

# Analysis of QoS in the User's Perspective of the Common Services in Cellular Systems UMTS/3G and LTE (A Case Study of mobile Networks in Angola).

BY

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## **ABSTRACT**

The purpose of this research is to determine the main factors affecting Quality of Service based on mobile Third Generation (3G) and Fourth Generation (4G) service in Angola. The main reason to stimulate the present study was the significantly low rate speed on 3G and 4G service among mobile users in Angola where unlike many other countries the rate of this usage runs in opposite way. Thanks to increasing advances in wireless communications devices, the number of mobile users has growingly increased and as a result the development of mobile commerce (e-commerce) has been accelerated. The research attempts to examine the factors predicting consumer intention for 3G and 4G adoption in Angola. For the purpose of the research, the diffusion of innovation model and some other variables are integrated including awareness, affordability, accessibility and acceptability. The research findings revealed that in view of consumers, acceptability, accessibility, affordability seem more significant than awareness in regard with 4G adoption. Identifying the above factors will drive telecommunication operators in Angola to provide more successful 4G services to enhance the rate of 4G service adoption.

## DECLARATION

I, **Helder Sebastiao Luemba Barros** hereby declare that I am the sole author of this dissertation entitled “Analysis of QoS in the User's Perspective of the Common Services in Cellular Systems UMTS/3G and LTE (A Case Study of mobile Networks in Angola)”. I authorize Midlands State University to lend this dissertation to other institutions or individuals for the purpose of scholarly research.

Signature.....

Date...../...../.....

## APPROVAL FORM

This dissertation is entitled “**Analysis of QoS in the User's Perspective of the Common Services in Cellular Systems UMTS/3G and LTE (A Case Study of mobile Networks in Angola)** ” by **Helder Sebastiao Luemba Barros** meets the regulations governing the awarding of the degree of *BSc Telecommunications Honours* by **Midlands State University**, and its approval for its contribution to knowledge and literary presentation.

**Supervisor**.....**Date**...../...../.....

## **DEDICATION**

To my Lovely mother ,Josefina Nhendo, who stilled me the courage to continue up to the conclusion of this degree programme Bsc Honours in Telecommunications. To my Brother Carlos Bandi, my fiancé Claudia Cipriano, Ambassador of the Republic of Angola in Zimbabwe Pedro Hendrick Vaal Neto, Classmates, friends and family in general.

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# CHAPTER 1

## INTRODUCTION

### 1.1 Background

Quality of service ('QoS') refers to the ability of a network or service to satisfy the end user. This includes aspects such as the mobile signal strength, availability of the services and the level of network congestion. The quality of Service of the Angolan mobile networks has been always questionable for the rest of the country including the capital city, Luanda, the mobile networks studied are Unitel and Movitel. This research was carried out in ten (10) provinces and in the provinces the capital city is included where the results tell the reality of the mobile communications in Angola.

In this research there are key factors that the researcher looked at in order to analyze the QoS offered by Angolan mobile networks, such as Call Quality and Call Dropping Rate, Price of Service, Network Coverage and Availability of Service on both technologies Third generation (3G) and Fourth generation (4G). Today telecommunications is driving many economies in the world due to their Quality of Service (QoS) and improving many lives around the world by bringing people together through mobile communication and social media which require internet of the mobile station in order to connect to the world.

Typically a good cellular network should meet the following criteria [13]

- (a) Good quality voice service;
- (b) Services and equipment of low cost terminals;
- (c) Possibility of international roaming;
- (d) Capacity utilization of mobile terminals (handheld);
- (e) Support new services and facilities;
- (f) Spectral efficiency;
- (g) Compatibility with Integrated Services Digital Network (ISDN).

Universal Mobile Telecommunications System (UMTS) is an evolution of Global System for Mobile Communications (GSM) / General Packet Radio Service (GPRS), which utilizes the Wideband Code Division Multiple Access (WCDMA) as a radio access technology, currently the main 3G technology worldwide. The Universal Mobile Telecommunications System compatibility with the Global System for Mobile Communications (GSM) system makes possible interoperability of services. In addition to the services supported by Global System for Mobile Communications (GSM) (voice, Short Message Service, Multimedia Service, etc.), Universal Mobile Telecommunications System adds mobility multimedia services (video telephone, video streaming, video conferencing, mobile TV, etc.) and allows access to the Internet and other data services with rhythms that have higher transmission than allowed by Global System for Mobile Communications (GSM) / General Packet Radio Service (GPRS). The mobile communication system Universal Mobile Telecommunications System (UMTS) / Wideband Code Division Multiple Access and Fourth Generation (4G) are currently the most widely used mobile technologies. Global System for Mobile Communications (GSM) technology is used by approximately 29 % of the population and accounts for over 80 % of the global mobile market (Figure 1.1 and Figure 1.2) [5]. There are over 784 networks in operation in more than 210 countries [?]. Long-Term Evolution, (LTE) is considered by many to be the natural successor to current-generation Third Generation (3G) technologies, in part because it updates Universal Mobile Telecommunications System (UMTS) networks providing significantly faster data rates for both uploading and downloading. The specification calls for downlink peak rates of at least 100Mb/s and an uplink of 50Mb/s, but going by real world tests its transfer speeds will likely range from 5-12Mb/s for downloads and 2-5Mb/s for uploads. Long Term Evolution (LTE) is being developed by a group of telecommunications associations known as the third Generation Partnership Project (3GPP), as an eight release of what has been evolving since 1992 from the Global System for Mobile Communications (GSM) family of standards. Besides speed, several other guidelines have been traced for wireless communication standards to qualify as Fourth Generation (4G). In a nutshell, they should be very spectrally efficient, should dynamically share and utilize the network resources to support more simultaneous users per cell, have smooth handovers across heterogeneous networks, offer high quality of service for next generation multimedia support, and should be based on an all-IP packet switched network.[12]

There are two fundamental aspects of Long Term Evolution (LTE). The first is that the technology finally leaves behind the circuit switched network of its Global System for Mobile Communications (GSM) roots and moves to an all-IP flat networking architecture. This is a significant shift which in very simple terms means that LTE will treat everything it transmits, even voice, as data. The other big change relates to the use of Multiple Input and Multiple Output (MIMO) technology, or multiple antennas at both the transmitter and

receiver end to improve communication performance. This setup can either be used to increase the throughput data rates or to reduce interference. [12]

## **1.2. Constitution of Angolan Mobile Networks**

### ***1.2.1 Movitel***

Movitel is the smaller of the two Angolan mobile phone companies. Its official name is Movitel Telecomunicações Sociedade Anonima (S.A) Movitel was originally created in 2003 as a subsidiary of the state owned Angola\_Telecom. In 2010, 80 percent of the company's capital was sold to various private companies: Portmil - Investimentos e Telecomunicações, Sociedade Anonima (S.A) Modus Comunicar, Sociedade Anonima (S.A) Ipangue, Sociedade Anonima (A.S) Lambda Investment and Novatel Wireless. The remaining 20 percent remain in the hands of the state owned (empresa publica) companies Angola Telecom and ENCTA. The seat of the company is the capital city Luanda. Movitel sells its services via a network of shops and recharging cards for pre-paid contracts are also sold by individual street sellers. Movitel claims to have more than 3 million customers out of a population of estimated 18 to 20 million people in Angola. [16].Movitel offers GSM based mobile communication for voice communications, text and multimedia messages, and mobile internet access. It has coverage in all 18 Angolan provinces. Movitel sets forth its roaming agreements with 500 mobile phone provides in 213 countries and territories in all continents. Currently (2013), this roaming coverage is available only for post-paid contracts. Pre-paid contracts may use roaming only in selected countries.[1,16]

### **1.2.2 Unitel**

Unitel Sociedade Anonima (S.A) is a company in Angola, a service provider in the mobile telecommunications area (cell phone), and was the first to operate with GSM technology in the Angolan market. It was established in 1998 and entered the market in 2001. In the third quarter of the same year, it took the lead in the market in number of customers. It has an official Slogan: “The next closest”. [15]. Since December 2004, the company provides mobile network coverage in the capitals of the eighteen provinces. In December 2011 the company began offering coverage for all municipal centers of the country. When it began the activity in Luanda and later in Benguela the company operated in the Global System for Mobile

Communications (GSM) 900 currently already operates in some areas in Global System for Mobile Communications (GSM) 1800. In late 2014, the company achieved the jointer 10 million customers in Angola.[1].

In Angola, the number of subscribers to mobile services based on Universal Mobile Telecommunications System (UMTS) exceeds seven million subscribers and less than 2 million subscribers for Long Term Evolution (LTE) technologies. These networks originate in a month more than 200 million voice calls, with an average duration of 112 seconds and are sent over 1,100 million Short Message Service (SMS). On average with each user sending 93 Short Message Service (SMS) every month and down fourth seven voice calls, of which 20 are on-net mobile [14] Voice and Short Message Service (SMS) services are the most used, however we are witnessing a sharp growth in the use of other services such as video telephone and broadband Internet access. Currently, both of the Angolan mobile operators have commercial offers of broadband, with download rates up to 1.02 Mbps for 3G and 17 Mbps for Fourth Generation (4G) in some areas of the capital city, Luanda only, but the most parts of the Capital city there are Second Generation (2G) and Third Generation (3G) coverage [1].

**Table 1.1 Distribution of Mobile subscribers in Angola [14]**

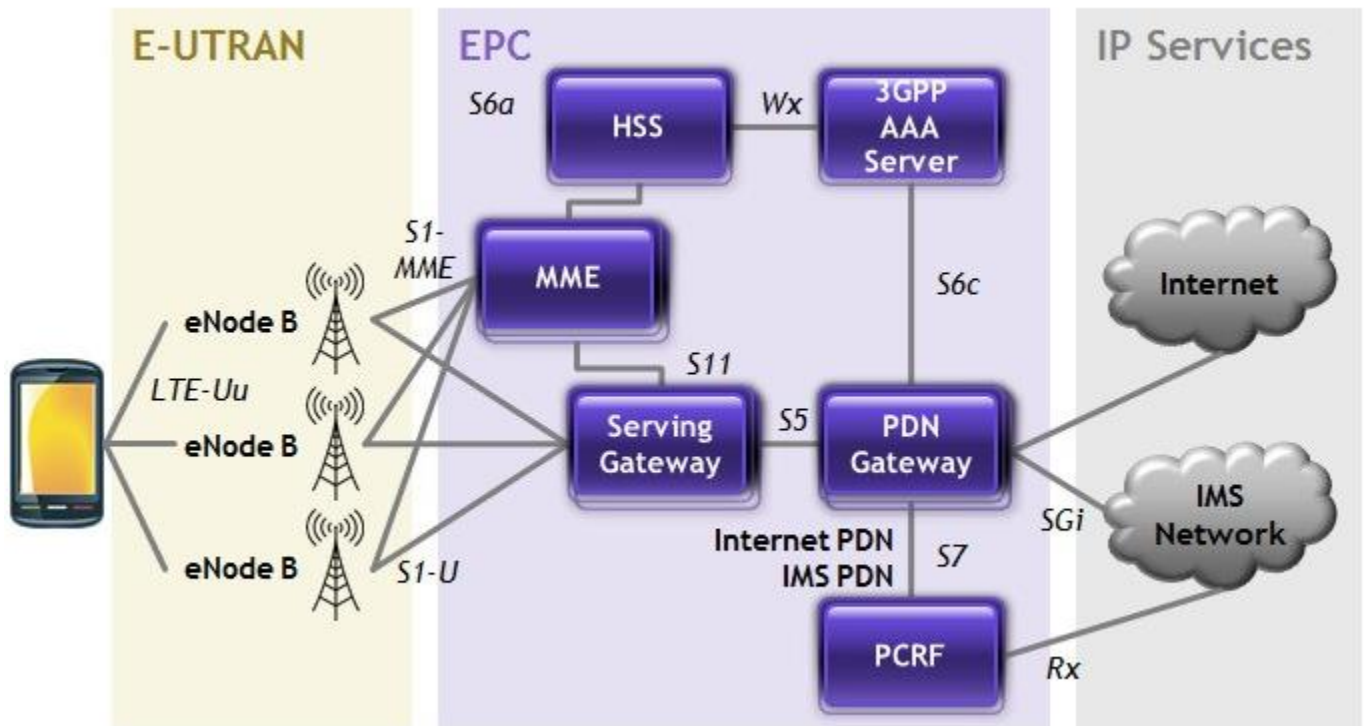
Operator	Subscribers (million)
Unitel	11,6
Movicel	3,9

In Universal Mobile Telecommunications System (UMTS) and Long Term Evolution (LTE) mobile communication systems, the Quality of Service (QoS) from the user perspective is of fundamental importance, in particular by radio nature of access, mobility and enabling the utilization rate they present.

In addition to having a sophisticated architecture and a great set of features, developed after more than ten years of work by 3GPP, and thousands of specifications pages, the goal is to ensure continuity of service, interoperability and roaming between operators.

Figure 1.1 illustrates the scenario aim at a high level of Voice over Long Term Evolution (VoLTE) architecture, which is evidenced by the existing integration between Long Term Evolution (LTE) / Evolved Packet Core (EPC) network and IP Multimedia Subsystem (IMS). This allows not only the voice service, but

also a rich variety of multimedia applications such as Short Message Service (SMS), Multimedia Service (MMS) etc. that move through the network. [9]



**Figure 1.1 Voices Over Long Term Evolution (VoLTE) with IP Multimedia Subsystem (IMS). [9]**

The IP Multimedia Service (IMS) is a concept for an integrated network of telecommunications carriers that would facilitate the use of Internet Protocol (IP) for packet communications in all known forms over wireless or landline; unfortunately, such a system is suffering from its own complexity through a sophisticated infrastructure that is heavy. By supporting many features, the full implementation of IMS will cost much time and money for operators, without any guarantee that in the end you might actually need all these new services. Also there is no assurance that the costs of such big investment are covered. Another point is that, although they are available in the market, mobile terminals known as User Equipment (UE), do not have a customer IP Multimedia Subsystem (IMS) fully integrated for this reason Angolan mobile operators should not proceed to the immediate approach FULL-IP Multimedia Subsystem (IMS).[11]

As explained earlier Angolan mobile operators are not ready to adopt an approach that supports LTE for voice calls in the IMS that is present in the network core. Several alternatives have been created in this sense, therefore, to give more time to the network and the devices that are ready and by deploying a gradual approach FULL-IMS, the use of temporary mechanisms becomes mandatory.

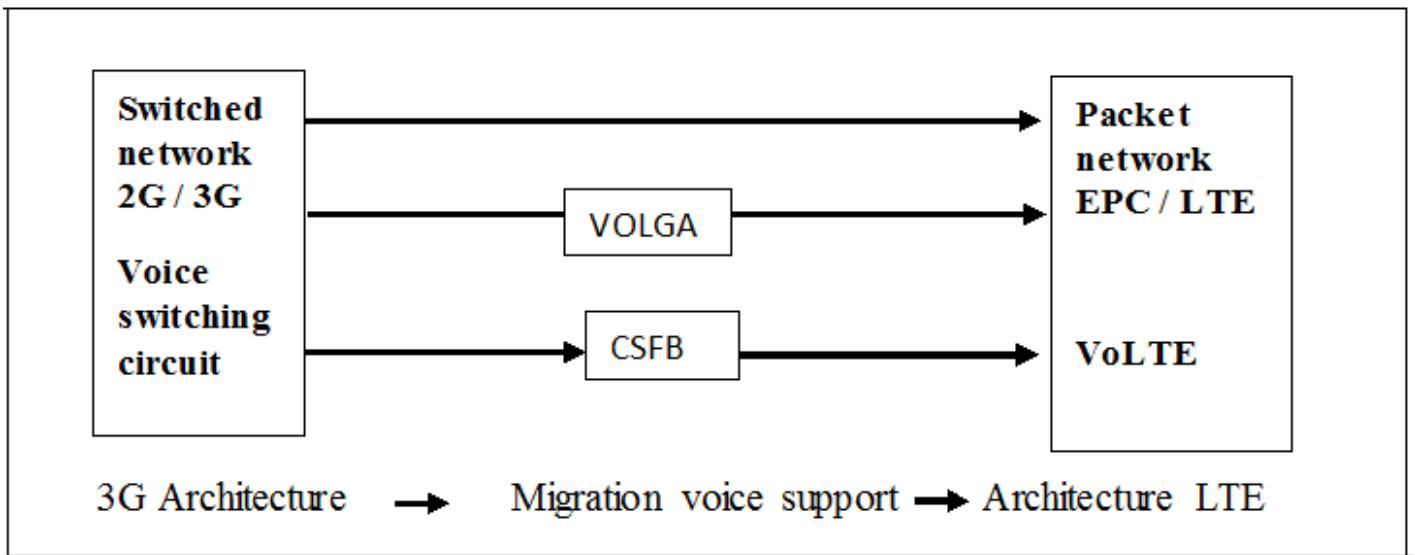
Among the alternatives are [17]:

- ❖ Circuit Switch Fall Back (CSFB) that offers the service to the end user using the current telecommunications network Global System for Mobile Communications (GSM) / Universal Mobile Telecommunications System (UMTS). Circuit Switch Fall Back (CSFB) allows voice solution single radio apparatus using the Long Term Evolution (LTE) network signaling to determine when to switch between the network data PS (packet-switch) and the voice network Second Generation (2G) / Third Generation (3G) Circuit Switch (CS). Although switching requires some technical challenges, Circuit Switch Fall Back is the solution to the reality of mixed networks of today and throughout the transition of future phases of the evolution of the Long Term Evolution (LTE) network.
- ❖ Voice over Long Term Evolution (VOLGA) via Generic Access [17], based on the Third Generation Partnership Project (3GPP), Generic Access Network (GAN) existing. The objective of Generic Access Network is to extend mobile services through a network of generic Internet Protocol (IP) access. According to the specifications of Voice over Long Term Evolution (VOLGA), the goal is to make the traditional switched Global System for Mobile Communications (GSM) / Universal Mobile Telecommunications System (UMTS) circuit services available to User Equipment (UE) accessing the Evolved Packet Service via Evolved Universal Mobile Telecommunications System Terrestrial Radio Access Network (E-UTRAN).
- ❖ The One Voice approach was announced in November 2009 after coordination between operators, handset manufacturers and network core developers. With its adoption by the Global System for Mobile Communications Association (GSMA), in January 2010 [volte 009], got support of the majority of operators and a strong line-up providers. The original scope of the One Voice concludes that one should have the basics of necessary specifications of IP Multimedia Subsystem (IMS), with the first focusing on voice, then power to direct the services that subscribers can cover. Thus one voice approach is a good solution to achieve the target solution IP Multimedia Subsystem (IMS) fully.
- ❖ With the presence of FULL-IP Multimedia Subsystem (IMS) in Evolved Packet System (EPS) and with the convergence of mobile networks, technology Voice over Long Term Evolution (VoLTE) is a support trend of Fourth Generation (4G) voice service in mobile telephone.

Great debates and polemics were initiated in different forums to decide which approach will be the final



solution to overcome the challenge of migration of voice service in switched networks Second Generation (2G) / Third Generation (3G) circuit for an Long Term Evolution (LTE) architecture packet-switched, as shown in figure 1.2 . The main objective of this work is to elucidate and describe possible architectures already documented and theoretical and practical studies to survey voice and data comparing characteristics and trends pointing to make possible the short and medium term the transmission of voice in Wideband Code Division Multiple Access (WCDMA) and Long Term Evolution (LTE) network.



**Figure 1.2 Voice Service Migration - Voice to LTE networks [17]**

### 1.3 The Importance of Quality of Service Measurements

There are premium subscribers who always want to have better user experience on their Fourth Generation (4G) device. These users are willing to pay more for high bandwidth and better network access on their devices. Not only the subscribers but some services itself need better priority handling in the network (e.g. VoIP call). To be able to full fill this, Quality of Service (QoS) plays the key role. Quality of Service (QoS) defines priorities for certain customers / services during the time of high congestion in the network.

The measurement of service quality, in particular the user's perspective, is of vital importance for the management and performance optimization of a mobile network, allowing operators to provide quality services without over its infrastructure. For the user, the quality of mobile networks indicators allow you to choose the network that best meets your needs. Mobile operators that from the user's perspective, providing

services with superior competitive advantages over competitors who belittle this aspect. Market research [20] shows that consumer frustration due to the quality of service is responsible for about 82 % of the network changes. It is also observed a chain effect, because one dissatisfied customer account, on average, 13 people a bad experience. Operators also cannot wait for the customer complaints to take corrective measures, since by each customer who complains there are 29 others who never do and simply change providers when they feel dissatisfied. The termination of relationship between a customer and an operator affect revenues and the image of the operators. So, the way on how to prevent these situations goes through a strategy that includes constant monitoring and improvement of service quality, as it is perceived by users. Other entities, such as sectoral regulators can conduct independent studies to assess the Quality of Service (QoS) from the user's perspective. They do this in order to provide the market, in particular consumers of free information on the performance of telecommunications services supported in mobile present communications systems in the market. [8]

The Quality of Service from the user perspective may be evaluated using three different and complementary mechanisms [50]:

- ❖ Customer Complaints;
- ❖ Network Statistics (measurements in network elements);
- ❖ Field tests (Drive-Tests and / or Walk-Tests carried out with commercial terminal equipment using the services of common user logic).

Customer complaints is when the customer is the end user of any service offered by any operator, and it's the first and only point to identify the Quality of Experience (QoS) for any service offered, and network statistics analysis refers to identifying problems and while the field tests allow you to check these problems, identify the causes and lead to solutions.

Conducting field tests (drive-tests), although costly, is the approach that has more advantages because it allows the analysis of services be made independently from the operation of the own mobile networks. For example, areas with poor radio coverage or even absent are also considered in the analysis, enabling the study results to translate into a good overall performance indicator of the networks in the user perspective. This is also the best method to carry out comparative analysis of the performance of various operators (benchmarking).

## **1.4 Research Scope and Aim**

The aim of the dissertation work is to evaluate the existing Quality of Service (QoS) performance of voice calls, messaging and data services in the 3G/UMTS and LTE networks. This Quality of Service assessment was carried for the Angolan Mobile Operators which are Unitel,SA and Movitel,SA. Questionnaires, Interviews and data from the National Regulator were used in this study.

## **1.6 Dissertation Layout and Structure**

*Chapter 2*, Presents the Literature Review which gives a brief overview of the area under study. This includes: a brief characterization of mobile communications systems Universal Mobile Telecommunications System (UMTS) and Long Term Evolution (LTE), the technological point of view. The most common mobile communication services are also characterized by identifying the various Quality of Service (QoS) classes as well as the expectations of users in this field.

*Chapter 3*, Presents the research methods and techniques used in the study. It clarifies the concept of Quality of Service in a user perspective and indicators are defined / parameters that allow quantify this quality. They are even set conditions in which they must be made of the quality analysis that the results reflect the actual quality of services.

In *Chapter 4*, Presents the research results. Validations and measurements are presented in this chapter.

Finally, in *Chapter 5* are presented and discussed the main findings resulting from the work done. They are also outlined some possibilities for future development in the field of Quality of Service (QoS) of mobile networks and services, whenever a user perspective.

# CHAPTER 2

## LITERATURE REVIEW

### 2.1 Introduction

This chapter will present the theoretical concepts necessary for understanding the problem and the proposed solution mentioned in this dissertation. In Section 2.2 literature review presents the basic concepts and evolution of mobile communications will be explained. Section 2.3 presents the current situation of telecommunications, with an emphasis on Long Term Evolution (LTE) networks. Section 2.4 will be presented stages of Long Term Evolution (LTE) evolution to voice calls and some approaches that arise as a temporary solution until the IMS present a complete implementation.

### 2.2 Evolution of Mobile Communications

To understand the current situation and the needs involved that resulted in the evolution of mobile networks, it is necessary to refer to the past and consider the progress made in the development of mobile communications and the impacts caused in daily life. The concept of mobile communication is very primitive and may be defined as the possibility of relative movement between parts, or systemic stakeholders. As a primary example has been mobile telephone, the concept of which is designed to better use the limited radio spectrum, while allowing for large coverage areas [12].

#### 2.2.1 First generation (1G)

The First generation of wireless telecommunication technology is known as 1G was introduced in 1980. The main difference between then existing systems and 1G was the invention of cellular technology and hence it is also known as First generation of analog cellular telephone. In 1G or First generation of wireless

telecommunication technology network contained many cells (Land area was divided into small sectors, each sector is known as cell, a cell is covered by a radio network with one transceiver) and so same frequency can be reused many times which results in great spectrum usage and thus increased the system capacity i.e. large number of users could be accommodated easily.

Use of cellular system in First generation (1G) of wireless telecommunication technology resulted in great spectrum usage. The First generation of wireless telecommunication technology used analog transmission techniques which were basically used for transmitting voice signals. First generation (1G) of wireless telecommunication technology also consisted of various standards among which most popular were Advance Mobile Phone Service (AMPS), Nordic Mobile Telephone (NMT), Total Access Communication System (TACS). All of the standards in First generation (1G) used frequency modulation techniques for voice signals and all the handover decisions were taken at the Base Stations (BS). The spectrum within cell was divided into number of channels and every call was allotted a dedicated pair of channels. Data transmission between the wire part of connection and Packet Switched Telephone Network (PSTN) was done using packet-switched network. [12]

### **2.2.2 Second Generation (2G)**

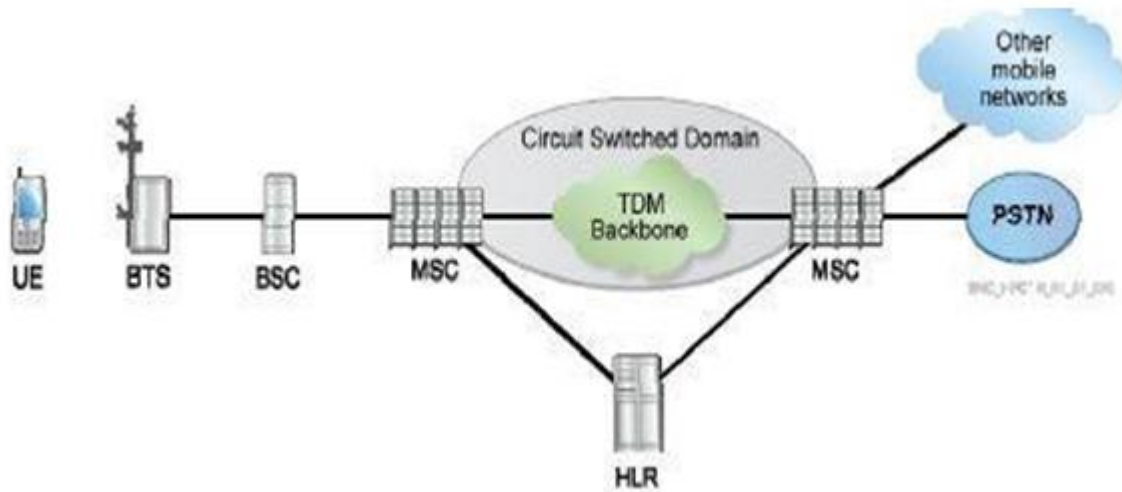
The Second generation (2G) mobile cellular systems used digital radio transmission for traffic. Thus, the boundary line between first and second generation systems is obvious: It is the analogue/digital split. The Second generation (2G) networks have much higher capacity than the First generation systems. One frequency channel is simultaneously divided among several users (either by code or time division). Hierarchical cell structures in which the service area is covered by macrocells, microcells, and picocells enhance the system capacity even further.

There are four main standards for Second generation (2G) systems: Global System for Mobile Communications (GSM) and its derivatives; Digital Advanced Mobile Phone System (D-AMPS); Code Division Multiple Access (CDMA); and Personal Digital Cellular (PDC). Global System for Mobile Communications (GSM) is by far the most successful and widely used Second generation (2G) system. Originally designed as a Pan-European Standard, it was quickly adopted all over the world. Only in the America has Global System for Mobile Communications (GSM) not reached a dominant position yet. In North America, Personal Communication System -1900 (PCS-1900; a Global System for Mobile Communications (GSM) derivative, also called Global System for Mobile Communications -1900 (GSM-

1900)) has gained some ground, and in South America and Chile it has a wide-coverage Global System for Mobile Communications (GSM) system. However, in 2001 the North America Time Division Multiple Access (TDMA) community decided to adopt the Third Generation Partnership Project (3GPP) – defined Wideband Code division Multiple Access (WCDMA) system as its Third Generation (3G) technology, and as an intermediate solution in preparing for Wideband Code Division Multiple Access many International System (IS-136) system did convert to Global System for Mobile Communications (GSM)/ General Packet Radio System (GPRS). The basic Global System for Mobile Communications (GSM) uses the 900-MHz band, but there are also several derivatives, of which the two most important are Digital Cellular System - 1800 (DCS-1800) also known as GSM-1800) and Personal Cellular System -1900 (PCS -1900) or (GSM-1900). [11]

The GSM network is comprised of the following elements: (see Figure 2.1) [37]

- ❖ EU: User Equipment: Any device used directly by the end user to communicate.
- ❖ BTS: Base Transceiver Station: A local cell used to facilitate wireless communication between the UE and the network.
- ❖ BSC: Base Station Controller: The BSC provides control of many BTS and acts as a hub for the Mobile Switching Center (MSC). The BSC handles the allocation of radio channels and controls handovers of BTS to BTS.
- ❖ MSC: Mobile Switching Center: MSC handles the management of voice calls of mobility and Short Message Service (SMS).
- ❖ HLR: Home Location Register: The HLR is a central database that contains details of each mobile subscriber.
- ❖ PSTN: Public Switched Telephone Network: A public communication system that provides telephone services.



**Figure 2.1 Nucleon Mobile 2G Network- Alcatel [28,35]**

### 2.2.3 Third Generation (3G)

Over time, the need to provide IP traffic was observed. In 2000, "General Packet Radio Service (GPRS)" was added to the existing GSM system to provide delivery of data services over a packet switched network. There was no change in the voice network and 2G systems were extended to 2.5G

With GPRS, users might have access to Internet and MMS (Multimedia Messaging Service) on their mobile devices. 2.5G systems were reinforced for 3G and 3.5G systems, offering higher data rates to support additional resources (multimedia applications) and meet the IMT-2000 (International Mobile Telecommunications-2000). The main 3G standards currently used are the UMTS (Universal Mobile Telecommunications System), based on GSM and download capacity of up to 56 Mbps nominal; and CDMA2000, CDMA-based, and enabling a download rate up to 14 Mbps.[35,37]

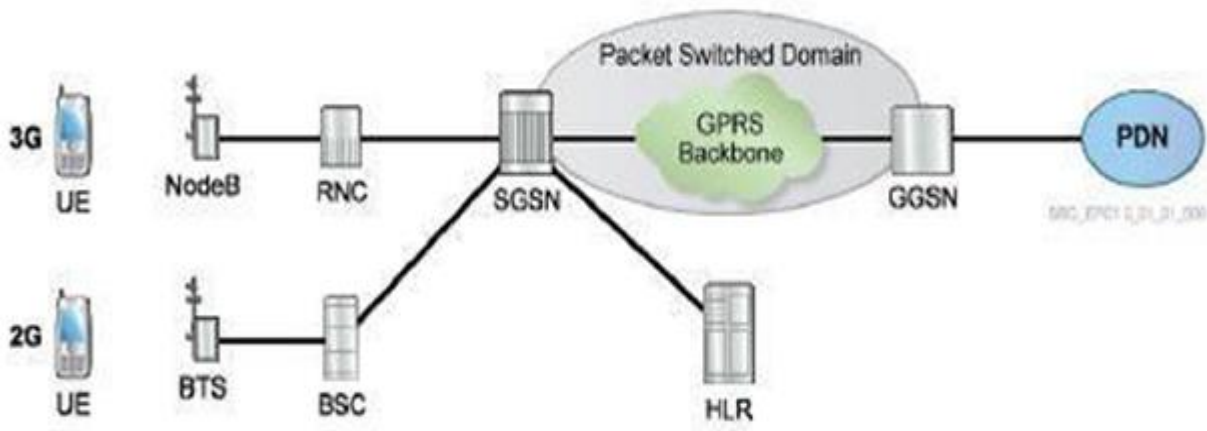
The GPRS network consists of the following elements: (see Figure 2.2) [37]

- ❖ User Equipment (UE): Any device used directly by the end user to communicate.
- ❖ Node Base Station (NodeB): A term to denote a base station in Third generation (3G) cell site technology. It is responsible for the radio link between the mobile user and the fixed part of the network. Equivalent used in Global System for Mobile Communications (GSM) Base Transceiver Station (BTS).

- ❖ Radio Network Controller (RNC) is responsible for controlling the Node Base Stations (BSs) that are connected to it.

Two new entities added to packet switching center:

- ❖ Serving General Packet Radio System (GPRS) Support Node: Serving GPRS Support Node (SGSN) handles Third generation (3G) for mobility management and is responsible for delivering data packets coming to and from the mobile stations.
- ❖ GGSN: Gateway GPRS Support Node: GGSN provides connectivity to external switching network packet, such as the Internet. It converts the GPRS packets coming from the SGSN into IP packets and sends them to the corresponding packet data network. GGSN also maintains routing necessary to tunnel IP packets to the SGSN serving a particular mobile station.
- ❖ Home Location Register (HLR): The main user database from a mobile network in which information from all mobile subscribers is stored. It contains information about the subscriber's identity, his telephone number, the associated services and general information about the location of the subscriber.
- ❖ Packet Data Network (PDN): data unit package carried by a packet switched network.



**Figure 2.2 Core 3G Mobile Network-Alcatel, Mobile Gateways for the LTE Evolved Packet Core**

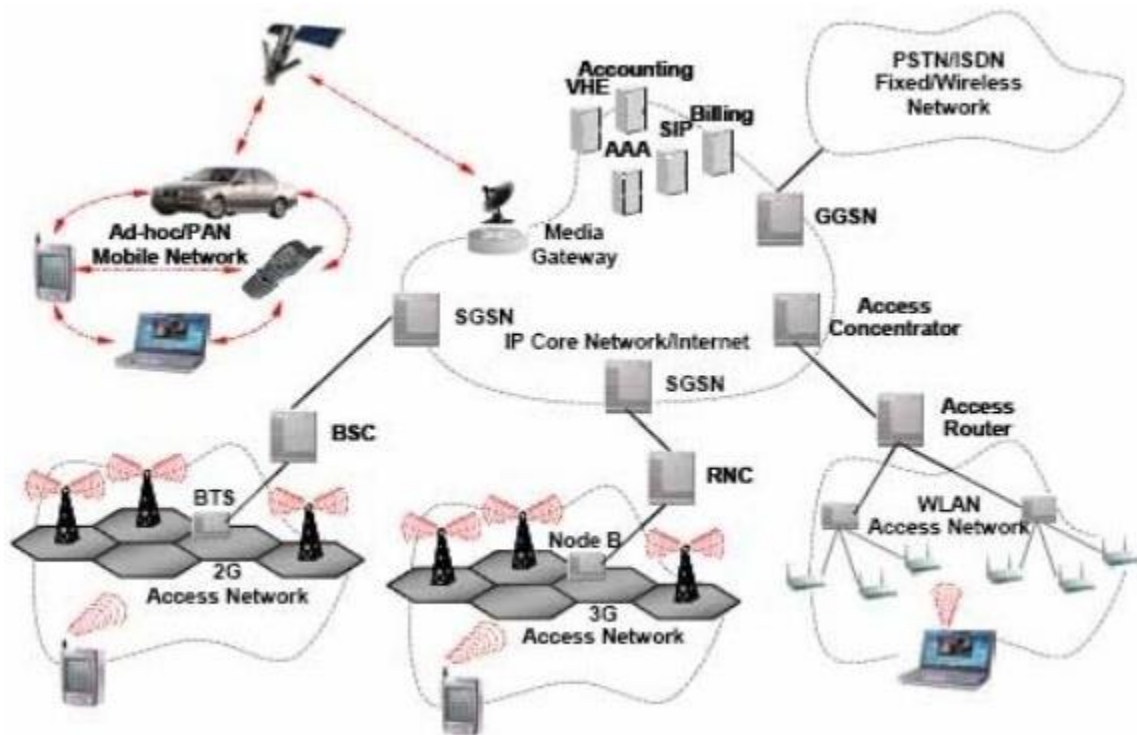


### ***2.2.4 Fourth Generation (4G)***

The Fourth generation mobile system was introduced in the late 2000s and was an all IP based network system. The main goal of 4G technology is to provide high speed, high quality, high capacity, security and low cost services for voice and data services, multimedia and internet over IP. The reason for the transition to all IP is to have a common platform to all the technologies developed so far. It has the capability 100Mbps and 1Gbps of .To use Fourth generation (4G) mobile network, multimode user terminals should be able to select the target wireless system. To provide wireless services anytime and anywhere, terminal mobility is a key factor in Fourth generation (4G).Terminal mobility implies automatic roaming between different wireless networks. The 4G technology integrate different existing and future wireless technologies (e.g. Orthogonal Frequency Division Multiplexing (OFDM), Multi Carrier Code Division Multiple Access (MC-CDMA), Last Area Synchronized Code Division Multiple Access (LAS-CDMA) and Network-Local Multipoint Distribution System (N-LMDS) to provide freedom of movement and uninterrupted roaming from one technology to another. Long Term Evolution (LTE) and Wireless Interoperability for Microwave Access (WiMAX) are considered as Fourth generation (4G) technologies.

The following are the five (5) acceptable characteristics of Fourth generation (4G):

- ❖ All IP based network architecture
- ❖ Higher Bandwidth
- ❖ Support for different access networks
- ❖ Including Wide Local Area Network (WLAN) technologies like IEEE 802.11
- ❖ Full integration of “hot spot’ and Cellular”
- ❖ Support for multimedia Applications



**Figure 2.3 4G Architecture**

## **2.3 LTE Networks and the Current Situation of Telecommunications**

Long Term Evolution introduces this change in the network core and offers a concept of Quality of Service (QoS) with simple nine (9) classes and some attributes for each class.[36] The Quality of Service (QoS) policy for each service is determined by the Evolved Packet Core (EPC) where an User Equipment (UE) calls to open a specific application. The new core will enable new business models and boost services such as high speed Internet, multimedia applications, social networks and online games and not only that revenue engine of the previous generation, composed of voice and Short Message Service (SMS).[37]

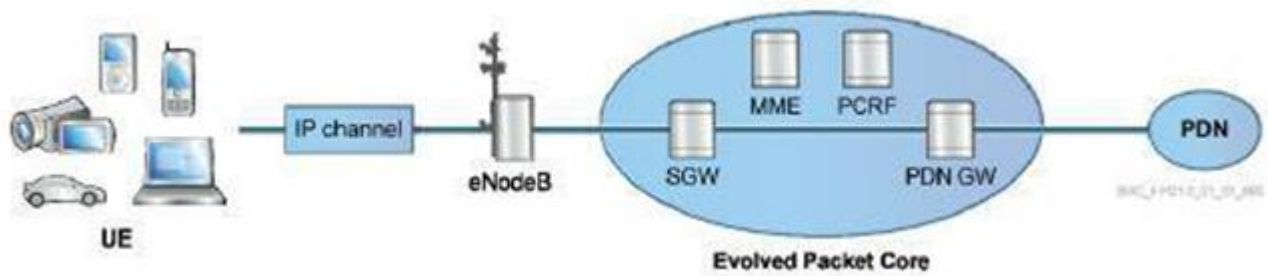
As stated, a Long Term Evolution (LTE) network provides a packet architecture all-IP end-to-end. An IP channel connects the User Equipment (UE) to the Evolved Node Base Station (ENodeB). The Evolved Packet Core is a packet switching core that consists of four elements: Serving Gateway (SGW), Mobility Management Entity (MME), Packet Data Network Gateway (PDN GW) and Policy and Charging Rules

Function (PCRF). The Evolved Packet Core (EPC) provides the user with IP connectivity to the data network (Packet Data Network).

The migration to Long Term Evolution (LTE) has been done gradually, by improving the core network and, initially, the introduction of Long Term Evolution (LTE) radio technology in high-demand areas. Hence, the need to interact with the existing Long Term Evolution (LTE) radio technology is crucial.

The 4G LTE network consists of the following: (see Figure 2.3) [37, 38]

- ❖ User Equipment (UE): Any device used directly by the end user to communicate.
- ❖ enhanced Node Base Station (eNodeB): among other functions is primarily responsible for all management of radio resources, including configuration, initial admission control and allocation of radio carrier and dynamically assigns radio resources to User's Equipment (UEs).
- ❖ Serving Gateway (SGW): This performs the routing of packets in the User Plane, while acting as mobility manager during the handover process inter-enhanced Node Base station (eNodeB) or handover between Long Term Evolution and other Third generation Partnership Project (3GPP) access networks, driving traffic these legacy networks to the Packet Data Gateway (PGW).
- ❖ Mobility Management Entity (MME): Which means it's completely responsible for all the control plane operations. It controls element of the access network. It is responsible for mobility management of User Equipment (UE), location procedures, paging and retransmissions. Also has the task of authenticating the user on the network through interaction with the Home Subscriber Server (HSS).
- ❖ Restriction Fragment Length Polymorphism (RFLP): This is responsible for supporting and detecting data service flows, allowing the tariff system and implement policies based on this data flow.
- ❖ Packet Gateway (PGW): It provides connectivity between the User Equipment (UE) and any external data network, and the output node and input user data traffic.
- ❖ Packet Data Network (PDN): It allocates Internet Protocol (IP) address to the User Equipment (UE) during default bearer setup. .



**Figure 2.4 Core 4G Mobile Network -Alcatel; Mobile Gateways for the LTE Evolved Packet Core [38]**

### ***2.3.1 Evolution of voice services in LTE networks***

Voice traffic on LTE devices is evolving as well as the mobile industry infrastructure towards a ubiquitous availability. The development of LTE smartphones come meet the high expectations of today, contributing to a better experience of mobile user and providing both voice as broader communication services. This evolution is shown in three steps, according to Table 2.2

***Table 2.1 Evolution of Voice services in LTE network- Adapted from [Qualcomm, Circuit Switch Fallback. Second phase of voice evolution for mobile devices LTE, 2012] [5]***

First Phase: LTE data devices	Second Phase: VOIP devices LTE	Third Phase: Convergence
LTE/ 3G Data + 2G/3G Voice	Simultaneous VoLTE + Rich data services	Multimedia Telephony + data Services
2011~ 2012	2013	2014~ 2015

***(a) First Phase***

In the first phase, currently in progress, all voice traffic is made by legacy networks of circuit switching (CS) while data traffic is by Long Term Evolution (LTE) packet-switched (PS) when and where available, and by Second generation (2G) / Third generation (3G) networks as an alternative in areas outside of Long Term Evolution (LTE) coverage. The single-radio solution was used rather than the dual-radio, although simpler because it is based solely on the device and no changes are required in the network, as it will simultaneously get the Long Term Evolution (LTE) data services and voice services from the circuit switched mode. However, the device may become more expensive and more energy consumption .Therefore, single radio solutions use Circuit Switched Fallback (CSFB) to switch between Long Term Evolution and Second generation (2G) / Third generation (3G) access mode. Circuit Switched Fallback (CSFB) became the predominant global interoperability solution for voice and Short Message Service (SMS) initial Long Term Evolution (LTE) equipment, mainly due to the cost, size, and attendant advantages of the solutions single-radio device side. In 2011, Circuit Switched Fallback (CSFB) was commercially launched in various regions around the world, and is the first step for the subsequent stages of evolution of voice over Long Term Evolution (LTE).

### ***(b) Second Phase***

The second phase in the evolution of voice on Long Term Evolution introduced Voice over Internet Protocol (VoIP) native over Long Term Evolution (VoLTE), along with advanced Internet Protocol (IP) multimedia services such as video telephone, High Definition (HD) Voice and Rich Communication Suite (RCS), instant messaging video sharing . This phase also uses a solution Single Radio Voice Call Continuity (SRVCC) that keeps voice calls with mobile users traveling between Long Term Evolution and non-Long Term Evolution coverage areas. Circuit Switched Fallback (CSFB) continues to be implemented during the second phase, to provide voice services to roamers and devices only Circuit Switched Fallback (CSFB).

### ***(c) Third Phase***

The third phase converges to a larger capacity and services of all-IP networks (voice and video over IP and Rich Communication System, (RCS) for continuous coverage of the full range of network access methods, including Long Term Evolution, Third generation (3G) / High Speed Packet Access (HSPA) used to increase packet data performance and Wi-Fi, with interoperability between operators and telephone legacy domains.

### 2.3.2 Long Term Evolution (LTE) and High Speed Packet Access (HSPA) Interworking

A mobile operator currently using High Speed Packet Access (HSPA) technologies is commonly used to refer to Universal Mobile Telecommunications System (UMTS) based Third generation (3G) networks that support both High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA) data for improved download and upload speeds, and migrating towards Long Term Evolution (LTE), will usually support soft hand-off (e.g., a dual-mode device which can switch mid-session depending on available coverage). This type of network is shown in figure 2.5

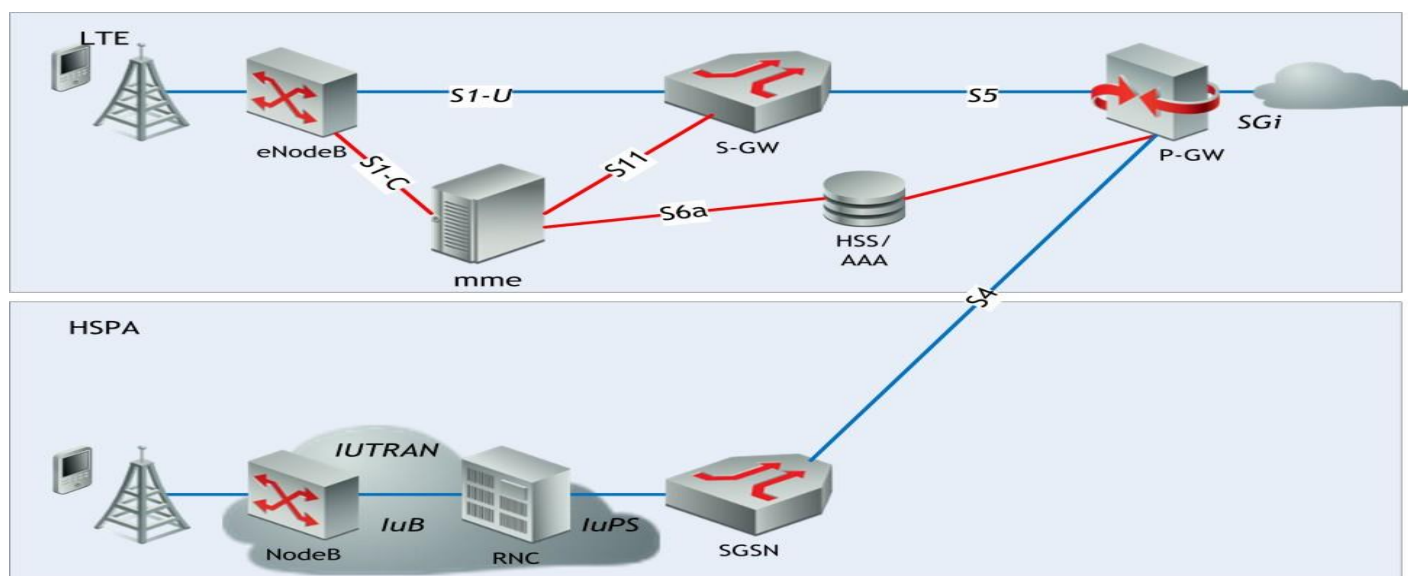
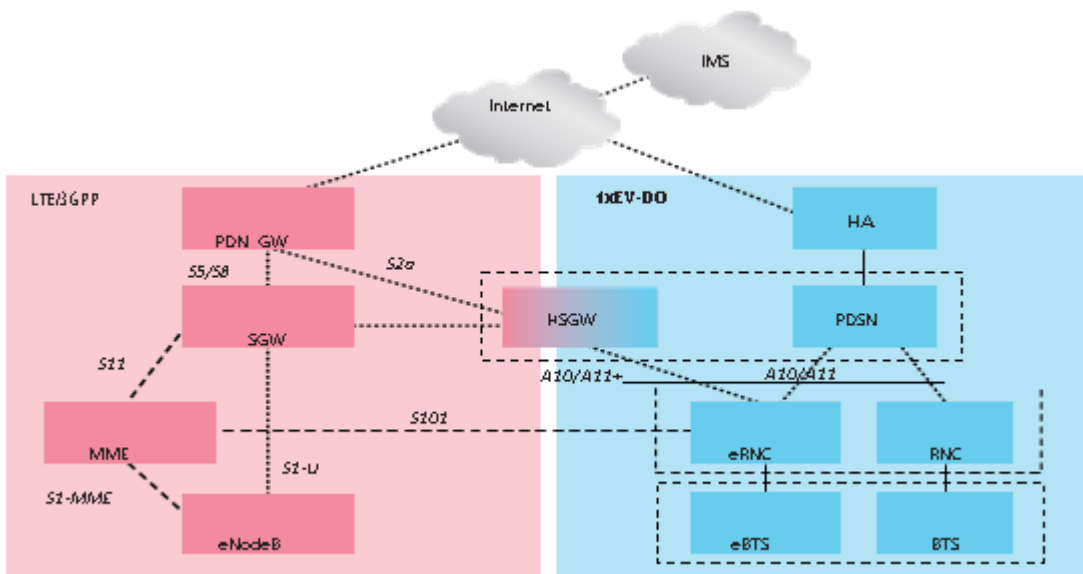


Figure 2.5 LTE and HSPA Interworking [17, 8]

### 2.3.3 CDMA & LTE Interworking

Some operators currently use Code Division Multiple Access (CDMA) which is a competing cell phone service technology to Global System for Mobile Communications (GSM) and Third generation Partnership Project two (3GPP2) technologies, and are migrating to Long Term Evolution (LTE). As part of the migration they may support soft hand-off (e.g., user-equipment that can start a session on one network and move to another mid-session). Hard hand-off techniques are not covered here. Figure 2.6 shows a network diagram for a mixed Code Division Multiple Access (CDMA) and Long Term Evolution (LTE) operator.



**Figure 2.6 LTE and CDMA Interworking, single Operator [17]**

**Table 2.2 Features and Mobile Technology Overview [6]**

Technology	1G	2G	2.5G	3G	4G
First Design (Year)	1970	1980	1985	1990	2000
Implementation (Year)	1984	1991	1999	2002	2010
Service	Analogue Voice	Digital Voice, SMS	High Capacity, Packetized Data	High Capacity, Broadband Data up to 2Mbps	High Capacity, Completely IP-Oriented, Multimedia data to hundreds of megabits (Mbps)
Standards	AMPS, TACS,NMT	TDMA,CDMA,GSM, PDC	GPRS, EDGE, 1XRTT	WCDMA, CDMA 2000, EV-DO, HSDPA	WIMAX, HSDPA, HIGH SPEED & IP BASED
Data Bandwidth	1.9 kbps	14.4 kbps	384 kbps	2 Mbps	200 Mbps
Multiplexing	FDMA	TDMA, CDMA	TDMA, CDMA	CDMA	CDMA
Core Network	PSTN	PSTN	PSTN, Packet Network	Packet Network	Internet (IP)
Key Features	Analogue ,primarily voice, less secure, support for low bit rate data	Digital, more secure, voice and Data	Digital , more secure , voice and data	Digital ,multimedia , global roaming across a signal type of wireless network, IP limited	Global roaming across multiple networks, 10Mbps-100Mbps, IP interoperability for seamless mobile Internet

## 2.4 Monitoring Quality of Service (QoS) of Mobile Network

Monitoring Quality of Service (QoS) of any telecommunication network requires continuous processes that measure values of the Key Performance Indicator (KPI) parameters in real-time and analyses the measured empirical data of the Key Performance Indicators (KPIs) that determines quality of Service to the subscribers.



The necessity of Quality of Service (QoS) is one of the key issues in order to design and analyse the Third generation (3G) / Universal Mobile Telecommunications System (UMTS) and Long Term Evolution (LTE) networks. Due to the ubiquitous bandwidth limitations for real-time applications in Third generation (3G) / Universal Mobile Telecommunications System (UMTS) and Long Term Evolution (LTE) network such as voice and video telephone and with increasing number of application, service classification and efficient resource management, it becomes quite laborious tasks. For this reason the service quality degrades in Third generation (3G) / Universal Mobile Telecommunications System (UMTS) network. Proper resource and traffic management are important factors to handle different types of applications in the network to improve the service quality in video and voice transmission. In order to manage the resources and to handle the traffic properly in the network, Quality of Service (QoS) implementation is necessary to provide better service as well as to fulfil the users' expectations. [5]

## **2.5 The Issues Affecting Quality of Service in Angola**

The following factors were identified as the major factors that require attention in order to improve the unacceptable Quality of Service (QoS) delivered by both Angolan networks.

- Network Congestion
- Limited Transmission Infrastructure.
- Security of Telecommunications Equipment or Facilities.
- Unreliable Public Power Supply.
- Lack of Information to the Consumer on downtime.
- Poor network Coverage (Unavailability of Services).

The Quality of Service (QoS) perceived by the customer depends on the performance archived by each component installed in the network and the service resources (end to end).

### ***2.5.1 Network Availability & Down Time***

Downtime or outage duration refers to a period of time that an NE (network element) fails to provide or perform its primary function. This is usually a result of the system failing to function because of an unplanned event (outage) or because of routine maintenance. The companies lose revenues directly at every failure. This forces savvy companies to proactively anticipate and prepare for problems before they occur in any Base station.[50]

## **CHAPTER 3**

### **RESEARCH METHODS AND TECHNIQUES**

#### **3.1 Introduction**

This chapter presents the research method and techniques employed in the study. In Section 3.2 Questionnaires, how many and why Questionnaires. 3.3 Verbal interviews. 3.4 Data from the National Regulator Instituto Nacional das Comunicacoes (INACOM).

#### **3.2 Questionnaires**

For the access of Quality of Service (QoS) from customer's Quality of experience (QoE), spectrum, two different types of questionnaires were drafted/designed and sent out by the author to two different classes of customers for the purpose of data collection within Angola and this include high school student, ordinary people, working professionals, university students which and technical personnel from unitel and movicel were chosen randomly and administrated in all ten (10) provinces. The total numbers are as follow:

Total High School Student for the ten (10) provinces were two hundred thirty eight (238) response.

Total Ordinary People for the ten (10) provinces were eighty-eight (88) respondents.

Total Working Professionals for the ten (10) provinces were seventy-nine (79) respondents.

Total University Students for the ten (10) provinces were one hundred and fifteen (115) respondents.

The total respondents were five hundred twenty (520) respondents for non-technical class and six (6) respondents from technical class both Unitel and Movitel technicians as shown in table 3.1 and 3.2 respectively. The typical questionnaires are shown in appendix 1 and appendix 2.

**Table 3.1 Number of Respondents from non-Technical Class of Customers**

Group Type	Province									
	Luanda	Benguela	Cabinda	Huila	Cunene	Huambo	Namibe	Bie	Malanje	Bengo
High School Student	35	23	45	20	15	20	20	17	19	24
Ordinary People	10	6	16	10	8	5	7	5	7	14
Working Professionals	13	8	20	8	5	6	4	3	5	7
University Students	10	15	22	9	16	10	8	6	8	11
Totals	68	52	103	47	44	41	39	31	39	56

**Table 3.2 The Outcome of the Questionnaires sent to Technical Personnel [51]**

No	Operator	Job description	Years of Service	Qualifications	Number of Questionnaires
1	Unitel	Network Technician	3	Degree in Computer Science and National Certificate in Electronic & Telecommunications	1
2	Unitel	Radio Engineer	7	Degree in Telecommunications	1
3	Movicel	Network Engineer	5	Degree in Computer Science & Cisco Certificate	1
4	Movicel	Radio Planning	6	Cisco certificate	1
5	Unitel	Vsat Engineer	5	Degree in Telecommunications & National Certificate	1
6	Movicel	Fibre Optic Engineer	4	Degree in Electronic & Telecommunications	1

### **3.3 Verbal Interviews**

#### ***3.3.1 Interview over Phone Calls***

Due to the expenses of travelling around the country and because Angola is a big country which has eighteen provinces, some interviews were administered through the phone calls using both classes of questionnaires, and from such, the author got twenty (20) responses.

Through phone calls the author managed to collect data from different individuals nationwide and the outcome was a number of 20 successful interviews.

#### ***3.3.2 Interview Face to Face***

Face to face interviews were carried out by the author within the provinces which he travelled where the response was sixty (60).

### **3.4 Data from National Regulator, Angolan Institute of Communications (INACOM)**

Angolan Institute of Communications (INACOM) [14] is a body whose purpose is to regulate and monitor the activity of providing telecommunications services, management and supervision of the radio frequency spectrum, being the regulator, the data provided by this body from its collections was also used in this research. The information from the regulator is usually not made possible for official reasons, however, in this research data concerning, average signal strength for radio coverage Third generation (3G) and Fourth generation (4G), call drop, block call, call

setup rate was available and it's presented in the next chapter. The evolution of Mobile Communication in Angolan is shown below in figure 3.1 and figure 3.2 respectively.

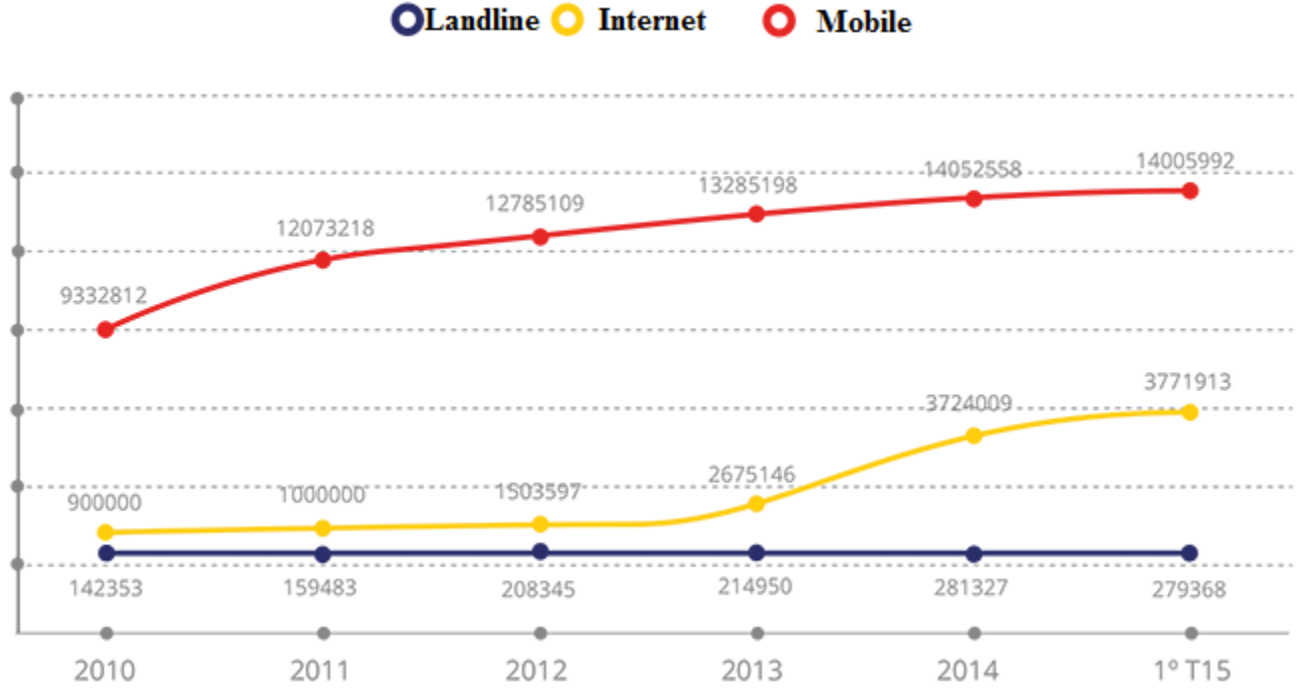
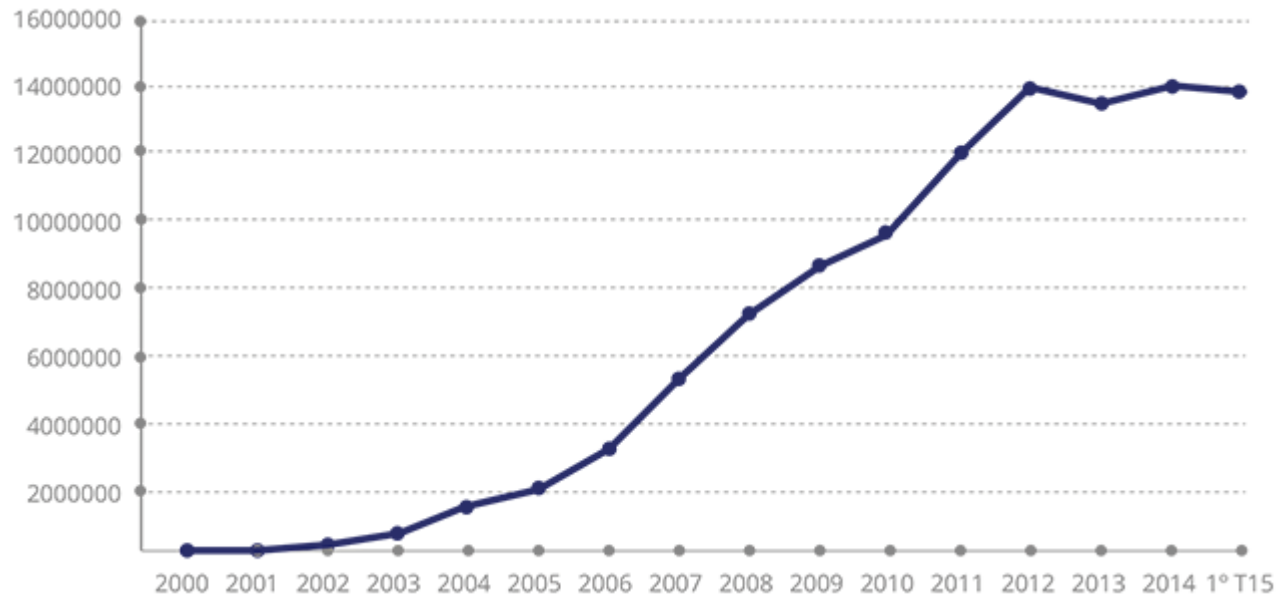


Figure 3.1 Evolution of the number of telephony and Internet users [14]



**Figure 3.2 Evolution of Number of Mobile Cellular Subscribers [14]**

### **3.5 Conclusion**

This chapter concluded the overview how data was collected. The results are presented in next chapter.

# CHAPTER 4

## RESULTS AND ANALYSIS

### 4.1 Introduction

This chapter, Presents the results and analysis of Quality of Service of the Angolan mobile operators. In section 4.2 Results based on Questionnaires. 4.3 Results based on Verbal Interviews. 4.4 Results based on data from National Regulator. 4.5 Summary of Results.

### 4.2 Results Based on Questionnaires

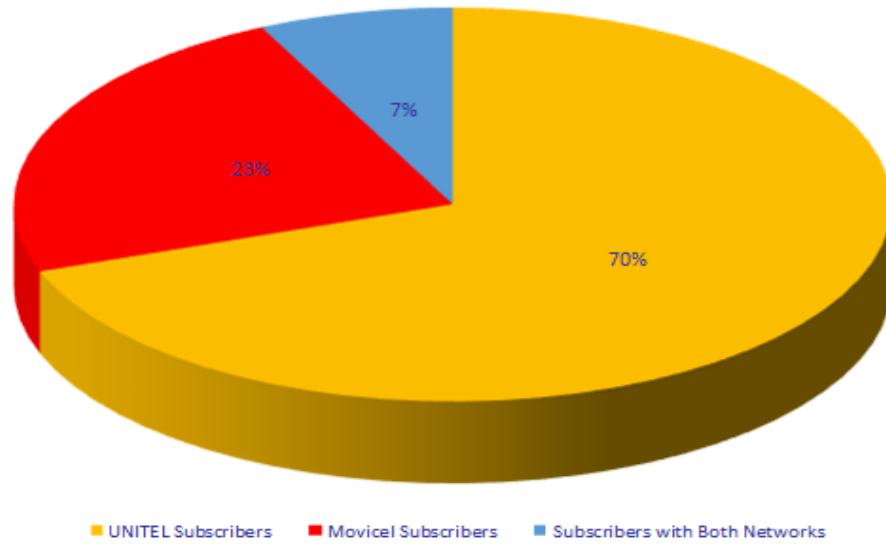
**Table 4.1 the average Signal Strength for Radio Coverage on WCDMA and LTE on Unitel and Movitel network**

		WCDMA		LTE	
		Operator A	Operator B	Operator A	Operator B
Coverage	Number of samples (measurements)	56	56	9	9
	Sign Medium level [dBm] level	-87	-89	-63	-67
	Signal Max [dBm]	-51	-49	-26	-28
	Signal Level Minimum [dBm]	-95	-93	-96	-98
	Standard Deviation [dBm]	10	10	11	11

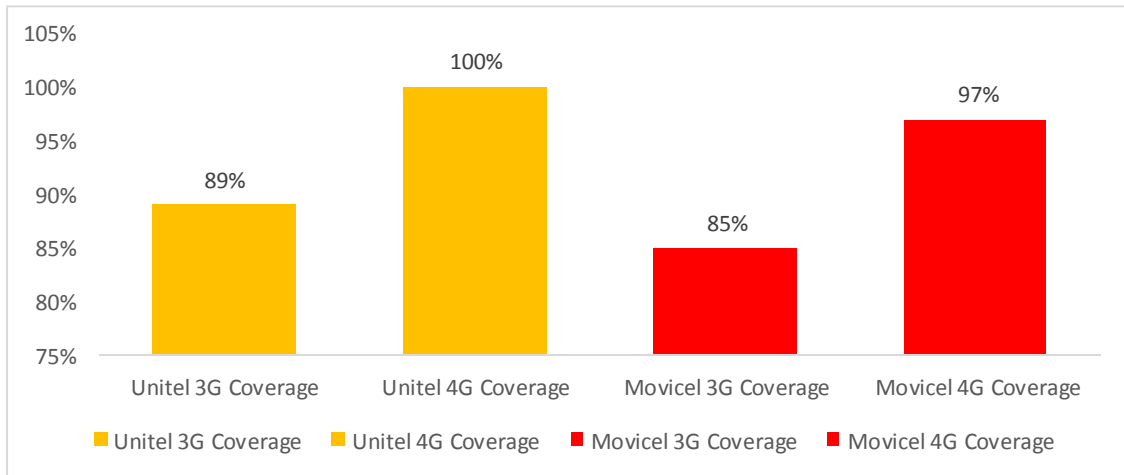


Note: In the above table 4.1 Operator A represents Unitel and Operator B represents Movitel.

### Mobile Subscribers Distribution in Angola



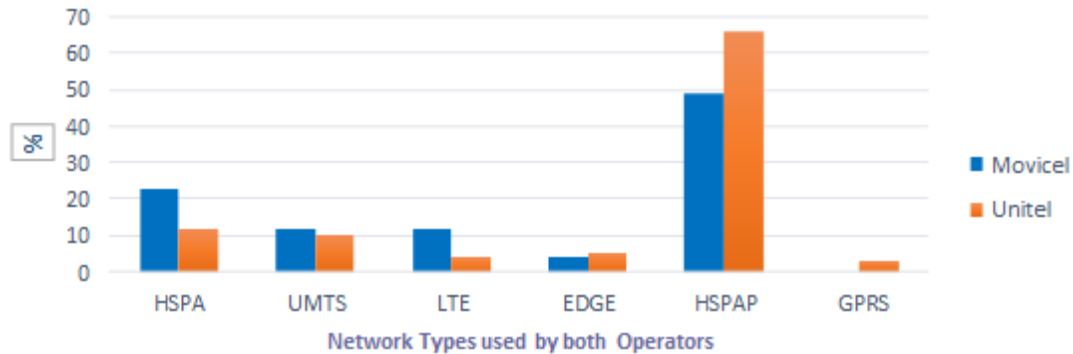
**Figure 4.1 Demonstration Rate of Subscribers using both Networks.**



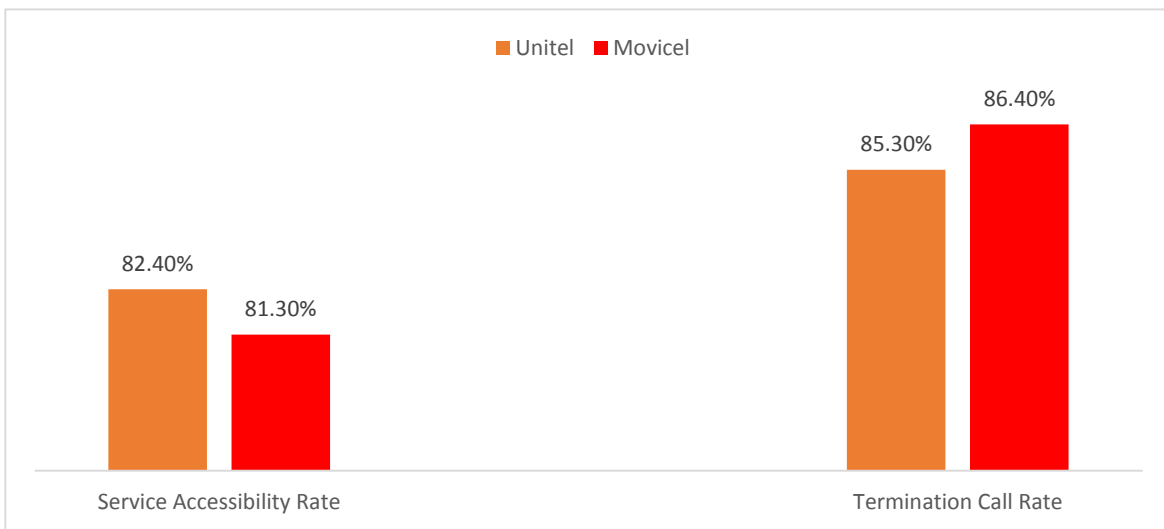
**Figure 4.2 Network Coverage of Unitel and Movitel based on 3G and 4G Technology**

The above figure 4.2 shows us the coverage of both networks with Third generation (3G) and Fourth generation (4G) technologies. The Fourth generation (4G) was analyzed based on one province which is the capital city (Luanda) since it's the only city where Long term Evolution (LTE) services are available for now, this is for both operators. Otherwise Third generation (3G) was analyzed based on the ten provinces visited by the author.

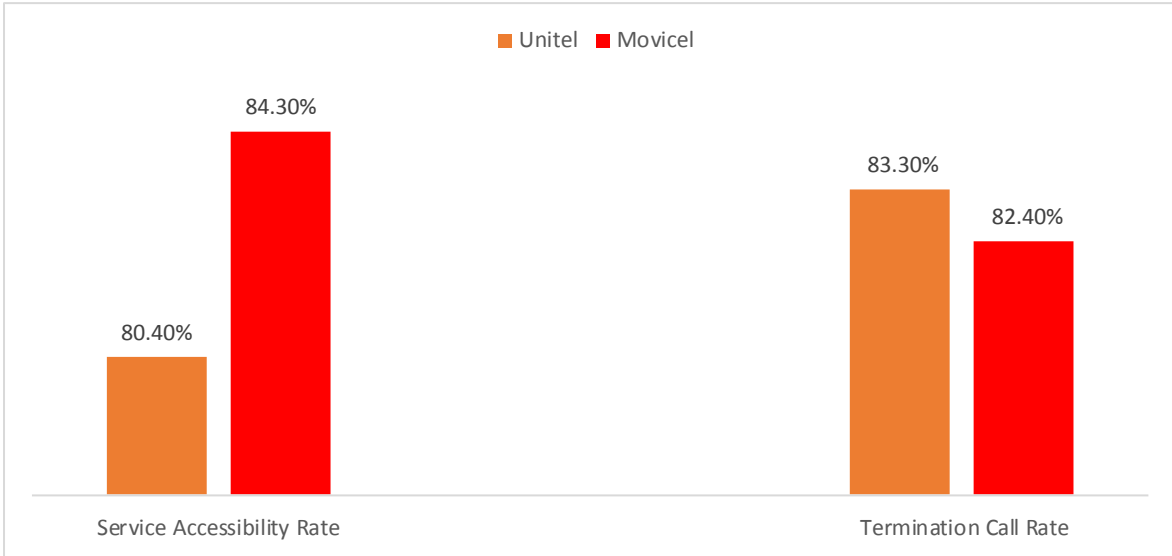
### 4.3 Results based on Verbal Interview



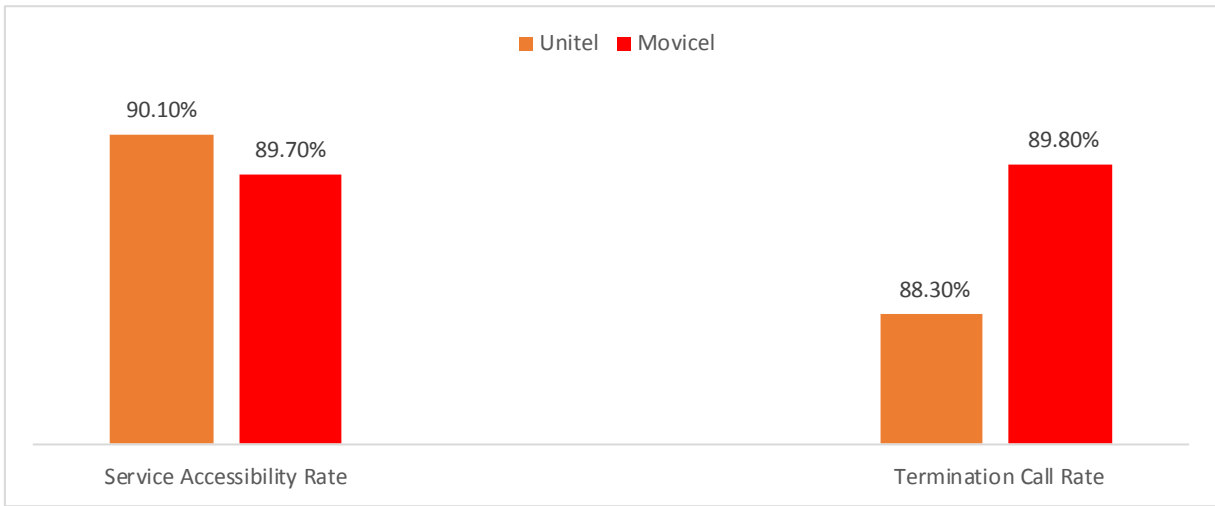
**Figure 4.3 Demonstration of Network types used by Unitel and Movitel**



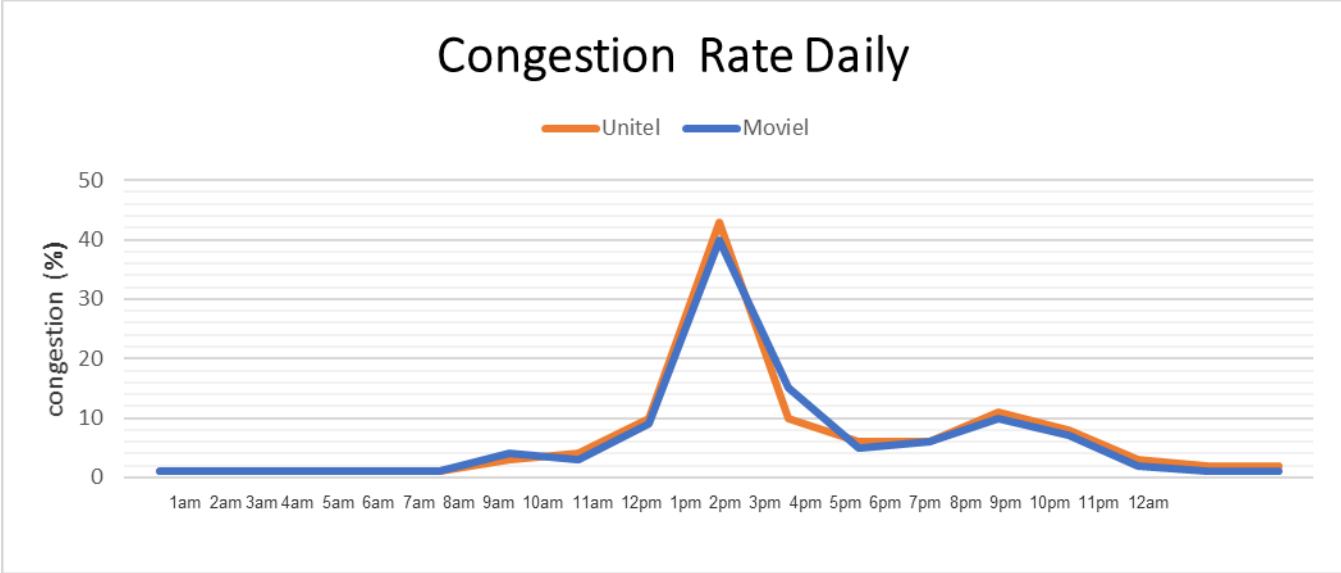
**Figure 4.4 Quality of Voice Call - Mobile to Landline**



**Figure 4.5 Quality of Voice Call - Landline to Mobile**

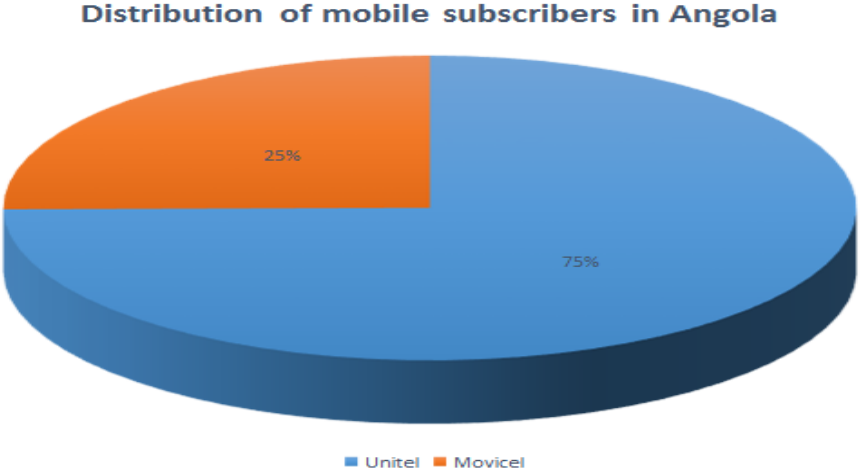


**Figure 4.6 Quality of Voice Call - Mobile to Mobile**

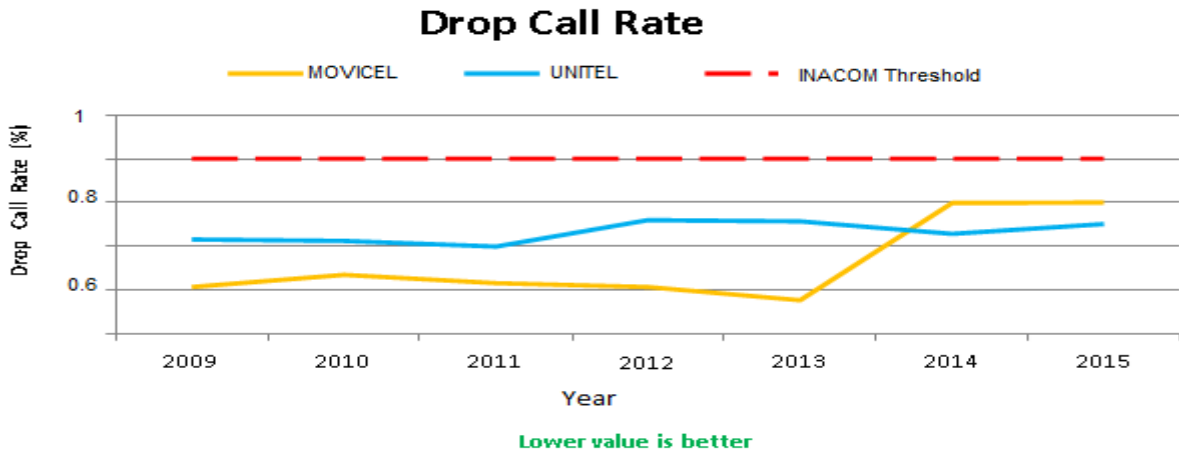


**Figure 4.7 Congestion Rate daily by Unitel and Movitel**

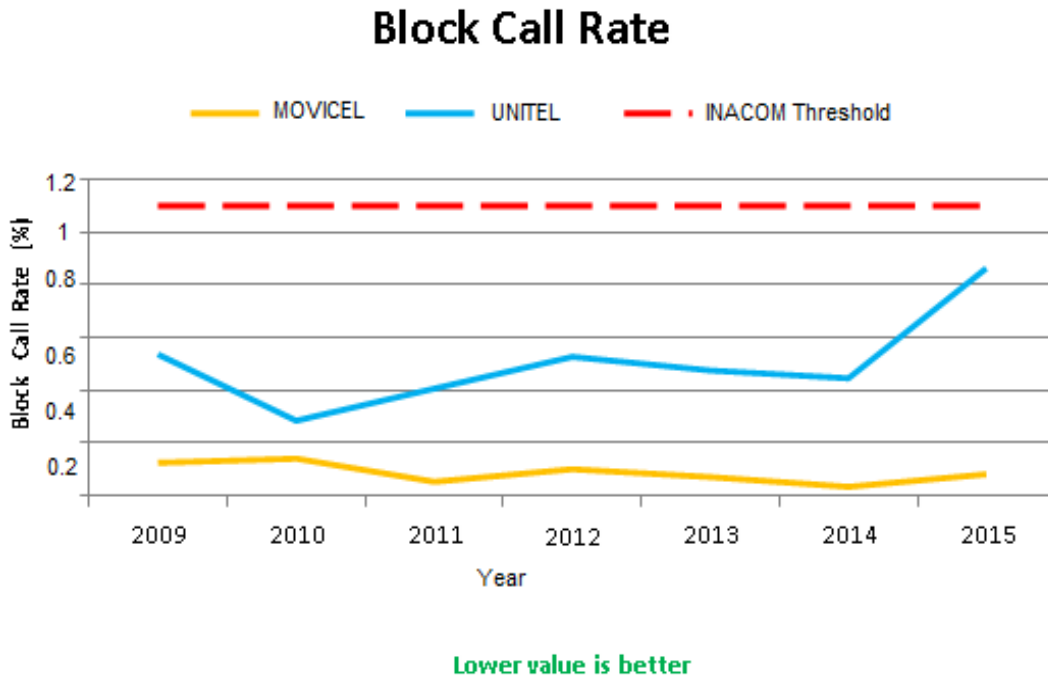
**4.4 Results on Data from National Regulator, Angolan Institute of Communications (INACOM)**



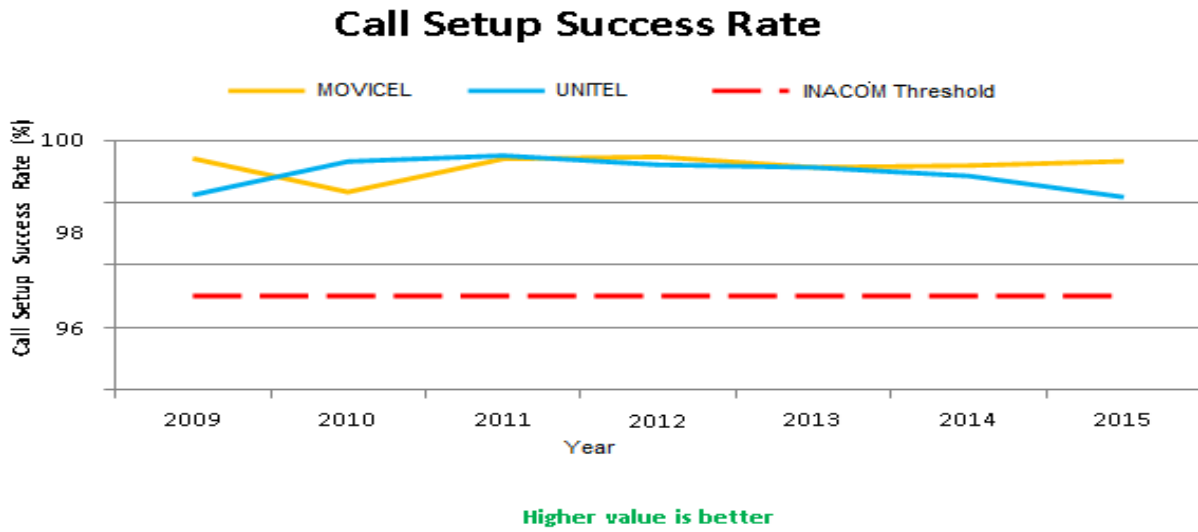
**Figure 4.8 Demonstration of Distribution of Mobile Subscribers for Angolan Networks.**



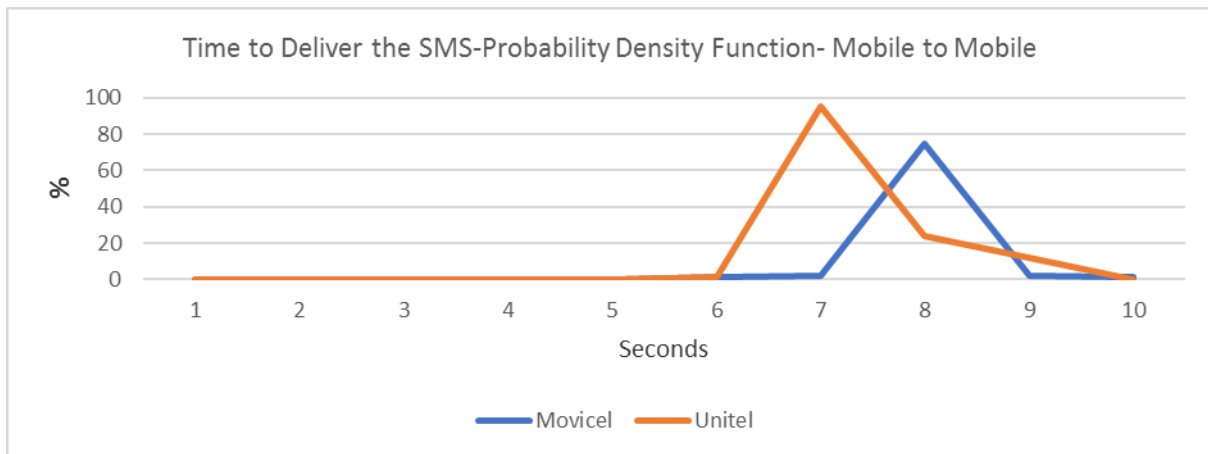
**Figure 4.9 Drop Call Rate for Unitel and Movitel**



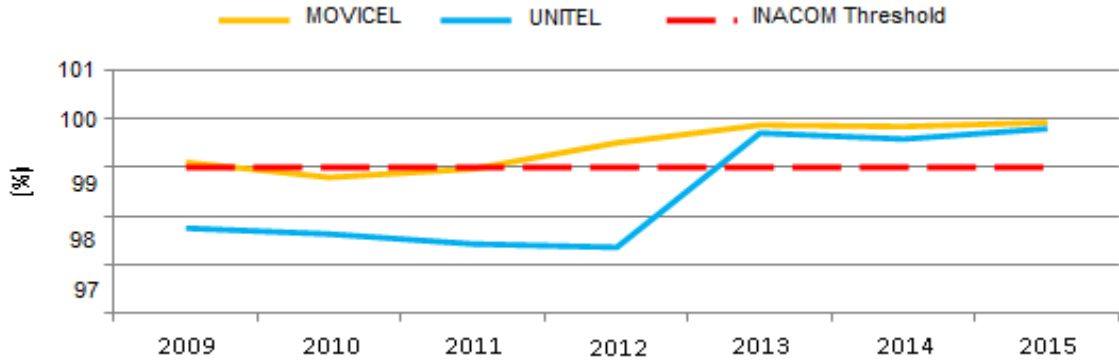
**Figure 4.10 Block Call Rate on Unitel and Movitel network**



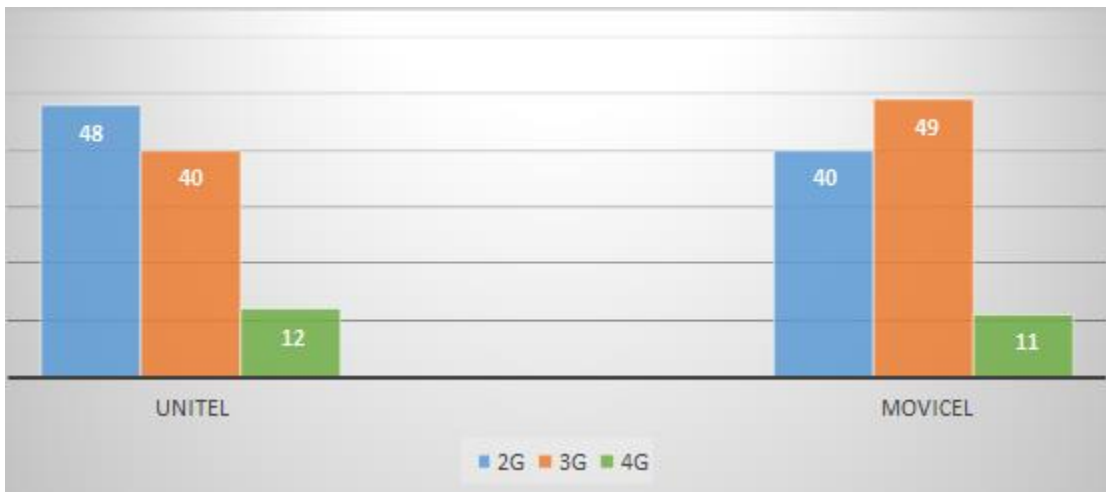
**Figure 4.11 Call Setup Success Rate for Unitel and Movitel Network**



**Figure 4.12 Time to Deliver the SMS Probability Density Function**



**Figure 4.13 Subscribers Complaints of Poor Quality of Service offered by Unitel and Movitel**



**Figure 4.14 Service Coverage/Availability of Service of both Operators**

The above figure 14 shows clearly that the predominant technology of Radio Coverage for Unitel and Movitel network is Second generation (2G), this implies that in most areas where the operators claim Third generations being deployed there is no full coverage.

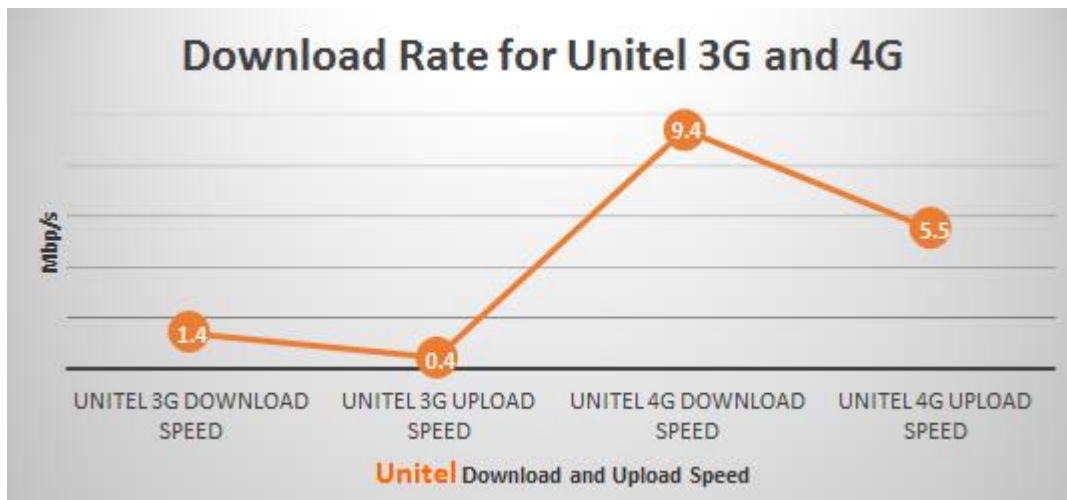


Figure 4.15 Unitel -download and upload speed based on 3G and 4G technology

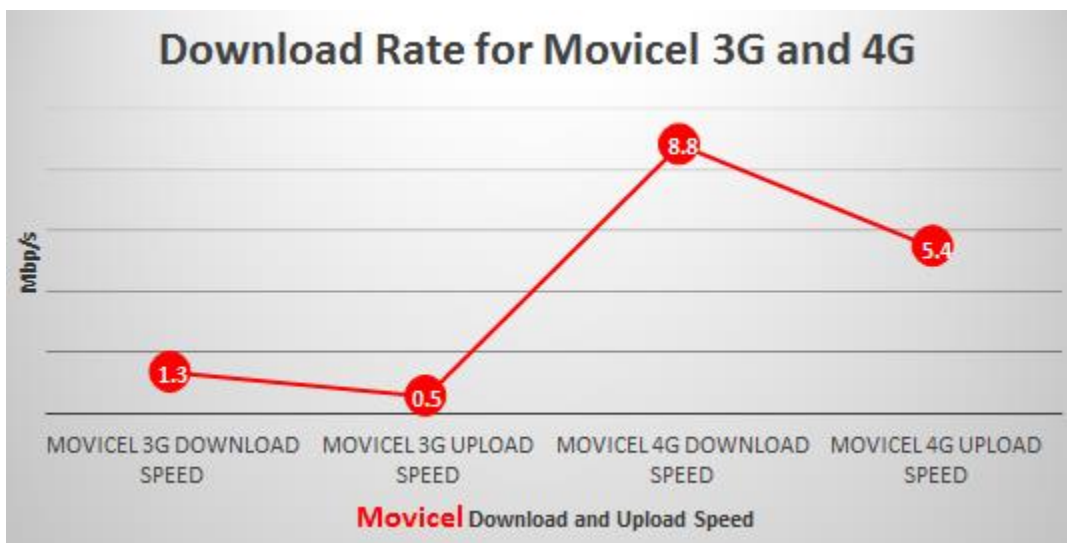


Figure 4.16 Movicel - download and upload speed based on 3G and 4G technology



## 4.5 Summary of Results

The methods and techniques used have yielded results that are an adequate characterization of the Quality of Service (QoS) provided by each of the studied mobile communication operators based on the Third generation (3G) and Fourth generation (4G). The radio levels recorded in section 4.4 based on Wideband Code Division Multiple Access (WCDMA) and Long Term Evolution show that both Unitel and Movitel have values within the recommended levels for the provision of services.

In figure 4.13 shows unacceptable level of complains which surpasses the national regulator threshold, this tells us that provinces like Cabinda, Malange Namibe and Bie have serious problems with regards to Third generation (3G) technology, this was also major concern to the author whereby by passing through these provinces customers really complained they can go for two days without any signal on their mobile stations (Cellphones), these places require fast response for the improvement of the mobile quality of service.

The most critical place is Cabinda whereby the absence of fiber communications, the operators use microwave links to connect to the rest of the country, which is not proper for a place with over 688,285 thousand of population.

The recorded results were based on questionnaires, interviews and data from the national regulator and based on these results, it's clear that Unitel demonstrates the most acceptable services offered to customers, this is also because Unitel performs better on the centre and on the south provinces of Angola.

## **CHAPTER 5**

### **CONCLUSION**

#### **5.1 Summary of Findings**

This chapter presents the Conclusion. In section 5.2 Recommendations. 5.3 Suggestion for Future Research. 5.4 Limitations.

The emergence of GSM technology has changed irreversibly the landscape of telecommunications. From that emerged the first commercial networks in 1991, the number of users has increased steadily.

Some years back, cellular third generation systems including UMTS, came to overcome some shortcomings of Second generation (2G) to allow high-speed access to broadband support services, such as voice, Internet access and multimedia applications.

Currently, given the high penetration rates and use of Wideband Code Division Multiple Access (WCDMA), the service quality from the user perspective is assumed as one of the main competitive advantages of market operators. More and more consumers were looking for services in ease of use and superior quality, uninterrupted and anywhere with high speed data for streaming, gaming, applications and Voice over Internet Protocol, that's how the Long Term Evolution technology was introduced and started to be deployed by mobile operators over the world including Unitel and Movivcel in order to attract customers for their services.

It was in this context that this research was carried out. The objectives were clear: to define indicators and test conditions, allow a user perspective, evaluate the quality of the most common services in mobile communications systems based on Third generations (3G) and Long Term Evolution (LTE) technologies.

The first aspect to be clarified was the concept of Quality of Service in the User Perspective, which is the perception of quality felt by a user when using any mobile service; indicates the degree of user satisfaction in terms of accessibility, retention and service integrity. It is usually expressed in terms of human feelings, like, "excellent", "good", "fair", "poor" and "bad" as opposed to Network Performance that is purely measured technical concept, expressed and understood in optic network or its elements, with little meaning for the user.

In a second aspect, the most common services were identified in the current mobile communication systems, because of their relevance to the end-users and made available by the various operators in the market. According to these principles, voice services were considered, video telephone, SMS, MMS, access to web pages (HTTP browsing), information transfer (FTP) and email. They also considered the availability and affordability of radio networks to support these services. For each service, specific indicators were defined to characterize the Quality of Service (QoS) in each stage of its use, namely, user satisfaction level indicators in terms of accessibility, retention and service integrity and also indicators of the degree of availability and accessibility of support networks service. These Quality of Service (QoS) indicators are based on data from Angolan national regulator (INACOM), interviews and questionnaires were carried out for the user's perspective on the use of mobile services , reflecting the various aspects that affect the quality of service to the end user.[39, 51]

The analysis allowed to know the radio levels of WCDMA and LTE technologies used by operators studied, verifying that there are very few Sites with Third generation (3G) and most sites have a predominant Second generation (2G) suitable only the provision of services.

The analysis for mobile communications services in Angola also allowed us to verify the accessibility, retention and integrity in which these services are provided. For the voice service it has been possible to identify the operator with the best performance being Unitel with more than 95.28% rate.

For messaging services it has been identified with regards to conditions for the provision of these services, particularly as regards the accessibility and rates and message delivery times. These services are performing well, especially the Short Message Service (SM), it was possible to identify the operator with better performance being Untel again.[14, 18]

Also for data services, the use of Quality of Service (QoS) indicators, defined in this work allowed the characterization of the performance of these services. There was an average accessibility to services, good information transfer speeds, given the limitations of the supporting technologies, significant differences in the two systems latencies and it was possible to identify the operator who had the best performance which is Unitel. It was also observed that there are degradations of download speeds and upload at night time between 10:00am to 17:00pm (approximately).

The results showed that the indicators and measurement profiles, defined and characterized in this work, are suitable for the evaluation of QoS in the user's perspective of the services and the most common mobile systems.[50]

Quality of Service (QoS) Based on Unitel and Movicel Networks Measurements were done in order to:

- ❖ Encourage the competition between the mobile operators
- ❖ Provide customer's totally independent results about Quality of Service (QoS) which is in accordance with International Telecommunications Union (ITU) regulation requirements.
- ❖ Fulfill law and rule book requirements assign to Angolan Institute of Communications (INACOM).

## **5.2 Recommendations**

- (a) For end users, the technological infrastructure that supports a mobile communications system assumes little relevance. What really interests them is to maintain a voice call, send and receive SMS, access the Internet, send and receive e-mail, or to see live the last goal of his favorite club, etc. All services should be supported seamlessly, anytime, anywhere. Thus, the central aim of any mobile communications system is the provision of services with a degree of quality to guarantee the satisfaction and loyalty of user.
- (b) The two operators have to improve on their network infrastructure because Inadequate Network Infrastructure is one of the factors affecting Quality of Service (QoS) in mobile communications in Angola.
- (c) Both unitel and Movitel have to be fairer with their subscribers, due to the lack of fairness from service providers being another factor affecting Quality of Service (QoS) in Cellular system in Angola.
- (d) INACOM as the regulator had never made effort for the improvements of Quality of Service (QoS) of mobile communication system, hence little effort by the regulator being another factor affecting Quality of Service (QoS) in mobile networks in Angola.

- (e) Both networks have to improve on this disease called Network Congestion by the use of the technique called Dynamic channel allocation (DCA).
- (f) Both networks have to inform the subscribers / end users about the downtime instead of keeping quiet and not sending messages of apology to the affected users.
- (g) Both operators have to continue training their technicians /engineers in order to improve their skills regarding to the field where they are into.

### **5.3 Suggestion for Future Research**

Quality of Service (QoS) indicators in the user's perspective in general, apply to the services, regardless of the supporting technology infrastructure. Since the recorded results show a strong correlation with the technology, in particular in respect of test parameters, and therefore its application to emerging technologies in the market, such as High Speed Download Packet Access (HSDPA), High Speed Upload Packet Access (HSUPA) and Long Term Evolution requires further study and development of appropriate parameterization test.

To extend the scope of this work to new services such as mobile TV and others that may present relevant use by consumers of electronic communications, it is necessary to define specific Quality of Service (QoS) indicators and eventually to reformulation of measurement methods and techniques.[37]

Opting for an intra-network perspective, the Quality of Service (QoS) analysis, has underlying objective analysis of issues and clear allocation of responsibility for the quality of service observed. However, while this approach continues to be hosting the largest share of the use of mobile services and, as such, is the largest contributor to the quality perceived by users, inter-network and roaming perspectives assume increasing importance, and the need to their inclusion

in Quality of Service (QoS) analysis. The deepening of the aspects presented in chapter two may be the starting point for this work.

Finally, the specifics of this type of networks, services and users make it difficult to define statistically representative samples, in geographical and temporal terms, opting usually for oversampling. The definition of sampling appropriate methods that would optimize the cost analysis of networks and services.

## **5.4 Limitations**

The research was based on a case study of Quality of Service ( QoS) for Angolan Mobile Operators, Unitel and Movitel, getting information from these two operators was not easy, the author only managed to get few from them, from national regulator and the rest the author had to carry out the questionnaires to the users in order to get the average of Quality of Experience from the users as mentioned before in previous chapters . This could not be well achieved as these companies were not willing to divulge information pertaining to security challenges on their products on offer.

Conclusions deduced were that this was so because no organization is prepared to give an advantage to its competitors by revealing its weaknesses.

The other issue is an issue of protecting one's brand and that came on to the forefront. The two operators want to maintain that they are offering the best services thereby attracting as many users/subscribers as possible.

Another limitation was the unwillingness of concerned technicians / Engineers of both operators to divulge information in their relevant department in compliance with the oath signed between the employers and the employees. With fear of being fired no one is willing to put his head on the block just for someone to research on issues which might negatively affect the performance of the company.

Another challenge was lack of information in the field of people being afraid to provide the relevant information regarding to the Quality of Experience (QoE) of the end users.



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# APPENDICES

Appendix 1:- (Questionnaires for none technical people)

Usa/Use [X]no quadro apropriado

Provincia/Province :

Operadora/Operator:

Questions for non-technical people

**1 Quais são as horas que você normalmente experimenta o tempo de inatividade (Serviços para baixo) e quanto tempo leva para ser normalizado?** (What are the times do you normally experience down time (Services down) and how long does it take to be up?)

.....  
.....

**2 Quantas tentativas você faz antes de você ter sucesso em uma chamada?** (How many tries do you make before you succeed in a call?)

4 Tentativas/ Tries  3Tentativas/ Tries  2Tentativas/Tries  Outros,Especifica

**3 O que você pode dizer sobre a velocidade da internet no seu telefone, a velocidade que você experimenta durante o dia e a noite?** (What can you say about the speed of the internet on your phone, the speed you experience during the day?)

l.....  
.....  
.....

**4 Você enfrentar alguns desafios no envio de SMS para alguém da mesma rede ou de rede diferente, se sim quantas vezes e quanto tempo leva?** (Do you face some challenges sending SMS some anyone with the some network or different network, if yes how often and how long does it take?)

5 mins     4 mins     3 mins     2 mins     Outros, Especifica

**5 Qual é o melhor momento para entrar na internet e porque desse tempo?** (What is the best time do go on the internet and why that time?)

I:.....

II:.....

Appendix 2 :-( Questionnaire for the technical people)

Provincia / Province:.....

Operadora / Operator:.....

Questions for the technical people

Usa/Use [X]no quadro apropriado

**1 Quanto tempo vocês levam para resolver inatividade ou quanto tempo é que inatividade leva na vossa rede?** (How long do you take to solve the Downtime or how long does the down time take in your companies?)

Usa/Use [X]no quadro apropriado

30 mins  20 mins  15 mins  10 mins  Outros,Especifica

**2 Quais são as causas usuais de inatividade em vossa rede?** ( What are the usual causes of Down time in your network?)

I :.....

II :.....

III:.....

IV:.....

V:.....

**3 Após o tempo de inatividade, a operadora envia uma mensagem pedindo desculpas aos clientes afetados e quanto tempo a mensagem leva para ser enviado?** ( After the down time, do you send the apologize message to the affected customers and how long does the message take to be sent?)

24 Horas  10 Horas  8 Horas  Outros, Especifica

**4 Qual é a duração média de tempo de inatividade por semana (tempo total de inatividade por semana / número de interrupções)?** (What is the Average duration of downtime per week (total downtime per week / number of outages)?)

l.....  
.....

**5 Qual é a perda  $E_r$  = Erlangs por site por hora?** ( What is the  $E_r$  = Erlangs loss per site per hour?)

l.....