INVESTIGATION
OF
HANDOVERS IN 3G UMTS TRAFFIC CLASSES

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ABSTRACT

The Universal Mobile Telecommunication systems are one of the emerging cellular phone technologies which are known as the 3G systems. It support the high speed data transfer, speech, web browsing, email, video telephony, multimedia and the audio streaming. These services are divided in to the classes depending upon the QoS requirements. With the development of these cellular networks, a major problem came up; it was the call handover from one cell to the other cell during an ongoing session without dropping the connection with the base station. A lot of techniques were developed and used to cope with this major issue. The user’s movement is a dynamic process considering its location. This means that the mobile users can change its way any time with any speed, so there should be a mechanism and a way that the network should be aware of this process. For this purpose different types of handovers techniques are used which include soft, hard and softer handovers.

The thesis work is about the investigation of different handovers in the 3G UMTS network which is the vital issue to the network to maintain the user’s connection during in the ongoing session with the user’s movement. The investigation is based on the UMTS QoS traffic classes. For this purpose the soft and the hard handovers techniques are analyzed in different scenarios implemented in the OPNET Modeler. To know and understand about the handover process between the Node B and the user equipment different statistics are calculated.
ACKNOWLEDGEMENTS

Thanks to ALL Mighty Allah, who is the creator of the world, for giving us the strength to complete our thesis work.

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We are also very grateful to our program coordinator, Mikeal Asman for his helping and assessment during our stay.

Last but not least, the efforts of the BTH student library for aiding us with the informative and most relevant books, IEEE journals and its enlightening databases.
Dedication

To Our Dear Parents
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<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>1G</td>
<td>1st Generation</td>
</tr>
<tr>
<td>2G</td>
<td>2nd Generations</td>
</tr>
<tr>
<td>3G</td>
<td>3rd Generations</td>
</tr>
<tr>
<td>3GPP</td>
<td>3rd Generation Partnership Project</td>
</tr>
<tr>
<td>4G</td>
<td>4th Generations</td>
</tr>
<tr>
<td>AUC</td>
<td>Authentication Unit</td>
</tr>
<tr>
<td>AMPS</td>
<td>Advanced Mobile Phone System</td>
</tr>
<tr>
<td>ATM</td>
<td>Asynchronous Transfer Mode</td>
</tr>
<tr>
<td>AMR</td>
<td>Adaptive Multi Rate</td>
</tr>
<tr>
<td>BER</td>
<td>Bit Error Rate</td>
</tr>
<tr>
<td>BPSK</td>
<td>Binary Phase Shift Keying</td>
</tr>
<tr>
<td>BFSK</td>
<td>Binary Frequency Shift Keying</td>
</tr>
<tr>
<td>BS</td>
<td>Base Station</td>
</tr>
<tr>
<td>BMC</td>
<td>Broadcast Multicast control</td>
</tr>
<tr>
<td>BSS</td>
<td>Base Station Subsystem</td>
</tr>
<tr>
<td>BTS</td>
<td>Base Transceiver Station</td>
</tr>
<tr>
<td>CC</td>
<td>Calling Channel</td>
</tr>
<tr>
<td>CDMA</td>
<td>Code Division Multiple Access</td>
</tr>
<tr>
<td>CD</td>
<td>Code Division</td>
</tr>
<tr>
<td>CN</td>
<td>Core Network</td>
</tr>
<tr>
<td>CDVCC</td>
<td>Coded Digital Verification Code</td>
</tr>
<tr>
<td>DCA</td>
<td>Dynamic Channel Allocation</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
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<td>--------------</td>
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<tr>
<td>DAMPS</td>
<td>Digital Advance Mobile Phone System</td>
</tr>
<tr>
<td>DC</td>
<td>Data Channel</td>
</tr>
<tr>
<td>DSL</td>
<td>Digital Subscriber Line</td>
</tr>
<tr>
<td>EDGE</td>
<td>Enhanced Data Rates for Global Evolution</td>
</tr>
<tr>
<td>ER</td>
<td>Equipment Register</td>
</tr>
<tr>
<td>FDMA</td>
<td>Frequency Division Multiple Access</td>
</tr>
<tr>
<td>FSK</td>
<td>Frequency Shift Keying</td>
</tr>
<tr>
<td>FACCH</td>
<td>Fast Associated Control Channel</td>
</tr>
<tr>
<td>FDD</td>
<td>Frequency Division Duplex</td>
</tr>
<tr>
<td>FD</td>
<td>Frequency Division</td>
</tr>
<tr>
<td>GSM</td>
<td>Global System Mobile</td>
</tr>
<tr>
<td>GMSK</td>
<td>Gaussian Minimum Shift Keying</td>
</tr>
<tr>
<td>GMLC</td>
<td>Gateway Mobile Location Center</td>
</tr>
<tr>
<td>GPRS</td>
<td>General Packet Radio Service</td>
</tr>
<tr>
<td>HLR</td>
<td>Home Location Register</td>
</tr>
<tr>
<td>IMT</td>
<td>International Mobile Telecommunications</td>
</tr>
<tr>
<td>LTE</td>
<td>Long Term Evolution</td>
</tr>
<tr>
<td>MIMO</td>
<td>Multiple Input and Multiple Output</td>
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<tr>
<td>MTS</td>
<td>Mobile Telephone Service</td>
</tr>
<tr>
<td>MTX</td>
<td>Mobile Telephone Exchange</td>
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<tr>
<td>MSC</td>
<td>Mobile Switching Center</td>
</tr>
<tr>
<td>MAC</td>
<td>Medium Access Control</td>
</tr>
<tr>
<td>MSE</td>
<td>Mobile Switching Center</td>
</tr>
<tr>
<td>NTM</td>
<td>Nordic Mobile Telephone</td>
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<tr>
<td>OFDMA</td>
<td>Orthogonal Frequency Division Multiple Access</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
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<tr>
<td>---------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>OFDM</td>
<td>Orthogonal Frequency Division and Multiplexing</td>
</tr>
<tr>
<td>OSI</td>
<td>Open Systems Interconnection</td>
</tr>
<tr>
<td>PSTN</td>
<td>Public Switch Telephone Network</td>
</tr>
<tr>
<td>PDN</td>
<td>Packet Data Network</td>
</tr>
<tr>
<td>PCF</td>
<td>Packet Control Terminal</td>
</tr>
<tr>
<td>PDCN</td>
<td>Packet Data Serving Node</td>
</tr>
<tr>
<td>PDCP</td>
<td>Packet Data Convergence Protocol</td>
</tr>
<tr>
<td>QoS</td>
<td>Quality of Service</td>
</tr>
<tr>
<td>RNC</td>
<td>Radio Network Controller</td>
</tr>
<tr>
<td>RAN</td>
<td>Radio Access Network</td>
</tr>
<tr>
<td>SACCH</td>
<td>Slow Association Control Channel</td>
</tr>
<tr>
<td>SS</td>
<td>Subscriber Station</td>
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<tr>
<td>TACS</td>
<td>Total Access Communication System</td>
</tr>
<tr>
<td>TC</td>
<td>Traffic Channel</td>
</tr>
<tr>
<td>TDMA</td>
<td>Time Division Multiple Access</td>
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<tr>
<td>UMB</td>
<td>Ultra Mobile Band</td>
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<tr>
<td>UMTS</td>
<td>Universal Mobile Telecommunication System</td>
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<tr>
<td>WiMAX</td>
<td>Worldwide Interoperability for Microwave Access</td>
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<tr>
<td>WAP</td>
<td>Wireless Application Protocol</td>
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<tr>
<td>WCDMA</td>
<td>Wide Code Division Multiple Access</td>
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CHAPTER 1: INTRODUCTION

With the advancement in the cellular communications, a major and important issue rise up, it was the call handover from one cell to the other cell without dropping the ongoing connection with the base station. A lot technique were developed and used to cope with this major issue. The user’s movement is a dynamic process considering its location. This means that the mobile users can change its way any time with any speed, so there should be a mechanism and a way that the network should be aware of this process.

Generally the handover process is done when the link quality decreases between the mobile equipment and the base station. About the information of the radio link quality which is present in the measurement report the network controller then decides whether the handovers phenomena to the other cell should be done or not. The handovers failures may occur due to the unavailability of the resources in the target cell or when the quality of the link becomes very less which is below some acceptable level before the ongoing call is handed over.

1.2 Objectives

The purpose of this master thesis is to study the effects of handovers on the communication between the base station or Node B and the mobile station. To achieve this goal the OPNET Modeler is used to simulate the handover process in different scenarios for different types of services.

During this whole process of handovers we will observe different types of statistics which is provided by the package are collected.

1.3 Outline of the Thesis

Chapter 1:

This chapter contains the introduction, objective of the thesis and the outline of the thesis.

Chapter 2:

This chapter is about the development from first generation 1G to fourth generation 4G, its evolution and development. Different technologies are discussed in details. The pros and cons of each generation are also discussed in this chapter.
Chapter 3:

This chapter is about the UMTS, WCDMA and its different layers and a detail description of UMTS architecture.

Chapter 4:

In this chapter we have discussed about UMTS QoS traffic classes. There are four classes each class has its own quality of service requirements.

Chapter 5:

This chapter is about handovers, its different types, causes of the handovers and the handovers in the UMTS network.

Chapter 6:

This chapter is about the introduction to the OPNET, introduction of the different layers in the OPNET and the OPNET UMTS Module.

Chapter 7:

This chapter is about the simulation and results discussion.

Chapter 8:

This chapter contains the conclusion and the future work.

The appendix has been attached at the end of the thesis which contains the steps of the simulation.
CHAPTER 2: INTRODUCTION

This chapter tells us about the evolution of mobile communication and how it has evolved through the history and which technologies were used. Mobile communication or we may say cellular communication has been constantly evolving and it has evolved from 1st generation to the 4th generation and now work is currently going on the 4th generation mobile system. Cellular technology has revolutionized our lives as in early days there were fixed land line phones and there was no way to connect to the world without fixed lines telephones, mobile communication has filled this gap and now we can be contacted anywhere any time. Mobile communication has evolved so much during the recent years huge amount of research is going on to improve this technology and make it better as the number of user’s increases day by day so all the technologies used face some problems which may be bad signal or poor voice quality.

In mobile communication we have keep in mind about the three sectors which are very important in this field one is the mobile operators which provides us with the network the other one is the cellular phone companies which make these devices to access the network and communicate with each other and the third one are the users so these three aspects make a cellular system [1].

Cellular technologies have came long way and are mostly written as 1st generation, 2nd Generation and 3rd generation networks as each new generation brings new technology and more high data rates than the previous one now research has been going on the and now 4G system is going to be introduced which is expected to be launched within the next year fig 2.1 shows the evolution toward 4th generation cellular system called 4G system.

![Fig 2.1: Towards 4G system](image-url)
2.1 Cellular Technologies Evolution from 1G to 4G:

Cellular Technologies can be divided into four generation which are 1st generation, 2nd generation, 3rd generation and finally 4th generation which currently being deployed in Europe.

2.1.1 1st Generation (1G) technology:

1st generation cellular system began in 1980’s and it started in many countries and in each country it had its own standards like in Scandinavian standards which was adopted in most of the Europe was called Nordic Mobile Telephone (NMT) and the first European system of NMT started in Sweden in 1981. The other standard which started in 1985 was called the Total access communication systems (TACS) which was the most popular in UK and some European countries Japan and Asia. In US the standard which was most popular was called Advance Mobile Phone service (AMPS). The standard which was popular in Germany was called (C-Netz) and in France this standard was called Radiocom 2000 [3]. The 1st generation mobile system suffered from many disadvantages as there was not data encryption in this technology as it used analog transmission and due to interference this technology suffered from poor voice quality and also due to inefficient spectrum usage the voice quality also suffered these were the main reasons due to which this technology was replace later on by 2G systems.

Nordic Mobile Telecom (NMT): NMT standard was first deployed in Scandinavia in 1981 and is this system used frequency modulation i.e. analog transmission and in the beginning NMT used 450 MHZ frequency band but late on 900 MHz frequency band was used [3].NMT basically consists f four major parts which are Mobile phone exchange MTX, Home Location register (HLR), Base station (BS) and Mobile station (MS). The control of the system is managed by MTX and HLR and these have an interface with Public Switch telephone Network (PSTN). NMT uses full duplex radio channels connection between BSs and MSs with frequency range from 900 or 450 MHz [4].

Types of NMT channels:

1. Calling channel (CC)
2. Traffic channel (TC)
3. Data channel (DC)
4. Combined traffic and calling channels (TC/CC)

- **Calling Channel (CC):** For calling each NMT BS uses one channel which is used for calling. CC is used for continuous signal transmission by the BS which is used by the mobile to identify about the mobile.
- **Traffic channel (TC):** TC is used for carrying of voice traffic.
- **Data channel (DC):** DC is used for measuring the strength of the signal on the mobile station and this information is then later used by the MTX for handover operation.
• **Combined traffic and calling channels (TC/CC):** This is used when the traffic channel is busy and MS in this case will use CC for making a call.

**Total Access Communication system (TACS):** This standard was most popular in UK, Japan and Asia and the frequency band used in this was 900 MHz

**Advance Mobile Phone Service (AMPS):** This system was made by Bell labs and in 1982 was launched in United States. This system operates at a frequency band of 800 MHz. We know that the mobile phone system is divided into cell that is why we call mobile phone as cellular phones. In AMPS system the cells are mostly 10 to 20 Km across from each other and each cell uses different frequency then the other so that the frequencies do not overlap and cause interference [5].

The AMPS uses full duplex 832 channels in which width of each of these channel which are simplex are 30 KHz and AMPS uses Frequency division Multiplexing FDM to for channel separation. In AMPS the 800 MHz waves or radio waves are about 40 cm long and these waves travel in a straight line and can also be reflected from buildings and trees and due to which the signal will suffer from interference and due to which our signal quality gets poor. These channels can be subdivided into four categories namely [5].

- Control channels which are used to manage the system from base station to the mobile station.
- Paging channels which are used to tell the mobile user about the incoming call.
- Access channels which are used for making call and these channels are bidirectional.
- Data channels which are used for sending voice or any data and these channels are also bidirectional.

In AMPS the signaling between the BS and MS is done at the rate of 10 kb/s but using Manchester encoding the bit rate can be extended to 20 kb/s. The frequency allocation for Amps system is shown in the Table below.

**Table 2.1:** Frequency Allocation for AMPS [7].

<table>
<thead>
<tr>
<th>Carrier side</th>
<th>Reverse Direction</th>
<th>Forward Direction</th>
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<tbody>
<tr>
<td>A (initial)</td>
<td>824-834 MHz</td>
<td>869-879 MHz</td>
</tr>
<tr>
<td>A (extended)</td>
<td>844-846.5 MHz</td>
<td>889-891.5 MHz</td>
</tr>
<tr>
<td>B (initial)</td>
<td>834-844 MHz</td>
<td>879-899 MHz</td>
</tr>
<tr>
<td>B (extended)</td>
<td>846.5-849 MHz</td>
<td>891.5-894 MHz</td>
</tr>
</tbody>
</table>

In AMPS the width of the physical channel is 30 kHz and it is only for only one mobile station in which the call is made by the mobile which is in the proximity of the cell. Frequency Modulation (FM) i.e. Analog FM with the deviation of 8 KHz is used for traffic...
channels which is used for transmitting voice. Frequency shift keying (FSK) i.e. Binary BFSK modulation technique in control channels at 10 kbps for signaling.

Table 2.2 Technical parameters for NMT and APMS mobile systems [6].

<table>
<thead>
<tr>
<th>Parameters</th>
<th>AMPS</th>
<th>NMT (450)</th>
<th>NMT (900)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency of Transmission</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• BS (Base station)</td>
<td>869-894</td>
<td>463-467.5</td>
<td>935-960</td>
</tr>
<tr>
<td>• MS (Mobile station)</td>
<td>824-849</td>
<td>453-457.5</td>
<td>890-915</td>
</tr>
<tr>
<td>Frequency separation between transmitter and Receiver [MHz]</td>
<td>45</td>
<td>10</td>
<td>45</td>
</tr>
<tr>
<td>Spacing between channels [KHz]</td>
<td>30</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Number of Channels</td>
<td>832</td>
<td>180</td>
<td>1000</td>
</tr>
<tr>
<td>Modulation of Audio signal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Frequency deviation [KHz]</td>
<td>FM ±12</td>
<td>FM ±5</td>
<td>FM ±5</td>
</tr>
<tr>
<td>Control signal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Modulation</td>
<td>FM ±8</td>
<td>FM ±3.5</td>
<td>FM ±3.5</td>
</tr>
<tr>
<td>• Frequency Deviation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2.2.2nd Generation (2G) technology:

The move from 1st generation to 2nd generation took place because the 2nd generation system provided many advantages the key factor was that the 2G system was completely digital and it had many advantages one the key advantage was that it was very easy to encrypt digital data then analog data so it’s very secure and in digital data it is very easy to correct the errors in the data using different error corrections schemes with these techniques we can correct the error in the bits we receive and with it help the data rates will be faster and there will be no delays in the signal and there will be an efficient usage of spectrum and in 2G digital data we can compress the data due to which we can accommodate more number of users on one base station on per MHz of the spectrum then a 1G system.

The 1G system used Frequency division multiple access (FDMA) scheme for users, 2G system uses time division multiple access (TDMA) in correspondence with Code division multiple access schemes CDMA [4].
2.2.1 IS -136 (D-AMPS):

IS-136 is new version AMPS and it operates at 800 MHz band and it is also called D-AMPS and is fully digital standard. D-AMPS have much in common with GGM but there are some incompatibility issues in the air interfaces [4]. IS-136 uses TDMA technology in which each user is given a different channel in the same time slot which allows the efficient usage of the spectrum. This technology has many advantage as increased security more efficient bandwidth utilization, encryption and also short messaging and paging service. The air interface structure for IS-136 is shown below.

![Air interface diagram](image)

The above figure shows the air interface signaling format for IS-136 D-AMPS system this figure shows that there are six conversations are currently going on the same bandwidth of 30 KHz that
were previously assigned for one user in analog cellular system. Here full rate vocoder is used which is efficient as it will occupy both the time slots A1 and A2 at the same time.

2.2.2 GSM:

The global system for Mobiles or GSM was introduced to replace the 1G technology to 2G technology. The frequency spectrum of GSM chosen was 935-960 MHz for Downlink and 890-915 MHz for uplink frequency and the channel spacing in FDM is 200 kHz thus providing 124 FDM channels. This when applied with TDM then it supports eight channels for communication per FDM channel.

GSM Architecture:

![GSM Architecture](image)

This figure shows the detailed GSM architecture it shows three parts in the GSM network, the mobile part consists of mobile equipment (ME) which is our mobile on which we can listen and dial phone calls and SIM which is provided by the network operators which we place in our mobiles to make our calls this makes the complete mobile system next is the base station subsystem (BSS) which consists of base station transmission system (BTS) and Base station controller (BSC) the BSS controls a group of BTS that are connected to BSC which is then linked to the Network subsystem which consists of Home location register (HLR) which contains the permanent data of the user, Visitor location register (VLR) which contain the temporary data of the user, Equipment identity register (EIR) which tells about the identity of the mobile equipment either it is authorized to make the call or not and authentication center (AUC) which allows the call to make by the users and this whole of NSS is then connected to public switch telephone network (PSTN) and Packet switched public data network (PSPDN). There are three interfaces in GSM network the interface between the mobile and NSS is called the UM interface which tells us about the radio link between the two units. The interface between BSS and NSS is called the Abis interface and it is basically a physical layer the interface between BSC and BTS is called the A interface and is basically for BSS management call control and for mobility management [10].
• **Services Offered By GSM:**

The most common services offered by GSM are short messaging service SMS and Multimedia messaging service MMS as SMS was only limited to text messages and the data it had was very little but in MMS we can not only transfer text but also our pictures this was a breakthrough in mobile as it offered much more data to be sent in a simple message.

• **Enhanced GSM Services:**

In order to upgrade GSM many new services were introduced to evolve to the 3G. General packet radio service GPRS and Enhanced data rate for GSM evolution were introduced to improve this service helped GSM to evolve to 3G universal mobile telecommunication system UMTS.

2.2.2.3 **GPRS:**

The main idea of integrating GSM and GPRS was to increase the connection per person by efficient utilization of the physical channel. It is called General packet radio service because the GPRS radio resources are only utilized when the data is being transferred between users during transmission and reception so it is efficient way of using the available radio resources and the same radio resource can be used by several users at the same time. It is used for application like email web browsing and WAP services and it operates on the protocol like TCP/IP and X.25. GPRS can give us data rates of 117 Kb/s.

![GPRS Architecture](http://example.com/gprs.png)

BSS = Base Station subsystem  
VLR = Visitor Location Register  
MSV = Mobile switching center  
PDN = Packet Data Network

**Fig 2.4:** GPRS Architecture [12].
2.2.2.4 Edge (Enhanced data rates for Global Evolution):

Edge technology provides the GSM network the capacity to handle the 3G networks. EDGE was designed to give high data rates for GSM network up to 472 Kbps. The GSM network provides user bit rates up to 14.4 kbps which is for circuit switched data and for packet switch data this rate can be up to 22.8 kbps. High data rates which can be possible with multi slot operation but GPRS and high speed circuit switched data (HSCSD) use modulation scheme i.e. Gaussian minimum shift keying (GMSK) so the bit rate is not that much increased.

Fig 2.5 shows the evolution of mobile data rates in terms of single radio timeslot in Kbps and it shows that EDGE technology gives the highest data rates so EDGE technology provided the basic migration from 2G networks towards UMTS 3G networks which were later implemented [13].

Edge technology can easily be implemented on the GSM network by installing one EDGE transceiver unit to each cell site but many GSM sites may be upgraded to EGDE by only upgrading the software on BSCs so when EGDE capabilities are required the system can be switched to EGDE and then run in normal mode when it is not required. EGDE is designed to be migrated to GSM and TDMA networks and thus offering multimedia services with speeds up to 472 kbps.

2.3.3rd Generation (3G) technology:

As number of countries started to develop 3G technology so there was a need for making some cooperation between different standardization bodies so that the same technology can be used on 3G networks worldwide so that a mobile phone can be operated in different countries on the 3G networks with changing or upgrading the mobile phones. The solutions provided by many standardization bodies was the same so the result of this partnership gave rise to third generation...
partnership program (3GPP) which came into existence 1998. The 3G designed by 3GPP consists of the following components

- **The access network**: The access network depends on the radio interface of Universal Terrestrial Radio Access (UTRA) which has two operation modes which are Frequency Division Duplex (FDD) and Time Division Duplex (TDD)

- **The core networks**: the core network developed for 3GPP is evolved from the GSM core network with the addition of some new technology like Gateway mobile location center (GMLC).

While developing toward 3G and the huge cost in development of 2G system it was necessary to provide easy access to the development of third generation so 3GPP adopted two new approaches to this one method was the development of a new radio access scheme which was based on wide CDMA (WCDMA) scheme which provided FDD and TDD modes of operations. And secondly it derived the network elements from 2G and 2.5G like Visitor location VLR, Authentication unit (AuC), Equipment register (ER), Home location Register (HLR) and Gateway GPRS support node (GGSN). The result of this was new mobiles with upgraded software and hardware changes in network elements which results in higher bandwidths for 3G networks [14].

### 2.3.1 UMTS:

Universal Mobile Telecommunication system (UMTS) network has three subsystems, which are User Equipment (UE), Access Network (AE) and Core Network (CN) as shown in the figure below.

![Fig 2.6: Basic structure of UMTS Network](image)

The UE is used by the subscriber to access the network. To connect to the network a UE interface with WCDMA air interface is referred to as Uu interface. Two modes i.e. FDD and TDD are used in this in which FDD is used for paired spectrum and TDD is used for unpaired spectrum. The AC performs the basic functions which are related to radio access techniques but in UMTS the access networks performs the functions which are only for the WCDMA interface. The Access network has basically two entities which are BTS and BSC which make the access network and the Core network performs the operations like call control mobility management,
switching and routing functions and it also contains the subscription information about the users [14].

2.3.2 CDMA2000:

CDMA2000 network was first launched in Korea in 2000 which provided data rates of 144 kbps and the voice quality was twice as that of the CDMAOne system. The system architecture that makes up the CDMA2000 is the same as the CDMAOne with the fundamental difference of the introduction of the packet data services. The introduction of packet data service meant that BTS and BSC should be upgraded to handle this packet data services.

The network of CDMA2000 consists of three major parts which are the Radio access network (RAN), Core network (CN) and Mobile station (MS). The CN can then be further divided into two parts one parts is that which interacts with the PSTN and the other which is connected to the internet. The figure below shows the architecture of CDMA2000 network

![CDMA2000 Architecture](image)

**Fig 2.7: CDMA 2000 Architecture [15].**

2.3.3 WCDMA:

Wide Code Division Multiplexing WCDMA emerged as the most widely used air interface for the 3G network. The 3GPP has created many specifications for the use of this technology in 3G networks and is and is referred to as UTRA (Universal Terrestrial Radio Access). WCDMA is evolved from CDMA system and uses Direct-Sequence (DS-CDMA) system in which the information bits in which user data is multiplied by the quasi-random bits
which are also called chips and this is taken from the CDMA system scheme of spreading codes. WCDMA supports high data rates because the user data rate can be changed from frame to frame thus supporting high data rates.

WCDMA used two modes i.e. FDD and TDD modes of operation in which FDD uses a separate 5 MHz carrier frequency for uplink and downlink transmission but in TDD only 5 MHz is the shared time between the uplink and downlink.

2.4. 4\textsuperscript{th} Generation (4G) technology:

The 4G mobile technology has many advantages over 3G networks, 4G networks can give us data rates of about 100 Mega bits per seconds (Mbps) and an efficient use of spectrum then the normal 3G networks, low latency and low cost, 4G mobile technology provides ever new and better way of providing higher level of graphic user interface and it provides high level of online gaming and more better video quality.

Long Term Evolution (LTE) which is also known as super G or 3.9G has been developed by the 3GPP project as an improvement to the UMTS system. LTE uses Orthogonal Frequency Division Multiple Access (OFDMA) and LTE will provide us download data rates of about 150 Mbps for multi antenna (2×2) multiple-input multiple-output (MIMO) which are for the highest terminal category and for upload it will be 50 Mbps. LTE make very efficient use of the spectrum with the available bandwidth of 1.25 MHz to 200 MHz.

![Fig 2.7: 4G Architecture [18]](image-url)
According to the working groups which will use this technology, the infrastructure and terminals that will be used in 4G network will use all the standards from 2G to 4G but the legacy system will be placed to adopt users in the existing infrastructure but the 4G network will all be based on packets i.e. it will be all IP based [18].
CHAPTER 3: UNIVERSAL MOBILE TELECOMMUNICATION SYSTEM- A DETAILED DESCRIPTION

3.1 Steps from the Beginning to UMTS:

There are different cellular generations developed. The first mobile telecommunication systems were installed in the car and it is also known as the MTS. These systems were upgraded and the outcome was Improved Mobile telephones service IMTS. Its range is very limited [22].

The first generations systems were analogue system. There basic characteristics were wider cells with a large range. The cost of infrastructure was low [21]. The transmission power of the user equipment and the base station should be high. An advance Mobile phone system comes in first generation.

The Global System for Mobile Communication GSM evolves due to the number of users’ incensement in the cellular systems. These systems are the second generation systems which are digital systems. This generation is still use in many parts of the world.

The third generation is developed by the IMT-2000 which is also known as the Universal Mobile Telecommunication Systems. Third generation provides different services which have different quality of service requirement. UMTS uses WCDMA radio interface. UMTS provides the data rate of 2 Mbps. It is basically based on the second generation technology GSM. The path from the GSM to the UMTS is shown in the following Figure 3.1.

![Migration of GSM to UMTS](image)

**Figure 3.1:** The Path from Gsm to UMTS [21].
3.2 Features of IMT-2000 Systems:

The following are the features of the IMT-2000 systems [22].

- Provides high data rates up to 2 Mbps.
- Transfer of the data symmetrically and asymmetrically.
- The qualities of the speech are high.
- Achieves greater spectrum efficiency.
- It’s available everywhere in all the network of IMT-2000.
- From the second generation systems, unseamed transitions.
- Provides the facility of the virtual home environment.

3.3 UMTS standardization:

There are many organizations involved in the development of the standardization of the 3 G which can be seen from figure below, each one prosecuting their own objective and interests. The international telecommunication union has defined some parameters and based on that third generation partnership project 3GPP is standardizing the UMTS. For the CDMA 2000 development the 3 GPP2 is also doing the same task to develop this standard. The 3GPP keeps contact with the different groups. These groups are from different region.

[Figure 3.2: Overview of UMTS Standardizations Organizations [21].]
In the meanwhile the 3GPP is standardizing GSM, EDGE and GPRS along with the UMTS standardization. In 2002 the 3GPP structure is shown in the figure 3.3.

![3GPP Organizational Chart](image)

**Figure 3.3:** 3GPP Organizational Chart [21].

The project co-ordination group in the 3GPP assigns duties to the different technical specification groups. Each group has its own functionality and task to be done. For example the technical specification group core network work with development of the infrastructure of the fixed network. Similarly the development of the radio access network development is the work of the Technical Specification Group Radio Access Network. The figure 3.4 shows the present timetable for the UMTS introduction. In the most countries of the Europe the licenses are already been given and many of the operators are working in the development of the network.
3.4 UMTS different Releases:

Like other standards, UMTS there are different stages of the development of the UMTS. For the 3G systems the frequency spectrum is shown in figure 3.5. The following sections give the description of the different releases of the UMTS.
3.4.1 UMTS Release 99

The Release 99 also known as R99. It is the base of the first UMTS systems in many places like in Europe and Japan. The following are the features of the UMTS R99 [21]. The UMTS release 99 is shown in the figure 3.6.

- It contains the frozen network as in the GSM Phase 2+.
- It supports greater data rates and supports for the QoS.
- It contains the USIM, a sim card for the identification of the users.
- From the very first the virtual Home Environments and other new platforms are not present.
- May be the core network cannot take the greater data rates of air interface.
3.4.2 UMTS Release 2000 (R4/R5):

The more development of the standard is done in the Release 4, 5 and 6. The following are features in bullets [21].

- It is based on the R99.
- Different new platforms are used like Sim Application Tool kit, Mobile Execution Environment etc. These are developed to support the latest services.
- The facility of the speech transcending is present.
- The support of the inter systems and the inter Release Roaming are present.
3.5 Stratum Division in UMTS:

If the users consider the process of the communication within the elements of the network individually, the communication process can be combining and the partners who are participating in the network in to something are called as the stratum [21]. The different functional stratums are shown in the figure 3.7.

![Functional Splitting](image)

**Figure 3.7:** UMTS Functional Divisions [21].

The terminal equipment and radio access network comes in the access stratum. The protocol stack of the Uu –interface works in this stratum. The signaling process which is above this protocol, between the user’s equipment and the core networks, their communication process is combining together in the non access stratum. Home stratum is another functional division in the UMTS, in which keys exchange in the process of communication for security purposes comes in this stratum.

3.6 WCDMA:

The proposal known as the European Telecommunications Standard Institute ETSI which is also known as the universal mobile telecommunication systems they call to use of the
WCDMA for the radio access. It consists of the two modes of the WCDMA. Thus the proposal consists of the frequency division duplex WCDMA for the paired bands and for the unpaired bands Time Division Duplex should be used.

The WCDMA is based on the CDMA. This scheme is asynchronous thus the installation and the integrations of the WCDMA indoor components with the infrastructure of the outdoor components. In the specifications of the WCDMA, ‘Wide band ‘means the wider carrier frequency. The carrier use in WCDMA is 5MHZ. The objective of this wider carrier is to support more data rates but using the wider carrier the spectrum required for it should be more. The radio protocol of the WCDMA is shown in the figure 3.8.

<table>
<thead>
<tr>
<th>DLC: PDCP</th>
<th>DLC: BMC</th>
</tr>
</thead>
<tbody>
<tr>
<td>DLC: RLC</td>
<td>Logical channels</td>
</tr>
<tr>
<td>DLC: MAC sub-layer</td>
<td>Transport channels</td>
</tr>
<tr>
<td>Physical Layer</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 3.8:** Architecture of the WCDMA radio protocol [22].

The figure shows the two lower layers. It has the physical and the DLC layer. The following sub layers results from splitting the DLC layer.

- Medium Access control MAC
- Radio link control RLC
- Packet data convergence protocol PDCP
- Broad cost/Multicast control BMC

Physical layer offer different transport channels to the MAC layer. Also different logical channels are offered by MAC sub layer to the RLC of layer 2 [22].

**3.6.1 Issues of the WCDMA physical layer:**

To the higher layers and the Mac layer the physical layer, it offers the transfer of the information service. Over the 5MHZ bandwidth of the channel it offers the air interface which is based on the Direct spread CDMA. For uplink and the downlink the WCDMA offers many
physical channels. The data are transfer through these channels using the logical channels. The WCDMA frame is 10 ms and has the two modes of operation.

- FDD
- TDD

The pros of the FDD is the transmitting and the receiving of the data at the same time however its main con is not good in the allocation of the available bandwidth. Whereas the TDD uses the frequency band same for the uplink and the downlink but it requires the good synchronizations time to ensure that the transmission of the mobile and base station does not overlap.

### 3.6.1.2 Features of the WCDMA physical layer:

The following are the features of the WCDMA physical layer.

- The capacities are increased by the use of the wider band.
- The spectrum efficiency has improved.
- Different channel coding methods are implemented and the support of the interleaving process improves the error rate.

There are different down link and uplink physical channels each have it own functions and role.

### 3.6.2 Issues of the WCDMA Data Link Control layer:

The support to upper layers is provided by this layer. It consists of MAC, BMC, PDCP and RLC sub layers. The MAC layer uses the logical channels and gives the support to the upper layers. The following are the services which it offers to the upper layers.

- The transformation of the unacknowledged MAC frames in the peer entities of MAC are performed by this layer.
- Volume of the traffic and the quality of the channel, these measurements are also performed by this layer.

### 3.6.2.1 Functions of MAC:

The following are the functions of MAC.

- Logical channels are mapped to the transport layer is the responsibility of this layer.
- The priority handling is done by the MAC
- It ensures the usage of transport channel, for this it elects the suitable format of transport.
- Multiplexing and the demultiplexing of the dedicated and common transport channel is the duty of this sub layer.
• Ciphering is done in this sub layer in order to provide the security.

3.6.3 Services of the RLC to the upper layers:

Between the peer entities of the RLC the connection establishment and release is done. It does not add any extra data to the information and transfers the data to the higher layers. It transfers the PDU’s to the higher layer but does not give any surety. To the higher layers it provides different QoS. It also informs the higher layers about the errors if it is unable to solve it.

3.6.3.1 Functions of the RLC:

The following are functions of the RLC sub layer.

• The reassembly and the segmentation process is done by this layer.
• The retransmission mechanism of data is also done here.
• To provide the security the ciphering is done in this sub layer.
• It can correct and detect errors.
• Flow control is also provided in this sub layer.

3.6.4 Services of the PDCP to the upper layers:

It can receive and transmit data to the higher layers.

3.6.4.1 Functions of the PDCP:

The following are the functions of the PDCP.

• The incoming PDU’s to the PDU’s of RLC layer are mapped by this sub layer.
• The layer 3 data which is known as PDU’s are transmitted and received using the process of compression and the decompression.

3.6.5 Services of the BMC to the upper layers:

The facility of broad casting and the multicasting transmission to the upper layers is performed by this sub layer.

3.6.5.1 Functions of the BMC:

The following are the functions of the BMC sub layer.

• This sub layer store messages which are to be broadcast to all users equipment belongs to some specific cells.
• The BMC messages are transmitted according to some schedule.
• The broadcasts which are corrupt are not transmitted to the upper layers.

3.7 **UMTS Architecture:**

The architecture of the UMTS consists of two main domains [21].

- The User Equipment Domain
- The Infrastructure Domain

The domains are shown in the following figure 3.9.

![Figure 3.9: UMTS Domains Divisions [21].](image)

3.7.1 **The User Equipment Domain:**

In this domain the services of the UMTS are acquired by the users of the UMTS. This domain further consists of the following parts.

- USIM Domain
- Mobile Equipment Domain
3.7.1.1 USIM Domain:

It is the smart card which is given to each UMTS user. Thus the sim card comes in the USIM Domain.

3.7.1.2 Mobile Equipment Domain:

The terminal features and functions come in this domain. It consists of the functions which the UMTS users need to access the network [21].

3.7.2 The Infrastructure Domain:

This domain is the main part of the architecture of the UMTS. This domain is further divided in to two parts.

- Access Network Domain
- Core Network Domain

3.7.2.1 The Access Network Domain:

The function of the radio access network and all the nodes are in the access network domain.

3.7.3 The Core Network Domain:

This domain is further divided in to three sub domains which are exactly alike in some cases [1].

- Serving Network Domain
- Transit Network Domain
- Home Network Domain

3.7.3.1 Serving Network Domain:

This sub domain consists of the features of the particular core network that at some particular time the UMTS user’s uses.

3.7.3.2 Transit Network Domain:

In the case that the serving network is not directly connected to home network the data passes to the transit network. The transit network functions are present in the transit network domain.
3.7.3.3 Home Network Domain:

The features and the functions done in the user home network come in the home network domain.

3.7.4 Universal Terrestrial Radio Access Network UTRAN:

UTRAN comes in the access domain. Between the core network and the user equipment it maintains it makes and keeps the Radio Access bearers among the above entities. It is responsible to make a connection between the core network and the mobile equipment. UTRAN consists of the following two main parts. The UTRAN works in the UTRAN-TDD and UTRAN-FDD modes.

- Radio Network Controller
- Node-B

The RNC and Node-B’s comes in the radio access network and these forms a UTRAN which is shown below in figure 3.10.

![Figure 3.10 UTRAN Network.](image-url)
3.7.5 Radio Network Controller RNC:

In the radio access network the RNC is the main node. Between the mobile equipment and the radio access network a number of the protocols are applied in the radio network controller through the lur interface with the other RNC’s of the core network. The function of the RNC is same as the function of the BSc in the GSM network. The radio resource management is controlled in more than one Node-B by the RNC. The following are tasks of the RNC [21].

- Through the radio interface it performs all the data transmission tasks.
- The radio resources are managed by this entity.
- The connection and the release of the radio bearers.
- The admission of the call control through the Call admission control.
- The allocation of the code is also the duty of this entity.
- The control of power.
- Helps in handovers and the scheduling of the packet.
- The relocation of the SRNS and the conversion of the protocol.
- The data coming from other networks are ciphered in the RNC’s.
- To enable the transformation of the various entities RNC can connect and switch to ATM connection.

There are three types of RNC’s.

- Serving RNC
- Controlling RNC
- Drift RNC

3.7.5.1 Serving RNC:

This RNC serves the user equipment because the user equipment is connected to this RNC. That is why this RNC is called as the serving RNC.

3.7.5.2 Controlling RNC:

It works with reference to the Node – B.

3.7.5.3 Drift RNC:

It works in the process of handover.

3.7.6 Node- B:

Its functions are similar to the BTS in the GSM network. The Node-B’s are also called as the radio network controller. The following are functions of the Node-B.
• Many cells are managed by the Node-B.
• The tasks which are attached to the radio interface is manage in the Node-B.
• The data splitting and the combination is also the duty of this entity.
• It helps in the process of handovers too.
• It uses the mechanism for power control known as the inner loop power control.

Node-B’s has three types which include the following.

• UTRA-TDD Node B
• UTRA-FDD Node B
• Dual Node B

3.8 Entities of the core network:

The following are the different parts of the core network which have different functionalities [23].

3.8.1 Mobile Switching Center MSC:

It is the switching entity. It supports the circuit switched connection. It also supports the mobility of the users. The current location of the user is known to the Msc. It also works in authentication and the user data encryption [23].

3.8.2 Visitor Location Register:

It is the data base and it stores the copy data from HLR. The VLR stores the dynamic data. The VLR Update the information when users change its area.

3.8.3 Home Location Register:

It is also the database same as the VLR. All the data of the users are stored in this database. Its main responsibly is the mobile user’s mobility.

3.8.4 Gateway Mobile Switching Center:

The circuit switch network between the outside network and the core network is provided by the GMsc.

3.8.5 Serving GPRS Support Node:

The user’s current location is stored in SGSN. It performs the functionality of the routing. Authentication and the copy of information of the user are stored in SGSN.
3.8.6 Gateway GPRS Support Node:

The internet is connected to this node. It is the gate way to other packet networks. Usually firewall is containing in this entity.

3.8.7 GPRS register:

It is the data base that is part of HLR. The packet switch transmission information is stored in this register.

All these entities of the UMTS access plane are shown in the figure 3.11.

![Architecture of the Access Stratum](image)

**Figure 3.11:** UMTS Access plane Architecture [21].

3.9 Types of Switching in the UMTS Core Network:

There are two types of switching done in the UMTS core network.

- Circuit Switching
- Packet Switching
3.9.1 Circuit Switching:

Its function is to get the support of the traffic control. It maintains the information of the user location. The switching functions perform for circuit switching by the core network is done by MSc, HLR, VLR, and the GMsc.

3.9.2 Packet Switching:

The packet switching tasks are performed by the serving GPRS support node and gateway GPR support node. The management of the mobility and the session is also done in this domain.

Both the circuit switching and the packet switching domain can be seen from the figure 3.9.

3.10 Interfaces of the UMTS:

The following are the different interfaces in the UMTS.

- Lub
- Lur
- Uu
- Iu
- Iu-cs
- Iu-ps

The following section gives a brief description of the above UMTS interfaces

3.10.1 Lub Interface:

The RNC and the Node-B’s are connected through the Lub interface. There are many functionalities of this interface which include the management of the information system, the validation of the message on the user side, management of the traffic on different channels like in control and the dedicated channel and timings and the management of the link status.

3.10.2 Lur Interface:

Two RNC’s are connected to the interface known as Lur interface. The functionalities of this interface include management of the traffic in different channels like dedicated and common transport channel and management of the SAAI connection.

3.10.3 Uu Interface:

The RNC and the mobile equipment through the Node –B’s are connected to this interface. The main functionalities of this interface include paging and the management of the
security, MAC/RLC reconfiguration and configuration and the handling of priority and the selection of the TFC.

3.10.4 Iu Interface:

The core network and the RNC’s are connected through the Iu interface. The main functionalities of the Iu Interface include establishment of the radio access bearers, its maintenance and the release is also the responsibility of this interface.

3.10.5 Iu-CS:

The RNC’s connected to the circuit switched domain of the core network through this interface.

3.10.6 Iu-PS:

The RNC’s connected to the packet switched domain of the core network through this interface.

The following figure 3.12 shows the different interfaces.

![Different Interfaces in UMTS](image)

**Figure 3.12:** Different Interface of UMTS [21].
3.11 Power Control:

Power control normalizes the transmission power of the mobile equipment and the RNC. It is very important to cope with the fading and the path loss. Greater capacity is gain by the regulation of the power transmission. To beaten the near far effects the received power equalization is very important. Also to minimize the interference level and the nosie in the cell power control is very important. There are three power control mechanisms used in the WCDMA.

- Closed loop power control
- Open loop power control
- Outer loop power control

3.11.1 Closed Loop Power Control:

From the mobile equipment the RNC measures the uplink signal and sends a command to the user’s equipment. The down link signal is monitor by the mobile equipment and the data is forwarded to the RNC. To accommodate the near far problem in uplink this algorithm is used. The main function of the closed loop power control is that the power equalization at the users equipment all time.

3.11.2 Open Loop Power Control:

This mechanism is the property of the user’s equipment for arranging a required power for the required receiver. The mobile equipment measures the pilot signal from the base station and sets the power of the signal according to the power of the receiver signal.

3.11.3 Inner Loop Power Control:

This power control is also called as the closed loop power control. The power received is kept constant in fading channel due to this power control. The near far terminal problem is reduced due to this power control mechanism.

3.11.4 Outer Loop Power Control:

This type of the power control is related to the long term fluctuations of the channels. This type of power control is also called as the slow closed loop power control
CHAPTER 4: UMTS TRAFFIC CLASSES

4.1 Introduction:

In second generation mobile networks the users can achieve bandwidth of about 10 to 40 Kbps which at that time was enough but as the technology developed the 3G services came and they provided data rates then the 2G networks as GSM. The improved data rates provided new services like video telephony, quick and efficient downloading of data. The 3G network has a new property which allows the user to handle the characteristics of the radio bearer. The characteristics which may define the radio bearer services are the delay through put and bit error rate.

In this section we will show that how Quality of service QoS features are provided in UMTS and how multimedia services are provided by using QoS engineering in UMTS. UMTS allows the user to handle the bearer characteristics which are most suitable for the user for the required application. During an active session it allows the bear properties to be renegotiated. The bearer negotiation is done by the user but in case of renegotiation it can be done either by the user or by the network itself.

4.2 UMTS bearer service Architecture:

The UMTS layered architecture of the bearer service is shown in the fig 4.1 below in which each bearer service provides an individual service using the services provided below. The end-to-end services consist of three components, the Terminal Equipment (TE), Mobile Terminal (MT) local bearer service and the UMTS bearer service and also the external bearer services.

The UMTS bearer services mainly consist of two parts which are the Radio Access and the Core Network bearer services. The Radio Access bearer services has the main function of transporting user data or signals between the MT and the serving GPRS support node (SGSN), and the function of the Core Network bearer service is the transportation of signals and user data between the Gateway GPRS support node (GGSN) and SGSN. Radio bearer services use the UTRA FDD/TDD services which are on the physical layer. The IU bearer services in the radio access network are mapped on the physical bearer services which are the ATM services or it may be IP over ATM bearer services. To provide Quality of service (QoS) the IETF Differentiated service (DS) feature is used at the Core Network (CN) bearer service. The SGSN has the task of transmission of packet switched data like that done in MSC and VLR nodes for circuit switching. To route the incoming data packet to the user the SGSN contains the current position of the user in addition to that SGSN also contains the routing functions and it handles the authentication
functions. The GGSN is actually the gateway to the packet data networks which may include internet which is connected to the GGSN.

![Architecture of UMTS bearer services](image)

**Fig 4.1**: Architecture of UMTS bearer services [18].

### 4.3 UMTS QoS requirements for internet Applications:

There are many internet applications like www services video streaming, voice and email etc. these all services have their own QoS requirements like some can be tolerant to packet loss while other are not tolerant, some can be tolerant to delay while other are not. Table 4.1 below shows the QoS requirements for the different UMTS service classes for different applications. Like we may see that in conversational voice or video may tolerate packet errors but it cannot tolerate delay same is the case with telnet sessions and online gaming that cannot tolerate packet loss while it may tolerate some delay. Browsing applications like www-browsing can tolerate delays then the normal but are not tolerant to packet errors. FTP and email applications can be tolerant to delay but cannot tolerate packet loss so this shows that each service has its own Qos requirements.
**Table 4.1** QoS requirements for Different Applications [19].

<table>
<thead>
<tr>
<th>Tolerant to errors</th>
<th>Audio and video conversation</th>
<th>Voice memo of audio and video</th>
<th>Online streaming of audio and video</th>
<th>Fax</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intolerant to errors</td>
<td>Online games, Telnet</td>
<td>Web Browsing, E-commerce</td>
<td>Messaging, images, FTP</td>
<td>Alerts for emails</td>
</tr>
</tbody>
</table>

**Conversational** (delay<<1 sec) **Interactive** (delay approx. 1sec) **Streaming** (delay<10 sec) **Background** (delay>10 sec)

### 4.4 UMTS service classes:

In UMTS there are four types of service classes which are

- Conversational
- Streaming
- Interactive
- Background classes

Each UMTS service class may be classified according to their QoS attributes in which each class have their own preferences as described below and they are divided into three groups or attributes namely

- **Delay**: transfer delay
- **Bandwidth**: for bit rates i.e. maximum bit rates
- **Reliability**: handling of traffic, allocation priority etc

The main factor which is most distinguishing between these attributes is the delay sensitivity which is different for each traffic class in these classes the conversational class is most delay sensitive while the background class is very insensitive to delay. UMTS bearer services and their attributes with different range of values are shown in Tables 4.2 and 4.3. The residual Bit Error Rate and the error ratio of SDU are derived from lengths of different CRC on layer 1 [19].
### Table 4.2 QoS requirements for UMTS [19].

<table>
<thead>
<tr>
<th>Type of Medium</th>
<th>Type of Application</th>
<th>Symmetry</th>
<th>Data rate</th>
<th>Parameters and their performance values</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>End-to-end one way delay</td>
</tr>
<tr>
<td>Audio</td>
<td>Conversation al voice</td>
<td>Two way</td>
<td>4 to 25 Kbps</td>
<td>&lt;150 ms preferred &lt;400 ms limit</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Delay in each class</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Data loss</td>
</tr>
<tr>
<td>Video</td>
<td>Video phone</td>
<td>Two way</td>
<td>32 to 384 kb/s</td>
<td>&lt;150 ms preferred &lt;400ms limit. Lip-synch. &lt;100ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data</td>
<td>Remote two way measurement</td>
<td>Two-way</td>
<td>&lt;28.8 Kbps</td>
<td>&lt;250 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Online Games</td>
<td>Two-way</td>
<td>&lt;1 Kbps</td>
<td>&lt;250 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Telnet</td>
<td>Two-way</td>
<td>&lt;1 Kbps</td>
<td>&lt;250 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>N/A</td>
</tr>
</tbody>
</table>

### Table 4.3 UMTS Bearer Services Value Ranges and Attributes [19].

<table>
<thead>
<tr>
<th>Traffic classes</th>
<th>Conversational</th>
<th>Streaming</th>
<th>Interactive</th>
<th>Background</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum bit rate (Kbps)</td>
<td>&lt; 2048</td>
<td>&lt; 2048</td>
<td>&lt; 2048</td>
<td>&lt; 2048</td>
</tr>
<tr>
<td>Maximum Transfer delay value (ms)</td>
<td>100</td>
<td>250</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4.4.1 Conversational class:

The conversational class is used for real time applications like real time conversation in which there should be very low end to end delay and the most common example of this will be the speech service which is over the circuit switched bearer. The internet has gain so much popularity in the recent times and due to this there has been growing need for multimedia communication like voice over IP and video telephony. Subjective calculation for audio and video conversation shows that the end to end delay should be less than 400 ms.

Adaptive Multi-Rate (AMR) codec is used as the speech codec in UMTS. For the Multi-Rate speech codec eight source rates are defined: 12.2, 7.95, 7.40, 6.70, 5.9, and 5.15. The radio access network controls the AMR rates. The speech codec for GSM EFR is 12.2 Kbps, for US-TDMA its 7.4 Kbps, for Japanese PDC codec its 6.7 kbps codec. The error concealment is provided by the AMR specification which makes the AMR speech codec to tolerate the Frame error rate of class A bits to about 1 percent without any distortion in speech quality. In UMTS H.324 is used in circuit switched network for video telephony [19].

4.4.1.2 Enabling Circuit Switched Video Telephony:

Video Telephony suffers from higher BER than the normal speech because in video telephony we use video compression but the delay sensitivity is the same as in speech. In UMTS the ITU-T Rec. H.324M is used for video telephony in CS links, while there are two options for video telephony in PS links which are ITU-T Rec.H232 and IETF SIP. The fig 4.2 shows the ITU Rec. H.324 model [20].

The H.324 includes different essential elements like H.223 which is used for multiplexing, H.245 is used for control, H.263 for video codec, G.723.1 is used for speech codec, and V.8bis as shown in the fig above. The technical features for a call consist of seven phases which are, setup, speech, modem learning, initialization, message, end, and clearing. In UMTS the call control mechanism uses V.8bis messages.
for seamless data communication. These messages are then interpreted and converted into UMTS messages and V.8bis.

![Fig 4.2: The ITU Rec.H.324 model [20].](image)

### 4.4.1.3 Enabling Packet Switched Video Telephony:

In UMTS PS multimedia communications is enabled by the H.323 ITU-T protocol standard. This standard is used to employ a model for peer-to-peer in which the Gateway GW or the source terminal is the peer for the destination terminal and this standard requires the terminals and GWs to provide their own processing functions for call control. The fig 4.3 shows the H.323 architecture which has family of standards like H225, H245 and H450.
Fig 4.3: The ITU Rec.H323 model [20].

4.4.1.3 Session Initiated Protocol (SIP):

The PS video telephony can also enabled by new method called session initiated protocol (SIP). SIP was developed by Multiparty Multimedia session control group MMSIC in IETF. Generally SIP is basically an application layer control signaling protocol which is used to modify or create or to terminate a session between one or more participants which may be like internet multimedia conference and internet telephony and the users in a session can communicate with each other through a network of unicast or multicast relations. The fig 4.4 shows the multimedia model for IETF. SIP uses five phases to setup and to terminate a multimedia call and these phases are

- User location: it is used to determine the end system which is used for connection;
- User capability: it is used to determine the parameters used in the media;
- Call setup: it is used to determine the calling parameters for calling and receiving parties;
- User availability: it is used to determine that is the user called is willing to answer the call or is the user available;
• Call handling: This is used for establishing and ending of calls.

No doubt SIP is the best protocol in UMTS for PS video telephony in UMTS and its use will result in better video telephony.

Fig 4.4: IETF multimedia model [20].

4.4.2 Streaming class:

Streaming as the name suggests that the transfer of information in the form of streams, this technique is used in internet browsing in which the display is shown even before the information has been completely transferred, to allow large asymmetry of different types of internet application this technique is highly tolerant to jitters. Streaming technique is used through which the packets traffic is smooth out through buffering and offers it as soon as it becomes available. So this can support web broadcast and also video on demand but as both of these applications can use the same techniques for video compression but they are different in terms of the coding, and protocols used in it. Thus two types of address or video applications are offered to more than one type of user which depends on the rate of transmission and delay sensitivity [20].
4.4.3 Interactive class:

Interactive class is used when the end user who may be a machine or a man is requesting any online data from remote equipment. And it depends on the application and purpose of the device which is under interaction, in context with internet applications an example of which is the web browsing its response time will depend on the type of information which we are requesting and it will also depend on the links quality and the type of protocols used in it. Applications like delay sensitivity which requires faster response time or interaction e.g. like in emergency devices and control systems etc. other applications like games, location and information services which are more tolerant to delays work more flexible [20].

4.4.4 Background class:

Applications like sms, emails and in case of data bases from where we request download which do not require any immediate actions and can tolerate delays even to one minute, delay in this class does not have and any serious consequence but a delay which is more than a minute is not that much tolerable but the accuracy is very important in this class so there must be error free communication in this class, like in control mechanism and in measuring performances accuracy is very important then delay [20].

4.4.4.1 IP Impairments Transmission sensitivity:

To finish the chapter on UMTS traffic classes we have shown a brief estimation of the different traffic classes in terms of packet loss and delay. The fig 4.5 shows us the sensitivity of different applications in terms of delay in IP environment.

Packet Loss

Fig 4.5: Delay Sensitivity of application in IP environment [20].
This figure above shows us the sensitivity of different applications in terms of delay which is on x-axis and packet loss estimation which is on y-axis. We see that the entries which are on the vertical axis do not tolerate any kind of packet loss, thus for a reliable service [20]
CHAPTER 5: UMTS HANDOVERS

5.1 Handover Concept:

In mobile communication handovers is refer to the transformation of an ongoing call or data from one channel to another which are connected to the core network. It enables the users of cellular technology to receive their calls anywhere and at any time so this process provides the mobility to the users, making it possible to the users to roam seamlessly from one cell to another cell. It is performed when the link quality between the base station and the mobile station on the move is decreasing from certain level of threshold.

In this process the existing link or the connection is tear down and the link is replaced by the cell to which the cellular user is handed on the cell to which the user is handed over is the target cell in this case. The network controller decides from the measurement reports about the link quality that the hand over process is needed to another cell or not. The inability of the network to make a new connection to the target cell is the handover failure. It occurs only when there are no resources or the quality of the radio link is very less from some threshold value in the target cell.

The request of the handover is same as the new call, the utilization of the resource should be optimized which is severe in order to make less the call dropping and blocking probabilities. But it is admitted that force dropping of present call is more worthy then the new call blocking.

5.2 Requirements of handovers:

The handover process is required when the following situations occurs.

- When the motion of the user equipment is very fast.
- The movement of the user’s equipment from one cell to another during an ongoing session.
- The experience of interference phenomena by the user’s equipment from the near cell.

These are some basic points due to which the network decides that the handover process is required.

5.3 Handovers Aim:

The main aim of the handover process is to allow the mobile users to roam freely from one mobile network to another either the network are same or different. To achieve the load
balancing in the different cell handover is also required and also to maintain the good radio quality of the link between the mobile users and the serving base station and to minimize the interference level.

5.4 UMTS Handovers:

An effectual process of the handover is necessary in the UMTS network which assures effective mobility, providing of the maintaining of ongoing session and quality of services. In addition the freedom to move within same or different network, the balancing of load and minimization of the interference level by allowing a good connectivity of the radio link to the base stations is main results of the UMTS handovers.

5.4.1 Handovers Types in UMTS:

The following are the different handovers types in UMTS.

- Horizontal Handovers
- Vertical Handovers
- Soft Handovers
- Hard Handovers
- Softer Handovers
- Intra System Handover
- Inter System Handover

5.4.2 Horizontal Handovers:

The transformation of an ongoing session from one cell to another cell having the same access technology is called the Horizontal Handover. For example if user equipment is connected with the radio ink with the GSM network the horizontal handover must be from GSM to GSM. Similarly the handovers between two UMTS network is the horizontal handover.

Figure 5.1: Horizontal Handover.
5.4.3 Vertical Handovers:

The transformation of an ongoing session or call from one cell to another cell having different access technologies is called vertical Handover. For example when a mobile user is moving from GSM based network to the UMTS network, here the access technologies are changed so the handover in this case is the vertical handover.

![Vertical Handover](image)

**Figure 5.2**: Vertical Handover.

Loose coupling and tight coupling are the two architectures’ used in the vertical handovers between UMTS and WLAN.

5.4.4 Hard Handovers:

In the hard handovers the old radio link is released first between the user equipment and the radio network controller before the new radio link is made between the user equipment and the radio network controller. Thus the source connection is broken first and then the target connection is made, so this type of handover is also called as “break before make”. These handoffs are designed to be instant in order to less the breaking of call. The network engineers felt the hard handovers as an event on the ongoing call [24].

In GSM system each cell has different frequencies to operate with, so these types of handoffs are used there too. Mobile users when entering the new cells that have different frequencies has to broke down the original connection and t will make a new connection with the target base station. It uses a simple algorithm, when the signal strength from the current base station decreases from the nearby cell whose signal strengths are stronger than the current cell.
Hard Handover (GSM, UTRA, TDD)

Figure 5.3: Hard Handovers [26].

In the UMTS to change the band of frequency between the user equipment and the UTRAN the hard handovers are used. The UMTS operator can demand for spectrum to increase the capacity so the many 5 MHZ band would used by one operator, the outcome here is the need of hard handovers between them. To change the cell that have the same frequency and when there is not the support of the micro diversity these hard handovers are used else when a user equipment is allocated a dedicated control channel, it move to the new and near cell of the UMTS network and when there is the possibilities of other handovers like soft or softer handover the hard handover is then an option and is performed [25].

- **Pros and Cons of Hard Handovers:**

  There are many pros and cons of hard handovers which are discussed in detail in the below section.

  **Pros:**
  
  - The hard handovers are simple and economical as the cellular phone hardware is not able to make connection with the two or more channels at the same time.
  - Only one channel is used at any interval of time which makes it simple and easy.

  **Cons:**
  
  - If the handover process is not successfully executed then call may be terminated or ended.
5.4.5 Soft Handovers:

In this type of handovers the user equipment communicates parallel from different Node-B’s with more than one sectors so the link are added and it is deleted in such a way the mobile equipment and the UTRAN always keeps a link. The technique known as micro diversity is used in this type which is known as at the same time many radio links are working and active. This technique has many advantages which are shown in the bullets below [26]

- The near-far effect is reduced.
- The connections are more repellent to shadowing.
- It offers the chance to transmit data the other Node-B’s and thus the communication is maintained.

The property of the CDMA is that the same frequencies are used by the all Node-B’s gives an edge to the soft handover. The user equipment connected to the Node-B is called as the User Equipment Active Set [27].

![Soft Handover (UTRA FDD)](image)

**Figure 5.4:** Soft Handovers [26].

These handovers are also called as “make before break “. It is because the connection is made first to the other Node-B and releases the older connection after making the connection to the target.

- **Pros and Cons of Soft Handovers:**

  There are also some pros and cons of the soft handover which are explained in the following section
Pros:

- Sophisticated handover type in which the call dropping probabilities are low as compared to hard handovers.
- The connection to the target cell are more reliable as compared to the source connection at which the user equipment is connected first and after the handover procedure the target connection are more reliable.

Cons:

- More than one radio links are used so the more complex hardware is needed for it in order to cope with the existing situation.
- More than one channel is used parallel in a single call so the handover process should be done in such a way that the dropping probabilities’ should be low as possible.

5.4.6 Softer Handovers:

It is the special type of the soft handover the communication moves parallel to the same Node-B’s having over its different sector [26].

The user equipment and RNC communicates with the two different air interface channels. So two different codes are required for downlink thus the user equipments can know the signal. Rake processing used in the user equipment can receive the two signals.
5.4.6.1 Inter System Handovers:

There are different radio access techniques like UMTS uses WCDMA GSM uses CDMA etc, so the inter system handovers are that type of handovers which takes place between different cells having different radio access techniques.

5.4.6.2 Intra System Handovers:

Only in the single system these handovers are found [28]. The dual mode terminal FDD-TDD these handovers can be observed. The handovers occurs from the techniques FDD to TDD. There are two special types of the inter system handovers which are explained in the following sections.

- **Intra Frequency Handovers:**

  In the WCDMA system if the intra system handover occurs with the cells having the carrier frequency same then this type of hand over is the intra frequency handovers.

- **Inter Frequency Handovers:**

  In the WCDMA system if the intra system handover occurs with the cells having the carrier frequency different then this type of hand over is the inter frequency handovers.

5.5 Strategies of Handovers:

The handover processes are carried out with different strategies each having its own pros and cons. The strategy is adopted and depends upon the quality of service which users require at that specific time and the cost of the network.

5.5 RNC role in the Handovers Process:

The soft handovers are easy if the Node-B’s taking part in the hand over process if the RNC’s are same. It becomes difficult if the Node-B’s are in control of unlike RNC’s. If the problems occurs in the Radio access network the core network is not permitted to be witting of the problem. Yet it is important if the communication between the RNC’s is impossible directly to each other over the interface-Iur.

As the figure 5.6, left cell number 1 is supplied with the mobile equipment. The connection is controlled by left RNC. Thus the RNC is also called as the controlling RNC. When the user equipment shows the movement to the border of cell number 1 the soft handover is performed. Two Node-B’s supplied the user equipment. The Node –B number 2 is controlled by the other RNC but the connection control is with the left RNC number 1. It serves as the serving RNC and the right RNC is controlled by the other RNC known as the Drift RNC. SRNC receives the not processed data from the drift RNC. DRNC receives the copy of data on the downlink from the SRNC and the attach Node-B’s to the user equipment receives the data. Node- B
number 1 role decreases as the user equipment moves to the Node-B number 2. So the old connection is broken down to the Node-b. This handover in UMTS involves the core network in the handover process. The drift RNC becomes the controlling RNC and now it controls the connection [26].

![Diagram of RNC role in the Handover Process](image)

**Figure 5.6:** RNC role in the Handover Process [26]
CHAPTER 6: INTRODUCTION TO THE OPNET AND UMTS MODULE

6.1 Introduction to the OPNET:

The OPNET Modeler gives the facility of the graphical user interface in which the users can model and simulate their networks. For developing different communication structures and implementing different scenarios, different hierarchal layers are present in the environment of the modeling. Users can build a detail model according to the requirement to do the analysis of the system. The systems are designed in the object oriented way, on compilation of the model its produces a discrete event simulation in the C language. After performing the simulation, the results are analyzed with the different statistics related to the performance provided by the OPNET. The following are the different layers in the OPNET which are explain below.

Figure 6.1: OPNET Modeler [29].
6.2 The Network Layer:

On the graphical map the network layer enables to specify the network topology. Different elements of the network can be placed on the network layer. Through different links these network elements can be connected. To perfume the mobility of the user equipment the trajectories can be created through the radio links. So it being the useful facility as the mobile UMTS users can be simulated. The sub network can be merging together in this layer. Using the network layer the network project can be built up. OPNET contains the wide library of node model having different technologies like UMTS, ETHERNET, and ATM etc.

![Network Editor Screen shot](image)

**Figure 6.2**: Network Editor Screen shot [29].

6.3 The Node Layer:

The nodes are build up in the node layer. The nodes are made up in the node editor using different transmitter, receiver, processor etc. These blocks are called as modules. These modules allow implementing the different node specific characteristics. The figure below shows the node level implementation of the UMTS Node B.
6.4 The Process layer:

This layer makes the possibility of programming the various modules which are used in the node layer in order to design and implement various protocols or the required behavior of the node. The OPNET has a wide kernel of standard procedures that are mostly used in the communication networks but it is possible to write the C++ codes which are the user’s specific function. The process editor uses Proto-C, which is the programming language which makes the combination of the C/C++ language and the state transition diagram.

6.5 OPNET UMTS Model:

OPNET Modeler presents the specialized models that cover the specific needs for the simulating and modeling the networks that poured on certain technology area. UMTS is the one of those models which is based on the 3GPP specification. The model focuses on UE-UTRAN-CN architecture as shown in the figure 6.4.
The User equipment model gives the functionality of the mobile equipment. It is responsible for the radio link termination. The UTRAN model consists of the Node B and the RNC. The core network is not fully implemented. The SGSN and the GGSN are included. The UMTS model supports wide range of a feature which resembles the real network. The four different traffic classes are defined in the model which is conversation, interactive, background and streaming. Different QoS profiles are defined for each traffic class. This allows studying various effects in the network.

The overall features of the UMTS OPNET Model are shown in the bullets below [29].

- It is based on WCDMA.
- It supports the four QoS classes
- It supports the user equipment UE, Node B, RNC, Repeater, GGSN and SGSN.
- It supports the hard, soft and the softer handovers.
- It supports the outer loop power control.
- It offers the facility of the set up, release and negotiation of the radio access bearers.
- It supports for the dedicated and the common control channels.
- It supports for the different modes like acknowledge, unacknowledged and the transparent RLC.
- It supports for the multiplexing of logical channel to the transport channel.
CHAPTER 7: SIMULATIONS

7.1 Introduction:

For the implementation of our different scenarios we have used the OPNET Modeler 14.5. Users can easily use this tool by simply selecting the different technologies from start up wizard and dragging of different devices like RNC, Node B, etc, interconnecting them with the desired links.

7.2 Handover Scenarios:

We have implemented two different scenarios for the two types of the UMTS traffic classes, one for the conversational class and other for the interactive class.

7.3 Entities of the Network and their Functions:

We have selected different network elements and configure it according to the requirement of our scenarios. The following are the entities which we have selected from the Object Palette Tree from the OPNET Modeler.

- Application Definition
- Profile Definition
- Umts_rnc
- UMTS_node_b
- Umts_ggsn_slip8
- Umts_sgsn
- FTP and HTTP Servers
- Umts_wkstn

All these network entities are configured according to the requirements of the two scenarios. These scenarios are explained in the following sections.

7.4 Handover with the UMTS Traffic class Interactive:

In this scenario we have two types of servers as in the interactive class we have the two type of the traffic i.e. FTP and HTTP. So for the support of the two types of traffic, we have configured two types of the servers. The FTP is first discussed which is followed by the HTTP statistics. In the scenario we have two users equipment. The user equipment one is moving with the specified trajectory. Both the FTP and the HTTP is running on the same user equipment one and they exchanged their information with their concern servers. Different statistics are collected which are explain below.
Figure 7.1: First Scenario.
7.5 Simulation Results:

In the figure 7.2, we can see that for the soft handover we have a peak at 31 sec and for the hard handover we have a peak at the 2 sec, which clearly shows that the download response for the soft handover is greater than the hard handover.

Figure 7.2: FTP Download Response Time (sec).

Figure 7.3: Total Transmit Load.
The figure 7.3, Total Transmit load, we can see that the total transmit load for the soft handover is higher where as the total transmit load for the hard handover is lower. The reason that the total download response for the hard handover is lower than the soft handover, so we can make an assumption that we have a higher transmit load then we may have a the download response higher for the hard handover.

![Figure 7.4: Total Received Throughput.](image)

The figure 7.4, Shows that the total received through put for the hard handover is low which is responsible for the low response time for the hard handovers where as for the soft handover we have a high total received through put. We have a peak average of 340 bits/sec and at the same instance average total transmit load is about 40 bits/sec for hard handover.

![Figure 7.5: HTTP Page Response Time.](image)
In the figure 7.5, we can see that the 25 sec is the peak of the soft handover page response time and the hard handover has the peak of 7.5 sec which shows that the soft handover has the page response time higher but this output may change the total receive and sent data changes and here in this case in hard handover we have a low transmit load and received throughput for hard handover so it is sure that its response time will be low.

7.6 Handovers with UMTS Traffic Class Conversational:

The scenario for the conversational class is implemented in the OPNET. Different statistics are collected for the conversation class is discussed in the following section.

![Figure 7.6: Second Scenario.](image-url)
7.6.1 Simulation Results:

![Graph of UMTS Active Cell Count]

In the user equipment the active set contains number of the Node Bs from which it is getting the signals or service. There are two Node Bs in our scenario, when the user equipment moves along the specified trajectory the cells are removed and added. The green lines in the figure 7.7 shows that the addition in the active set cell count and the red lines shows that the from the active set the nodes are removed and their corresponding active set value decreased when the red line appears which means that the Node B’s are removed. The duration in which the blue line is set to value 2 is that time when the user equipment is receiving signals from the two Node B’s and so the user equipment has the active set of the value 2. That area is called as the overlapping region in which the user equipment has the value of 2.
Figure 7.8: Packet End to End Delay.

The figure 7.8 shows that for the soft and the hard handover there is almost no difference between the packet end to end delays.

Figure 7.9: Received Throughput (bits/sec).

The figure 7.9 shows the received throughput, which tells us that for the users in the soft handover the received throughput is equal to the user in the hard handover for low mobility.
From the figure 7.10, it can easily be concluded that the users in the soft handover has the transmit load equal as compared to the user in the hard handover. The soft and the hard handovers have almost the same behavior in the low mobility.

It is cleared from the figure 7.11, that the red dots are higher and blue dots are lower which means that the hard handover has higher uplink transmission power then the soft handover.
8.1 Conclusion:

The thesis work is about the handovers in the 3G universal mobile telecommunications systems.

Chapter 1 is about the introduction and the objective of the thesis of the thesis. This chapter also contains the outline of the thesis report.

Chapter 2 is about the different generations in the cellular technology from 1G to 4G. A detail description is given of each of the cellular generation.

Chapter 3 is about the migration towards the 3G systems, architecture of the UMTS and a detail description of each and every block in the system. Wide band CDMA system is discussed in details and also its different layers are explained in its different sections. Also the functions of WCDMA layers described here.

Chapter 4 is about the UMTS QoS traffic classes. Each of the traffic class is discussed in this chapter.

Chapter 5 contains the handovers process; its types and the handovers in the UMTS network are discussed and explained.

Chapter 6 is about the introduction to the OPNET. The detail description of the UMTS OPNET model is explained. Different nodes and the network elements of the UMTS network in the OPNET are discussed in detail. Also different layers in the OPNET are explained here.

Chapter 7 is about the simulation. Different scenarios are created and the results are collected and explained here. Different statistics are calculated and the handovers phenomena’s are discussed in details through these results.

Chapter 8 is the overall conclusions from the thesis work and the future work is discussed.

This thesis work gives an impression of the main factors which are being affected by the soft and the hard handovers techniques in terms of the overall capacity of the network and the UMTS QoS classes.
To know and understand about the handover process between the Node B and the user equipment different statistics are calculated. On these measurements we have observed that how different types of the traffic is effected in terms of the load and the delay.

8.2 Future Work:

The future attention will be given to the capacity and the coverage issues such as the cell breathing and the handovers effect on these issues with respect to the QoS traffic classes of the UMTS. Different handovers algorithms and the power control can be implemented and their overall effect on the users and the network can be monitored.
APPENDIX A

STEPS OF SIMULATION

• Step 1:
  Start with the OPNET Modeler 14.5

• Step 2:
  Click on the file and make a new project.
• **Step 3:**
  Choose a campus network, press next and select the empty scenario as shown in figure below.

• **Step 4:**
  Add the UMTS Module as follows.
• **Step 5:**
  After clicking on next, an object palette tree will appear as shown in figure below.
• **Step 6:**
  Configure the profile configuration.
• **Step 7:**
  Now configure the application definition which has been configured to have two applications.
• **Step 8:**
  Now configure the UMTS workstation as shown below.
• Step 9:
Similarly configure the FTP and HTTP server attributes as shown in figure below.
• Step 10:  
Now in the end choose the individual DES statistics.
Step 11:
Manage the scenarios and collect the results.
REFERENCES


[27] Sumit Kasera & Nishit Narang, “3G Networks Architecture, Protocols and Procedures (Based on 3GPP Specifications for UMTS WCDMA Network)

[28] J. Laukkanen “UMTS Quality of service concept and Architecture”, University of Helsinki, 4-5-2000