# Simulation and Analysis of Multicast Scheme in UMTS Network

**Major Project Report**

Submitted in partial fulfillment of the requirements

for the degree of

**Master of Technology**

**In**

**Electronics and Communication Engineering**

**(Communication Engineering)**

By


**Bamniya Kishor Himsinh**

**(08MECC02)**



**Department of Electronics & Communication Engineering**

**Institute of Technology**

**Nirma University**

**Ahmedabad-382 481**


**May 2010**

# Simulation and Analysis of Multicast Scheme in UMTS Network

**Major Project Reprot**

Submitted in partial fulfillment of the requirements

for the degree of

**Master of Technology**

**In**

**Electronics and Communication Engineering**

**(Communication Engineering)**

By

**Bamniya Kishor Himsinh**

**(08MECC02)**

Under the Guidance of

**Prof. Sachin Gajjar**

**Department of Electronics & Communication Engineering**

**Institute of Technology**

**Nirma University**

**Ahmedabad-382 481**

**May 2010**

# Declaration

This is to certify that

i) The thesis comprises my original work towards the degree of Master of Technology in Communication Engineering at Nirma University and has not been submitted elsewhere for a degree.

ii) Due acknowledgement has been made in the text to all other material used.

**Bamniya Kishor Himsinh**

# Certificate

This is to certify that the Major Project entitled **"Simulation and Analysis of Multicast Scheme in UMTS Network"** submitted by **Bamniya Kishor Himsinh (08MECC02)**, towards the partial fulfillment of the requirements for the degree of Master of Technology in Electronics & Communication (Communication) of Nirma University, Institute of Technology, Ahmedabad is the record of work carried out by him under my supervision and guidance. In my opinion, the submitted work has reached a level required for being accepted for examination. The results embodied in this major project, to the best of our knowledge, haven't been submitted to any other university or institution for award of any degree or diploma.

Date: Place: Ahmedabad

Internal Guide

(Prof. Sachin Gajjar)
Assistant Professor,EC

External Guide

(Mr. Nikky Shah)
RF Engineer,
Nokia Siemens Network

HOD

(Prof. A. S. Ranade)
Professor, EC

Director

(Dr. K Kotecha)
Director, IT, NU

# Acknowledgements

I am deeply indebted to my thesis supervisor Prof. Sachin Gajjar for his constant guidance and motivation. He has devoted significant amount of his valuable time to plan and discuss the thesis work. Without his experience and insights, it would have been very difficult to do quality work.

I would like to express my gratitude and sincere thanks to Prof. A. S. Ranade Head of Electrical Engineering Department and Dr. D. K. Kothari Coordinator M.Tech Communication Engineering program for allowing me to undertake this thesis work and for his guidelines during the review process.

I wish to thank my friends of my class for their delightful company which kept me in good humor throughout the year.

Last, but not the least, no words are enough to acknowledge constant support and sacrifices of my family members because of whom I am able to complete the degree program successfully.

**- Bamniya Kishor Himsinh**
**08MECC02**

# Abstract

The mobile communication industry is renowned for its technical innovation,rapid growth and tantalizing promises. In contrast to the dramatic downterm in the general communications market, the mobile sector has continued to grow and evolve.UMTS (Universal Mobile Telecommunications System) is a family of third generation mobile networks designed to offer high bandwidth radio access. UMTS has been specified as an integrated solution for mobile voice and data with wide area coverage.

This report work addresses the analysis and the improvement of the multicast mechanisms in MBMS (Multimedia Broadcast/Multicast Service) through the exploitation of high levels of Radio Resource Management. MBMS is a solution for transferring video and audio clips, although real streaming is also possible via the system. Multicast is an efficient method of supporting group communication as it allows the transmission of packets to multiple destinations using fewer network resources. Even if UMTS has not been designed for supporting multicast mechanisms, (MBMS) framework of UMTS supports multicast mechanism.

The most important part of this report is the multicast scheme, here the multicast routing mechanism with the multicast group management is descibed. The critical parameters for the evaluation of the scheme are the number of users within the multicast group, the amount of data sent to the multicast users, the density of the multicast users within the cells and finally the type of transport channel used for the transmission of the multicast data over the air. In this thesis, the performance of multicast scheme is analyzed in terms of its performance with respect to number of multicast users and number of packets per multicast users.

# Contents

# List of Tables

# List of Figures

# Chapter 1

# Introduction

The world has witnessed an explosion in the growth of mobile communications in recent years. In fact, year 2002 marked a turning point in the history of telecommunications where the number of mobile subscribers overtook the number of fixed-line subscribers on a global scale, and mobile became the dominant technology for voice communications. Continuous improvement of mobile phones, networks and communication technologies provides users with enhanced existing services and continuous stream of new innovative mobile services. The third generation of mobile technologies (3G) is advancing possibilities again one step further in the near future. Besides already existing services, multimedia streams (e.g. TV on mobile phones) and transmission of broadband data will be offered. Furthermore arbitrary data and applications for smart phones, multimedia clips and streams and many other services will be available for a large group of users. Such services will utilize data transmission or streaming from one server to many users. A system feature required is to provide these transmissions in an efficient way. The Standardizations of Multimedia Broadcast and Multicast Service (MBMS) are dedicated to this task. MBMS is a new unidirectional (downlink only) Point-to-Multipoint service introduced in Universal Mobile Telecommunication System (UMTS) Release 6 specifications in which the same data is transmitted from a single source entity to multiple recipients. The novelty with MBMS architecture is that it enables the efficient usage of radio-network and core-network resources by allowing the network resources to be shared. Power control is one of the most important aspects in MBMS due to the fact that Node Bs transmission power is a limited resource and must be shared among all MBMS users in a cell. The main purpose of power control is to minimize the transmitted power, thus avoiding unnecessary high power levels and eliminating inter-cell interference. Consequently, the analysis of transmitted pow er plays a fundamental role in the planning and optimization process of UMTS radio access networks.

Different transport channels can be used to transmit MBMS data, each one with different power requirements. The benefits of using different transport channels for the transmission of the multicast data over the UTRAN interfaces are investigated in this project. The selection of the most efficient transport channel in terms of power consumption is a key point for the MBMS performance, since a wrong channel selection could result to a significant decrease in the total capacity of the system. The transport channels, in the downlink, currently existing in UMTS which could be used to serve MBMS are the Dedicated Channel (DCH), the Forward Access Channel (FACH) and the High Speed Downlink Shared Channel (HS-DSCH). Each channel has different characteristics in terms of power control. In this work, a power based scheme for the selection of the most efficient channel is investigated. The primary factor which influences the transmission power is the number of the users in the cell. To investigate the appropriate transport channel a model with 19 hexagonal cells has been implemented and interference has always been considered [2].

## 1.1 Background And Approach

### 1.1.1 UMTS in general

UMTS network is split in two main domains: the User Equipment (UE) domain and the Public Land Mobile Network (PLMN) domain. The UE domain consists of the equipment employed by the user to access the UMTS services. The PLMN domain

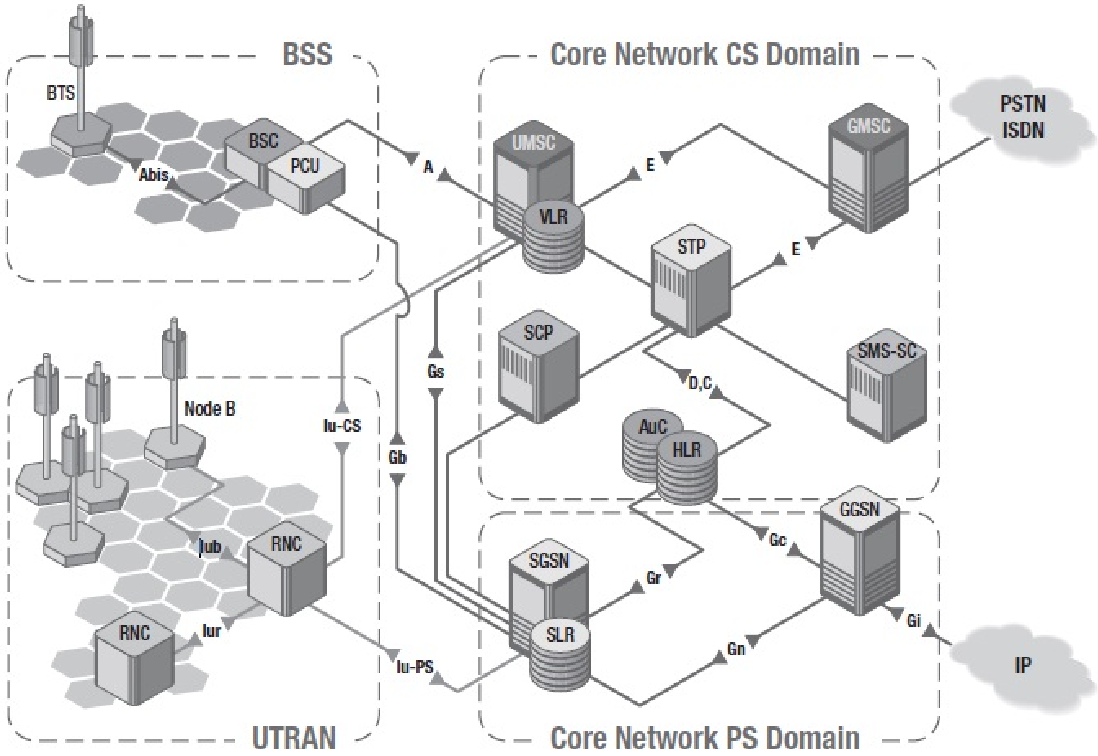


Figure 1.1: UMTS Architecture

consists of two land-based infrastructures: the Core Network (CN) and the UTRAN. The CN is responsible for switching/routing voice and data connections, while the UTRAN handles all radio-related functionalities. The CN is logically divided into two service domains: the Circuit-Switched (CS) service domain and the Packet-Switched (PS) service domain. The CS domain handles the voice-related traffic, while the PS domain handles the packet transfer [16].

The PS portion of the CN in UMTS consists of two kinds of General Packet Radio Service (GPRS) Support Nodes (GSNs), namely Gateway GSN (GGSN) and Serving GSN (SGSN). SGSN is the centerpiece of the PS domain. It provides routing functionality interacts with databases (like Home Location Register (HLR)) and manages many Radio Network Controllers (RNCs). SGSN is connected to GGSN via the Gn interface and to RNCs via the Iu interface. GGSN provides the interconnection of UMTS network (through the Broadcast Multicast-Service Center) with other Packet

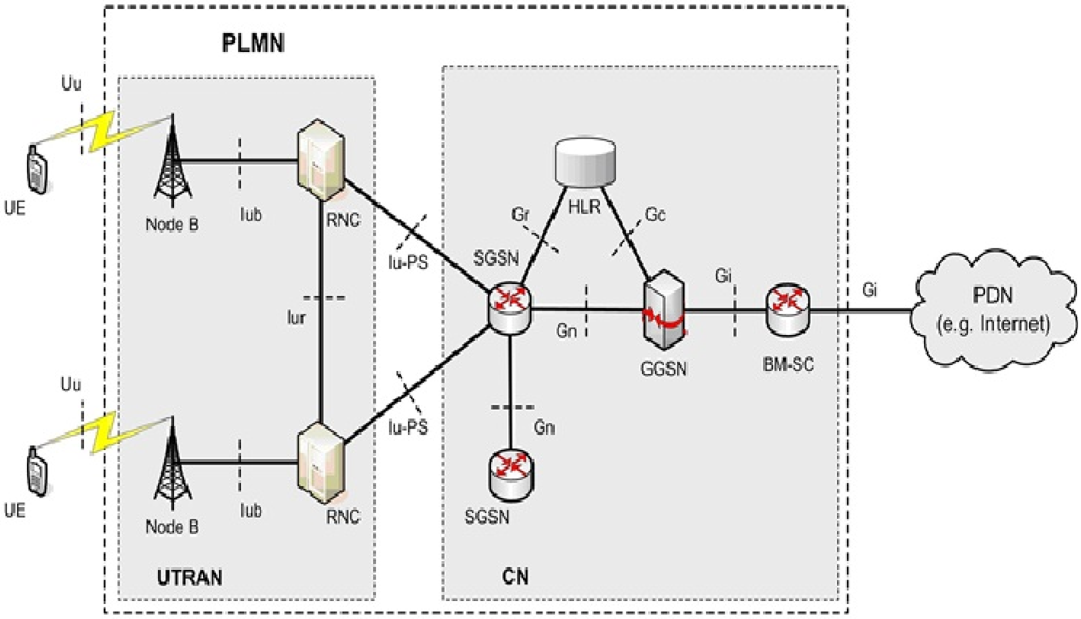


Figure 1.2: Modification in UMTS Architecture for Provision of MBMS Framework

Data Networks (PDNs) like the Internet.

UTRAN consists of two kinds of nodes: the first is the RNC and the second is the Node B. Node B constitutes the base station and provides radio coverage to one or more cells. Node B is connected to the User Equipment (UE) via the Uu interface (based on the Wideband Code Division Multiple Access, WCDMA technology) and to the RNC via the Iub interface.

Regarding the transmission of the packets over the Iub and Uu interfaces, it may be performed on common (i.e. FACH), dedicated (i.e. DCH) or shared (i.e. HS-DSCH) transport channels.

### 1.1.2 MBMS Framework of UMTS

Multimedia Broadcast Multicast Service (MBMS) is a novel framework, extending the existing UMTS infrastructure that constitutes a significant step towards the so-called Mobile Broadband. MBMS is intended to efficiently use network and radio resources, both in the core network and, most importantly, in the air interface of UMTS Terrestrial Radio Access Network (UTRAN), where the bottleneck is placed to a large group of users. Actually, MBMS is a Point-to-Multipoint service in which data is transmitted from a single source entity to multiple destinations, allowing the network resources to be shared. MBMS is an efficient way to support the plethora of the emerging wireless multimedia and application services, such as Mobile TV and Streaming Video by supporting both broadcast and multicast transmission modes.

In MBMS rich wireless multimedia data is transmitted simultaneously to multiple recipients, by allowing resources to be shared in an economical way. MBMS efficiency is derived from the single transmission of identical data over a common channel without clogging up the air interface with multiple replications of the same data. From the service and operators' point of view, the employment of MBMS framework involves both an improved network performance and a rational usage of radio resources, which in turns leads to extended coverage and service provision. In parallel, users are able to realize novel, high bit-rate services, experienced until today only by wired users.

The MBMS framework requires minimal modifications in the current UMTS architecture. As a consequence, this fact enables the fast and smooth upgrade from pure UMTS networks to MBMS-enhanced UMTS networks. The major modification in the existing UMTS platform for the provision of the MBMS framework is the addition of a new entity called Broadcast Multicast-Service Center (BM-SC) as shown in figure 1.2. Actually, BM-SC acts as entry point for data delivery between the content providers and the UMTS network and is located in the PS domain of the CN. The BM-SC entity communicates with existing UMTS/GSM networks and external PDNs.MBMS has the major benefit that the network infrastructure already exists for mobile network operators and the deployment can be cost effective compared with building a new network for the services. The broadcast capability enables to reach unlimited number of users with constant network load. Further it also enables the possibility to broadcast information simultaneously to many cellular subscribers.

## 1.2 3G/UMTS services

### 1.2.1 Mobile TV

If there is one service category that epitomises the growing popularity of 3G/UMTS, it is mobile TV. It is a term that is used loosely to cover a range of differentiated services, but Mobile TV typically means offering subscribers access to a choice of themed channels, allowing them to watch their favourite shows as well as bespoke content that has been specifically created and optimised for mobile consumption.

A key enabler for the fast-growing popularity of mobile TV has been the viewing experience itself. Mobile screens are getting larger while supporting higher resolutions and larger colour palettes. In parallel with this, improved power management makes it practical to watch a ten-minute clip of a soap opera without flattening the phones battery.

By the end of 2005, Orange France was already proposing more than 50 live 3G mobile TV channels  at that time the most extensive offering in the market. Orange has also made early moves to grab ownership of the mobile cinema market with its Orange Short Film Festival. Coinciding with the annual film festival in Cannes, the event showcases drama, documentaries and animations specifically created for viewing on mobiles [17].

It is unsurprising that television broadcasters are moving to cement strategic relationships with mobile operators. One example of this is the tie-up between Vodafone UK and BSkyB to offer Vodafone Live! customers a Sky Mobile branded package of news, video, weather and other tailored clips.

### 1.2.2 The emergence of mobile video and self-produced content

Mobile phones are not just being used to watch the news: today they are being used to make it. An increasing number of high-profile events have been relayed on the world stage through footage captured on mobile phones. While it may fall far short of broadcast quality, mobile video enabled by the data throughput of 3G has become an essential medium in its own right.

The evolution of mobile devices with video cameras, editing tools and significant amounts of on-board storage space means that consumers can create and share their own mini movies without the need for a camcorder or any additional hardware or software.

3G has provided much of the impetus for consumer phenomena like YouTube. There are reputedly more than 100 million video downloads served per day from this popular portal that invites contributors to share their own clips. While not exclusively a mobile service, many of these videos have been originated on mobile devices. Similarly, operators are themselves tapping into the groundswell in demand for self-originated content. For example, 3UK partnered with media producer Endemol to offer See Me TV which stimulated 4,000 uploads and 40,000 downloads in its first four months of operation.Nokia has created its own blogging portal aimed at users of its Nseries handsets, encouraging them to create, edit, store and share their own video content [1].

### 1.2.3 Music on the move: customers flock to mobile music

Mobile music is another service category that is rapidly gaining traction with 3G/UMTS customers. In the early days of 3G, much was made of the technologys ability to deliver full-motion video clips and provide access to the Internet. But while the promise of video-based services captured much initial industry enthusiasm, the importance of music on mobile devices was arguably underestimated in some quarters. To put the appeal of mobile music services in context, downloading a full-length song can take a minute or less via 3G/UMTS. This contrasts with five minutes or more on GRPS.

The future for mobile music undoubtedly lies in tighter interplay between devices and the management of on-line music content libraries. The definition of mobile music will also extend to embrace music video clips, TV clips and other valueadded extras. With the commercial interests of record companies and their artists protected by effective rights management schemes, continued growth in operator revenues from this popular, high-value channel looks certain.

## 1.3 Problem Statement

UMTS (Universal Mobile Telecommunications System) is a family of third generation mobile networks designed to offer high bandwidth radio access. UMTS has been specified as an integrated solution for mobile voice and data with wide area coverage. MBMS framework of UMTS supports multicast mechanism. This thesis describe the MBMS scheme and its functioning. The major goal of the thesis is simulation and analysis of MBMS scheme.

## 1.4 Thesis Organization

This report work addresses the analysis and on the improvement of the multi- cast mechanisms in MBMS(Multimedia Broadcast/Multicast Service) through the exploitation of high levels of Radio Resource Management.MBMS is a solution for transferring video and audio clips, although real streaming is also possible via the system.

Chapter 2 describe the evolution of UMTS architecture. It includes basics of WCDMA,channels which are used in UMTS network,HSPA(High Speed Packet Access),HSPA+ technology and UMTS's long term evolution.

Chapter 3 begins the description of MBMS(Multimedia Broadcast Multicast Service) with a detailed explanation of the architecture,MBMS channel and its protocols.

Chapter 4 explains the mechanism of multicast scheme. This scheme is based on routing lists. This chapter includes several phase of multicast scheme.

Chapter 5 includes simulation and analysis of the multicast scheme. In this chapter, there is an analysis of a multicast scheme for UMTS and the delivery of the multicast packets to a group of mobile users and have analyzed the performance of such a delivery in terms of the telecommunication cost.

# Chapter 2

# UMTS from Release '99 to HSPA

## 2.1 UMTS Architecture

The UMTS system consists of a number of logical network elements that each has a defined functionality. Functionally the network elements are grouped into the Radio Access Network 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 specified. From a specification and standardization point of view, both UE and UMTS Terrestrial Radio Access Network (UTRAN) consist of completely new protocols. On the contrary, the definition of Core Network (CN) is inherited from GSM. This gives the system with new radio technology a global base of known CN technology that accelerates and facilitates its introduction, and enables such competitive advantages as global roaming.The UMTS architecture is shown in Figure 2.1. The main elements of the UMTS Core Network are:

- HLR (Home Location Register) is a database located in the CN that stores the master copy of the users 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

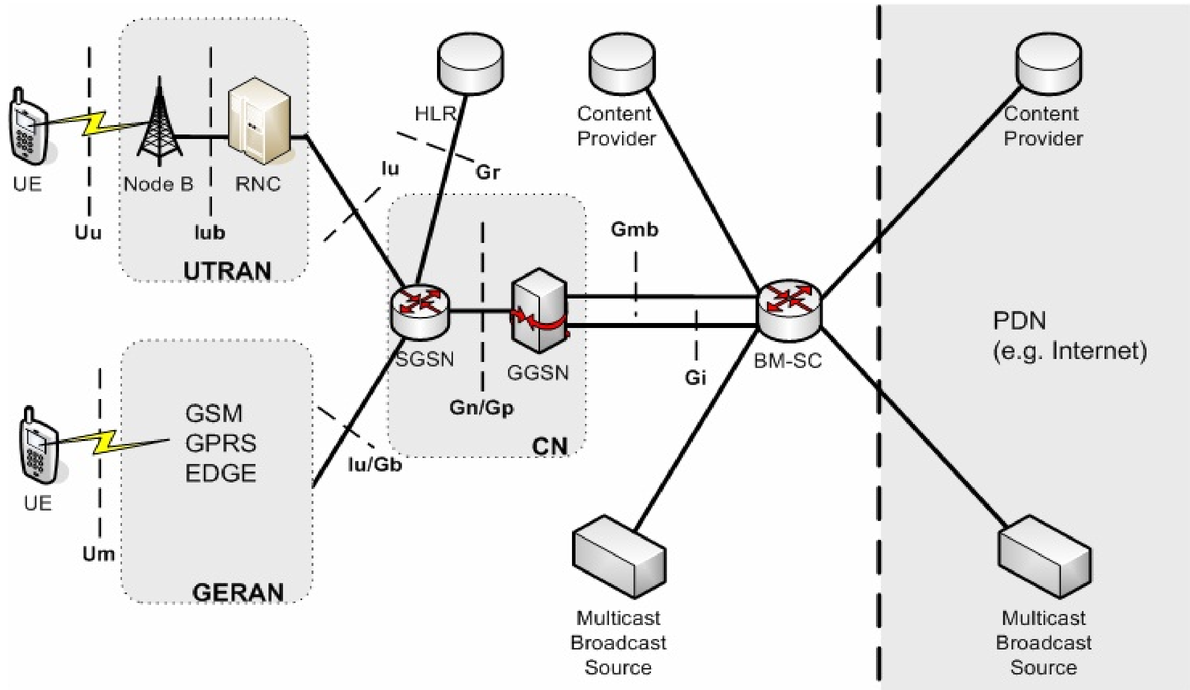


Figure 2.1: UMTS architecture

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 MSC/VLR and/or SGSN, i.e. on the level of the serving system.

- MSC/VLR (Mobile Services Switching Centre/Visitor Location Register) are the switch (MSC) and database (VLR) that serve the UE in its current location for Circuit Switched (CS) services.

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

- SGSN (Serving GPRS Support Node) functionality is similar to that of MSC/VLR but is typically used for Packet Switched (PS) services.

- GGSN (Gateway GPRS Support Node) 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. They provide circuit-switched connections, like the existing telephony service.
- PS networks. They provide connections for packet data services. The Internet is one example of a PS network.

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 smartcard.
- Uu interface. This is the WCDMA radio interface through which the UE accesses the fixed part of the system, and is therefore probably the most important open interface in UMTS.
- Iu interface which connects UTRAN to the CN.
- Iur interface which connects RNC to each other.
- Iub interface which connects a Node B and an RNC.

UTRAN consists of one or more Radio Network Sub-systems (RNS). An RNS consists of one Radio Network Controller (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. 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). Main functions of the Node B are to perform channel coding and interleaving, rate adaptation and spreading. It also performs some basic Radio Resource Management operations such as the power control.

UTRAN has the following functions:

- User Data Delivery. Through Iu and Uu interfaces;
- Systems access control. It allows user to connect and to use UMTS services;
- Radio channel coding and decoding;
- Mobility Functions;
- Radio resources management.

By systems access control, UTRAN allows access control, i.e. accepts or refuses new users to not overload the network on preserving low interference, and congestion control. The mobility functions are handover, which depends on power level measurements to preserve the QoS, and user position. Node Bs and RNCs can handle the handover. Actually the handover between base stations belonging to the same Node B is managed only by the Node B. Instead the handover between base station belonging to different Node B but to the same RNC is managed by RNC through Iub interface. Finally the handover between base station belonging to different Node B and different RNCs is managed by RNCs by Iur interface [12]. The radio resources management functions are the following:

- Radio resources configuration, which manages the radio resources on configuring the common transport channels;
- Radio channels monitoring, which generates channel characteristics estimations;
- Connection establishment and release;
- Power control.

As shown in Figure 2.2, the protocol structure consists of two main layers, the Radio Network Layer and the Transport Network Layer. All UTRAN-related issues are visible only in the Radio Network Layer, and the Transport Network Layer represents

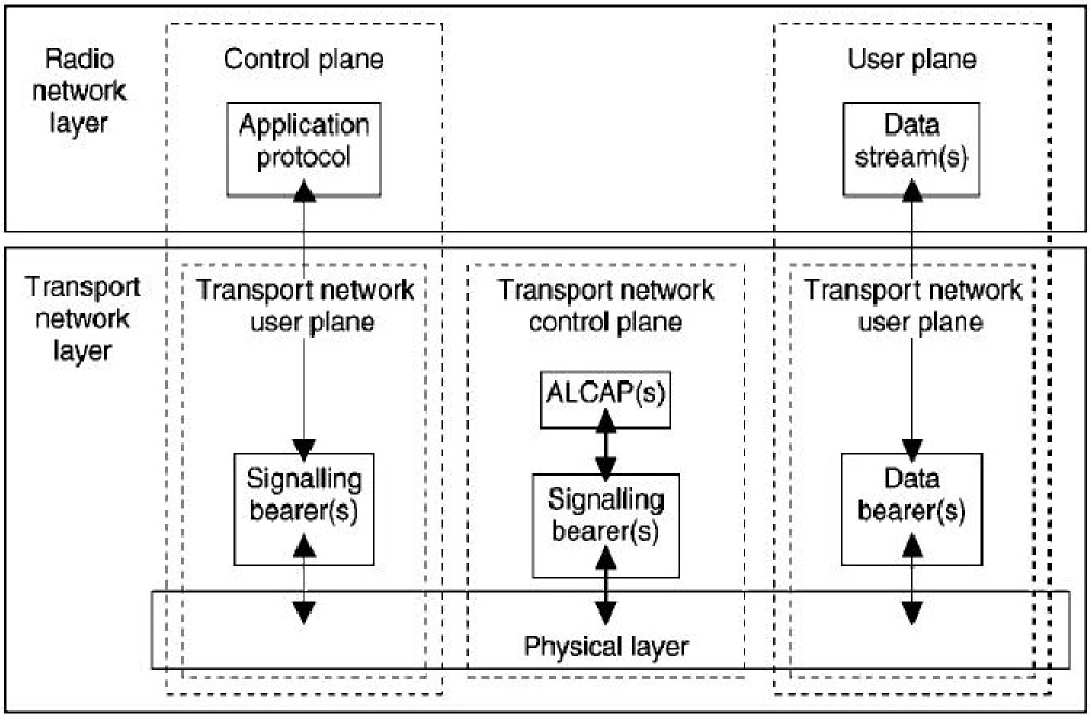


Figure 2.2: Protocol Model for UTRAN

standard transport technology that is selected to be used for UTRAN but without any UTRAN-specific changes. The Control Plane is used for all UMTS-specific control signalling. 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. The User Plane includes the Data Stream, and the Data Bearer for the Data Stream. The Transport Network Control Plane is used for all control signalling within the Transport Layer. The Transport Network Control Plane is a plane that acts between the Control Plane and the User Plane [19].

## 2.2 WCDMA

WCDMA is a wideband Direct-Sequence Code Division Multiple Access (DS-CDMA) system, i.e. user information bits are spread over a wide bandwidth by multiplying the user data with quasi-random bits (called chips) derived from CDMA spreading codes. In order to support very high bit rates (up to 2 Mbps), the use of a variable spreading factor and multicode connections is supported. The chip rate of 3.84 Mcps leads to a carrier bandwidth of approximately 5 MHz. The wide carrier bandwidth of WCDMA supports high user data rates and also has certain performance benefits, such as increased multipath diversity. WCDMA supports highly variable user data rates, in other words the concept of obtaining Bandwidth on Demand (BoD) is well supported. The user data rate is kept constant during each 10 ms frame. However, the data capacity among the users can change from frame to frame. This fast radio capacity allocation should typically be controlled by the network to achieve optimum throughput for packet data services. WCDMA supports two basic modes of operation: Frequency Division Duplex (FDD) and Time Division Duplex (TDD). In the FDD mode, separate 5 MHz carrier frequencies are used for the uplink and downlink respectively, whereas in TDD only one 5 MHz is timeshared between the uplink and downlink. Uplink is the connection from the mobile to the base station, and downlink is from the base station to the mobile. Fast power control is one of the most important aspects in WCDMA. Without it, a single overpowered mobile could block a whole cell. Figure 2.3 show the problem and the solution in the form of closed loop transmission power control. Mobile stations MS1 and MS2 operate within the same frequency, separable at the base station only by their respective spreading/coding codes. It may happen that MS1 at the cell edge suffers a path loss, say 70 dB above that of MS2 which is near the base station BS. If there were no mechanism for MS1 and MS2 to be power-controlled to the same level at the base station, MS2 could easily overshot MS1 and thus block a large part of the cell, giving rise to the so-called near-far problem. The optimum strategy in the sense of maximizing capacity is to equalise the received power per bit of all mobile stations at any times. If the measured SIR is higher than the target SIR, the base station will order the mobile station to reduce the power; if it is too low it will order the mobile station to increase its power. This measure-command-react cycle is executed at a rate of 1500 times per second (1.5 kHz) for each mobile station and thus operates faster than any significant change of

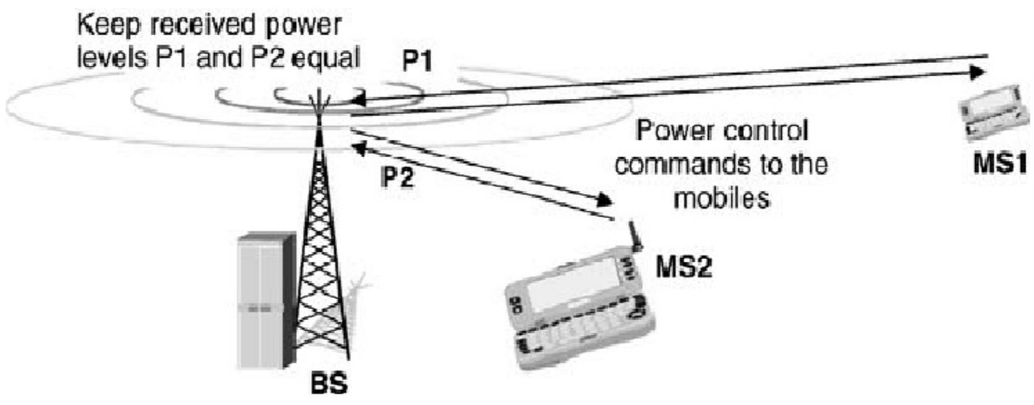


Figure 2.3: Power Control

the path. The same closed loop power control technique is also used on the downlink, though here the motivation is different: on the downlink there is no near-far problem due to the oneto- many scenario. It is, however, desirable to provide a marginal amount of additional power to mobile stations at the cell edge, as they suffer from increased other-cell interference [10]. In addition to spreading, part of the process in

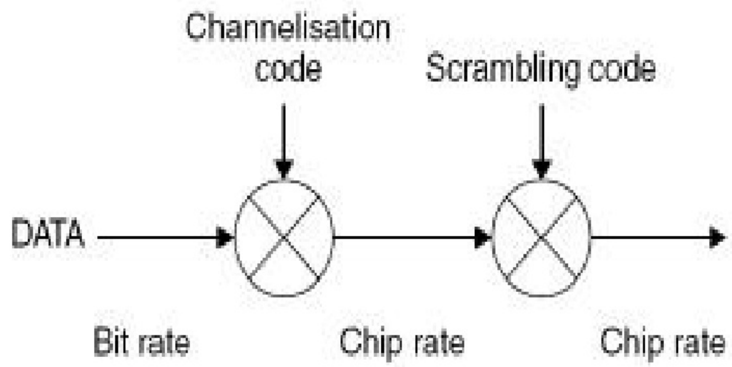


Figure 2.4: Spreading and Scrambling

the transmitter is the scrambling operation. This is needed to separate terminals or base stations from each other. 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. With scrambling, it would not matter if the actual spreading were performed with identical codes for several transmitters. Figure2.4 shows the relationship of the chip rate in the channel to spreading and scrambling. As the chip rate is already achieved in spreading by the channelisation codes, the symbol rate is not affected by the scrambling.

Transmissions from a single source are separated by channelisation codes, i.e. downlink connections within one sector and the dedicated physical channel in the uplink from one terminal. The spreading/channelisation codes of UTRAN are based on the Orthogonal Variable Spreading Factor (OVSF). The use of OVSF codes allows the spreading factor to be changed and orthogonality between different spreading codes of different lengths to be maintained. The codes are picked from the code tree, which is illustrated in Figure 2.5. In case the connection uses a variable spreading factor, the proper use of the code tree also allows despreading according to the smallest spreading factor. This requires only that channelisation codes are used from the branch indicated by the code used for the smallest spreading factor. The downlink orthogonal codes within each base station are managed by the radio network controller (RNC) in the network.

## 2.3 UMTS Channels

Logical channels allow communication between the RLC and MAC layers in UTRAN, and they are characterised by the type of information that is being transferred across these layers. As a result, there are logical channels for the transfer of user traffic, Traffic Channels, and also logical channels for the transfer of control information, Control Channels, which can be either dedicated to specific users or common to a set or to all of them. Logical channels are mapped onto transport channels in the MAC layer. In UTRAN the data generated at higher la yers is carried over the air with transport channels, which are mapped in the physical layer to different

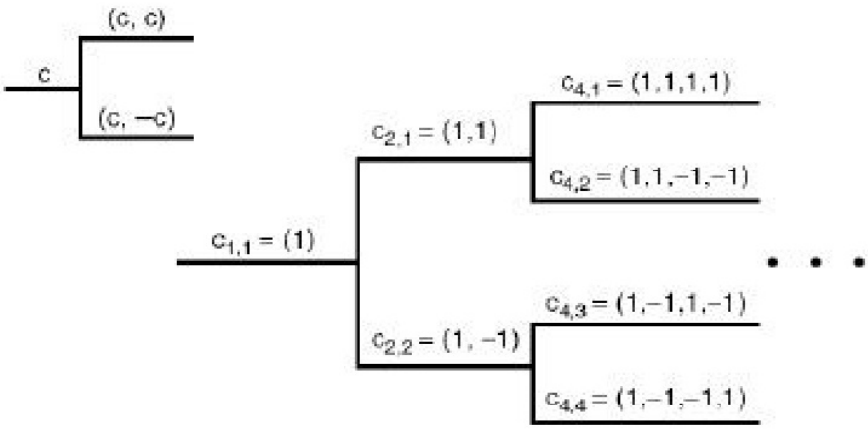


Figure 2.5: Spreading/Channelisation code tree of UTRAN

physical channels. The physical layer is required to support variable bit rate transport channels to offer bandwidth-on-demand services, and to be able to multiplex several services to one connection. Each transport channel is accompanied by the Transport Format Indicator (TFI) at each time event at which data is expected to arrive for the specific transport channel from the higher layers. The physical layer combines the TFI information from different transport channels to the Transport Format Combination Indicator (TFCI). The TFCI is transmitted in the physical control channel to inform the receiver which transport channels are active for the current frame; the exception to this is the use of Blind Transport Format Detection (BTFD) that will be covered in connection with the downlink dedicated channels. The TFCI is decoded appropriately in the receiver and the resulting TFI is given to higher layers for each of the transport channels that can be active for the connection. The interface between physical and higher layers is represented by the Iubinterface between the Node B and RNC. Two types of transport channel exist: Dedicated Channels and Common Channels. The main difference between them is that a common channel is a resource divided between all or a group of users in a cell, instead a dedicated channel resource, identified by a certain code on a certain frequency, is reserved for a single user only [10], [15].

### 2.3.1 Logical Channels

The most important Control Logical Channels are:

**Broadcast Control Channel:** Broadcast Control Channel (BCCH) carries control information that is broadcast to all the users of a given cell in the form of System Information messages. Such information includes cell specific parameters (e.g. cell identifiers, code sequences, timers, etc.) that must be known by the UE before trying to camp on a given cell. This channel is only defined in the downlink direction. BCCH is mapped onto BCH Transport Channel.

**Paging Control Channel:**Paging Control Channel (PCCH) is used to notify incoming calls or messages to the users in a given area. All the UEs in idle mode should listen to this channel periodically. This channel is only defined in the dow nlink direction. PCCH is mapped onto PCH Transport Channel.

**Dedicated Control Channel:**Dedicated Control Channel (DCCH) transfers signalling information corresponding to a specific UE. It is a point-to-point bi-directional channel that exists for each UE that has a RRC connection with the RNC. Examples of messages that are transferred through this logical channel are connection establishment messages, radio resource control messages or measurement reports. DCCH is mapped onto DCH, RACH and CPCH transport channels.

**Common Control Channel:** Common Control Channel (CCCH) would be equivalent to the DCCH channel but for UEs that do not have yet a RRC connection with the RNC and by users executing cell reselection procedures while transmitting in common channels. As a result, the UE should make use of shared physical and transport channels including the corresponding UE identity in the transmitted messages. An example of the utilisation of the CCCH would be the initial message that is transmitted by a UE during a connection establishment and the corresponding channel allocation response from the network. CCCH is mapped onto RACH transport channel.

Two types of Logical Traffic Channels are defined:

**Dedicated Traffic Channel:** Dedicated Traffic Channel (DTCH) is defined in the user plane and transfers the information corresponding to a given service dedicated to a single user. It exists both in the uplink and downlink direction. Different DTCH channels may coexist for a given UE whenever several services are provide d simultaneously (e.g. data and voice connections). DTCH is mapped onto DCH, RACH and CPCH transport channels.

**Common Traffic Channel:**Common Traffic Channel (CTCH) carries dedicated user information to a group of UEs in a given cell (e.g. for the transfer of SMS Cell Broadcast Messages providing information depending on the geographical area). It is a point-to-multipoint unidirectional channel.

### 2.3.2 Transport Channels

UMTS Release '99 has only one dedicated transport channels:

**Dedicated Channel:**The only dedicated transport channel is the Dedicated Channel (DCH). The dedicated transport channel carries all the information intended for the given user coming from layers above the physical layer, including data for the actual service as well as higher layer control information. The content of the information carried on the DCH is not visible to the physical layer, thus higher layer control information and user data are treated in the same way. The dedicated transport channel is characterised by features such as fas t power control, fast data rate change on a frame-by-frame basis, and the possibility of transmission to a certain part of the cell or sector with varying antenna weights with adaptive antenna systems.

UMTS Release '99 has six different common transport channels:

**Broadcast Channel:** The Broadcast Channel (BCH) is a transport channel that is used to transmit information specific to the UTRA network or for a given cell. One terminal which wants to register to the cell needs to decode the broadcast channel.

**Forward Access Channel:** The Forward Access Channel (FACH) is a downlink transport channel that carries control information to terminals known to be located in the given cell. This is used, for example, after a random access message has been received by the base station. It is also possible to transmit data packets on the FACH. There can be more than one FACH in a cell. One of the forward access channels must have such a low bit rate that it can be received by all the terminals in the cell area. With more than one FACH, the additional channels can have a higher data rate. The FACH does not use fast power control, and the messages transmitted need to include in band identification information to ensure their correct receipt. The FACH, carried on the secondary common control physical cha nnel (S-CCPCH) can be used for downlink packet data as well [9].

**Paging Channel:**The Paging Channel (PCH) is a downlink transport channel that carries data relevant to the paging procedure, that is, when the network wants to initiate communication with the terminal. The terminals must be able to receive the paging information in the whole cell area.

**Random Access Channel:**The Random Access Channel (RACH) is an uplink transport channel intended to be used to carry control information from the terminal, such as requests to set up a connection. It can also be used to send small amounts of packet data from the terminal to the network. For proper system operation the random access channel must be heard from the whole desired cell coverage area, which also means that practical data rates have to be rather low, at least for the initial system access and other control procedures.

**Uplink Common Packet Channel:**The uplink common packet channel (CPCH) is an extension to the RACH channel that is intended to carry packet-based user data in the uplink direction. The reciprocal channel providing the data in the downlink direction is the FACH. CPCH uses fast power control. The uplink CPCH transmission may last several frames in contrast with one or two frames for the RACH message.

**Downlink Shared Channel:**The downlink shared channel (DSCH) is a transport channel intended to carry dedicated user data and/or control information; it can be shared by several users. In many respects it is similar to the forward access channel, although the shared channel supports the use of fast power control as well as variable bit rate on a frame-by-frame basis. The DSCH does not need to be heard in the whole cell area and can employ the different modes of transmit antenna diversity methods that are used with the associated downlink DCH. The downlink shared channel is always associated with a downlink DCH.

### 2.3.3 Physical Channel

A brief overview of the most important physical channels are given below:

**Dedicated Physical Data Channel:**The Dedicated Physical Data Channel (DPDCH) carries the information of a DCH transport channel. It exists both in the uplink and downlink directions and makes use of closed loop power control[15].

**Dedicated Physical Control Channel:**The Dedicated Physical Control Channel (DPCCH) is related to a DPDCH and transmits physical layer signalling information (e.g. power control commands and synchronisation sequences).

**Primary Common Control:**The Primary Common Control Physical Channel (P-CCPCH) only exists in the downlink direction and has a fixed channel bit rate of 30 kb/s, corresponding to a spreading factor of 256. It is used to carry the BCH transport channel.

**Secondary Common Control Physical Channel:**The Secondary Common Control Physical Channel (Secondary CCPCH) carries two different common transport channels: the Forward Access Channel (FACH) and the Paging Channel (PCH). The two channels can share a single Secondary CCPCH or can use different physical channels. This means that in the minimum configuration each cell has at least one Secondary CCPCH. The spreading factor used in a Secondary CCPCH is fixed and determined according to the maximum data rate. The maximum data rate usable is naturally dependent on the terminal capabilities [9].

**Synchronisation Channel:**The Synchronisation Channel (SCH) is used for cell search and is the first channel that a terminal must detect before being able to measure a new cell. It allows the synchronisation at frame and time slot levels as well as the determination of the code sequence being used by the P-CCPCH channel that contains the BCH.

**Common Pilot Channel:**The Common Pilot Channel (CPICH) is used by the terminals to make power measurements of the different cells. The measured level of this channel determinates whether or not the corresponding cell can be used.

**Physical Random Access Channel:**The Physical Random Access Channel (PRACH) is used in the uplink direction and carries the RACH transport channel.

**Physical Common Packet Channel:**The Physical Common Packet Channel (PCPCH) exists in the uplink direction and transmits the CPCH transport channel.

**Physical Downlink Shared Channel:**The Physical Downlink Shared Channel (PDSCH) carries the DSCH transport channel. Different bit rates are available.

## 2.4 HSPA: Speed and Capacity to Support New Services

### 2.4.1 In pursuit of the wireline experience: HSPA introduced

One of the key objectives of third generation technology has been to deliver an improved end-user experience for mobile data applications while ensuring the costs of delivery make the service economic to both end-user and service provider. As wireline broadband services based on Digital Subscriber Line (DSL) and cable technologies become more prevalent, mobile data connectivity must offer a comparable end-user experience if the service is to be attractive in the marketplace. A major development in the improvement of end-user experience is now available through High Speed Packet Access (HSPA). HSPA will be launched to the market in two phases, the first offering improvements in the downlink (HSDPA) while in a second phase the uplink will offer an improved uplink performance (HSUPA).

HSPA is a step along the path of technology evolution which UMTS offers. Improvements to HSPA are already being proposed, these are known as HSPA+, while a proposal for Long Term Evolution (LTE) is currently making its way through standards. Each of these steps will be discussed in this paper. However, at this point it is worthwhile to compare the different steps in the UMTS evolution path in terms of technical characteristics, performance and cost.

### 2.4.2 HSPA market strengths and features

There are two significant improvements that will be perceptible to the end-user with the launch of HSPA: improved throughput and improved latency. In addition, operators will benefit from a significant increase in network capacity for data services.

**Improved throughput**

UMTS networks deployed based on the 3GPP Release 99 standard offer a maximum theoretical data throughput per user of 384 kbps. With HSDPA there is the possibility to offer the end-user up to 14.4 Mbps in the downlink. How often or how many users will be able to achieve this throughput will obviously depend sson network and radio conditions as well as the type of terminal being used. A more reasonable scenario will see a large number of users with a category 6 HSDPA terminal allowing them to communicate at data speeds up to 3.6 Mbps. This is already almost a factor of 10 increase from the maximum throughput available to 3G/UMTS users today. This will bring new applications such as high quality video streaming as well as faster music and entertainment downloads, and improved time savings for ubiquitous corporate e-mail services.

**Improved latency**

One of the major improvements with HSPA technology is the improvement in network latency or round trip delay for data applications. First deployments of HSDPA indicate a round trip delay of as low as 60ms, meaning that many realtime interactive services can be delivered over HSDPA. This will be true for Voice and Video but also for applications such as multi-user gaming where immediate real-time interaction with other users is key to stimulate high levels of game usage. This will be the key enabler for the beginning of a new era of mobile multimedia over UMTS networks and terminals.

**Improved capacity**

With the introduction of new improved coding and modulation with HSPA, the spectral efficiency of the access network is much improved. Early tests and measurements indicate that the data capacity available in the standard UMTS carrier bandwidth of 5MHz is increased by a factor of 5 with the upgrade to HSDPA. This will offer a much improved cost structure for offering data services with the cost per bit reducing significantly. This should help drive adoption rates of mobile data services as the cost to deliver the services to a wider audience will be significantly decreased.

### 2.4.3 Services and market potential

HSPA offers the opportunity of a new service experience for 3G users. In understanding the impact of HSPA on the service offering, the UMTS Forum categorises services into three categories:

a. Services unchanged user experience

b. Services with improved user experience

c. New services enabled by HSPA.

Services such as SMS or low speed browsing are unlikely to see a significant enduser improvement, although the capacity for offering these services will be significantly improved.

The improved speed and latency of HSPA will offer a much improved end-user experience for services such as Multimedia Messaging, Mobile TV, e-mail and music downloads. This improved facility of usage can be expected in turn to stimulate usage levels. Among the new services expected to be enabled by HSPA and the evolution

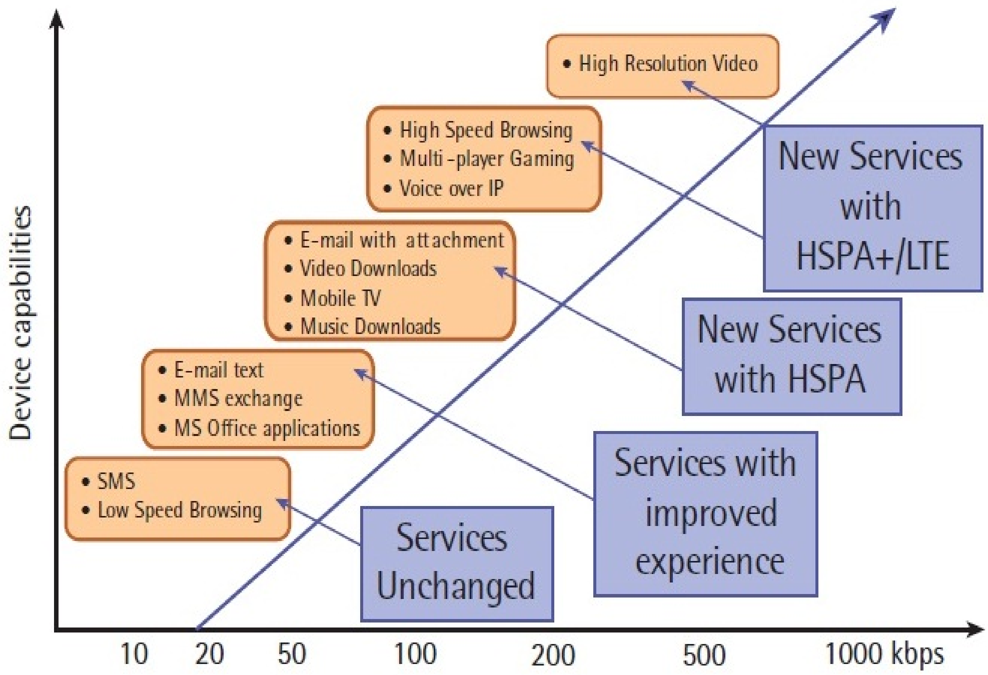


Figure 2.6: HSPA delivers new services and an enhanced user experience

to HSPA+ and LTE will be Voice over IP, multi-user gaming and high resolution video as shown in figure 2.6. A full-length music track downloaded as an MP3 file, for example, takes around a minute using 3G/UMTS, while with HSDPA, this time is reduced to fifteen seconds or less. HSPA has the opportunity to become the worlds leading 3G technology within the next few years. In Report, The Global Market for High Speed Packet Access (HSPA): Quantitative and Qualitative analysis, the UMTS Forum forecasts that, by 2012, there will be almost 1 billion users of HSPA technology globally as shown in figure 2.7.

The report also forecasts that HSPA will make a significant impact on the revenues from mobile data services. The report forecasts that mobile data revenues will increase from 17bn in 2006 to 120bn in 2012.

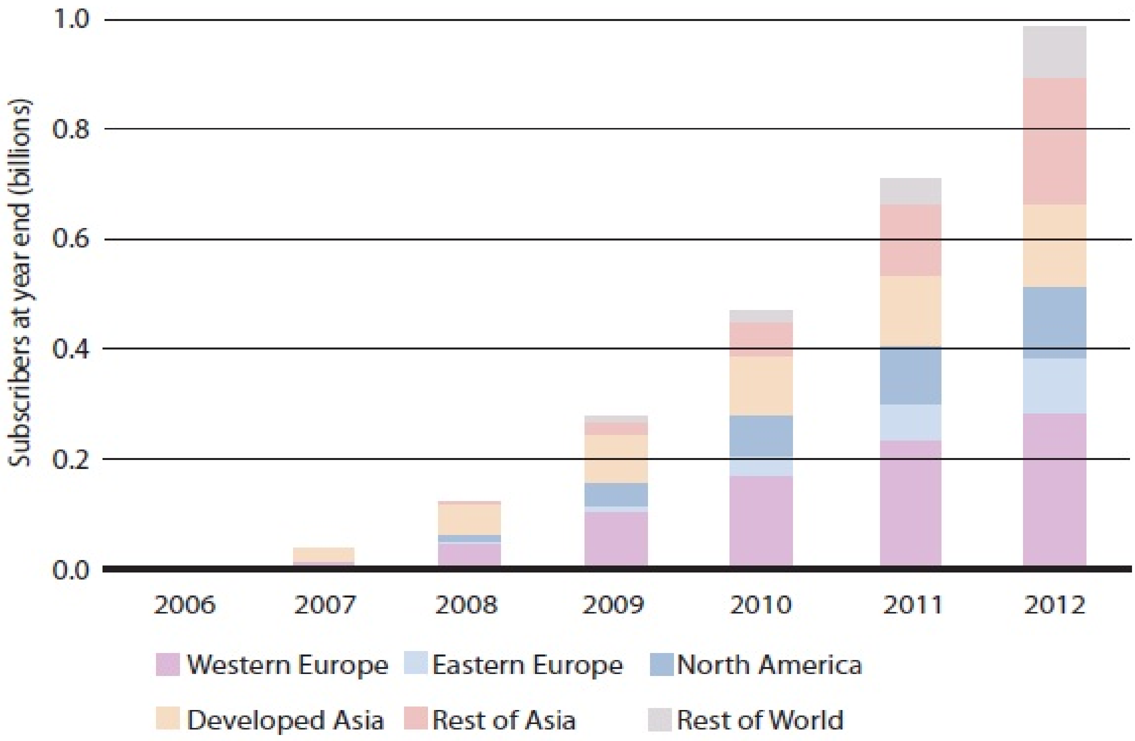


Figure 2.7: HSPA users will approach 1 billion by 2012

### 2.4.4 HSPA key technological features

HSDPA introduces a number of new technical capabilities to the radio access network which, when combined, offer a significant improvement for both endusers and operators. These are:

#### HSDPA

**High Speed Downlink Shared Channel (HS-DSCH)**

The HS-DSCH is a shared channel with a number of Spreading Factor 16 (SF-16) CDMA codes. Within each 2ms TTI, a constant spreading factor of 16 is used with a maximum of 15 parallel channels in the HS-DSCH. These channels may all be assigned to one user during the TTI, or may be split amongst several HSDPA users.

**Transmission Time Interval (TTI) of 2ms**

The shorter 2ms TTI (compared with TTI of between 10ms and 80ms in UMTS R99) means that the system is more reactive to changing user or radio conditions and can quickly allocate capacity to users.

**Fast scheduling**

Fast data traffic scheduling means that variations arising from changing radio conditions can be accommodated and that the BTS is able to allocate as much as possible of the particular cells capacity to a particular user for a short period of time. This means that a user is able to receive as much data as radio conditions will allow.

**Adaptive Modulation and Coding (AMC)**

Adaptive Modulation Coding (AMC) with fast link adaptation means that the modulation and coding formats can be changed in accordance with variations in the channel conditions, leading to a higher data rate for users with favourable radio conditions. Whereas UMTS Release 99 used only Quadrature Phase Shift Keying (QPSK) modulation, HSDPA provides the ability to use 16-QAM when the link is sufficiently robust, which can lead to a significant increase in data rate.

**Fast Hybrid Automatic Response reQuest (HARQ) techniques**

Fast H-ARQ enables erroneous packets to be re-sent within a 10ms window, ensuring that the TCP throughput remains high. In addition, in HSDPA the mechanisms for ARQ are moved to the BTS (from the RNC in R99). By using these approaches, all users, whether near or far from the base station, are able to receive the optimum data rate.

### HSUPA

Similarly to HSDPA in the downlink, HSUPA defines a new radio interface for the uplink communication. The overall goal is to improve the coverage and throughput as well as to reduce the delay of the uplink dedicated transport channels[13]. From a 3GPP point of view, the first set of standards was approved in December 2004, and performance aspects were finalised during the summer of 2005. E-DCH is the name adopted in 3GPP for HSUPA which is in 3GPP Release 6. Key technical capabilities introduced with HSUPA are:

**A dedicated uplink channel**

Unlike HSDPA, HSUPA remains based on a dedicated channel. A series of new channels is introduced for both signalling and traffic to improve overall uplink capabilities.

**H-ARQ**

Like HSDPA, HSUPA introduces fast retransmissions based on the Hybrid ARQ Protocol for error recovery at the physical layer.

**Fast Node B scheduling**

Within the limits set by the RNC, the Node B scheduling enables the Node B to control the set of Transport Format Codes from which the UE may choose. This will enable improved coverage and capacity in the uplink.

## 2.5 HSPA+

Operators have already invested massively in the deployment of 3G/UMTS networks and will continue to invest over the coming years, increasing coverage of existing networks and deploying new 3G/UMTS networks in developing countries.They naturally wish to maximise their return on these investments. An evolutionary approach to standardisation supports this requirement. Phased enhancements to the 3G/UMTS standards are made possible by the continuing improvements in underlying technologies. While standardisation work is not yet complete, enhancements currently being defined by 3GPP under the banner HSPA+ consider two significant improvements to HSPA. These are an enhanced air interface plus a simpler, more cost efficient architecture [11].

### 2.5.1 More traffic, same equipment: HSPA+ defined

The main improvements are to the air interface. HSPA+ will have increased spectral efficiency and average rates per cell. This will help support increasing traffic, especially traffic from data services, without having to deploy new sites and with limited hardware upgrades of existing equipment.

- MIMO is being introduced to increase spectral efficiency in hot spots by an estimated 10 to 20 percentage; MIMO requires additional antennas, possibly hidden in rearranged antenna systems, and transmitters in existing base stations

- 64 QAM modulation is being proposed to increase data rates under good propagation conditions, contributing to an overall 20

Architectural improvements for HSPA+ are also being discussed in 3GPP where several items are being analysed. The objectives are a simpler and more cost efficient architecture for mobile broadband access services, together with better delay performance.

- A simpler architecture would result from the elimination of macro diversity and the associated RNC node. All RAN functions would be put in the Node B, directly connected through the current Iu interface to the core network. Although macro diversity is a key feature of CDMA-based technologies, its elimination is made possible through two considerations:

  a. The introduction of HSPA in the downlink has been done with very limited use of macro diversity

  b. HSPA in the uplink is based on macro diversity for optimal performance but in dense areas downlink capacity is the limiting factor; a decrease in the theoretical capacity of the uplink is acceptable as this limit is never reached.

- Better delay performance will result from integration of the 3G/UMTS network with the forthcoming 3G LTE/SAE network

## 2.6 Looking to the Future: 3G/UMTS Long Term Evolution

### 2.6.1 Planning ahead: technology choices in a complex world

#### Dimensioning for the future

The past decade has seen explosive growth in mobile communications within every single continent across the globe. Spearheaded by GSM systems, the mobile communications sector in many countries is now experiencing subscriber penetration levels approaching or even exceeding 100%. Voice traffic continues its apparently inexorable migration from fixed to mobile networks. Multimedia services are starting to take hold as 3G/UMTS networks are rolled out attracting subscribers at a faster rate than the first GSM networks and appealing terminal devices become widely available [16]. In just a decade, mobile communications has had a massive impact on economies and societies. That impact is continuing as the previously voice-centric mobile networks embrace data and video services and as convergence irreversibly changes the structure of the telecommunications industry. The amalgamation of mobile communications and the Internet is set to strengthen as broadband access networks are deployed and legacy PSTNs are replaced by all-IP environments. These new dimensions make planning for the future an urgent but daunting task. The underlying problem is unpredictability the future can no longer be approached as an extrapolation of the past. No-one can be certain what mix of products and services the next generation of users will be demanding from the information and communications industries a decade from now.

Voice services will undoubtedly be part of that demand. When digital cellular systems were originally designed, voice was the primary target service. System design focused on technology issues. Figure 2.8 shows the evolution of fixed/mobile systems and Internet with respect to user data rates. Planning for the long term evolution of 3G/UMTS is no longer a one-dimensional exercise of selecting the technology with

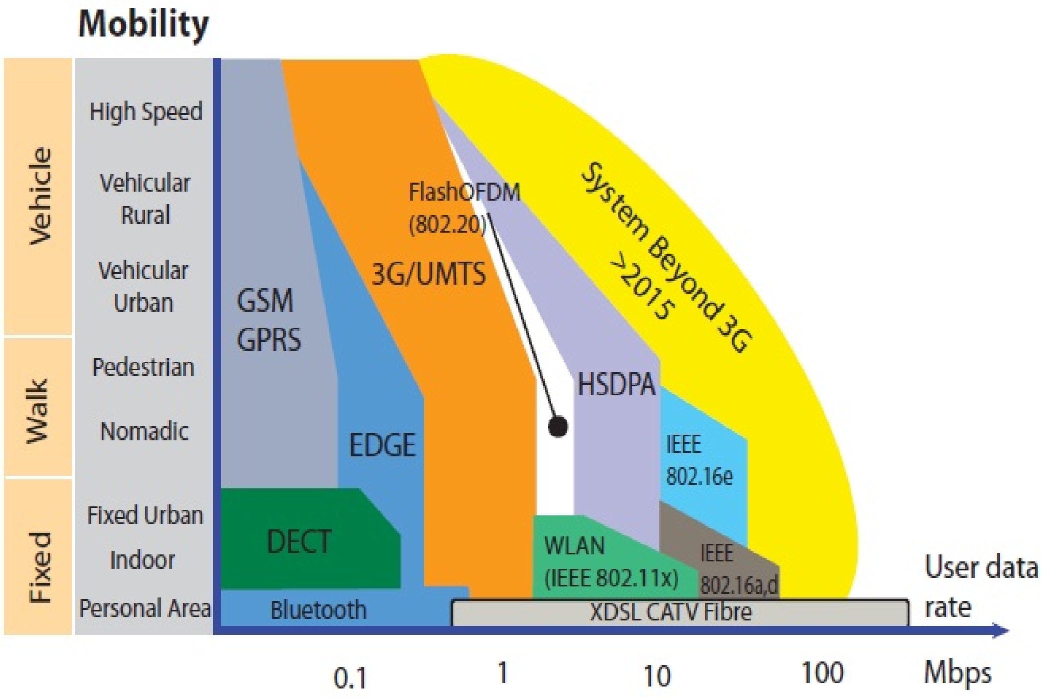


Figure 2.8: Evolution to higher bitrates drives convergence between fixed/mobile systems and the Internet

the best performance. Which technological approach could best satisfy the required criteria for coverage, capacity and quality in a mobile environment? Technology choices are still a major factor in the planning of future systems but no longer such a dominant factor as in the past.

The addition of mobile multimedia and internet services with 3G systems such as UMTS introduced a new dimension. Different services impose different requirements on radio access technologies and networks. The anticipated mix of services became an important factor in system specifications. Market demand for different categories of service became one of the important design criteria Market demand for new services remains a key consideration in the planning for the evolution of 3G/UMTS. But yet another dimension has emerged as a vital factor affecting the design of evolved systems. Compatibility with existing systems has become an important requirement,

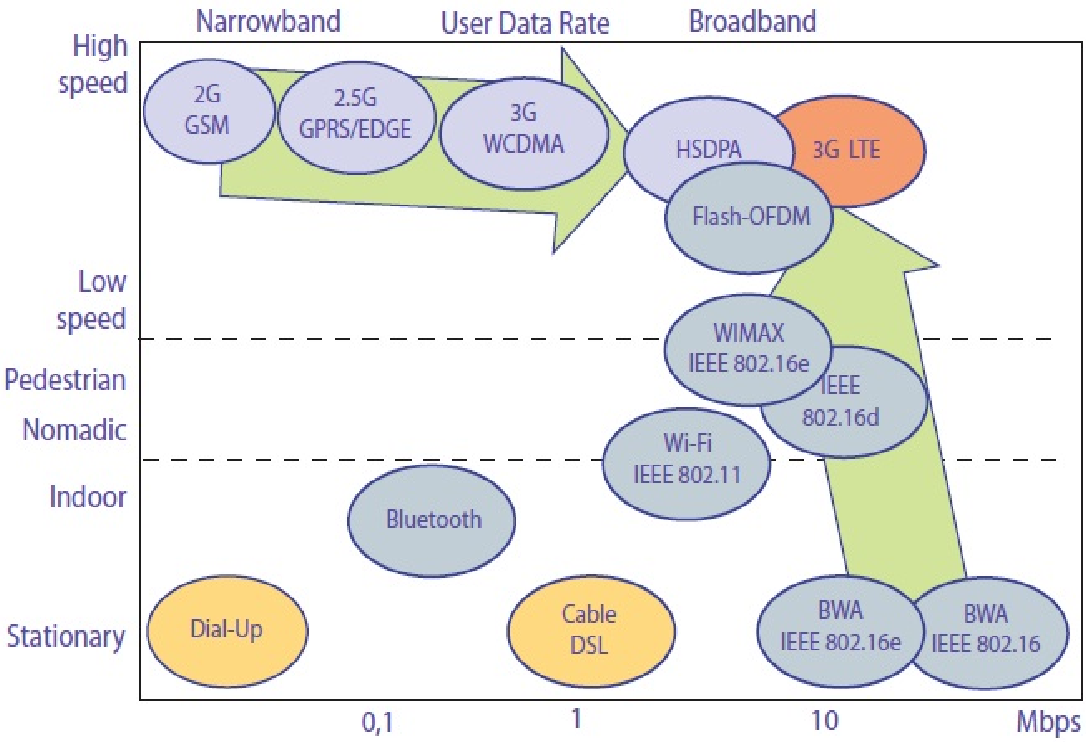


Figure 2.9: Trends in Mobile Wireless Access - Several technologies move in the same direction: Mobile Broadband

allowing both users and operators to retain the benefits of the existing rich portfolio of services in the most cost effective fashion.

### 2.6.2 Technology options: balancing performance and flexibility

#### Addressing the limits of physics

Elements being considered as part of this 3G/UMTS Long Term Evolution include a packet-optimised radio access technology with reduced latency, higher user data rates, improved system capacity and coverage, and reduced cost for the operator. Support for both wider and narrower transmission bandwidths than UMTS is planned, giving LTE significant flexibility for deployment in a wide range of environments.

Peak data rates rather than user data rates are often quoted as a measure of the

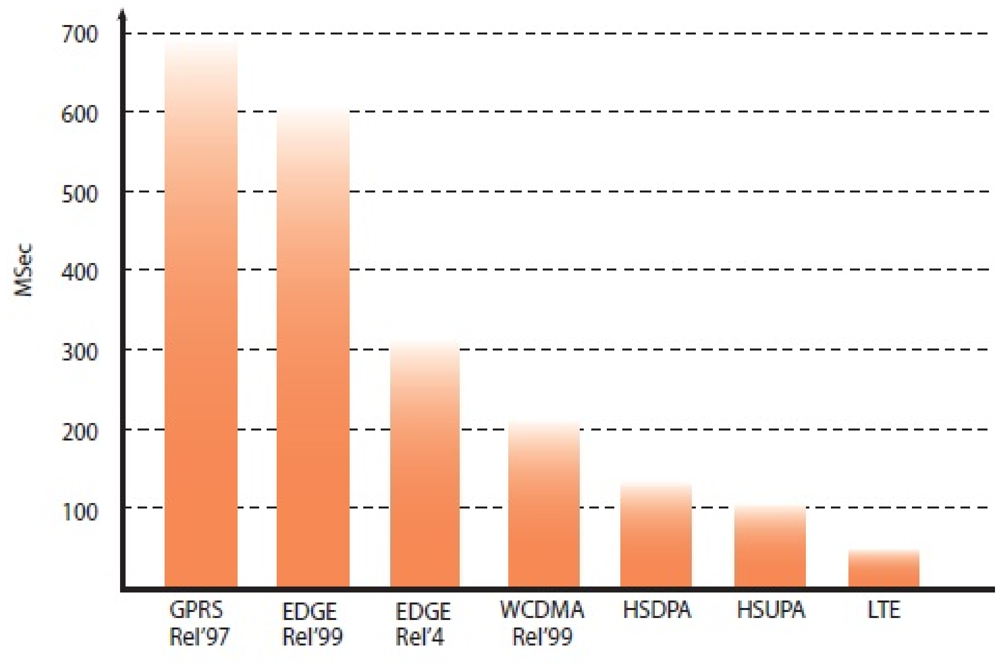


Figure 2.10: Latency Comparison

performance of 3G mobile networks. But peak data rates represent theoretical limits, in practice signalling overhead will reduce the available data rate which then has to be shared between users. The individual data rates experienced by those users will vary with time according to network loading and radio link conditions. Peak data rates are simply not a good indicator of user experience or network quality. Life is far more complex.In fact no single figure such as peak or user data rate can quantify network performance in a meaningful way as such parameters are not independent. For example, increasing the data rate will reduce the range of a cell. The effect is not insignificant a tenfold increase in data rate halves the range. The downlink range of a cell is largely determined by the peak data rate and the base station transmit power. That is just one example of the inevitable trade-off between capacity and coverage.

Base stations can transmit far more power than mobile terminal devices, particularly if those devices are battery-powered handsets, and so the ultimate limiting factor in the range of a cell is the uplink transmit power. The advanced modulation and coding schemes that deliver the highest data rates and capacity require a high quality transmission path conditions not always found over a radio link. Propagation conditions that vary over time and space result in transmission errors, requiring information to be resent and a fallback to less critical but less efficient modulation and coding schemes. In contrast to the controlled conditions of wireline networks, wide area wireless systems have to operate in an inherently tough and unstable environment.

**Finite resources: bandwidth and practical limits on mobility**

Higher data rates can be most reliably achieved by increasing bandwidth, either by combining channels effectively increasing the bandwidth at the expense of capacity, techniques used very successfully by enhancements such as EDGE and HSPA or by utilising higher bandwidth channels. Different generations of air interface technologies have all gone this route from narrowband TDMA systems such as GSM with 200 kHz channels, through CDMA systems such as 1xEV DO with 1.25 MHz channels to wideband CDMA systems such as UMTS with 5 MHz channels [18].

The option of increasing bandwidth to deliver higher data rates is also incorporated within 3G LTE which can support transmission bandwidths wider than 5 MHz. 3G/UMTS LTE will deliver broadband over 10, 15 and 20 MHz channels. It will also support bandwidths less than 5 MHz down to 1.25 MHz in fact to allow for flexibility in whichever frequency bands the system may be deployed.

It is impractical to support mobility in spectrum above 3 GHz, and GSM and UMTS systems typically operate in frequency bands around 900 MHz and 2 GHz. Higher frequencies experience greater diffraction loss on non line-of-sight paths and so they have shorter range than these bands. The lower frequencies with greater range are preferable for the provision of wide area coverage in rural and suburban areas doubling the frequency almost halves the non line-of-sight range and so could require four times the number of cells to achieve the same coverage.

Achieving 20 MHz channel widths is difficult in the lower frequency bands currently used by UMTS. So the highest data rates, not needed for all services, may require deployment at higher frequencies, perhaps in hotspot or pico cell configurations. The greater amount of spectrum available in the high frequency ranges will allow 3G LTE to keep pace with advances in data rate anticipated over fixed access lines.

But in-building penetration gets worse with increasing frequency not an ideal situation, as the services requiring the highest data rates are liable to be deployed in indoor nomadic rather than outdoor mobile scenarios. This conflict is another example of interdependence and the need for trade-offs. Network latency (the time taken for data to traverse the network) can be more important than user data rates or throughput, where real-time services such as voice are concerned. 3G LTE has the challenging target of reducing latency in the radio access network to less than 10 ms to enable VoIP services.

## 2.7 3G LTE and SAE

The cellular technologies specified by 3GPP are the most widely deployed in the world, with the number of users exceeding 2 billion in 2006. The latest step being studied and developed in 3GPP is an evolution of 3G and an evolved radio access referred to as the Long-Term Evolution (LTE). To support the new packet-data capabilities provided by the LTE radio interfaces, an evolved core network has been developed. The work on specifying the core network is commonly known as System Architecture Evolution (SAE).

To obtain these aims the requirements for LTE are divided into several different areas:

- Capabilities, which targets are 300 Mbit/s for downlink and 75 Mbit/s for uplink

- System performance, which includes throughput, mobility and coverage

- Architecture, which should be packet based, although real-time and conversation class traffic should be supported
- Radio resource management, which support the end-to-end QoS
- General aspect, which includes the cost aspect.

The SAE system should be able to operate with more than the LTE radio access network and there should be mobility functions allowing a mobile terminal to move between the different radio access systems. In fact, the requirements do not limit the mobility between radio access network. Roaming is a very strong requirement for SAE, including inbound and outbound roaming to other SAE networks. Furthermore, interworking with legacy packet-switched and circuit-switched services is a requirement. Of course, the SAE requirements require that the traditional services such voice, video, messaging and data file exchange should be supported. Several charging models, including calling party pays, flat rate, and charging based on QoS is required to be supported in SAE [8].

## 2.8 Summary

The basic idea of the UMTS network development is to separate the core and access networks. UMTS network is designed from the beginning for flexible delivery of any type of service and it uses WCDMA radio access solution to bring advanced capabilities. The services are divided into person-to-person services, content-to-person services and business connectivity. Person-to-person refers to a peer-to-peer or intermediate server based connection between two persons or a group of persons. Content-to-person services are characterised by the access to information or download of content. Business connectivity refers to the laptop access to internet using WCDMA as the radio modem. UMTS allows asymmetric services and uses Bearer Service. Bearer Service is a transport service which includes all the necessary characteristics to guarantee QoS, i.e. signalling and user data delivery.

# Chapter 3

# Multimedia Broadcast/Multicast Service

## 3.1 Introduction

3GPP Release 6 brings efficient support for broadcast services into WCDMA through the introduction of Multimedia Broadcast Multicast Services (MBMS), suitable for applications like mobile TV. With MBMS, multiple terminals may receive the same broadcast transmission instead of the network transmitting the same information individually to each of the users.

Initially, the need for the mobile phones to support a variety of multimedia mobile services at high data rates has led to the definition of 3rd Generation (3G) Mobile Cellular Networks and the choice of WCDMA for the radio access technique. A consequence of using WCDMA is that capacity of 3G systems is not hard limited. This means that an additional user entering the system cannot be blocked because of the limited amount of available channels. If a sufficient number of spreading codes is available, the interference due to increased load will be the main capacity-limiting factor in the network. Later on, the need for efficient data distribution when a large number of users want to receive the same data has led to the definition of Multimedia

Broadcast Multicast Service (MBMS) System.

## 3.2 MBMS Description

There are three types of MBMS User Service:

- Streaming services, which provide a stream of continuous media, i.e. audio and video. For example, if text includes some content on the Internet, a user can easily access the content without entering the URL for himself. It needs time synchronisation.

- File download services, which deliver binary data (file data) over an MBMS bearer. An MBMS client (i.e. UE) activates an appropriate application, and utilises the delivered data.

- Carousel services, which are services that combine aspects of both the Streaming and File download services described above. Similar to the streaming service this service includes time synchronisation. However, the target media of this service is only static media (e.g. text and still images). The benefit of this service is that it is possible over a low bit-rate bearer.

MBMS supports multicast-broadcast services in a cellular system, thereby combining multicast and unicast transmissions within a single network. With MBMS, the same content is transmitted to multiple users located in a specific area, the MBMS service area, in a unidirectional way. The MBMS service area typically covers multiple cells, although it can be made as small as a single cell. Broadcast and multicast describe different, although closely related scenarios:

- The broadcast mode is a unidirectional point-to-multipoint transmission of multimedia data from a single source entity to all users in a broadcast service area. In broadcast, a point-to-multipoint radio resource is set up in each cell being part of the MBMS broadcast area and all users subscribing to the broadcast service simultaneously receive the same transmitted signal. No tracking of users movement in the radio access network is performed and users can receive the content without notifying the network. Mobile TV is an example of a service that could be provided through MBMS broadcast. The broadcast mode should allow terminals to minimise their power consumption. The reception of the traffic in the broadcast mode is not guaranteed. The receiver may be able to recognize data loss.

- The multicast mode allows the unidirectional point-to-multipoint transmission of multimedia data (e.g. text, audio, picture, video) from a single source point to a multicast group in a multicast service area. The multicast mode is intended to efficiently use radio-network resources e.g. data is transmitted over a common radio channel. In the multicast mode there is the possibility for the network to selectively transmit to cells within the multicast service area which contain members of a multicast group. In multicast, users request to join a multicast group prior to receiving any data. The user movements are tracked and the radio resources are configured to match the number of users in the cell. Each cell in the MBMS multicast area may be configured for point-topoint or point-to-multipoint transmission. In sparsely populated cells with only one or a few users subscribing to the MBMS service, point-to-point transmission may be appropriate, while in cells with a larger number of users, point-to-multipoint transmission is better suited. Multicast therefore allows the network to optimize the transmission type in each cell. An example of a service using the multicast mode could be a football results service for which a subscription is required. Multicast mode generally requires a subscription to the multicast subscription group and then the user joining the corresponding multicast group. The subscription and group joining may be made by the PLMN operator, the user or a third party on their behalf (e.g. company). Multicast mode shall be interoperable with IETF IP Multicast. This could allow the best use of IP service

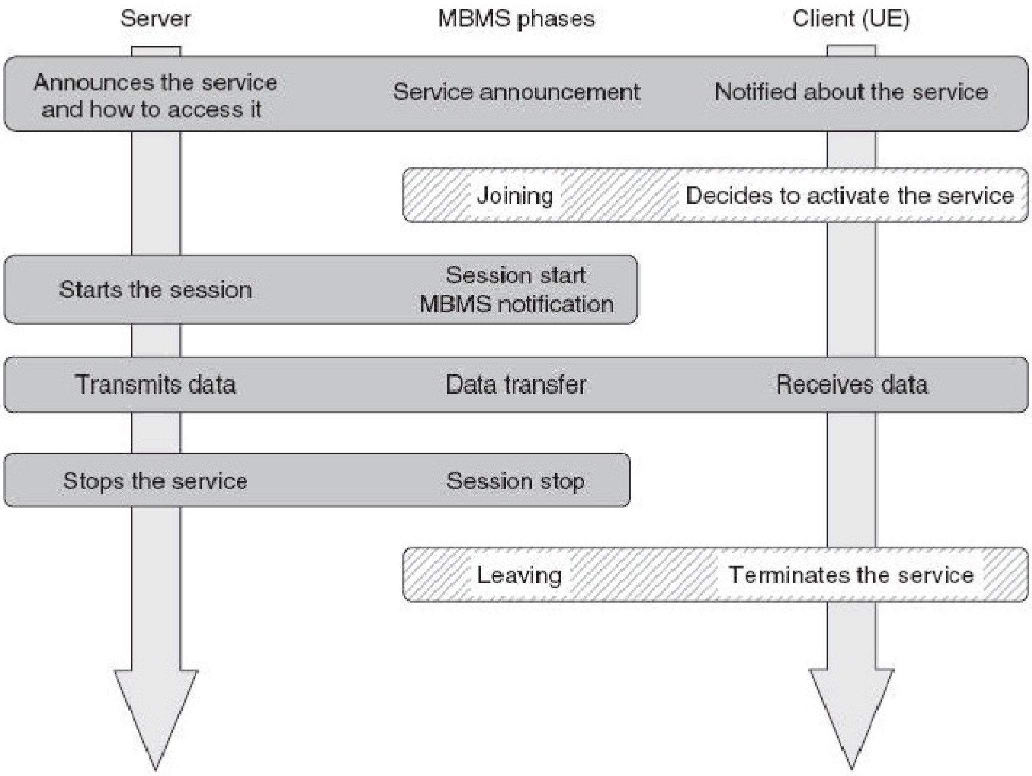


Figure 3.1: Example of typical phases during a MBMS session

platforms to help maximize the availability of applications and contents so that current and future services can be delivered in a more efficient manner [4].

In Figure 3.1, typical phases during an MBMS session are illustrated [9]. In case of multicast, a request to join the session has to be sent to become member of the corresponding MBMS service group and, as such, receive the data. Before the MBMS transmission can start, the BM-SC sends a session-start request to the core network, which allocates the necessary internal resources and request the appropriate radio resources from the radio-access network. All terminals of the corresponding MBMS service group are also notified that content delivery from the service will start. Data will then be transmitted from the content server to the end users. When the data transmission stops, the server will send a session-stop notification. Also, users who want to leave an MBMS multicast service can request to be removed from the MBMS service group [9], [7].

One of the main benefits brought by MBMS is the resource savings in the network as a single stream of data may serve multiple users. This is showed in Figure 4.2, where three different services are offered in different areas. As seen in the figure, the data stream intended for multiple users is not split until necessary. For example, there is only a single stream of data sent to all the users in cell 3. This is valid also from a radio-interface perspective, in fact MBMS data transmission should adapt to different RAN capabilities or different radio resource ava ilability, e.g. by reducing the bitrate of the MBMS data. Depending on the number of users that have joined to receive the content via the MBMS, the network can select whether to use point-to-point or point-to-multipoint transmission. In the former case, DCH is used as the transport channel and in the case where several UEs want to receive the same service, FACH is used as the transport channel in a particular cell. On the physical layer, the FACH is mapped on S-CCPCH and DCH respectively of the DPDCH. Obviously, point-to-multipoint transmission puts very different requirements on the radio interface than point-to-point unicast. User-specific adaptation of the radio parameters, such as channel-dependent scheduling or rate control, cannot be used as the signal is intended for multiple users. The transmission parameters such as power must be set taking the worst case user into account as this determines the coverage for the service. Frequent feedback from the users, for example, in the form of Channel Quality Indicator (CQI) reports or H-ARQ status reports, would also consume a large amount of the uplink capacity in cells where a large number of users simultaneously receive the same content. Imagine, for example, a sports arena with thousands of spectators watching their home team playing, all of them simultaneously wanting to receive results from games in other locations whose outcome might affect their home team. Clearly, user-specific feedback would consume a considerable amount of capacity in this case [20].

The UTRAN shall decide, based on the number of UEs in a particular cell, which mode of MBMS operation to use, and if the situation changes, the network can transfer the UEs between different states of MBMS reception. Typically, there need to be more than just a few UEs to receive the same content in order to make the use of a broadcast channel without power control efficient enough. From the above discussion, it is clear that MBMS services are power limited and maximizing the diversity without relying on feedback from the users is of key importance. The two main techniques for providing the diversity for MBMS services are:

- Macro-diversity by combining of transmissions from multiple cells.
- Time-diversity against fast fading through a long 80 ms TTI and application level coding.

Fortunately, MBMS services are not delay sensitive and the use of a long TTI is not a problem from the end-user perspective. Additional means for providing diversity can also be applied in the network. Receive diversity in the terminal also improves the performance, but as the 3GPP UE requirements for Release 6 are set assuming single -antenna for UEs, it is hard to exploit this type of diversity in the planning of MBMS coverage [3].

Combining transmissions of the same content from multiple cells (macro-diversity) provides a significant diversity gain, in the order of 4-6 dB reduction in transmission power compared to single-cell reception. Two combining strategies are supported for MBMS:

- Soft combining: which combines the soft bits received from the different radio links prior to (Turbo) decoding. In principle, the UE descrambles and RAKE combines the transmission from each cell individually, followed by soft combining of the different radio links. Note that, in contrast to unicast, this macro-diversity gain comes for free in the sense that the signal in the neighboring cell is anyway present. Therefore it is better to exploit this signal rather than treat it as interference. However, as WCDMA uses cellspecific scrambling of all data transmissions, the soft combining needs to be performed by the appropriate UE processing. This processing is also responsible for suppressing the

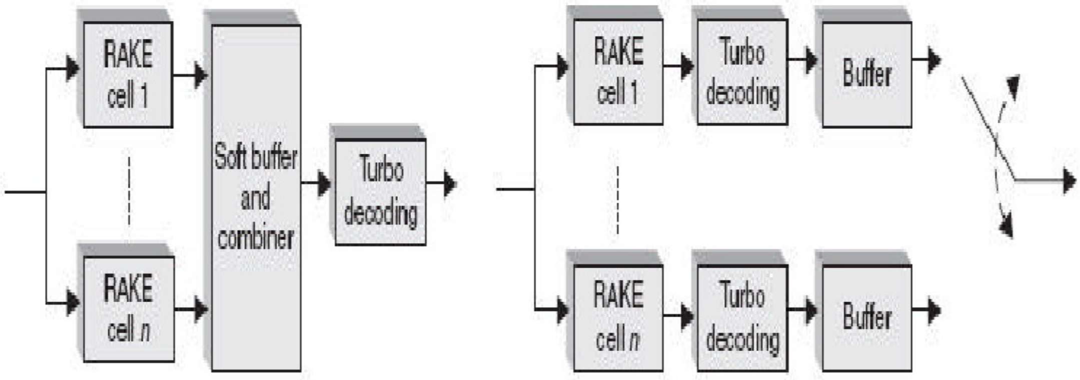


Figure 3.2: Soft and Selection Combing principles

interference caused by (non-MBMS) transmission activity in the neighboring cells. To perform soft combining, the physical channels to be combined should be identical. For MBMS, this implies the same physical channel content and structure should be used on the radio links that are soft combined.

- Selection combining: which decodes the signal received from each cell individually and for each TTI selects one (if any) of the correctly decoded data blocks for further processing by higher layers.

The principles of both are showed in Figure 3.2.

From a performance perspective, soft combining is preferable as it provides not only diversity gains, but also a power gain as the received power from multiple cells is exploited. Relative to selection combining, the gain is in the order of 23 dB. The reason for supporting two different combining strategies is to handle different levels of asynchronism in the network. For soft combining, the soft bits from each radio link have to be buffered until the whole TTI is received from all involved radio links and the soft combining can start, while for selection combining, each radio link is decoded separately and it is sufficient to buffer the decoded information bits from each link. Hence, for a large degree of asynchronism, selection combining requires less buffering in the UE at the cost of an increase in Turbo decoding processing and loss of performance. The UE is informed about the level of synchronism and can, based upon this information and its internal implementation, decide to use any combination scheme as long as it satisfies the minimum performance requirements mandated by the specifications. With similar buffering requirements as for a 3.6 Mbit/s HSDPA terminal, which is the basis for the definition of the UE MBMS requirements, soft combining is possible provided the transmissions from the different cells are synchronized within approximately 80 ms, which is likely to be realistic in most situations [14].

## 3.3 Architecture to support MBMS

MBMS architecture enables the efficient usage of radio -network and core-network resources, with an emphasis on radio interface efficiency. MBMS is realized by the addition of a number of new capabilities to existing functional entities of the 3GPP architecture and by addition of a number of new functional entities. In the Figure 3.3 the architecture to support MBMS is showed [11]. The existing PS Domain functional entities (GGSN, SGSN, UTRAN, GERAN and UE) are enhanced to provide the MBMS Bearer Service to deliver IP multicast datagrams to the multiple receivers using minimum network and radio resources. Next there is a brief description of the entities involved in the management of MBMS.

### 3.3.1 Broadcast Multicast Service Centre (BM-SC)

The BM-SC provides functions for MBMS us er service provisioning and delivery. It may serve as an entry point for content provider MBMS transmissions, used to authoriz e and initiate MBMS Bearer Services within the PLMN and can be used to schedule and deliver MBMS transmissions. Particularly, the BM-SC consists of five sub-functions:

- Service Announcement function;

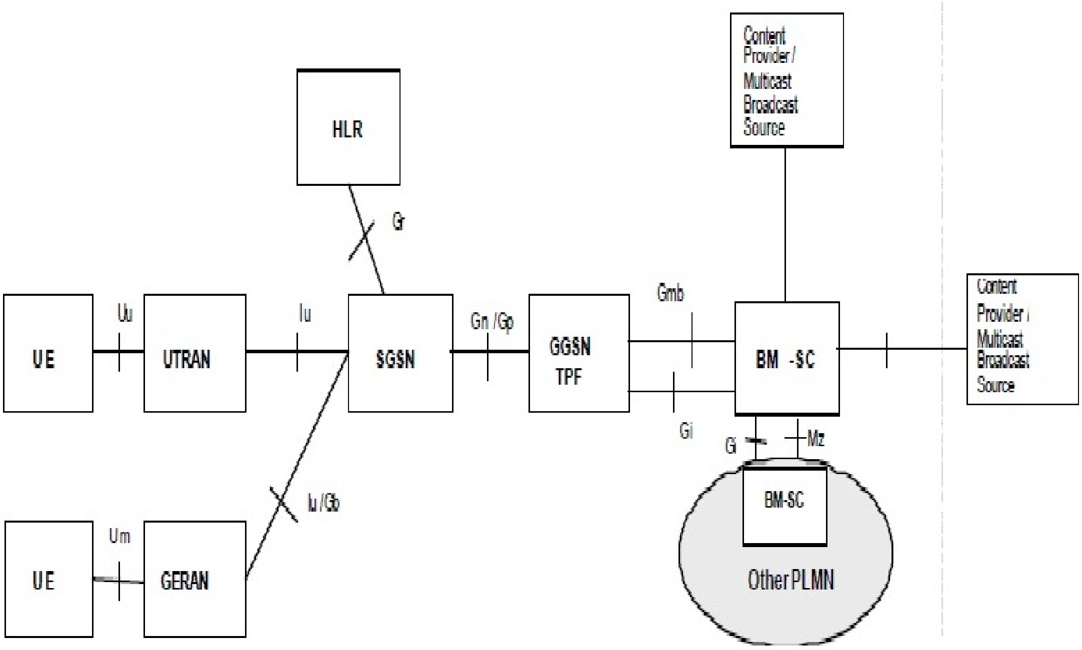


Figure 3.3: Reference architecture to support the MBMS bearer service

- Session and Transmission function;
- Proxy and Transport function;
- Membership function;
- Security function.

The BM-SC Service Announcement function shall be able :

- To provide the UE with media descriptions specifying the media to be delivered as part of an MBMS user service (e.g. type of video and audio encodings);
- To provide the UE with MBMS session descriptions specifying the MBMS sessions to be delivered as part of an MBMS user service (e.g. multicast service identification, addressing, time of transmission, etc.);
- To deliver media and session descriptions by means of service announcements using IETF specified protocols over MBMS multicast and broadcast bearer

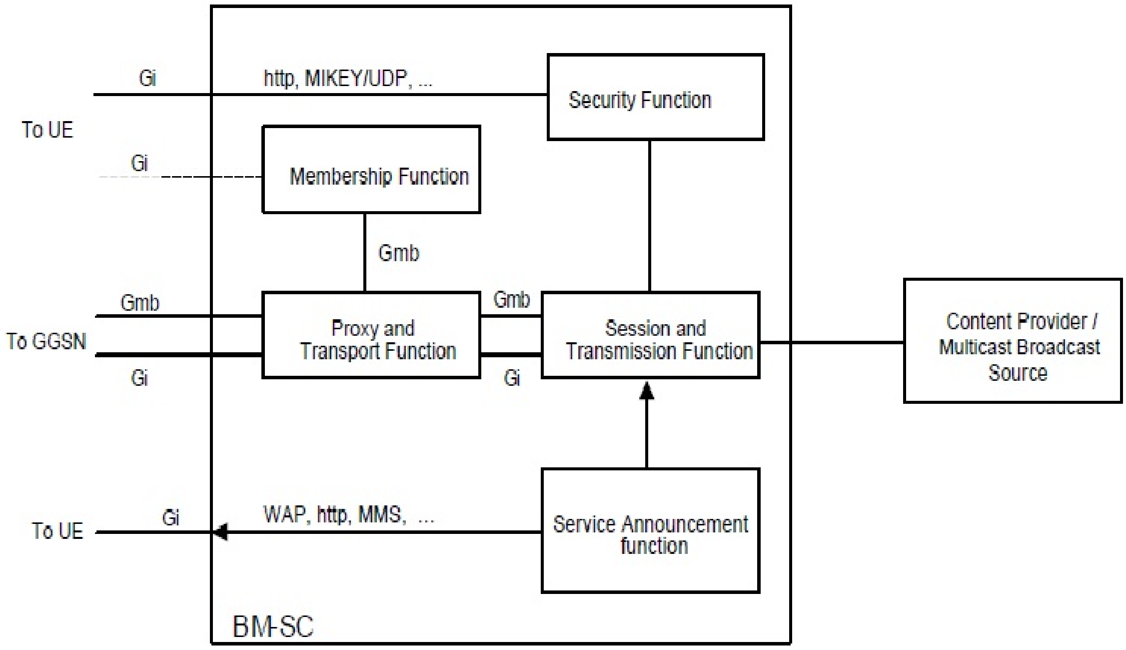


Figure 3.4: BM-SC functional structure

services. Service announcements, triggered by the BM-SC but not necessarily sent by the BM-SC, should be realized by PUSH mechanism (WAP push), URL (WAP, HTTP), SMS (point-topoint), SMS-CB cell broadcast and other mechanisms could be considered in future releases.

The Service Announcement Function is a user service level function.

The BM-SC Session and Transmission Function will be able:

- To schedule MBMS session transmissions and retransmissions, and label each MBMS session with an MBMS Session Identifier to allow the UE to distinguish the MBMS session retransmissions. The BM-SC Session and Transmission Function allocates a unique TMGI (Temporary Mobile Group Identity) per MBMS bearer service. Each transmission and subsequent retransmission(s) of a specific MBMS session are identifiable by a common MBMS Session Identifier passed at the application layer in the content, and also passed in a shortened form (i.e. the least significant octet) in the MBMS Session Start Request message to the RNCs/BSCs. The full MBMS Session Identifier should be used by the UE to identify an MBMS session when completing point -to-point repair, while the shortened MBMS Session Identifier is included by the RANs in the notification messages for MBMS;

- To provide the GGSN with transport associated parameters such as quality-of-service and MBMS service area;

- To initiate and terminate MBMS bearer resources prior to and following transmission of MBMS data;

- To send MBMS data. It could also apply favorable error resilient schemes e.g. specialized MBMS codecs or Forward Error Correction schemes;

- To authenticate and authorize external sources and accept content from them. The Session and Transmission Function is a user service level function and it triggers bearer level functions when MBMS sessions are scheduled.

The BM-SC Proxy and Transport Function is a Proxy Agent that shall be able:

- To manage signalling over Gmb reference point between GGSNs and other BM-SC subfunctions, e.g. the BM-SC Membership Function and the BM-SC Session and Transmission Function;

- To handle when BM-SC functions for different MBMS services are provided by multiple physical network elements; routing of the different signalling interactions shall be transpare nt to the GGSN;

- To generate charging records for content provider charging of transmitted data. Content provider name is provided to BM-SC Proxy and Transport function over Gmb at session start.

The BM-SC Proxy and Transport function may act as an intermediate device for the MBMS data sent from the BM-SC Session and Transmission function to the GGSN. The Proxy and Transport Function may be divided further into a Proxy function managing the control plane (Gmb) and a Transport function managing the multicast payload. The Proxy and Transport Function is an MBMS bearer service function.

The BM-SC Membership function shall be able :

- To provide authorization for UEs requesting to activate an MBMS service;
- To have subscription data of MBMS service users;
- To generate charging records for MBMS service users.

The Membership Function is an MBMS bearer service level function, but it may also provide user service level functions e.g. membership management etc. In this case it does also have a Gi interface.

MBMS user services may use the Security functions for integrity and/or confidentiality protection of MBMS data. The MBMS Security function is used for distributing MBMS keys (Key Distribution Function) to authorized UEs.

### 3.3.2 User Equipment

The UE shall support functions for the activation/deactivation of the MBMS bearer service and security functions as appropriate for MBMS. The UE should, depending on terminal capabilities, be able to receive MBMS user service announcements, paging information (non MBMS specific) and support simultaneous services (for example the user can originate or receive a call or send and receive messages while receiving MBMS video content). Moreover the MBMS user service should be able to cope with losses in the MBMS data reception occurring in case of contemporary arrive of data and paging or announcements. The UE shall be able to synchronize with the SGSN which MBMS UE contexts are still active. Depending upon terminal capability, UEs may be able to store MBMS data The MBMS Session Identifier contained in the notification to the UE shall enable the UE to decide whether it needs to ignore the forthcoming transmission of MBMS session (e.g. because the UE has already received this MBMS session).

### 3.3.3 UTRAN/GERAN

UTRAN/GERAN are responsible for efficiently delivering MBMS data to the designated MBMS service area, they are both Radio Access Networks (RAN) for the MBMS architecture.

The UTRAN/GERAN shall :

- Support mechanisms for efficient delivery of MBMS data in multicast mode, e.g. the number of users within a cell prior to and during MBMS transmission could be used to choose an appropriate radio bearer;

- Support the initiation and termination of MBMS transmissions by the core-network, taking into account that MBMS transmissions may be initiated and terminated intermittently ;

- Be able to receive MBMS data from the core-network over Iu bearers shared by many UEs;

- Support both intra-RNC/BSC and inter-RNC/BSC mobility of MBMS receivers. Mobility is expected to cause limited data loss. Therefore, MBMS user services should be able to cope with potential data loss caused by UE mobility;

- Be able to transmit MBMS user service announcements, paging information (non MBMS specific) and support other services in parallel with MBMS (for example depending on terminal capabilities the user could originate or receive a call or send and receive messages while receiving MBMS video content).

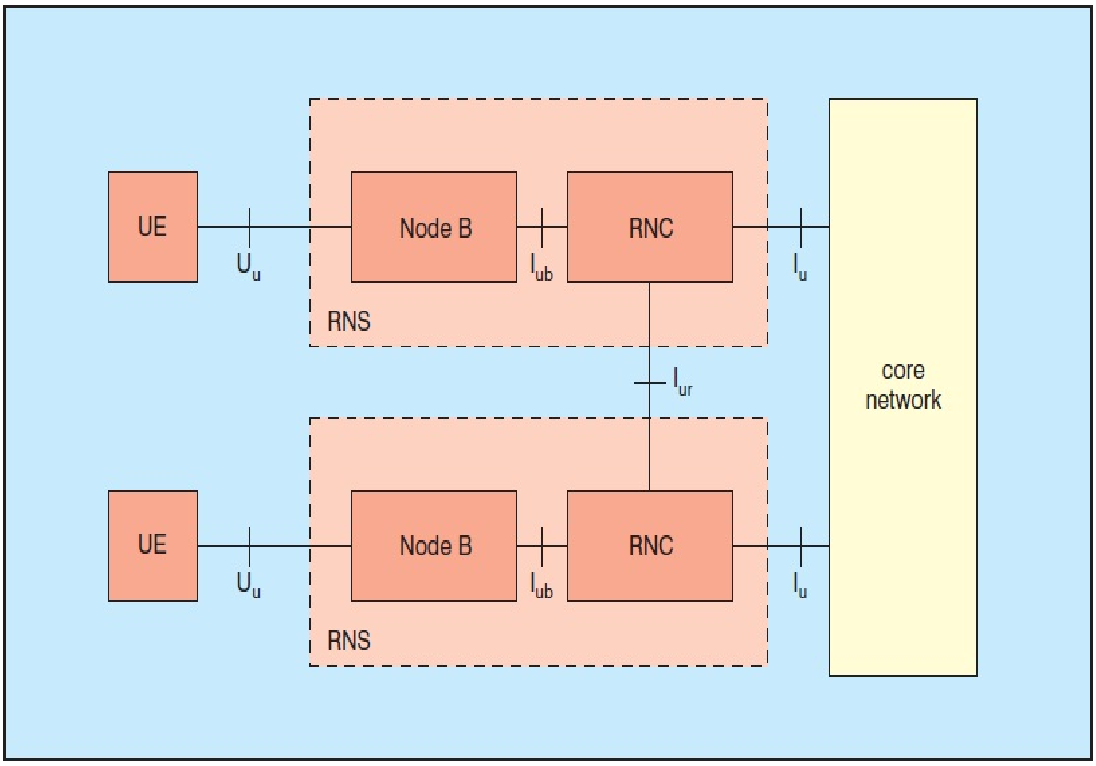


Figure 3.5: UTRAN structure

### 3.3.4 SGSN

The SGSN's role within the MBMS architecture is to perform MBMS bearer service control functions for each individual UE and to provide MBMS transmissions to UTRAN-GERAN. The SGSN will give following services:

- Provide support for intra-SGSN and inter-SGSN mobility procedures. Specifically this requires the SGSN to store a user-specific MBMS UE context for each activated multicast MBMS bearer service and to pass these contexts to the new SGSN during inter - SGSN mobility procedures;
- Be able to indicate its MBMS support to the UE as well as it shall be able to synchronize with the UE, which of the UE's MBMS UE contexts are still active;
- Be able to generate charging data per multicast MBMS bearer service for each

user. The SGSN does not perform on-line charging for either the MBMS bearer service or the MBMS user service (this is handled in the BM-SC);

- Be able to establish Iu and Gn bearers shared by many users upon receiving a session start from the GGSN. Likewise, the SGSN shall be able to tear down these bearers upon instruction from the GGSN.

### 3.3.5 GGSN

The GGSN role within the MBMS architecture is to serve as an entry point for IP multicast traffic as MBMS data.

The GGSN will give following services:

- Be able to request the establishment of a bearer plane for a broadcast or multicast MBMS transmission upon notification from the BM-SC;

- Be able to tear down the established bearer plane upon BM-SC notification. Bearer plane establishment for multicast services is carried out towards those SGSNs that have requested to receive transmissions for the specific multicast MBMS bearer service;

- Be able to receive MBMS specific IP multicast traffic and to route this data to the proper GTP tunnels set-up as part of the MBMS bearer service;

- Provide features that support the MBMS bearer service and are not exclusive to MBMS. Examples are Message Screening (not needed if the MBMS sources are internal in the PLMN), Charging Data Collection and Flow Based Charging.

## 3.4 MBMS channels

In UTRA the data generated at higher layers is carried over the air with transport channels, which are mapped in the physical layer to different physical channels. One requirement in the design of MBMS was to reuse existing cha nnels to the extent possible [9]. Therefore, the FACH transport channel and the S-CCPCH physical channel are reused without any changes. To carry the relevant MBMS data and signaling, three new logical channels are added to Release 6:

- MBMS Traffic Channel (MTCH), carrying application data.
- MBMS Control Channel (MCCH), carrying control signaling.
- MBMS Scheduling Channel (MSCH), carrying scheduling information to support discontinuous reception in the UE.

As shown in Figure 3.6, all these channels use FACH as the transport channel type and the SCCPCH as the physical channel type. In addition to the three new logical channels, one new physical channel, MBMS Indicator Channel (MICH), is introduced to support MBMS. MICH used to notify the UE about an upcoming change in MCCH contents.

### 3.4.1 MTCH

The MTCH is the logical channel used to carry the application data in case of point-tomultipoint transmission (for point-to-point transmission, DTCH, mapped to DCH or HSDSCH, is used). One MTCH is configured for each MBMS service and each MTCH is mapped to one FACH transport channel. The S-CCPCH is the physical channel used to carry one (or several) FACH transport channels. The RLC for MTCH is configured to use unacknowledged mode as no RLC status reports can be used in point-to-multipoint transmissions. To support selective combining, the RLC has been enhanced with support for in-sequence delivery using the RLC PDU sequence numbers. This enables the UE to do reordering up to a depth set by the RLC PDU sequence number space in case of selection combining. The leftmost part of the Figure 3.6 illustrates the case of point-to-point transmission, while the middle and rightmost parts illustrate the case of point-to-multipoint transmission using the MTCH. In the

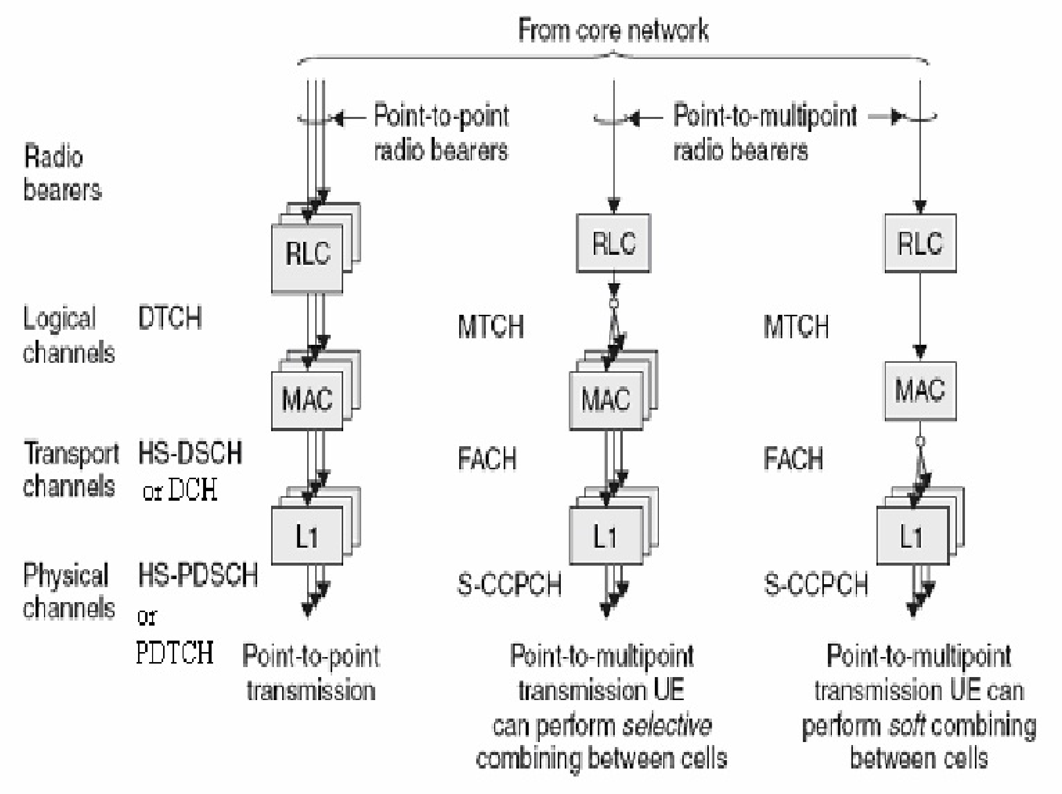


Figure 3.6: MBMS Channels Mapping

middle part, one RLC entity is used with multiple MAC entities. This illustrates a typical situation where selection combining is used, where multiple cells are loosely time aligned and the same data may be transmitted several TTIs apart in the different cells. Finally, the rightmost part of the figure illustrates a typical case where soft combining can be used. A single RLC and MAC entity is used for transmission in multiple cells. To allow soft combining, transmissions from the different cells need to be aligned within 80. 67 ms (assuming 80 ms TTI).

### 3.4.2 MCCH and MICH

The MCCH is a logical channel type used to send control signaling necessary for MTCH reception. One MCCH is used in each MBMS-capable cell and it can carry control information for multiple MTCHs. The MCCH is mapped to FACH (note, a

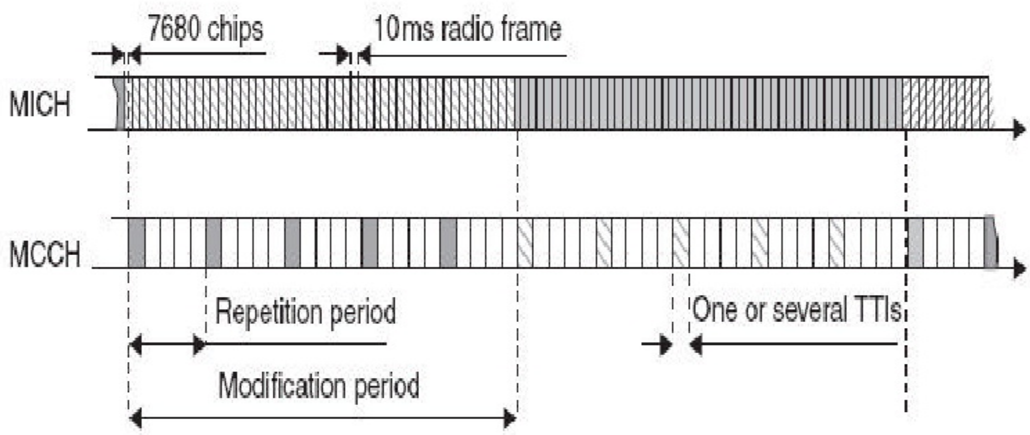


Figure 3.7: MCCH transmission schedule

different FACH than used for MTCH), which in turn is transmitted on an S-CCPCH physical channel. The same S-CCPCH as for the MTCH may be used, but if soft combining is allowed for MTCH, different S-CCPCHs for MTCH and MCCH should be used. The reason for using separate SCCPCHs in this case is that no selection or soft combining is used for the MCCH, and the UE receives the MCCH from a single cell only. The RLC is operated in unacknowledged mode for MCCH. Where to find the MCCH is announce d on the BCCH (the BCCH is the logical channel used to broadcast system configuration information). Transmission on the MCCH follows a fixed schedule as illustrated in Figure 3.7. The MCCH information is transmitted using a variable number of consecutive TTIs. In each modification period, the critical information remains unchanged and is periodically transmitted based on a repetition period. This is useful to support mobility between cells; a UE entering a new cell or a UE who missed the first transmiss ion does not have to wait until the start of a new modification period to receive the MCCH information. The MCCH information includes information about the services offered in the modification period and how the MTCHs in the cell are multiplexed. It also contains information about the MTCH configuration in the neighboring cells to support soft or selective combining of multiple transmissions. Finally, it may also contain information to control the feedback from the UEs in case counting is used.

Counting is a mechanism where UEs connect to the network to indicate whether they are interested in a particular service or not and is useful to determine the best transmission mechanism for a given service. For example, if only a small number of users in a cell are interested in a particular service, point-to-point transmission may be preferable over point-tomultipoint transmission. To avoid the system being heavily loaded in the uplink as a result of counting responses, only a fraction of the UEs transmit the count ing information to the network. The MCCH counting information controls the probability with which a UE connects to the network to transmit counting information. Counting can thus provide the operator with valuable feedback on where and when a particular service is popular, a benefit typically not available in traditional broadcast networks.

To reduce UE power consumption and avoid having the UE constantly receiving the MCCH, a new physical channel, the MICH (MBMS Indicator Channel), is introduced to support MBMS. Its purpose is to inform UEs about upcoming changes in the critical MCCH information and the structure is identical to the paging indicator channel. In each 10 ms radio frame, 18, 36, 72, or 144 MBMS indicators can be transmitted, where an indicator is a single bit, transmitted using onoff keying and related to a specific group of services. By exploiting the presence of the MICH, UEs can sleep and briefly wake up at predefined time intervals to check whether an MBMS indicator is transmitted. If the UE detects an MBMS indicator for a service of interest, it reads the MCCH to find the relevant control information, for example when the service will be transmitted on the MTCH. If no relevant MBMS indicator is detected, the UE may sleep until the next MICH occasion.

### 3.4.3 MSCH

The purpose of the MSCH is to enable UEs to perform discontinuous reception of the MTCH. Its content informs the UE in which TTIs a specific service will be transmitted. One MSCH is transmitted in each S-CCPCH carrying the MTCH and

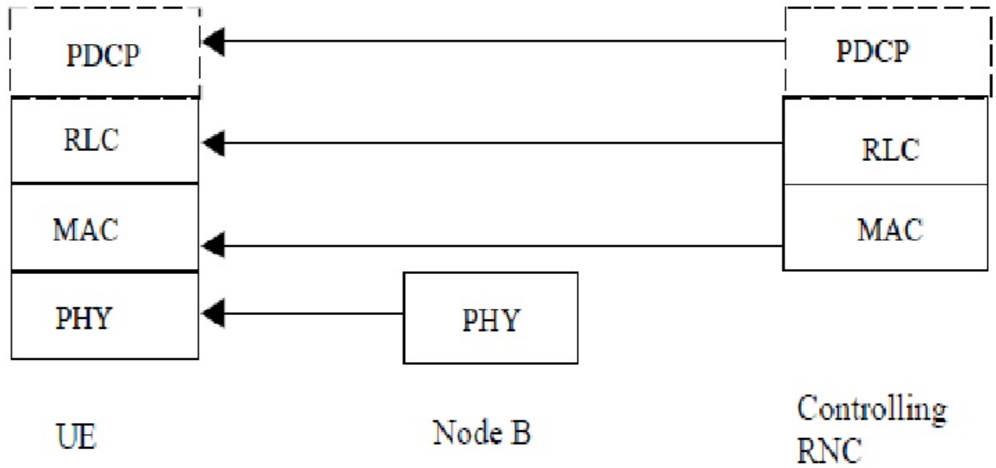


Figure 3.8: User Plane Protocol Stack

the MSCH content is relevant for a certain service and a certain S-CCPCH.

## 3.5 MBMS Protocols

### 3.5.1 User Plane Protocol Stack

Figure 3.8 illustrates the protocol termination for MCCH in MBMS, which is P-t-M control channel. MBMS functionalities are included in MAC and RRC. In case of P-t-P transmission, DCCH is used for MBMS and the protocol termination for DCCH mapped on DCH and FACH.

Figure 3.8 shows the User Plane Protocol Stack in UTRAN. PDCP sub-layer performs header compression-decompression for the MBMS traffic. In the UTRAN side, there is one PDCP entity per cell supporting MBMS or MBMS Cell Group for each MBMS service in each RNS. The shared PDCP entity in the UTRAN duplicates all PDCP PDUs to every RLC entity for every cell belonging to one MBMS Cell Group. In the UTRAN, there is one RLC entity for each MBMS service in each cell or cell group in case of utilization of selective combining or maximum ratio combining in TDD, and one MAC entity for each cell. In the UE side, there is one PDCP and

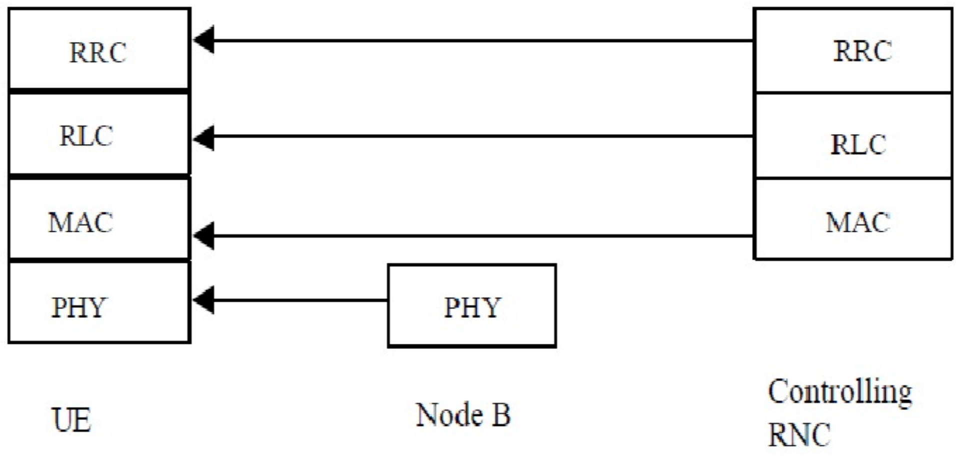


Figure 3.9: Control Plane Protocol Stack

RLC entity for each MBMS service in each UE. In each UE there is one MAC entity per received cell when UE is performing the selective combining between these cells. In case of P-t-P transmission, DTCH is used for MBMS transmission and the protocol termination for DTCH mapped on DCH and RACH/FACH.

### 3.5.2 Control Plane Protocol Stack

Figure 3.9 illustrates the protocol termination for MCCH in MBMS, which is P-t-M control channel. MBMS functionalities are included in MAC and RRC. In case of P-t-P transmission, DCCH is used for MBMS and the protocol termination for DCCH mapped on DCH and FACH.

## 3.6 MBMS over HSPA

As S-CCPCH lacks of power control it would seem feasible to provide p-t-m transmission over HSDPA as it supports flexible link adaptation methods. Usage of HSDPA for p-t-m MBMS delivery could be useful from link efficiency point of view as well as it would give flexibility to allocate capacity between MBMS and other services. In fact HSDPA includes fast link adaptation and therefore can provide good link perf ormance. Since separate radio resources are needed for each MBMS User Equipment (UE), the required Node B transmission resource allocation depends linearly on the number of active MBMS users per cell. Therefore P-t-P HSDPA solution is a suitable solution for MBMS service delivery for a limited amount of users requesting the same service. When the amount of users increases it is more efficient to use P-t-M MBMS transmission using Forward Access Channel (FACH). However in 3GPP Release 6, P-t-M MBMS solution suffers from moderate link performance due to lack of link adaptation, although link performance can be improved with advanced UE receivers (e.g. UE receive diversity). Macro diversity with soft or selective combining at UE is needed to ensure continuous coverage over whole cell area with MBMS service bit rates (e.g. 128 kbps). On the other hand, reserving transmission capacity in a fixed manner from all cells for a MBMS service may lead to inefficient use of radio resources if there are no active MBMS users in all cells. MBMS services can be also used for local area information such as traffic announcements, local news or weather reports, when the local area could be even a single cell. In this kind of scenario, reservation of transmission capacity over mult iple cells would lead clearly to poor use of radio resources. A better approach would be to use single cell transmission either with a p-t-m (if there are several users requesting the same service) or P-t-P transmission mode (if there are only few users requesting the same service). One possibility to introduce more flexibility to MBMS is to extend HSDPA use for MBMS. In P-t-M MBMS over HSDPA scheme the same HS-PDSCH connection is shared by multiple users while still maintaining HS-PDSCH link features, like link adaptation with Adaptive Modulation Coding (AMC) and H-ARQ. However, these features were defined for HSDPA unicast service and there may incur some efficiency loss due to UEs experiencing different levels of fading when using P-t-M transmission mode. Without any link adaptation there are different parameters to be set in case of HSDPA usage for p-t-m transmission. Depending on selected Transport Format and Resource Combination (TFRC), which defines transport block size, number of used multi-codes and modulation, the number of transmissions should also be defined. UE reported Channel Quality Indicator (CQI) can be used for the link adaptation, although it is not well suited for streaming traffic with constant bit rate. In addition to CQI UE also reports Acknowledgments (ACK) and Negative Acknowledgments (NACK) for Layer 1 transport blocks [6] .

## 3.7 Summary

3GPP Release 6 brings efficient support for broadcast services into WCDMA through the introduction of Multimedia Broadcast Multicast Services (MBMS), suitable for applications like mobile TV. With MBMS, multiple terminals may receive the same broadcast transmission instead of the network transmitting the same information individually to each of the users. Initially, the need for the mobile phones to support a variety of multimedia mobile services at high data rates has led to the definition of 3rd Generation (3G) Mobile Cellular Networks and the choice of WCDMA for the radio access technique. A consequence of using WCDMA is that capacity of 3G systems is not hard limited. This means that an additional user entering the system cannot be blocked because of the limited amount of available channels. If a sufficient number of spreading codes is available, the interference due to increased load will be the main capacity-limiting factor in the network. Later on, the need for efficient data distribution when a large number of users want to receive the same data has led to the definition of Multimedia Broadcast Multicast Service (MBMS) System.

# Chapter 4

# A Multicast Packet Forwarding Mechanism

Consider the scheme shown in Figure 4.1 for the analysis of the mechanism and suppose that a UE wants to join a multicast group provided by the GGSN. In this case, the UE sends a message to the GGSN, requesting the list of the available multicast groups. When the message reaches the GGSN, the GGSN sends a reply to the UE with the available multicast groups. The UE decides the multicast group(s) that wants to join and sends this information to GGSN so as to add it to the specific multicast group(s). Thus, every time that, packets for the specific multicast group are available, the correspondent UE will receive them. Additionally, the UE can send a leave message and the GGSN has to delete from the members of the specific multicast group.

For the multicast transmission there are introduce the TMRL and PMRL in every node of the network except the UEs. The TMRL keep temporary information from the messages coming from the UEs that it serves, with destination the GGSN.Thus, when the messages finally reach the GGSN, the reply messages are routed appropriately by checking the corresponding record in the TMRL of each intermediate node so as to be delivered to the correct UE. In parallel, when a message coming from the GGSN

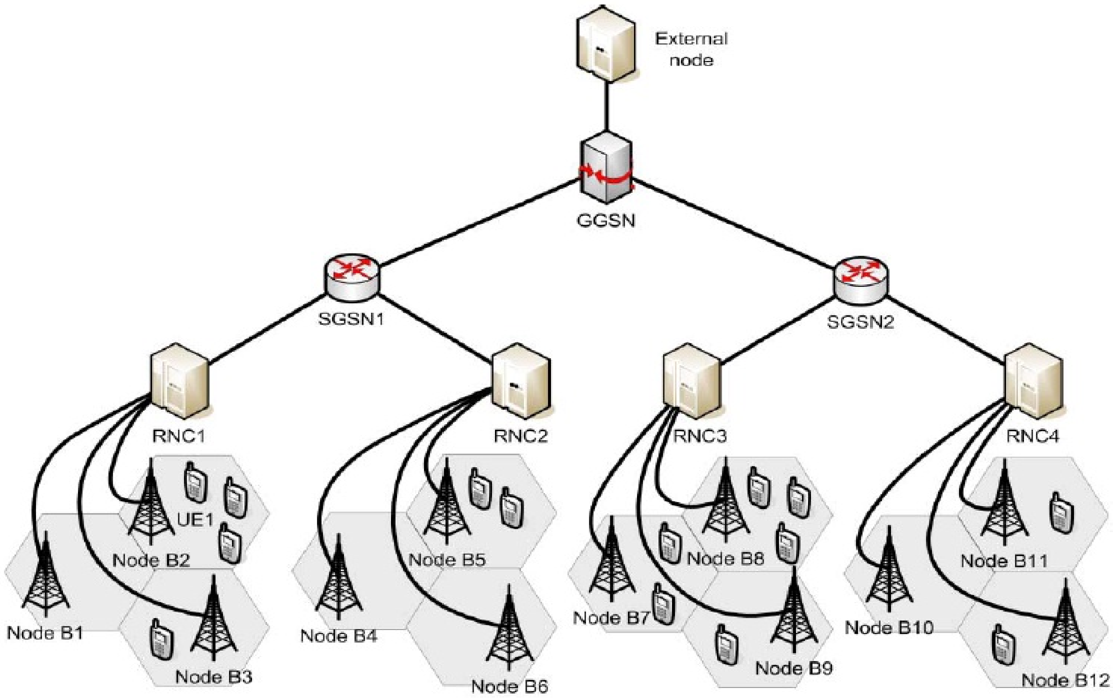


Figure 4.1: Multicast packet transmission

to a UE is routed, the PMRL of the intermediate nodes are updated appropriately from the corresponding record of the TMRL which in turn, is deleted. An update in the PMRL means either a new record or an update in an existing record. The first case occurs when the specific node does not serve any other users that are members of the multicast group, while the second case occurs when there are already members of this multicast group served by the specific node .

## 4.1 Routing Lists and Packet Forwarding

Before analyzing the multicast packet forwarding mechanism using TMRL and PMRL, there are the additional information that the nodes of the UMTS network should store. Obviously, the GGSN that organize the multicast group, ought to keep an additional list with the multicast groups and the correspondent UEs that have joined them. This information is kept in the Multicast Groups List (MGL) (Figure 4.2) and the GGSN

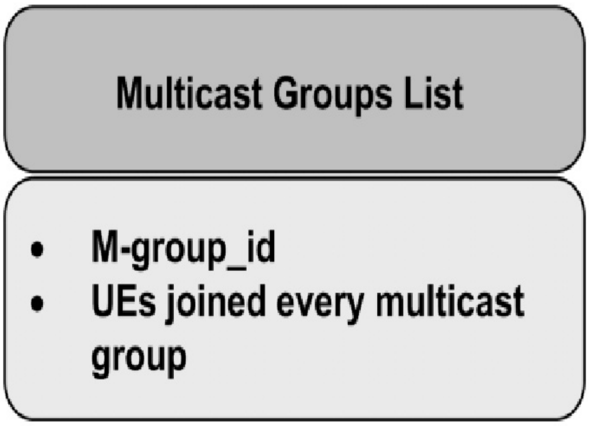


Figure 4.2: Multicast Groups List (MGL) in the GGSN

has the opportunity to retrieve the UEs belonging to a specific multicast group. It is essential that this list is fully updated at every moment for the correct transmission of the packets to the UEs that have joined a multicast group. Obviously, there is a possibility that a multicast group has no members, which in turn means that the correspondent record in the MGL in the GGSN does not contain any UEs .

In addition, every node of the UMTS network (except the UEs) maintains two routing lists: the TMRL and the PMRL (Figure 4.3). The concept behind the introduction of the TMRL, is that when a UE sends a message to the GGSN (such as join or leave a multicast group), the nodes in the path between the UE and GGSN temporary keep useful information of the received packets from the node of the previous level. Likewise, in the PMRL of each node,it record the nodes of the next level that the messages for every multicast group should be forwarded. The TMRLs are used in cases that the traffic departs from the UE with destination the GGSN, such as a request for a service, a joining or a leaving of a specific multicast group. After a reply to this request from the GGSN, the corresponding record in the TMRL is deleted and either a new record in the PMRL of the node is created, or an existing record is updated. Thus, in the PMRL of a node, we keep the nodes of the next level

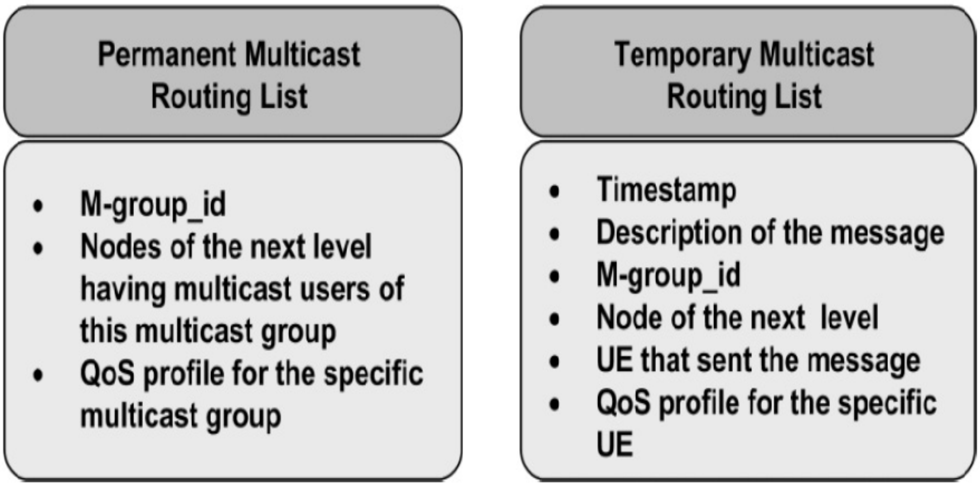


Figure 4.3: Permanent and Temporary Multicast Routing Lists(PMRL and TMRL)

that the packets of a specific multicast group should be forwarded .

In the following,I describe a steps of the packet forwarding mechanism for the multicast routing in UMTS with the use of the above described lists (Figure 4.2, Figure 4.3) in every node of the network. Since the UEs are known to the network,consider that the Subscription phase is completed. Thus, the Service Announcement phase follows:

a. Suppose that a UE wants to become a member of an MBMS service of the network. Thus, it sends a message to the Node B that it resides, with final destination the GGSN requesting the available multicast services.

b. The correspondent Node B receives the message from the UE and stores the current time, the description of the message (request of the available multicast groups), the sender UE and the QoS profile of the specific UE in its TMRL. Then it forwards the message to the correspondent RNC.

c. The correspondent RNC receives the message from the Node B and stores the current time, the description of the message (request of the available multicast groups), the sender UE, the Node B that the message forwarded and the QoS profile of the specific UE in its TMRL. Then it forwards the message to the correspondent SGSN. The same procedure occurs in the SGSN and finally the message reaches the GGSN.

d. The GGSN try to authenticate the sender UE. If the authentication is successful, the GGSN sends an appropriate message to the corresponding SGSN with final destination the specific UE containing the list of the available multicast groups.

e. The SGSN receives the message from the GGSN. Then, it checks its TMRL for a record containing the specific UE and the correspondent description (request of the available multicast groups) and decides the correct RNC that the message should be forwarded so as to reach the correct UE. As the message is forwarded to the RNC, the correspondent record in the TMRL of the SGSN is deleted and an appropriate update occurs in the PMRL of the SGSN as described above. The same procedure occurs in the RNC and Node B and finally the UE receives the message from the GGSN .

At this time, the UE has the list of the available MBMS user services and the Service Announcement phase is completed. The Joining phase (Figure 4.4) follows:

a. The UE decides that it wants to join a specific multicast group and sends an appropriate message to the Node B that it resides with final destination the GGSN.

b. The correspondent Node B receives the message from the UE and stores in its TMRL the current time, the description of the message (join), the specific mobile group ID id of the requested multicast group, the sender UE and the QoS profile of the specific UE. Then it forwards the message to the correspondent RNC.

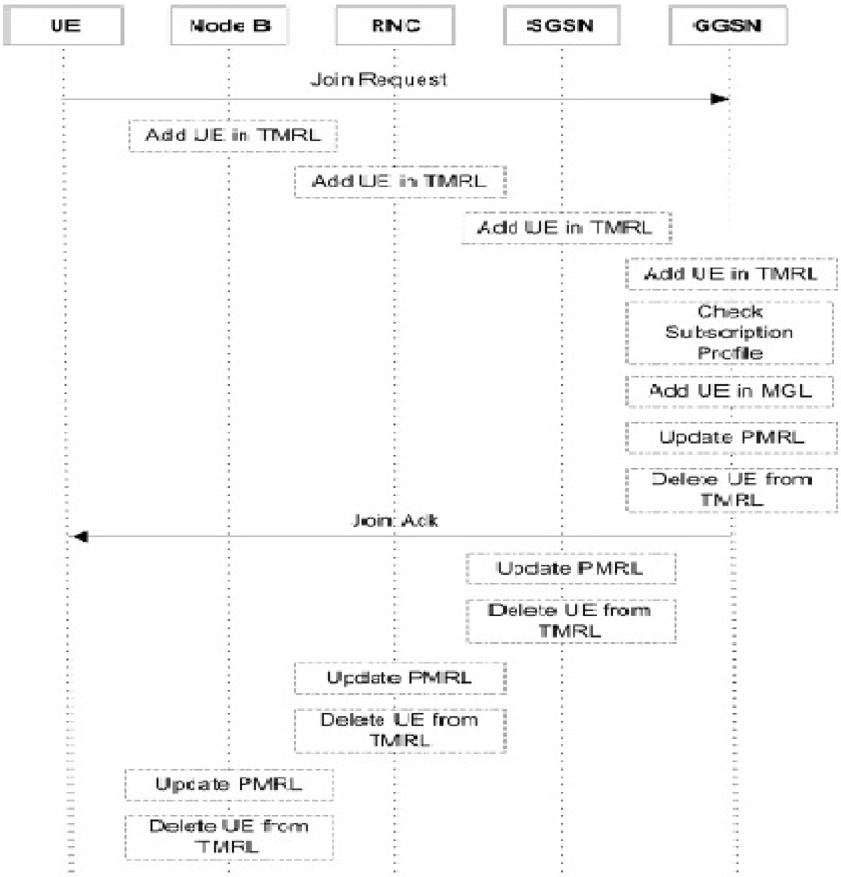


Figure 4.4: Joining Phase

c. The correspondent RNC receives the message from the Node B and stores the current time, the description of the message (join), the specific mobile group ID, the sender UE, the Node B that the message was forwarded and the QoS profile of the specific UE, in its TMRL. Then it forwards the message to the correspondent SGSN. The same procedure occurs in the SGSN and finally the message reaches the GGSN.

d. The GGSN adds the specific UE to the correspondent record of the MGL for the requested mobile group ID and the UE becomes a member of this multicast group. Then, the GGSN searches the TMRL for the specific UE with description of the message join for the specific mobile group ID and decides the correct SGSN that the reply message should be sent. As we described above, the correspondent record of the TMRL in the GGSN is deleted, while an existing record in the PMRL is updated, or a new record is created. The same procedure occurs in every path from the GGSN to the UEs that want to join a multicast group. Finally, the message reaches the UE.

The phases that follow are Session Start, MBMS Notification, Data Transfer, Session Stop, where the data are transferred from the GGSN to the UEs. In these phases each node of the network that receives a packet of a multicast group, it searches the PMRL for the record of this mobile group ID and decides the nodes of the next level that the packet should be forwarded. Finally, the packet reaches the UEs that are members of this multicast group. Obviously, the Data Transfer phase constitutes the main phase of the multicast packet forwarding mechanism. Thus, in the following paragraphs, we describe the exact steps of this procedure:

a. Firstly, the GGSN is ready for the transmission of a packet with destination a specific multicast group. Then, it searches its PMRL for the specific mobile group ID and determines which SGSNs serve UEs that are members of the specific multicast group and reside in their respective service areas. Then, the packet is forwarded to these SGSNs.

b. The correspondent SGSNs receive the multicast packet and they search their PMRL to determine which RNCs are to receive this packet. Then, the packet is forwarded to the appropriate RNCs. The same procedure occurs in the RNCs and the Node Bs. Finally, the multicast packet is transmitted to the UEs that are members of the multicast group [6].

The above described procedure occurs until all the packets of the specific multicast service are transmitted to appropriate UEs. The latest phase, Leaving, is a little different from the above, since the UE sends the message to the GGSN (Figure 4.6). The exact procedure is described with the following steps:

a. The UE decides that it wants to leave a specific multicast group that until then

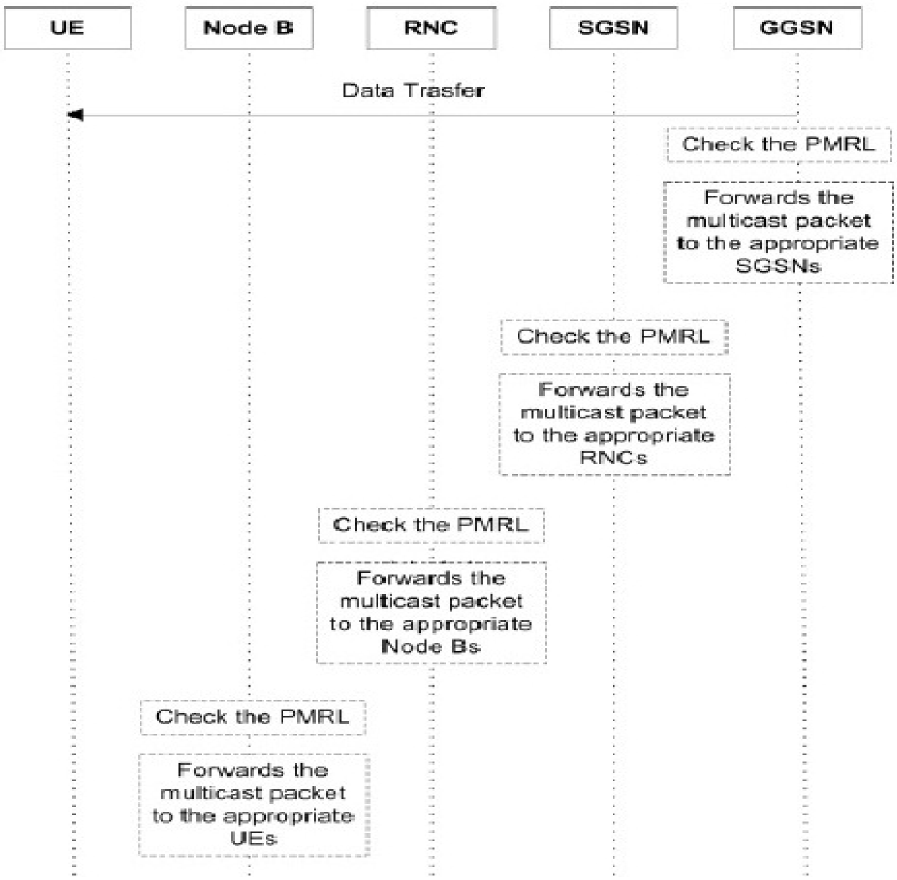


Figure 4.5: Data Transfer Phase

it was a member of it. Thus, it sends an appropriate message to the Node B that it resides, with final destination the GGSN.

b. The correspondent Node B receives the message from the UE and stores in its TMRL the current time, the description of the message (leave), the mobile group ID of the multicast group that the UE wants to leave, the sender UE and the QoS profile of the specific UE. Then it forwards the message to the correspondent RNC.

c. The correspondent RNC receives the message from the Node B and stores the current time, the description of the message (leave), the mobile group ID of the multicast group that the UE wants to leave, the sender UE, the Node B that the message forwarded and the QoS profile of the specific UE in its TMRL.

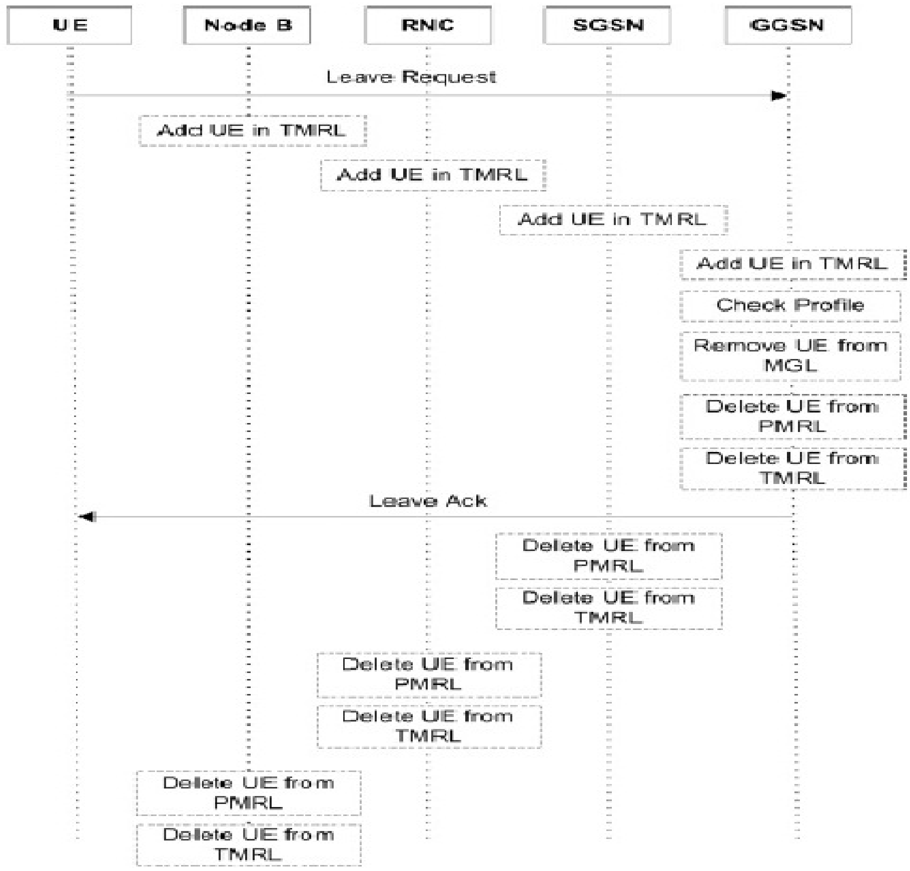


Figure 4.6: Leaving Phase

Then it forwards the message to the correspondent SGSN. The same procedure occurs in the SGSN and finally the message reaches the GGSN.

d. The GGSN removes the specific UE from the correspondent record of the MGL. Thus, the UE is not any more a member of this multicast group and future packets for this multicast group would not be transmitted to this UE. Then, the GGSN searches the TMRL for the specific UE with the description of the message leave and the specific Mobile group ID and decides the correct SGSN that the reply message should be sent. As we described above, the correspondent record of the TTRL in the GGSN is deleted, while an existing record in the PMRL is updated, or a new record is created. The same procedure occurs in every node of the network and finally the message reaches the UE. At this time, the UE knows that the procedure of the leaving of the multicast group has been finished successfully [6].

## 4.2 Summary

In a multicast scheme for UMTS, the Permanent Multicast Routing List (PMRL) and Temporary Multicast Routing List (TMRL) were introduced in each node of the network except UEs. Minor modification in the UMTS architecture is needed, which means that, this mechanism is easily implemented. Therefore, there are steps that essential for a successful MBMS multicast service provision. Since the Data Transfer phase is the most important phase in the multicast service, the experiments were focused in the transmission of the multicast data.Simulation results show that the proposed mechanism for the multicast packet forwarding in UMTS works correctly and performs efficiently.

# Chapter 5

# A Performance Study of Multicast Scheme

## 5.1 A Multicast Approach for UMTS

Figure 5.1 shows a subset of a UMTS network. In this architecture, there are two SGSNs connected to an GGSN, four RNCs, and twelve Node Bs. Furthermore, eleven members of a multicast group are located in six cells. The BM-SC acts as the interface towards external sources of traffic. In the presented analysis, assume that a data stream coming from an external PDN through BM-SC, must be delivered to the eleven UEs as illustrated in Figure 5.1

For the efficient multicast packet forwarding mechanism, every node of the network (except the UEs) maintains a Routing List. In this list of each node, system record the nodes of the next level that the messages for every multicast group should be forwarded. Additionally, system keep information regarding the QoS profile of the specific multicast group. This information is useful for congestion avoidance and rate control. Obviously, the BM-SC that organizes the multicast mechanism, ought to keep an additional list with the multicast groups (Multicast group id) and the correspondent UEs that have joined them. This information is kept in the Multicast

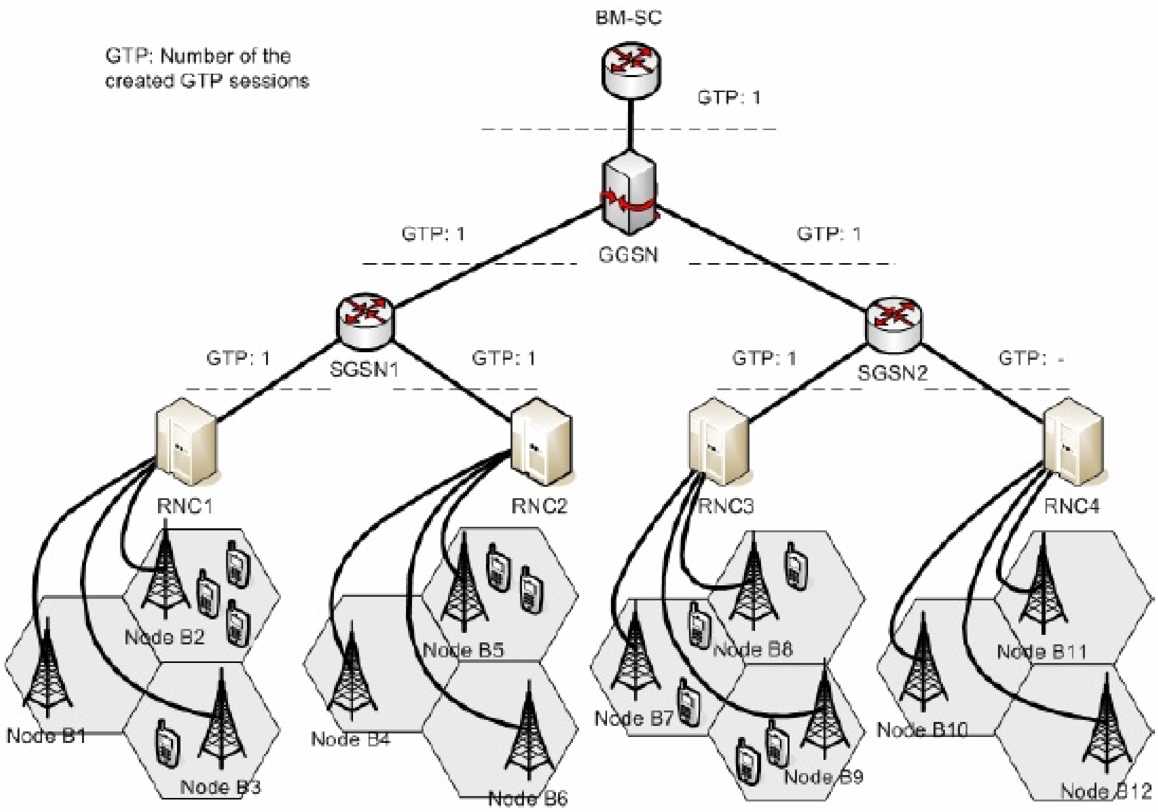


Figure 5.1: Packet delivery in UMTS

Groups List and the BM-SC has the opportunity to retrieve the UEs belonging to a specific multicast group. It is essential that these lists are fully updated at every moment for the correct transmission of the packets to the UEs that have joined a multicast group. Obviously, there is a possibility that a multicast group has no members, which in turn means that the correspondent record in the Multicast Group List in the BM-SC does not contain any UEs.

Additionally, the phases that the multicast mechanism follows are these that have been presented above in the MBMS service provision (Figure 5.2). In the following, there are describing the main steps of the multicast packet forwarding mechanism. Firstly, consider that the UEs are known to the network, thus the Subscription phase is completed. In the Service Announcement phase, the routing lists of the nodes are filled with the useful information. This procedure can be initialized either from

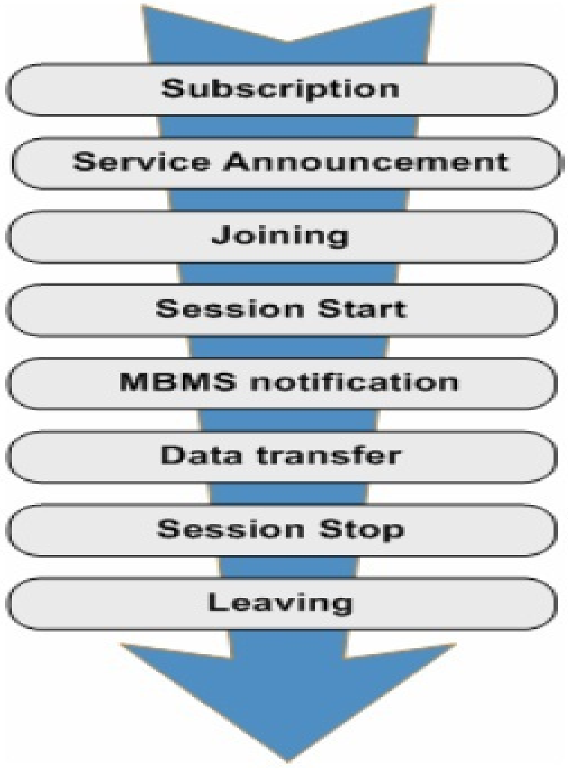


Figure 5.2: Phases of MBMS multicast service provision

the UEs or from the BM-SC (i.e. Software upgrades). In the former case, consider a UE that decides to become a member of a multicast service. Thus, it sends an appropriate message to the BM-SC requesting this service. Then, every node located in the path between this UE and the BM-SC, when it receives the message from the UE, it updates its routing list and forwards the message to the next node. In the second case, the BM-SC initializes the Service Announcement phase. Since the BM-SC does not have any information regarding the location of the multicast members, a paging procedure at RA and URA level is necessary for the updating of the routing lists of the nodes. The phases that follow are Session Start, MBMS Notification, Data Transfer and Session Stop, where the data are transferred from the BM-SC to the UEs. In these phases, each node of the network that receives a multicast packet, searches its routing list and decides the nodes of the next level that the packet should be forwarded. Finally, the packet reaches the UEs that are members of the multicast group.

With multicast, the packets are forwarded to those Node Bs that have multicast users. Therefore, in Figure 5.1, the Nodes B2, B3, B5, B7, B8, B9 will receive the multicast packets issued by the BM-SC. We briefly summarize the five steps occurred for the delivery of the multicast packets. Firstly, the BM-SC receives a multicast packet and forwards it to the GGSN that has registered to receive the multicast traffic. Then, the GGSN receives the multicast packet and by querying its routing list, it determines which SGSCs in its service area have multicast users residing in their respective service areas. In Figure 5.1, the GGSN duplicates the packet and forwards it to the SGSN1 and the SGSN2.

After both destination SGSNs have received the multicast packet and having queried their routing list, they determine which RNCs must receive the multicast packet. The destination RNCs receive the multicast packet and send it to the Node Bs that have established the appropriate radio bearers for the multicast application. In Figure 5.1, these are Node B2, B3, B5, B7, B8, and B9. The multicast users receive the multicast packet on the appropriate radio bearers, either by point-to-point channels transmitted to individual users separately or by point-to-multipoint channels transmitted to all group members in the cell.

In this approach, each multicast packet is initially transmitted from the BM-SC to the GGSN. This procedure implies that the first GTP session is created between the BM-SC and the GGSN. The GGSN forwards exactly one copy of the multicast packet to each SGSN that serves multicast users. This leads to the creation of one GTP session between the GGSN and the SGSN1 and one GTP session between the GGSN and SGSN2 (Figure 5.1). Having received the multicast packets, the SGSN1 forwards exactly one copy of the multicast packet to the RNCs that serve multicast users, which are the RNC1 and the RNC2. In parallel, the SGSN2 forwards the multicast packets to the RNC3, which is the only RNC, covered by the SGSN2 that serves multicast users. Regarding the edges between the SGSNs and the RNCs in

Figure 5.1, the first GTP session is created between the SGSN1 and RNC1, the second between the SGSN1 and RNC2 and the third one between the SGSN2 and RNC3. Finally, the RNCs forward the multicast packets to those Node Bs that multicast users reside in and have established the appropriate radio bearers. Additionally, Figure 5.1 shows the exact number of the GTP sessions created in edges of the network for the multicast scheme.

The analysis presented in the above paragraphs, covers the forwarding of the data packets between the BM-SC and the Node Bs (Figure 5.1). Therefore, the transmission of the packets over Uu and Iub interfaces may be performed on dedicated (Dedicated Channel - DCH) or common transport channels (FACH). DCH is a point-to-point channel and hence, it suffers from the inefficiencies of requiring multiple DCH to carry common data to a group of users. However, DCH can employ fast closed-loop power control and soft handover mechanisms to achieve a highly reliable channel.point-to-multipoint MBMS data transmission uses the forward access channel (FACH) with turbo coding and QPSK modulation at a constant transmission power. Multiple services can be configured in a cell, either time multiplexed on one FACH or transmitted on separate channels, although in the latter case a single UE may not be able to receive multiple services. Control information, for example, available services, neighboring cell information indicating which of the neighboring cells that transmit the same content and so forth, is transmitted on a separate FACH [4].

## 5.2 Performance study of the Multicast Scheme

In this section Evaluation of the Multicast Scheme presented in terms of the telecommunication costs, of the multicast scheme presented in the previous section. Consider a more general UMTS network topology and different transport channels for the transmission of the multicast data [5].

In particular, consider a subset of a UMTS network consisting of a single GGSN and $N_{SGSN}$ SGSN nodes connected to the GGSN. Furthermore, each SGSN manages a number of $N_{ra}$ RAs(Routing Areas). Each RA consists of a number of $N_{rnc}$ RNC nodes, while each RNC node manages a number of $N_{ura}$ URAs(UTRAN Registration Areas). Finally, each URA consists of $N_{nodeb}$ cells. The total number of RNCs and cells are:

$$N_{RNC} = N_{SGSN}.N_{ra}.N_{RNC} \tag{5.1}$$

$$N_{NODEB} = N_{SGSN}.N_{ra}.N_{RNC}.N_{ura}.N_{nodeb} \tag{5.2}$$

The total transmission cost for packet deliveries is considered as the performance metric.Make a further distinction between processing costs at nodes and transmission costs on links.Now assume that there is a cost associated with each link and each node of the network for the packet deliveries. Apply the following notations:

| | |
|---|---|
| $D_{gs}$ | Transmission cost of packet delivery between GGSN and SGSN |
| $D_{sr}$ | Transmission cost of packet delivery between SGSN and RNC |
| $D_{rb}$ | Transmission cost of packet delivery between RNC and Node B |
| $D_{DCH}$ | Transmission cost of packet delivery over the air with DCHs |
| $D_{FACH}$ | Transmission cost of packet delivery over the air with FACH |
| $p_g$ | Processing cost of packet delivery at GGSN |
| $p_s$ | Processing cost of packet delivery at SGSN |
| $p_r$ | Processing cost of packet delivery at RNC |
| $p_b$ | Processing cost of packet delivery at Node B |

The total number of the multicast UEs in the network is denoted by $N_{UE}$. For the cost analysis, define the total packets per multicast session as $N_p$. Furthermore, network operators will typically deploy an IP backbone network between the GGSN, SGSN and RNC. Therefore, the links between these nodes will consist of more than one hop. Additionally, the distance between the RNC and Node B consists of a single hop ($l_{rb} = 1$). In this analysis , assume that the distance between GGSN and SGSN is $l_{gs}$ hops, while the distance between the SGSN and RNC is $l_{sr}$ hops.

In multicast, the SGSNs forward a single copy of each multicast packet to those RNCs serve multicast users. After the correct multicast packet reception at the RNCs the RNCs forward the multicast packets to those Node Bs that have established the appropriate radio bearers via Dedicated or Common Transport Channels. The total cost for the multicast scheme is derived from the following equation where $n_{SGSN}$, $n_{RNC}$, $n_{NODEB}$ represent the number of SGSNs, RNCs, Node Bs respectively, that serve multicast users .

$$M_s = [p_g + n_{SGSN}(D_{gs} + p_s) + n_{RNC}(D_{sr} + p_r) + n_{NODEB}.p_b + X]N_p \tag{5.3}$$

$$X = n_{NODEB}.N_{UE}.D_{rb} + D_{DCH}.N_{UE}, \quad ifchannel = DCH \tag{5.4}$$

$$X = n_{NODEB}.D_{rb} + D_{FACH}.n_{NODEB}, \quad ifchannel = FACH \tag{5.5}$$

The parameter X represents the multicast cost for the transmission of the multicast data over the Iub and Uu interfaces. This cost of the multicast scheme depends mainly on the distribution of the multicast group within the UMTS network and secondly on the transport channel that is used. In cells that the multicast users density is high, the use of common channels such as FACH is preferable to the use of a DCH since the latter is reserved only for a single user.

An issue that should be noticed regarding the eqn(5.4 and 5.5) is that the first term in each of the equation represents the packet delivery cost over the Iub interface which depends on the radio bearer used for the transmission of the data over the Iub. In this case, use the FACH as transport channel each multicast packet send once over the Iub interface and then the packet is transmitted to the UEs that served by the corresponding Node B. However, in same case, use DCHs for the transmission of the multicast packets over the Iub each packet is replicated over the Iub as many times as the number of multicast users that the corresponding Node B serves.

## 5.3 Simulation Environment:Matlab

The MATLAB, high-performance language for technical computing integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include

- Math and computation
- Algorithm development
- Data acquisition
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including graphical user interface building

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. It allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar noninteractive language such as C or Fortran.

The name MATLAB stands for matrix laboratory. MATLAB was originally written to provide easy access to matrix software developed by the LINPACK and EISPACK projects. Today, MATLAB engines incorporate the LAPACK and BLAS libraries, embedding the state of the art in software for matrix computation.

MATLAB has evolved over a period of years with input from many users. In university environments, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering, and science. In industry, MATLAB is the tool of choice for high-productivity research, development, and analysis.

MATLAB features a family of add-on application-specific solutions called toolboxes. Very important to most users of MATLAB, toolboxes allow you to learn and

| | | | | | |
|---|---|---|---|---|---|
| Dgs | 36 | ps | 1 | Dfach | 5 |
| Dsr | 18 | pr | 1 | lgs | 6 |
| Drb | 6 | pb | 1 | lsr | 3 |
| pg | 1 | Ddch | 3 | lrb | 1 |

Table I: Chosen parameters values

apply specialized technology. Toolboxes are comprehensive collections of MATLAB functions (M-files) that extend the MATLAB environment to solve particular classes of problems. You can add on toolboxes for signal processing, control systems, neural networks, fuzzy logic, wavelets, simulation, and many other areas.

## 5.4 Simulation Parameters

For cost analysis of the multicast scheme, first evaluate the cost in function of a number of parameters. The first parameter is the number of the total packets per multicast session ($N_p$) and the second one is the number of the multicast users ($N_{UE}$).Assume a more general network configuration than that illustrated in Fig. 5.1, with $N_{SGSN}$ =10, $N_{ra}$ =10, $N_{rnc}$ =5, $N_{ura}$ =5 and $N_{nodeb}$ =5. As seen in the equation 5.3, the cost of the scheme depends on a number of other parameters. Thus,choose the value of these parameters appropriately, taking into consideration the relations between them. The chosen values of the parameters are presented in Table I.

The packet transmission cost (Dxx) in any segment of the UMTS network is proportional to the number hops between the edge nodes of this network segment. For the cost analysis and without loss of generality, assume that the distance between the GGSN and SGSN is 6 hops ($l_{gs} = 6$), while the distance between SGSN and RNC is 3 hops ($l_{sr} = 3$).

In this analysis, the values for the transmission costs of the packet delivery over the air with each of the two transport channels are different. More specifically, the transmission cost over the air with Dedicated Channels ($D_{DCH}$=3), is smaller than the cost of the packet delivery over the air with FACH ($D_{FACH}$=5). The main difference between the Dedicated and Common resources is that FACH does not allow the use of fast power control.The MBMS service can take significant portion of the sector power if FACH is used to carry the MBMS traffic. As a Common Channel (FACH) needs to be received by all the UEs in the cell, also those near the cells border, it requires more radio resources (power) than a DCH.

In order to calculate the number of the UMTS nodes that serve multicast users, define the following probabilities:

| | |
|---|---|
| $P_{SGSN}$ | The probability that an SGSN serve multicast users |
| $P_{RNC}$ | The probability that an RNC serve multicast users |
| $P_{NODEB}$ | The probability that an Node B serve multicast users |

For the cost analysis, assume $P_{SGSN}$=0.4, $P_{RNC}$=0.3 and $P_{NODEB}$=0.4. Consequently, the number of the SGSNs, the RNCs and the Node Bs that serve multicast users is derived from the following equations:

$$n_{SGSN} = N_{SGSN}.P_{SGSN} = 4 \tag{5.6}$$

$$n_{RNC} = N_{RNC}.P_{SGSN}.P_{RNC} = 60 \tag{5.7}$$

$$n_{NODEB} = N_{NODEB}.P_{SGSN}.P_{RNC}.P_{NODEB} = 600 \tag{5.8}$$

## 5.5 Simulation Results

Figure 5.3 presents the cost of the multicast scheme in function of the $N_p$ for different transport channels (DCH and FACH) used for the transmission of the multicast data over the air. The y-axis presents the total cost of the multicast scheme, while the xaxis shows the total packets per multicast session.

Regarding the use of DCHs, in Figure 5.3,it denotes the costs of three different values of the number of multicast users. Figure 5.3 indicates that the multicast cost

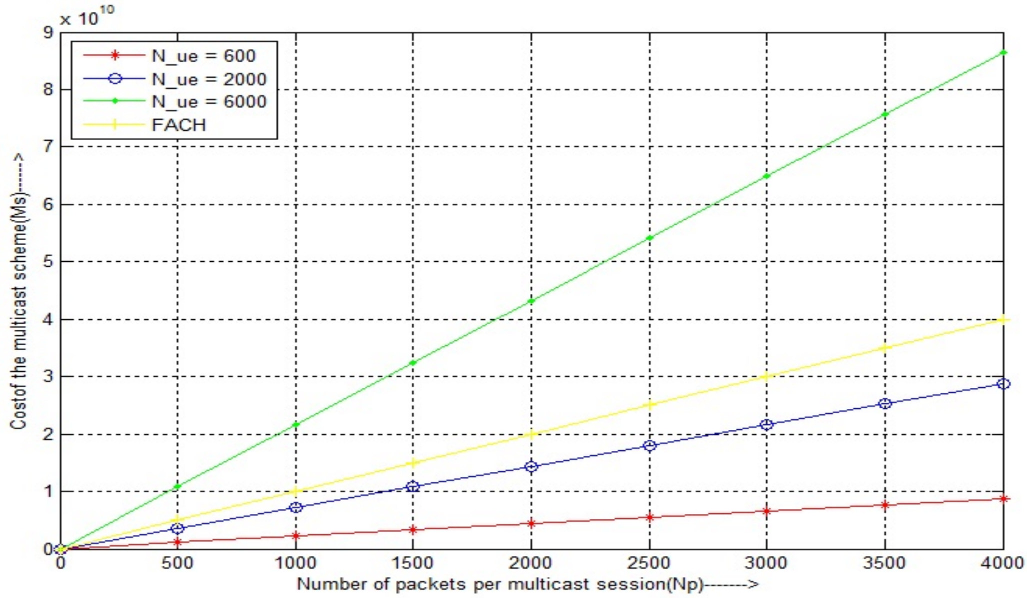


Figure 5.3: Cost of the multicast scheme against Np for different transport channels

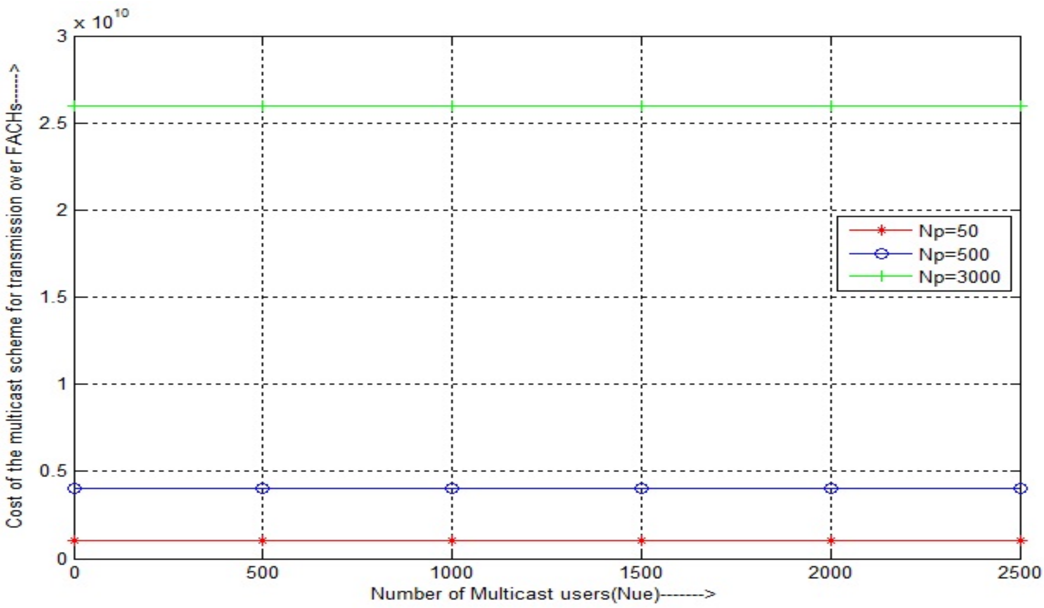


Figure 5.4: Costs of the multicast scheme against $N_{UE}$ over FACH

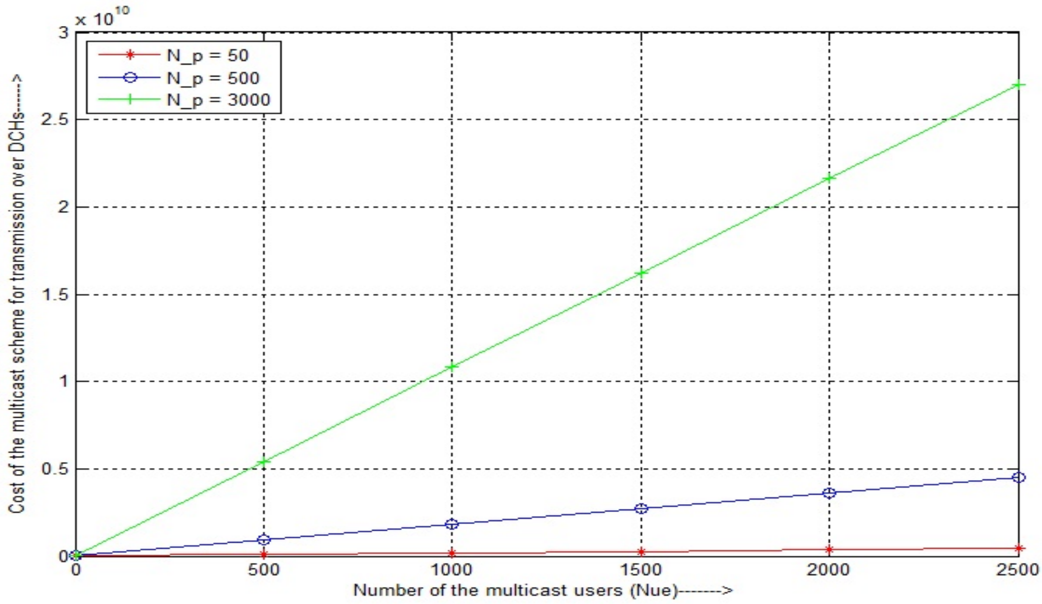


Figure 5.5: Costs of the multicast scheme against $N_{UE}$ over DCH

increases rapidly when the amount of the multicast data increases. Furthermore, for a given $N_p$, the multicast cost increases as the members of the multicast group increase. This is because the greater the number of multicast users is, the greater the number of DCHs needed for the transmission of the multicast data over the air and finally the greater the multicast cost is according to eqn (5.3) and eqn (5.4). Additionally, eqn (5.3) shows that when use FACH for the transmission of the multicast data over the air, the cost of the multicast scheme depends only on the number of packets per multicast session and not on the number of multicast users. This can be shown in Figure 5.3 from it observe that the greater the Np is, the greater the multicast cost becomes.

Another interesting observation that comes out from Figure 5.3 is that for small numbers of multicast users the use of DCHs is preferable to the FACHs. One of the key assumptions in MBMS is that if the number of UEs within a cell using a particular MBMS service is high enough, it will be advantageous to broadcast the MBMS data stream over the whole cell. If the number of UEs is low, serving each UE through DCHs means might be more efficient.

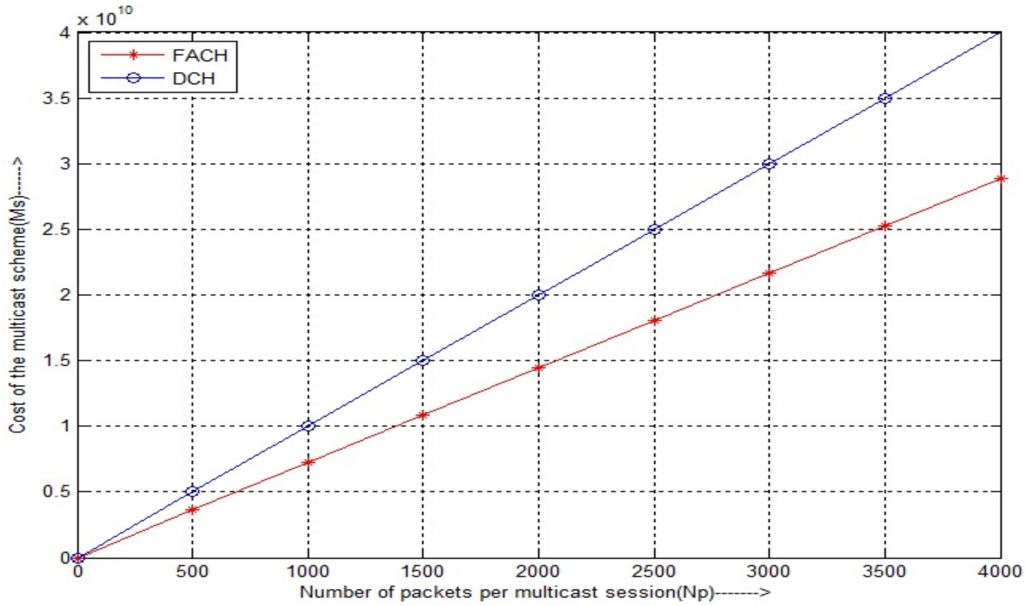


Figure 5.6: Costs of the multicast scheme against $N_p$

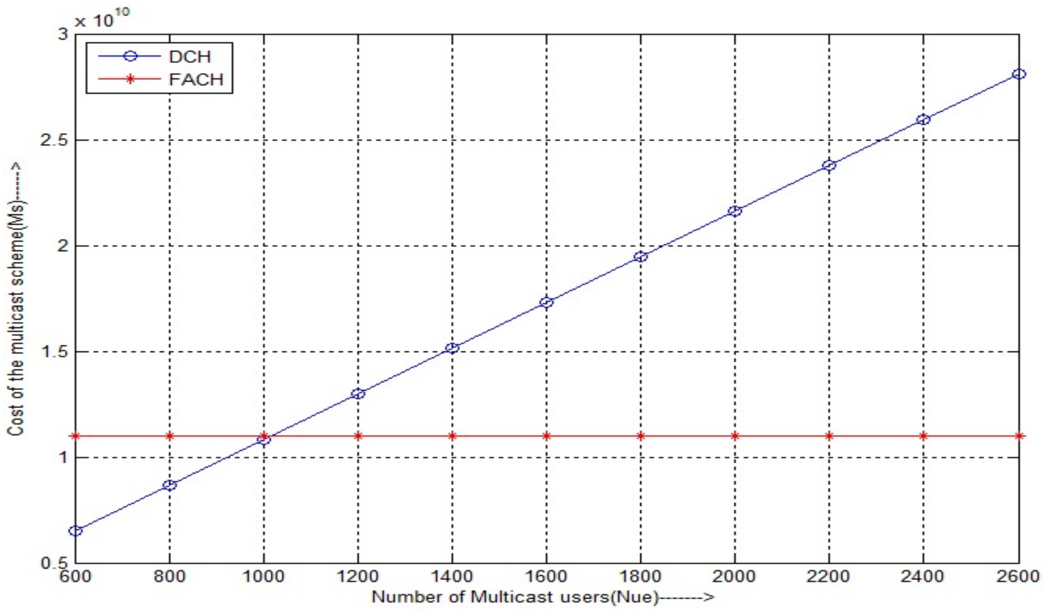


Figure 5.7: Costs of the multicast scheme against $N_{UE}$

Furthermore, by observing the cost of the multicast scheme in function of the $N_{UE}$ (Figure 5.4), three different values of the number of the total packets per multicast session ($N_p$) have been calculated. Figure 5.4 presents the cost of the multicast scheme against $N_{UE}$ in case we use FACH for the transmission of the multicast data over the air. According to Figure 5.4, the cost of the multicast scheme is independent from the number of multicast users in that case , use FACH for the transmission of the multicast data over the air. The cost of the multicast scheme in this case depends mainly on the number of Node Bs that serve multicast users. Only one FACH per cell is established and it is capable of supporting a great number of multicast users in this cell. Regarding the multicast cost against $N_{UE}$ in case of the DCHs, the relation between them is predictable, since the greater the number of the multicast UEs is, the greater the cost becomes (Figure 5.5).

Figure 5.6 indicates that with multicast, the total transmission cost if use common channels such as FACH is lower than the cost if use DCHs. More specifically, Figure 5.6 presents the costs of the multicast scheme in function of the $N_p$ (for $N_{UE}$=2000) using different transport channels, while Figure 5.7 presents the costs of the multicast scheme in function of the $N_{UE}$ (for $N_p$=3000) using different transport channels.

## 5.6 Summary

In this chapter ,there is an analysis of a multicast scheme for UMTS and the delivery of the multicast packets to a group of mobile users and have analyzed the performance of such a delivery in terms of the telecommunication cost. Considering a general network configuration,so we can observe the cost of a multicast scheme in function of a number of parameters. Such parameters are the number of multicast users within the multicast group, the amount of data sent to the multicast users and finally the density of the multicast users within the cells. Additionally, we can saw the performance of the multicast scheme considering different transport channels for the transmission of the multicast data over the air from the results.

# Chapter 6

# Conclusion

This theses is about a multicast scheme for the packet forwarding mechanism in the Universal Mobile Telecommunications System (UMTS). The scheme relies on the introduction of the Permanent Multicast Routing List (PMRL) and Temporary Multicast Routing List (TMRL) in each node of the network except UEs. In the PMRL we record the nodes of the next level that the messages for every multicast group should be forwarded. The TMRL is useful for the temporary record of information from the path from the mobile users to the GGSN. Additionally, a Multicast Group List (MGL) is kept in the GGSN which records the members of each multicast group. These lists lead to the decrement of the transmitted packets and the more efficient use of the network resources in the multicast routing in UMTS. In this thesis, I describe the exact steps that the multicast packets are transmitted to the members of each multicast group. Furthermore, special issues such as joining/leaving a multicast service are described.

It is known that multicast is an efficient method of supporting group communication as it allows the transmission of the packets to multiple destinations using fewer network resources. Along with the widespread deployment of the third generation cellular networks and the fast-improving capabilities of the mobile devices, content and service providers are increasingly interested in supporting multicast communications over wireless networks and in particular over Universal Mobile Telecommunications

System (UMTS). In this theses, a multicast scheme for UMTS is analyzed. I describe the multicast routing mechanism behind our scheme as well as the multicast group management functionality of the scheme. Furthermore, I describe an evaluation of scheme in terms of its performance. The critical parameters for the evaluation of the scheme are the number of users within the multicast group, the amount of data sent to the multicast users, the density of the multicast users within the cells and finally the type of transport channel used for the transmission of the multicast data over the air.

# References


[1] *3G/UMTS Evolution:towards a new generation of broadband mobile services.* UMTS forum, 2006.

[2] *3GPP Mobile Broadband Innovation Path To 4G*, 2009.

[3] Fakhrul Alam. Simulation of third generation cdma systems. Master's thesis, Virginia Polytechnic Institute and State University, 1999.

[4] Antonios Alexiou, Dimitrios Antonellis, and Christos Bouras. A multicast approach for umts: A performance study. Technical report, University of Patras,Greece, 2007.

[5] Antonios Alexiou, Dimitrios Antonellis, and Christos Bouras. Power efficient radio bearer selection in mbms multicast mode. Technical report, University of Patras,Greece, 2007.

[6] Antonios Alexiou, Dimitrios Antonellis, and Christos Bouras. Supporting group communication in wcdma networks. Technical report, University of Patras,Greece, 2007.

[7] Mehwish Bashir and Salman Afsar. Implementation of universal mobile telecommunication system. Technical report, University of Faisalabad, 2005.

[8] Daniel collins Clien Smith. *3G WIRELESS Networks.* McGRAW HILL Communication, second edition edition, 2005.

[9] Erik Dahlman, Stefan Parkvall, Johan Skold, and Per Beming. 3g evolution, hspa and lte for mobile broadband. 2007.

[10] Harri Holma and Antti Toskala. Wcdma for umts, radio access for third generation mobile communications. 2004.

[11] Harri Holma and Antti Toskala. *WCDMA For UMTS-HSPA Evolution and LTE.* John Wiley and Sons, 2007.

[12] The International Engineering Consortium. *UMTS Protocols and Protocol Testing*, 2004.

[13] Markku Maijala Jan Derksen, Robert Jansen and Erik Westerberg. Hsdpa performance and evolution. *Ericsson Review No. 3*, 2003.

[14] Francesco Lagana. Evaluation of channel switching threshold for mbms in umts networks. Master's thesis, University of Petras, 2008.

[15] Jordi Perez-Romero, Oriol Sallent, Ramon Agusti, and Miguel Angel Diaz-Guerra. Radio resource management strategies in umts. 2005.

[16] Juergen Plart Ralf Kreher and Torsten Ruedebusch. Umta utran signaling. *Tetronix*, 2008.

[17] R Ramachandran. Evolution to 3g mobile communication. *RESONANCE*, 2003.

[18] K. W. Richardson. Umts overview. Technical report, ELECTRONICS and COMMUNICATION ENGINEERING JOURNAL, June 2000.

[19] Ken Richardson. Umts overview. *Electronics and Communication Engineering Journal*, JUNE 2000.

[20] Keiichi Yasumoto Teruo Higashino, Hirozumi Yamaguchi and Keiichi Shimada. Toward future innovation of mobile communication systems. Technical report, Graduate School of Information Science and Technology, Osaka University, Japan, 2006.