Czech University of Life Sciences Prague

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Diploma Thesis

Mobile Telephony and Internet in Afghanistan: Issues of Network Coverage and Quality of Service

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Mohammad Asif

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Mobile Telephony and Internet in Afghanistan: Issues of Network Coverage and Quality of Service

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Objectives of thesis

The thesis investigates the Network Coverage and Quality of Service of Mobile Networks in Afghanistan. The main objectives of research are to study the current state of Quality of Service and Network Coverage of Mobile Networks in Afghanistan.
The partial goals are such as:
- to study the current state of Network Coverage and Quality of Service Provide by Mobile Networks in Afghanistan,
- to analyze the challenges and weakness from both technical and end users' perspectives, and
- to recommend solutions based on survey from end users and interviews with Mobile Operators and Government Telecom Regulatory Authority namely ATRA.

Methodology

Methodology of the thesis is based on literature study and practical research. At the beginning the literature review will be done and then own research on the given criteria will be performed. The own research will be done through questionnaire survey and interviews. When the data is collected and analyzed, the practical recommendation will be given and conclusion of the research will be formulated.

The proposed extent of the thesis

60 – 80 pages

Keywords

Mobile Internet, Mobile Telephony, Mobile Network Coverage, Quality of Service in Mobile Networks, Quality of Experience, 3G Mobile Networks, 4G Mobile Networks.

Recommended information sources

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Declaration

I declare that I have worked on my diploma thesis titled "*Mobile Telephony and Internet in Afghanistan: Issues of Network Coverage and Quality of Service*" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the diploma thesis, I declare that the thesis does not break copyrights of any their person.

In Prague on 30 March 2016 _____

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I should first and foremost, thank my master thesis advisor, Dr. Milos Ulman, who was most responsible for helping me make this work a success. His encouragement and guidance combined with a superior, in-depth knowledge in the area of mobile communication have enabled me to complete this research. Dr. Ulman's patience and kindness have made him not only an excellent advisor, but also a friend. He was always there to answer me any question and share his comments on some new ideas I might have had.

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I would also like to thank the Government of the Czech Republic for providing me a fully funded master's degree scholarship. I hope and I pray for further strong bilateral relationship and friendship between two great countries; Afghanistan and the Czech Republic.

Last but not least, I would like to leave the remaining space in memory of my Grandma (1945 – 2014). I will miss her deeply in my graduation ceremony.

Mobilní telefonie a Internet v Afghánistánu: Problematika Pokrytí sítě a Kvalita Služeb

Souhrn

Na základě dostupné literatury a na základě zkušeností autora v oboru, existují významné výzvy v oblasti pokrytí sítě a kvality služeb mobilní telefonie a mobilního internetu v celulárních sítích v Afghánistánu. Tyto problémy byly hlavními důvody, které vedly autora zjistit kritické, hlavní a vedlejší úkoly, a dále navrhnout adekvátní řešení založené na analýze dat, testování hypotéz, dostupných pokročilých technických schématech. Autor provedl rozhovory s koncovými uživateli, provozovateli a také se zástupci organizací MCIT a ATRA.

Mezi hlavní zjištění nerovnost žen a mužů, generační propast a nízká úroveň gramotnosti v přístupu k mobilním službám v Afghánistánu. Získaná data dále ilustrují stupeň spokojenosti koncových uživatelů s pokrytím sítě, kvalitou služeb mobilní telefonie a mobilního internetu. Dále jsou indikovány nejvíce obtěžující situace, které koncoví uživatelé zaznamenali během telefonního hovoru a používání mobilního připojení na internet. Výsledky naznačují, že většina koncových uživatelů používá mobilní telefon pro telefonní služby a většina stížností pramenila z nízké intenzity signálu, nízké rychlosti přenosu dat, blokovaných hovorů, ztracených hovorů a nízké intenzity signálu ve venkovských oblastech (např. na vesnicích, venkově a v blízkosti hranic). Závislosti mezi specifickými proměnnými, které byly testovány, a na základě výsledku chí - kvadrát testů byla určena úroveň závislosti mezi proměnnými. Pokročilá technická schémata pokrytí sítě a kvality služeb navržené různými výzkumníky byla rovněž přezkoumána.

Na základě výsledků, autor doporučuje nasazení malých buněk, zvýšení počtu testů, instalaci základnových stanic na vhodných místech, nasazení nejnovějších samo konfiguračních a samo optimalizačních schémat předávání hovoru mezi sousedními buňkami, zvýšení hodnot parametrů základnových stanic, nasazení vyššího řádu sektorizace a zvýšení počtu TRX základnových stanic jako vhodná řešení pro odstranění stávajících problémů v oblastech pokrytí sítě a kvalitu služeb mobilní telefonie a mobilní internet v Afghánistánu.

Klíčová slova: Mobilní telefony, mobilní internet, pokrytí sítě, kvalita služeb, kvalita použití, mobilní sítě.

Mobile Telephony and Internet in Afghanistan: Issues of Network Coverage and Quality of Service

Summary

Based on available literature and author's experience in field, there are some challenges existing in the area of network coverage and quality of service of mobile telephony and mobile internet of cellular networks in Afghanistan. These challenges were main driving forces which moved author forward, in order to specifically find that, which are critical, major and minor, and furthermore propose adequate solutions based on analysed data, tested hypotheses, available advanced technical schemes, and conducted interviews with end users, operators, the MCIT and the ATRA.

Among main findings belong, gender inequality, generational divide, and low level literacy in access to mobile service in Afghanistan. Obtained data further illustrates, the satisfaction degree of end users from the presence of network coverage, quality of service of mobile telephony and mobile internet. It furthermore indicates, the most annoying situations which end user experience during telephony conversation and mobile internet in the country. The Results show that, the majority of end users use mobile phone for telephony service, most of the complaints have raised from low signal intensity, low data rate, blocked call, dropped call, and low signal intensity in rural area (e.g. villages, countryside and borders). The dependency between specific categorical variables have been also tested, and based on the result of the chi – square test, the level of dependency between them are determined. Advanced schemes of network coverage and quality of service proposed by various research scholars have been also reviewed in order to study and furthermore address the existing challenges technically.

Based on the results, author recommends deployment of small cells, increasing number of drive tests, appropriate location for BTSs installation, deployment of recent self – configured/self – optimized schemes of handover and neighbouring cell list, increasing the value of the base station parameters, deployment of high order Sectorization, and increasing of numbers of TRXs of base station as adequate solutions for removing existing challenges in the areas of network coverage and quality of service of mobile telephony and mobile internet in Afghanistan.

Keywords: Mobile Telephony, Mobile Internet, Network Coverage, Quality of Service, Quality of Experience, Cellular Networks.

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1. Introduction

Expectations of mobile phone user from presence of improved network coverage in any populous area, enhanced quality of service (QoS) of mobile telephony and higher data rate of mobile internet have moved operators, vendors, researchers and standardization bodies forward, to introduce new techniques and propose advance schemes in the area of wireless cellular communication. Recent statistics provided by the International Telecommunication Union (ITU) show that, globally 95% of populous area covered by 2G cellular networks and 69% by 3G service (29% of rural and 89% urban areas). Based on this statistics, there are still more populous areas (both rural and urban) in the world, which need to be covered and people need to be accessed by telecom service, as basic human rights. Furthermore, network coverage in existing covered area needs to be improved, QoS and quality of experience (QoE) to be enhanced (ITU, 2015).

The Afghan telecom sector is no exception, it has had tremendous growth since 2002. So far, 2.4 billion U.S Dollars have been invested in both private and public sectors, millions of citizens have been connected, thousands of jobs have been created and hundreds of small and medium businesses have been emerged. Despite the success in connecting of Afghans together and with the rest of the world, there are still main challenges remaining on the road to success. Some of the existing challenges in telecom sector can be listed as following: 11% of populous area is not covered by telecom service, existing network coverage needs to be improved in terms of availability and reliability, both 2G and 3G services provided by cellular networks to be enhanced, compare to other South – Asian countries a necessary change needs to be brought in current service prices, completion of national optical fibre backbone, and finding a secure, reliable and multi - route gateways for international telephony and internet traffic.

1.1 Background

The telecom sector is at the developing stage in Afghanistan. The 3rd generation mobile technology has already deployed in most rural and urban areas. Some provinces are under 2G and 2.5G coverage, while citizens of some populous areas still don’t have access to mobile phones and the internet service. Building a modern national telecom infrastructure, where all populous areas covered by telecom service, citizens to be accessed by high quality of service and exchange information anytime, anywhere with

reasonable prices are the major priorities of the Afghan Government. AFTEL (Afghan Telecom Corporation) and Salam, state – owned fixed line operator and mobile GSM operator are, respectively, two main building blocks of telecom Infrastructure in the country. The private sector has also played significant role in mobile industry. AWCC (Afghan Wireless Communication Company), Etisalat – Afghanistan (ETA), MTN – Afghanistan (MTNA) and Roshan are the largest investors of the global system for mobile communication in the country.

Recent statistics provided by the Afghanistan Telecommunication Regulatory Authority (ATRA) show that, 89% of populous area of the country is under mobile service coverage, there are 6,189 installed BSs (Base Stations), 23,114,471 people have access to mobile phones, 748,223 are 3G broadband subscribers, 1,856,781 are internet subscribers, and 2.4 billion USDs have been invested in the sector, which have resulted in long term economic growth in the country (ATRA, 2015).

A national optical fibre ring has been implemented by AFTEL in three phases. The purpose of this project is to connect all provinces and districts of the country by optical mean. The capacity of the optical fibre will let operators to deliver service with enhanced quality and reasonable price. So far, 3,100 kms optical fibre has laid, which connects 21 provincial capitals as well as connects Afghanistan with its neighbours. It has been planned that four more provincial capitals will be connected with the ring at the end of 2016 (ESCAP, 2015). On the other hand, each GSM network operator has its own high capacity microwave backbones across the country. In some locations, mobile operators have also interconnections with AFTEL optical fibre. However, all of these three cases play significant role in increasing of data rate, widening network coverage and improving of overall performance of the networks which directly effect on end user satisfaction degree. All of these efforts have been made, in order to provide improved network coverage in any populous area and also provide telecom service with enhanced quality and reasonable price.

This thesis covers network coverage and quality of service of mobile telephony and mobile internet provided by five GSM operators in Afghanistan. The document hereby, focuses on the topic from both technical and end user perspectives. The available state of the art have been reviewed, filed research and interviews have been conducted, existing challenges in the area have been addressed, adequate solutions have been suggested and further research directions have been proposed in next chapters subsequently.

2. Objectives and Methodology

This chapter addresses the motivations, objectives, and methodology of the research. It furthermore contains main research questions. Research framework and design have been also discussed, and at the end, the organization of the document is described.

2.1 Research Motivations

The ordinary mobile phone user satisfaction degree is affected by three parameters which are: access to service anytime / anywhere, the quality of service and the price of service. It's necessarily important of end users to understand, which technologies are being used by operators in order to offer the service. They just want to be connected to network all the time and enjoy enhanced quality of service with as much reasonable price as possible.

Afghans are no exception, based on author's experience in the field and refer to (8AM.af, 2012) (Hamim, 2013) (Maiwand, 2012) (Naweer, 2011), the mobile phone users complain from all of three mentioned metrics of mobile service. On the other hand, no research has been conducted and no particular literature is available on these challenges in the country. In order to fill the gap, this topic has been chosen, studied and adequate solutions only related to network coverage and quality of service have been proposed. It should be noted that the issue of high price of mobile service is still an open research area and is not covered by this document.

Refer to result in chapter four, majority of end users are using mobile phone for telephony service, most of the complaints have raised from low signal intensity, low data rate, blocked call, dropped call, and low signal intensity in rural area (e.g. villages, countryside and borders). Therefore, author recommends deployment of small cells, appropriate location for base stations installation, increasing the value of the base station parameters, increasing number of base station TRXs, and deployment of high order Sectorization as adequate solutions for removing existing challenges in the areas of network coverage and quality of service of mobile telephony and mobile internet in Afghanistan.

2.2 Objectives

The main objectives of this research are, to study the current status of network coverage and quality of service of mobile telephony and mobile internet of five GSM

operators in Afghanistan, analyse the existing problems and propose adequate solutions from both end user and technical perspectives.

It should be noted that, this document only addresses existing network coverage and quality of service. Study of expanding of network coverage to non – covered areas and emerging quality of service of mobile networks in Afghanistan are out of the main objectives of this research.

In order to address the topic, it has been decided to: study the current status of the cellular coverage and quality of service, conduct field and online survey with end users, perform interviews with MCIT, ATRA and operators, analyse the challenges and weaknesses from both technical and end user perspectives, and suggest appropriate solutions based on data interpretation and interviews. Advanced available schemes and proposals recommended by various laboratories and research institutions around the world have also significant role in order to study the topic technically.

2.3 Methodology

A survey, from 1,515 mobile users (812 respondents via online survey from almost all 34 provinces and 703 respondents through personal interviews within 14 specific provinces) has been conducted in order to study network coverage and QoS of mobile telephony and mobile internet from end user perspective. On the other hand, recent advanced technical schemes proposed by various research scholars on the topic have been reviewed. Refer to existing available literature, based on survey's output, interpretation of hypothesis, advanced technical schemes related to the topic, adequate solutions and proper recommendations have been suggested in order for the service providers to improve network coverage and increase overall performance of quality of service of mobile network in the country.

The collected data has been processed in SAS (Statistical Analysis Software) in order to analyse and furthermore interpret the result. As long as all variables of collected data is categorical, thus, the dependency between variables have been tested. Contingency tables have been created and chi-square test has been performed for specific variables in order to test dependency between them. After running the chi - square test, the critical test value has been compared with the value of distribution table, considering degree of freedom. Based on this comparison, the hypothesis is either rejected or not, and the result of the dependency is interpreted subsequently.

The MCIT and the ATRA are state - owned institutions which are in charge, to issue licence to vendors and operators, to regulate the service provided by operators, to make policies and strategies for the ICT sector, and to take decisions for achieving fully competitive marketplace. So, it is really important to have their opinions on the research, thus, interviews with MCIT and ATRA representatives have been conducted in order to understand which steps to be further taken by government for improving network coverage and enhancing quality of service.

Operators have also their own policies and strategies for providing enhanced quality of service and improved network coverage, therefore, the author has also conducted interviews with the representatives of GSM operators to address, how to overcome the challenges in the area, existing in their networks.

2.4 Main Research Questions

The following main research questions are to be answered in this document:

I. How to remove non – covered zones and simultaneously improve existing network coverage of mobile operators in Afghanistan, where all Afghan citizens have access to service anytime in any populous area?

II. Which techniques, schemes and technologies should be used by mobile operators in order to provide existing mobile telephony service with enhanced quality in both rural and urban covered areas, in Afghanistan?

III. Which techniques, schemes and technologies should be used by mobile operators in order to provide existing mobile internet service with enhanced quality in both rural and urban covered areas, in Afghanistan?

2.5 Research Framework and Design

The design and framework of this research are shown in Figure – 1, where each phase has been described in details. As shown, research on existing knowledge, analysing of network coverage and quality of service of mobile telephony and mobile internet provided by cellular networks in Afghanistan, performing online survey and personal interviews with end users, testing statistical hypothesis, interpret the result of the data, conducting interviews with MCIT, ATRA and operators, finding conclusions, recommending solutions, specifying further research directions, and writing down the report are subsequently the main parts of this research.

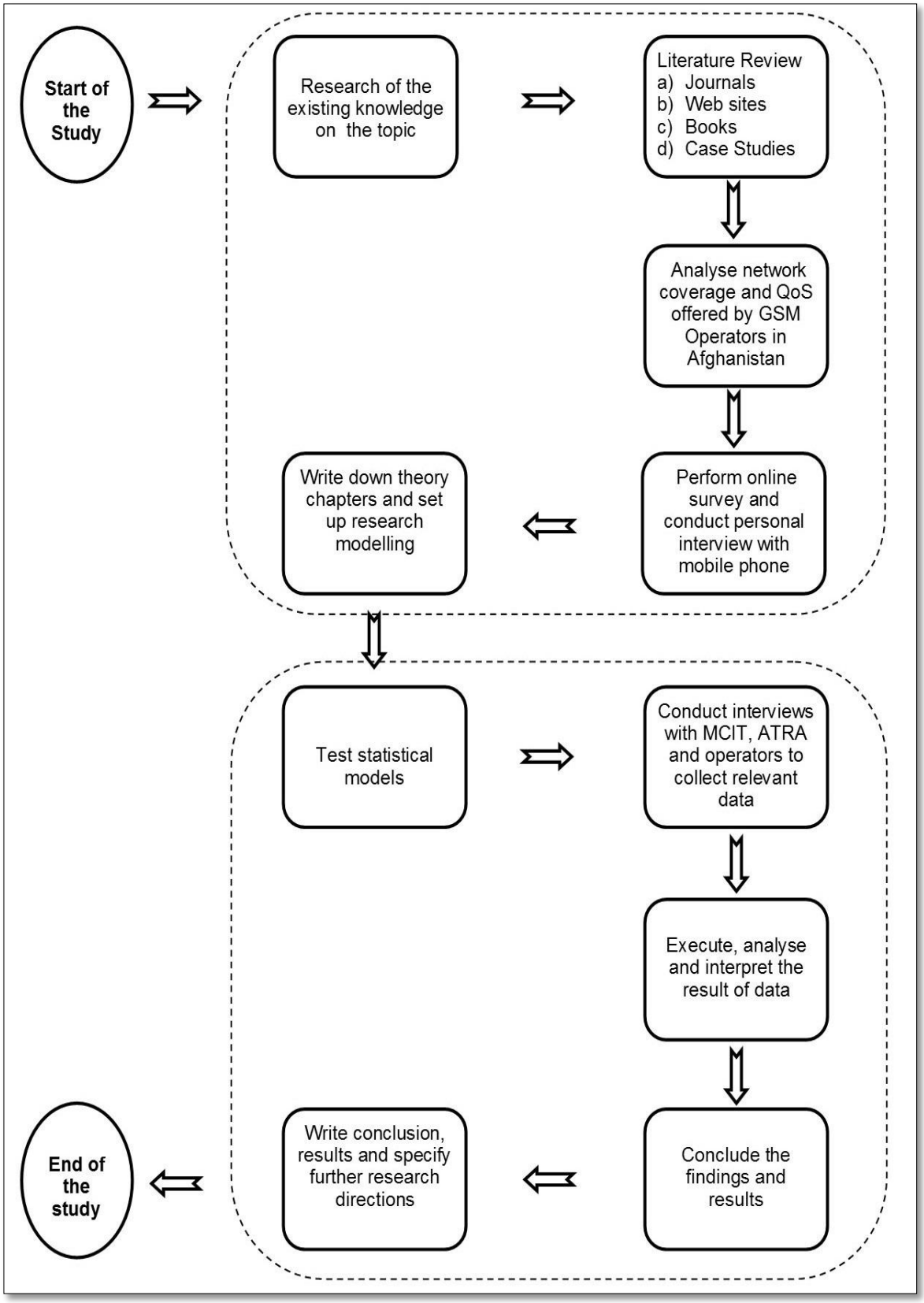

Figure 1 – Research framework and design

Source: Author's own work

2.6 Research Structure

This document contains five chapters and an appendix. The first chapter is the introduction, which covers the background of the research topic. In second chapter, objectives and methodology of the research have been discussed. In third chapter, a detailed look to available literature related to the topic have been reviewed. The fourth chapter is the practical part, the data which has been obtained from survey of end users has been analysed and statistical models have been tested, the data has been furthermore interpreted and based on the result the adequate solutions and proper recommendations for the challenges have been suggested from both technical and end user perspectives. In the fifth chapter, main findings and results are discussed, further research directions, limitations and answers to the research questions have also presented. The sixth chapter concludes the document.

Last but not least, an appendix has also been attached to this document. The appendix contains, the questionnaires, which have been used in collecting of primary data from end users through both online survey and personal interviews.

3. Literature Review

Researchers, vendors, network operators and standardization bodies around the world recognize the importance of presence of mobile service in any populous area (network coverage), quality of service (QoS) and furthermore quality of experience (QoE). All of these three parameters have significant role in increasing of satisfaction degree of mobile users who are already customers of service provider, attracting of new customers to network operator and keeping them for long and very long period of time (Haryadi, 2013).

Almost all existing wireless networks are based on cellular technology, where a particular geographical area is covered through a set of small cells called cluster. The term cell is used for a small mobile network covered area which obtains from low power transmitters / receivers called base station. The cell can be further divided into smaller area called Sector. Each cell can be 3, 4, 6 and even 12 sectors. The process of cell division into sectors is called Sectorization. A mobile network topology consists of hundreds of clusters. Once topology has designed, it is possible to add and remove cells to/from existing network for expanding and optimization purposes.

Various methods are available in order to provide and furthermore optimize network coverage as wide as possible. But there are some certain phenomena, including coverage blackspot, distant location of base stations and so on, which reduce the strength of signal of network coverage and furthermore cause dropped call, blocked call, noise during conversation, difficulty of hearing other party voice, slow mobile internet, internet timeouts and increased battery usage which highly impact on quality of experience. Recently, different schemes have been proposed and many techniques have been developed in order to measure, improve and optimize existing network coverage. Most of these techniques have been described here in details.

Once a particular geographical area has covered by the cellular network, the operator has to maintain the quality of service. A set of requirements should be defined by both operator and vendor for the network in order to deliver enhanced quality of service to the end user. The end user has also a sort of metrics, which evaluates the performance of the network. This evaluation of mobile network by the end user is called quality of experience (QoE). Couple of schemes and proposals are available, in order to optimize quality of service in the network and increase end user satisfaction degree, which will be discussed in coming sections in details.

As mentioned in second chapter; 1, 515 end users have been interviewed (through both online survey and personal interview). This data has been processed in SAS for obtaining of various updated statistics related to network coverage, QoS and QoE of mobile operators in Afghanistan. Available network coverage and QoS schemes have been reviewed in order to find appropriate solutions for improving network coverage and enhancing quality of service.

3.1 Mobile Network Coverage

Network coverage is actually a particular geographical area, in which mobile network propagates radio waves through base stations in order to provide service for mobile phone users. Coverage is basically illustrated as percentage (%) of the resident population who are able to use mobile user equipment (UE) for telephony or internet services inside or outside of their own homes (Mishra, 2007).

As mentioned earlier, the coverage area is divided into cells and each cell is covered by one base station. The cell can be also divided into smaller geographic areas which is called sectors. Each cell can be non- sector (Omni), two sectors, three sectors, four sectors, six sectors and so on (Wang, 1999). When cells grouped together within a specific geographic area form cluster.

Existing mobile networks use both macro and small cells. The traditional GSM networks use macro cells. These cells are currently found mostly on highways or rural areas and cover wider locations. Small cells (Micro, Pico and Femto) can also be integrated with macro cell for enhanced quality of service and improved coverage purposes. The deployment of small cells on one hand increase overall performance of the network and provide full coverage, on the other hand raise many challenges, including mobility management, radio resource management and complexity of handover process (Smallcellforum, 2012).

One of the key characteristics of a cellular system is the ability to reuse frequencies in order to improve coverage and increase capacity of the network. Adjacent cells must use different frequencies, however, there is no problem with two cells sufficiently far apart from each other operating on the same frequency band. Frequency reusing technique improves capacity and spectral efficiency. In this concept, the frequencies allocated to the network are reused in cells and clusters. Neighbour cells use different frequencies, and it can be only reused for those cells which are located far away from each other. In frequency reuse technique mutual

interference between cells should be considered. In theory, cell is expressed in hexagonal form, but in practice it is quite different from theoretical form and can be found in various shapes and sizes. The shape and size of cell depend on surrounding area and various parameters of the base station (Mishra, 2007).

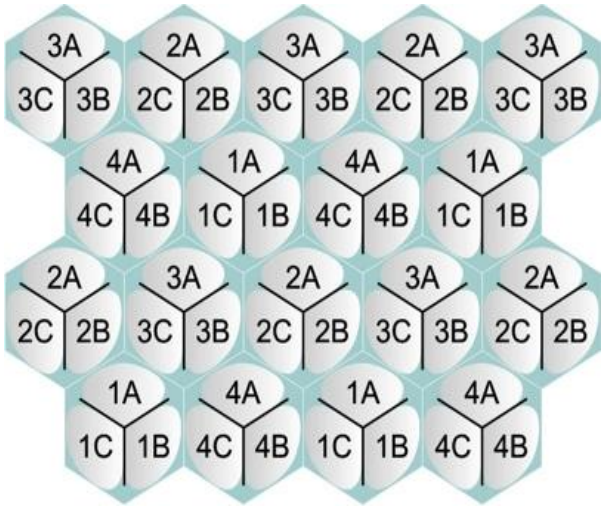

Figure 2 – Cell clusters and frequency reuse

Refer to Figure -2 (Teq, 2013), three base stations are located together in one site. These base stations are in three sectors named A, B and C. As shown, each sector covers 120^0 target area. In traditional GSM900, as long as 124 frequencies are available, then the normal solution is to use four – cell repeating scheme and frequencies are needed to be reused (Teq, 2013).

Multiple access techniques have also significant role in improving of capacity and expanding of coverage of cellular networks. As far as second generation technologies use TDMA and FDMA, thus it is easy to plan network more efficiently, because the different parts of the network use different frequencies in different time intervals, so each part can be individually planned and individually configured. While third generation technologies, mainly UMTS and CDMA2000 use WCDMA, which make the planning phase more complicated because same frequency is used by neighbour cells, so the inter - cell interference should be strongly concerned.

In WCDMA systems, network capacity and coverage are related to each other. The size of cell coverage changes with the change in capacity and number of users, which is called Cell - Breathing. Cell - breathing is a term in WCDMA system, where the coverage area of a base station depends on the number of users and capacity. If there are more subscribers the cell becomes small and if there are less subscribers the cell

coverage area becomes larger. In fact, capacity and coverage area are indirectly proportional to each other. While in traditional FDMA and TDMA systems (e.g. GSM), each subscriber is provided by full transmit power of base station, but in CDMA system (e.g. UMTS and CDMA2000), output power of base station is divided among all active subscribers.

One of the major services which is provided by cellular systems is mobility management. It is a fundamental requirement of mobile network that lets end user moves from one cell to the next, it has to be possible to hand the call over from the existing base station, to that of the next with no discernible disruption to the call. Mobility management is basically a set of functions for controlling and supervising of user equipment in a cellular network to locate them in order to deliver the required services and to maintain their connections when they are moving within coverage area (Johnson, 2008). It is one of the most critical features in a cellular communications system due to the direct effect on user experience, network performance and power consumption. Mobility management has two main components which are location management and handover management.

Location management enables a cellular system to track the current location of mobile equipment within network. When users do not engage in any communication and simply move around, the system has to track them in order to provide possible service to them. This also requires mobiles to inform the system when they move, thus the system can locate them based on previously reported information.

Handover management is another key function by which wireless network supports mobility and maintains QoS. There are two terms, which mainly use for this process: cellular handover is used within the European Union, whereas cellular handoff is used in the North America. HO enables network to maintain UE's connection during moving from the coverage area of one cell/sector to another. HO is process of transferring an ongoing voice call or data session from one cell connected to the CN to another. HO is divided into two broad categories: Hard HO and Soft HO. In Hard HO, current resources are released before new resources are used. However, in Soft HO, both existing and new resources are used during the process.

3.1.1 Cellular Technology

As mentioned earlier, a cell is a specific geographical area covered by a cellular telephone transmitter. The transmitter itself is called the cell site or base station. Cells

are arranged in a honeycomb pattern for providing local, regional and national coverage. The cell provided by a base station can be from one mile to twenty miles in diameter, depending on terrain and transmission power. Several coordinated cell sites are called a cell system. As long as all existing mobile technologies are using this scheme for providing service, that's why the cellular term is always attached to mobile networks (Raciti, 1995). Cellular communication system is a set of coordinated cells, which covers a specific geographic area and the cellular technologies are the techniques, schemes and methods which provide coverage, maintaining and supervision of UE connections

Basically, cells are categorized in two groups which are macrocells and small cells. Macrocell provides radio coverage served by a high power cellular base station. This cell provides a larger coverage than any types of small cell. The antennas for macrocell are mounted on ground-based masts, rooftops and other existing structures, at a height that provides a clear view over the surrounding buildings. Macrocell base stations have power outputs of typically tens of watts. Macrocell performance can be increased by increasing the efficiency of the transceiver. These cells are usually installed in rural areas or highways and cover up to tens of kilometres.

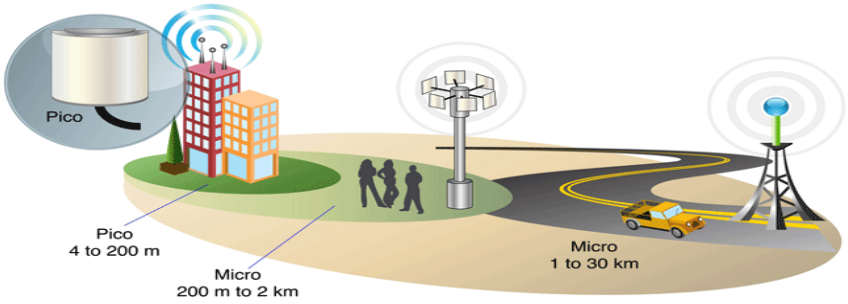

Figure 3 – Mobile network cell types

As shown in Figure – 3 (Callahan, 2013), small cells, have smaller coverage area compare to macrocell base stations. Small cells operate in both licensed and unlicensed bands and cover from 10 meters up to 2 kms. These cells are categorized into three main types: Microcells, Pico cells and Femtocells (Smallcellforum, 2012).

Micro – cells: The coverage area of this cell is from 200 m to 2 km and used to increase capacity and improve network coverage in existing macro cellular networks. These cells are installed both indoors and outdoors.

Pico – cells: This cell covers smaller area than microcells e.g. buildings, train stations, shopping malls and so on, which reach up to 200 meters or less (Callahan, 2013). The main purposes of these cells are, to extend indoor coverage where outdoor signal do not reach or exist at lower levels, and to add more capacity in area where huge amount of users are using mobile service (Networks, 2011).

Femtocells: The base station of this type of cell is self – contained, has lower – power and typically designed to use in homes or small businesses. As shown in Figure – 4 (Saunders, 2009), these cells cover in the order of 10 meters. Deployment of femtocells benefits both to the operator and to the consumers. The attractions of femtocells are improvements to both network coverage, especially indoors, and to capacity. Femtocells improve coverage because of fulfilling of gaps existing in the macro cell coverage area and eliminate loss of signal which occur through buildings. Deployment of femtocells also improves capacity by reduction of the number of user equipment attempting to use main network cells and by the offloading of traffic through user's network (via the internet) to the operator's infrastructure (Saunders, 2009).

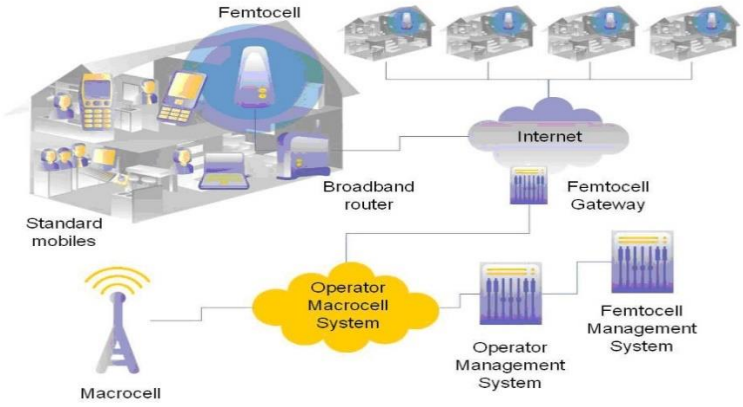

Figure 4 – Deployment of femtocells in macrocellular network

3.1.2 Sectorization and Antenna Types

The last and the closest equipment from network side which is directly communicating with UEs is an antenna. It is an electronic device which converts electrical waves to radio waves and vice versa in order to transmit and receive user data and telephony services through an air interface (Scholz, 2000). The designing and choosing of an appropriate antennas for network have significant role in the performance of network coverage and quality of service. Polarization, Gain, Beam

width, Power density, Impedance, and effective length and aperture are the fundamental parameters that characterize an antenna (Scholz, 2000).

There are different antenna types, which are being used in existing mobile cellular technologies. Antennas can be classified in several ways. One way is the frequency band of operation. Others include physical structure and electrical/electromagnetic design. Most simple, non – directional antennas are basic dipoles or monopolies. More complex, directional antennas consist of arrays of elements, such as dipoles, or use one active and several passive elements, as in the Yagi antenna.

New antenna technologies are being developed that allow an antenna to rapidly change its pattern in response to changes in direction of arrival of the received signal. These antennas and the supporting technology are called adaptive or "smart" antennas. Below are some of the common antenna types which are being used in existing cellular technologies.

Omni – Directional Antenna: This antenna radiates or receives equally well in all directions. It is also called "non-directional" antenna, because it does not favour any particular direction (Cisco, 2007). This antenna is applicable where 360^0 azimuth coverage is required. In UMTS Networks, this type of antenna is used mainly for indoor coverage, homes or dense urban area. This omnidirectional antenna is designed for the frequency of 1800-2100 MHz (3G, UMTS) and has a gain of 14dBi.

Directional Antenna: Gain and directivity are intimately related in antennas. The directivity of an antenna is a statement of how the Radio Frequency (RF) energy is focused in one or more directions. Because the amount of RF energy remains the same, but is distributed over less area, the apparent signal strength is higher. This apparent increase in signal strength is the antenna gain. The gain is measured in decibels over either a dipole (dBd) or a theoretical construct called an isotropic radiator (dBi). So, the directional antenna transmits or receives radio frequencies in one or more specific directions. These antennas have one main lobes and more minor lobes (Cisco, 2007). This antenna is usually installed on highways and rural areas.

A directional antenna has to be aligned very exactly to the UMTS station, it will be connected to. It has a gain of 17dBi and can build up UMTS connections on high distances. This directional antenna is specially designed for the 1800-2170 MHz (3G, UMTS) frequency band.

30, 60 90 and 120 Degree Sector Antennas: Generally speaking, a sector antenna is mainly directional microwave antenna with a specific sector – shaped radiation pattern. Some portion of the circumference of a circle measured in degrees of arc. 60°, 90° and 120° designs are typical, often with a few degrees 'extra' to ensure overlap and mounted in multiples when wider or full-circle coverage is required. The 120^0 sector antenna covers one of the third parts of the full coverage, thus three 120^0 sector antennas are needed to cover a 360^0 full coverage in UMTS or any cellular networks. This sector antenna is appropriate for installation in any environmental weather condition.

Three sector antennas ($3*120^0$) mainly use in traditional macro cellular networks. Whenever the demand for capacity increase, then this type of antenna cannot fulfil the user requirements and need to be installed more antennas or by other mean the sectors should be increased in order to provide enough capacity. To increase or widen the coverage area, thus the number of serving clients, several sector antennas are installed on the same supporting structure.

Four sectors ($4*90^0$), six sectors ($6*60^0$) and twelve sectors ($12*30^0$) are the sectors which are used to provide high capacity and increase the performance of network coverage. But it should be noted that increase of Sectorization increases the number of softer handover in the networks and existing of overlapping increases the number of soft handover which impact on network performance.

3.1.3 Network Coverage Measurement Methods

Variety of proposals have been developed and many schemes have been suggested in order for operators and users to measure the coverage of cellular networks in a specific geographical area. Generally speaking, some of the measurement methods are using percentage as a unit of network coverage, while some other methods do not. In this thesis the most valuable and appropriate schemes and methods are discussed.

The recent report (ECC REPORT, 2007) published by Electronic Communication Community (ECC) of the European Conference of Postal and Telecommunication Administrations (CEPT) describes a traditional method for network coverage measurement. The report illustrates that logging of UE to the network is an appropriate criteria in order to decide whether the area is covered by an operator or not. The report suggests specific technical parameters in order to measure network

coverage. These parameters include Received Signal Code Power (RSCP), Signal – to –interference - ratio Ec / I0 and Received Signal Strength Indicator (RSSI).

RSCP is actually a collected RF energy after correlation which is given in dBm. Ec / I0 is given in dB, is a ratio of the received energy per chip and interference level. RSSI is given in dBm, it is a value which takes both the RSCP and RSSI in to account. The RSSI can be obtained through the following formula.

$$RSSI\ [dBm] = RSCP\ [dBm] - Ec/I0\ [dB]$$

The report also suggests the minimum critical values for all these three parameters which have been obtained through the simulations.

The Ec / I0 has fixed values in UMTS networks and the simulation of this report recommend (Ec / I0 > -9 dBm) which is shown in Figure – 5 (ECC REPORT, 2007).

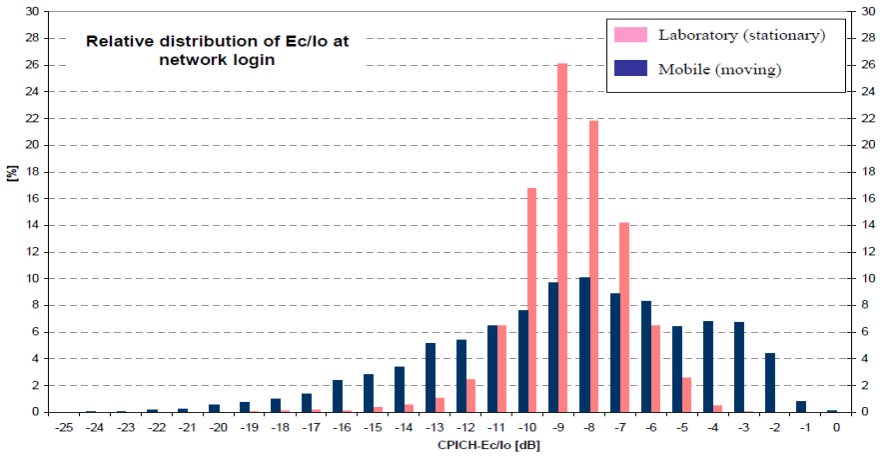

Figure 5 – Minimum Ec / I0 value to login to network

Refer to the Ec / I0 value of -9 dBm the minimum value of RSCP based on simulations is (RSCP > -114) and the minimum value of RSSI is (RSSI > -106 dBm). The Figure – 6, illustrates these values (ECC REPORT, 2007).

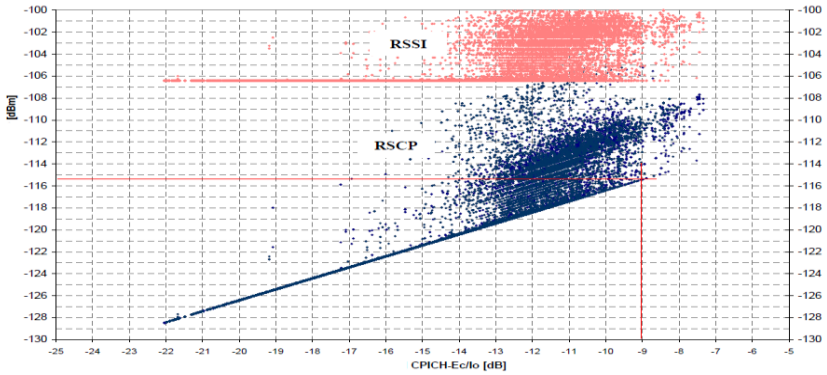

Figure 6 – RSSI and RSCP minimum values to login to network

The above values recommended by simulations and it is suggested for UMTS network planners to set them as minimum input values of mentioned parameter as the receiver input.

A white paper published by Anritsu (Anritsu, 2011) proposes to use Synchronization Signal (SS) power in order to measure network coverage in LTE. SS is an appropriate parameter in LTE in order for the operators to measure the QoS of downlink and its data rates.

Figure 7 – LTE coverage map in Google earth using Anritsu tool

SS has fixed value which correlates to the eNodeB maximum output power and then the maximum output power relates to the user sensitivity. Anritsu developed a tool based on this scheme, which called MT8221B BTS Master, this tool makes it easy and cheap in order to measure network coverage rather than drive test. A test of coverage map by this equipment has shown in Figure – 7 (Anritsu, 2011).

3.1.4 Network Coverage Optimization Techniques

Once a geographical area is covered by a mobile network, the base stations have deployed and the frequency has been planned, furthermore, it needs to be optimized continuously in order for the UEs to be covered by an improved coverage. Optimization is a vital component for an effective management of network coverage. So far, many methods have been proposed for a proactive optimization, some of these have been addressed here.

The proper location of a base station has significant role in improving of performance of network coverage. A practical case study (TelecoAntennas, 2015) on a Telstra‘s cell tower with 90^0 sector antenna uses four types of frequencies (156 MHz, 477 MHz, 885 MHz and 2147 MHz) with the same output power has been performed. The simulation result shows that huge amount of Blackpost is caused by the wrong

selection of tower location and a large area is still uncovered of the network services. This issue is illustrated in Figure – 8 (TelecoAntennas, 2015). The simulation furthermore explores that the lower the frequency is the greater distance is travel and that's why in next generation mobile technology it is preferred to use lower band frequencies in order to achieve greater network coverage.

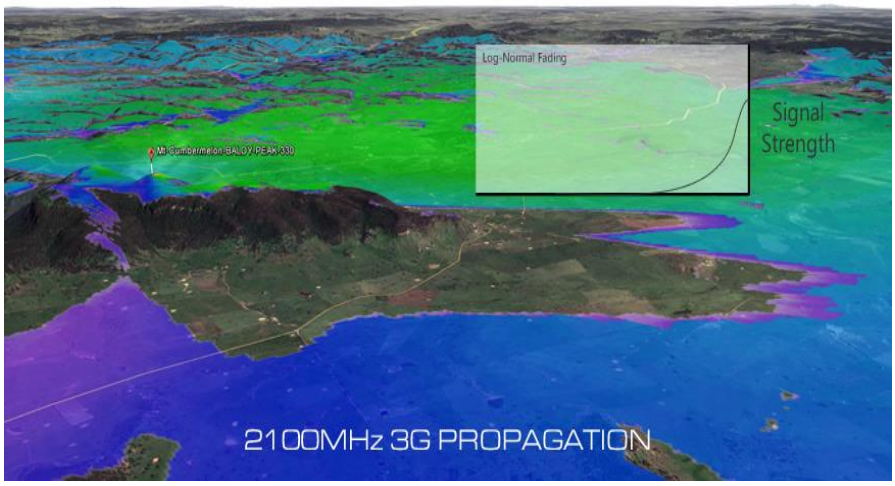

Figure 8 – Blackspot causes due to wrong selection of tower location

Using propagation models are another tools in order to predict network coverage. These are mathematical attempts which model the real radio environment as closely as possible. The paper written by (Sharma1, 2011) used Asset's Path Loss Model in a dense urban macro cellular environment and then the Received Signal Strength (RSS) has been calculated in order to determine the network coverage. The authors suggest that Antenna height, antenna power and antenna tilt are three parameters which influence on the improvement of network coverage.

The authors have tested antenna with height of (20 – 25) meters, with power of (38 – 43) dBm and with tile of (1^0 – 5^0). Based on simulations, the authors further propose that antenna height and power should be high while the antenna tilt should optimum. 25m height, 43dBm power and 2° tile are the values of the above mentioned parameters subsequently for obtaining better coverage.

Deployment of small cells within coverage area of a macrocell is another promising trend for operators to improve network coverage and simultaneously increase capacity of downlink layer. These small cells can cover a small range of distance with low user support, but provide high data rate. In some cases, small cells can be owned and completely controlled by end users. This scheme leads to provide both indoor and outdoor ubiquities coverages. There are couple of available schemes

for various cellular technologies that proposed by many research papers considering the deployment of small cells in the network.

The (Yeh, et al., 2008) proposes the deployment of small cells in WiMAX networks. The Authors consider a hierarchical overlay structure where macro cells and femto cells are deployed together. The femto cells and macro cells are furthermore assumed to work in the same frequency range and also using wired backhaul such as cable and DSL. The simulation result shows that, capacity (particularly downlink transmission) is increased and coverage is improved, but the challenge which is available on deployment of this scheme is higher amount of handovers. Because small cells are deployed massively, so the number of handovers is increased and the challenge of mobility management is raised which effect on the overall efficiency of network.

The proposal submitted by (Baumgartner & Bauschert, 2013) recommends, an energy efficiency scheme where author assumes first deployment of small cells UMTS radio access network and then considers to shut down the small cells in low traffic density. This scheme is more energy efficient.

Continuously drive test to get statistical data in order to improve network coverage is another scheme. In this scheme parameters, such as, signal quality, Interference, dropped calls, blocked calls, anomalous events, call statistics, service level statistics, quality of service information, handover information and neighbouring cell information can be measured and further more adequate solutions for improving network coverage can be provided.

However, there are a lot of schemes available in the literature, but the objectives of these methods, including the above are to optimize network coverage continuously. These methods can be deployed during configuration and optimization phases, but usually it is more applicable while optimization.

3.1.5 Mobile Network Coverage Footprints in Afghanistan

As mentioned, 89% of populous area of the country has been covered by cellular networks while still 11% of populous area don't have access to mobile phone and internet as basic human rights. There are 5 GSM and 2 CDMA operators, which provide service to Afghan citizens. But the country's mountainous terrain and lack of infrastructure are natural opponent phenomena's of network coverage.

ATRA has allocated frequency for 2G within the range of (890 – 960) MHZ and (1710 - 1880) MHZ and for 3G mobile networks within the range of (1920 - 2170)

MHZ. The PGSM uplink is operating in (890 – 915) MHZ while the downlink in operating in (935 – 960) MHZ. The EGSM uplink and downlink frequencies are (880 - 915) MHZ and (925 - 960) MHZ respectively. (1710 - 1785) MHZ is downlink and (1805 - 1880) MHZ is uplink frequencies for the DCS 1800. The 3G networks are operating in the country within (1920 – 2170) MHZ, (1920 - 1980) MHZ is uplink and (2110 - 2170) MHZ is downlink frequencies. The state – owned operator AFTEL and Wasel Telecom are CMDA based networks, the ATRA has allocated (826.11 - 843.35) MHZ for uplink and (871.11 - 888.35) MHZ for downlink (ATRA, 2014).

Figure – 9 (ATRA, 2015) and Figure – 10 (ATRA, 2015) express, the up to date mobile telephony and mobile internet coverage footprints in Afghanistan. As shown in Figure – 9 that, all 34 provinces are covered by 2G (CDMA and GSM) cellular system, while the figure – 10 illustrates that, except (Nimruz, Ghor, Uruzgan, Daykundi, Nuristan and Badghis) all other provinces are covered by 3G technologies either by one or more operators.

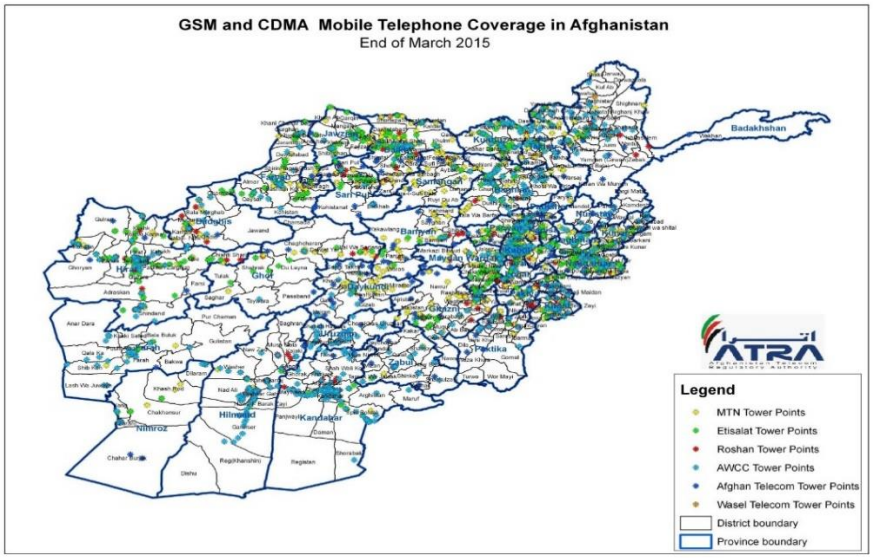

Figure 9 – Mobile network coverage in Afghanistan

MTN and Roshan are the operators which have provided detailed information for reference purposes on network coverage. MTN is covering 33 out of the 34 provinces and its service is available to 72% of the country's population (MTN, 2016). Roshan is covering all 34 provinces, including 230 cities and serving approximately 60% of Afghan citizens. Detailed maps and information on network coverage of Etisala – Afghanistan, Salam and AWCC can be found in (ATRA, 2015).

The coverage footprint and detailed information on both traditional cellular networks and existing 3G networks of each of the operators can be found individually in (ATRA, 2015).

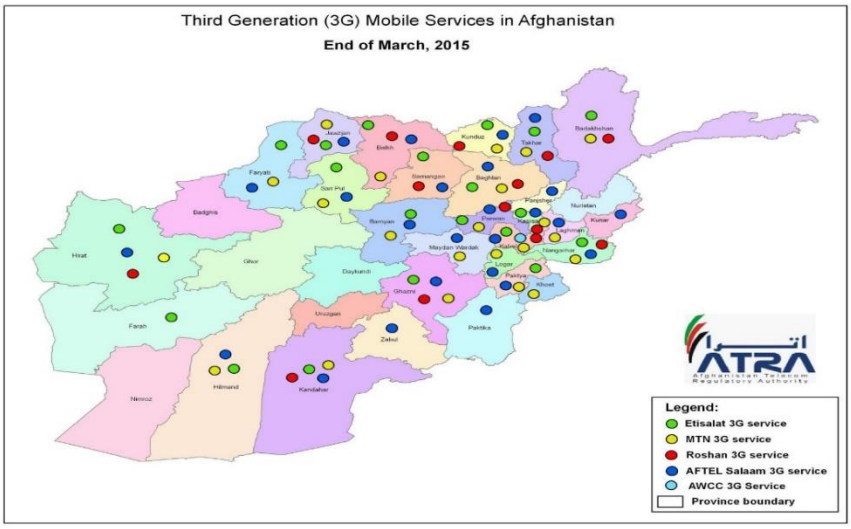

Figure 10 – Third generation mobile service in Afghanistan

As mentioned in second chapter, there is no available literature so far which include detailed information about network coverage in Afghanistan as well as end users‘ expectations from the operators to bring necessary change in this area. Thus remaining part of the network coverage and the result of the updated statistics, which obtained from the survey is discussed in fourth chapter.

3.2 Quality of Service of Mobile Networks

Quality of Service (QoS) in general in telecommunication and particularly in cellular network is the capability of the service provider to provide better and satisfactory service over different technologies to its end users, which includes voice quality of mobile telephony, signal strength, low blocking call probability, low dropping call probability, high data rates of mobile internet and multimedia applications, and so on.

Basically, there are two approaches of defining measurement and assessment of quality in mobile networks, these approaches should meet certain requirements. The first approach is the measurement of performance of QoS mechanisms and schemes from network perspective which is called quality of service (QoS). The QoS contains a set of mechanisms and schemes which deployed in the network and simultaneously should meet defined conditions. The metrics which include in the QoS (e.g., bandwidth,

packet loss, delay, jitter, packet loss rate, packet error rate, throughput, dropped call probability, blocked call probability) are described further (Sánchez, 2005). The second approach is the measurement of performance of network form end user perspective which is called quality of experience (QoE). The QoE includes overall satisfactions of end user from network and the ability that network meets their expectations during operations. Some of the QoE metrics include degraded seconds, errored seconds, unavailable seconds, and etc. (Lakhtaria, 2010).

The main difference between QoS and QoE is that, QoS is objective approach in order to assess the success of performing within a specified network subsection while the QoE is rather subjective, which is measured end – to – end, and involves human – related criteria.

QoS can be explained in both quantitative and qualitative manners. For instance, if the service is prioritized by network in categories, where first priority is given to telephony, second priority to short message service, third priority to web browsing, and fourth priority to e-mail and so on, is the qualitative description of the QoS. It can be illustrated by quantitative manner such as description of throughput, delay, bandwidth, blocked call and dropped call. For instance, the video streaming may require 32 kbps in order to reproduce in the mobile terminal, the GSM network bandwidth for an individual users is 13.6 kbps and so on can be quantitative. The quantitative manner is much more complex rather than qualitative (Sánchez, 2005).

Existing and emerging complicated service in internet networks are needed to be controlled and managed better than traditional networks. The Best Effort (BE) service was not an issue in the last decade, but nowadays it does matter in existing heterogeneous networks. In fixed telecommunication network, increasing the backbone capacity and access to end user bandwidth, while in wireless network, radio resource management are vital issues to be discussed in order to measure and subsequently manage the QoS.

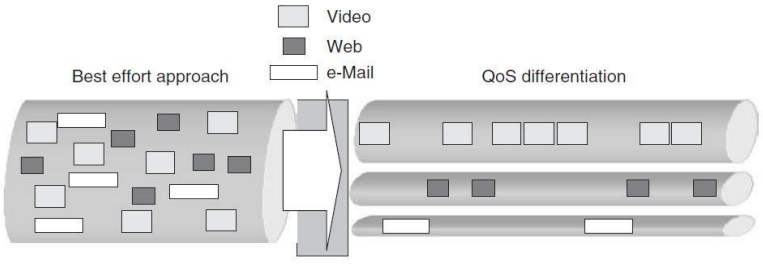

Figure 11 – QoS differentiation and best effort approach

In the first step, networks should define a set of technique for QoS in order to support real – time service and new mobile data applications.

Later on, packet should be classified and network should treat it, considering number of active users and application requirements. Figure – 11 (Scholz, 2000), shows this mechanism in more details and easily, where packets of video, web and e-mail are classified. Figure – 11, furthermore illustrates that high priority is given to video and less priority is given to e-mail in order to guarantee the lowest delay and use the bandwidth efficiently.

Wireless data use both cellular and IP based network environments. Both of these networks have different protocols and functionalities, so a unified or cooperative standardization is needed in order to obtain optimum QoS for end users. Internet Engineering Task Force (IETF) and third Generation Partnership Project (3GPP/3GPP2) are working together to provide unified and standardized environment where services are mixed of both IP based and cellular networks.

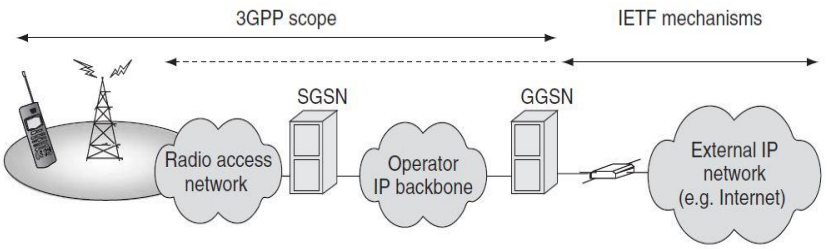

Figure 12 – End to end QoS management

So far, various schemes and proposal have been suggested in both IP based and cellular heterogeneous networks in order to deliver an effective QoS to the end user. The most well – known schemes in the IP based network, which have been proposed by the IETF are the Differentiated Services (DiffServ), Integrated Services (IntServ) and Multi-Protocol Label Switching (MPLS). While in the cellular networks the first ever QoS framework defined by 3GPP release 97 and later much more proposal have been suggested by researchers. Figure – 12 (Scholz, 2000) illustrates, that, how the 3GPP and the IETF standards cooperate in order to provide, enhance and unified quality of service.

Proper classification of the data services can also help network to manage the service and to have control of it, in order to increase end user satisfaction degree and

use resource adequately. Table – 1 (Scholz, 2000), shows the data service classification in the network, which allows network to have control weight and quality requirements.

Table 1 – Data service classification

Service	Reliability	Delay	Guaranteed bit rate
e-Mail	High	High	No
Fax	Low	High	No
Web/WAP browsing	High	Medium	No
Audio/video streaming	Low	Medium	Yes
Audio/video conference	Low	Low	Yes

Table – 1, furthermore illustrates, that, how services are classified according to reliability, delay and guaranteed bit rate in data networks and furthermore how does network treat them.

3.2.1 Quality of Service Parameters in Mobile Networks

Quality of service parameters, from network and operator perspectives in mobile communication era can be generally divided into two groups which are technical and managerial (Seth, et al., 2007). The managerial parameters consist of functional and internal quality which cover the mechanisms of delivering services to the end users, top management and leaders' commitment to QoS, team technical capacity building and so on. The technical parameters include performance of cellular mobile communication network for e.g., bandwidth, throughput, drop calls and etc., which are discussed further in details. All of these parameters which discussed have directly or indirectly effect on the satisfaction degree of end user and on quality of experience.

In this thesis most focus is on the technical parameters of quality of services and furthermore metrics of quality of experience will be discussed. The managerial parameters of quality of service are out of the main objectives of this thesis.

The Overall voice quality of mobile telephony and high data rate of mobile internet are functions of many factors and technical parameters such as delay, bandwidth, throughput, blocked call, dropped call, errors and loss frames, echo and so on. During designing of an algorithm for enhancing of quality of service in wireless cellular networks, it is highly recommended that these parameters should be taken into account in order to remove barriers on the way to enhanced services.

The technical parameters of quality of service of mobile networks are the most important part of service delivery. They are vital to the network performance and have

direct influence on end user's satisfaction. As a major part of this research, these parameters have been used in both, survey of mobile phone users and studying of available algorithms, thus a detailed overview of some of the important and mostly used parameters is taken below:

Delay: It is the main parameter of quality of service in both fixed / mobile and packet / circuit networks. Delay is basically the elapsed time for bits / packets to be transmitted from the sender, through mobile network, and received at the receiver. The higher the value of the delay is, the greater the stress on the transport protocol is to operate efficiently and provide enhanced quality of service. The velocity of the nodes, the number of the hops, and average distance travelled in one hop are three parameters which are considered in wireless cellular networks. The number of the nodes in the architecture also play an important role in the delay, the more nodes in the architecture are involved the more delay is between sender and receiver during an active session, the less nodes are involved in the architecture the less the delay is between sender and receiver thus the throughput is high (Caushaj, et al., 2014).

In designing of algorithm or generally in the planning phase of a network, it is really important to understand and simultaneously count for the delay components in the network. If network designer and planner calculate and count all delay occur in the nodes, it ensures the overall performance of the network and also improves the satisfaction degree of end users.

Bandwidth: It is the most well-known parameter for both technicians and for the end user of mobile phones. Through, this parameters end users can easily understand, how much data they can transmit / receive in a specific period of time. In telecommunication, the following two definitions are available for bandwidth in literature:

- Bandwidth is data transfer rate, or by other mean, the amount of the data which can be carried out from one point to another in a specific time period (mainly measure in seconds). Bandwidth is measured in bits per second (bps), all existing mobile networks have a speed of megabits per second (Mbps) or even can be gigabits per second (Gbps).
- Bandwidth can be a range of frequency or difference between the highest and the lowest frequencies. For example, the frequency range of GSM operators in Afghanistan is (890 - 960) MHz, means the 2G mobile networks can only operate within this range of frequencies in the country. In this case, the

bandwidth can be measured in hertz. Although, this meaning of bandwidth is used in cellular networks of spectrum allocation for the operator which is the real and original meaning of bandwidth.

Bandwidth has significant role in satisfaction degree of end users and can be a vital parameter which highly influences on quality of experience of mobile phone end users. The higher the bandwidth the mobile telephony / internet is the more end users are satisfied with the operator.

Throughput: In mobile communication, throughput is the actual data rate of a device or network that can be transferred from one location to another in a given time. This data can be delivered either over physical or logical channels, and it can also be bypassed through a particular node in the network. Throughput is usually measured in bits per second (bps), data packets per second (pps) and data packets per time slot.

The main difference between bandwidth and throughput is that, bandwidth is the theoretical maximum amount of data that can be transmitted per unit of time from one location to another, while throughput is the real and the actual data rate that can be transmitted from a node in the network to another in a given time.

Packet Loss: In packet based switching technologies such as GPRS, EDGE, UMTS and existing LTE and LTE – A, when packets (either a single or more) of data travel from a source across the network and fail to reach its destination is called packet loss. Packet loss is typically caused due to network congestion and it is measured as percentage of packets lost with respect to packets sent.

Packet loss is closely associated with quality of service of mobile networks. Different technologies and networks have various strategies for assigning of maximum rate of packet loss. For example, In the VoIP networks, losing of one or two data packets cannot effect on the conversation, while losing of (5 – 10) % of the packets, highly influence on QoS (Mansfield & Jr., 2010). On the other hand, dropping of even a single packet while transmitting of web pages or a document can cause losing a part of the file, thus highly reliable protocols are used in order to retransmit the dropped packets.

Prediction of packet loss rate of a network to network designers and furthermore its measurement to technicians are necessary in order for the network to deliver the service effectively which increase end user satisfaction degree.

Packet Error Rate: It is a measurement method in order to test performance of an Access Terminal (AT) of a receiver (RX). PER is described in percentage (%), which

is number of FTAP not successfully received by AT to the number of FTAP sent to the AT.

Bit Error Rate: In digital transmission system when a transmitter sends a sort of bits to a destination, sometime either one or more bits are alerted due to e.g., noise, interference, synchronization errors or so on. These alerted bits are received incorrectly by the receiver. The BER, same as PER can be described in percentage (%), is the number of the bit errors divided by the number of the total bits sent by a transmitter within a time interval.

The BER has vital role on the QoS of mobile telephony and mobile internet in the wireless cellular systems. If the transmission media between the source and destination is good enough, and the SNR is high, then the BER will be very small, which has significant effect on the overall system performance. On the other hand, if there is noise in the system, then the BER will occur, which has a negative impact on the system performance.

Jitter: It is basically the variation in the delay of receiving packets of packet – switching based technology network. When packets are sent from the transmitter side toward its destination in a continuous stream, these packets alerted due to, e.g., network congestion, improper queening or sometimes due to configuration errors. As shown in Figure – 13 (Cisco, 2006), the constant delay which is located within the packet stream cannot remain the same due to mentioned phenomenon and change to different time interval, this change in the packet stream is called Jitter (Cisco, 2006).

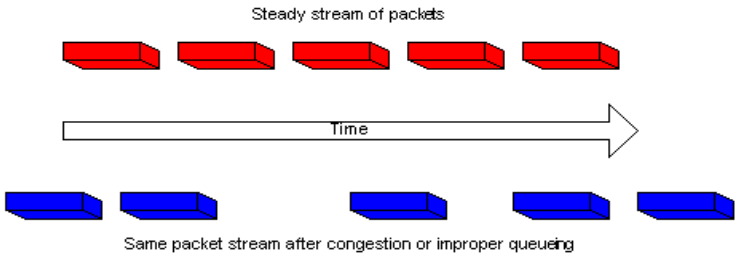

Figure 13 – Jitter in packet based technologies networks

Dropped – call: When two parties are talking on cellular phones and during the conversation, the call disconnects on its own, without any of the parties intentionally disconnecting is denoted as dropped call. Mostly, there are two reasons for call drops in the network. The most drop calls can happen when the users during the conversation travels into a zone where is no network coverage and the network doesn't able to detect

the cellular phone. Another reason can be that, the allocated bandwidth is being used elsewhere and there is no sufficient bandwidth in order to allocate for the conversation. The dropped call is measured in percentage (%), which is also called dropped call rate. The DCR, is used to measure the percentage of calls dropped due to technical problems or coverage gaps in the service provider's network as a ratio of the total number of calls successfully established.

Blocked – Call: In mobile communication when a circuit group is fully occupied and it is unable to accept further calls, this situation is call blocking. Due to blocking in mobile communications systems, calls are lost, these calls are called blocked call. The blocked call is also measured in percentage (%), and it is used to measure the percentage of calls blocked due to congestion in the service provider's network as a ratio of the total number of call attempts made to access and establish a voice call.

Blocked Calls = Lost call / Offered calls

Hand – Over blocking: In cellular networks, the phone users are moving from the coverage zone of a BTS to another, thus the network should handle the conversation and the ongoing call should be handled to the target cell. In some cases, the calls are lost due to complex handover procedures or due to occupied channels in the target cell, thus the call blocks from the system. Blocking call has massive effect on decreasing of QoS and QoE of wireless cellular network.

Above are the well – know and mostly used parameters, which effect on the quality of mobile telephony and mobile internet in wireless cellular networks. However, there are, several other events which can have high influence on both quality of service and quality of experience. The service provider needs to optimize the network and check these parameters of each node and the entire network continuously in order to offer service with enhanced quality.

The mobile network operator uses KPIs (Key Performance Indicators) in order to measure the performance of each node and overall network in order to be aware of and use appropriate schemes if any problem exists.

3.2.2 Quality of Experience Parameters and Metrics

As discussed in previous sections, Quality of Experience (QoE) is the measurement of the overall level of end user satisfaction of the service with his/her favourite mobile operator. QoE is often used in Information and Communication

Technology as an indication of the overall satisfaction with the service, the user receives from the network. Refer to existing literature, roughly 82% of mobile phone users‘ defections are due to frustration over the services provided by operator and the inability of the service provider to deal with the service efficiently. The research indicates that one disappointed customer tells 13 other customers about his/her bad experience with the service provider. The literature furthermore shows that, for every customer, who calls for a problem to customer service department, there are 29 others who will never raise the problem, and the survey shows that 90% of these customers will leave the operator once they become unsatisfied with the services (Vuckovic & Stefanovic, 2006).

Experience with the service provides by an operator is developed by end users‘ interacting with the network through a directly subjective process. From an end user perspective, various parameters and metrics of the service have importance in determining of Qualit of Experience. Some of the end users of an operator will prefer cost, while others value reliability. These parameters have vital role in keeping customer with the operator for long and very long period of time, thus it is essential for the service provide to understand its customers‘ needs and expectations. There are many factors which affect QoE including cost, reliability, availability, efficiency, privacy, security, interface user friendliness and user confidence.

Enhanced quality of experience illustrates that the mobile phone user experience with the operator is good enough, but, low the quality of experience indicates that the end users experience of the network is not sufficient (Vuckovic & Stefanovic, 2006).

3.2.3 QoS Optimization Schemes in Wireless Cellular Networks

Mobile communication plays vital role in today’s fastest growing technology and maximum priority has to be given to its quality of service. The end users have to be satisfied without wasting the available network resource. The QoS is related to both end users, and cellular service provider. It specifically means that, satisfying of customers with wasting network resources or saving network resources without satisfying of end users can not said to be quality of service. In this section, those mechanisms which affect customer satisfaction without wasting network resources are discussed.

It is really important to distinguish mobile network traffic based on priority level, it specifically means that some traffic classes should be given higher priority over some other classes. For example: voice traffic compare to data traffic should be considered as the most important service and high priority should be given to it, because voice traffic is more delay sensitive rather than data traffic. On the other hand, more preference has to be given to those customers who pay more in order to get better services, without affecting the QoS of remaining customers who pay the normal fee. In order to deploy all these scenarios, effective QoS schemes and proposals are needed to be deployed on the network.

It is really important in existing and emerging mobile networks to consider QoS in each layer (e.g. Physical, TCP/IP, Application and so on) individually and deploy their own schemes. This and some other schemes developed by many research scholars, which are effective to deploy in existing and emerging mobile networks are discussed below.

One of the traditional methods to improve cellular network performance is to continuously optimize network by performing RF and post processing measurement. The continuous network optimization improves network performance thus it helps service provider to attract more customer and simultaneously keep existing customersfor long and very long period of time.

The common test which is used for network optimization and post processing measurement is drive test. The tests should be performed in the area where service provider wants to test the network. The main objective of this test is to obtain enough sampling of calls which made in specific period of time and reseanable speed. The reports obtained for the test contains all required metrics of quality of service e.g. number of made calls, number of dropped / blocked calls (if), user equipment recieving power, speech quality and so on. The result of the report helps operator to understand where the capacity needs to be increased, which part of the networks has weak signal strenght and where coverage should be enhanced. Understanding and analysing of network status has vital role in the optimization of quality of service and based on avaliable information obtained from drive test helps operators to deploy appropriate strategies in order remove existing challenges and enhance QoS from the network (Sharma & Bansal, 2014).

Deployment of small cells in the network is another strategy in order to enhance indoor and outdoor network coverage and increase data rates, which effect on both

quality of service of cellular system and quality of experience. Heterogeneous environment helps operator to remove existing non – covered zones and increase coverage overlapping in the network. Both of these advantages can be obtained due to the massive deployment of small cells, thus the high number of end users may theoretically serve. On the other hand, the increase number of cells existing in a particular zone increase interference as well as increase number of soft and softer handovers, which are the main challenges on the road to successfully deploy small cells and obtain the highest performance (Kelif, et al., 2013).

Increasing of number of sectors and carriers (TRX) of base station are two effective methods which increase capacity. Traditionally, a macrocell with 3 sectors are using to cover 360^0 geographical area. But high data rate demands of end users will not be acquired by this scheme, thus high order sectorization and increasing of TRXs are appropriate solutions to be deployed by the operator. Available literature proposes two, three, four, six and even twelve sectors. These mechanism can help network providers to accommodate a greater number of subscribers and improve coverage to support both telephony and various data services. But despite the advantages obtained from high order sectorizations, some of the challenges also rise with this mechanism which are increasing the amount of handover and interference (Sheikh, et al., 2013).

Base station‘s location and Antenna’s orientation have also impact on enhancing of quality of service of cellular networks. A scheme proposed in (Lempiäinen, 2003) illustrates that UMTS needs more small base station site locations and antenna orientation deviations. The result of the paper explains that, during radio access planning phase, massive concentration should be paid on the base station location rather than on base station site and antenna’s configurations. The result furthermore indicates that the most appropriate scheme to achieve high capacity and increase data rata is to deply six sector strategy by utilizing 330 half power narrow beam antenna on abscissa, in the network.

Base Station‘s Antenna Beam width has also impact on the capacity of cellular networks. The scheme proposes by (Niemelä & Lempiäinen, 2003) discusses the downlink direction capacity of WCDMA cellular networks radio capacity. The result of the simulations shows that base station’s antenna horizontal beam width for the 65° , 90° and 33° sectors have significant role in enhancing of QoS. Thus, it can also be an appropriate method for increasing of QoS of cellular networks.

4. Practical Part

The main goals of the research have been described thoroughly in second chapter. In this chapter, the data, which has been collected from 1,515 mobile phone users in Afghanistan is executed in SAS, and furthermore interpreted. The document subsequently, suggests adequate solutions for the existing challenges in the areas of network coverage and quality of service of mobile telephony and mobile internet based on survey‘s interpretation and recent advanced technical schemes. The chapter also indicates the satisfaction degree of end users from network coverage and quality of service, gender inequality exists in access to telecom service in the country, and some more general indicators e.g. level of literacy and so on. The pilot survey has launched, then the online version and personal interview conducted from (Aug – Dece) 2016.

The main part of this research is to create hypotheses and interpret the result. The end users of mobile phone can only measure the quality of service and network coverage through qualitative manner. That’s why, the collected data is categorical, and the dependency between variables need to be tested. There are totally eight out of fourteen variables in the survey, which have been chosen for dependency testing. The following four hypotheses are created out of eight variables:

First Hypothesis

Is there any dependency between the categorical variables of “*Education level*” and “*Purpose of using of mobile phone*” of end users of cellular networks in Afghanistan?

Second Hypothesis

Is there any dependency between the categorical variables of “*No network coverage*” and “*Satisfaction degree of network coverage*” of end users in some locations of cellular networks in Afghanistan?

Third Hypothesis

Is there any dependency between the categorical variables of “*Situations which occur during telephony*” and “*Satisfaction degree of QoS of telephony*” of end users of cellular networks in Afghanistan?

Fourth Hypothesis

Is there any dependency between the categorical variables of “*Situations which occur during mobile internet*” and “*Satisfaction degree of QoS of mobile internet*” of end users of cellular networks in Afghanistan?

This chapter is organized as following: firstly general indicators and hypotheses are tested. Secondly, conducted interviews are presented, and furthermore the proposed adequate solutions have been discussed.

4.1 Data Analysis

Various social categories within the Afghan community use mobile phones for different purposes. In this survey, the end users were asked of some of the general social statuses e.g. the operator they are using, the time the users spent with the operator and so on. Figure – 14 shows, the gender of the respondents participated in the survey. From total 1,515 respondents, 25% of the users are female while 75% are male. The result of the survey indicates that, there is massive gender inequality exists in access to mobile services in Afghanistan.

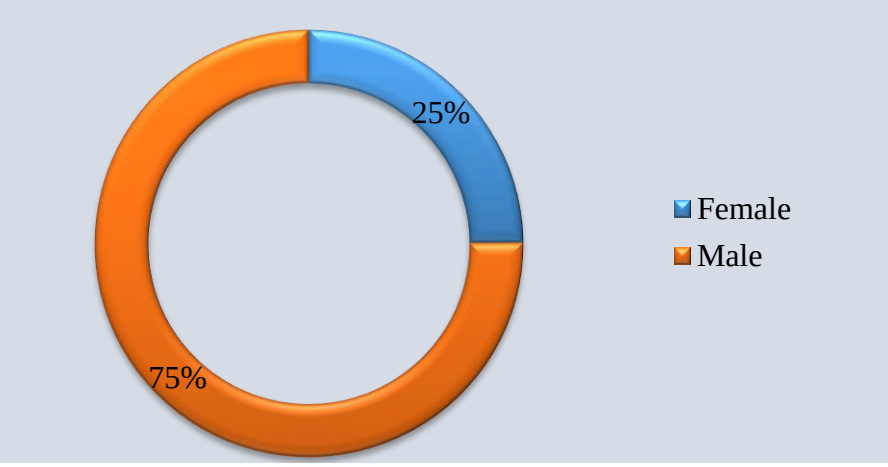

Figure 14 – Gender of mobile phone users

Source: Author's own work (1,515 random samples)

There are couple of reasons of being of gender inequality in using of mobile phones in a developing country such as Afghanistan. Many research scholars have pointed out that, high illiteracy rate of female, patriarchal societies, limited access to ICTs, structural and cultural barriers within society are main reasons which increase and keep gender inequality in developing world. As long as study of gender inequality in the ICT sector of Afghanistan is out of main goals of this thesis, and on the other hand, there is no literature exists in this era, thus it can be an open research area (Gurumurthy & Chami, 2014).

The respondents have further been asked, about their ages. The result of the survey in Figure – 15 shows that; 11% of mobile phone users are under 18, 6% are aged

45, 24% are between 30 – 45 years, and 59% are between 18 – 30 years old in Afghanistan. It can be concluded, from the result of the survey that, there is a huge generational divide in use of cell phone in Afghanistan. The teens and youths do use mobile phone for various purposes in their daily routines more than older aged generations. It is normal for Afghan youth (depends on level of literacy as well) to use smartphones in order to do vitually everything on it, while most of the elder don't.

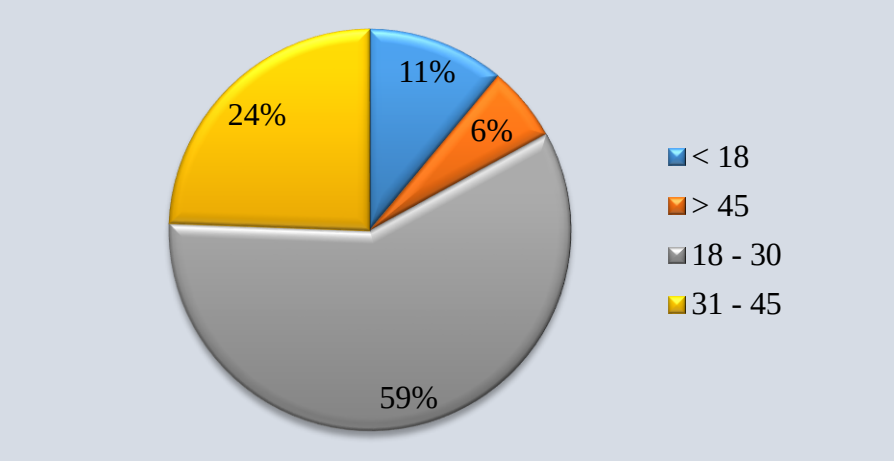

Figure 15 – The age of end users of mobile networks

Source: Author's own work (1,515 random samples)

The Level of literacy has significant role in using of mobile phone for both internet and telephony purposes. On the other hand, available literature indicates that using of mobile phone increases level of literacy as well. Recent statistics provided by the Kabul office of UNESCO shows that, the literacy rate in the country is 31% of the population mainly adult (over 15 years age), (UNESCO, 2014). Cultural norms of female not attending schools and spending time to manage the household, security problems on the way to schools, and in some cases family are not interested in the rural area to allow girls to attend the classes are main challenges on the road to enhance level of literacy in Afghanistan. The result of the survey in Figure – 16 shows that, 33% of Afghans who do use mobile phones are having bachelor degree, 28% of the citizen who use mobile phones are high school graduates, 8% are illiterates, 10% are having intermediate school educations, 8% are with master degree holders, 0.003% are PhD and 13% of mobile phone users are having primary educations.

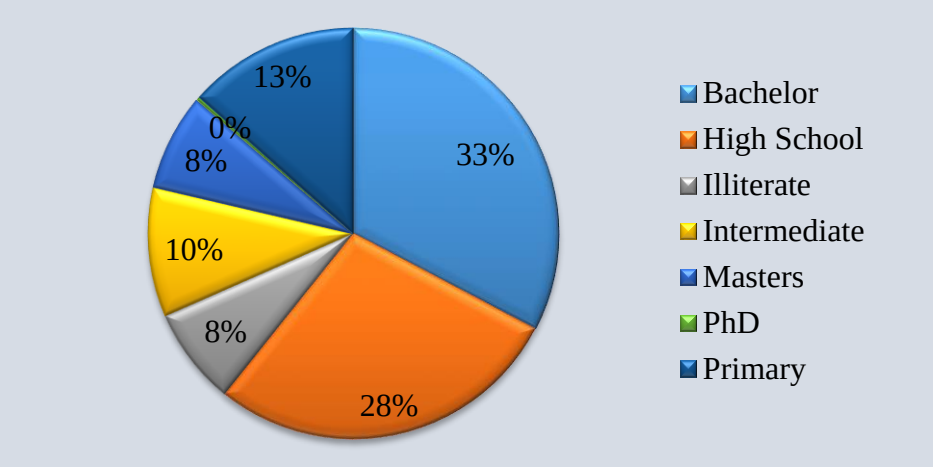

Figure 16 – Level of literacy of mobile phone users

Source: Author's own work (1,515 random samples)

Mobile phone users use a cellular phone in order to send/ receive message, access to internet, send/ receive email, download apps, get directions, recommendations or other location – based information, listen to music, participate in a video call or video chat, "Check in" or share your location, and so on. In the questionnaire, all of the mentioned applications of mobile are divided into 3 categories, mobile for internet purposes, mobile for telephony purposes and mobile for both internet and telephony purposes. The result of the survey in Figure – 17 shows that, 47.72% of end users are using mobile phone for telephony purposes, 48.51% of end users are using mobile phone for both telephony and mobile internet purposes, while the rest, 3.76% are using mobile phone for only mobile internet purposes in Afghanistan.

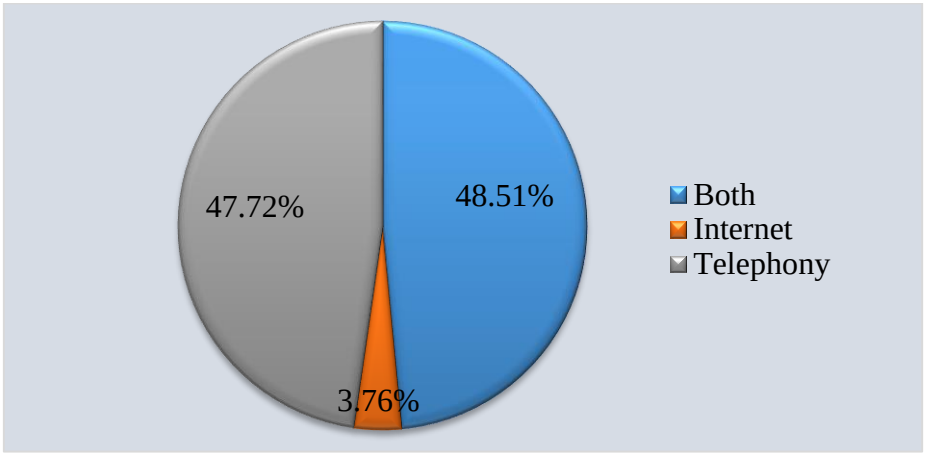

Figure 17 – Mobile phone usage purposes

Source: Author's own work (1,515 random samples)

It can be concluded from the result that, still a massive population of the country either don't have access or don't have skills to use the internet. The low rate of literacy, security challenges, geographical location of some areas are the main challenges, which impact on the internet deployment and usage in Afghanistan.

Both GSM and CDMA based operators are operaing in Afghanistan. But the main objectives of this thesis are on GSM Networks (AWCC, ETA, MTNA, Roshan and Salam).

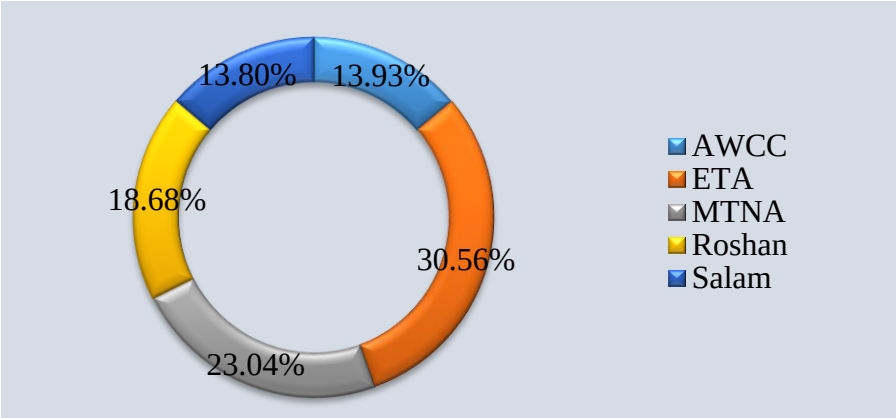

Figure 18 – Mobile networks end users

Source: Author's own work (1,515 random samples)

The result of the survey in Figure – 18 shows that, AWCC has 13.93% of mobile phone users, ETA has 30.56%, MTNA has 23.04%, Roshan has 18.68% and Salam has 13.80% of mobile phone users in Afghanistan. It can be concluded from the result of the survey that, ETA is the leading telecom operator in Afghanistan from end user perspective while Salam is at the end of the list.

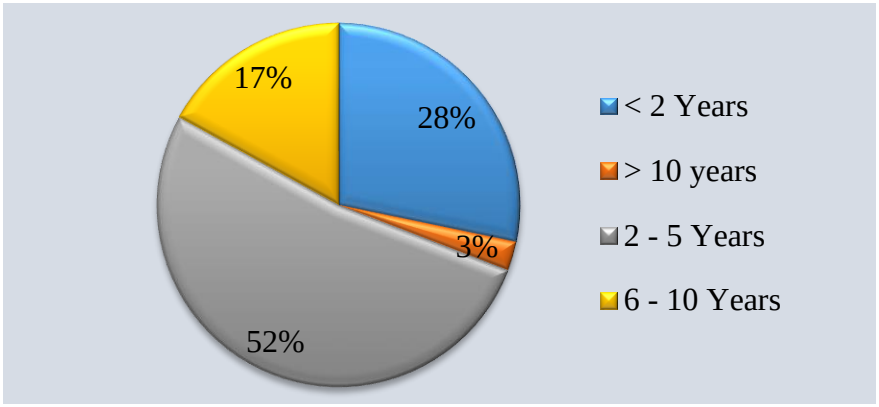

Figure 19 – Time which end users spent with operators

Source: Author's own work (1,515 random samples)

The time users spend with their favourite operators or, the policies and the strategies of the service providers which keep customers for long and very long period of time depends on enhanced quality of service, wide network coverage area and reasonable rates of the service. The result of the survey in Figure – 19 shows that, 52% of the end users of cellular networks stay with their favourite operators from 2 – 5 years, 17% from 6 – 10 years, 28% less than 2 years, and 3% of users more than 10 years in Afghanistan.

The end users were asked about their overall statistifction degree from network coverage. The result in Figure – 20 shows that, 42.44% of the mobile users are satisfied, 19.47% are unsatisfied, 7.32% are very satisfied, 5.08% are very unsatisfied, and 25.67% of mobile phone users are neutral from network coverage in Afghansitan.

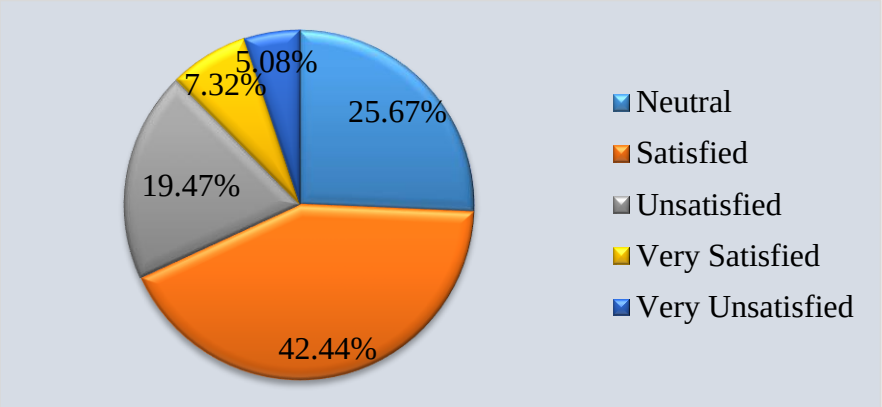

Figure 20 – Satisfaction degree of end users from network coverage

Source: Author's own work (1,515 random samples)

The survey further asks about the situations that end users experience when, they are located, or not under network coverage. Figure – 21 shows that, how much percentage of the end users in Afghanistan complain from no network coverage in some locations of the country. The result of the survey shows that, 8.38% of mobile phone users experience no network coverage in the boarders, 13.0% in the main cities, and 25.6% in the countryside.

The result in Figure – 21 shows that, 15.4% of end users experience, no network coverage on highways, 32.8% in villages, 4.6% of end users are totally satisfied and don't experience no network coverage in any locations.

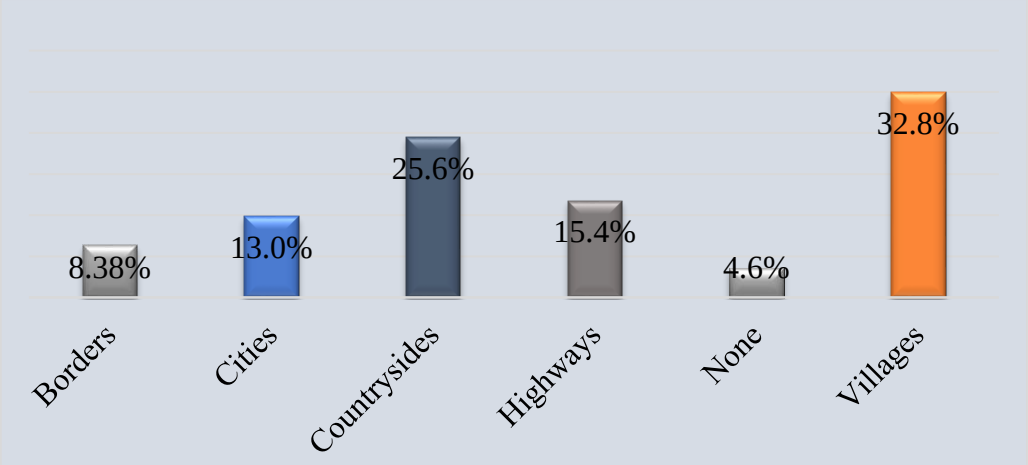

Figure 21 – Locations where no network coverage exists

Source: Author's own work (1,515 random samples)

The end users further asked about the quality of service of mobile telephony. The result is shown in Figure – 22 indicates that, 8.2% of the cell phone users are very satisfied, 44.8% are satisfied, 27.6% are neutral, 16.1% of the end users are unsatisfied, and 3.08% are very unsatisfied with the quality of the service of mobile telephony provided by GSM network operators in Afghanistan.

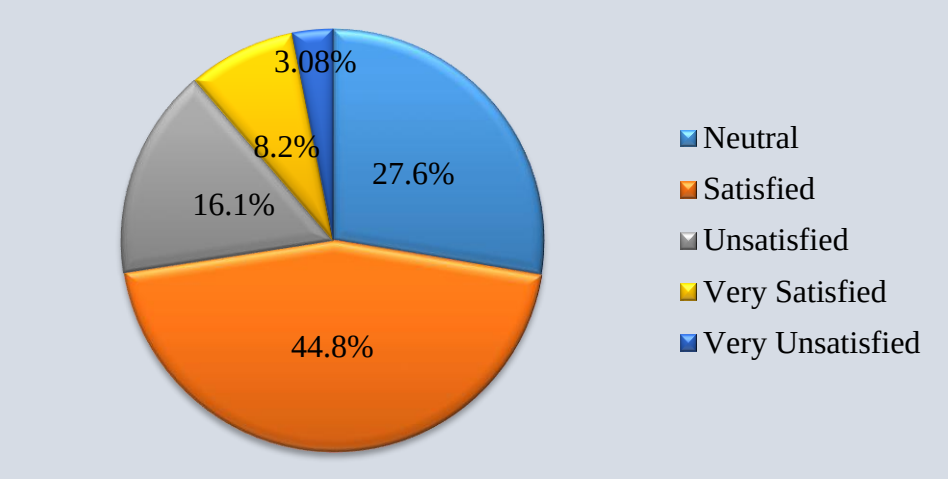

Figure 22 – Satisfaction degree of end users from QoS of telephony

Source: Author's own work (1,459 random samples)

The survey explores the situations which occur during telephony conversation and decrease satsification degree of the end users of the mobile networks in Afghanistan. Figure – 23 shows that, 17.6% of the end users of mobile phone experience blocked call (the situation when end user cannot be connected to the

network and receive the "network busy" message back from the operator) during telephony conversation.

The result shows that, 16.5% of the end users are complaining from the dropped call (The situation when the telephony conversation of an end user is cut off due to unknown reasons, before they finish). 10.8% end users were also complaining from Echo (When either called or calling party hear his/her own voice back on the conversation line).

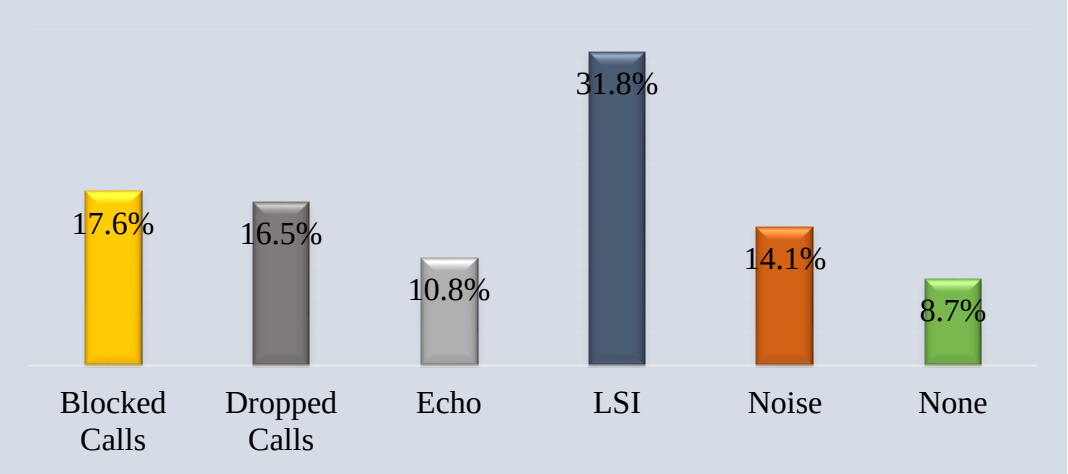

Figure 23 – Situations occur during, before or after telephony

Source: Author's own work (1,459 random samples)

The result shows that, 31,8% of end users complain from low signal intensity during and before of telephony conversation. Although the end users don't have any tools to measure the level of the signal, but they do know from the sign of signal on the screen which shows how the strenght of the signal of her/his mobile phone in the target area is.

Noise (the unwanted sounds which disturb end users' conversation during telephony call) while telephony conversation is another phenomenon which ends users are complaining in Afghanistan. The survey shows that, 14.1% of the end users, experience noise while telephony conversation in Afghanistan.

All of these situations which occur during telephony conversation, decrease the quality of the service provided by the operator and also decrese end user satisfaction.

On the other hand, the result of the survey indicates that, 8.7% of end users in the country experience none of the above situations during or before telephony

conversation they are quite satisfied with the service provided by their favourite operator.

Figure – 24 shows the usage of various mobile internet technologies in Afghanistan. The result of the survey indicates that, 73% of mobile phone users are using 3G internet technologies, 14% are using EDGE (Enhanced Data Rate for GSM Evolution), 7% of the end users use GPRS (General Packet Radio Service), and the rest 6% of the end users use the mobile networks SIM card for Wi – Fi purposes in Afghanistan.

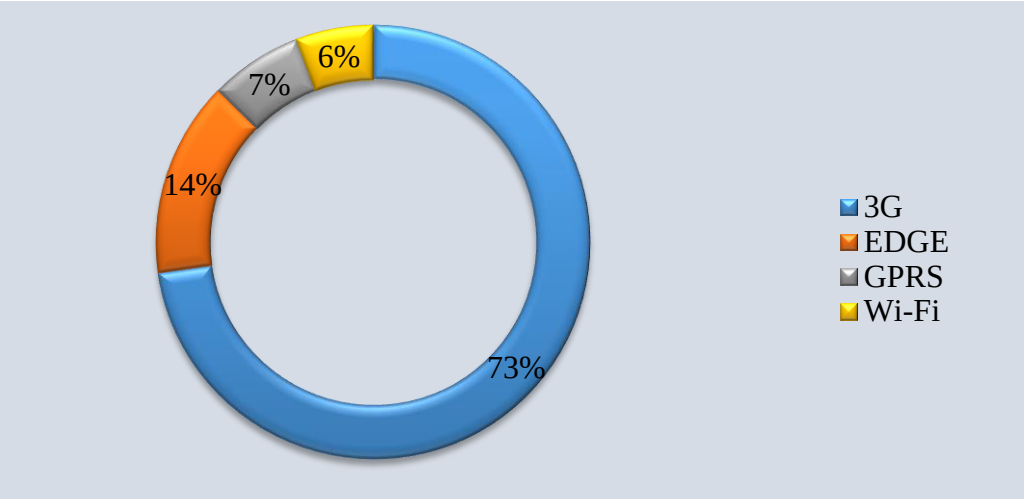

Figure 24 – Usage of various mobile internet technologies

Source: Author's own work (887 random samples)

Figure – 25 shows, the satisfaction degree of quality of service of mobile internet in Afghanistan. The result of survey indicates that, 29% mobile internet users are Neutral with the quality of service. The result, furthermore shows that, 29% of mobile internet users are satisfied with the QoS, 32% are unsatisfied, 5% are very satisfied, and 12% of the mobile internet users are very unsatisfied in Afghanistan.

It should be noted that, totally 1,515 end users were asked in the survey. Within this set of sample, 887 were using mobile internet (either with telephony or not) and 1459 were using mobile for telephony purpose (either with mobile internet or not), therefore in the analysing part of the data, the exact number of the sample for each of the part has been taken and it is various accordingly.

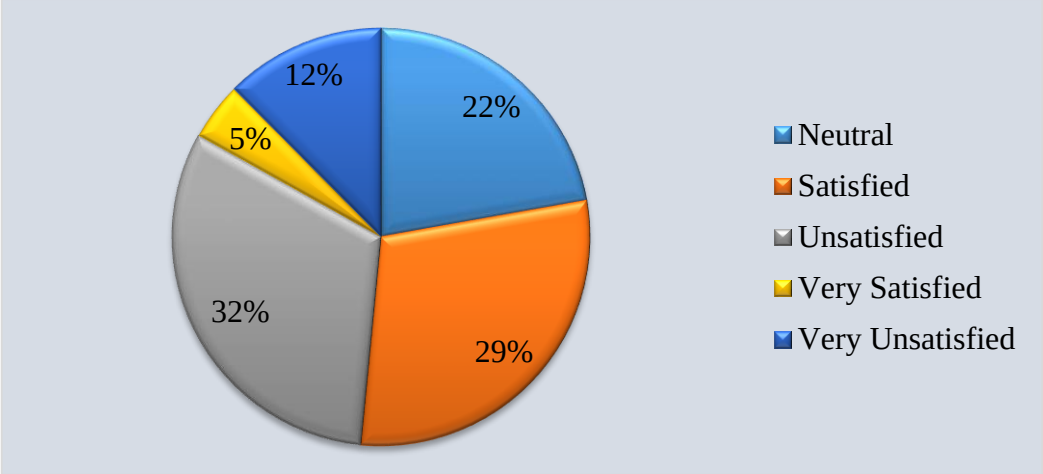

Figure 25 – Satisfaction degree of end users from QoS of mobile internet

Source: Author's own work (887 random samples)

Figure – 26 shows, the situations which occur during the usage of mobile internet in Afghanistan. The result of survey indicates that, 32.5% of end users of mobile internet limited coverage area of mobile internet, 26.9% experience low data rate, 12.8% experience lower performance during mobility, 23.9% experience low signal strength, and 3.7% are totally satisfied with the mobile internet and experience none of the mentioned situations during mobile internet usage in Afghanistan.

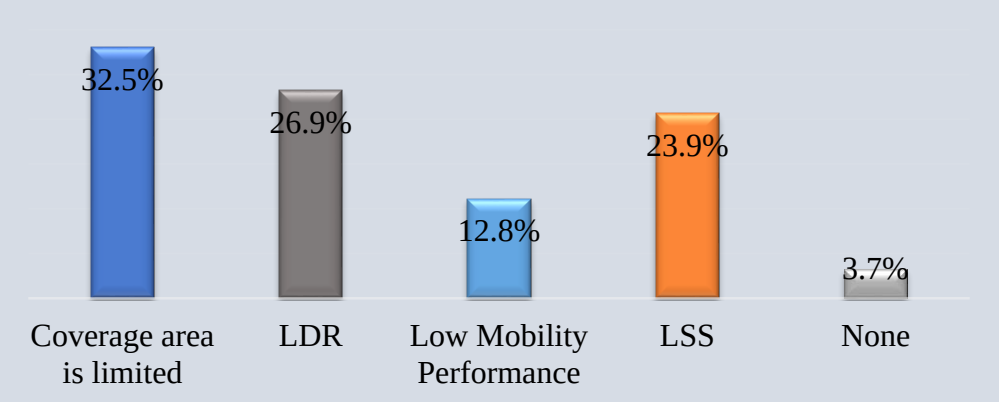

Figure 26 – Situations which occur during mobile internet usage

Source: Author's own work (887 random samples)

All of the general indicators of mobile phone users including, gender, education, time that end users spent with their favourite operators, various internet technologies, satisfaction degree of end users form QoS of mobile telephony and internet, and the situations which occur during telephony conversation and using of mobile internet have

been analysed and interpreted in this section. In the coming section, four hypotheses which have been described earlier will be discussed and the dependency among them will be tested.

4.2 Hypotheses Testing

The current status of mobile network coverage, quality of service of mobile internet and mobile telephony, along with the available techniques and schemes for measurement and optimization purposes have been discussed in details. In this section, four hypotheses will be tested and furthermore the obtained results will be interpreted.

The indicators chosen for test method are mainly the choices of the author of the thesis aiming to check for dependency or relationship between them. The whole database is considered as a sample in the tests, thus there is no random sample selection out of the database, for some of the indicators, there will be missing values, which by default will be ignored by the SAS.

4.2.1 Methodology

There are totally eight variables, which make four hypotheses. All variables are categorical, the dependency between them are needed to be tested, that's why the methodology for four of the hypotheses is same. To test the dependency of the two categorical variables, all variables should be put into a new table with the each variable frequency, denoted as contingency table. The null and alternate hypotheses are furthermore needed to be constructed, the first type error value (α level = 0.05) and test criterion (Chi – Square) to be performed. After running the test, the critical test value with the distribution table value considering the degree of freedom. Based on comparison, the hypothesis is either rejected or fail to reject and the result of the dependency is furthermore interpreted. The formula which is used for the chi – square test is following:

Equation 1 – The Chi – Square testing formula

$$\chi^2 = \sum_{i=1}^{k} \sum_{j=1}^{m} \frac{\left(n_{ij} - n_{oj}\right)^2}{n_{oj}}$$

4.2.2 First Hypothesis

Is there any dependency between categorical variables of "*Education level*" and "*Purpose of using of mobile phone*" of end users of cellular networks in Afghanistan?

Both variables and their catagories along with frequencies have been shown in Figure – 27. The figure shows, how the data is structured in a table form. Each category of "*Purpose of using of mobile phone*" has a corresponding "*Education level*" category.

Null Hypothesis H0 = There is no dependency between categorical variables of "*Education Level*" and "*Purpose of using of mobile phone*".

Alternate Hypothesis H1 = There is dependency between categorical variables of "*Education Level*" and "*Purpose of using of mobile phone*".

Table Analysis

Results

The FREQ Procedure

Table of Purpose of Using of Mobile by Education Level

		Education Level							
		Bachelor	High School	Illiterate	Intermediate	Masters	PhD	Primary	Total
Purpose of Using of Mobile									
Both	Frequency	361	208	8	26	92	3	37	735
	Expected	240.15	206.67	56.277	74.713	55.792	2.4257	98.97	
Internet	Frequency	26	19	0	3	2	1	6	57
	Expected	18.624	16.028	4.3644	5.7941	4.3267	0.1881	7.6752	
Telephony	Frequency	108	199	108	125	21	1	161	723
	Expected	236.23	203.3	55.358	73.493	54.881	2.3861	97.354	
Total	Frequency	495	426	116	154	115	5	204	1515

Statistics for Table of Purpose of Using of Mobile by Education Level

Statistic	DF	Value	Prob
Chi-Square	12	429.9240	<.0001
Likelihood Ratio Chi-Square	12	467.9877	<.0001
Mantel-Haenszel Chi-Square	1	151.9871	<.0001
Phi Coefficient		0.5327	
Contingency Coefficient		0.4702	
Cramer's V		0.3767	

WARNING: 24% of the cells have expected counts less than 5. (Asymptotic) Chi-Square may not be a valid test.

Pearson Chi-Square Test	
Chi-Square	429.9240
DF	12
Asymptotic Pr > ChiSq	<.0001
Exact Pr >= ChiSq	.

Likelihood Ratio Chi-Square Test	
Chi-Square	467.9877
DF	12
Asymptotic Pr > ChiSq	<.0001

Figure 27 – Contingency table and the Chi – Square test of first hypothesis

Source: Author's own work

From the test result shown in Figure – 27, it can be observed that degree of freedom for test statics is 12. The chi – square test value having 12 degree of freedom is 429.9240. The table value compare with alpha level (0.05) and 12 degrees of freedom is 21.026 which is less than the test value, therefore the null hypothesis can be rejected.

429.9240 > 21.026 > Reject H_0.

Based on the chi – square test result, it can be concluded that there is a dependency between the categorical variables of "*Education level*" and "*Purpose of using of mobile phone*".

The power of dependecy shown by phi coeffienct value is 0.5327, therefore it can be claimed that there is a high dependency between two categorical variables.

4.2.3 Second Hypothesis

Is there any dependency between categorical variables of "*No network coverage*" and "*Satisfaction degree of network coverage*" of end users in some locations of cellular networks in Afghanistan?

Both variables and their catagories along with frequencies have been shown in Figure – 28. The figure shows how the data is structured in a table form. Each category of "*No network coverage*" has a corresponding "*Satisfaction degree of network coverage*" category.

Null Hypothesis H0 = There is no dependency between categorical variables of "*No network coverage*" and "*Satisfaction degree of network coverage*".

Alternate Hypothesis H1 = There is dependency between categorical of "*No Network coverage*" and "*Satisfaction degree of network coverage*".

From the result of the test, shown in Figure – 28, it can be observed that degree of freedom for test statics is 20. The chi square test value having 20 degree of freedom is 307.4957. The table value compare with alpha level 0.05 and 20 degree of freedom is 31.410 which is less than the test value, therefore the null hypothesis can be rejected.

307.4957 > 31.410 > Reject H0.

Based on the chi square test result, it can be concluded that there is a dependency between categorical variables of "*No network coverage*" and "*Satisfaction degree of network coverage*".

The power of dependecy shown by phi coeffienct value is 0.4505, therefore it can be claimed that there is a high dependency between two variables.

The FREQ Procedure

Table of Satisfication degree of Network by No Network Coverage

Satisfication degree of Network(Satisfication degree of Network Coverage)		No Network Coverage						Total
		Borders	Cities	Countrysides	Highways	None	Villages	
Neutral	Frequency	45	55	94	57	6	132	389
	Expected	32.609	50.583	99.882	60.083	17.974	127.87	
Satisfied	Frequency	35	69	188	117	23	211	643
	Expected	53.902	83.611	165.1	99.315	29.71	211.36	
Unsatisfied	Frequency	31	47	71	35	1	110	295
	Expected	24.729	38.36	75.746	45.564	13.63	96.97	
Very Satisfied	Frequency	8	7	16	21	39	20	111
	Expected	9.305	14.434	28.501	17.145	5.1287	36.487	
Very Unsatisfied	Frequency	8	19	20	4	1	25	77
	Expected	6.4548	10.013	19.771	11.893	3.5578	25.311	
Total	Frequency	127	197	389	234	70	498	1515

Statistics for Table of Satisfication degree of Network by No Network Coverage

Statistic	DF	Value	Prob
Chi-Square	20	307.4957	<.0001
Likelihood Ratio Chi-Square	20	189.9771	<.0001
Mantel-Haenszel Chi-Square	1	0.0298	0.8630
Phi Coefficient		0.4505	
Contingency Coefficient		0.4108	
Cramer's V		0.2253	

Pearson Chi-Square Test	
Chi-Square	307.4957
DF	20
Asymptotic Pr > ChiSq	<.0001
Exact Pr >= ChiSq	.

Likelihood Ratio Chi-Square Test	
Chi-Square	189.9771

Figure 28 – Contingency table and the Chi – Square test of second hypothesis

Source: Author's own work

4.2.4 Third Hypothesis

Is there any dependency between categorical variables of "*Situations which occur during telephony*" and "*Satisfaction degree of QoS of telephony*" of end users of cellular networks in Afghanistan?

Both variables and their catagories along with frequencies have been shown in the Figure – 29. The figure shows how the data is structured in a table form. Each category of "*Situations which occur during telephony*" has a corresponding "*Satisfaction degree of QoS of telephony*" category.

Null Hypothesis H0 = There is no dependency between categorical variables "*Situations which occur during telephony*" and "*Satisfaction degree of QoS of telephony*".

Alternate Hypothesis H1 = There is dependency between categorical "*Situations which occur during telephony*" and "*Satisfaction degree of QoS of telephony*".

From the test result, shown in Figure – 29, it can be observe that degrees of freedom for test statics is 20. The chi square test value having 20 degree of freedom is 338.1011. The table value compare with alpha level 0.05 and 20 degrees of freedom is 31.410 which is less than the test value, therefore the null hypothesis can be rejected.

338.1011 > 31.410 > Reject H0.

Based on the chi square test result, it can be concluded that there is a dependency between categorical variables of of "*Situations which occur during telephony*" has a corresponding "*Satisfaction degree of QoS of telephony*".

The power of dependecy shown by phi coeffienct value is 0.4816, therefore it can be claimed that there is a high dependency between two variables.

Table Analysis

Results

The FREQ Procedure

Table of Situations which occur during Te by Satisfication degree of QoS of T

		Satisfication degree of QoS of T(Satisfication degree of QoS of Telehphony)					
		Neutral	Satisfied	Unsatisfied	Very Satisfied	Very Unsatisfied	Total
Situations which occur during Te(Situations which occur during Telehphony)							
Blocked Calls	Frequency	90	105	37	13	13	258
	Expected	71.313	115.91	41.584	21.235	7.963	
Dropped Calls	Frequency	64	127	37	5	9	242
	Expected	66.89	108.72	39.005	19.918	7.4691	
Echo	Frequency	31	93	21	12	2	159
	Expected	43.949	71.43	25.628	13.086	4.9074	
LSI	Frequency	151	193	87	16	18	465
	Expected	128.53	208.9	74.949	38.272	14.352	
Noise	Frequency	61	76	52	16	1	206
	Expected	56.94	92.545	33.203	16.955	6.358	
None	Frequency	6	61	1	58	2	128
	Expected	35.38	57.503	20.631	10.535	3.9506	
Total	Frequency	403	655	235	120	45	1458

Frequency Missing = 57

Statistics for Table of Situations which occur during Te by Satisfication degree of QoS of T

Statistic	DF	Value	Prob
Chi-Square	20	338.1011	<.0001
Likelihood Ratio Chi-Square	20	264.2056	<.0001
Mantel-Haenszel Chi-Square	1	28.1329	<.0001
Phi Coefficient		0.4816	
Contingency Coefficient		0.4339	
Cramer's V		0.2408	

Pearson Chi-Square Test	
Chi-Square	338.1011
DF	20
Asymptotic Pr > ChiSq	<.0001
Exact Pr >= ChiSq	.

Figure 29 – Contingency table and the Chi – Square test of third hypothesis

Source: Author's own work

4.2.5 Fourth Hypothesis

Is is there any dependency between categorical variables of "*Situations which occur during mobile internet*" and "*Satisfaction degree of QoS of mobile internet*" of end users of cellular networks in Afghanistan?

Both variables and their catagories along with frequencies have been shown in the Figure – 30. The figure shows how the data is structured in a table form. Each category of "*Situations which occur during mobile internet*" has a corresponding "*Satisfaction degree of QoS of mobile internet*" category.

Null Hypothesis H0 = There is no dependency between categorical variables of "*Situations which occur during mobile internet*" and "*Satisfaction degree of QoS of mobile internet*".

Alternate Hypothesis H1 = There is dependency between the categorical of "*Situations which occur during mobile internet*" and "*Satisfaction degree of QoS of mobile internet*".

Table Analysis

Results

The FREQ Procedure

Table of Satisfication degree of QoS of M by Situations which occur during Mo

		Situations which occur during Mo(Situations which occur during Mobile Internet)					
		Coverage area is limited	LDR	LSS	Low Mobility Performance	None	Total
Satisfication degree of QoS of M(Satisfication degree of QoS of Mobile Internet)							
Neutral	Frequency	51	50	65	21	3	190
	Expected	61.484	51.495	45.28	24.638	7.1028	
Satisfied	Frequency	99	39	64	32	16	250
	Expected	80.9	67.757	59.579	32.418	9.3458	
Unsatisfied	Frequency	81	91	54	45	1	272
	Expected	88.019	73.72	64.822	35.271	10.168	
Very Satisfied	Frequency	12	9	0	7	11	39
	Expected	12.62	10.57	9.2944	5.0572	1.4579	
Very Unsatisfied	Frequency	34	43	21	6	1	105
	Expected	33.978	28.458	25.023	13.616	3.9252	
Total	Frequency	277	232	204	111	32	856

Frequency Missing = 659

Statistics for Table of Satisfication degree of QoS of M by Situations which occur during Mo

Statistic	DF	Value	Prob
Chi-Square	16	139.2927	<.0001
Likelihood Ratio Chi-Square	16	118.4710	<.0001
Mantel-Haenszel Chi-Square	1	2.0009	0.1572
Phi Coefficient		0.4034	
Contingency Coefficient		0.3741	
Cramer's V		0.2017	

Pearson Chi-Square Test	
Chi-Square	139.2927
DF	16
Asymptotic Pr > ChiSq	<.0001
Exact Pr >= ChiSq	.

Figure 30 – Contingency table and the Chi – Square test of fourth hypothesis

Source: Author's own work

From the test result, shown in Figure – 30, it can be observed that degrees of freedom for test statics is 16. The chi square test value having 16 degree of freedom is 139.2927. The table value compare with alpha level 0.05 and 16 degree of freedom is 26.296 which is less than the test value, therefore the null hypothesis can be rejected.

139.2927 > 26.296 > Reject H0.

Based on the chi square test result, it can be concluded that there is a dependency between categorical variables of "*Situations which occur during mobile internet*" and "*Satisfaction degree of QoS of mobile internet*".

The power of dependecy shown by phi coeffienct value is 0.4034, therefore it can be claimed that there is a high dependency between two variables.

Table 2 – Hypotheses result summary

Hypotheses	Chi - Square	Degree of Freedom	Distribution Table Value	Result
Dependency between "*Educational lever*" and "*Purpose of using of mobile phone*".	429.924	12	21.026 (α level = 0.05)	429.924 > 21.026 > Reject H_0
Dependency between "*No network coverage*" and "*Satisfaction degree of end user*"	307.495	20	31.410 (α level = 0.05)	307.495 > 31.410 > Reject H0.
Dependency between "*Different situations of mobile telephony*" and "*Satisfaction degree of end user*"	338.101	20	31.410 (α level = 0.05)	338.101 > 31.410 > Reject H0.
Dependency between "*Different situations of mobile internet*" and "*Satisfaction degree of end user*"	139.292	16	26.296 (α level = 0.05)	139.292 > 26.296 > Reject H0.

4.3 Conducted Interviews

Once the result of the survey has obtained and the hypothesis have been interpreted a series of interviews have been conducted with the ATRA, MCIT and the representatives of operators. The interviews with end users have been conducted during the survey period. During the interviews with the ATRA, the MCIT and

operators different aspect of mobile communication sectors of Afghanistan have been discussed, but information only related to the network coverage, quality of service of mobile internet and mobile telephony is included in the following text. It should be noted that, the opinions expressed herein are those of concerned organization's representatives and end users, and do not necessarily express the views of the author.

4.3.1 Interviews with the Representatives of the ATRA and the MCIT

The following two questions have been asked from representative of the ATRA/MCIT. Mr. Mohammad Yasin Samim (Spokeperson to the MCIT). ATRA is basically working the leadership of MCIT, therefore, their mission, policies and strategies are same.

Question 001: Which policies and strategies are planned by MCIT in order to expand and simultaneously optimize network coverage in Afghanistan?

Answer: One of the main projects which is run by MCIT/ATRA in order to expand network coverage to rural areas and villages is the TDF (Telecom Development Fund) for Afghanistan. In order to promote rural access to telecom services and expand network coverage to them, the MCIT/ATRA is funding the construction of a specific number of base stations using the TDF under the Universal Access Program (UAP). The construction projects of these base stations are awarded to the mobile network operators on a competitive basis and will be operated and maintained by these operators upon completion.

Secondly, the MCIT/ATRA continuously monitor the network coverage and quality of service provided by operators. Each month a detailed report is submitted by the operator. The technical team of the MCIT/ATRA analyse, in case of problems and complaints, the operator is recommended to optimize network coverage or increase quality of service in that particular area.

Question 002: Which techniques and Schemes are proposed by MCIT and ATRA to operators in order to bring necessary changes in the era of quality of service of mobile telephony and mobile internet in Afghanistan?

Answer: Under the telecom law of the Afghanistan, operators are being allowed to deploy any standard technique permitted by the MCIT/ATRA. But, the government is also responsible to corporate with operators mainly in the transmission of data. A national optical fibre backbone has been installed throughout the country which helps operators to exchange information with reasonable price.

4.3.2 Interviews with the Representatives of Operators

The following two questions were asked from representatives of three operators. Mr. Ghulam Nabi (Salam Telecom), Mr. Naweed Ahmad Nawa (Roshan) and Mr. Mirwais Fazli (ETA). The author has contacted many times AWCC and MTNA but didn't receive feedback on time. All the representatives almost have had the same answers, therefore, it joined and written below.

Question 001: Which methods are being used by your team for optimization of network coverage and quality of service in Afghanistan?

Answer: Three of the operators are being used almost the same methods and tests for the optimization of network coverage and quality of service. The drive test is the most common test, which is being performed monthly and quarterly considering geographical location and population of each area. The statistics obtained from these and other tests are analysed, the existing problem of each area is processed and furthermore adequate schemes are used in order to improve network coverage and enhance quality of service.

These RF specialists mostly focused on the usage of, high order sectorizations, increasing of number of TRX, and deploying of new base station as traditional methods to increase capacity and enhance network coverage.

Question 002: Which solutions your team is planning to deploy in order to increase the degree of satisfaction of mobile phone users from mobile telephony and mobile internet services?

Answer: Representatives have had the same answer for this question as well. They are being conducted monthly and quarterly tests in order to study each area individually. After detailed study of network status of each area, the revenue which is network suppose to obtain is compared with the cost and furthermore, it is decided to use which of the available method for increasing quality of service and enhancing of network coverage. A detailed and updated statistics from network help operator to remove existing challenges, and these data can obtain through a series of drive and other RF tests.

4.3.3 Interviews with End Users

A part of this research is to have end users comments about service provided by mobile operators in Afghanistan. During the survey, end users were asked to share their

opinions, criticizes and experiences with their previous and current favourite mobile operators. All of these comments have categorized and discussed below.

One of the main issues, which, end users were complaining from is the rate of the service, particularly between telephony service of end users of different national and international operators. A mobile phone user (Hasibullah, from Nangarhar province) shares his opinion as following:

"Price of mobile telephony service in Afghanistan is still very high compared to neighbor countries. . The operators just collect our money, they don't care of the service provide to us. Mobile Internet service in all networks is very poor and prices are very high. Even mobile internet of some networks is not available in main cities like Jalalabad."

The SIM card registration process is another issue to be concerned. The end users expect that every mobile phone user should register his/her sim card in order to participate in bringing of strong national security in the country.

One of the biggest challenges in the mobile sector of the country is, that, non – state elements force operators to switch off base stations during the night. High number of end users complain that, no network coverage during the night in their hometowns is a serious issue. These end users were suggesting from non – state elements to end up to the switching off of base stations and recognize the importance of mobile service during the night as basic human rights.

Some of the end users of mobile telephony in Afghanistan complain from the inequality in the presence of network coverage, quality of service of mobile telephony and internet in rural and urban areas. These end users believe that, network operators should cover all populous areas of the country with the same level of coverage parameters and quality of service metrics. One of the end users (Ajmal, from Parwan province) shares his opinion as following:

"I am totally unsatisfied with all network operators that operate inside the country. They never think of making things better like telephony conversation quality, mobile Internet quality and so on. One of the issues is that, they offer service in villages and countrysides with very poor quality while in cities with enhanced quality. It is not fair, they just full their pockets with money, nothing more."

The interviews with end users furthermore indicate that, they are very unsatisfied with the non – covered zone and noise during telephony conversation made

by military vehicles and bases in the country. One of the mobile phone users (Ahmad Javed, from Kandahar provice) shares his concerns as following:

"One of the thing which I don't like is to make either temporarily non – covered zones or to disturb my phone conversation by military vehicles and bases. When I talk on the phone with someone, either military vehicles cross the road or I walk near to their bases I heard unwanted and annoying voices on phone which is due to military equipments. Sometimes, even the coverage is blocked by them and I don't see any sign of coverage on my phone's screen."

Last but not least, some of the end users were concerned about the security of their information travelling across the networks. One of the end users (Marzia, from Balkh province) shares her concern as following:

"When I read WikiLeaks report on the internet, I scared of talking on the phone. I feel that someone is sitting in the network and have full control on hearing of my phone conversations or reading my chats on social applications."

4.4 Proposed Schemes and Recommended Solutions

So far, existing schemes for the optimization of network coverage and quality of service of mobile service have been addressed. The current status of existing challenges on the topic has been addressed. The data obtained from the survey for studying network coverage and quality of service from the end user perspective have been executed in SAS and the result have been interpreted. As mentioned in the second chapter, the main objectives of this research are to propose an adequate solution solution from both technical and end user perspectives. Refer to to the result of the research, the following schemes are recommended by the author in order to be deployed by mobile network operators for improving network coverage and enhancing quality of service in Afghanistan.

The first and the most important traditional method to recognize network weaknesses, find existing challenges and based on the reports improve cellular network performance is to continuously optimize the network by performing RF and post processing measurement. The continuous network optimization improves network performance. One of the common schemes recommended is to increase drive test. The operators should have great customer relationships through customer service departments, to hear their complaints and share it technical departments for removing

the problems from the network. The drive test is useful for both network coverage and quality of service.

Based on the interpreted result, the mobile phone users most of the time, experience no network coverage in rural areas (villages and countryside) and on highways. Different schemes are available in order to remove these barriers and to provide appropriate signal strength. Refer to population and geographical location of Afghanistan, the deployment of high order Sectorization is the appropriate scheme in order to remove non – covered zone. High order Sectorization strategy is not only efficient for improving network coverage, but helps to increase the quality of service.

Refer to data analysis, mobile phone end users mostly experience low signal intensity, dropped call and blocked call than any other situation before, during and after telephony conversation. There are couple of available schemes in order to remove these challenges from the networks. Increasing the parameters of base stations in order to propagate radio waves efficiently is one of the schemes that is proposed for increasing of signal strength. Blocked call mostly occurs due to low available capacity in the network, efficient use of the spectrum should be concerned in order for the base station to provide service with enough capacity. One of the situations, which end users were complaining was dropped call. There are couple of reasons due to them a call can be dropped, e.g. limited bandwidth, inappropriate handover strategies, and inefficient neighbour cell list configuration and optimization.

Handover is a crucial task in cellular system which maintains the continuity of data and telephony sessions and its failure causes the termination of ongoing call or mobile internet. That’s why deployment of the most recently schemes for the operator is suggested. On the other hand, neighbouring cell list (NCL) plays vital role in the decreasing of dropped call probability. Deployment of an efficient scheme for the configuration and optimization of NCL is recommended to enhance the quality of mobile telephony. Increasing base station capacity can also help decrease blocked/dropped call probability.

Increasing the number of carriers (TRXs) can be also useful, considering geographical location and population of the area. This scheme is helpful to increase the capacity of a base station, which leads to enhance quality of experience. But base station can support a limited number of TRXs, therefore, this scheme will be more useful if combined with one of the mentioned proposed solutions.

Refer to the survey, users were asked about the quality of mobile internet. Most of the end users experience limited coverage area for mobile internet, low data and weak signal strength. In existing heterogeneous infrastructure, it is recommended that the ATRA and MCIT should permit operators to allow their end users in order to install a femtocell for improving indoor coverage and capacity.

Deployment of small cells in the network is another strategy in order to enhance indoor and outdoor network coverage and increase data rates, which effect on both quality of service of a cellular system and quality of experience. It is recommended that the operator should deploy this scheme in urban areas, where massive numbers of users are living.

During the survey and interview, some of the end users were complaining from improper location of the base station, thus from technical point of views it is highly recommended to choose appropriate location for base station installation. Base station location and Antenna orientation have also impact on enhancing of quality of service of cellular networks.

Refer to the tested hypotheses, there is high dependency between different situation occur before, during and after telephony conversation and the satisfaction degree of end users. It is also has been tested that, there is a dependency between non – covered zone and satisfaction degree of end user from network coverage. The test result of the fourth hypothesis indicates that, situations which occur during mobile internet have effect on end user satisfaction. Based on obtained result, it is recommended to operators in order to deploy advanced and recent schemes for the optimization of network coverage and quality of service of mobile telephony and mobile internet.

The ATRA and MCIT, have responsibilities to work with the operator and make and launch the policies and strategies in order to provide enhanced quality of service, improved network coverage with reasonable price to the Afghan citizens. All of these goals can be only achieve, when they work hard together and simultaneously listen to end user expectations from their favourite operator.

5. Results and Discussion

This chapter presents reflection of the research. The first section, presents findings and major results. The second section, answers to main research questions. The third subchapter, contains a detailed discussion on the proposed solutions. The pros and cons of the proposed schemes are also discussed there. The last section, specifies further research directions and overviews the limitations.

5.1 Findings and Results

Based on available literature and author's experience in field, there are some challenges existing in the area of network coverage and quality of service of mobile telephony and mobile internet of cellular networks in Afghanistan. These challenges were main driving forces which moved author forward, in order to specifically find that, which are critical, major and minor, and furthermore propose adequate solutions based on analysed data, tested hypotheses, available advanced technical schemes, and conducted interviews with end users, operators, the MCIT and the ATRA.

Among main findings belong, gender inequality, generational divide, and low level literacy in access to mobile service in Afghanistan. Obtained data further illustrates, the satisfaction degree of end users from the presence of network coverage, quality of service of mobile telephony and mobile internet. It furthermore indicates, the most annoying situations which end user experience during telephony conversation and mobile internet in the country. The Results show that, the majority of end users use mobile phone for telephony service, most of the complaints have raised from low signal intensity, low data rate, blocked call, dropped call, and low signal intensity in rural area (e.g. villages, countryside and borders). The dependency between specific categorical variables have been also tested, and based on the result of the chi – square test, the level of dependency between them are determined. Advanced schemes of network coverage and quality of service proposed by various research scholars have been also reviewed in order to study and furthermore address the existing challenges technically.

Based on the results, author recommends deployment of small cells, increasing number of drive tests, appropriate location for BTSs installation, deployment of recent self – configured/self – optimized schemes of handover and neighbouring cell list, increasing the value of the base station parameters, deployment of high order Sectorization, and increasing of numbers of TRXs of base station as adequate solutions

for removing existing challenges in the areas of network coverage and quality of service of mobile telephony and mobile internet in Afghanistan.

5.2 Answers to Main Research Questions

Main research questions which were presented at second chapter have been answered based on data analysis, hypotheses testing, and available advanced technical schemes as following.

I. How to remove non – covered zones and simultaneously improve existing network coverage of mobile operators in Afghanistan, where all Afghan citizens have access to service anytime in any populous area?

Data founds that, 8.38% of mobile users experience gaps of "*non – covered zone*" in the boarders, 13.0% in main cities, 25.6% in countryside, 15.4% on highways, 32.8% in villages, while 4.6% of end users are totally satisfied and don't experience any non – covered gaps in any location of the country.

On the other hand, results obtained from chi – square test illustrates that, there is a high dependency between categorical variables of "*No network coverage in some locations*" and "*Satisfaction degree of end user from network coverage*". It specifically means that, if, end user experiences "*non – covered zone*" in any populous area, it will decrease his/her satisfaction degree, which highly influence on the grade of quality of experience. Therefore, mobile network operators in Afghanistan need to concentrate on finding of these non – covered gaps and subsequently remove them from network.

To conclude, author recommends for the operators to, deploy small cells in urban or massive populous area; deploy high order Sectorization method on highways, in country side, in borders, and in villages; increase level of base station parameters; increase number of drive tests; and concentrate to find appropriate location for the installation of base station, in order to remove non – covered zones and simultaneously improve existing network coverage in Afghanistan.

II. Which techniques, schemes and technologies should be used by mobile operators in order to provide existing mobile telephony service with enhanced quality in both rural and urban covered areas, in Afghanistan?

Data explores that, 16.5% of mobile users experience dropped call, 17.6% blocked call, 10.8% echo, 31.8% low signal intensity, 14.1% noise, while 8.7% are

totally satisfied of and don't experience none of the above situations during or before telephony conversation.

On the other hand, results obtained from chi – square test illustrates that, there is a high dependency between categorical variables of "*Situations which occur during telephony*" and "*Satisfaction degree of QoS of telephony*". It specifically means that, if, end user experiences "*any of the above situation e.g. blocked call, dropped call and so on*" before or during telephony conversation, it will decrease his/her satisfaction degree and will highly influence on the grade of quality of experience. Therefore, it is highly recommended for mobile network operators in Afghanistan to concentrate on upgrading current of network capacity considering geographical location and population of the area. The operators also need to focus on finding and furthermore removing of these unwanted situations of mobile telephony from network.

To conclude, author recommends for operators to, deploy small cells in urban or massive populous areas (for capacity increasing purposes); deploy most recent self – configured and self – optimized handover and neighbouring cell list schemes; effeciently use the available spectrum; increase base station parameters in country side, borders, and villages; increase number of drive tests; increase number of TRXs of base station; and concentrate to find appropriate location for the installation of base station.

III. Which techniques, schemes and technologies should be used by mobile operators in order to provide existing mobile internet service with enhanced quality in both rural and urban covered areas, in Afghanistan?

The result of survey indicates that, 32.5% of mobile users experience limited coverage area of mobile internet, 26.9% low data rate, 12.8% lower performance during mobility, 23.9% low signal strength, while 3.7% of end users in Afghanistan totally satisfied with the mobile internet and don't experience none of the mentioned situations.

On the other hand, result obtained from chi – square test illustrates that, there is high dependency between categorical variables of "*Situations which occur during mobile internet*" and "*Satisfaction degree of QoS of mobile internet*". It specifically means that, if end user experience "*any of the above situation e.g. low data rate, limited internet coverage area, and so on*" in any populous area, it will decrease his/her satisfaction degree, which highly influence on the grade of quality of experience. Therefore, it is highly recommended for mobile network operators in Afghanistan to concentrate on upgrading of current cellular data, increase data bandwidth of base

station considering geographical location and population of the area. The operator also need to concentrate on find and furthermore removing of these mentioned situations of mobile internet from network.

To conclude, author recommends for operators to, deploy small cells in urban or massive populous area (for increasing mobile data rate); deploy high order Sectorization; increase level of base station parameters; increase bandwidth of cellular data in each base station, increase number of TRXs of base station; deploy dedicated internet approach, increase drive tests; and concentrate to find appropriate location for the installation of base station.

5.3 Discussions

So far, the existing challenges in the area of network coverage, quality of service of mobile telephony and mobile internet in Afghanistan have been described, and adequate solutions from both technical and end user perspectives have been proposed. In this section a detailed discussion on the pros and cons of recommended solutions will be taken.

The deployment of small cells in macro cellular environment on one hand increase capacity and enhance network coverage, on other hand raises many challenges in the area of mobility and radio resource management. In case of deployment of this scheme, there will be huge amount of low and high power transmitters which make environment more heterogeneous. When user is moving in such heterogeneous environment, there will be more need for handovers, the network should be able to support end user mobility, this situations leads to more complexity in network.

High order Sectorization in rural area is second proposed solution. It increases capacity and enhances coverage, but interference and increasing of softer – handover are main challenges which rise with deployment of this scheme.

Finding appropriate location for installation of base station is another proposed solution to be deployed by mobile operators in Afghanistan. This can be only helpful where in a specific geographical area non – covered zones are available. It can remove gaps in network coverage but cannot increase capacity.

Increasing of number of carriers (TRXs) can be also useful, considering geographical location and population of the area. This scheme is helpful to increase the capacity of a base station, which leads to enhance quality of experience. But base station

can support a limited number of TRXs, therefore, this scheme will be more useful if combined with one of the mentioned proposed solutions.

Increasing of number of drive tests for optimization purpose, is a traditional scheme, which mostly use by all cellular network operators around the world. However, this method helps to find existing gaps in network coverage, measure the quality of service of mobile telephony and mobile internet. But, high number of these tests will lead to spend more time, money and personal in order to collect relevant data and furthermore analyse the problems.

Increasing of value of base station parameters is one of the proposed solution for rural area. This can be helpful in some specific cases, e.g. less population but wider area and so on. However, increasing of values of parameters from defined standards rise additional challenges e.g. environmental effect and so on.

The proposed schemes have been thoroughly discussed. Each of them has its own characteristics, pros and cons. But appropriate time of the deployment of these schemes require detailed study of geographical location, population of the area, and government regulatory policies of the country.

5.4 Limitations and Further Research Directions

The research conducted in this thesis has lead to some useful conclusions for mobile communication sector of Afghanistan. However, it has also uncovered some areas that have limitations and perhaps need additional study. The purpose of this subchapter is therefore to identify the limitations and discuss the need for further research.

One limitation of the conducted research is not including of the measurement of parameters of network coverage and quality of service of live networks in Afghanistan. The survey for this research is conducted to study network coverage and quality of service from end user perspective. However, it is recommended for further study to, conduct experiments on live networks and furthermore suggest adequate solutions for each of the province and districts individually.

There is a limited focus of this research on the interviews conducted with Operators, the MCIT and the ATRA. The representatives of these organizations were hesitating due to security reasons of sharing the details of their policies and strategies to improve network coverage and enhance quality of service. However, the culture which aims to provide researchers and the public with free access to academic work,

has been growing in the country. This research was actually a beginning step and author hopes there will be limited barriers on the way of further studies on mobile networks in Afghanistan.

The survey includes 1,515 end users. Almost half of the respondents were collected online. Refer to generational divide, level of literacy, geographical locations and population of each of the province and the country, it would be much more adequate if the size of samples from personal interviews were more than existing one. But due to, unavailability of financial resources, the data analyses and statistical tests have been performed on the available samples. Therefore, it is recommended for further study to increase number of personal interview of end users.

6. Conclusion

The main objectives of this research are, to study the current status of network coverage and quality of service of mobile telephony and mobile internet of five GSM operators in Afghanistan, analyse the existing problems and propose adequate solutions from both end user and technical perspectives.

In the introduction chapter, some global statistics in the area of network coverage and quality of service have been presented and indicated that how these two parameters are important for a service provider in order to continue business and to keep consumers for long and very long period of time. The Afghan telecom sector has been also reviewed, some basic statistics and indicators of mobile networks have been discussed.

The statement of the problem, objectives, goals, main research questions, methodology, and research framework and design have been thoroughly described in second chapter. Available literature and author's experience in the field, were main driving forces for conducting this research. According to main research questions, the topic should be discussed from both technical and end user perspectives, thus, a methodology has been followed, where survey is conducted in order to study end user expectations, advanced schemes in the area of network coverage and quality of service are studied in order to address the problem form technical point of view, and later on adequate solutions are recommended based on findings and results.

Available literature is necessary to be reviewed in order to analyse the problem adequately. Detailed study of network coverage, quality of service, and available schemes in the area of coverage and quality of service optimization of mobile networks are presented in the third chapter. The parameters, which are defined by standardization bodies, and operators are required to follow have been also presented. Expectations of end user from mobile networks and the parameters of quality of experience have been also discussed. The chapter also contains network coverage footprints in Afghanistan.

The most important part of this research is presented in chapter four, where the collected data is executed in SAS in order to analyse some general indicators of mobile phone users, satisfaction degree of end users from network coverage and quality of service and furthermore test the dependency between specific categorical variables.

Dependency of four hypotheses have been also tested in fourth chapter. The null and alternate hypotheses have been constructed, the first type error value (α level =

0.05) have been set and Chi Square test has been executed. After running the test, the critical test value has been compared with distribution table value, considering degree of freedom. Based on this comparison, the hypothesis is either rejected or not and the result of the dependency has been interpreted. The result of the chi – square test shows that, there is, a high dependency between all variables of four hypotheses, therefore, it is necessary for operators to concentrate on end users expectations, considering the recommended schemes and proposed solutions by author.

In fifth chapter, all of the study, existing literature, tested hypotheses, analysed data, and available schemes in the area of network coverage and quality of service considered, in order to find key answers for main research questions. Limitation during survey and this study have been addressed, and further research directions have been specified.

Based on the results, author recommended deployment of small cells, increasing number of drive tests, appropriate location for BTSs installation, deployment of self – configured/self – optimized schemes for handover and neighbouring cell list, increasing the value of the base station parameters, increasing number of carriers (TRXs), and the deployment of high order Sectorization as adequate solutions for removing existing challenges in the areas of network coverage and quality of service of mobile telephony and mobile internet in Afghanistan.

To conclude, mobile network operators in Afghanistan need to focus on deployment of more recently developed schemes in the providing of network coverage, and quality of service of mobile telephony and mobile internet. The service providers need to improve professional, but personal, oriented customer approach. Of course, focusing on end users expectation and paying more attention to them will lead to spend more time and money. But, results of this study show that customers expect this individual attention and these parameters highly effect on the grade of quality of experience, which lead to customer loyalty. The result further shows that, enhanced service quality is positively correlated with customer loyalty, the more improved coverage and enhanced quality of service is provided by operator the longer end users will stay with operator.

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8. Appendix

This section presents, the questionaries' which has been used during survey and personal interviews with end users.

Survey Report

Czech University of Life Sciences Prague
Department of Information Technology
Kamycka 129, 165 21 Praha 6 Suchdol, Prague — Czech Republic

This survey is for a research being conducted on, "*Mobile Telephony and Internet in Afghanistan: Issues of Network Coverage and Quality of Service*" at the department of information technology, Czech university of life sciences Prague, Prague – Czech Republic. The goal of the research is to, what extent Afghans are satisfied with quality of service of mobile Internet, mobile telephony, and network coverage, in the country and how do they evaluate their favorite GSM operator.

Please take a moment to complete this survey. All your responses along with your identity will be kept confidential.

Questions and answers:

1: Which province are you living?

Answer: ( )

2: How old are you?

Answer: (<18 / 18 – 30 / 31 – 45 / > 45)

3: What is your gender?

Answer: (Male/Female)

4: What is the level of your education?

Answer: (PhD / Masters / Bachelor / High / Intermediate / Primary 'School' / Illiterate)

5: Which GSM operator are you using?

Answer: (AWCC / Etisalat / MTN / Roshan / Salam)

6: How long have you been with your current mobile operator (years)?

Answer: (< 2 / 2 – 5 / 6 – 10 / > 10)

7: For what purpose do you use mobile phone the most?

Answer: (Telephony / Internet / Both)

8: How satisfied are you with network coverage of your favorite operator?

Answer: (Very satisfied / Satisfied / Neutral / Unsatisfied / Very unsatisfied)

9: Where do you often experience no network coverage?

Answer: (Highways / Cities / Villages / Countryside / Country Borders / None)

10: How satisfied are you with Quality of Service of mobile telephony of your favorite operator?

Answer: (Very satisfied / Satisfied / Neutral / Unsatisfied / Very unsatisfied)

11: Which Situation do you often face while using mobile for telephony purposes?

Answer:

A: Hear your voice back (Echo)

B: Low Signal intensity

C: You actually hear some unwanted sounds which disturb your conversation (Noise)

D: Your call can not be connected or you receive the "Network busy" message back from operator (Blocked Calls)

E: Due to unknown reasons your conversation is cut off, before you finish (Dropped Calls)

F: None of the above

12: Which Mobile Internet Technology are you using?

Answer: (GPRS / EDGE / 3G / Wi – Fi / Do not use Mobile Internet)

13: How satisfied are you with Quality of Service of mobile internet of your favorite operator?

Answer: (Very satisfied / Satisfied / Neutral / Unsatisfied / Very unsatisfied)

14: Which situation do you often face while using mobile for internet purposes?

Answer:

A: Low data rate

B: The Internet coverage area is limited

C: Low signal Intensity

D: Low performance while moving around

E: None of the above

15: Please do not hesitate to share your ideas, criticizes, and experience related to the topic.

Technical Explanations

1: Network Coverage is the place where you able to receive and make a call and use mobile Internet is called network coverage area.

2: Quality of Service is actually the overall performance of services provided by your favorite mobile operator.

Declaration

I ..... declare that, this survey is my own work for a research on "*Mobile Telephony and Internet in Afghanistan: Issues of Network Coverage and Quality of Service*". I do acknowledge that, I have interviewed different categories of end users (male, female, young, old, illiterate, literate and etc.) in the specified geographical area and filled this report faithfully.

In……..... Signature …….