 4 brings a number of new features that can be applied partly in both UMTS and GSM networks and partly only in UMTS network.

Bearer Independent CS Architecture

Bearer Independent CS Architecture is able to provide more efficient data transmission resources than the traditional circuit-switched technology. In BICC (Bearer Independent Call Control) data transport and control is decentralized to each other. This enables to use one single set of L3 (Layer 3) protocols (e.g. DTAP in TS 24.008 or MAP in TS 29.002) on top of different transport resources, as ATM (Asynchronous Transfer Mode), IP, STM (Synchronous Transfer Mode) or even new ones. External behaviour of network is same in both cases when user is connected to classical CS Domain or BICC network. Also, none of the protocols used on the radio interface is modified by this feature. As a result, for example there is no need for the terminals to support IP even if IP is the transport protocol used in the network. [9, p.7]

The basic principle is that the MSC is split into an MSC server and a (Circuit-Switched) Media Gateway (CS-MGW), which is illustrated in Figure 5. The external interfaces remain the same as much as possible as for a monolithic MSC. The MSC server provides the call control and mobility management functions, and the CS-MGW provides the stream manipulating functions, i.e. bearer control and transmission resource functions. The same applies to the GMSC, split into a GMSC server and a CS-MGW. [9, p.8]

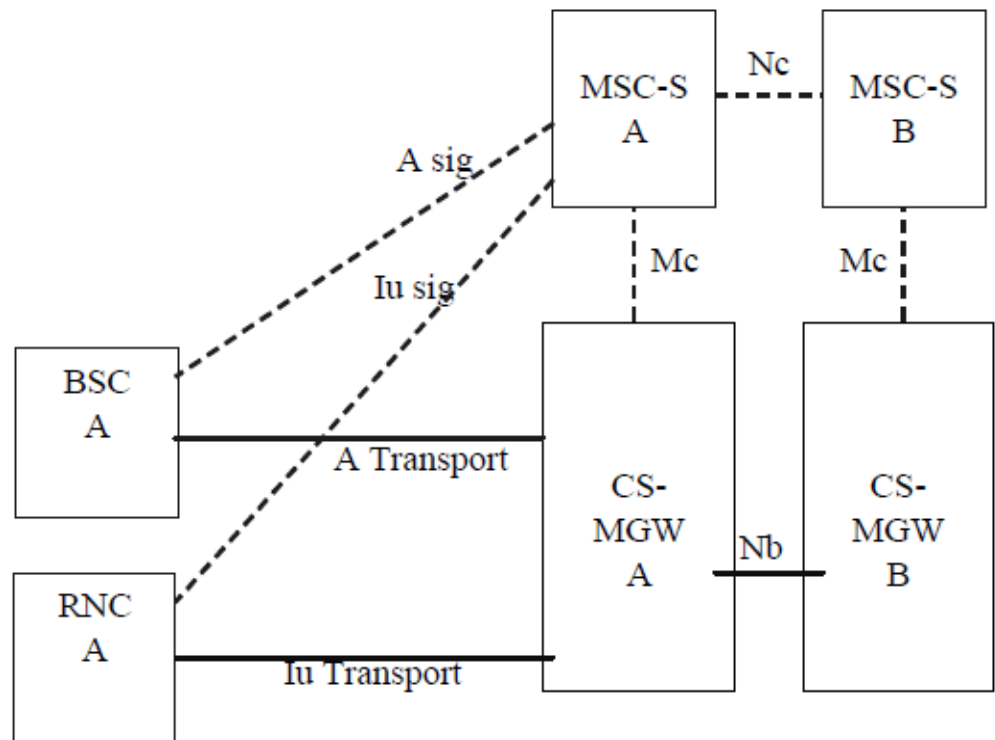


Figure 5, BICC network architecture [9, p.8]

Also, there are new interfaces in BICC architecture. Mc-interface is found between the (G)MSC Server and CS-MGW. MSC Servers are connected via Nc-interface and CS-MGWs via Nb-interface. [9, p.9]

General speech coding concepts

In a normal UE to UE call configuration, the Speech Signal is first encoded in the originating UE and sent to BSC over the Air Interface. Signal is converted to A-law or μ -law in the local transcoder (TRAU), carried over the fixed network, transcoded again in the distant transcoder, sent over the distant Air Interface and finally decoded in the terminating UE. Figure 6 illustrates signal path in BICC. [9, p.10]

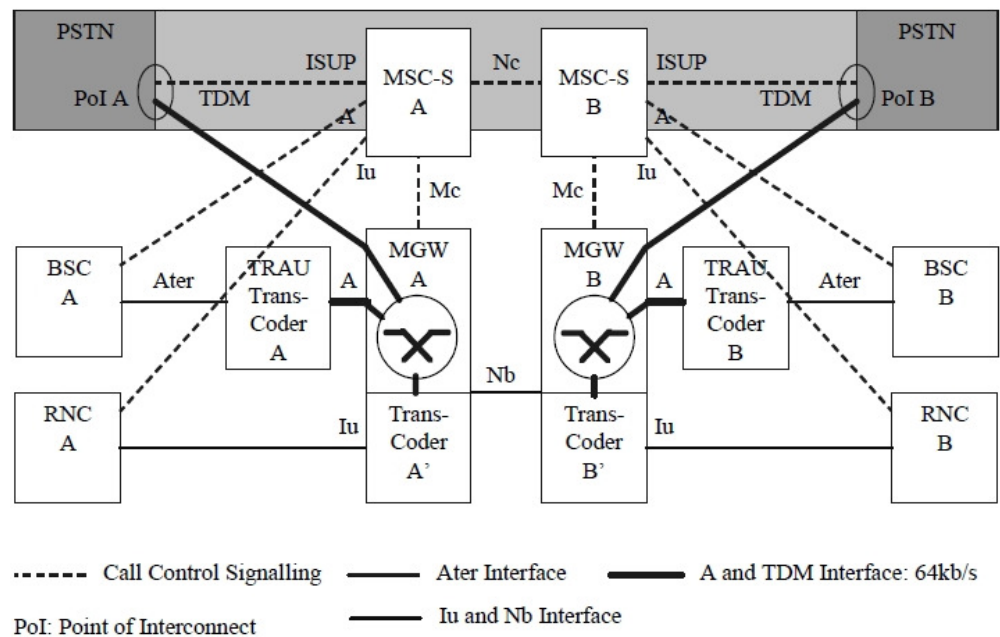


Figure 6, BICC with A- and Iu-Interfaces [9, p.10]

Figure 6 presents the different types of transcoding taking place for end-to-end calls, in case BICC is used. The end-user is a PSTN-user (upper part of the Figure), a GSM/GERAN user (middle part) or a UMTS-user (lower part). The radio interface and the UEs are not shown. [9, p.10]

Transparent End-to-End PS mobile streaming application (PSTREAM)

The applications which can be built on top of streaming services can be classified into "on-demand" and "live" information delivery. Examples of the first category are music and news-on-demand applications. Live delivery of radio and television programs are examples of the real-time category. PSTREAM enables a multitude of streaming applications to be deployed by content providers, without the need for them to own many different servers. The mobile users can also access much more content.

3GPP TS 26.233 defines the usage scenarios, overall high level end-to-end service concept, and lists terminal related functional components. It also lists any identified service interworking requirements. [9, p.14]

UTRA FDD Repeater

A repeater is a device that receives, amplifies and transmits the radiated or conducted RF carrier both in the downlink direction and in the uplink direction. It converts the signal down to IF (Intermediate Frequency), amplifies

and filters it and converts it back to RF without processing the signal in base band. Figure 7 shows a simple schema of the use of a repeater. [9, p.19]

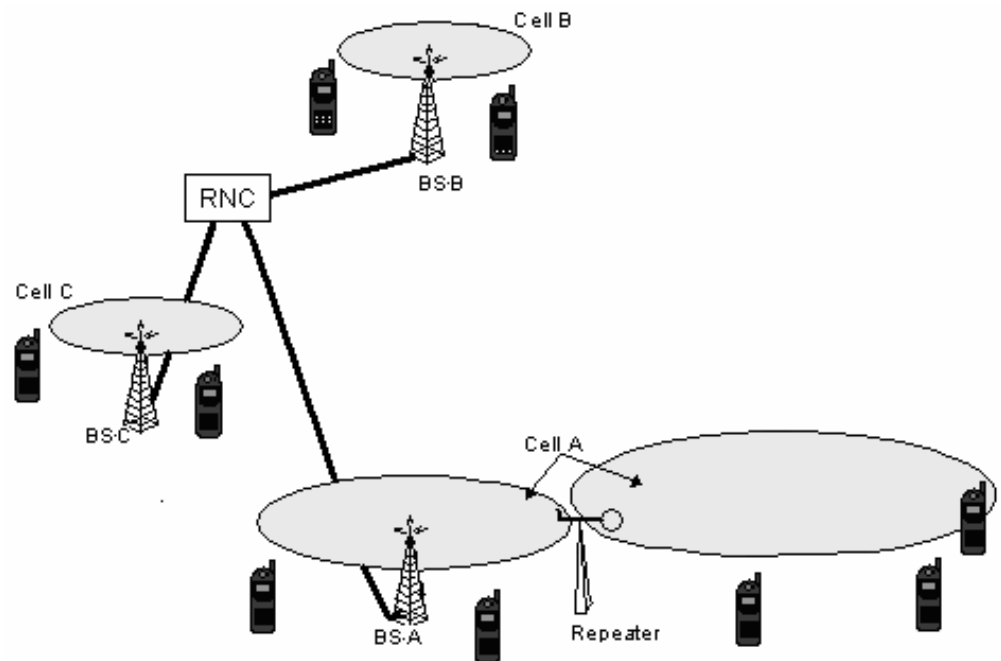


Figure 7, Use of a repeater in UTRA FDD [9, p.19]

As illustrated in Figure 7, an attenuated signal from Base Station -A is put through a repeater and Cell A is expanded by coverage area of the repeater. Transmission capacity can not be increased with repeater, but increased coverage area can reach more end-users. Requirements for repeaters are specified in TS 25.106 and TS 25.143.

2.2.3 Release 5

3GPP Release brings significant changes to core network architecture. Whereas in Release '99 there are only two domains in the core network, CS and PS, in Release 5 a new IP Multimedia Subsystem (IMS) domain is introduced.

IMS

IP Multimedia Subsystem (IMS) is a generic architecture for offering multimedia and voice over IP services. IMS employs an enhanced PS domain, and uses its services to offer IMS multimedia services. The IMS standard will speed the adoption of IP based multimedia on user equipment. IMS will make Internet technologies, such as web browsing, e-mail, instant messaging and video conferencing available to everyone from any location. The vi-

sion for the IMS core network is maximum flexibility and independence from the access technologies. Figure 8 illustrates a simplified structure of IMS network.

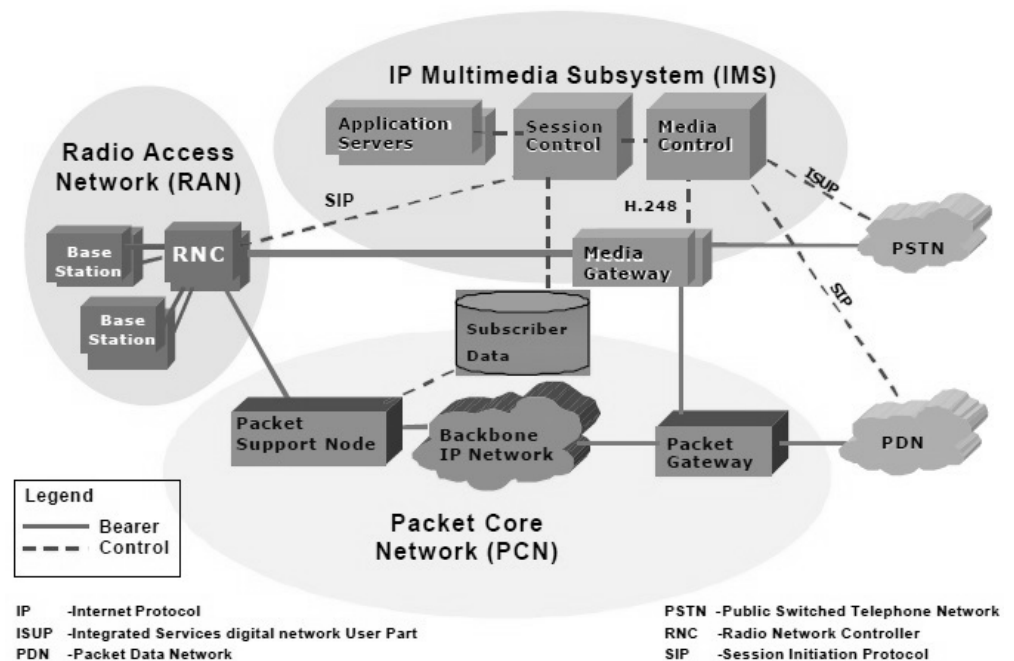


Figure 8, IMS and connected networks [15]

As shown in Figure 8, the Radio Access Network provides the over-the-air connection from the user equipment to the core network. It also provides low level mobility management. The Packet Core Network provides transport for the signaling and bearer, and high level mobility management. The IMS provides the control of applications, control of sessions, and media conversion. Within the IMS, media control, session control, and application control are separated in distinct entities.

HSDPA

High Speed Downlink Packet Access (HSDPA) is a major work item for 3GPP Release 5. The HSDPA concept has been designed to increase downlink packet data throughput by means of fast physical layer (L1) re-transmission and transmission combining, as well as fast link adaptation controlled by the Node B. Release 5 HSDPA can provide theoretical maximum data rate of 14.4 Mbps using 15 HS-DSCH (High Speed Downlink Shared Channels) code allocation and 16-QAM modulation. These functions require more resources from Node B in order to transmit data without any losses. Iub interface between Node B and RNC requires a flow control

mechanism to ensure that Node B buffers are used properly in case of buffer overflow.

Scheduling decisions are done also in Node B. The idea in HSDPA is to enable a scheduling that can provide most of the cell capacity to one user for a very short of time, when conditions are favourable. Fast fading of users can be prevented by optimized scheduling. The physical layer packet combining means that the user equipment stores the received data packets and if decoding has failed, the new transmission is combined with the old one before channel decoding. [5, p.307-310; 13, p. 462-463]

VoIP (Voice over Internet Protocol)

VoIP enables voice transfer in packet-switched all-IP network. Actually VoIP is not an improvement in voice transfer, but it is a mechanism that forces voice services into a packet-switched network not optimized to handle them. It had to be accomplished in order to use packet-switched IP everywhere. Current VoIP technology can provide a bandwidth efficient and low cost communication. A notable proprietary VoIP implementation is the Skype protocol, which is in part based on the principles of P2P (Peer-to-Peer) networking. [13, p.428]

2.3 UMTS Network Architecture

The Network is divided into domains and reference points, which are shown in Figure 9.

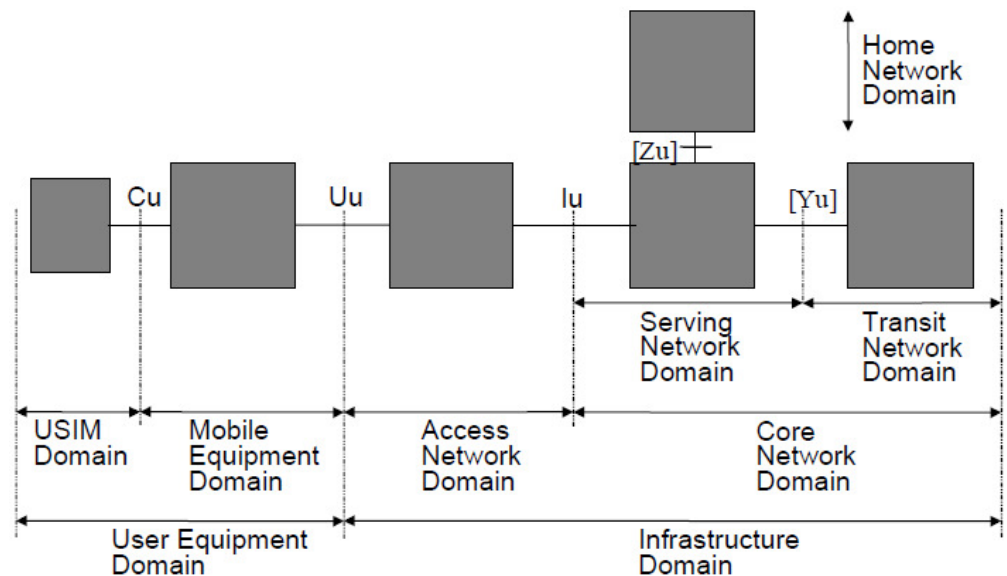


Figure 9, UMTS domains and reference points [11, p.7]

Uu-interface divides domains into two main domains, User Equipment Domain and Infrastructure Domain.

User Equipment Domain is composed of the Mobile Equipment, which is responsible of communication over Uu-interface and USIM that holds the service information.

Infrastructure Domain is composed of Access Network Domain and Core Network Domain. Access Network consists of Node B and Radio Network Controller (RNC). Core Network (CN) consists of Home Network domain, which contains permanently all the user specific data and is responsible for management of subscription information. CN includes also Serving Network and Transit Network Domains. [5, p.76; 11, p.7]

UMTS is one of the third generation mobile systems developed within ITU's recommendations. It is widely used all over Europe, including Finland. UMTS utilizes a great number of second and first generation systems and aims at reusing all available resources from older technology networks. The UMTS network can be divided into three different systems: UTRAN (Universal Terrestrial Radio Access Network), CN (Core Network) and UE (User

Equipment). The UMTS network architecture's components and interfaces are presented below in Figure 10. [4, p.9; 5, p.75]

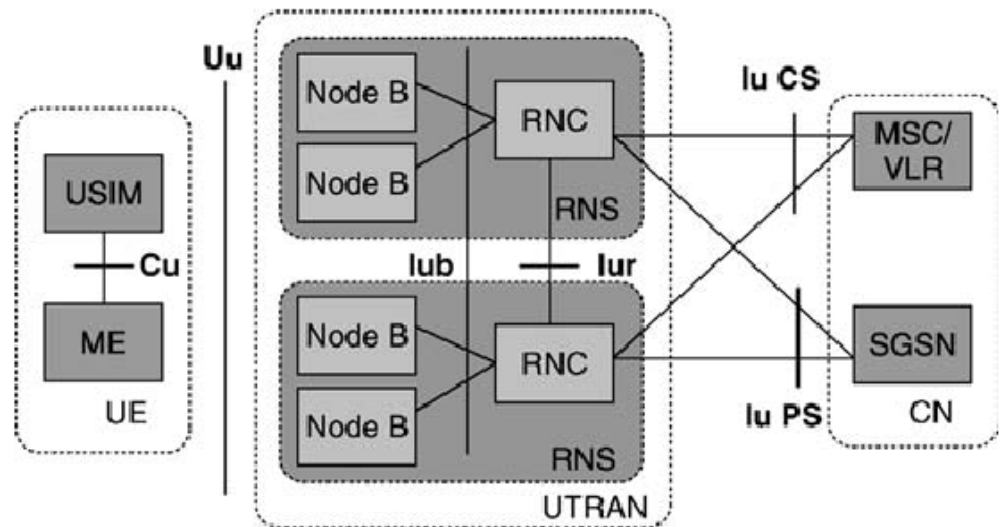


Figure 10, UMTS architecture [5, p.78]

As shown in Figure 10, user equipment (UE), UTRAN and Core Network (CN) are the main components in UMTS architecture. UTRAN handles all radio-related functionality. It consists of two parts:

- Node B converts the data flow between the Iub and Uu interfaces, e.g. channel coding and interleaving, rate adaptation and spreading. It also performs some basic radio resource management operations.
- RNC functions as an access point between UTRAN and CN. It is also in control of the radio resources in its domain.

The definition of Core Network is adopted from GSM network, while UE and UTRAN have been designed to meet the needs of WCDMA technology. The inherited Core Network simplifies the introduction of new technologies and offers advantages, such as global roaming.

2.4 Radio Network Controller

Radio Network Controller (RNC) is the controlling and switching element of the UTRAN. It merges UTRAN to Core Network through Iu interface and is connected to Node B via Iub interface. RNC also has a third interface called Iur for inter-RNS connections. Figure 11 illustrates the architecture of the RNC.

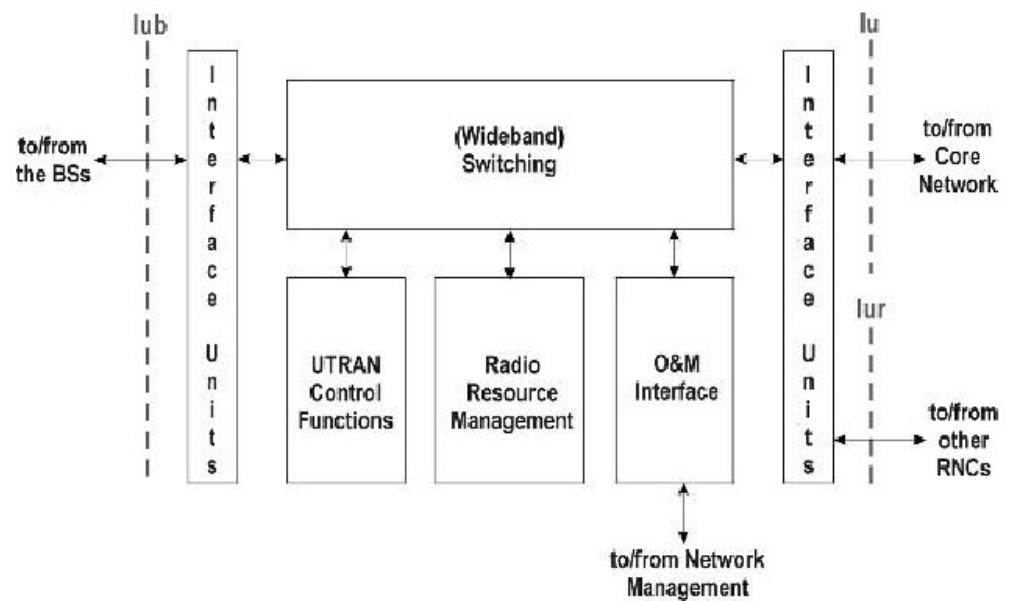


Figure 11, Basic logical architecture of the RNC [4, p.111]

When Iur interface is implemented in the network, the UE can be attached to the network through several RNCs with different logical roles during radio connection. These roles are Serving RNC (SRNC), Drifting RNC (DRNC) and Controlling RNC (CRNC).

The SRNC's main function is to maintain the Iu interface to CN and terminate the transport of user data and RANAP (Radio Access Network Application Protocol) signalling between UE and CN. SRNC also handles the L2 processing of the data and Radio Resource Control (RRC) between UE and UTRAN. Basic Radio Resource Management, such as mapping of Radio Access Bearer, handover decisions and outer loop power control, are executed in SRNC. One UE connected to UTRAN has only one SRNC.

The DRNC can be any other RNC than SRNC. The role of DRNC is used when UE needs to connect to another cell. It handles the data between the

interfaces lub and lur, except when the UE is using common or shared transport channels.

The CRNC is responsible for traffic and load control in Node B. It also handles admission control and code allocation. [4, p.11; 5, p.79]

2.5 lub Interface

The lub interface transfers information between RNC and Node B. Figure 12 illustrates the logical model of lub interface and its three layers: radio network layer, transport network layer and physical layer.

The lub interface signalling procedure NBAP (Node B Application Part) is divided into two components: Common and Dedicated NBAP.

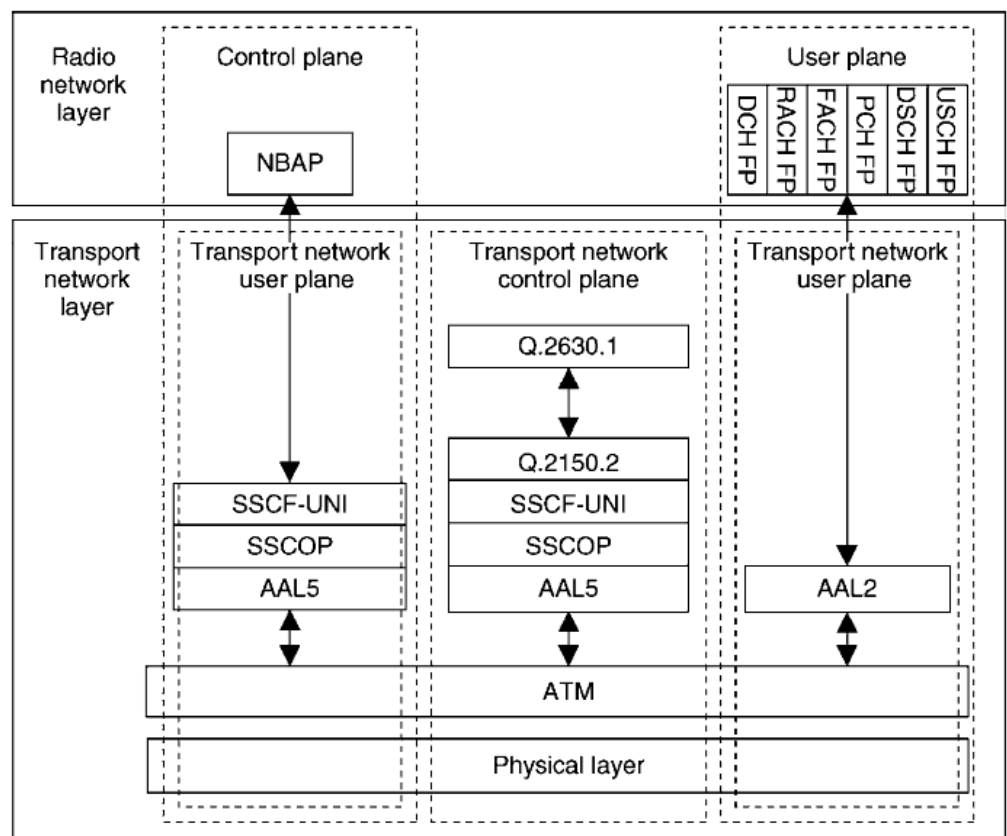


Figure 12, lub interface [5, p.91]

In the following the different planes of network layers are explained more in detail.

User Plane

All information sent and received by the user, such as the coded voice in a voice call or the packets in an Internet connection, are transported via the User Plane. [5, p.81]

Control Plane

The Control Plane is used for all UMTS-specific control signalling. It includes the Application Protocol (NBAP in Iub), and the Signalling Bearer for transporting the Application Protocol messages. The Application Protocol is used, among other things, for setting up bearers to the user equipment. [5, p.81]

Transport Network User Plane

The Data Bearers in the User Plane, and the Signalling Bearers for the Application Protocol, also belong to the Transport Network User Plane. The Data Bearers are directly controlled by the Transport Network Control Plane during real-time operation, but the control actions required for setting up the Signalling Bearers for the Application Protocol are considered O&M (Operation and Maintenance) actions. [5, p.82]

Transport Network Control Plane

The Transport Network Control Plane is used for all control signalling within the Transport Layer. It includes the ALCAP (Access Link Control Application Part) protocol that is needed to set up the transport bearers for the User Plane. It also includes the Signalling Bearer needed for the ALCAP. The introduction of the Transport Network Control Plane makes it possible for the Application Protocol in the Radio Network Control Plane to be completely independent of the technology selected for the Data Bearer in the User Plane. [5, p.81 - 82]

2.6 Node B

Node B is located between two interfaces, Uu and Iub. Uu is the WCDMA radio interface through which the UE accesses the fixed part of the system. Iub is the interface between Node B and RNC. The main function of the Node B is to perform the air interface L1 processing which includes for example channel coding and interleaving, rate adaptation and spreading. It

also performs radio signal receiving and transmitting, signal filtering and amplifying, signal modulation and demodulation and interfacing to the RAN. Hence, it can be considered as the radio edge of the UTRAN. Figure 13 illustrates the logical model of Node B. [4, p.101; 5, p.80]

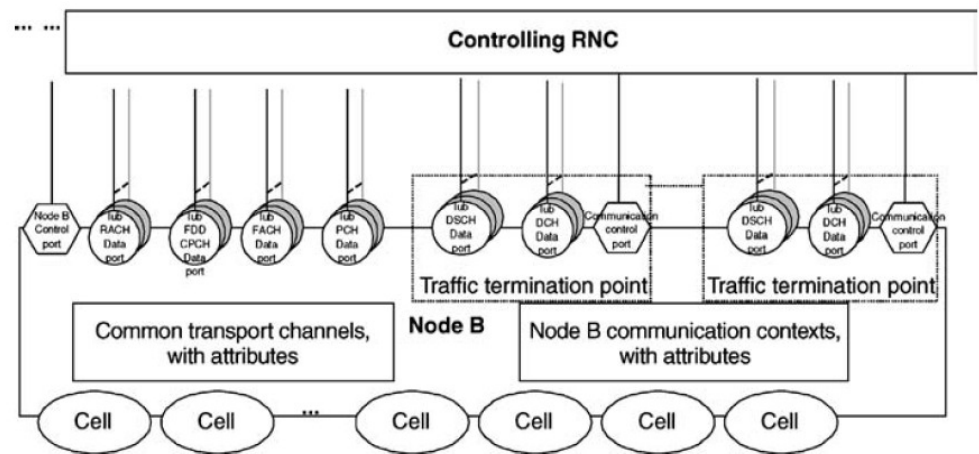


Figure 13, Logical model of Node B [5, p. 92]

As seen in Figure 13, the logical model of Node B consists of a common control port and a set of traffic termination points which are controlled by dedicated control ports. Traffic termination point controls multiple mobiles having dedicated resources in Node B. Dedicated data ports convey the corresponding traffic from termination point. Common data ports outside the traffic termination points are used to transmit RACH (Random Access Channel), FACH (Forward Access Channel) and PCH (Paging Channel) traffic. [5, p.91-92]

Having now introduced the basic concept of UMTS WCDMA technology, the study next describes the network structure and its components bringing the theoretical information in to a practical level.

3 NETWORK STRUCTURE

This chapter describes the laboratory network setup and the components used in it.

The laboratory network was set up using the Nokia Flexi WCDMA Base Station, Nethawk RNC/Iub Simulator and Nokia N73 3G cell phone. Orga Test Systems provided USIMs used in configuration. Figure 14 illustrates the laboratory network architecture.

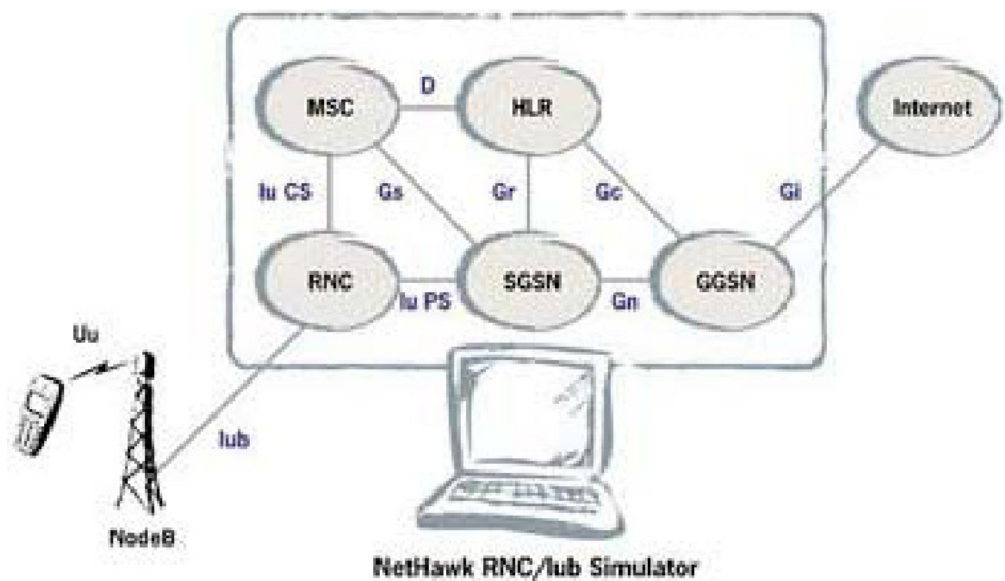


Figure 14, Laboratory Network architecture [12]

Laboratory network was partly simulated and therefore did not contain all the physical elements of UMTS network. The Nethawk RNC/Iub Simulator enables flexible way for setting up a working network without physical components of Core Network infrastructure.

3.1 Nethawk RNC/Iub Simulator

The Nethawk RNC/Iub Simulator is a PC based tool for traffic and signalling simulation on UMTS WCDMA UTRA-FDD network. It uses an open Iub interface standardized by 3GPP specifications. Signalling transactions can be monitored without user input due to an automated simulator response for incoming messages. The simulator also enables 3G protocol analysis as well as creating and modifying scripts.

3.1.1 Procedures and Protocols

The simulator provides support for common 3G signalling procedures in the lub interface. It has a complex user interface for inserting all control commands. Procedure sequences can also be recorded and run as scripts.

The supported procedures are as follows:

- radio bearer setup and release
- radio link setup and release
- FACH/PCH and RACH setup and release
- RRC connection setup and release (chapter 4.2)
- mobile originated call setup and mobile terminating call setup
- AAL2 signalling and location update
- packet-switched call and call release

Message template files are used by the simulated protocols to generate and update protocol messages at run-time. Some parameter values are fixed and some values are defined by protocol emulator.

RNC/lub simulator supports the following protocols:

- UNI (User To Network)
- AAL2 (ATM Adaptation Layer 2) Signalling
- AAL5
- Frame Protocol
- MAC (Medium Access Control)
- RLC (Radio Link Control)
- NBAP (Node B Application Protocol)
- RRC (Radio Resource Control)
- CC (Call Control)
- MM (Mobility Management)

Figure 15 illustrates the structure of the simulator and indicates the protocols listed above. [18, Introduction, Protocol engine sub-system overview]

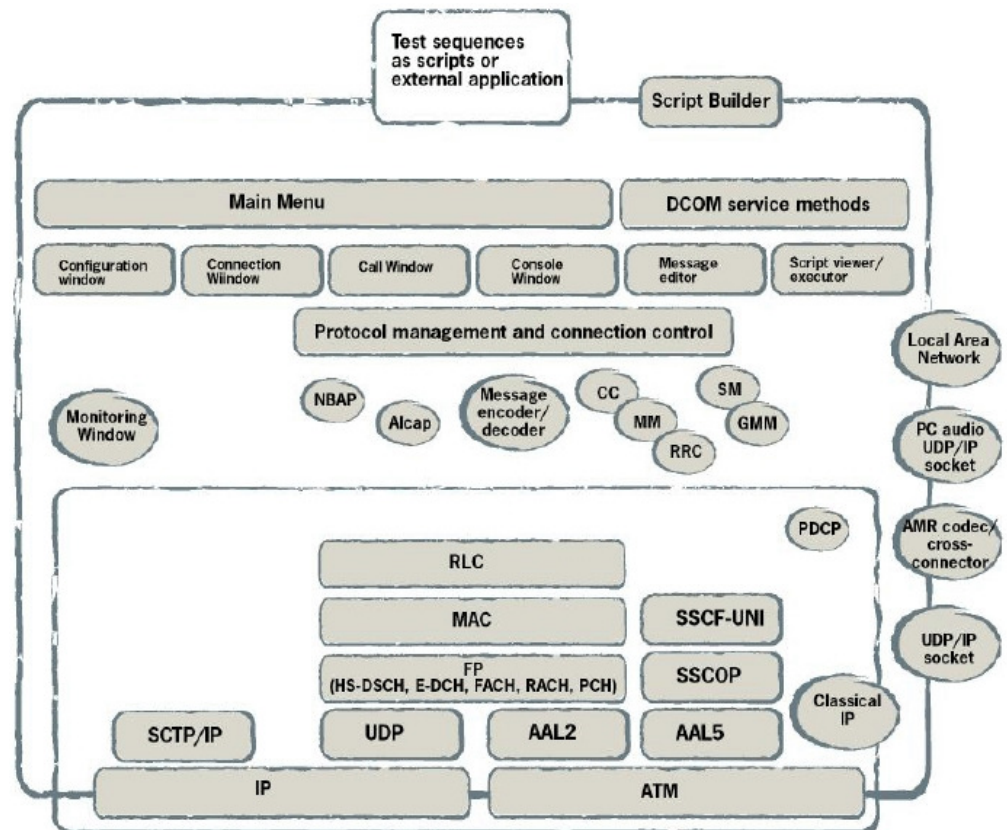


Figure 15, RNC/lub simulator overview [18, Introduction]

Figure 15 presents the Nethawk RNC/lub simulator structure at a very abstract level. The upper section of the figure presents the user components and the lower section describes the protocol management and connection control functions.

3.1.2 Simulator Components

The Nethawk RNC/lub simulator sales package includes a PC based commissioning software for user interface, N2/N3C CardBus adapter, D3 PCI bus adapter and required cables or fibres. Nethawk N2 CardBus adapter is shown in Figure 16.

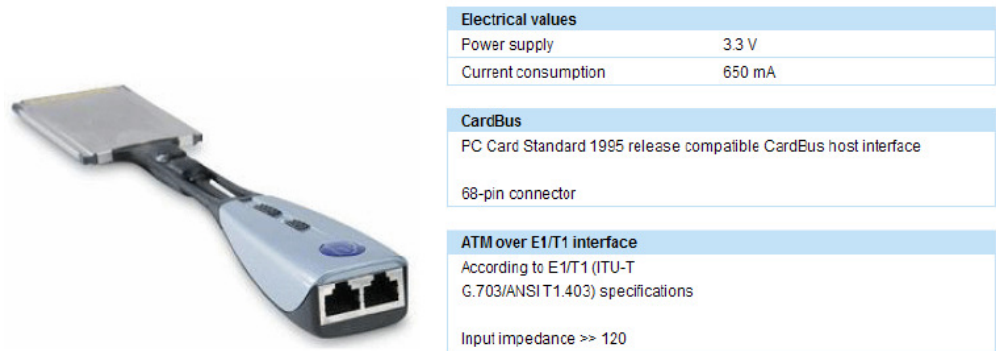


Figure 16, Nethawk CardBus N2 Adapter [18, Specifications and performance; 12]

The adapter uses a CardBus slot for PC connection and has two RJ45 style PCM (Pulse Code Modulation) connectors for base station connection. The present study concentrates on the N2 adapter and it was used for constructing the laboratory network.

The simulator software requires Microsoft Windows XP Professional operating system with Service Pack 1 or Windows 2000 Professional with Service Pack 4 installed on the PC. It requires also MSXML, WinPCap and CardBus or PCI bus slot. [18, Preparing for installation]

3.2 Nokia Flexi WCDMA Base Station

The Nokia Flexi WCDMA Base Station was used in this study to provide the connection between UE and RNC. It offers high capacity data transfer with quick base station installation and decreased power consumption. It supports distributed base station architecture and can be installed both indoors and outdoors. Nokia Flexi WCDMA Base Station is shown in Figure 17. [19]



Figure 17, Nokia Flexi WCDMA Base Station

The Nokia Flexi WCDMA Base Station supports HSPA (High Speed Packet Access) and WCDMA, and it has a modular architecture and it is compatible with OBSAI (Open Base Station Architecture Initiative) specifications. These features will later also allow operators to deploy new technologies within the network. [19]

3.3 User Equipment

Nokia N73 mobile phone was used in the study for testing data transfer. It supports GSM 850/900/1800/1900 and WCDMA 2100 frequency bands. Its maximum data transfer speed in WCDMA network is 384kbit/s for both up-link and downlink.



Figure 18, Nokia N73 Mobile Phone

Two USIMs were used for subscriber authentication in the network. Specifications for both USIMs are:

1. Orga SIM number: 8949000409290006074 (23.1)
IMSI: 234881000000007
2. Orga SIM number: 8949000409290006082 (23.1)
IMSI: 234881000000008

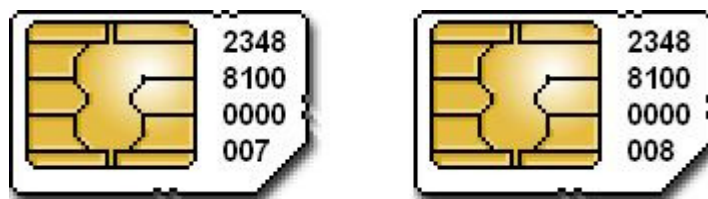


Figure 19, USIM cards

The aim of this chapter was to explain and illustrate the used network components in more detail and give a clear view of the laboratory network structure. The next chapter describes the protocols and connection setup procedures when connecting user equipment to internet.

4 CONNECTING UE TO INTERNET

The process of connecting UE to internet was analyzed with TEMS Investigation 6.1 software. TEMS Investigation 6.1 is an air interface test tool for UTM cellular networks. It allows monitoring of voice channels as well as data transfer over packet-switched and circuit-switched connections. During the connection a log file was created using TEMS. In this chapter, results of the log file are used to interpret the protocols and connection setup procedures. Figure 20 illustrates the overview of TEMS Investigation 6.1 user interface.

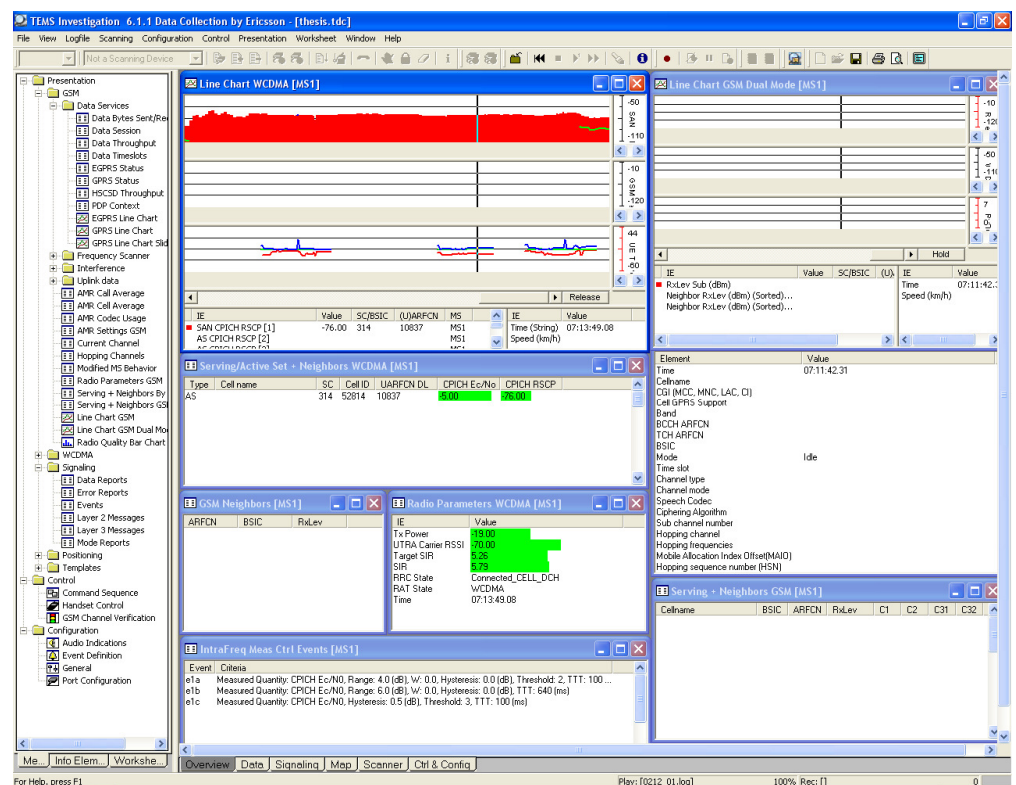


Figure 20, Overview of TEMS Investigation 6.1 user interface

As shown in Figure 20, TEMS is very capable of versatile measurements in cellular networks.

4.1 PDP Context Activation

In order for the mobile terminal to communicate with external data network, a packet data protocol context (PDP Context) must be activated between UE (also MS, Mobile Station) and SGSN. PDP Context activation procedure, initiated by UE, is executed in network layer (L3) using SM (Session Management) protocol. It provides versatile information about the data connection and network. PDP Context activation process is shown in Figure 21. [17, p.120 - 122]

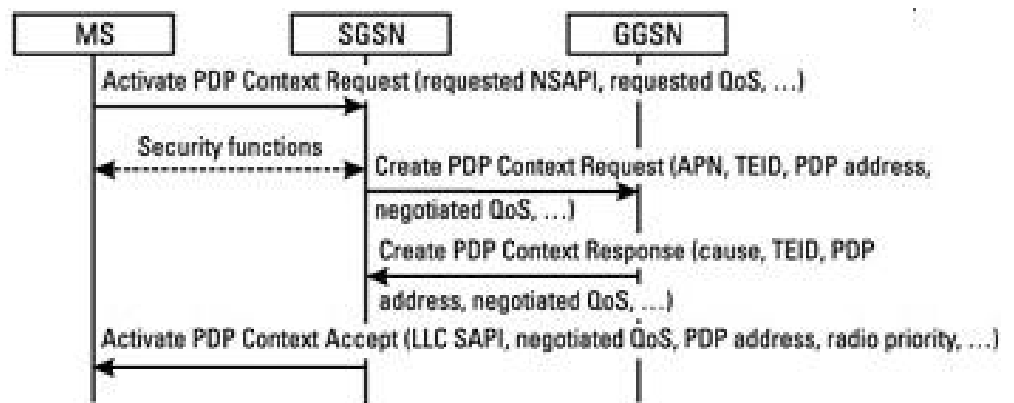


Figure 21, PDP Context activation [16]

Figure 21 illustrates how PDP Context activation messages are transported between Mobile Station, SGSN and GGSN.

4.1.1 PDP Context Request

Communication with external data network begins with PDP Context Request. UE sends PDP Context Request to SGSN with parameters such as requested NSAPI, LLC SAPI, QoS, PDP address and APN. Figure 22 illustrates PDP Context Request message details.

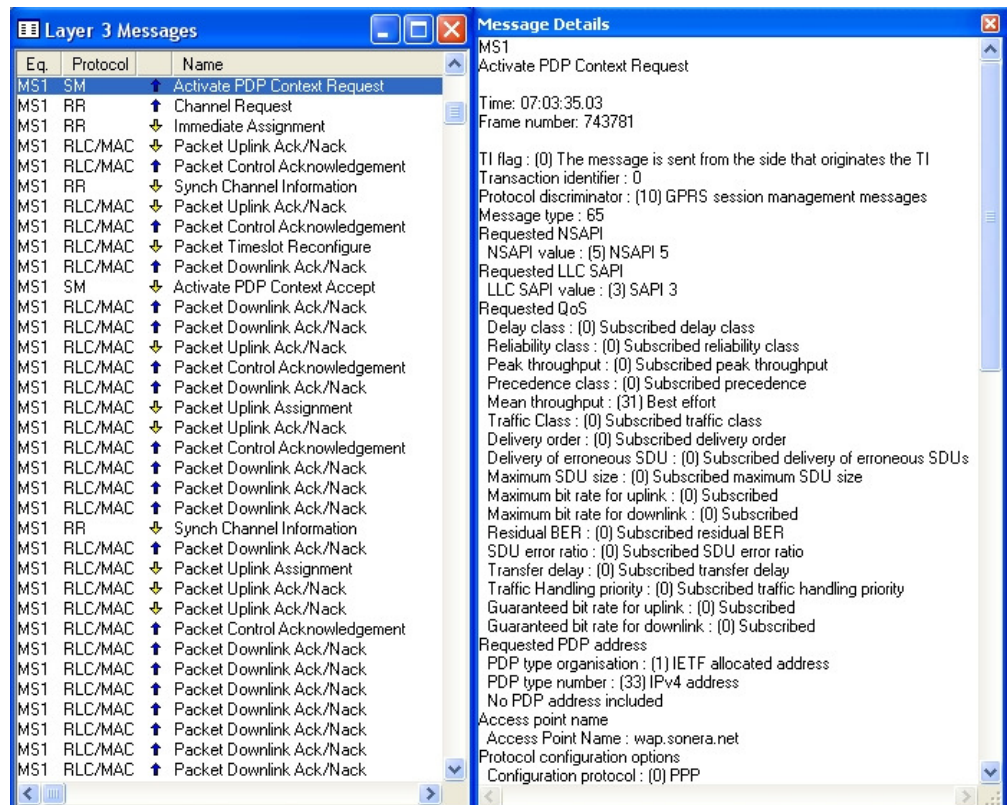


Figure 22, PDP Context Request in TEMS Analyzer

NSAPI (Network Service Access Point Identifier) is an index that uses the services provided by the SMDCP (Sub Network Dependent Convergence Protocol) layer for GPRS data transfer.

LLC SAPI (Logical Link Control Service Access Point Identifier) identifies the SAP used for GPRS data transfer at the LLC layer.

QoS (Quality of Service) defines the quality of service related to the PDP context.

PDP Address identifies the UE address related to the PDP context. It consists of the PDP address type (IPv4) and address information containing the IP address.

APN (Access Point Name) is the reference for GGSN to route packets.

With information provided above, a PDP Context Request is possible to be initiated.

4.1.2 PDP Context Accept

After GGSN has processed PDP Context Request (see Figure 21), SGSN responds to UE with PDP Context Accept message containing negotiated parameters, as shown in Figure 23.

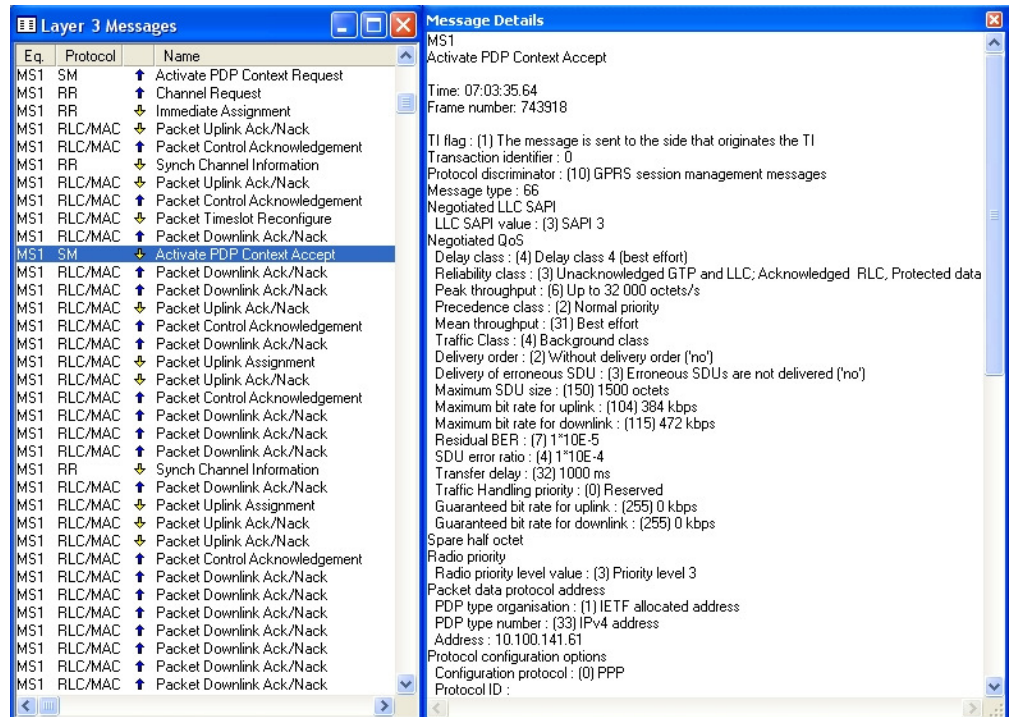


Figure 23, PDP Context Accept in TEMS Analyzer

Message details indicate that very specific QoS parameters are negotiated during PDP Context Activation process.

When PDP Context Activation is ready, TEMS Analyzer compiles an overview of negotiated parameters, as presented in Figure 24.

PDP Context [MS1]	
Element	Value
Active PDP Contexts	1
PDP NSAPI	5
PDP LLC SAPI	3
PDP Delay Class	Delay class 4 (best effort)
PDP Reliability Class	Unacknowledged GTP and LLC; Acknowledged RLC, Protected data
PDP Precedence Class	Reserved
PDP Peak Throughput	Up to 32 000 octets/s
PDP Mean Throughput	Best effort
PDP Radio Priority	Priority level 3
PDP Access Point Name	wap.sonera.net
PDP Address	10.100.141.61

Figure 24, PDP Context Activation ready in TEMS Analyzer

Figure 24 illustrates, that requested values in PDP Context Request message (4.1.1) are set and the UE is ready to connect to the external data network.

4.2 RRC Connection establishment

A Radio Resource Control (RRC) connection is needed to be established between UE and RNC when UE is connecting to internet, as shown in Figure 25.

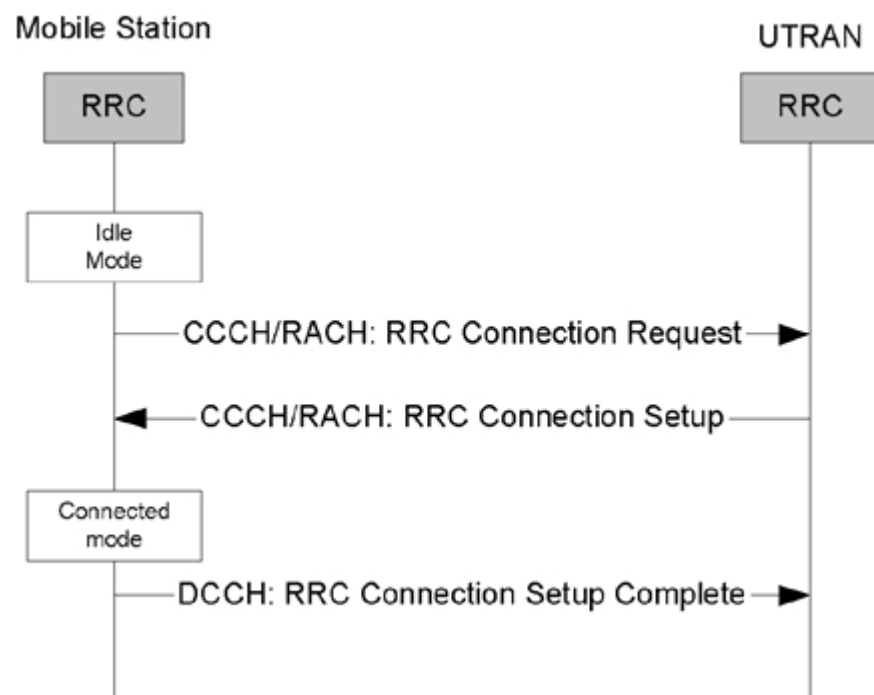


Figure 25, RRC connection establishment [5, p.162]

The RRC connection establishment procedure is initiated when the upper layers in the user equipment need to establish a signalling connection and UE is in idle mode. RRC connection request is sent through Common Control Channel (CCCH), as presented in Figure 26.

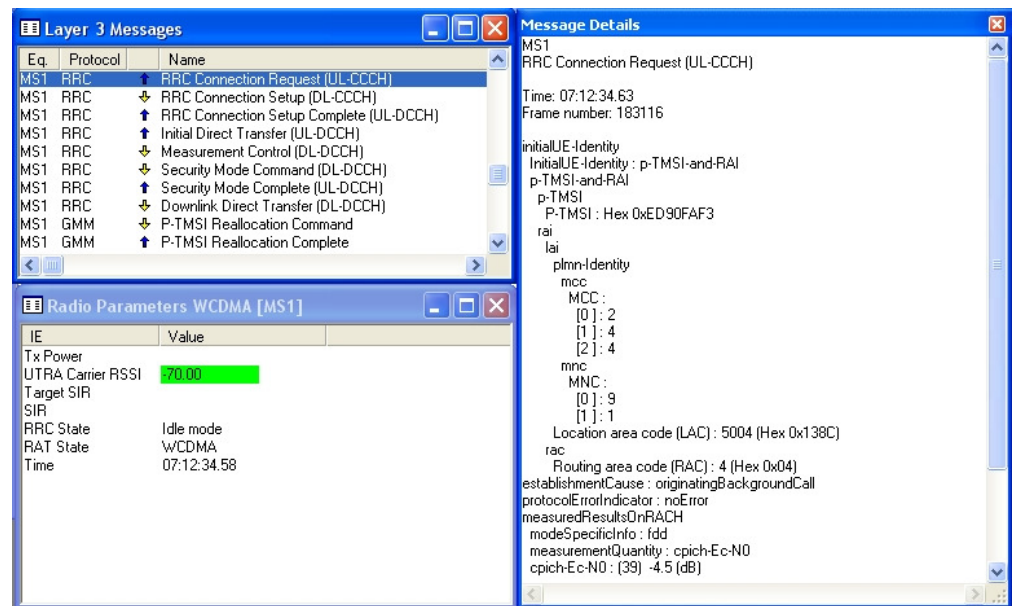


Figure 26, RRC connection request in TEMS analyzer

Message details provide more specific information about RRC connection request. It indicates Mobile Country Code (MCC), Mobile Network Code (MNC) Location Area Code (LAC) and Routing Area Code (RAC). MNCs specified in Finland are shown in Figure 27.

MCC	MNC	Brand	Operator	Status
244	03	DNA	DNA Oy	Operational
244	05	Elisa	Elisa Oyj	Operational
244	07	Nokia	Nokia Test Network	Operational
244	08		Unknown	Operational
244	10		TDC Oy	Unknown
244	11	VIRVE	Suomen Erillisverkot Oy	Operational
244	12	DNA	DNA Oy	Operational
244	14	AMT	Ålands Mobiltelefon	Operational
244	15	SAMK	Samk student network	Operational
244	21	Saunalahti	Elisa Oyj	Operational
244	29		Scnl Truphone	Unknown
244	91	Sonera	TeliaSonera Finland Oyj	Operational

Figure 27, MNCs in Finland [Wikipedia]

RRC connection setup is a large message containing significant information to be used in further configuration. This information includes transport format sets and transport channel information. When RRC Connection Setup message includes a dedicated channel assignment, the user equipment will be in

connected mode in CELL_DCH state. RNC sends RRC connection setup message also through CCCH, as shown in Figure 28.

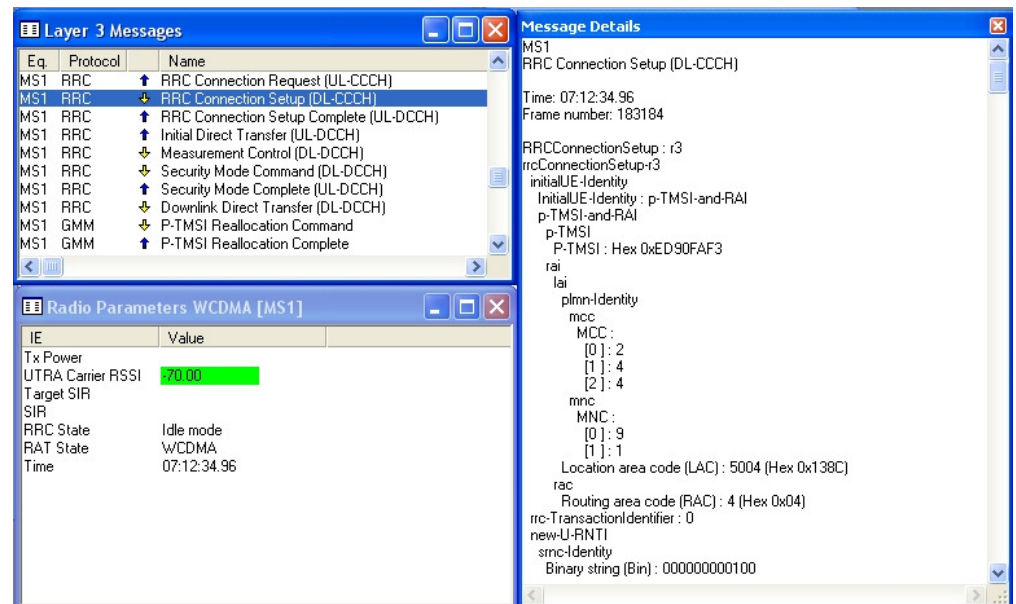


Figure 28, RRC connection setup in TEMS analyzer

RRC Connection Setup Complete message is sent by UE through Dedicated Control Channel (DCCH). In previous phases RRC state was in Idle mode, but in this phase it can be seen that UE is connected to RNC in CELL_DCH state, as presented in Figure 29.

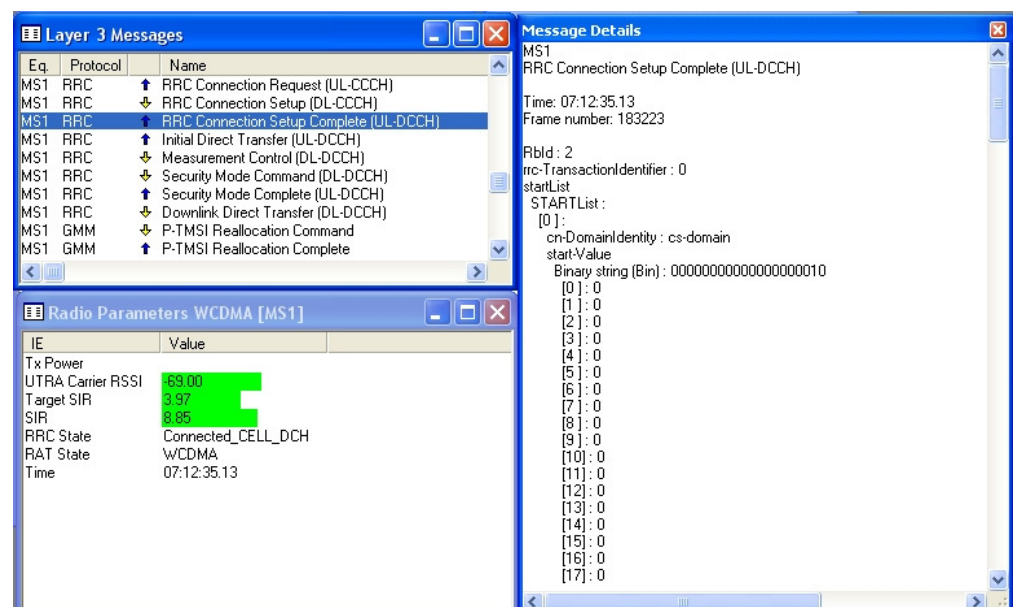


Figure 29, RRC connection setup complete in TEMS analyzer

After RRC Connection setup procedure is accomplished, RRC is able to perform its main functions. RRC controls the configuration of the lower layers in the protocol stack, and has control interfaces to each of the lower layers.

When UE is connected to RNC and RRC Setup Complete message is sent, TEMS Investigator 6.1 is able to collect more information about the connection.

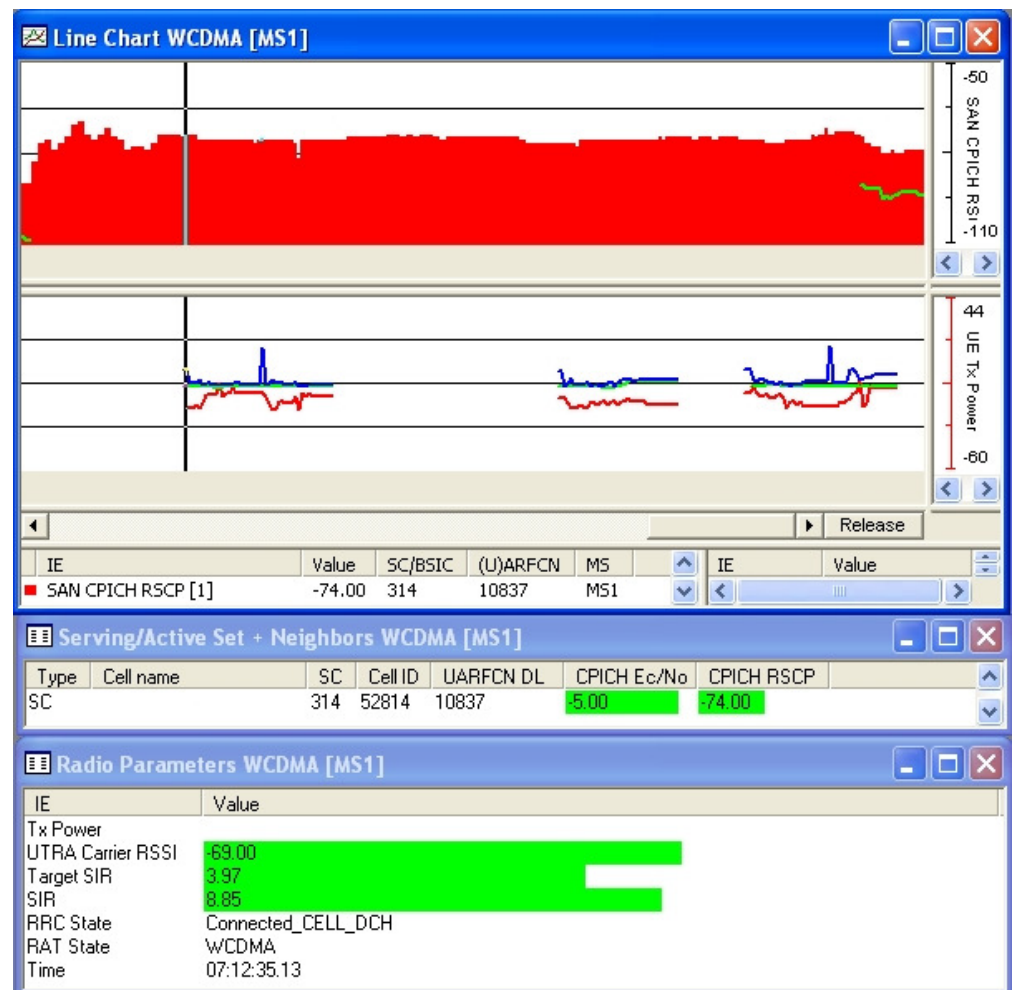


Figure 30, WCDMA analysis in TEMS analyzer

UTRA Absolute Radio Frequency Channel Number (UARFCN) is used to identify frequencies in the UTRA frequency bands. It is derived from the frequency through following formula

$$\text{UARFCN channel number} = \text{Frequency in MHz} * 5$$

Following values can be calculated in the chart, illustrated in Figure 30

- DL UARFCN: 10837
- DL Frequency: 2167.4 MHz
- UL UARFCN: 9887
- UL Frequency: 1977.4 MHz
- Frequency Band: UMTS 2100

The relationship between UARFCN and downlink frequency is described in 3GPP TS 25.101 and shown in Figures 31 - 33.

Operating Band	UL Frequencies UE transmit, Node B receive	DL frequencies UE receive, Node B transmit
I	1920 – 1980 MHz	2110 – 2170 MHz
II	1850 – 1910 MHz	1930 – 1990 MHz
III	1710-1785 MHz	1805-1880 MHz

Figure 31, UTRA FDD frequency bands [14]

Operating Band	TX-RX frequency separation
I	190 MHz
II	80 MHz.
III	95 MHz.

Figure 32, TX-RX frequency separation [14]

Operating Band	Uplink UE transmit, Node B receive	Downlink UE receive, Node B transmit
I	9612 to 9888	10562 to 10838
II	9262 to 9538 and 12, 37, 62, 87, 112, 137, 162, 187, 212, 237, 262, 287	9662 to 9938 and 412, 437, 462, 487, 512, 537, 562, 587, 612, 637, 662, 687
III	8562 to 8913	9037 to 9388

Figure 33, UTRA Absolute Radio Frequency Channel Numbers [14]

Figure 30 also provides the following information

- Type: SC (Serving Cell)
- Scrambling Code (SC): 314
- Cell ID: 52814
- CPICH Ec/No: -5 dB
- CPICH RSCP: -74dBm

In the downlink Scrambling Codes are used to reduce the inter-base-station interference. Typically, each Node B has only one scrambling code for UEs

to separate base stations. Since a code tree under one scrambling code is used by all users in its cell, proper code management is needed. In the up-link Scrambling Codes are used to separate user equipments.

CPICH (Common Pilot Channel) E_c/N_0 is the received energy per chip divided by the power density in the band.

CPICH RSCP (Received Signal Code Power) is the absolute power level of the CPICH as received by UE.

Measured CPICH E_c/N_0 and CPICH RSCP values indicate that connected cell is performing at good level to establish a successful connection. If transmitted and received signals attenuate significantly, UE attempts to find more suitable cell for stronger connection.

5 CONCLUSIONS

The purpose of this study was to setup the UMTS WCDMA network in the laboratory of Metropolia and to analyse network layer protocol activation for packet data access.

3rd Generation mobile network enables significantly more versatile services and faster data transmission than its predecessor 2nd Generation GSM network. The structure of the network is more complex and controlling is more difficult than before. It is due to the compatibility for the future services and adjustments.

The practical part of this study consisted of setting up the laboratory network and analysing protocol activation for packet data access. During network configuration the lack of information and the lack of support from the manufacturer of the RNC/lub Simulator led to the use of the trial and error method. After being able to correctly compile the laboratory network, the measurements with TEMS analyser were less painful to accomplish.

Subscriber connection to network was established using Nokia N73 3G mobile phone. It was equipped with ORGA Systems SIM cards for test purposes. The subscriber connection was successfully accomplished and its functionality was verified by simple packet data access to network.

Collected data from the network layer protocol activation was very detailed and assisted in understanding of the necessary procedures during data connection. Measurements also indicated that connected cell was performing at adequate level to maintain a successful data connection.

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