

**AN IMPROVED MODEL FOR KEY PERFORMANCE
INDICATORS ANALYSIS FOR MOBILE NUMBER
PORTABILITY SCHEME FOR GSM SUBSCRIBERS IN
NIGERIA**

BY

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APPROVAL PAGE

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CERTIFICATION

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DECLARATION

I, Nnochiri, Ifeoma Uzochukwu, a Postgraduate student of Electronic Engineering, University of Nigeria , Nsukka declare that the work embodied in this thesis is original and has not been submitted by me in part or in full for any other diploma or degree of this or any other University.

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Date

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DEDICATION

I dedicate this Research work to God Almighty for his infinite mercies and Provisions.

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ABSTRACT

In Nigeria today it been observed that when changing from one GSM network operators to the other, customers has to give up their old numbers and adopt a new one. As a result, they face switching costs associated with informing people about changing their number, printing new business cards, missing valuable calls from people that do not have the new number, etc. In this research the Key Performance Indications (KPI) of network providers and the causes of poor quality service quality by GSM network operators in Nigeria were examined. The review findings leads to a novel method of subscriber authentication in mobile cellular networks and its implementation framework in future mobile phones and devices. Mobile Number portability (MNP) Java VSIM Suite was suggested to all mobile network operators and the migration of subscriber to adopt. Mobile Number Portability is a circuit-switch telecommunications network feature that enables end users to retain their telephone numbers when changing service providers, service types, and/or locations. A Fuzzy logic block set of MATLAB/Simulink and Java programming language with Netbeans 7.0 and XAMP Control panel were used in realizing Mobile Number portability (MNP) of different mobile operators. A set of benchmarks which are considered as crucial for deployment while taking cognizance of user's requirements of mobile devices shows that in the KPI investigations for MTN, GLO, ETISALAT and AIRTEL Mobile operators are still yet to deliver a uniform and efficient QoS. Furthermore, the approach demonstrates the replaceability of the existing SIM card GSM architecture with an adequate trusted software module proposed to develop an improved model for MNP scheme for GSM subscribers in Nigeria using KPIs.

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CHAPTER 1

INTRODUCTION

1.1 Background Of Study

The conventional GSM networks in Nigeria suffers from poor quality of service and congestion effects . Objective measurement in the context of quality of service in mobile cellular networks has presented a major challenge for both the stakeholders and end-users. This is traced to the peculiarities associated with the QoS metrics. However, the distinguishing characteristics for networks QoS evaluation must tend towards two major ends: a credible and reliable assessment of the likelihood that users will find a particular service satisfactory; and the determination on how system performance could be changed when that assessment shows that users are not likely to be satisfied. In recent past, approaches of proposed network quality of service metrics, took little cognizance the interests of the users of telecommunications services and the perspective of the experts who design, build, and operate the systems that deliver those services [2].

Wireless mobile Internet is migrating towards an integrated system of Internet and telecommunication technologies in order to fulfill the future requirements of GSM networks i.e ubiquitous communication with best service availability. This demands a rapid progress in GSM networks and Internet technologies QoS analysis. Some suggests that Quality of Service should be based on reliability, availability, security, assurance, simplicity and flexibility of the network as criteria for judgment. Others based their study on user's satisfaction using coverage, call quality, promotions and offering of incentives and rewards, prices of services, billing etc. ĩ J.D Power and Associates Survey in United Kingdom (2008).

Consequently, Global System for Mobile Communications (GSM) Association in her 2007 convention in Sutherland identified a list of indicators for mobile phone quality of service assessment. These indicators include Network Accessibility, Service Accessibility, Service Integrity, and Service Retainability.

Accordingly, the incessant complaint by GSM network users in Nigeria concerning the services by their providers is a strong indication that Quality of service rendered by the network operators

is below average. This challenge has been criticized by both industry and consumer groups among other stakeholders in the sector.

In finding the lasting solution to the problem, the NCC as a body responsible for the regulation of GSM in Nigeria, in the last quarters of the year 2011 issue out the threshold levels on the Key Performance Indicators (KPIs) for ascertaining QoS of all the GSM networks in the country. Hence, stipulates some sanctions to any operator who fails to meet it. The KPIs considered in this work includes: Call Completion Rate (CCR), Call Setup Success Rate (CSSR), Call Drop Rate (CDR), Call Handover Success Rate (CHSR) and Standalone Dedicated Control Channel (SDCCH). This research will therefore focus on the four standards metrics used in assessing the performance of mobile networks viz: Accessibility (i.e. getting to the network), Retainability (i.e. staying on the network), Connection Quality or Service Integrity (i.e. service experience while using the network), and finally the Network Coverage. (i.e the geographical region covered by one mast)

Therefore, evaluation of the mobile cellular networks proposed in this research will center on these standard metrics for objective measurement to show the current KPI status in Nigeria as a case study and the implementation of Mobile Number portability (MNP) to all mobile network operators.

1.2. Problem Statement

One common feature of GSM networks in Nigeria is poor network services as expressed by over 170 million end users considering their real-time service subscriptions to the various network operators. Network Congestion is not left out of the observed challenges. Besides, the mobile node platform lacks an intrinsic decision algorithm for future services integrations as well as poor sensitivity or high Bit Error Rates. These challenges are being experienced via inability to set up calls, call drops, occasional service outages, cross-talks and network congestions among others. Again, the designers of GSM networks have not adequately put into consideration design goals for the GSM porting flexibility. Consequently, network poor quality of service results as the number of customers increases and integration of new web application becomes difficult since they are not originally provisioned for in the design. This work on the reengineering of GSM network for an improved MNP scheme for GSM subscribers seeks to

solve this problem. Hence this research, will seeks to ascertain the compliance index of selected GSM network operators, the factors responsible for network failure and the feasibility of GSM network integration to set a new enhancement panacea to the unending Quality of service problem in Nigeria. A new architecture that will address KPI issues while demonstrating a new integration framework will gain a wide acceptance among the stakeholders, researchers, and users.

1.3. Aims and objectives of the Work

This research is aimed at developing an improved model using MNP scheme for GSM subscribers vis-a-vis their KPIs using Fuzzy logic blockset having identified the performance of Mobile Cellular Networks in Nigeria. Other Specific objectives include:

1. To carry out empirical analysis on the GSM networks KPIs as well as analysing the data collected using drive test approach.
2. To demonstrate migration algorithm using the reference architectural JAVA based VSim MNP suite for GSM network integration.
3. To develop a prototype GSM module for MNP which demonstrates a good BER performance depicting an excellent QoS results
4. To use fuzzy logic to detect the network with the best KPIs

1.4 Justification of the Work

The dynamism of today's real time services demands a robust GSM network that is efficient, scalable, cost-effective, service-oriented, and responsive to business needs. This research seeks to achieve a stable QoS considering the proposed fuzzy integration platform for GSM networks. GSM future technologies and its implementation schemes that meet the above criteria will be widely celebrated. Besides, running a virtual SIM with MNP suite as trusted and protected software on a mobile device will allow for significant expansion of services by introducing new usage scenarios and business models, cost reduction and more flexibility, while guarantying a high level of security in its architecture. This work will consequently serve as an eye opener to all the critical stakeholders and researchers in GSM design implementations and deployments while complying with stipulated or regulatory body criteria.

1.5 Scope of the Work

This work will cover initial investigations on GSM KPI compliance index using generic SIMs with the Qvoice Tool. In the study, various schemes viz: Customer Complaints [9], Network Statistics [10] and Drive Tests will be reviewed while using fuzzy datasets to monitor evaluate and analyze the QoS in order to arrive at an appropriate decision and status in this work. The Drive test will be carried out using QVOICE as a measurement tool which is a Quality of service measurement equipment installed in a special purpose-built vehicle to enable set up test with minimal vibration and shock while the vehicle is on motion. This real-time measurement equipment by Ascom operates both on GSM 2.5G and 3G networks and purposely manufactured for data acquisition over a live network [11]. It is robust, portable transceiver equipment with high speed scanner that can measure up to 8 channels simultaneously and accommodate 4 mobile. It has two different components: (a) QVM- data collection part and (b) QVP - data analysis part. The test site will be Abuja and the KPI metrics includes viz::

- (a) Call Completion Rate (CCR);Call Setup Success Rate (CSSR);Call Drop Rate (CDR);
- (b) Call Handover Success Rate (CHSR); Standalone Dedicated Control Channel (SDCCH).

Moreover, in this work, the analysis & performance of mobile networks in Nigeria based on above mentioned KPIs using Drive Test in collecting the data is presented. These KPIs performances will be merged together to form an overall QoS report of the network. We will provide the analysis of the result obtained during the field measurement using these KPIs as basic unit for QoS monitoring. The QVOICE equipment will be used as a measurement tool to test the networks and collect data samples. In addition, we will illustrate the effect the coverage and mobility management on the overall service performance. From above, a formulation for MNP based on Mobile Trusted Computing reference Architecture is presented using a MATLAB fuzzy integration model for the GSM networks, a reengineered MSimNPS suite with a security architecture and realtime simulation testbed that scales efficiently in terms of performance, cost-economy, convergence, stability and ease of integration for future realtime services for end users.

1.6 Dissertation report organization

This dissertation is divided into six chapters:

Chapter one presents introduction of GSM networks and KPIs

Chapter two reviewed the mobile cellular evolutions, their architectural generations, the GSM KPI as QoS metrics, TCG reference architecture, SMART/SIM cards, Mobile Number Portability and matlab fuzzy logic with ANFIS.

Chapter three presents the methodology, system analysis, real-time system methodology, QoS evaluation criteria, key performance indicators, ASCOM mobile test strategy, test bed description and field measurements, data collection method, analysis process framework

Chapter four presents the MNP modeling using fuzzy network and system implementation

Chapter five presents the results and discussion of the research.

While Chapter six presents the conclusion and recommendations.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to GSM Telephony

According to the website, GSM (Global System for Mobile Communications), was defined as a standard set developed by the European Telecommunications Standards Institute (ETSI) to describe protocols for second generation (2G) digital cellular networks used by mobile phones [12]. The GSM standard was developed as a replacement for first generation (1G) analog cellular networks, and originally described a digital, circuit switched network optimized for full duplex voice telephony. This was expanded over time to include data communications, first by circuit switched transport, then packet data transport via GPRS (General Packet Radio Services) and EDGE (Enhanced Data rates for GSM Evolution or EGPRS). Further improvements were made when the 3rd Generation Partnership Project (3GPP) developed third generation (3G) UMTS standards followed by fourth generation (4G) LTE Advanced standards [12].

The mobile radio network technology family of the 3GPP as well as its predecessor ETSI (European Telecommunications Standards Institute), including GSM/EDGE (Global System for Mobile communications/ Enhanced Data rate for GSM Evolution) and UMTS/HSPA (Universal Mobile Telecommunication System/ High Speed Packet Access) technologies, now accounts for over 85% of all mobile subscribers worldwide. The further increasing demand on high data rates in new applications such as mobile TV, online gaming, multimedia streaming, etc., has motivated the 3GPP to work on the long term evolution (LTE) project since late 2004. Overall target was to select and specify technology that would keep 3GPP's technologies at the forefront of mobile wireless well into the next decade [13].

2.1.1 GSM Carrier Frequency

GSM networks operate in a number of different carrier frequency ranges (separated into GSM frequency ranges for 2G and UMTS frequency bands for 3G), with most 2G GSM networks operating in the 900 MHz or 1800 MHz bands. Where these bands were already allocated, the 850 MHz and 1900 MHz bands were used instead (for example in Canada and the United

States). In rare cases the 400 and 450 MHz frequency bands are assigned in some countries because they were previously used for first-generation systems. Most 3G networks in Europe operate in the 2100 MHz frequency band.

Regardless of the frequency selected by an operator, it is divided into timeslots for individual phones to use. This allows eight full-rate or sixteen half-rate speech channels per radio frequency. These eight radio timeslots (or eight burst periods) are grouped into a TDMA frame. Half rate channels use alternate frames in the same timeslot. The channel data rate for all 8 channels is 270.833 kbit/s, and the frame duration is 4.615 ms. The transmission power in the handset is limited to a maximum of 2watts in GSM 850/900 and 1 watt in GSM 1800/1900 [12].

According to [14], the demand for wireless communication had grown rapidly and the capacity of cells in the existing digital cellular mobile networks, like GSM, need to meet the increased demand. The work observes that the network operators are now facing the problem of how to increase the capacity of an existing network without noticeable degradation of quality of service. In this case different solutions have been foreseen but the most obvious solution in place has been that of extending the GSM band or increase the number of serving channels or frequencies in an area. However the overall available GSM spectrum is limited and is usually divided between 2 or 3 network operators leaving a spectrum of not more than 10 MHz for each operator [14]. Before expanding more on the review issues of GSM QoS, a review of the various GSM cellular networks will be presented below.

2.2 GSM Network Technologies and Their Evolutions

After the first generation-1G GSM network comes Second Generation-2G , Third Generation-3G Evolution and Post-3G Future Generations.

Post-3G Future Generations will be presented below as the 4th, 5th and next generation Evolutions.

2.2.1 Fourth Generation- 4G Evolution

The 4G refers to International Mobile Telecommunications Advanced, (IMT-Advanced), as defined by ITU-R [25]. According to[26], in telecommunications, 4G refers to the fourth generation of mobile phone mobile communication technology standards which is a successor of the (3G) standards. A 4G system provides mobile ultra-broadband Internet access, for

example laptops with USB wireless modems, to smart phones, and to other mobile devices. Conceivable applications include amended mobile web access, IP telephony, gaming services, high-definition mobile TV, video conferencing, 3D television and Cloud Computing [26].

In the world today, two 4G candidate systems are commercially deployed: the Mobile WiMAX standard (at first in South Korea in 2006), and the first-release Long Term Evolution (LTE) standard (in Oslo, Norway since 2009).

In September 2009, the technology proposals were submitted to the International Telecommunication Union (ITU) as 4G candidates [29].

Basically all proposals in 4G are based on two technologies:

- LTE Advanced standardized by the 3GPP
- 802.16m standardized by the IEEE (i.e. WiMAX)

In Nigeria, the implementations of Mobile WiMAX and first-release LTE is largely considered a stop gap solution that will offer a considerable boost until WiMAX 2 (based on the 802.16m spec) and LTE Advanced are deployed. Though, the latter's standard versions were ratified in spring 2011, but are still far from being implemented [27]. A summary of the technologies that have been studied as the basis for LTE Advanced is included in a technical report in [30].

2.2.1.1 IMT-2000 compliant 4G standards

These includes viz:

- i. LTE Advanced

The Long Term Evolution Advanced (LTE-A) is essentially an enhancement to LTE network. It is a candidate for IMT-Advanced standard, formally submitted by the 3GPP organization to ITU-T in the fall 2009, and expected to be released in 2013 [26]. LTE-A offers an upgrade path that makes it more cost effective for vendors to offer LTE and then upgrade to LTE Advanced which is similar to the upgrade from WCDMA to HSPA. It is observed that LTE and LTE Advanced will make use of additional spectrums and multiplexing to allow it to achieve higher data speeds [31]. Coordinated Multi-point Transmission will also allow more system capacity to help handle the enhanced data speeds. Release 10 of LTE is expected to achieve the IMT Advanced speeds.

Release 8 currently supports up to 300 Mbit/s of download speeds which is still short of the IMT-Advanced standards [32]. Table 2.1 shows the data Speeds of LTE Advanced while fig 2.1 shows the Long Term Evolution (LTE) 4G MODEM.

Table 2.1: Data Speeds of LTE Advanced

	LTE Advanced
Peak Download	1Gbits
Peak Upload	500Mbits

ii. IEEE 802.16m or Wireless MAN-Advanced

The IEEE 802.16m or Wireless MAN-Advanced evolution of 802.16e is under development, with the objective to fulfill the IMT-Advanced criteria of 1 Gbit/s for stationary reception and 100 Mbit/s for mobile reception [33].



Figure 2.1: Samsung 4G LTE Modem [33].

iii. Mobile WiMAX (IEEE 802.16e)

The Mobile WiMAX (IEEE 802.16e-2005) mobile wireless broadband access (MWBA) standard is branded as 4G, and offers peak data rates of 128 Mbit/s downlink and 56 Mbit/s uplink over 20 MHz wide channel.

Table 2.2: Data Speeds of Wimax

	LTE Advanced
Peak Download	128Mbit/s
Peak Upload	56Mbit/s

2.2.1.2 Key features in 4G Candidate Systems

The following key features can be observed in all suggested 4G technologies:

- i. Physical layer transmission techniques are as follows [34]:
 - MIMO: To attain ultra high spectral efficiency by means of spatial processing including multi-antenna and multi-user MIMO
 - Frequency-domain-equalization, for example multi-carrier modulation (OFDM) in the downlink or single-carrier frequency-domain-equalization (SC-FDE) in the uplink: To exploit the frequency selective channel property without complex equalization
 - Frequency-domain statistical multiplexing, for example (OFDMA) or (single-carrier FDMA) (SC-FDMA, a.k.a. linearly precoded OFDMA, LP-OFDMA) in the uplink: Variable bit rate by assigning different sub-channels to different users based on the channel conditions
- ii. Turbo principle error-correcting codes: To minimize the required SNR at the reception side
- iii. Channel-dependent scheduling: To use the time-varying channel

- iv. Link adaptation: Adaptive modulation and error-correcting codes
- v. Mobile-IP utilized for mobility
- vi. IP-based femtocells (home nodes connected to fixed Internet broadband infrastructure)

As opposed to earlier generations, 4G systems do not support circuit switched telephony.

2.2.2. Fifth Generation- 5G Evolution and Next Generation Evolutions.

According to [35], the 5G (5th generation mobile networks or 5th generation wireless systems) is a term used in some research papers and projects to denote the next major phase of mobile telecommunications standards beyond the current 4G/IMT-Advanced standards. 5G does not describe any particular specification in any official document published by any telecommunication standardization body. Although updated standards that define capabilities beyond those defined in the current 4G standards are under consideration, those new capabilities are still being grouped under the current 4G standards.

2.3. Adoption Index/Market Readiness

In this research, a study on 3G, 4G and 5G shows that in Nigeria today, these evolutions are slowly gaining popularity and acceptance following the relatively slow global adoption.

As part of the challenges, in some instances, 3G networks for example do not use the same radio frequencies as 2G, so mobile operators must build entirely new networks and license entirely new frequencies, especially so to achieve high data transmission rates. Other delays could be due to the expenses of upgrading transmission hardware, especially for UMTS, whose deployment required the replacement of most broadcast towers. Due to these issues and difficulties with deployment, the operators have not able to update their technological capabilities.

In Nigeria, GSM network operators are gradually rolling out 3G and HSDPA networks with the deployment of several terminal base stations to operate 3G mobile networks. Besides the roll-out of 3G networks has been delayed owing the enormous costs of additional spectrum licensing fees by the regulatory bodies like NCC.

We therefore conclude that if the GSM evolutions will continue with this rapid pace and the Nigerian network providers lacks commensurate infrastructure to deliver the relevant services using QoS index, then under utilization of technological evolutions will set a backward trend for country. This research will only focus on GSM quality of service and already existing architectures before proposing a novel framework for integration.

2.4. An Overview of GSM Cellular Architecture

The GSM mobile communication network is a cellular structured, wireless network. Each cell represents an elementary geographic area (Picocell, Microcell, Macrocell). In GSM 1.02 [36] a mobile cellular network is subdivided into three areas:

- Radio Subsystem (RSS),
- Network- and Switching Subsystem (NSSS), and
- Operation and Maintenance Subsystem (OMSS)

The functional architecture of such subsystems is illustrated in Figure 2.2, followed by a subsequent description of the depicted network components.

2.4.1 The Radio-Subsystem (RSS)

The Radio-Subsystem (RSS) is responsible for the wireless communication within a mobile cellular network. It consists of the Mobile Station (MS) and the components of Radio Access Network (RAN).

- **Mobile Station (MS):** The Mobile Station (MS) is the terminal equipment of a subscriber. It is composed of the Mobile Equipment (ME) and the Subscriber Identity Module (SIM). The MS is a user handset that connects to the BTS over the Um air interface. It consists of Mobile Equipment (ME) that contains a unique International Mobile Equipment Identity (IMEI) and a Subscriber Identity Module (SIM) card that stores a unique International Mobile Subscriber Identity (IMSI) and authentication key. These secure numbers are also stored in the network and used to properly identify and authorize the subscriber. Again, the MS does not authenticate the network to which it connects, enabling malicious attacks by falsifying a man-in-the-middle BTS.

In this work, by adding a framework module to the Module, ie equipped with an embedded hardware-based trust-anchor, describe as Mobile Trusted Platform (MTP) for network portability (MNP), this work seeks to enhance service delivery in 2G/3G domain.

- **Radio Access Network (RAN):** A Radio Access Network (RAN) is formed by several Base Station Subsystems (BSS). Each BSS consists of a Base Station Controller (BSC) with a set of associated Base Transceiver Station (BTS). All radio related functionality is controlled by the BSC, which handles the protected communication between the MS and the BTS. In this context, we stress that the GSM standard only stipulate an encrypted channel between the MS and BTS, which leads to flaws and vulnerabilities to the GSM communication system [39].

The BTS provides the radio interface for MSs within its serving cell. A BTS can contain multiple transceivers for transmitting and receiving on multiple frequencies and sectors in one cell. The actual management and functionality is controlled by the BSC over the A-bis interface. A network of BTSs and the governing BSC makes up the Base Station Subsystem (BSS). Also, the BSC manages the resources, services, and networking of multiple BTSs. Radio frequencies are mapped into logical channels, and dedicated channels are allocated as needed for signaling and traffic connections. A MS sends location update requests to the BSC to allow the network to track it. The BSC also collects periodic measurement reports from a connected MS in order to decide if handover to a better quality cell (inter-BTS) or frequency (intra-BTS) is required, including during a call [40].

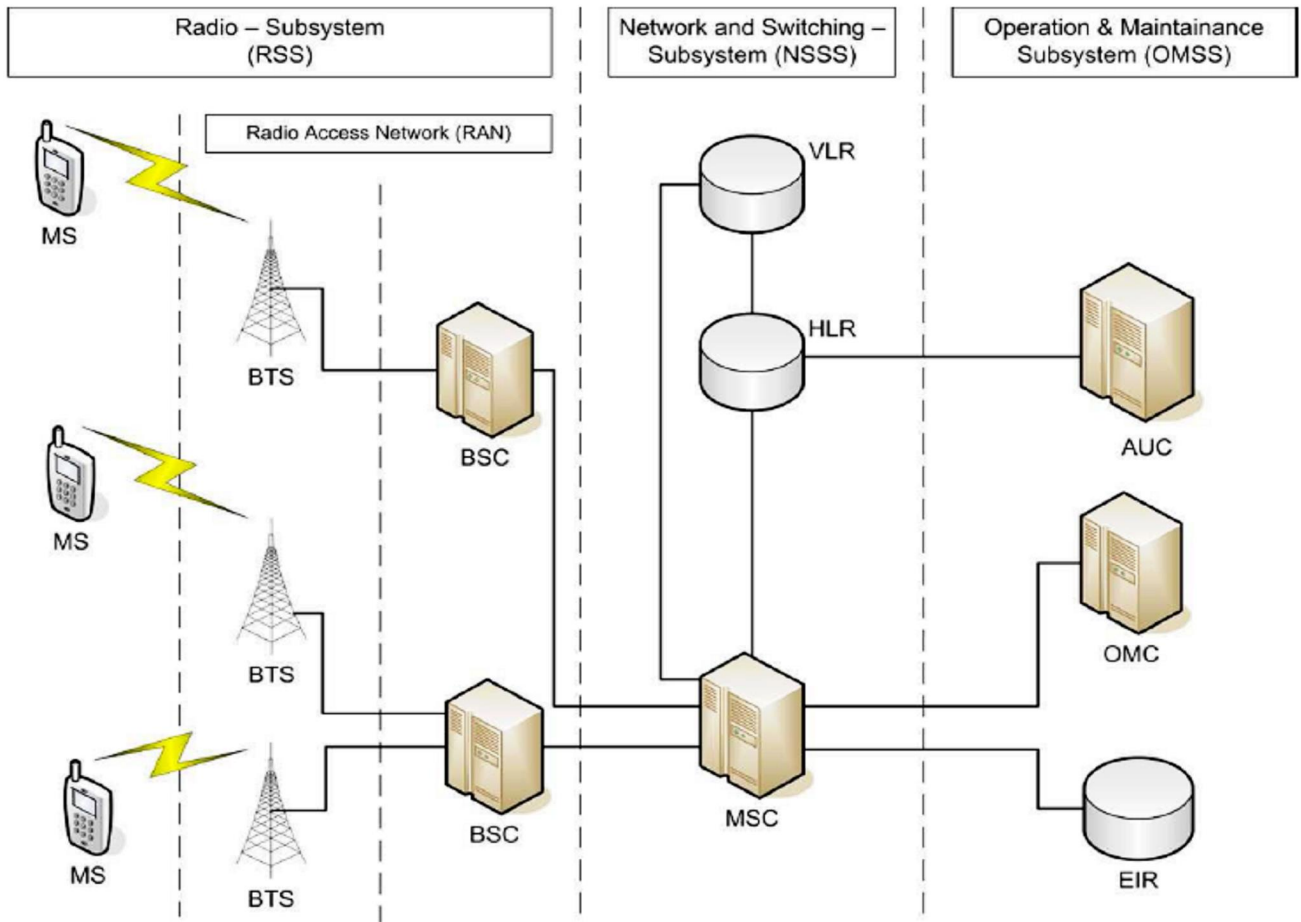


Figure 2.2: Functional Architecture of a Generic GSM mobile Network [40].

2.4.2. Network- and Switching Subsystem (NSSS)

The Network- and Switching Subsystem (NSSS) implement the underlying cellular switching and network communication technology. Significant components of a NSSS are the Mobile Switching Center (MSC), the Home Location Register (HLR) and the Visitor Location Register (VLR).

- Mobile Switching Center (MSC): The Mobile Switching Center (MSC) represents the central node of a NSSS and controls a set of dedicated BSCs and associated BTSs. The main task of a MSC is to set up circuit-switched connections so that data can be transferred between the communication participants.

All communication are relayed and maintained across cell boundaries, so that all inbound and outbound connections are controlled, managed and monitored by this network component.

- **Home Location Register (HLR):** The Home Location Register (HLR) is a data repository assigned to a MSC. It stores individual information of each subscriber (e.g. IMSI, MSISDN, SST) and temporary informations (e.g LAI, MSRN) of the subscriber. In a GSM network, at least one HLR is present and every subscriber is assigned to one specific HLR.

- **Visitor Location Register (VLR):** The Visitor Location Register (VLR) denotes another data repository of a MSC. It contains subscriber informations, similar to the HLR, but it stores only information for external subscribers who are temporary located inside the area of responsibility of a MSC. Typically, a VLR refers to several MSCs, but one MSC always uses one VLR.

2.4.3. Operation and Maintenance Subsystem (OMSS)

The main tasks of the Operation and Maintenance Subsystem (OMSS) are administration, authorization and accounting of subscribers, and maintenance of the GSM network components. The OMSS consists of the Authentication Center (AuC), the Equipment Identity Register (EIR) and the Operation and Maintenance Center (OMC).

- **Authentication Center (AuC):** The Authentication Center (AuC) is an important component in the security architecture and is usually integrated as a part of the HLR. It provides information of identification and authentication of a subscriber, and pre-computes authentication triplets, which are used to identify and authorize a subscriber. Such a triplet consists of a challenge *RAND*, the correct response *SRES*, and the communication key *Kc*.

- **Equipment Identity Register:** The Equipment Identity Register (EIR) holds a black, white and grey list aiming to protect against device theft. The EIR checks the status of a MS while performing the login procedure. A device is either listed as an non-approved, valid or as monitored.

- **Operation and Maintenance Center (OMC):** The OMC acts as the operation and maintenance center in a GSM network. It is used for installing, configuring and supervising network components of a MNO.

As discussed above, the Network Switching Subsystem (NSS) is the component of a GSM system that carries out call switching and mobility management functions for mobile phones roaming on the network of base stations [41]. It is owned and deployed by mobile phone operators and allows mobile devices to communicate with each other and telephones in the wider Public Switched Telephone Network (PSTN). The work still explained that the MSC represents the edge toward the BSS and on the other side as Gateway MSC (GMSC), the connection point to all external networks, such as the PSTN or Integrated Services Digital Network (ISDN). GSM is a circuit-switched network, which means that there are two different types of physical links to transport control information (signaling) and traffic data (circuit).

2.5. Mobility Management

Mobility Management (MM) is one of the major functions of a GSM or a UMTS network that allows mobile phones to work. Mobility management is the process of keeping track of and locating users so that calls arriving for them can be directed to their current location (Brown & Mohan 1997). In GSM networks, MM is completely handled between the MS and the Network Sub System (NSS).

For all GSM architectures, micromobility and macromobility are two fundamental concepts that contribute to QoS enhancement or degradations [47]. Many works on these concepts are studied in [48]. In mobility perspective, MS changes speed and direction. MSs are generated and simulated not to travel in straight lines at constant speed throughout the course of the entire simulation. In real situation, the direction of travel must change before reaching the end destination. The speed of each interval must occasionally change and may even decrease to zero. Figure 2.14, describes mobility models for cellular environment to represent MSs movement as discussed in [49]. Basically, mobility models are classified into two categories [50]. The first category is called entity mobility models, where all nodes in the system move independently from each other. The second category is called group mobility models, where sets of nodes move as groups. As noted in [51], cellular mobility models focus their attention on individual movements. Rarely do more complicated issues such as group movement come into play. As a result, in cellular mobility models: Random Walk Model, Constant Velocity Fluid-Flow Model, and Random Gauss-Markov [51]. Model is very common to test the behavior of cellular

strategies. But, this work will only focus on QoS investigations for a vendor networks while proposing a novel framework for its integration for enhanced QoS.

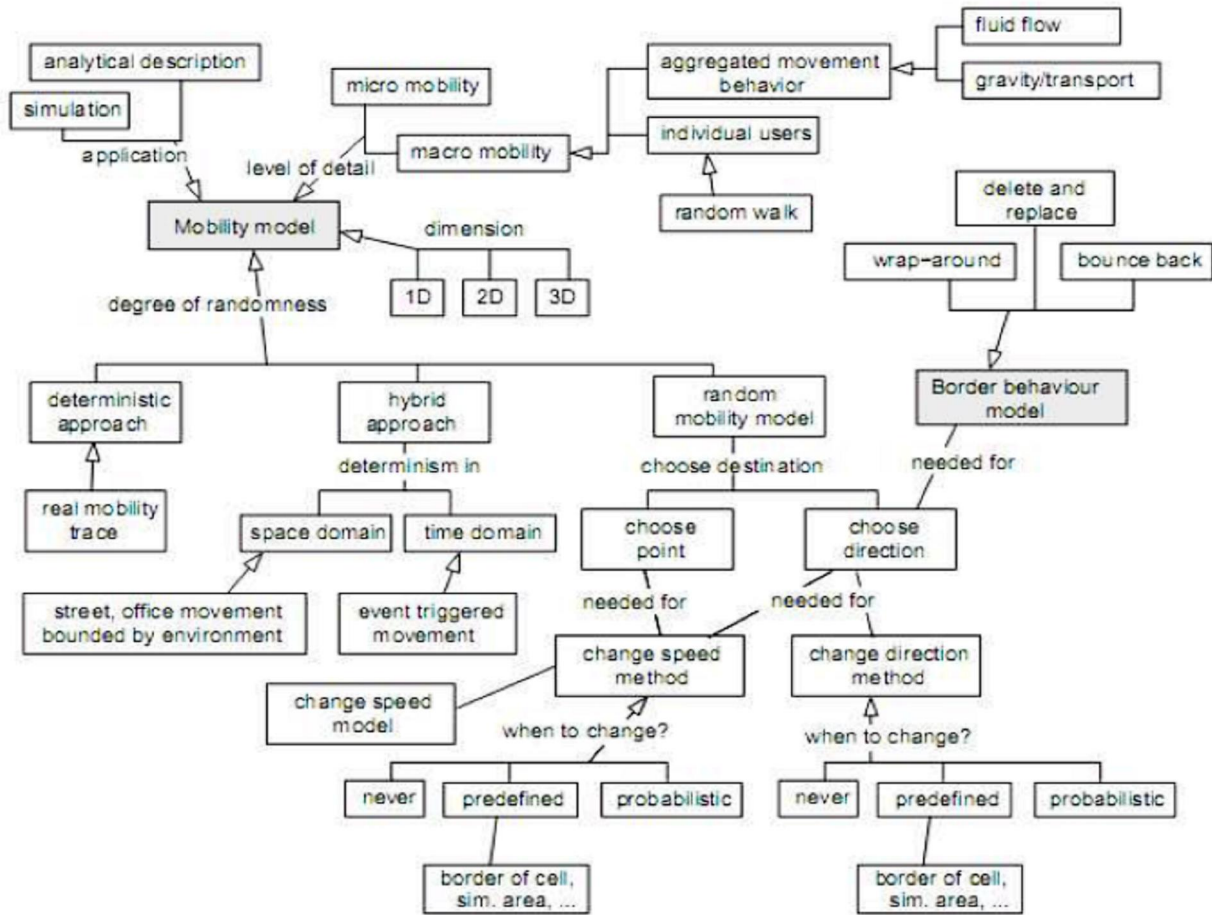


Figure 2.3: A concept Map of Mobility Models [49]

2.6. QoS in GSM Networks

This work so far have discussed GSM evolutions, cellular architectures, and mobility management models, etc. In this section, related works on GSM QoS will be reviewed.

The Nigerian Communications Act (No 19 of 2003)[53] defines Quality Of Service regulations for fixed and wireless operators for the year 2012 and has been documented in the website [38]. The Nigerian Communications Commission is empowered to establish minimum Quality of Service (QoS) standards in service delivery for the telecommunications industry. These QoS standards ensure that consumers continue to have access to high quality telecommunications service by setting basic minimum quality levels for all operators.

These standards define the lower and upper bounds of acceptability of such technical issues as transmission rates, error rates, call completion rates, etc. and commercial consumer issues such as access to customer care centres, billing integrity and other characteristics that can be measured and improved. As a result, every mobile operator in Nigeria offering 2G/3G services is expected to adhere to the mandate Nigerian Communications Commission (NCC) at the specified frequency in the year. Against this policy, table 2.2 shows the enlisted stipulations of the regulatory body for four major networks including MTN,GLO,Etisalat and Airtel starting from year 2011 to the updated year 2012.

2.6.1. Quality of Service and Key Performance Indices (KPI) for GSM Networks

Generally, the term Quality of Service (QoS) in various context and applications could have various definitions, but most definitions point towards end user satisfaction, expectations or fulfill requirements. According to [54], the International Organization for Standardization (ISO) gave an initial general definition of quality in ISO 8402 as "the totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs" and in the year 2000 it was replaced by ISO 9000 which defines quality as the "degree to which a set of inherent characteristics fulfils requirements".

For a new framework in GSM telephony to work, Monitoring QoS of any telecommunication network requires continuous processes that measure values of the Key Performance Indicator (KPI) parameters in real-time, its analysis of measured empirical data to determines quality of service rendered to the subscribers. There are many network parameters that evaluate the quality of delivered network service [38],[53] viz: Call Setup Success Rate, Call Setup Failure Rate.

Call Success Rate, Call Drop Rate, Call Retention Rate, System Response Time, Handover Statistics, Number of Handovers per call, and Voice Quality as a MOS value and Airtime Recharge Performance.

In 2007, the NCC held a Public Forum [55] to identify issues affecting QoS in Nigeria while seek a lasting remedy to the current QoS challenges in the 2G/3G industry and make recommendations on way forward. The forum identified the following issues as factors that require attention in order to improve the unacceptable QoS delivered on the various networks.

- Network Congestion
- Limited Transmission Infrastructure.
- Security of Telecommunications Equipment or Facilities.
- Unreliable Public Power Supply.
- Lack of Information to the Consumer on downtime.

The Nigerian Communications Commission (NCC) conducted QoS audit of the four networks in Nigeria for a period of 21 days from September 21, 2004 to October 11, 2004 [56]. The tests were in two categories namely; voice network performance/quality and Prepaid Performance Test while investigating on the above KPIs [57].

In their work, the authors in [58] investigated and analyzed the Quality of Service (QoS) of cellular mobile networks in Nigeria using some Network Key Performance Indicators (KPI). Their study though was limited to Visafone Mobile Network which is licensed to provide fixed wireless access telecommunications services on State by State basis in Nigeria under the license category classified as Private Network Links (PNL).

The results obtained showed that busy hour TCH Congestion Ratio was 0.0062 (which is lower than the NCC stipulated value of 2%). Also, the busy hour CDR was 0.7129 (below the NCC threshold of 2%) and the Busy hour CSSR was 98.7267 which is within the expected threshold set by NCC. However, a study on CDMA network service was carried out.

The work in [59] presented a precise analysis of mobile users behavior in terms of mobility and traffic that would help to optimize capacity for both circuit and packet switched services. Their research work employed the multiplicity of techniques for the capacity analysis of GSM network in Nigeria. In the work, enhanced stochastic knapsack was evaluated for resource sharing approach in multi-services while using erlang Loss Model for SMS capacity analysis. The authors used offered traffic ie Lost Traffic based to dimension the system resources. The work was actualized by the characterization of a typical representation of the Northern part of Nigeria. The work observed that traffic modeling is the critical part of networks modeling, it is the key point on performance evaluation for any communication network and thus group traffic Model grouped into two series, namely, smooth and non smooth model.

Firstly, the work examines source, volume and type of data generation by analytical method, then investigated the kind of channel allocation with respect to the frequency hopping types and proposes the best spectral efficiency. They further used grade of service (GoS) parameters in the multiservice GSM network to ascertain (fairer source allocation, a QoS metric) in the traffic mix environment.

Finally, in its model derivation, a multiservice Traffic model for an enhanced Knapsack of capacity C , with steady state probability of process was used to satisfy the conditional probability of occurrence of state in Stochastic Knapsack. The work then developed a traffic model for a GSM network designed to meet heterogeneous service requirements of different applications. The work showed a lower service rate for homogenous services.

A study in [60] evaluated the significance of price (call rate), service quality, service availability, promotion and brand image and its effect in users' perception in selecting a mobile telecommunication services provider in the Nigerian telecommunication market, using Ibadan, a Nigerian municipality as a case study.

The author observed that the paramount interest of mobile service providers is to achieve optimum consumers satisfaction so as to retain them, as evaluating the perception of a mobile user in a highly competitive telecommunication market is very a crucial factor leading toward competitiveness and success. In their work, it was gathered that no work have carried an investigation to assess the influence of the attributes of the mobile operators on users' choice of mobile service operators in the life of the Nigerian mobile users. This formed their focal point of study, which was to understand the factors that influence mobile phone users in their choice of a mobile phone service provider in the Nigerian mobile telecom market. The work then examined the influence of call rate (price), service quality, service availability, promotion, and brand image on mobile phone users' perception in selecting a service provider using structural equation modelling (SEM). A conceptual model shown in figure 2.15.

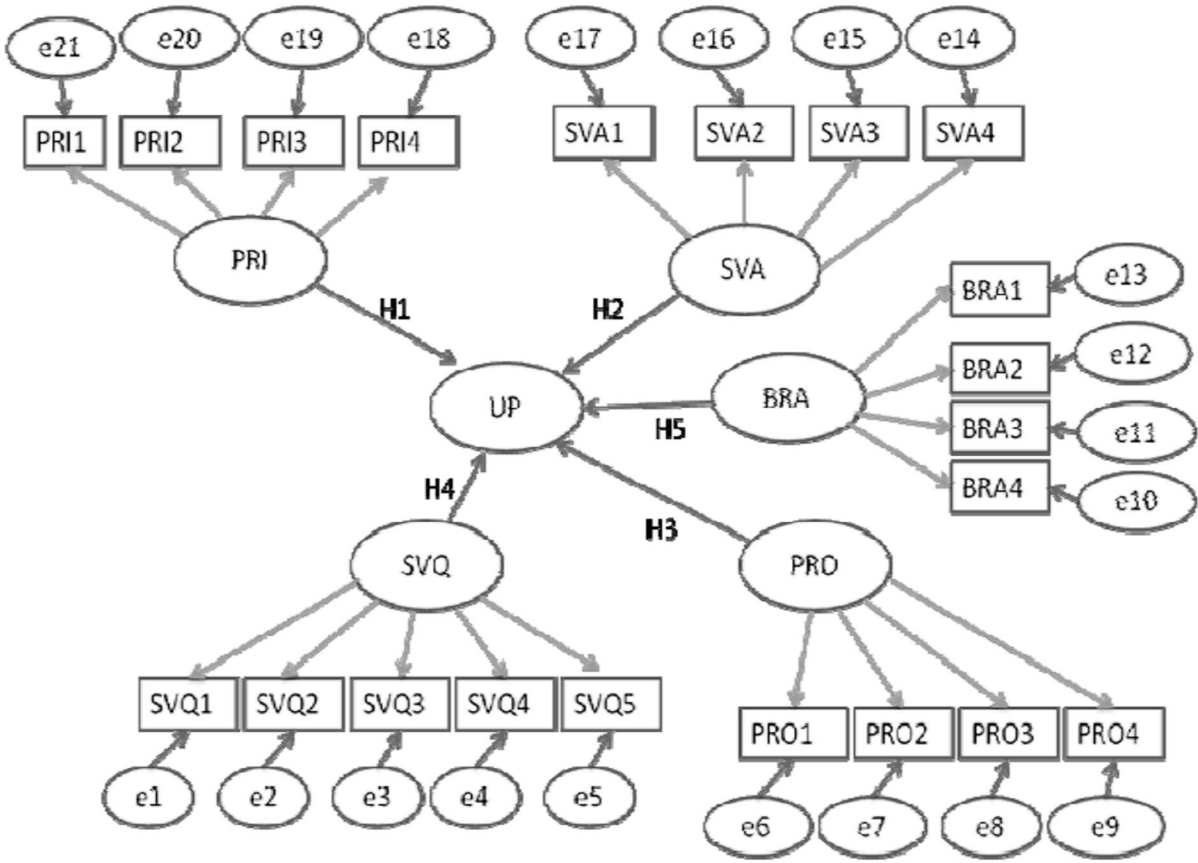


Figure 2.4a: Structural Model specification for the relationship between user perception towards service quality (SVQ), price or call rate (PRI), service availability (SVA), promotion (PRO) and brand image (BRI) [60].

Figure 2.4 presents the conceptual model adopted for the study. The author explained that, the first four constructs (price, service availability, service quality and promotion) were adopted from a similar study carried out in [61] using the Malaysian experience whereas, the last construct brand image, was from empirical literature [62]. In the centre of the model are the latent variables (PRI = Price/Call rate, SVA = Service availability, BRA = Brand image, SVQ = Service quality, PRO = Promotion, UP = User perception) represented with circles, and towards the perimeter are manifest variables (PRI1...PRI_n, SVA1...SVA_n, BRA1...BRA_n, SVQ1...SVQ_n, PRO1...PRO_n) represented with squares. The lines with an arrow in one direction show a hypothesized direct relationship between the variables. It should originate at the causal variable and point to the variable that is caused.

For every endogenous variable, a residual term is added in the model. Generally, a residual term is a circle with the letter E written in it, which stands for error.

Based on the conceptual model in Figure 2.4, the work then formulated the following hypotheses viz:.

H01: Call rate (Price) has no significant influence on mobile phone user perception in selecting a mobile telecommunication service provider.

H02: Service availability has no significant influence on mobile phone user perception in selecting a mobile telecommunication service provider.

H03: Promotion has no significant influence on consumer perception in selecting a mobile telecommunication service provider.

H04: Service quality has no significant influence on mobile phone user perception in selecting a mobile telecommunication service provider.

H05: Brand image has no significant influence on mobile phone user perception in selecting a mobile telecommunication service provider.

After a questionaring surey, factor analysis and factor loading was carried out while testing the above formulated hypothesis leading to figure 2.4b.

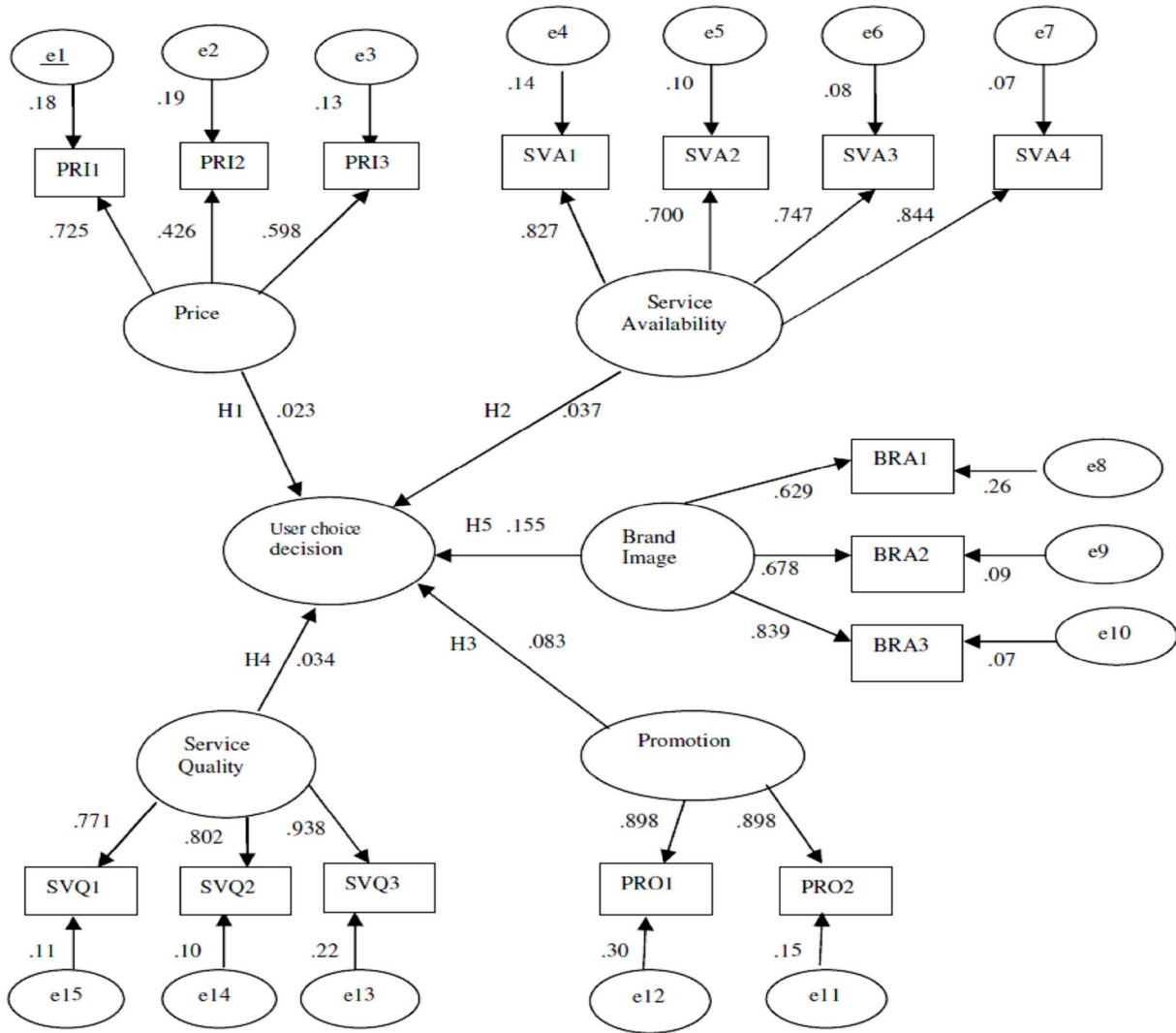


Figure 2.4b: Structural Equation Model diagram of the degree of relationship in Consumer Perceptions towards Service Quality (SVQ), Call rate/Price (PRI), Service Availability (SVA), Promotion (PRO), and Brand image (BRA) [60] .

In the first formulation, their result in Figure 2.4b showed that Call rate (price) emerged as the most important factor that affects customers' perception in selecting mobile operator with the results ($r^2 = .023$, $p < 0.05$) showing the degree of significance. In the second case, The result ($r^2 = 0.037$, $p < 0.05$) in Figure 2.4b showed that Service availability directly affects customers' perceptions in selecting mobile telecommunication services provider. In the third case, the result in Figure 2.4b showed that Promotion does not have a significant effect on users' intention in

buying telecom service and therefore, no positive impact on the users' perceptions in selecting a mobile operator. In the fourth case, Service quality emerged as the most important factor next to Call rate (price) that affects customers' perception in selecting telecom service (see Figure 2.4b). Their study showed that service quality has positive impact on users' perceptions. This work strongly agrees on these deductions which lead to the following recommendations in [60] viz:

1. The Nigerian Communication Commission should, by way of policy, assume the control and management of base stations from the network operators such that all mobile network operators would make use of same base stations but operate on different frequencies and pay rental fees to NCC or her designated agent. This would eliminate the high cost of building and maintaining base stations incurred by the various operators and consequently reduces operational cost.
2. The network operators should reduce their expenditure on promotional activities and brand building, but rather invest on network extensions, quality service delivery and product and services outlets infrastructures, while also concentrating on price reduction strategies as a way of increasing subscribers' base.
3. With the planned introduction of Mobile Number Portability (MNP) by Nigerian Communication Commission (NCC), which favours mobile operators with the best customer satisfaction, the finding of this study would provide these operators with the indicators to focus their business and marketing strategies [63].

This dissertation will leverage on these recommendations to formulate an enhance framework which will serve as a solution to the incessant challenges in the GSM industry in Nigeria.

The following are the KPI considered in this research viz [90]:

- Call Setup Success Rate (CSSR) is the rate of call attempts until traffic channel is successfully assigned.

$$\text{CSSR} = \frac{\text{No. of successfully seizures of SDCCH}}{\text{Total No. of requests for seizure of SDCCH channel}} \times 100\%$$

- Call drop rate (CDR) is the rate of calls not completed successfully.

$$\text{CDR} = \frac{\text{No. of TCH drop rate after assignment}}{\text{Total No. of TCH assignment}} \times 100\%$$

- Call handover success rate (CHSR) is the rate of successful handovers (intracell + intercell).

$$\text{CHSR} = \frac{\text{No. of successful (intracell + intercell) handovers} \times 100\%}{\text{Total No. of handover requests}}$$

Call handover success rate can be divided into two types: handover success rate and radio handover success rate.

- Call completion rate is the rate of successful completion of both incoming and outgoing calls.

$$\text{CCR} = \frac{\text{No. successful completed inbound or outbound calls} \times 100\%}{\text{Total no. of placed or received calls}}$$

Note: CCR does not take into account calls that dropped, missed or abruptly terminated.

- SDCCH is used for providing signalling service required by the user. It carries signalling data following the connection of the mobile with base station and just before a TCH assignment is issued by the base station. The SDCCH maintains connection between MS and BS. It is really an intermediate and temporary channel that accepts newly completed call from BSC and holds the traffic while waiting for the Base station to allocate a TCH channel. SDCCH is used to send authentication, user validation and alert messages as the mobile synchronizes itself with the frame structure and waits for TCH. SDCCH is the rate at which timing advance, validation and authentication of user is successfully completed.

$$\text{SDCCH} = \frac{\text{No. of successful TCH seizure or assigned} \times 100\%}{\text{Total no. of TCH request}}$$

2.6.1.1 QoS Evaluation Criteria

Quality of service is a measure of the reliability and usability of the telecommunications network. Three quality aspects of a mobile network that are fundamental from the user's point of view are presented:

- Coverage:** It indicates the geographic extent over which the network will reliably provide service. The strength of the signal is measured using test equipment and this can be used to estimate the size of the cell. Poor coverage can be caused by

- insufficient sites number, bad network configuration (antennas direction, antennas position), installation and maintenance problems.
- ii. **Accessibility:** Consists in the ability of a mobile network to set up and hold calls from mobile-fixed networks and from mobile-mobile networks.
 - iii. **Audio Quality:** It means the conversation perception for successfully setting up calls over a predetermined period of time. There are many factors which can degrade the speech quality of the end-to-end connection: Propagation conditions, poor coverage, external interference, co-channel interference, terminals quality.

2.7. Challenges Facing QoS Service Provisioning In Nigeria

1. Interference

The signal at the receiving antenna can be weak by virtue of interference from other signals. These signals may be from the same network or may be due to man-made objects. However, the major cause of interference in a cellular network is the radio resources in the network. Indeed, high capacity increases interference because of reuse of frequency technique.

There three kinds of interference:

i. Co-Channel interference: occurs when radio transmitters from two adjacent cells transmit on the same channel, in the same TDMA timeslot. When this happens, the signal is temporarily distorted. The result will be poor speech quality, drop-outs or even complete call losses in voice calls, GPRS data connections will slow down significantly. Co-channel interference cannot be avoided, since the same channels must be re-used in other cells not far apart. In GSM various techniques have been developed to reduce the problem, for example discontinuous transmission, frequency hopping, power control and adaptive multi-rate coding. However, the problem remains the ultimate limiting factor for network capacity.

ii. Adjacent channel interference: This phenomenon is due to the use of two frequencies having adjacent bandwidth by sites not well separated,

iv. Co-site interference: occurs when two neighbouring frequencies are used in the same site.

To avoid this problem, many actions can be taken: Operators should choose an adequate cluster for frequency reuse technique, change antenna direction and reduce the BTS transmission power.

2. Congestion

A network is congested when the available resources are not sufficient to satisfy the experienced workload traffic.

3. Coverage Problems

The BTS coverage can stretch 30Km as maximum diameter depending on the traffic in urban or rural areas. Coverage problem appears if waves transmitted by the mobile can not reach the nearest BTS or if waves transmitted by the BTS are not received with sufficient power which can be detectable by the mobile. Sufficient coverage can be caused by antennas special disposition, we can consider the case of an obstruct between the antenna and the mobile (building, mountain. To resolve this problem, operators have to take many actions in concerned sites :

- i. Adding sites: This solution is preferred in the case of coverage absence or if waves transmitted by BTS antennas can not reach the nearest area with sufficient power,
- ii. Antennas change such as tilting, changing antennas orientation.
- iii. Configuration change: This action aims to rise many antenna parameters such as transmission power (BS_TXPWR_MAX).

4. Call/session drop problem

This problem is caused by:

i) BSS Drop:

It is due to an interior materiel problem in the BTS. To avoid this kind of problem, we have to check the BTS software or do drive test in the concerned site.

ii) *Radio drop:* The call or session is dropped because of a problem in the radio interface. To identify the exact cause of dropping, the following have to verified, viz:.

- If the cause is quality, dropping is caused by congestion,
- If the cause is interference, the cell can be interfered. Thus, a comparison on the frequency of the concerned cell to those of its neighbours must be carried out.

Else, we can « tilt »neighbouring sites antennas,

- If the cause is RXLEV degradation, dropping is due to cell poor coverage or to a problem in materiel cell components.

iii.) Session drop because of a transmission Challenge: A transmission problem means that there is a problem in interfaces or transit delay Overtaking.

- **Call/Session set up failure problem**

The first thing to check is the coverage. If we have in the concerned site good coverage, we have to see if channels are congested. First, we have to check circuit channels and then packet channels. Session set up failure may also be caused by Gb interface congestion or BSS problem

2.8. SMART Cards

This section starts with an introduction to the concept of smart cards in general and then goes into more detail about the main subject of interest, the SIM card [64]. The smart card technology is based upon standards that are created and maintained primarily by:

- ISO (international standardization organization) [65].
- IEC (international engineering consortium), in cooperation with ISO [66]. - ETSI (European Telecommunications Standards Organization) [67].
- 3GPP (3rd Generation Partnership Project) [67] in cooperation with ETSI. - Global Platform Group [68]. It is on these organizations home pages that the standardization whitepapers, drafts and the like can be found and downloaded. ETSI and 3GPP papers are free, but the ISO charges a fee for their services. References to various standards from these organizations are mentioned in the overview is found Figure 2.5.

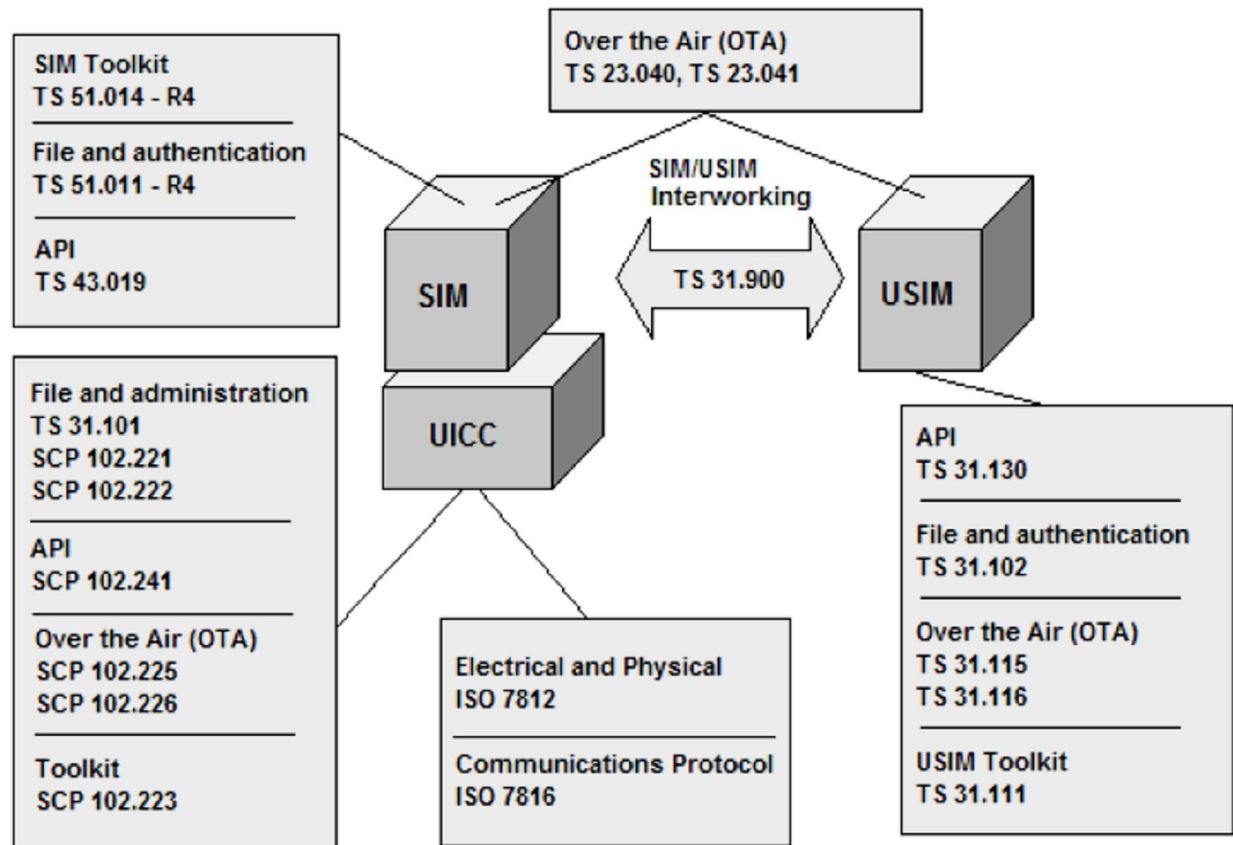


Figure 2.5: Overview of some of the SIM card standards shared between ETSI and 3GPP (TS and SCP above) [68].

From figure 2.5, these rely on the foundation smart card standards, especially ISO 7812 and ISO 7816 [69]. SCP here stands for Smart Card Platform which basically is an adaption of the Java Card Platform for SIM cards. A smart card comes in three physical sizes, as credit-card sized (credit cards), as the smaller 5x15mm (See Figure 2.6) version found in mobile phones and as the new micro SIM format (12x15 mm).



Figure 2.6: A Smart Card Picture; (a SIM card for use in mobile phones, size is 25x15 mm) [64].

Figure 2.7 show typical specification ranges for a smart card found in cellular phones or on payment cards. The hardware platform aspect of a modern smart card is called a Universal Integrated Circuit Card (UICC) [64].

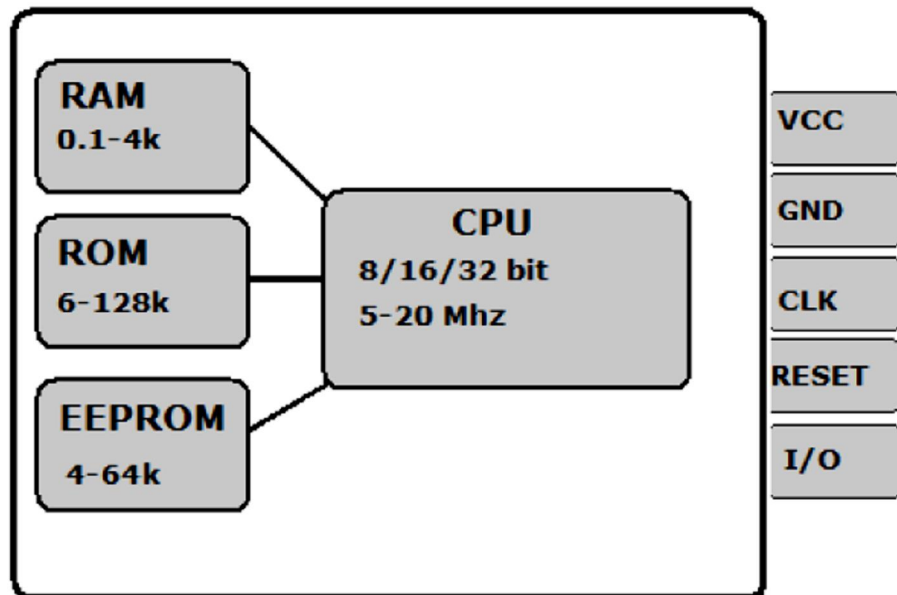


Figure 2.7: Smart card Specifications in cellular Phones/Payment Cards [64].

2.8.1 Features of Smart Card Hardware

Some basic features of a smart card hardware is presented in [64] viz:

CPU: The CPU is historically 8-bit; typically a Motorola 6805 or Intel 8051 derivate. Today, the normal type is 16-bit (Java Card 3 based generation which uses 32-bit RISC processors). The CPU can go into standby/sleep mode to save power where it uses much lower clock rates.

RAM: The RAM Size ranges from few hundred bytes to several megabytes; typically it is 1-4 kilobytes. There are often two types of RAM, internal that is used by the low level operating system and external (XRAM) that is used by the applications.

ROM: This contains the smart cards core operating system and support libraries. Sizes ranges from 6 kilobytes up to a few hundred kilobytes.

EEPROM/Flash: Programmable nonvolatile memory types which persists stored data also when not powered, but can be very slow to write (100-1000 times slower than RAM). The smart card's file system is stored in this kind of memory. Typically sizes are from 4 to 64k (up to 2 GB on recent cards [70]). The size of this memory type is often printed on the physical card itself (512k or similar).

Communication: Serial half-duplex 9600 bps (up to 115kbps for modern cards) communication interface/protocol between card and host. Half duplex means either the card or the host is sending data, not both simultaneously. Some recent cards also provide support for USB (up to 12Mb/s) and/or NFC (Near Field Communications) and RFID (Radio Frequency Identification).

Encryption and security: Most cards have custom encryption/signature (hash) verification hardware since the main CPU can be quite slow (especially for code running in a virtual machine). Usually it supports DES /3DES, RC4 but also more recently AES, RSA, DSA, COMP128 and Public Key Infrastructure (PKI) [71]. PKI private keys never leave the card. A hardware random generator is often present to provide more secure encryption key generation. The smart card has to provide protection against tampering (see table 2.4).

2.9. SUBSCRIBER IDENTITY MODULE (SIM) for Mobile Equipment

2.9.1. What is a SIM Card?

A SIM, Subscriber Identity Module, is the removable circuit board found in a modern cellular phone. It carries the network identity information and is a type of smart card which can also be found on payment cards, ID cards and so on. In context, a smart card could be referred to as a Subscriber Identity Module application on a smartcard that stores data for GSM/CDMA Cellular telephone subscribers. Such data includes user identity, network authorization data, personal security keys, contact lists and stored text messages. Security features include authentication and encryption to protect data and prevent eavesdropping.

The smartcard with Subscriber identity module application is generally known as SIM card. But, In reality, the SIM is effectively a mass-market smartcard. When the SIM is viewed as a smartcard, it opens up security possibilities that resonate far beyond the mobile world.

By combining stored evidence of identity (such as a key) with personal information, only the user will know (a password, for example), it offers the same two-tier authorisation provided by smartcards. The SIM, a feature unique to the mobile world, has applications far beyond those for which it was originally designed. It was created to remotely authenticate users to the network and to the billing systems that allow operators to generate revenues from voice traffic. The GSM standards as specified by ETSI requires authentication of a mobile subscriber through a secure device (the SIM card).

2.9.2. GSM SIM Network parameters

All SIM cards contain network parameters and encryption keys at well-defined places in the file system (Table 2.4). The file system also contains the network base application(s), these applications are responsible for communicating and authenticating with the operators network (handshaking encryption keys and so on).

Table 2.4: File System Element Type

File type	Name	Description
MF	Master File	File system root directory
DF	Dedicated File	Directory file (can contain DF and EF elements)
EF	Elementary File	Data file

Most of these parameters are defined when the SIM is manufactured because they need root user access to the card or reside in ROM. A short list of necessary files (EFs) needed to use a SIM card in the network, is discussed in GSM 11.11 [67] and are outlined below:

- The phone number (called MSISDN).
- SIM's network identity; the IMSI (International Mobile Subscriber Identity).
- A unique SIM serial number (called SSN and/or ICC-ID [72]).
- A 128 bit network authentication/signing key⁶ (called K_i) to authorize the phone to the network.

- PIN code (entered by user when user starts the phone).

2.9.2.1 Functionality of the SIM CARD

The SIM card performs the following valuable functions:

- 1) **Identification** of a subscriber: The IMSI programmed on the SIM card, is the identity of a subscriber. Each IMSI is mapped to a mobile number and provisioned on the HLR to allow a subscriber to be identified.
- 2) **Authentication** of a subscriber: This is a process, where, using the authentication algorithm (COMP128V3 for 2/2.5G GSM, CAVE for CDMA and Milenage for 3G) on the SIM card, a unique response is provided by each subscriber based on IMSI, K_i (stored on SIM) and RAND (provided by network). By matching this response with values computed on the network a legal subscriber is logged on to the network and he or she can now make use the services of the mobile service provider.
- 3) **Storage**: To store phone numbers and SMS.
- 4) **Applications**: The SIM Tool Kit or GSM 11.14 standard allows creating applications on the SIM to provide basic information on demand and other applications for m-commerce, chatting, cell broadcast, phonebook backup, location based services etc. Figure 2.20 shows a classification of basic function of SIM in GSM System.

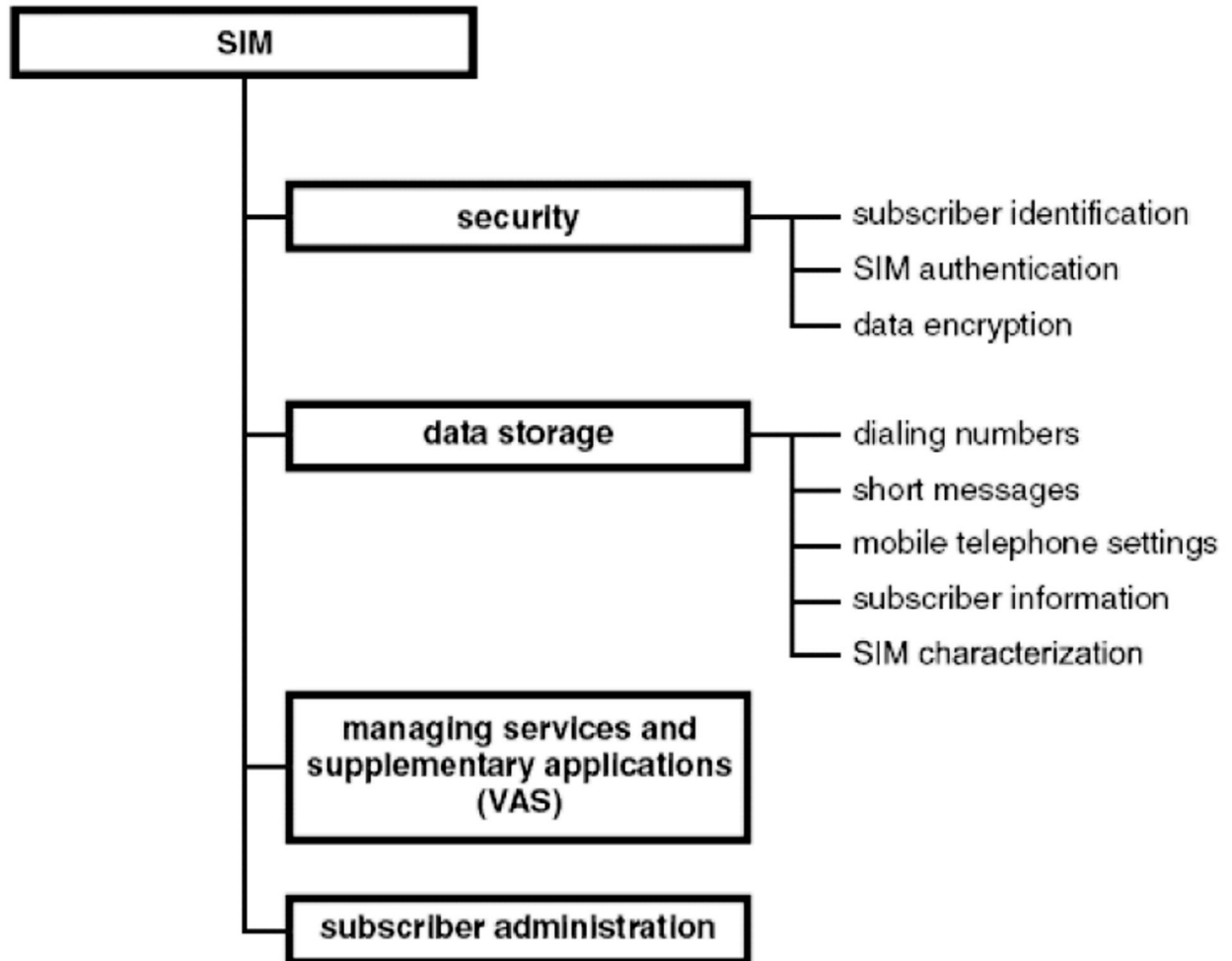


Figure 2.8: Classification of Basic Function of SIM in GSM System

Subscriber information, such as the IMSI (International Mobile Subscriber Identity), is stored in SIM which can be used to store user-defined information such as phonebook entries. One of the advantages of the GSM architecture is that the SIM may be moved from one Mobile Station to another. This makes upgrades very simple for the GSM telephone user. The author in [64] opines that the Smartcard is very secure and provides viz:

- i) The secure loading of the applications
- ii) Secure data storage for the application data and application cryptographic keys
- iii) Secure Crypto operation support.

However, Application security depends on the application design and smartcard only provides a secure platform for developing secure applications. The security of smart card is similar to the security offered by Hardware Security Module (HSM)

2.9.2.2 SIM Security

The Presence of Cryptographic algorithm and secret key in SIM card makes the SIM card secure. The most sensitive information of SIM card is the cryptographic algorithm *A3*, *A8*, *secret Ki*, *PIN*, *PUK* and *Kc*. *A3*, *A8* algorithm were written into the SIM card in the producing process. PUK code is held by the operator. *Kc* was derived in the process of encryption from *Ki*.

The other factors which make the SIM secure includes the PIN and PUK:

- i. PIN is Personal Identification Number, here two PINs exist (PIN 1 and PIN2) and it limited attempts on PIN access
- ii. PUK is PIN Unblocking Code- Resetting PUK, resets the PIN

Some ways of storing data in SIM includes viz:

1. As GSM Files

The data used for Telcommunication and GSM operation are all stored over the files. Telco/operator can change the data this file in a secure channel. Only upon successful verification of file access condition, a file can be read. All files are protected by access conditions.

2. Data on the SIM is protected by administrative keys which are in hexadecimal and it is proven, that to compromise the security of a SIM, one requires physical access to the SIM, enormous supercomputing ability and lots of time to crack one single card.

2.9.3. Authentication of a Cellular Phone with the GSM Network

The authentication process is done by the SIM card (more specifically by the GSM application running on the card) and is based on a challenge-response pattern [73]. The details falls outside the scope of the thesis, but the basics are shown below in Figure 2.9.

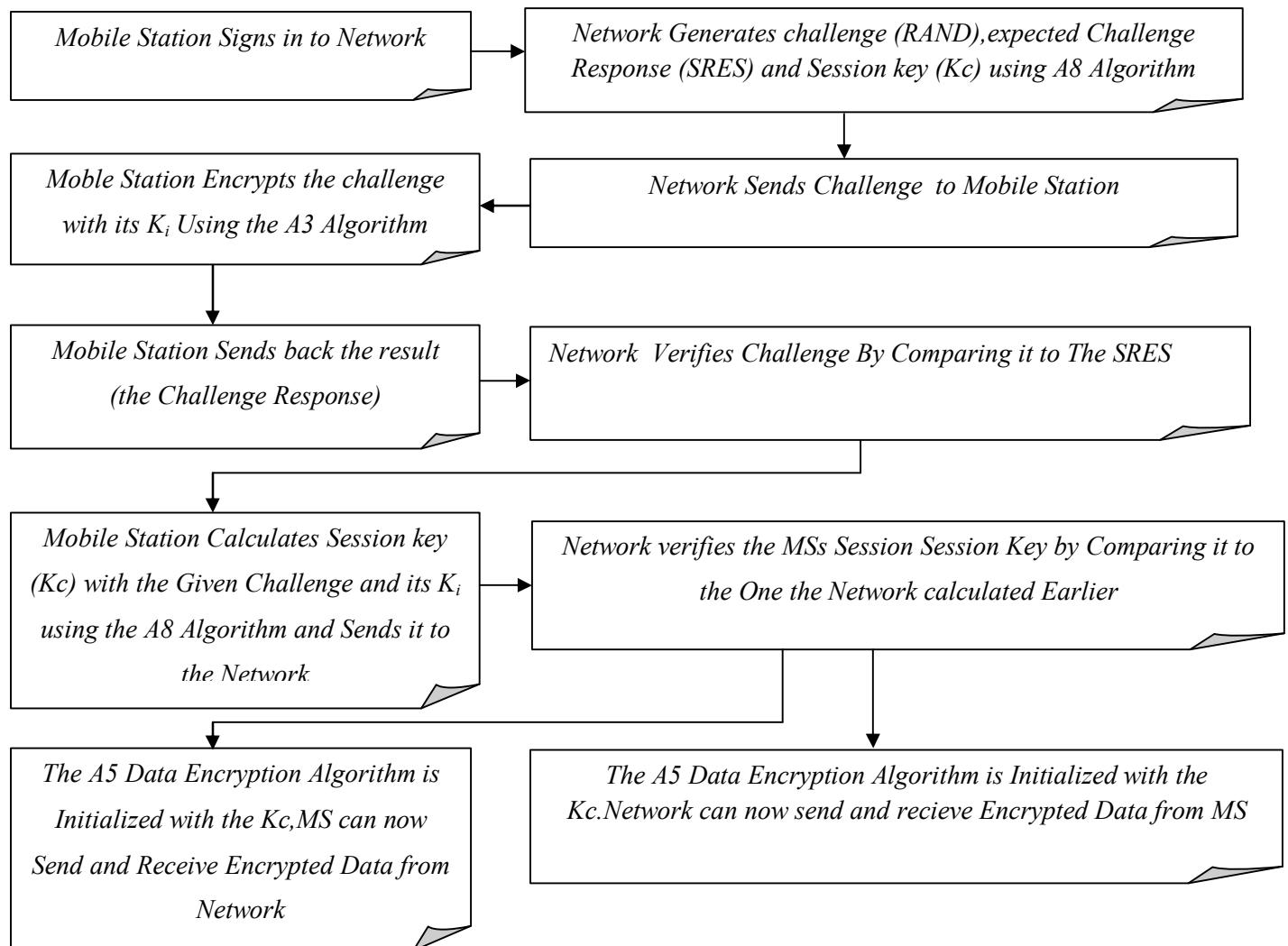


Figure 2.9: Simplified diagram over GSM-based Handset Authentication with the network.

A handset (in literature also called UE-User Equipment ME-Mobile Equipment; MS-Mobile Station) contacts its network. The network then contacts the home location register (HLR) for the operator in question. The HLR looks up the users account by the phone's MSISDN. In the

account the corresponding K_i is stored (among other things). The HLR then generates a set of keys (based on MSISDN/IMSI and the K_i). These are sent back as a challenge token (a question of type "return to me the result if you encrypt the given random data with your key").

The SIM card sends back its signed response to the network which verifies it with what the HLR calculated.

If it is accepted the SIM generates a 64-bit session key called K_c (through the A8 algorithm). This is based on the K_i and the received challenge token. This session key is used to initialize the A5 encryption algorithm (on both sides) that is hence used during further communication. GSM suffers from the limitation that it is only the handset that is verified by the network, not the other way around. An imposter (needing a fake base station) could thus try to figure out the handset's K_i by issuing challenges and looking at the response it gets back.

2.9.3.1 SIM Interest Groups

As seen in Figure 2.10, there are several interest groups and other factors driving the SIM card technology forward. The more important standardization organizations involved are shown in grey.

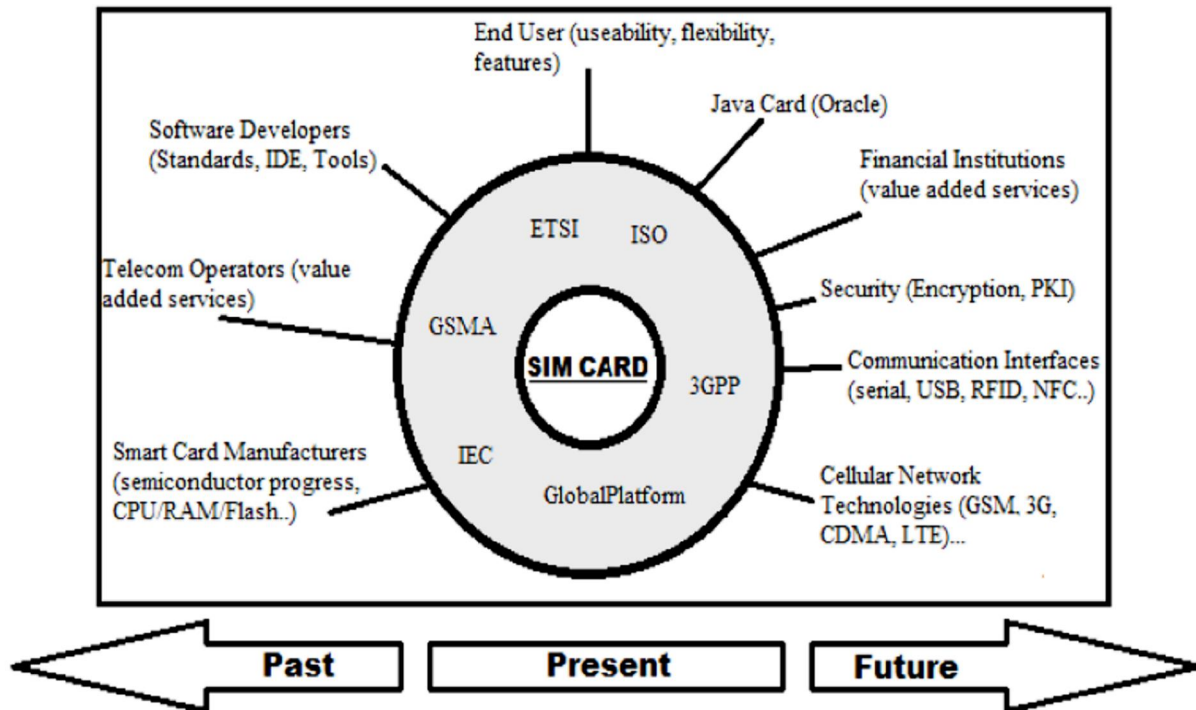


Figure 2.10: Some of the aspects that drive the SIM card evolution.

The security vulnerabilities (in terms of trust) of figure 2.9 will be discussed using TCG reference architectural framework later in this section. This dissertation is of the opinion that the previous security discussions on 2G/3G will hardly fit into the next mobile phone generations as observed in [1], hence there is a need for a more robust security integration on the enduser mobile equipment.

2.10 Trusted Computing Group

In order to increase the level of security of mobile phones and mobile devices, the Trusted Computing Group (TCG), a consortium of leading hardware and software vendors, has for eight years back published a specification draft [1]. This specification offers new potentials for implementing trust in mobile computing platforms by introducing a hardware-based trust anchor. This hardware chip is called Mobile Trusted Module (MTM). The TCG MPWG holds to the idea that all next-generation mobile phones will be equipped with a MTM compliant to that specification.

In this work, a novel approach subscriber authentication in mobile cellular networks to be implemented in the next generation of mobile phones and devices will be explored. Therefore, several architectural dimensions will be considered and evaluated while focusing on the following benchmarks which are seen as crucial for development and production, as well as for market and user's requirements of mobile devices such as mobile phones: (1) Security and Trustworthiness, (2) Cost-effectiveness, (3) Flexibility and Scalability, (4) Portability and Mobility, and (5) Usability, Compatibility and Acceptance.

2.11. Benchmarks and Evaluation Criteria

Due to the evolution of next-generation mobile devices, a reconsideration and evaluation of the current mechanisms for SIM-based subscriber authentication is reasonable.

However, a sustainable evaluation of the different solutions is only feasible if a set of appropriate criteria and benchmarks is defined.

Therefore, the following global benchmarks are identified:

(1) Security

The proposed architecture for subscriber authentication in next generation mobile network will require a set of security characteristics, which are better with respect to conventional SIM cards, and provide a good evidence trustworthiness.

(2) Cost-effectiveness

An important issue is the cost-value ratio of the underlying hardware architecture. In particular, this affects non-redundancy of cost intensive components without a significant loss of security, depending on the intended use-case.

(3) Flexibility and Scalability

Mobile services require a sufficient degree of flexibility and adaptability when external requirements arise, and the ability to be readily enlarged or modified.

(4) Portability and Mobility:

The associated subscriber credentials have to be removable and readily transportable from one device to another. Thus, it enables a subscriber to use its credential with an arbitrary terminal.

(5) Usability, Compatibility and Acceptance

The proposed architecture has to ensure an appropriate level of usability and acceptance with a functional interface and grammar compliant to actual standards.

Based on these criteria, we compare a set of existent approaches for current mechanisms for SIM-based subscriber authentication and a proposed authentication model based on TCG reference architecture.

2.12. Mobile Number Portability

The telecommunications reforms attracted attention from various schools of thought, especially with regards to drivers of competition. Research studies on MNP as encapsulated in the literature review include both *ex ante* and the *ex post* studies. An *ex ante* study is described as a study which occurs before the facts. In the case of MNP, it means that studies were conducted before its introduction in order to investigate if consumers were aware about MNP and to generally determine if countries were ready to embrace it. An *ex post* study occurs after the facts; such studies were conducted after MNP was implemented in order to review its effects.

2.12.1. The review of academic literature on MNP

There are several academic studies conducted on MNP in order to investigate its effects on consumers. Fundamentally, MNP is not looked at in isolation but as another component of competition which was introduced to benefit consumers. This section of our research looks at why and how scholars conducted studies on MNP and importantly, provides research results which will assist the researcher to formulate her theoretical framework for the study.

In the early days of local competition, number portability may appear to new competitors to be crucial to their success and to the incumbent to be technically a very tall order. On the other hand regulators are likely to see local number portability as at least a serious option wherever there is competition and modern exchanges. They will also be considering free phone and mobile number portability where substantial benefits seem to be available at relatively low cost [80]. In reference to Melody, the introduction of number portability will enable a competitive environment not only to consumers but also new market entrants.

2.12.2. Research on the effects of MNP in various countries and regions

A study in the UK was conducted by Olla and Patel (2002) on the mobile telecommunications market. It was established that Mobile phones are an integral part of people's everyday lives. The study further found that over 70% of consumers owned mobile phones and that high mobile usage was as a result of competition growth. The UK study was conducted before the implementation of MNP and its purpose was to assess the level of readiness by consumers in embracing MNP.

Authors in [81] conducted a survey for Nashua Mobile on MNP in South Africa. Like in the UK, the study was conducted prior to the implementation of MNP in November 2006. Their sampling was segmented into corporate, small and medium enterprise as well as consumers. They interviewed about 1100 South Africans both in urban and rural areas. Interviews were conducted per province and according to the community's indigenous language. Language proficiency was imperative in order to ensure that respondents provided answers based on the understanding of the subject and its objective [81].

Questions included the awareness on MNP and the intention of subscribers to change networks. According to the research findings, about 50% of the respondents indicated that they would switch operators as they expected mobile calls to be cheaper.

Lyons (2006) in [82] conducted an econometric analysis making reference to similar studies which have been made by researchers in various countries from 1999 to 2004. These studies relate to the *ex ante* costs analysis of MNP by regulators for the UK in 1997, 1998 in Hong Kong and 2000 in Ireland, and *ex post* empirical examinations for the EU, the UK, the US and South Korea.

The main focus of his analysis was based on information from 38 countries that ported between 1999 until 2004. The findings were as follows:

• When the quality of service was put together with porting times, it had an impact on the switching rates and average prices,

• In some countries, MNP was associated with increased switching and lower prices especially for countries which had porting times fewer than five days,

• Countries with less stringent porting times had not experienced churn or revenue effects [82].

Further studies conducted found that technology was a contributing factor to MNP quality which also entails porting times and reliability [83]. Lyons cited a study [84] on the importance of choosing technology for number portability, and had similar findings in his empirical research. Some of the findings concluded that MNP was free for some subscribers whilst others were charged fees [82].

Lyons cited two studies on the classification of MNP benefits, by [85][86]. Their studies looked at the *ex-ante* empirical methodology on customer costs emanating from MNP. The classification is based on Type 1, Type 2 and Type 3 benefits.

Lyons (2006) indicated that:

Type 1 is categorised into Type 1A and Type 1B. Type 1A benefits are accrued by mobile telephone users who would change network operator even if MNP were not available. The benefits occur in the form of reduced switching costs. A study conducted in South Korea found that switching costs could be reduced by up to 35%. Another benefit for Type 1A is the avoidance of 'dual sourcing' whereby in the absence of MNP, some customers may choose to retain the mobile services in order to receive calls on their existing on their existing mobile

service. Type 1B benefits occur to users who choose to port their number because of the availability of MNP. [87] posits that: "the reasons that customers switch will represent genuine economic benefits only to the extent that new operators offer lower charges or higher quality because they are more efficient than existing operators" [87].

Type 2 customer benefits: are those incurred by mobile telephone users who would not change network operator if MNP were not available. These include the costs of SIM cards, handset changes and other migration costs. These costs have been implicitly been netted out.

Type 3 benefits are benefits that confer to other subscribers when a subscriber ports his number. IDA (2000) describes Type 3 as follows:

These external benefits will likely be greater for subscribers who call many other subscribers and include the following:

Continued validity of non-porting subscribers' public and private directories and memorised numbers;

- Reduced problems with faxes sent to/received by the wrong fax machines since they do not identify whether the responding fax machine belongs to the intended recipient;
- Reduced telephone operator assistance; and
- Reduced wrong number/billing disputes

According to Lyons, the *ex-ante* evaluation on the benefits of MNP concluded that MNP would provide welfare gains if expenditure on the benefits of MNP outweighed the cost of network investment, process changes and operating costs to make number portability, in this case by operators. In Lyons's view, previous *ex ante* evaluation focused more on Type 1 benefit and Type 3.

Lyons further looked at the empirical study by [88] which was conducted in countries such as Australia, Germany, Hong Kong, Ireland, the Netherlands and the UK and reported that: the long porting period discouraged customers to port, as it happened in UK, but could not conclude that a shorter period was a determining factor in attracting customers to switch their numbers; whilst high charges to customers were a deterrent to porting, it could not be concluded on the other hand that zero charges attracted demand for porting.

Lyons also cited individual markets on MNP and looked at the study conducted by [89] who conducted a study in South Korea about factors which attracted customers in porting their

numbers. They found out that there was willingness by customers to pay an average of 3.24% of their monthly bill for a mobile number portability option. Willingness to pay (WTP) showed a strong positive association with income, awareness of MNP, and intention to switch.

According to Lyons, a similar study was conducted in South Korea by [89]. It was reported that MNP reduced switching costs by at least 35%.

Furthermore, switching took place during the first year of MNP, and it took place mostly with larger operators. Another study was done in Hong Kong and found out that the market was highly competitive with 7 mobile operators.

A study conducted by [90] looked at Finland, Italy, Singapore and Germany. In Finland MNP was only applicable to contract users who were 96% of the total users. Finland is one of the countries which had a positive report on the impact of MNP to its consumers. This was attributed to enforcement powers which the regulator had. Bundled services, SIM ï lock, lock in contracts and long contracts were banned [90].

Buehler *et al* (2006) explored a similar study done by Lyons [86]. They found that the introduction of MNP encourages competition in the market which is of interest to regulators. Regulators as mentioned previously are mandated to ensure competition in the industry. They found that actually MNP does not take place free of charge. As much as operators incur costs for technological upgrades, consumers to a certain extent are expected to pay for porting.

A study by [91] concluded that direct costs are costs incurred by operators and include the development of technology for MNP and its implementation and the database infrastructure that had to be built for this process. The indirect costs are those paid by consumers for calls to ported numbers as they cannot distinguish between networks when placing calls.

But countries such as Portugal, Ireland and Belgium informed customers through SMS when they placed calls on or off net [91].

In [92], an analysis on the switching cost was conducted and found out that they were reduced subsequent to the introduction of MNP and improved the welfare of consumers.

Podvystskiy (2006) cites studies by [95]; view that switching costs are a function of policy makers and feels they are the ones responsible for ensuring these get reduced [93].

An article by Ben Omodi on views from Africa indicates that when MNP was introduced in Kenya in December 2010, four mobile operators cut voice tariffs and SMS charges and this move was expected to have positive impact for consumers.

Omodi (2010) wrote:

By granting customers the freedom to move from one operator to another, the telecoms industry is headed for very exciting times. With MNP, differentiation amongst mobile service providers will no longer be based on pricing but a combination of value propositions mainly value added services, customer service and network coverage and quality, said Meza, who was the first to reduce call and SMS tariffs heralding the current price wars (p.3)

In [94], authors examined the trade-off between competition improvement and consumer ignorance associated with MNP. Like other academic research on MNP, they focused on the introduction of MNP as the abolishment of switching costs. They found that mandatory MNP did not create welfare for consumers. Moreover, they reported that the introduction of MNP gave rise to a consumer ignorance problem. They argue that ignorance occurs when consumers are not aware of termination charges and this becomes a trigger for operators to increase their charges. Further to their analysis was the regulation on termination charges. They conclude that if regulations on termination charges are applicable, then under such conditions, MNP will be beneficial to consumers.

Noticeably, most literature emphasises the benefits of MNP on consumers to be quality of service, low costs and choice. However, 'keeping the number' is also seen as the consumer benefit. The same sentiment is shared by [94] who mentioned that in terms of property rights, a subscriber becomes a sole owner of the phone number and its control. Prior to the introduction of MNP, consumers had to keep up with unsatisfactory service by service providers just to keep their number [94].

Lastly is the policy and regulatory implications. Igbal (2007) posits that a precondition for the introduction of MNP should be the technical aspects with regards to the implementation, pricing and payment mechanism. MNP requires technical proficiency and that includes technical proficiency of the regulator [95].

2.12.3. Conceptual framework on MNP

There have been both qualitative and quantitative studies in the literature. As explained earlier, [82] conducted an econometric analysis which is an empirical research. He segmented the benefits of MNP in three categories: first benefits obtained by customers who switch. Second, benefits by all mobile telephony users and lastly, benefits obtained by those calling to ported numbers.

a. Quality of service

Melody (2003) describes competition as the driver of low costs, and quality service and customer attraction and retention among other drivers. This study will investigate if reasons for porting among other were due to quality of service. Quality of service in this context is based on the consumer's interpretation as it has different meanings. Operators look at the quality of service as the availability of network coverage, upgraded technology and manageable drop calls [80].

b. Porting information

In South Korea MNP became a success month after it was introduced. Contributory factors according to [82] were strong positive association with income and awareness of MNP among others. Other countries could not make a positive impact on consumers because of consumer's ignorance on the concept of MNP.

c. Porting times

Previous literature informs us that porting times were one the determining factors in the success or failure of MNP. The researcher has noted however, that research made on the time frames regarding MNP could not conclusively indicate if the short time was an indication of porting success. This study will investigate if porting times in South Africa took longer or shorter than in other countries such as Hong Kong or South Korea, but the determining factor mainly will be the time frame contained in the MNP regulations.

d. Consumer awareness

When MNP was introduced, many countries conducted *ex ante* and *ex post* assessment to determine if consumers were aware about MNP and investigated if they were ready to embrace it. Customer Education was included in the regulation framework. An *ex post* study was conducted in South Korea about the effect of MNP and the research results showed that consumers ported because they were aware about MNP [82].

e. Churn coverage

Churn rate refers to the proportion of contractual customers or subscribers who leave a supplier during a given time period [96].

f. Value added service

Value added service includes internet data services and video or picture services which are accessible from mobile connection, all bundled together.

This triple play is a competition trend which came as a result of innovation.

Initially these bundled were sold separately. For instance, the 3G card at the beginning was sold separately, but due to competition, different operators began to adopt this trend. These days, whether one is a pre-paid or contract, services are the same. Most handsets and services allow for other value added services.

g. The switching costs

The switching barrier refers to the difficulty of switching to another provider that is encountered by a customer who is dissatisfied with existing service, or to the financial, social and psychological burden felt by a customer when switching to a new carrier. Essentially if consumers continue to encounter switching barrier then they will be forced to remain with their existing operator.

2.12.4. Mobile Number Portability - How to PORT From Network A to Network B

In this case, any mobile number from any GSM network only can migrate under MNP to induce a drive for excellent service and customer care among the operators.

i. Formulation of MNP Scenario

Now let's analyze a hypothetical scenario of Mr A with phone number 08051234567 who wants to PORT from GLOB to AIRTEL. Firstly, Mr A has to go to Airtel office to get this done. There, he will be given a new AIRTEL SIM which will still bear his phone number (08051234567). As such the former GLO number now becomes the AIRTEL number completing the porting process.

ii. Scenario Description Terms for the MNP (Porting Process)

Begin ()

Subscriber: *Mr. A*

Receipt Network: AIRTEL Network → Network Which *Mr.A* is Porting into

Donor Network: GLO Network → Network Which *Mr.A* is porting from

Port In: *Mr.A* is Porting in to Airtel

Port Out: *Mr.A* is Porting out from GLO

Now ()

To port from **GLO** → **AIRTEL**,

Mr.A visit a Customer Service Center of the Airtel (Recipient Operator) && Make a request
K

- i. K (Request): Fill a MNP Form
- ii. Provide a Valid Proof of Identification with a recent passport
- iii. Registered SIM card of Donor network (Must have registered **GLO** Sim with **GLO**) → Porting to **GLO**
- iv. **GLO** Sim *Mr.A* wants to Port must be currently Active
- v. Send PORT as SMS to 3232, using the **GLO** Sim that he wants to port

- vi. After satisfying this requirement, *Mr.A* will be issued a new AIRTEL Sim which he will insert into his Mobile device, **Not** Immediately but after a Stipulated period of time by which time the GLO Sim must have deactivated.
- vii. The recipient network (**AIRTEL**) will send *Mr.A's* request to Number Portability Clearing house where the request will be processed.
- viii. **If** the line to be ported, the registered owner of the line && the request are Validated OK, **Then**
- ix. *Mr.A's* **GLO** Sim will be deactivated and the new **AIRTEL** Sim given to him become **ACTIVE**.
- x. Any Credit on his **GLO** Sim will Not be Carried to his new **AIRTEL** Sim
- xi. The new Sim will be placed on the recipient network's default tariff plan, or a plan of his preference if applicable.
- xii. *Mr.A* will Not be able to port from AIRTEL to any other network within 90days

The form is titled 'Subject' and contains a dropdown menu labeled 'select enquiry subject'. Below this is the 'Personal Details' section, which includes fields for First Name, Last Name, Email, Location (a dropdown menu labeled 'select your location'), Occupation, and Gender (radio buttons for Male and Female). The 'Porting Details' section follows, featuring a table with three rows for porting. Each row has a 'Number(s) for porting' field, a 'Network' dropdown menu (labeled 'select'), and a 'Mobile #' field. Below each 'Network' dropdown are three radio buttons for 'Prepaid', 'Postpaid', and 'Data'.

Figure 2.11: A Typical MNP Form [88]

2.12.5 Limitations of MNP

The following are the identified limitation of the scheme, viz [88]:

- i. Highly unattractive as it involves several bureaucratic processes
- ii. It takes time to be effected, hence very inflexible and unpredictable
- iii. Porting with respect to mission critical services eg. E-banking, Payment platforms, etc is undependable.
- iv. Reasons for wanting to leverage MNP are still unsatisfied, viz:
 - Inadequate product offerings
 - Poor customer Service
 - Poor data/internet service
 - Poor network coverage
 - Unattractive call/SMS rate
- v. It involves costs burden on the part of the intenders (those that wants to port)
- vi. Increase in rate directly affects the revenues of the service provider.
- vii. Increases price competition.
- viii. It may put pressure on margins, as product innovation costs and marketing costs may increase.
- ix. Increased investments in back-end services.

Against these background as well as the poor QoS investigated in [89], this research then proposed a unified system that seeks to improve the framework of MNP. This work leveraged the MNP concept to model a robust network integration framework and its architecture for the considered parameters. As such, the integration framework formulated in this thesis will take cognizance of these parameters to setup a fuzzy rule base which can be used to generate the 3D surface diagrams for the trusted reference architecture.

2.13. Fuzzy Logic and Adaptive Neuro-Fuzzy Inference System (ANFIS)

According to [42], Fuzzy logic is a superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth - truth values between "completely true" and "completely false".

Fuzzy logic is a form of many-valued logic; it deals with reasoning that is fixed or approximate rather than fixed and exact. It was introduced by Dr. Lotfi Zadeh of UC/Berkeley in the 1960's as

a means to model the uncertainty of natural language [83]. A basic simple fuzzy control system could be simply characterized.

It accepts numbers as input, then translates the input numbers into linguistic terms such as Slow, Medium, and Fast (fuzzification). Fuzzification is the process of changing a real scalar value into a fuzzy value. Rules then map the input linguistic terms onto similar linguistic terms describing the output. Finally, the output linguistic terms are translated into an output number (defuzzification). Defuzzification is the process of producing a quantifiable result in fuzzy logic, given fuzzy sets and corresponding membership degrees [42].

The authors in [84] used fuzzy technique to encode Mobile Station (MS) movement. MS trajectories are stored in the terminal as a dictionary and then used to measure the signal power in order to obtain the fuzzy symbol. The calculation finds the similarity between the string containing the path followed and the possible paths contained in the hybrid dictionary. The authors in [85] described and analyzed handoff decision techniques, as well as the parameter on which handoff depends using fuzzy logic. In the following part of this section, fuzzy logic theory is presented.

a. Fuzzy Set Theory

Fuzzy logic is a form of multi-valued logic derived from fuzzy set theory to deal with reasoning that is approximate rather than precise. Unconventional expert systems, which are mainly symbolic reasoning engines lacks the capability of fuzzy expert systems which are oriented toward numerical processing. The rules in a fuzzy expert system are usually of a form similar to the following:

if x is low and y is high then $z = \text{medium}$

where x and y are input variables, z is an output variable, *low* is a membership function (fuzzy subset) defined on x , *high* is a membership function defined on y , and *medium* is a membership function defined on z . The part of the rule between the *if* and *then* is the rule's *premise* or *antecedent*. This is a fuzzy logic expression that describes to what degree the rule is applicable. The part of the rule following the *then* is the rule's *conclusion* or *consequent*. This part of the rule assigns a membership function to each of one or more output variables. Most tools for working with fuzzy expert systems allow more than one conclusion per rule.

In MATLAB software, expert system engine can be developed in the fuzzy tool box using Mamdani and Takagi-Sugeno. Mamdani is well suited to human input [86].

A Fuzzy Inference System (FIS) is a way of mapping an input space to an output space using fuzzy logic and it's available in MATLAB software. A FIS tries to formalize the reasoning process of human language by means of fuzzy logic (that is, by building fuzzy If-Then rules). FIS are used to solve decision problems, i.e. to make a decision and act accordingly. The Mamdani-style fuzzy inference process is performed in four steps: fuzzification of the input variables, rule evaluation (inference), aggregation of the rule outputs (composition), and defuzzification.

b. Structure of a Fuzzy Inference System

Fuzzy model consists of four modules. The first module is the fuzzification that transforms the crisp value(s) into the fuzzy values. The fuzzy values are inferences based upon the rule base incorporate in knowledge based. These rules are supplied by the domain expert(s). All the outputs obtained from the inference engine are integrated and defuzzified by the defuzzification module that transform the fuzzy output to crisp value(s).

The first two parts of the fuzzy inference process, fuzzily the inputs and applying the fuzzy operator, are exactly the same. In general as shown in Figure 2.12 and figure 2.13, a fuzzy inference system consists of four modules [42],[87] viz:

- 1) Fuzzification module: transforms the system inputs, which are crisp numbers, into fuzzy sets.

This is done by applying a fuzzification function.

- 2) Rule/Knowledge base: stores IF-THEN rules provided by experts.

- 3) Inference engine: simulates the human reasoning process by making fuzzy inference on the inputs and IF-THEN rules.

- 4) Defuzzification module: transforms the fuzzy set obtained by the inference engine into a crisp value.

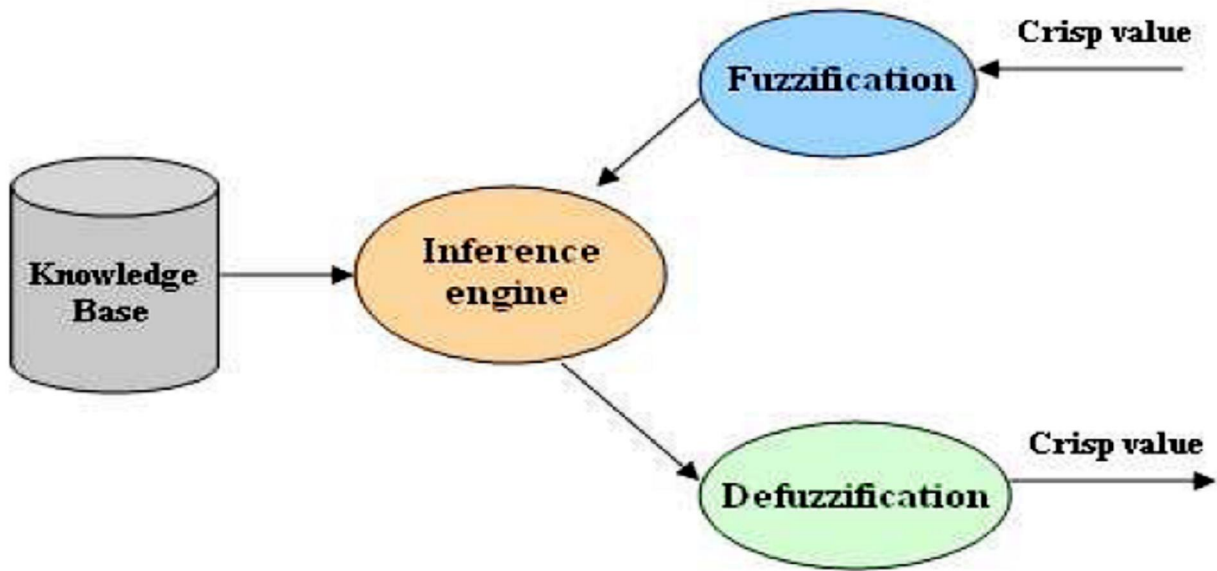


Figure 2.12 Fuzzy inference system [42]

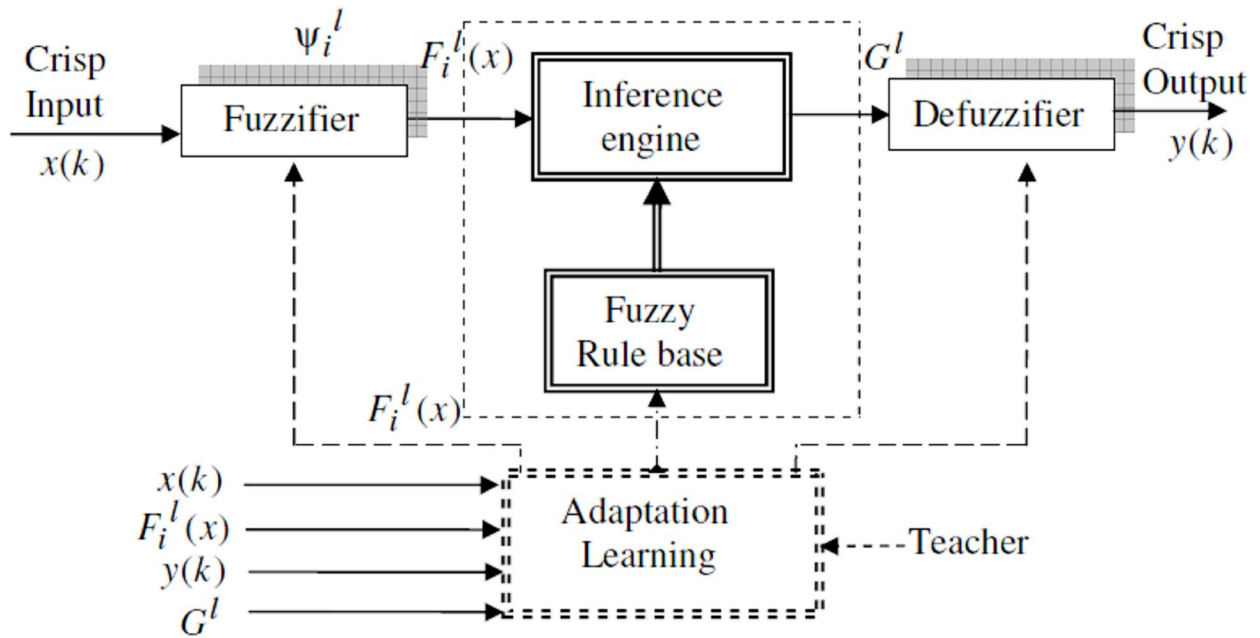


Figure 2.13: A typical Fuzzy Logic System [87]

As shown in figure 2.13, the basic building block of fuzzy logic system is well depicted in [87]. Here the fuzzifier converts the real world crisp input sample $x_i(k)$ to a fuzzy output F_i^l described by the membership function ψ_i^l . This provides the degree to which the input scalar $x_i(k)$

belongs to the fuzzy set F_i^l . The inference engine provides the relationship between the fuzzy input in terms of membership functions and the fuzzy output of the controller using a set of IF ϵ . THEN rules derived from the rule base. The rule l in the fuzzy rule base can be defined as $R^{(l)}: \text{IF } x_1 \text{ is } F_i^l \text{ and } \dots \text{and } x_n \text{ is } F_i^l \text{ Then } y \text{ is } G^l$

The Defuzzifier converts the inference G^l to provide the crisp output $y(k)$. In fuzzy system, the rule base is generated in advance with expert knowledge of the system under consideration. In this thesis, Mamdani was selected for the network integration management for the proposed GSM design strategy and framework while still using it to implement the customer decision rules.

2.14. Summary of Review works

This chapter have reviewed the mobile cellular evolutions, their architectural generations, the GSM KPI as QoS metrics, TCG Reference Architecture, Smart/SIM Cards, Mobile Number portability and MATLAB Fuzzy logic with ANFIS. This work views the Virtual SIM platform as a means for Subscriber Network Migration

It shall be seen in the progress of this thesis, that the implemented Portability suite using virtual SIMs (JAVA JRE) will turn out to be a suitable and sustainable solution, that is able to compete with the GSM SIM-based solutions in software context. It will also demonstrate the substitutability of a SIM card with an adequate software replacement supported and protected by a trustworthy operating system, and is based on a single small-scale trust virtual conformant to the TCG MPWG Reference Architecture.

CHAPTER 3

METHODOLOGY AND SYSTEM ANALYSIS

3.1. Methodology

This work starts its investigation with the drive test facility of NCC in Abuja for data collection while comparing the QoS data with NCC reference dataset. This chapter will provide an insight into network performance management and quality of service (QoS) of GSM operators network. The methodology adopted identifies the components of QoS and the available mechanisms to analyze and evaluate them. This part also identifies important key performance indicators (KPIs) that need to be monitored and optimized and cites important data collected by protocols analyser in Air interface.

3.1.1. QUALITY VOICE MACHINE (QVM)

In configuration of calls for the measurement, intra-network call was made between master and slave channels of the QVM. This was done because it is always difficult to identify particular network that is responsible for failures in inter-network calls. Although additional testing equipment can be interfaced with response or collated data from the respective networks being monitored. But unfortunately network operators are likely would not allow an independent investigative monitoring of the interfaces between its network and another for comparison purposes.

3.1.2. ASCOM MOBILE TEST STRATEGY AND AMTS QoS SUPERVISION TECHNIQUE

Ascom, a leading provider of Mission-Critical Communications, newly introduced Network Testing division.



Figure 3.1: AMTS Measurement Infrastructure (Ascom, NCC senario) comprising of QVM and QVP.

Drive tests allow the mobile network to be tested through the use of a team of people who take the role of users and take the QoS measures to judge the QoS of the network. This test does not apply to the entire network, so it is always a statistical sample. Drive test equipment depicted in figures 3.1 includes:

- i. **MS:** a mobile supporting GSM and GPRS equipped with special software. It is called trace mobile,
- ii. **GPS** (Global Positioning System): It is a satellite system that provides users with location of the measurement point,
- iii. **PC:** It is a computer equipped with interface carte RS 232 in order to make the link between the serial output of the MS and the serial port of the PC.

ASCOM Drive test tools offer the measurement of many indicators viz:

- Longitude, Latitude (X, Y) of the measurement point,
- **RXLEV:** RXLEV gets values between -110dBm and -48dBm. It characterizes the coverage of the network. RXLEV is a GSM unit and is defined as $P \text{ (dBm)} + 110$ where P represents the received power. Distinguishing RXLEV_{SUB} where DTX is enable and RXLEV_{FULL} where DTX technique is not activated.

RXLEV	Evaluation
$RXLEV \geq -60\text{dBm}$	Deep Indoor
$-72\text{dBm} \leq RXLEV < -60\text{dBm}$	Indoor
$-82\text{dBm} \leq RXLEV < -72\text{dBm}$	Incar
$-94\text{dBm} \leq RXLEV \leq -82\text{dBm}$	Outdoor
$RXLEV < -89\text{dBm}$	Poor coverage

Table 3.2a RXLEV Evaluation

3.1.3 Quality of the Received signal (RXQUAL): is a key parameter for evaluating network performance. It indicates the Bit Error Rate (BER). RXQUALFULL were distinguish where the received signal quality is averaged over a time interval containing both periods of voice information and periods of no transmission and RXQUALSUB where the received signal quality is averaged only over the periods when voice information is present.

Table 3.2b: Correspondence between RXQUAL and BER

RXQUAL	BER
0	Less than 0.2%
1	From 0.2% to 0.4%
2	From 0.4% to 0.8%
3	From 0.8% to 1.6%
4	From 1.6% to 3.2%
5	From 3.2% to 6.4%
6	From 6.4% to 12.8%
7	Greater than 12.8%

Time Advance (T-ADV): Time Advance gets values between 0 and 63.

MS_TXPWR_MAX: MS maximum allowed transmission power.

LAC: Location Area Code,

Cell_Id: Cell identification number,

BSIC: It is used to distinguish between two BTSs using the same beacon channel. It is better to allow the same BSIC to two BTSs in the same cluster,

TIME: Measurement time,

MODE: idle or dedicated,

RXFREQ: It is the frequency number of the channel allowed to the MS in reception,

BCCHFREQ, BSIC, RXLEV of the six neighbouring cells,

BER: Bit Error Rate is the ratio of erroneously received bits to all received bits. It is important to notice that BER is evaluated before channel decoding, i.e. after equaliser. BER is used for defining the RXQUAL value according to Table 3.2b.

FER: Frame Erasure Rate displays the percentage of lost or bad speech frames. This field is not displayed if the attached mobile does not support frame erasure measurements. The FER range is 0 to 100%,

It was noted that two different modes of measurement are available for this tool viz:

- The Connected mode used when a communication has been established and TCH channel has been provided.
- In Idle mode, when the mobile phone is not connected to the network. Only information from the BCCH channel such as received signal level and the normal procedures of the disconnected mode like cell re-selection are available and network events.

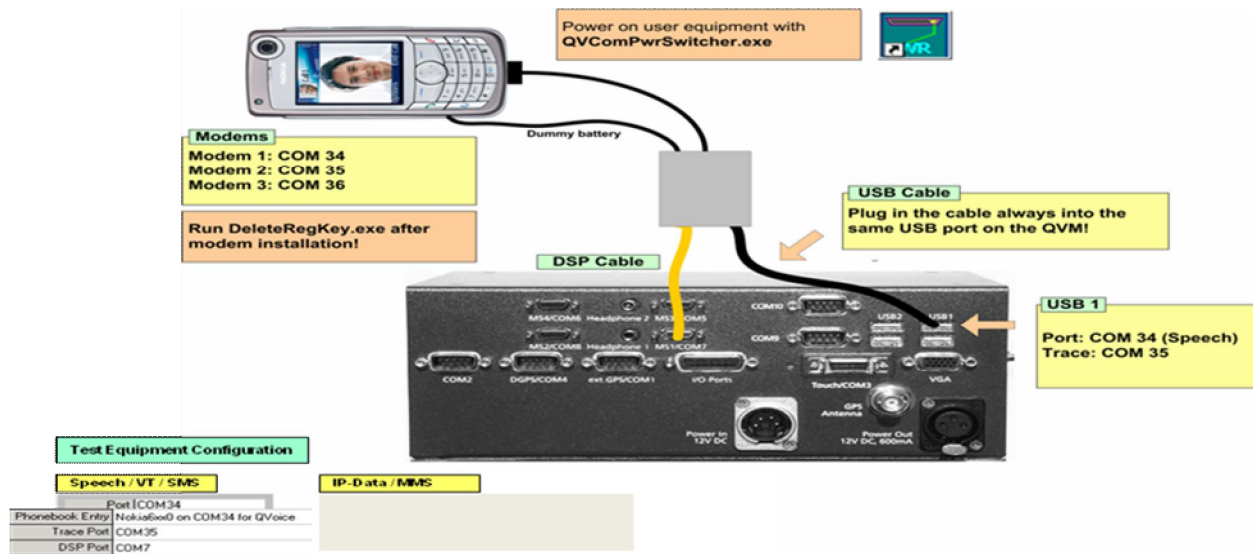


Figure 3.2: QVM Interfacing Structure

From figure 3.2, for KPI initial setup, the test equipment was configured and saved, using the save (the diskette) icon on the tool bar. The following are the attributes that needs configuration, viz:

1. **Channel Mode:** Specify whether the channel (phone) is a MASTER or SLAVE.
2. **TYPE OF TEST:** Specify the type of test the channel mode will measure eg. Speech, SMS, MMS, IP data (data transmission through the internet) or VT (video Telephony).
3. **MASTER PHONE NUMBER:** Enter the phone number of the Master SIM card.
4. **SLAVE PHONE NUMBER:** Enter the phone number of the Slave SIM card.
5. **PORT (the modem port):**

3.1.4a. TEST BED DESCRIPTION AND FIELD MEASUREMENTS

This section describes the step by step procedures that have been conducted during the drive test. In order to understand the test bed description that has been set in this project, a brief description will be given on the measurement tool that has been used for performing the QoS measurements. This monitoring tool is needed for exploring the characteristics of the UMTS network. This can be done later by analyzing the recorded data during the drive test. The QoS monitoring system which in this project is the QVOICE consists of two main components; **QVM** (Data acquisition part) and **QVP** (Data evaluation part).

- The QVM (QVOICE Mobile) is a mobile piece of equipment that is used in measurement car for drive test. It is controlled by software that is windows-based and all the parameters such as max time for downloading one web page and the server domain name to be accessed. During the call or transfer, the performance of the network and air interface engineering data is recorded by the QVM.
- QVOICE Presentation (QVP) is the evaluation unit. The recorded data is imported to the QVP part for further tasks E.g. Generating reports, maps, analysis etc.

3.1.4b. Conceptual Test Bed Topology

In this work, the Test Bed topology shows the GSM/3G network with a mobile vehicle carrying the drive test QVM work and the ones that are influenced by the Internet and the public server. It means that the results will show exactly how the user will experience the service. Figure 3.3 and figure 3.4 shows the testing topology for KPI measurement.

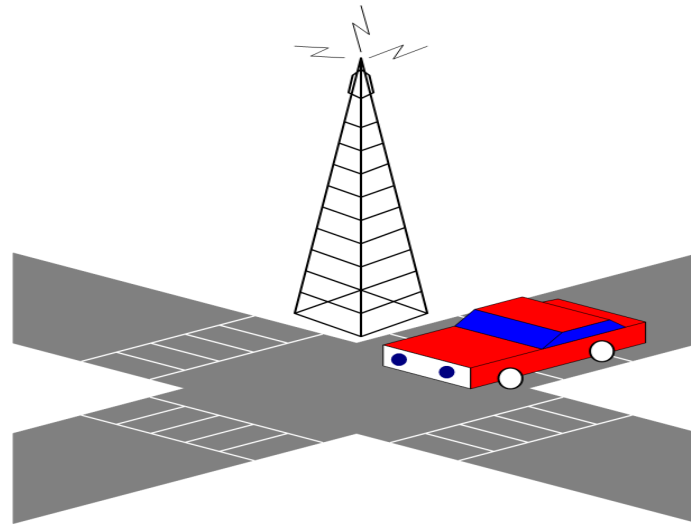


Figure 3.3: Drive Test Model

Drive Test Measurement Chain.

- i. System Configuration (GPS, measurement mode)
- ii. Test Equipment QVM and QVP.
- iii. Location Indoor / Outdoor via Ascom drive strategy.
- iv. Measurement Program via QVP
- v. Measurement Job via QVP
- vi. Viewer / Trace / Tab-sheet via QVP

vii. Workspace via QVP

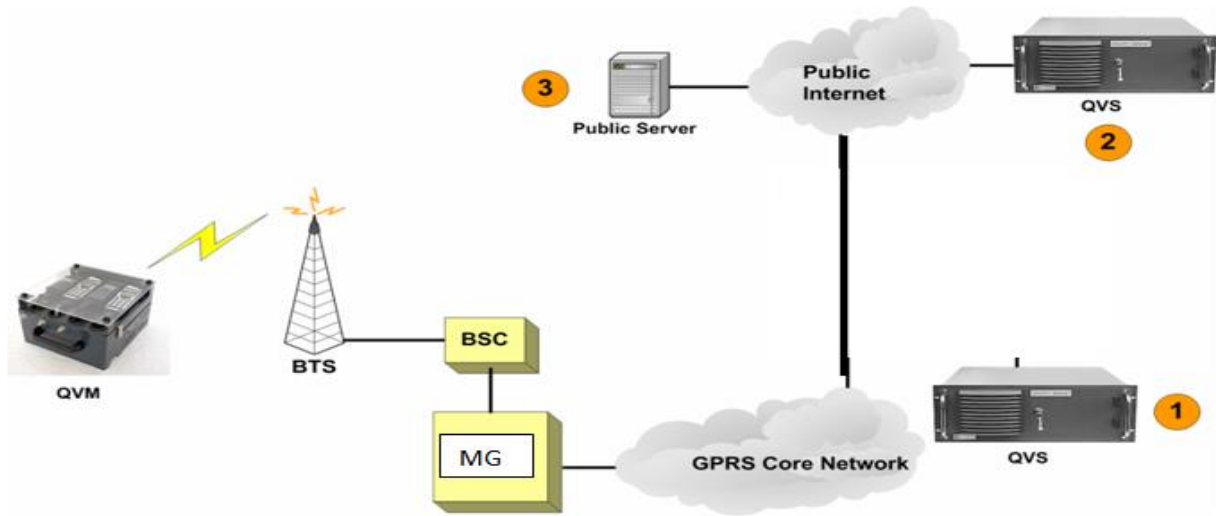


Figure 3.4: Structural drive test GSM Topology.

The captured data via QVM is sent to QVS via the public internet (public server) or via the BTS incase of calls.

3.1.5. MEASUREMENT ENVIRONMENT

In this research, federal capital territory Abuja environment was used as a test-bed for the drive test macromobility study. Figure 3.5 to figure 3.8 shows the sites covered from where the drive test scheme was carried out. The following are the areas viz: Garki District Area 7ð TafawaBalewa Road, Garki District Area 8- Muhammadu Buhari Way Garki District Area 11- Emeka Anyaoku street, Garki District Area 11- Herbert Marcualay Way. These areas are located in the north central part of Nigeria. The city has an area of about 713km squares with a population of about 776,298 inhabitants. It is an urban area made up of mid-range and few tall buildings. Its day-time temperature fluctuates between 28°C to 30°C, while night-time ranges from 22°C to 23°C. It has high altitude and undulating terrain.

The investigation was conducted for Dec.2011-Jan 2012, Jan 2012- Feb.2012- CDMA), March and April,(2012-GSM) and validated in the above areas of country Federal Capital Territory (FCT) beside other selected cities in all the six geo-political zones of the country, where all the four GSM networks considered are operating. The GSM networks studied are MTN, Glo, Airtel

and Etisalat. The study was conducted using ASCOM infrastructure of NCC. The primary data obtained from this investigation was later compare with secondary data from NCC reference QoS dataset (www.ncc.gov.ng) which gave the same result. Consequently, NCC PKI data was leveraged in making the deductions.

Three Key Performance Indicators (KPIs) namely; Traffic Channel Congestion Ratio (TCH cong. Ratio), Call Drop Ratio (CDR) and Call Setup Success Ratio (CSSR) were selected for the evaluation of four GSM networks in Abuja metropolis majorly via the existing Base Station Controller (BSC) areas. The selected parameters are perceived to have direct impact to subscriber experiences on the network in the independent survey.

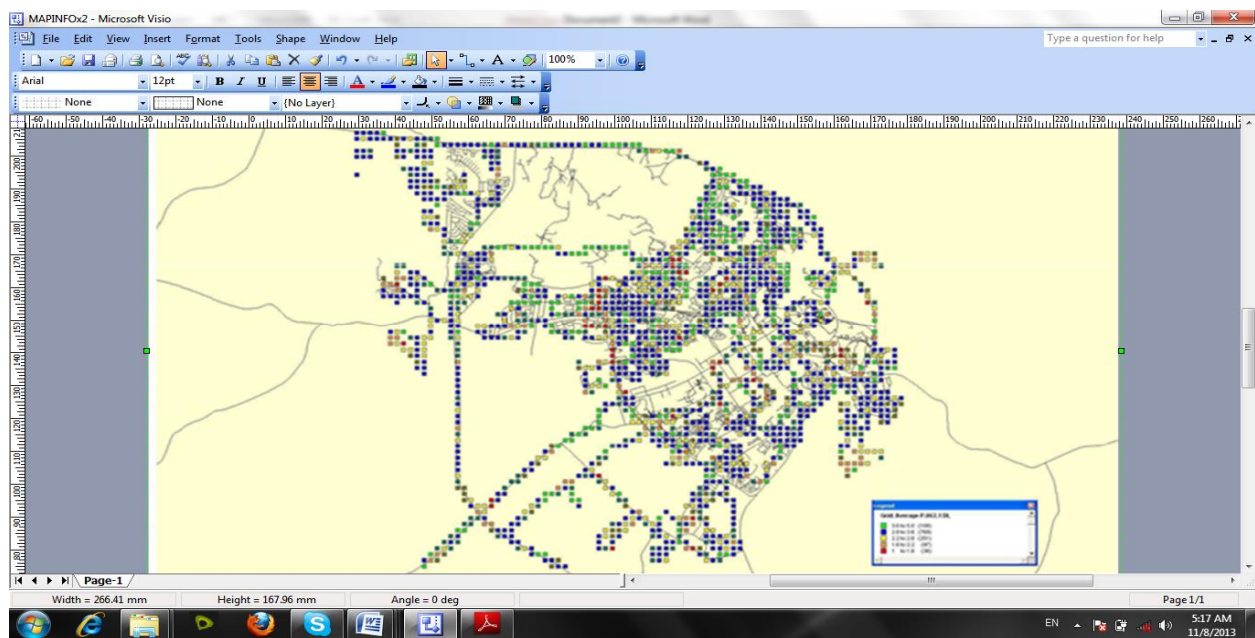


Figure 3.5a: Visio MapInfo [52]

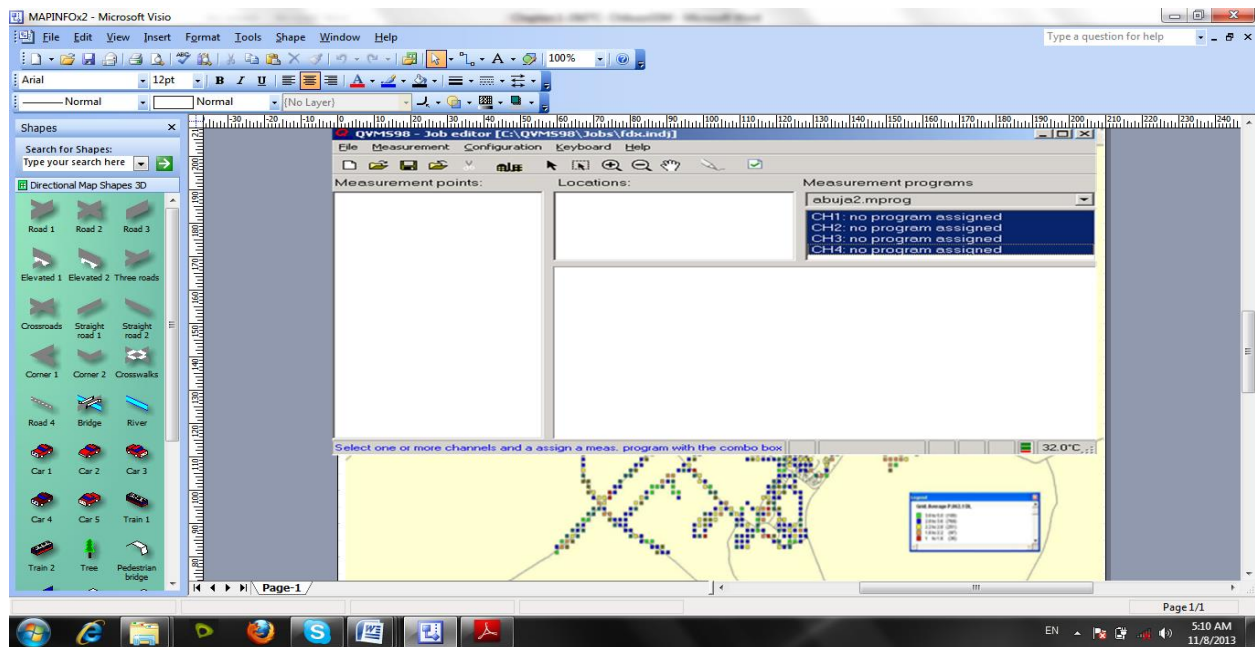


Figure 3.5b: QVP Visio MapInfo [52]

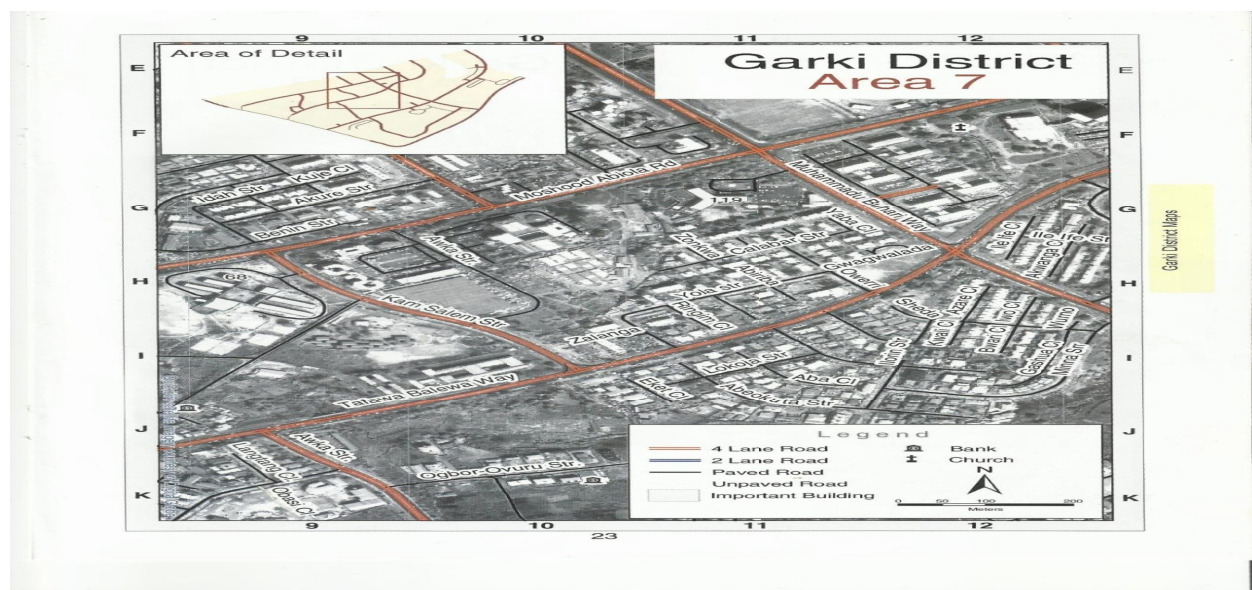


Figure 3.6: Garki District Area 7ð TafawaBalewa Road [52]

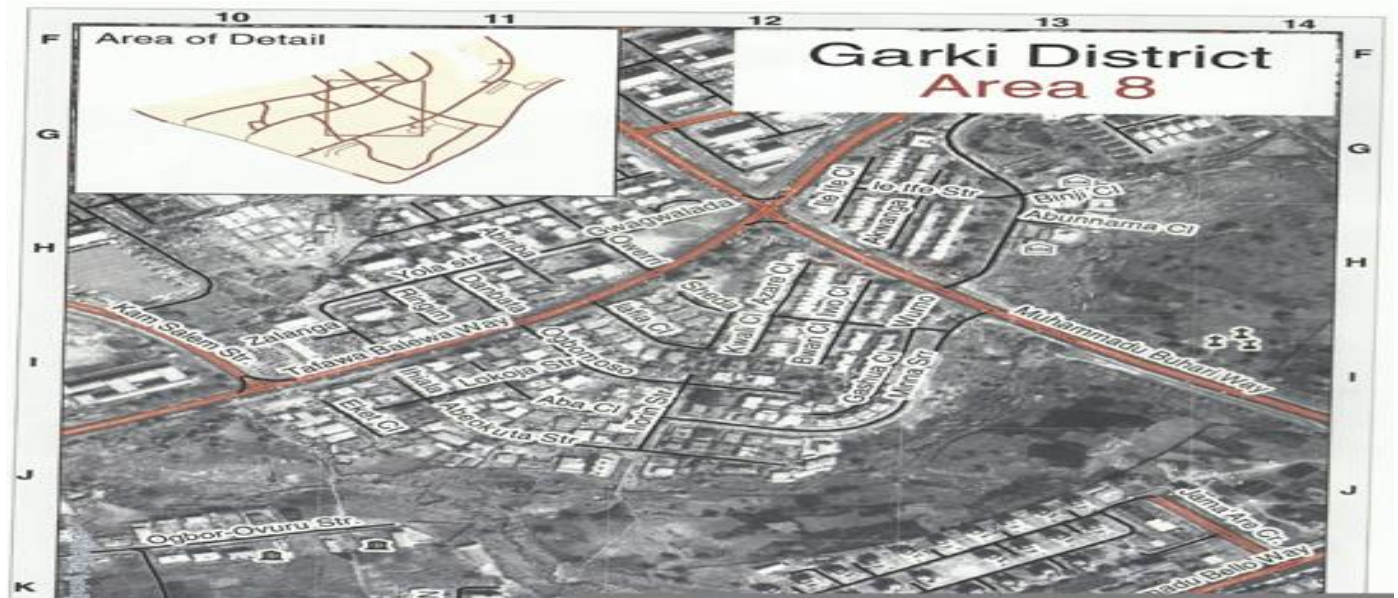


Figure 3.7: Garki District Area 8- Muhammadu Buhari Way [52]



Figure 3.8: Garki District Area 11- Herbert Marcualay Way [52].

3.1.6. MACROMOBILITY DATA COLLECTION

3.1.6.1 Data Collection Method

During the drive test in urban areas of figure 3.6 to figure 3.8 where the Master Slave call initiation is accessing the live UMTS Network in Abuja, the data was recorded from the air interface. The test was done during morning session, afternoon session (Peak hours), and night session. The average speed of the car was 80 Km. the Slave was a mobile piece Sagem OT290 which establishes the connection with a Master node configuration in the QVM panel as well as to the public server via live UMTS network. The QVM receives the location information from an external GPS receiver.

The sample measurements were generated from the BTSs which also provided the File Transfer Protocol (FTP) services to the Network Management System (NMS). The NMS in the QVP captures the KPI data values viz: CSSR, CDR and TCH Congestion Ratio measurements for the period of the study. The NMS is hosted on a central server which is connected to other network elements such as BSC, BTS, MSC, HLR etc. The server with its NMS software was configured to retrieve BTS measurements of remote MSCs and its BSCs. The collated data from the QVP were sorted and analyzed as shown in Tables 3.4 to 3.17b.

The framework for KPI QoS investigations was captured as shown in figure 3.4, considering the available number of base stations in the metropolis. The data captured using the MapInfo tool of the QVM, which was later imported into the QVP for post-processing in order to trace locations congestions and poor coverage, see figure 3.5a and figure 3.5b.

3.1.6.2 Analysis Process Framework

After collecting information from the techniques described above, different indicators were combined and analysed in order to detect problems. Figure 3.9 shows the flowchart test Procedures for Ascom Drive test.

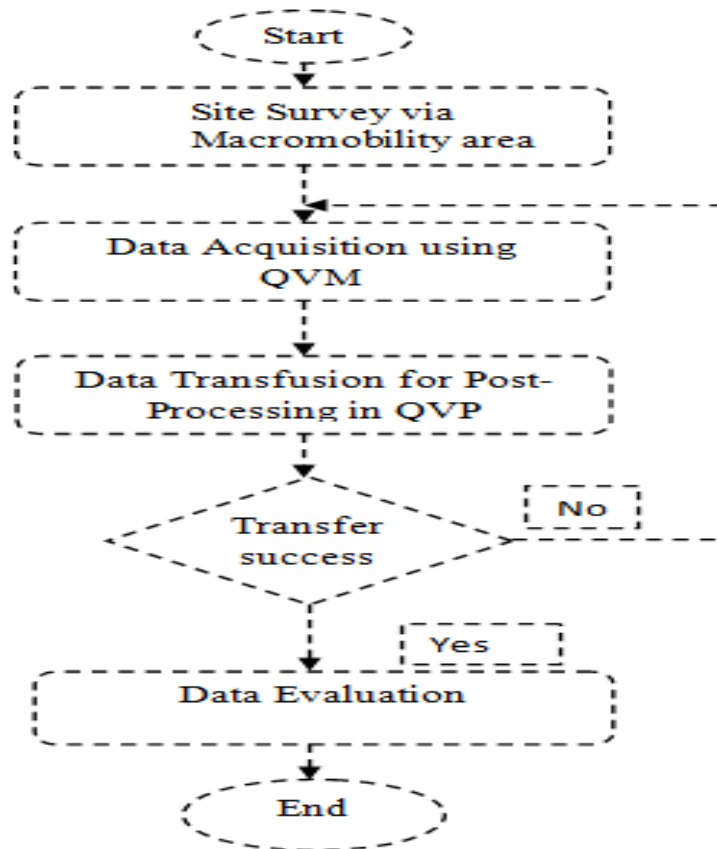


Figure 3.9: Methodology for QoS Data gathering

As shown in figure 3.9, the approach for QoS involves site survey, using QVoice viz-a-vis drive test macromobility. Data transfer for post processing is carried out but if transfer success is satisfied, evaluation is then carried out, else the QVoice continues the data acquisition process.

3.1.6.3 Post Processing Data Analytics

The post processing of data was done at the lab for a period of one week. The post processing procedure (Architecture), consists of a QVP client connected to the QVP server through the Intra-Network. The QVP client has applications installed in it for the data processing. These applications include QVP map, QVP Presentation, QVP report, QVP Expert, QVP network analyzer, Mapinfo Visio map, etc (figure 3.5a and figure 3.5b). QVP map generates a map view of the data. The QVP report generates a report of the processed data.

3.1.6.4 Data Analysis and Results

Sample of hourly traffic pattern in respect to CSSR, CDR and TCH Congestion were collated from the QVP Network Monitoring System and the data were basically used to sample the

performance of all the mobile GSM network operators which was consistent with the NCC[100] as shown in Table 3.17b.. An analysis of the collated data was analyzed below but the measured data was evaluated against the threshold values set by the NCC which are outlined below as:

- a. Target value for Busy Hour (BH) TCH congestion Ratio: 2%
- b. Target value for BH CDR: 2%
- c. Target value for CSSR: 98%

Some of the KPIs includes: CSSR i Call Set-Up Success Rate, DCR i Drop Call Rate, TCH_CONG i Traffic Channel Congestion, SDCCH i Stand Alone Dedicated Control Channel Congestion.

The data samples for the hours of this survey was used to determine the QOS judgment on these KPI values was based on this busy hour. The Busy Hour Call attempt (BCHA) Traffic occurred at morning rush hour by 8.00am. The peak period duration (7.00am to 10.00pm) which concedes with the average peak periods used by most networks was also considered in this analysis.

In the next sections, we seek to analyze the summary of KPI data analyzed against its operator Table 3.4 shows the macromobility data set for Avg. QoS KPI for March, 2012. The data which reflects the call pattern in respect of CSSR, CDR, CHSR, CCR and SDCCH showing the performance of the networks as it varied over the day.

As depicted in Table 3.4, from the average values of CSSR, it was observed that setup success rates of GLO operator was close to the threshold (i.e.98%) with Etisalat having the worst performance. The CDR of Operators like Glo and MTN has less satisfactory behavior in DCR while Etisalat and Airtel offered better performance relatively.

Table 3.4: Macromobility Data Set For Avg. QoS KPI for March, 2012

Network Operator	Avg. CSSR (%)	Avg. DCR (%)	SDCC (%)	Avg. TCHCON(%)
NCC Target	≤ 98	≤ 2	≤ 0.2	≤ 2.0
GLO	98.33	1.13	0.39	1.09
MTN	97.07	1.33	0.58	1.33

ETisalat	94.38	0.86	1.64	1.40
Airtel	97.39	0.86	0.58	0.54

In the month of April the average of the KPI values were represented in Table 3.5, where overall performance of GLO was found to be the best on CSSR.

Table 3.5: Macromobility Data Set For QoS KPI April, 2012

Network Operator	Avg. CSSR (%)	Avg. DCR (%)	SDCC (%)	Avg. TCHCON (%)
NCC Target	≤ 98	≤ 2	≤ 0.2	≤ 2
GLO	98.02	1.17	0.39	1.09
MTN	96.42	1.41	0.61	0.89
ETisalat	96.88	1.22	1.36	1.95
Airtel	97.48	0.92	0.47	0.55

Table 3.6: Macromobility Data Set for Avg. QoS KPI for March, 2013

Network Operator	Avg. CSSR (%)	Avg. DCR (%)	SDCC (%)	Avg.TCH_CONG (%)
NCC Target	≥ 95.50	≤1.90	≤ 1.00	≤1.80
GLO	97.73	1.79	0.69	0.44

MTN	96.45	1.54	0.45	0.57
ETisalat	98.72	1.25	0.12	0.11
Airtel	97.73	0.77	0.19	0.57

Table 3.7: Macromobility Data Set for Avg. QoS KPI for April, 2013

Network Operator	Avg. CSSR (%)	Avg. DCR (%)	SDCC (%)	Avg.TCH_CONG (%)
NCC Target	95.50	1.90	1.00	1.80
GLO	94.60	1.77	0.74	0.50
MTN	96.58	1.47	0.13	0.58
ETisalat	98.79	1.08	0.10	0.11
Airtel	97.57	0.83	0.18	0.41

Table 3.8: Macromobility Data Set for Avg. QoS KPI for May, 2013

Network Operator	Avg. CSSR (%)	Avg. DCR (%)	SDCC (%)	Avg.TCH_CONG (%)
NCC Target	95.50	1.90	1.00	1.80
GLO	96.57	1.75	0.74	0.48

MTN	96.43	1.60	0.14	0.76
ETisalat	99.01	0.84	0.10	0.07
Airtel	97.34	0.83	0.14	0.24

Table 3.9: Macromobility Data Set for Avg. QoS KPI for June, 2013

Network Operator	Avg. CSSR (%)	Avg. DCR (%)	SDCC (%)	Avg.TCH_CONG (%)
NCC Target	95.50	1.90	1.00	1.80
GLO	96.83	1.67	1.62	0.41
MTN	97.12	1.34	0.70	1.52
ETisalat	98.50	0.58	0.57	0.21
Airtel	96.66	0.84	0.51	0.88

Table 3.10: Macromobility Data Set for Avg. QoS KPI for July, 2013

Network Operator	Avg. CSSR (%)	Avg. DCR (%)	SDCC (%)	Avg.TCH_CONG (%)
NCC Target	95.50	1.90	1.00	1.80
GLO	96.65	1.66	0.74	0.47
MTN	96.86	1.48	0.11	0.58
ETisalat	99.14	0.95	0.11	0.06
Airtel	97.68	0.95	0.15	0.40

Table 3.11: Macromobility Data Set for Avg. QoS KPI for August, 2013

Network Operator	Avg. CSSR (%)	Avg. DCR (%)	SDCC (%)	Avg.TCH_CONG (%)
NCC Target	95.50	1.90	1.00	1.80
GLO	96.67	1.37	1.49	0.95
MTN	96.67	1.32	0.69	1.28
ETisalat	98.84	0.53	0.70	0.24
Airtel	96.76	0.74	0.54	0.87

Table 3.12: Macromobility Data Set for Avg. QoS KPI for September 2013

Network Operator	Avg. CSSR (%)	Avg. DCR (%)	SDCC (%)	Avg.TCHCON (%)
NCC Target	96.00	1.70	0.80	1.50
GLO	96.49	1.48	1.57	1.10
MTN	97.74	1.27	0.48	0.92
ETisalat	98.75	0.75	0.29	0.17
Airtel	96.46	0.76	0.64	1.02

Table 3.13: Macromobility Data Set For QoS KPI Dec 2011

Network Operator	Avg. CSSR (%)	Avg. DCR (%)	Avg. TCHCON (%)
NCC Target	≥ 98	≤ 2	≤ 2
STARCOMMS	97.72	1.21	0.81
MULTILINKS	95.17	2.01	1.81

VISAFONE	99.81	0.48	0.1
ZOOM	Nil	Nil	Nil

Table 3.14: Macromobility Data Set For QoS KPI JAN, 2012

Network Operator	Avg. CSSR (%)	Avg. DCR (%)	Avg. TCHCON (%)
NCC Target	≤98	≤2	≤2
STARCOMMS	96.43	2.02	0.31
MULTILINKS	96.18	2.01	0.9
VISAFONE	99.87	0.46	0.07
ZOOM	Nil	Nil	Nil

Table 3.15: Macromobility Data Set for Avg QoS KPI for Jan 2014

Network Operator	Avg. CSSR (%)	Avg. DCR (%)	Avg. SDCONG (%)	Avg. TCHCON(%)
NCC Target	≤98	≤1	≤0.20	≤2.0
GLO	96.89	1.19	0.58	0.79
MTN	96.85	1.21	0.17	0.55
ETisalat	99.20	0.55	0.10	0.27
Airtel	96.99	0.84	0.40	0.79

Table 3.16: Macromobility Data Set For QoS KPI FEB, 2012

Network Operator	Avg. CSSR (%)	Avg. DCR (%)	Avg. TCHCON (%)
NCC Target	≤ 98	≤ 2	≤ 2
STARCOMMS	9.19	1.62	0.047
MULTILINKS	98.81	1.02	0.14
VISAFONE	99.8	0.46	0.067
ZOOM	Nil	Nil	Nil

Using a similar method in [90], the KPI data collated for table 3.17a and table 3.17b were grouped into strata on hourly basis against individual operators as shown below:

Table 3.17a: KPI data for March, 2012 and April, 2012

KPI data for March, 2012					
Name of operators	CSSR (Target $\geq 98\%$)	CDR (Target $\leq 2\%$)	CCR (Target $\geq 96\%$)	CHSR (Target $\geq 98\%$)	SDCCH (Target $\leq 0.2\%$)
MTN	97.07	1.33	96	95.14	0.58
GLO	97.33	1.13	96.44	97.73	0.39
ETISALAT	94.38	0.86	93.05	89.67	1.64
AIRTEL	97.39	0.86	96.56	96.64	0.58
KPI data for April, 2012					
Name of operators	CSSR (Target $\geq 98\%$)	CDR (Target $\leq 2\%$)	CCR (Target $\geq 96\%$)	CHSR (Target $\geq 98\%$)	SDCCH (Target $\leq 0.2\%$)
MTN	96.42	1.41	95.78	94.67	0.61
GLO	97.02	1.17	96.45	97.67	0.39
ETISALAT	96.88	1.22	95.81	91.28	1.36
AIRTEL	97.48	0.92	96.59	96.33	0.47

Table 3.17b: KPI data for March, 2012 and April,2012

DAYS	CSSR RATE (%) E=98%				CDR(%) E=2%				CHSR % E=98%				CCR (%) E=96%				SDCCH E=0.2			
	OBSERVED VALUES (O)				OBSERVED VALUES (O)				OBSERVED VALUES (O)				OBSERVED VALUES (O)				OBSERVED VALUES (O)			
	MTN	GLO	ETS	AIRTEL	MTN	GLO	ETS	AIRTEL	MTN	GLO	ETS	AIRTEL	MTN	GLO	ETS	AIRTEL	MTN	GLO	ETS	AIRTEL
1	97.49	97.00	9400	96.39	1.31	1.00	0.80	1.36	95.98	97.50	92.05	97.04	96.00	96.00	90.67	95.00	1.06	0.80	1.50	0.50
2	97.00	98.33	98.39	97.50	1.30	1.13	0.76	0.85	95.50	97.23	94.50	95.10	95.50	95.44	91.50	97.06	1.00	0.33	1.00	0.60
3	95.50	97.20	95.00	97.00	1.29	1.30	0.90	94.50	98.00	93.00	96.50	97.00	97.50	88.00	96.50	0.50	0.50	0.40	1.70	0.48
4.	97.50	97.50	96.00	98.00	0.97	0.97	0.75	0.75	96.00	97.50	95.50	96.00	96.50	96.50	87.50	96.00	0.30	0.80	1.90	0.55
5.	96.00	97.33	93.50	97.00	1.62	1.62	0.60	0.60	91.50	97.00	0.60	0.60	91.50	97.00	97.00	97.00	0.50	0.39	1.80	0.65
6.	98.20	96.00	94.50	97.50	1.25	1.50	0.85	0.80	94.00	98.50	0.85	0.80	94.00	98.50	98.30	98.00	0.40	0.31	1.64	0.70
7.	97.80	98.00	92.34	98.74	1.57	0.64	1.36	0.76	90.80	96.34	1.36	0.76	90.80	96.34	92.10	95.86	0.36	0.50	1.94	0.58
Average	97.07	97.33	94.39	97.39	1.33	0.86	0.86	0.86	93.05	96.64	97.33	93.05	96.64	96.64	96.48	96.56	0.58	0.39	1.64	0.58

CHAPTER 4

MNP MODELING USING FUZZY NETWORK

4.1. Mamdani Fuzzy Inference System for Network Integration

In this research, fuzzy Logic Toolbox was used in MATLAB Simulink environment to model and integrate different networks. After creating the fuzzy systems using the GUI tools, the FIS Editor displays general information about a fuzzy inference system. Using the Mamdani-type inference, as was defined for the Fuzzy Logic toolbox, this expects the output membership functions to be fuzzy sets. After the aggregation process, there is a fuzzy set for each output variable that needs defuzzification. Figure 4.1 shows the Mamdani-type inference framework used in this work.

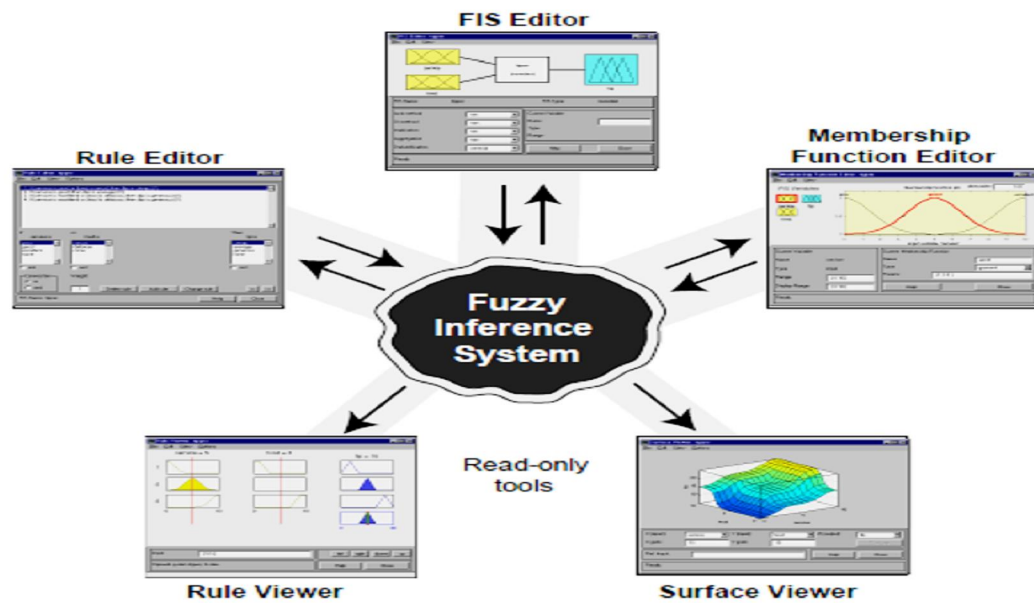


Figure 4.1: Mamdani Inference System [101]

In the fuzzy logic toolbox, there are five parts of the fuzzy inference process as shown in figure 4.1, viz:

1. Fuzzification of the input variables

2. Application of the fuzzy operator (AND or OR) in the antecedent
3. Implication from the antecedent to the consequent,
4. Aggregation of the consequents across the rules.
5. Defuzzification.

Specifications and Assumptions

This work introduced two major control strategies to realize the framework of the fuzzy trusted design, viz : Intelligent network integration for the control and process variables.

i. Intelligent integration

The intelligent network integration used the rule base of the fuzzy algorithm to control the dynamic network switching system.

ii. Process Variables

The fuzzy core was adapted to take faster decisions with respect to the process variables $F(n)$ (in Equ 4.1) and $C(n)$ (in Equ 4.1).

Equ. 4.1 shows the process model of the trusted computing Engine which incorporates four process variables and control variables.

The multivalued fuzzy model processes its inputs by allowing linguistic variables classification such as low, high, medium, normal. Unlike binary logic, fuzzy system do not restrict a variable to be a member of a single set, but recognize that a given value may fit to varying degrees. The Fuzzy summation block which operates by testing variables with *IF-THEN* rules, was used to produce appropriate responses. Each rules then weighted by a degree of fulfillment of the rule invoked, this is a number between 0 and 1, and may be thought of as probability that a given number is considered to be included in a particular set. A wide variety of shapes was considered such as possible, fulfillment functions, with triangles and trapezoids being the most popular. Membership functions

$$\mu(F_n, C_n) = \exp (-(|F_n, C_n|)^{I_p}) \quad \dots \text{eqn} \quad 4.1$$

Where F_n = GSM networks, C_n = Customer Parameters, and I_p = index parameter. These are the system chosen parameters whose values are tested and used to generate the surface diagrams in this work. The functions were chosen because of their flexibility, by changing

them, whole families of different functions can be obtained. For $\mu(F_n, C_n) = \exp(-(F_n, C_n)^{lp})$, these are non normalized Gaussian density.

The degree of fulfillment for such a rule in this work was chosen to be the minimum of the degrees of fulfillment of the antecedent clauses. The total output of the control system is calculated as weighted sum of the responses to all n rules outputs. Outlined below is the step by step modeling approach in the trusted fuzzy logic summation block model.

Step 1. Fuzzification of Inputs (Process variables)

The first step is to take the inputs (the process variables, (F_n, C_n)) and determine the degree to which they belong to each of the appropriate fuzzy sets via membership functions. In the Fuzzy Logic Toolbox, the input is always a crisp numerical value limited to the universe of discourse of the input variable and the output is a fuzzy degree of membership in the qualifying linguistic set. Fuzzification of the input amounts to either a table lookup or a function evaluation in the rule base and inference engine.

Step 2. Application of the Fuzzy Operator

After the process variables have been fuzzified, the degree to which each part of the antecedent has been satisfied for each rule is ascertained. If the antecedent of a given rule has more than one part, the fuzzy operator is applied to obtain one number that represents the result of the antecedent for that rule. This number will then be applied to the output function. The input to the fuzzy operator is two or more membership values from fuzzified input variables. The output is a single truth value.

Step 3. Application of the Implication Method in the Rule Editor

Before applying the implication method, the rule's weight was taken care of in the FIS. Every rule has a *weight* (a number between 0 and 1), which is applied to the number given by the antecedent in the rule editor. From time to time the weight of one rule in the GNIS fuzzy core is varied relative to the others by changing its weight value to something other than 1. Once proper weighting has been assigned to each rule, the implication method is implemented. In this context, a consequent is a fuzzy set represented by a membership function which weights appropriately the linguistic characteristics that are attributed to it. The consequent is reshaped using a function

associated with the antecedent in the rule editor. The input for the implication process is a single number given by the antecedent, and the output is a fuzzy set. Implication is implemented for each rule in the rule editor.

Step 4. Aggregation of All Outputs

The fuzzy decisions are based on the results of testing all the rules in an FIS. The rules are combined in order to make intelligent decisions. Aggregation is the process by which the fuzzy sets that represent the outputs of each rule are combined into a single fuzzy set. Aggregation only occurs once for each output variable, just prior to the defuzzification phase.

Step 5. Defuzzification

The input for the defuzzification process is a fuzzy set (the aggregate output fuzzy set) and the output is a single number which serves as a control signal for driving the output interface systems. As much as fuzziness helps the rule evaluation during the intermediate steps, the final desired output for each variable is generally a single number (drive signal). However, the aggregate of a fuzzy set encompasses a range of output controlled values, and so must be defuzzified in order to control the dashboard or other output interface units.

The centroid calculation, (the TE defuzzification method) which returns the center of area under the curve in the FIS model was carefully setup. There are five built-in methods supported by the MATLAB fuzzy blockset: centroid, bisector, middle of maximum (the average of the maximum value of the output set), largest of maximum, and smallest of maximum.

This work leverages on the open and easily modifiable fuzzy inference system (FIS) structure of the Fuzzy Logic Toolbox. In this context, within the basic constraints of the input process, this work customized the fuzzy inference process for the TE application achieves a highly available and reliable system. Figure 4.3 depict membership function for Glo while figure 4.4 shows the FIS membership function for MTN.

The considered control variables/entities comprises of networks (N_1 to N_{I+n}), and C_n . The membership situation is divided into Low, Medium, Normal, High and Very High States for all the process variables as shown in Equ 4.1. The definition of membership function

was done using the fuzzy literal algorithm implemented in the fuzzy inference Engine (FIS).

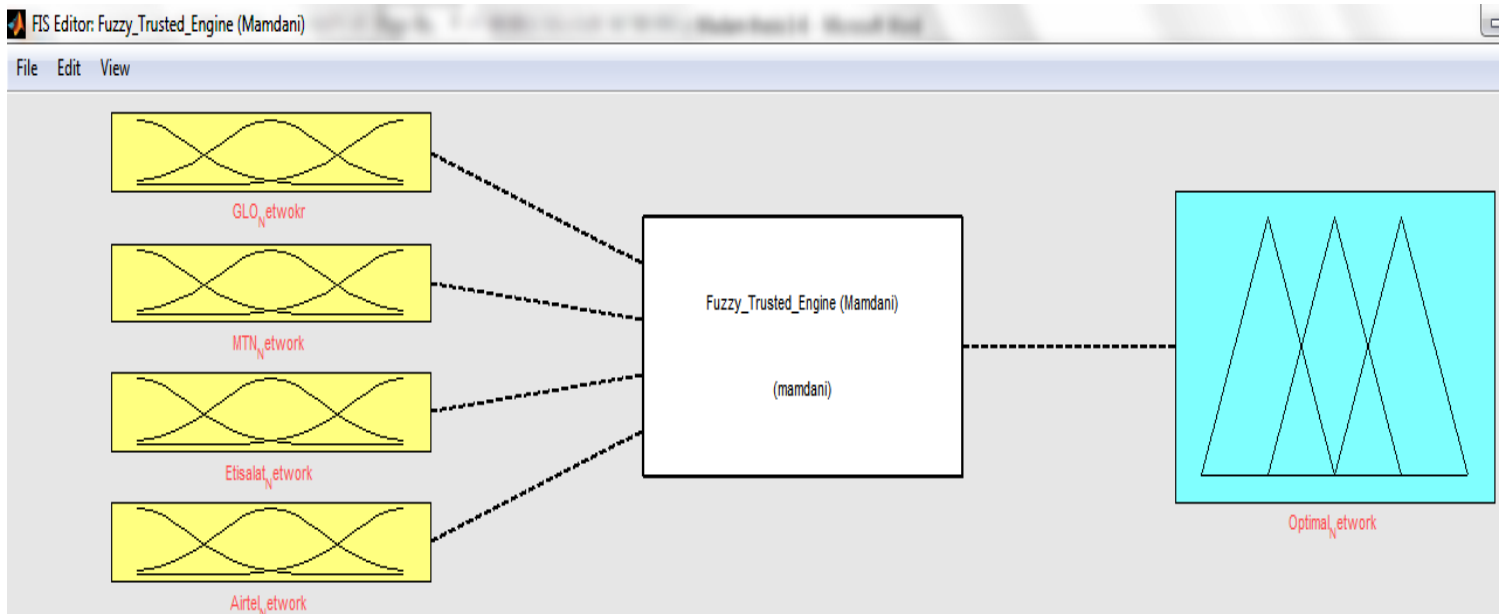


Figure 4.2: Mamdani Inference System (TE) for GSM Networks

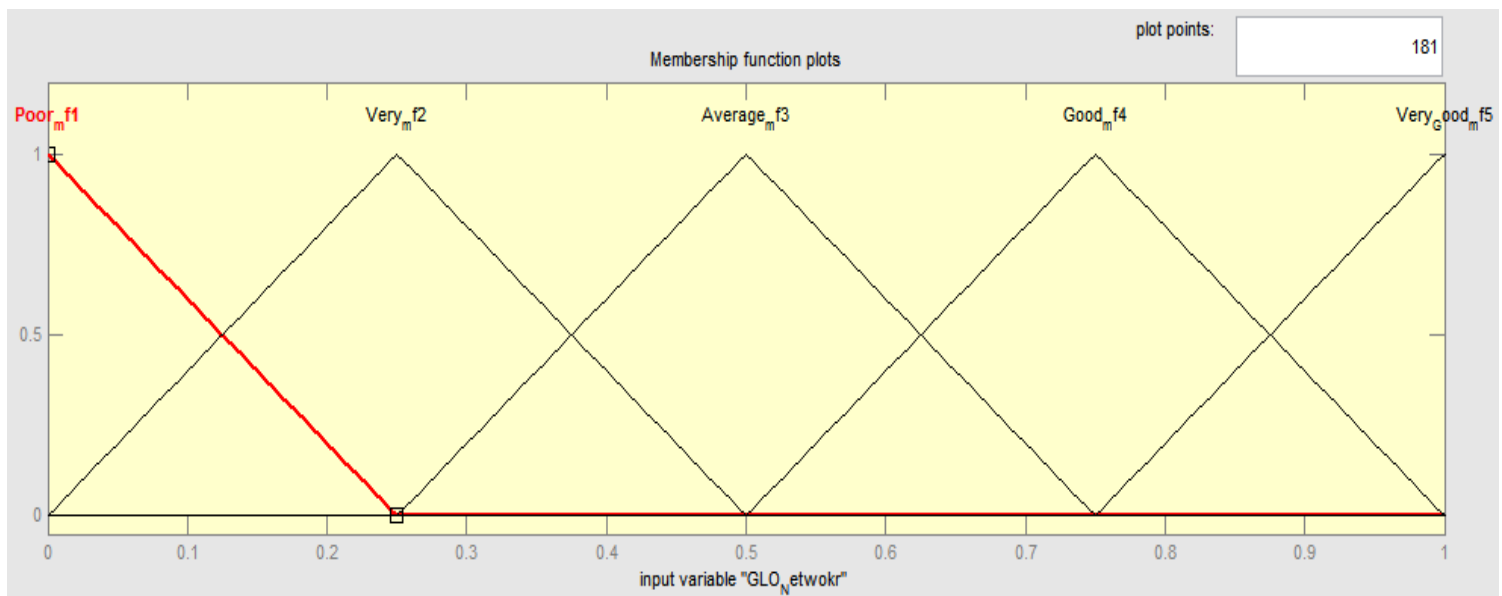


Figure 4.3: Membership functions for GLO Network

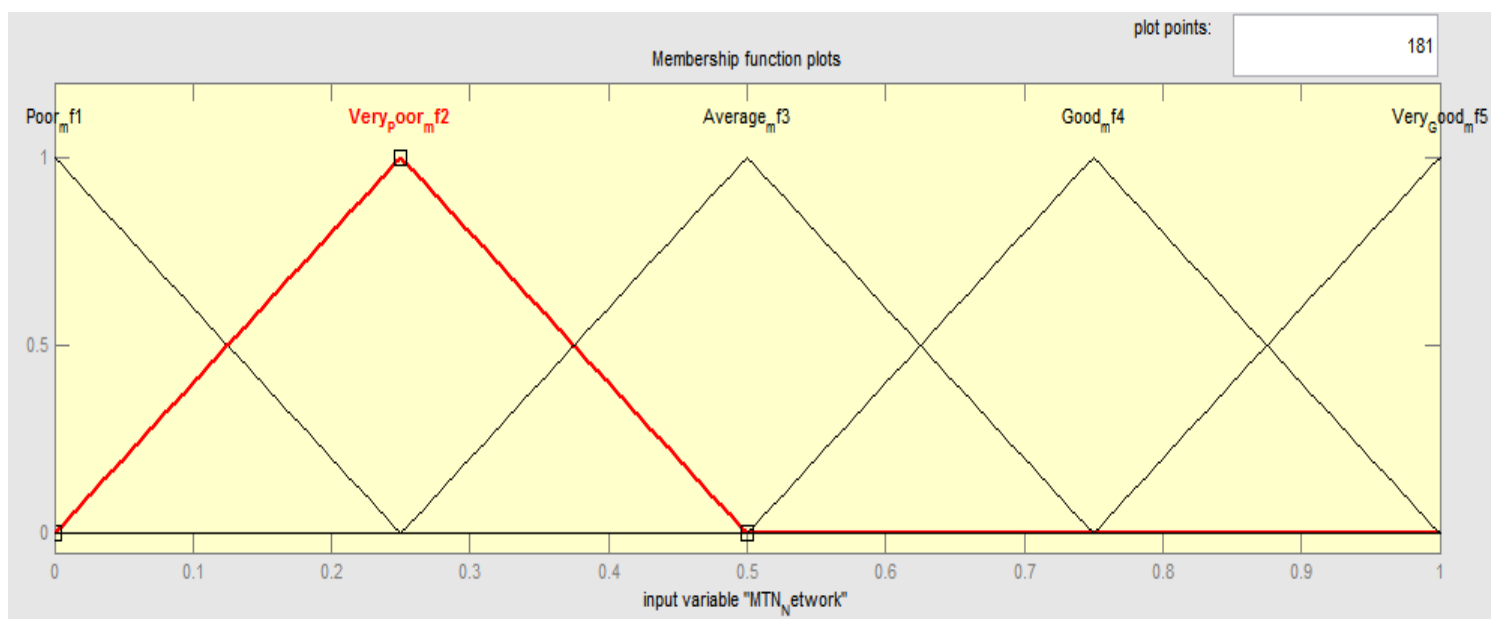


Figure 4.4: Membership functions for MTN Network

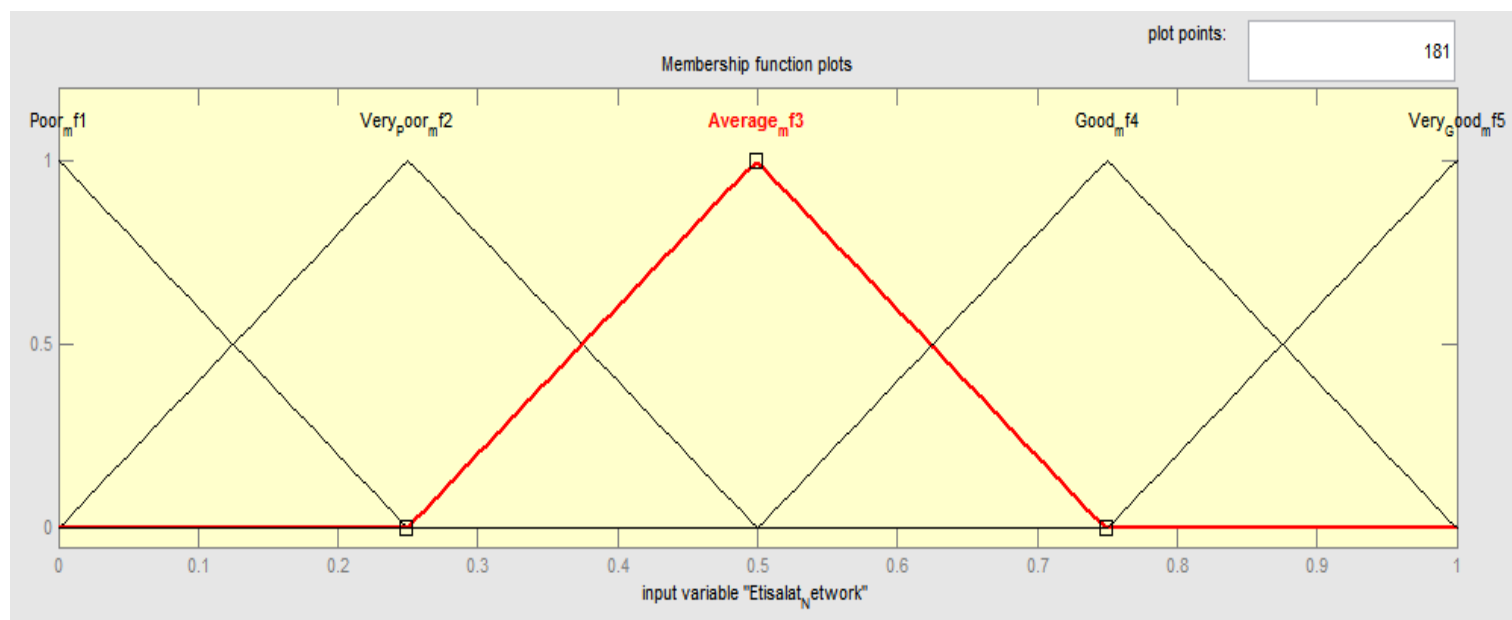


Figure 4.5: Membership functions for Etisalat Network

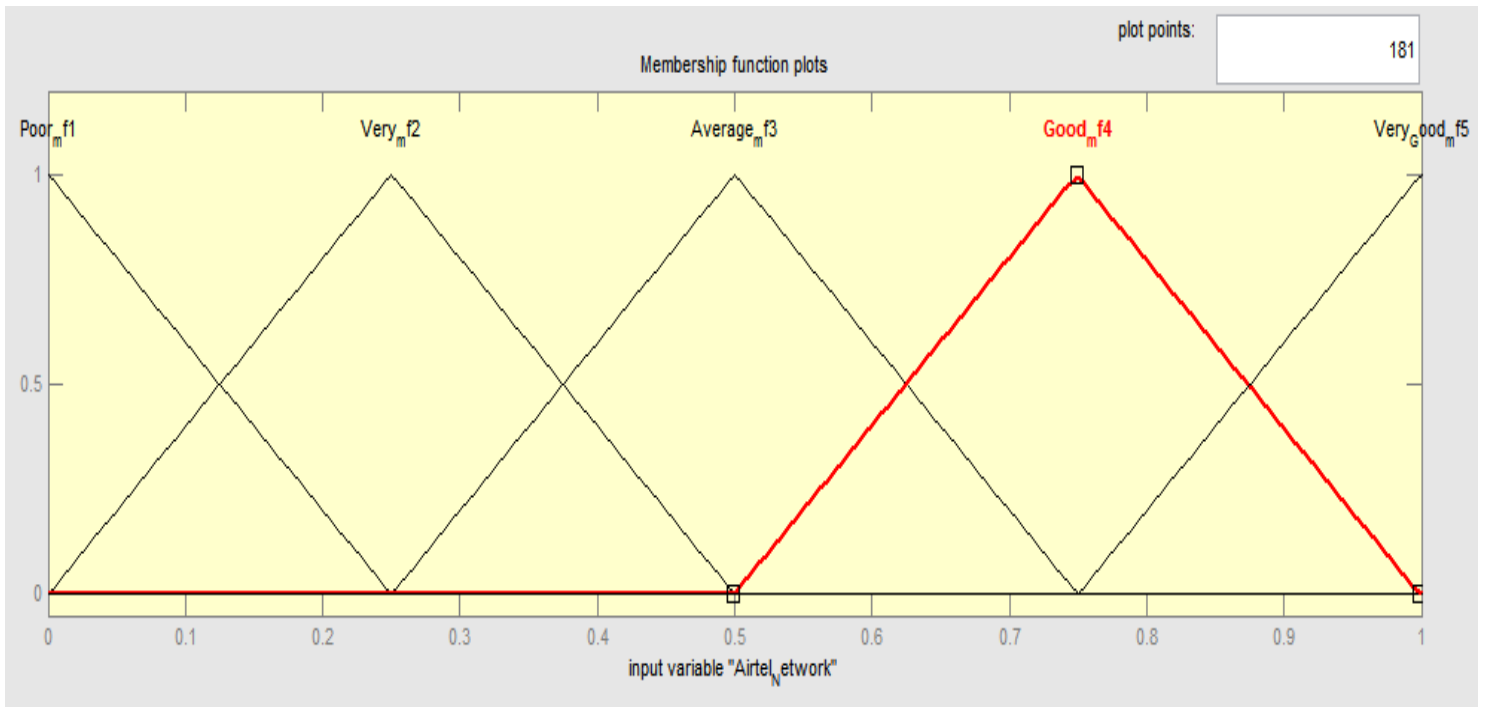


Figure 4.6: Membership functions for Airtel Network

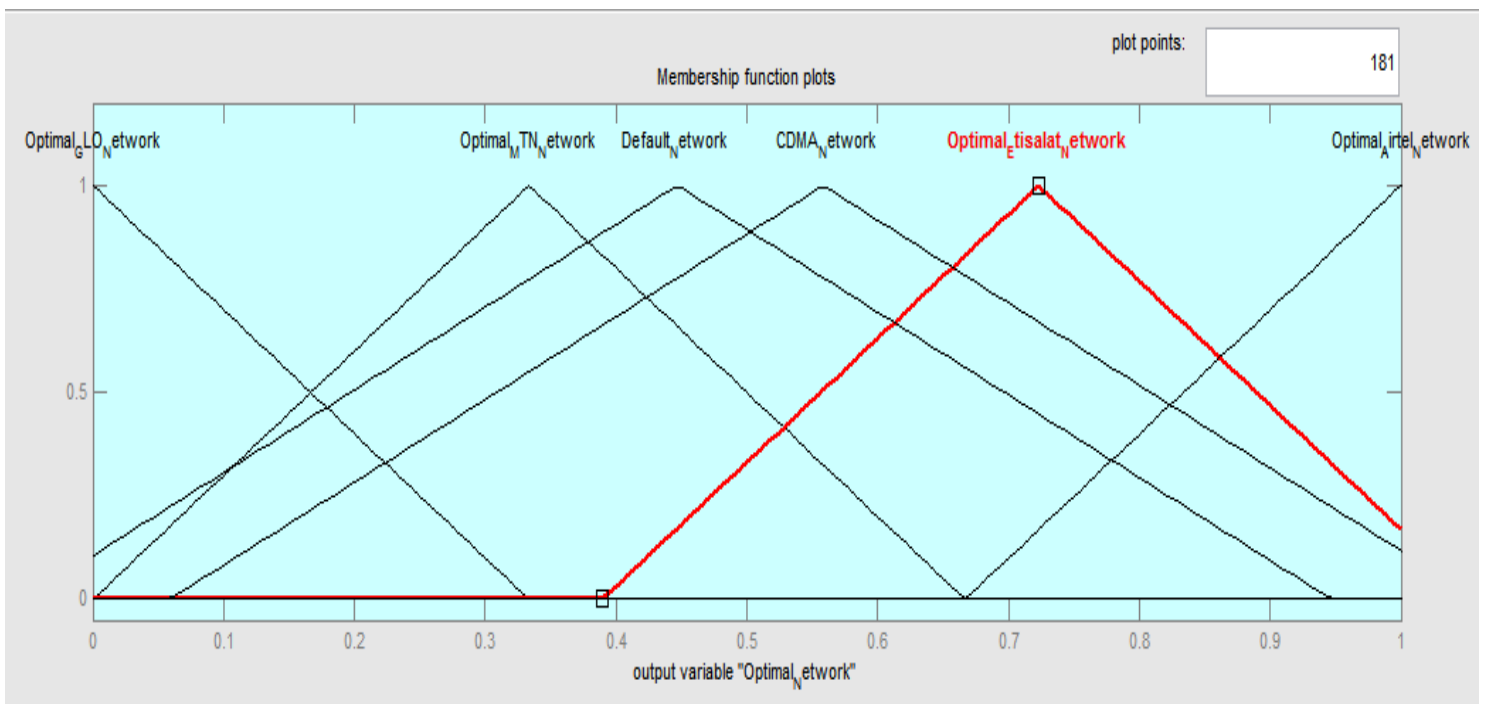


Figure 4.7: Membership functions for Output Decision Network

5. If (GLO_Netwokr is Poor_mf1) and (MTN_Network is Very_Good_mf5) and (Etisalat_Network is Poor_mf1) and (Airtel_Network is Poor_mf1) then (Optimal_Network is Optimal_MTN_Network) (1)
6. If (GLO_Netwokr is Poor_mf1) and (MTN_Network is Poor_mf1) and (Etisalat_Network is Very_Poor_mf2) and (Airtel_Network is Poor_mf1) then (Optimal_Network is CDMA_Network) (1)
7. If (GLO_Netwokr is Poor_mf1) and (MTN_Network is Poor_mf1) and (Etisalat_Network is Average_mf3) and (Airtel_Network is Poor_mf1) then (Optimal_Network is Optimal_Etisalat_Network) (1)
8. If (GLO_Netwokr is Poor_mf1) and (MTN_Network is Poor_mf1) and (Etisalat_Network is Good_mf4) and (Airtel_Network is Poor_mf1) then (Optimal_Network is Optimal_Etisalat_Network) (1)
9. If (GLO_Netwokr is Poor_mf1) and (MTN_Network is Poor_mf1) and (Etisalat_Network is Very_Good_mf5) and (Airtel_Network is Poor_mf1) then (Optimal_Network is Optimal_Etisalat_Network) (1)
10. If (GLO_Netwokr is Poor_mf1) and (MTN_Network is Poor_mf1) and (Etisalat_Network is Poor_mf1) and (Airtel_Network is Very_mf2) then (Optimal_Network is Optimal_Airtel_Network) (1)
11. If (GLO_Netwokr is Poor_mf1) and (MTN_Network is Poor_mf1) and (Etisalat_Network is Poor_mf1) and (Airtel_Network is Average_mf3) then (Optimal_Network is Optimal_Airtel_Network) (1)
12. If (GLO_Netwokr is Poor_mf1) and (MTN_Network is Poor_mf1) and (Etisalat_Network is Poor_mf1) and (Airtel_Network is Good_mf4) then (Optimal_Network is Optimal_Airtel_Network) (1)
13. If (GLO_Netwokr is Poor_mf1) and (MTN_Network is Poor_mf1) and (Etisalat_Network is Poor_mf1) and (Airtel_Network is Very_Good_mf5) then (Optimal_Network is Optimal_Airtel_Network) (1)
14. If (GLO_Netwokr is Very_Poor_mf2) and (MTN_Network is Poor_mf1) and (Etisalat_Network is Poor_mf1) and (Airtel_Network is Poor_mf1) then (Optimal_Network is CDMA_Network) (1)
15. If (GLO_Netwokr is Very_Poor_mf2) and (MTN_Network is Very_Poor_mf2) and (Etisalat_Network is Poor_mf1) and (Airtel_Network is Poor_mf1) then (Optimal_Network is CDMA_Network) (1)
16. If (GLO_Netwokr is Very_Poor_mf2) and (MTN_Network is Average_mf3) and (Etisalat_Network is Poor_mf1) and (Airtel_Network is Poor_mf1) then (Optimal_Network is Optimal_MTN_Network) (1)
17. If (GLO_Netwokr is Very_Poor_mf2) and (MTN_Network is Good_mf4) and (Etisalat_Network is Poor_mf1) and (Airtel_Network is Poor_mf1) then (Optimal_Network is Optimal_MTN_Network) (1)
18. If (GLO_Netwokr is Very_Poor_mf2) and (MTN_Network is Very_Good_mf5) and (Etisalat_Network is Poor_mf1) and (Airtel_Network is Poor_mf1) then (Optimal_Network is Optimal_MTN_Network) (1)
19. If (GLO_Netwokr is Very_Poor_mf2) and (MTN_Network is Poor_mf1) and (Etisalat_Network is Very_Poor_mf2) and (Airtel_Network is Poor_mf1) then (Optimal_Network is CDMA_Network) (1)
20. If (GLO_Netwokr is Very_Poor_mf2) and (MTN_Network is Poor_mf1) and (Etisalat_Network is Average_mf3) and (Airtel_Network is Poor_mf1) then (Optimal_Network is Optimal_Etisalat_Network) (1)
21. If (GLO_Netwokr is Very_Poor_mf2) and (MTN_Network is Poor_mf1) and (Etisalat_Network is Good_mf4) and (Airtel_Network is Poor_mf1) then (Optimal_Network is Optimal_Etisalat_Network) (1)

If	and	and	and	Then
GLO_Netwokr is	MTN_Network is	Etisalat_Network is	Airtel_Network is	Optimal_Network is
Poor_mf1	Poor_mf1	Poor_mf1	Poor_mf1	Optimal_GLO_Network
Very_Poor_mf2	Very_Poor_mf2	Very_Poor_mf2	Very_mf2	Optimal_MTN_Network
Average_mf3	Average_mf3	Average_mf3	Average_mf3	Optimal_Etisalat_Network
Good_mf4	Good_mf4	Good_mf4	Good_mf4	Optimal_Airtel_Network
Very_Good_mf5	Very_Good_mf5	Very_Good_mf5	Very_Good_mf5	Default_Network
none	none	none	none	CDMA_Network
				none

Figure 4.8: Rule base Editor for the GSM network process variables

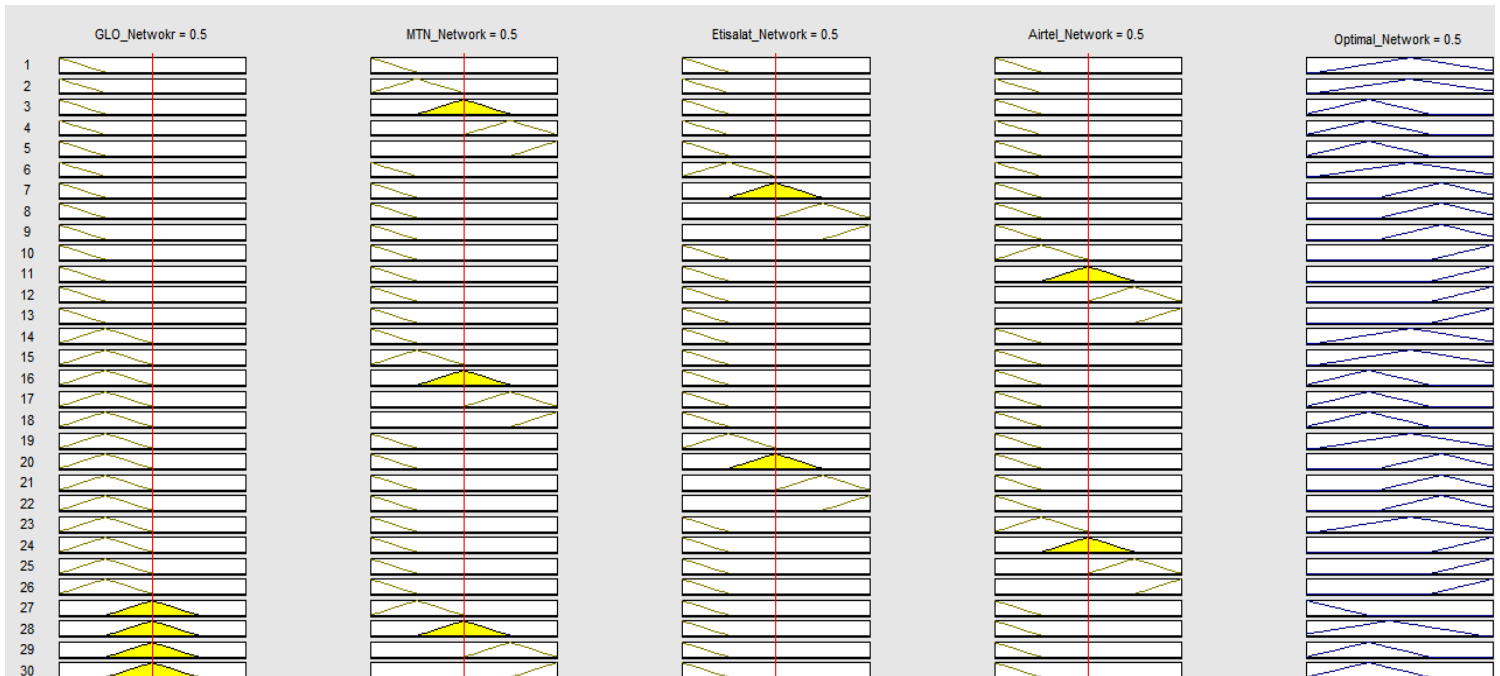


Figure 4.9: Rule base Optimal points for the process variables (75 rule base centriods)

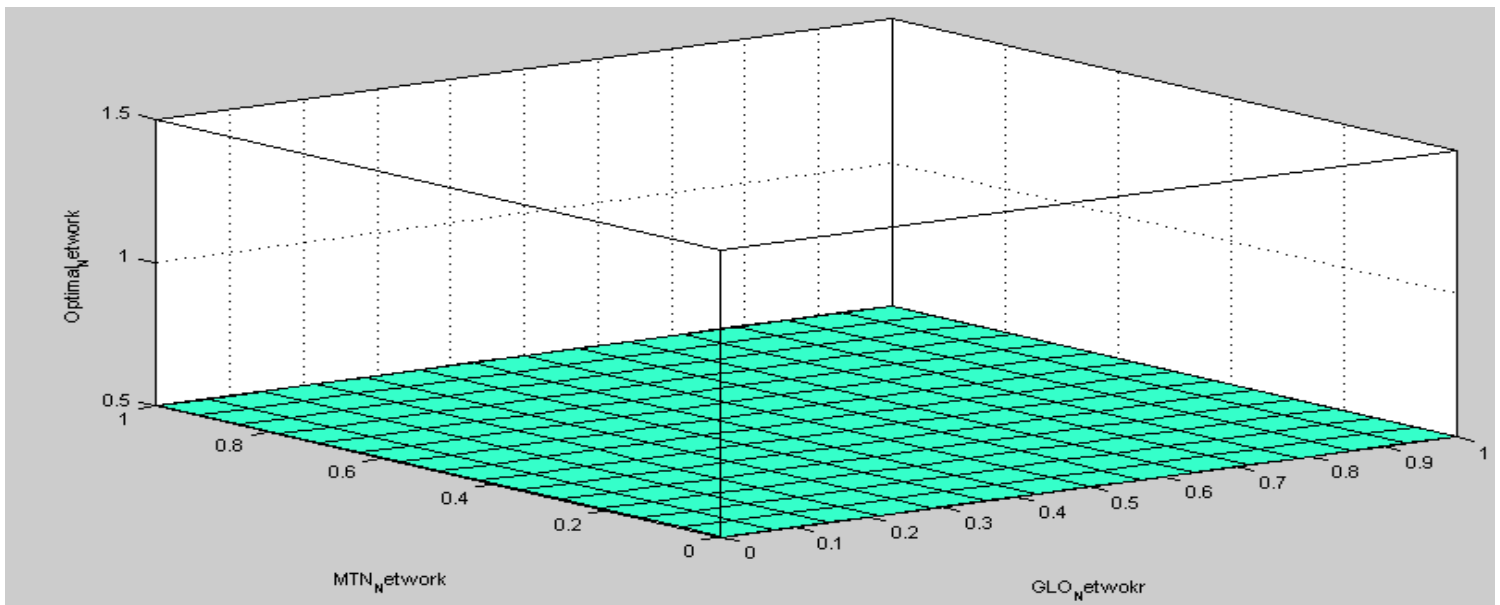


Figure 4.10: Surface diagram for the process variables

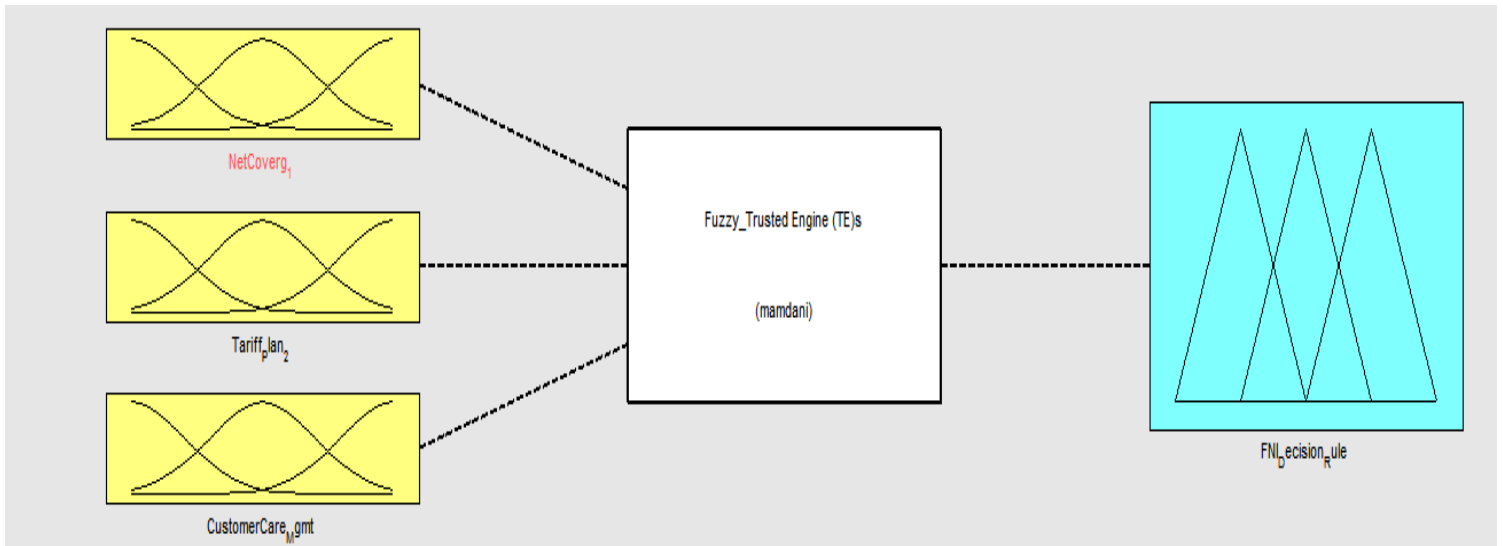


Figure 4.11: FIS for the system for the customer network parameters.

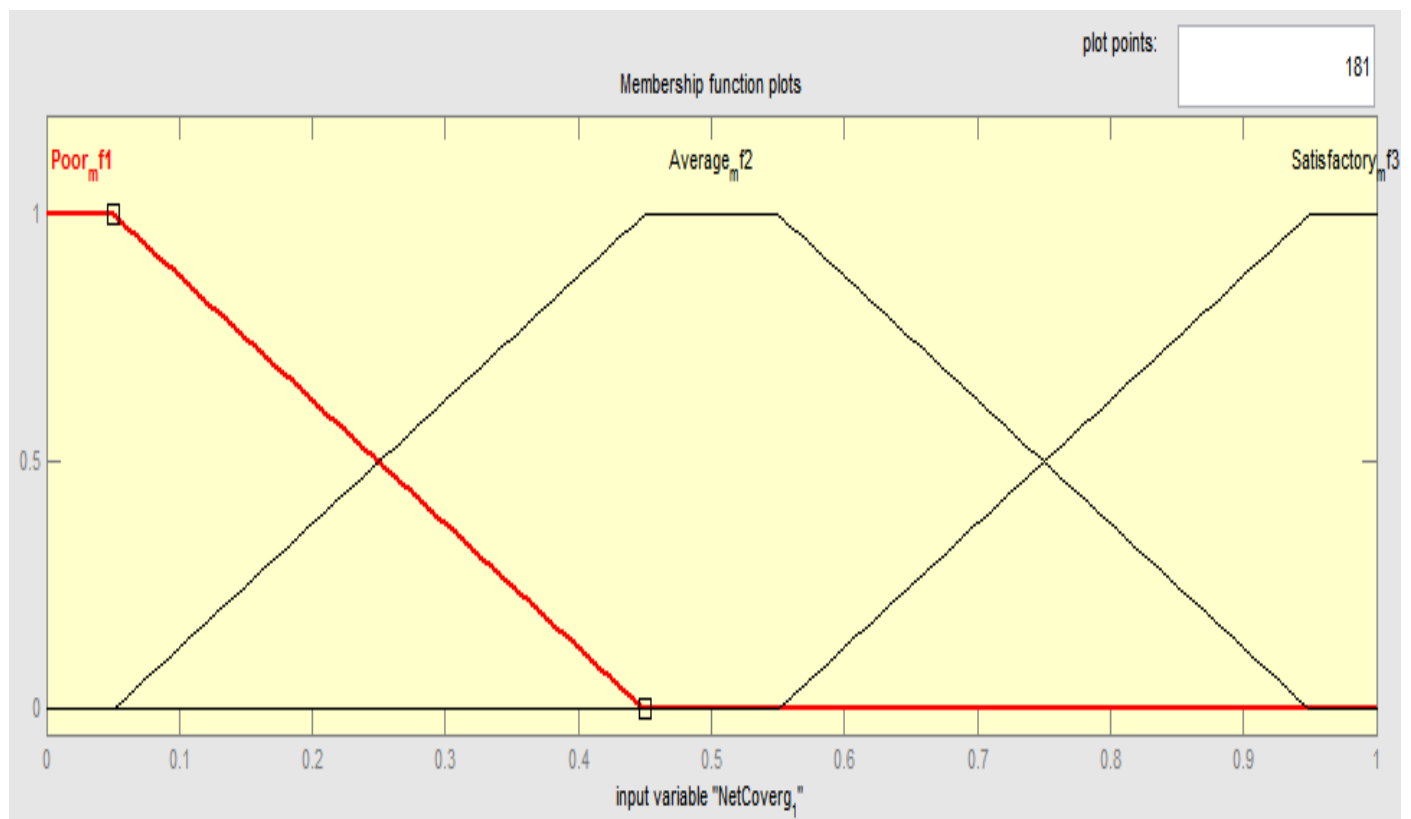


Figure 4.12: Membership functions for Customer variable (Network_Coverage)

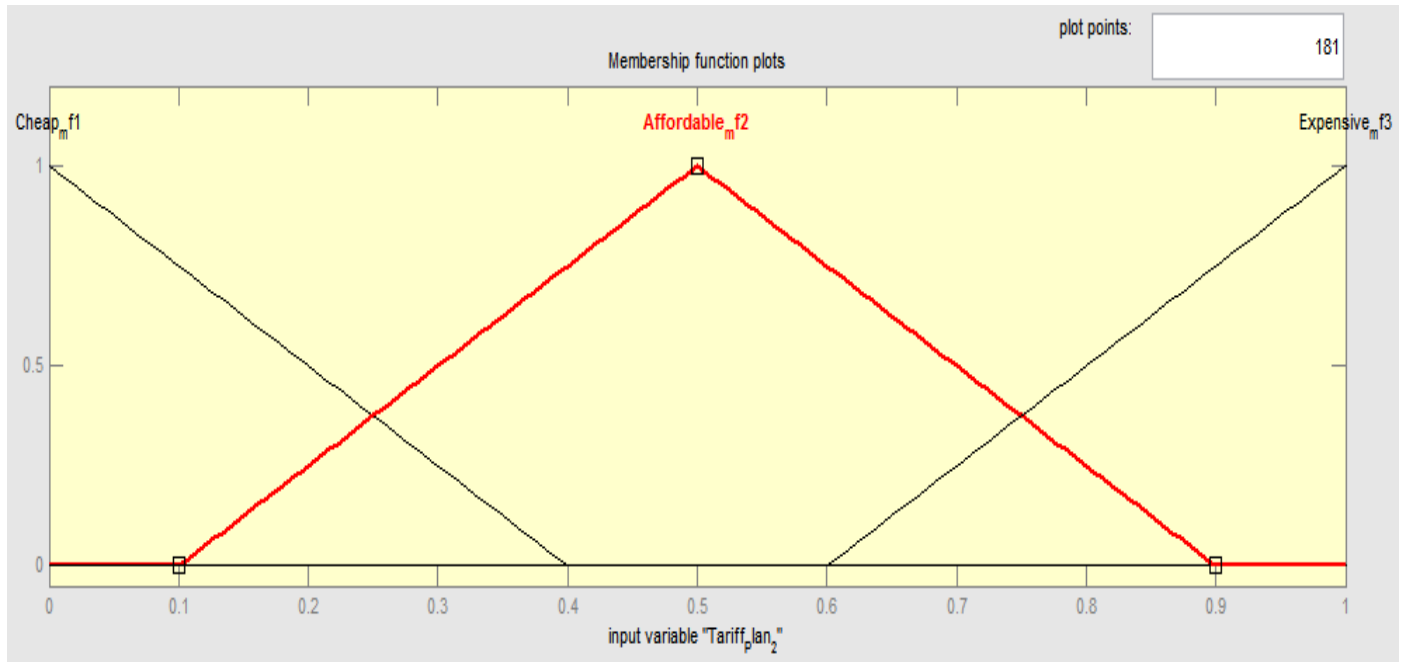


Figure 4.13: Membership functions for Customer variable (Tariff_Plan)

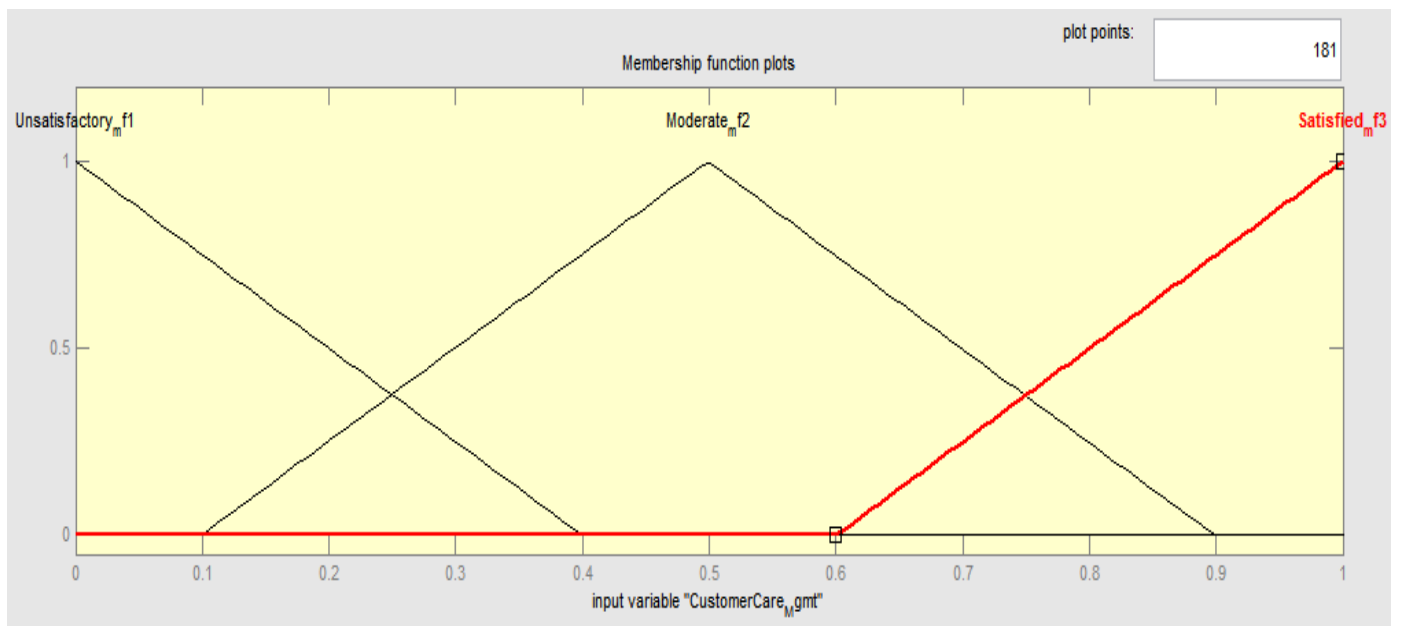


Figure 4.14: Membership functions for Customer variable (Customer care management)

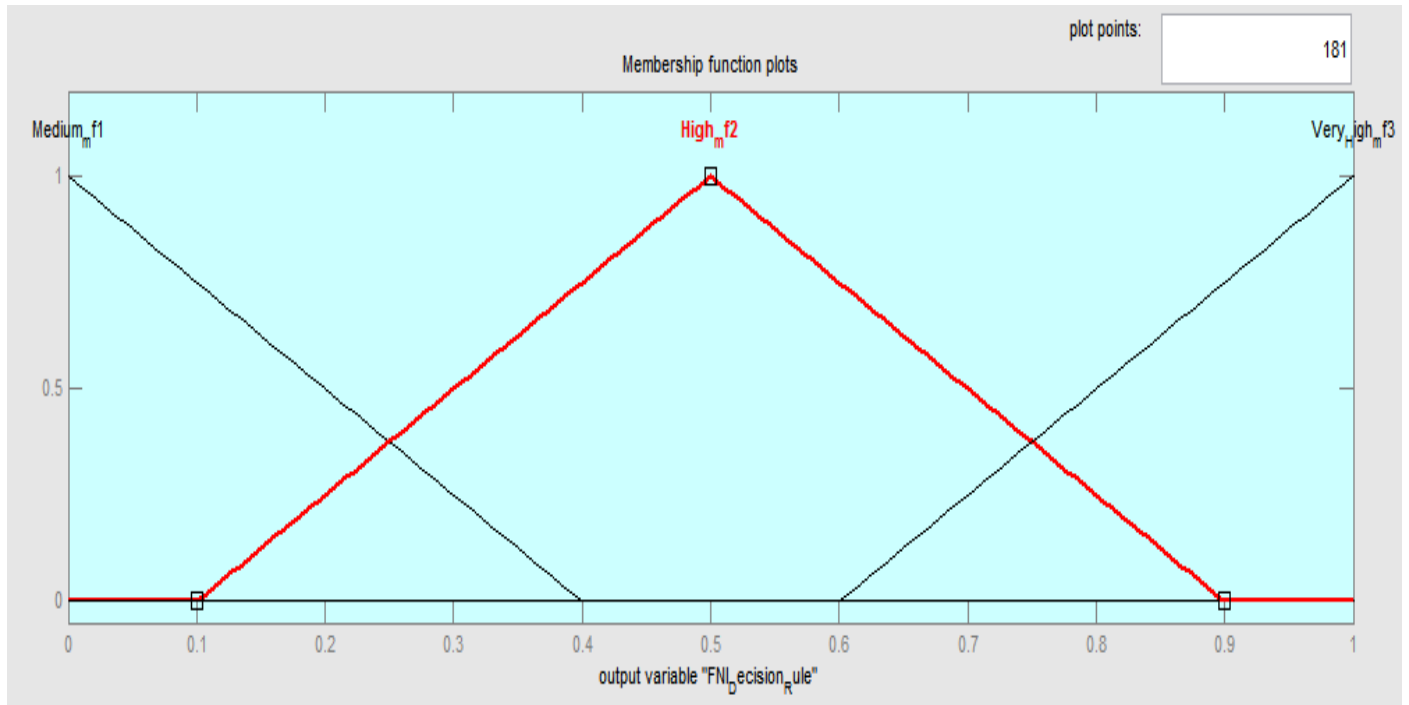


Figure 4.15: Membership functions for Output decision rule

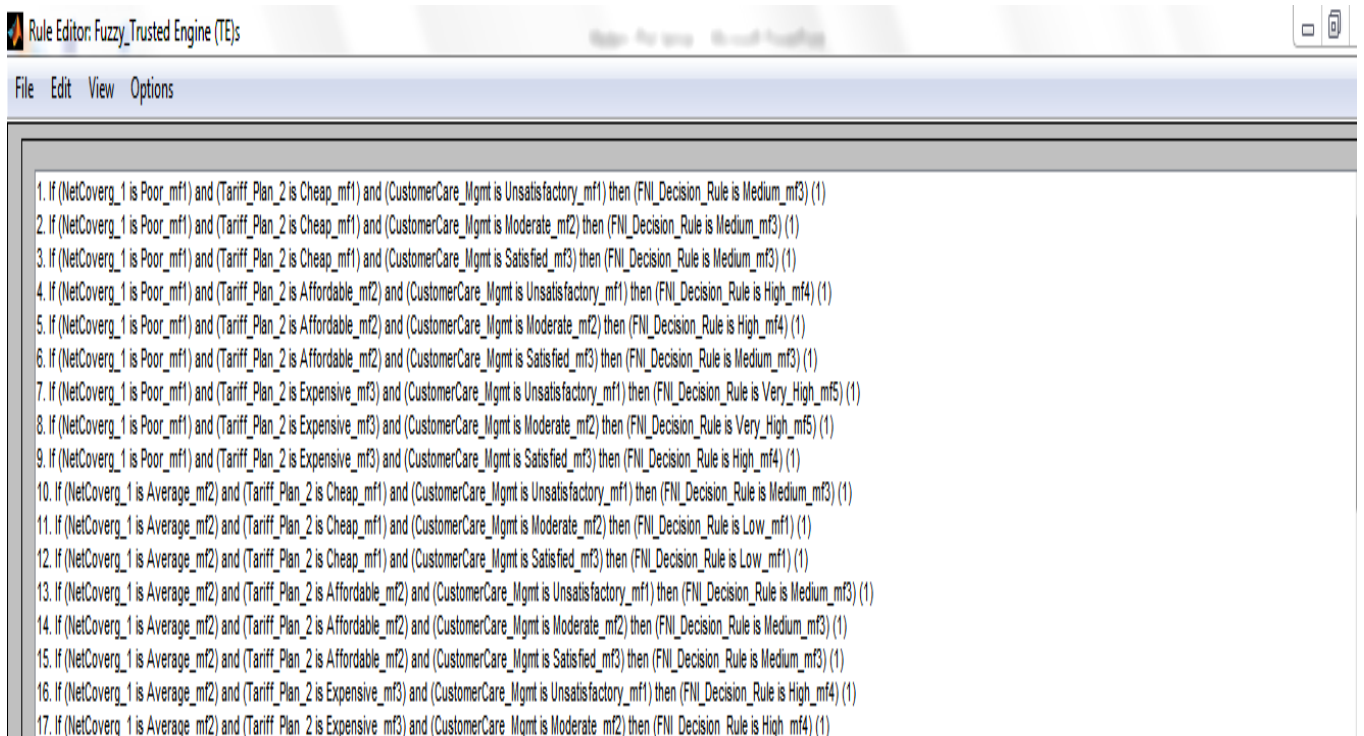


Figure 4.16: Rule base Editor for customer GSM network process variables

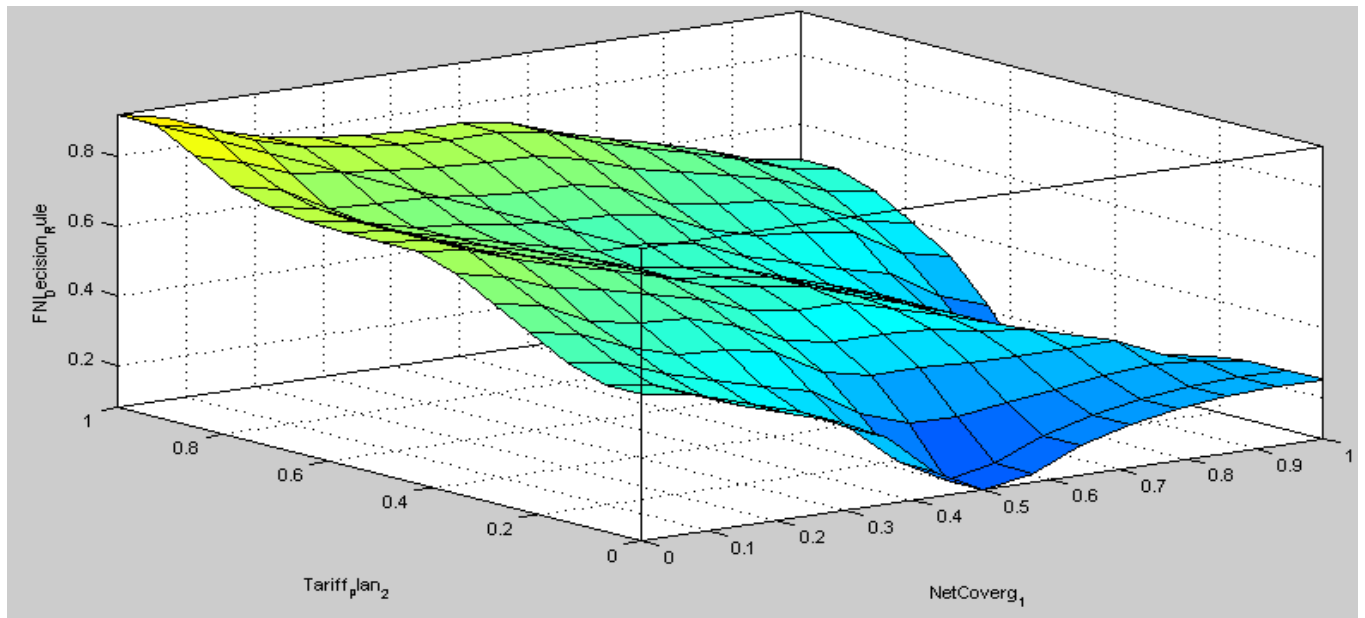


Figure 4.17: Surface diagram for customer GSM network process variables (Tariff and Network Coverage)

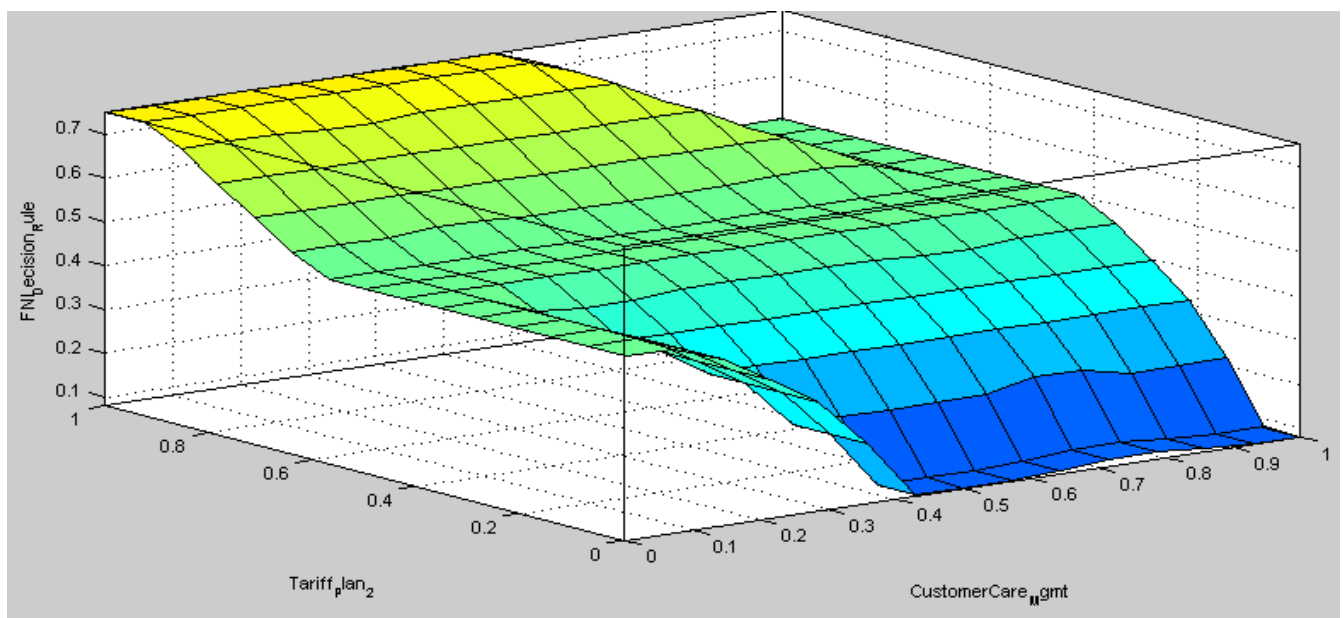


Figure 4.18: Surface diagram for customer GSM network process variables (Tariff and Customer care)

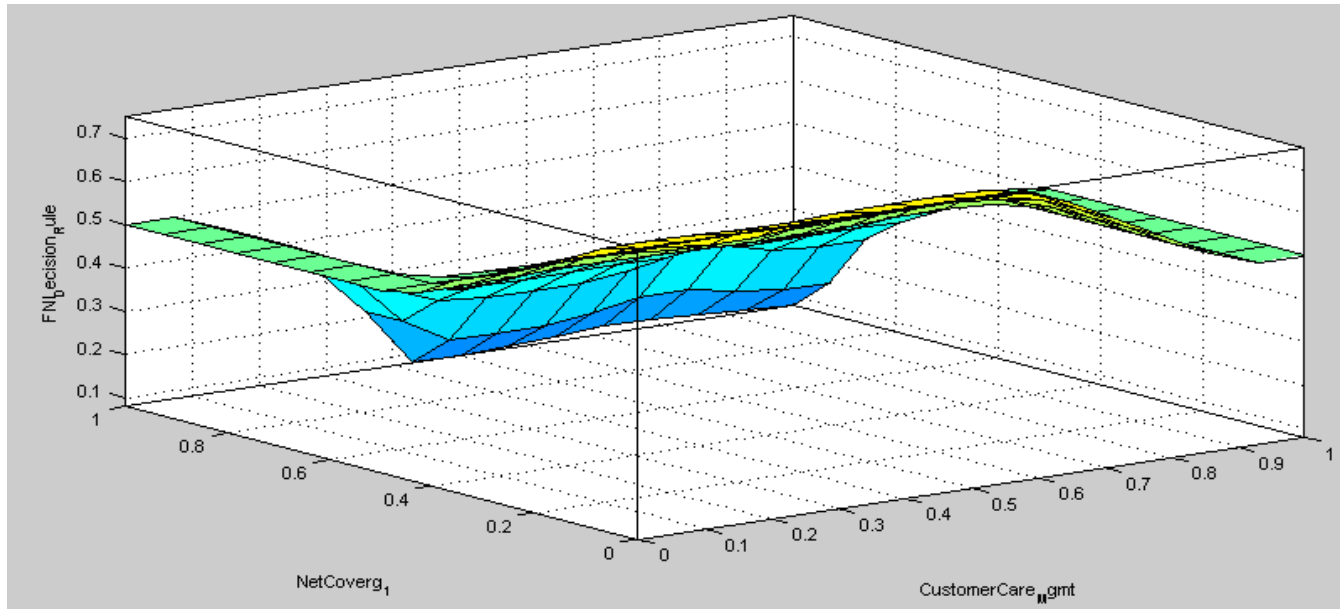


Figure 4.19: Surface diagram for customer GSM network process variables (Network Coverage and customer care management)

4.2. System Implementation

4.2.1. Object Oriented Analysis and Design Methodology

The NetBeans platform was used to develop MNVSim leveraging software development lifecycle (SDLC). This allowed application to be developed from a set of modular software components called modules vis-vis Object oriented programming. The NetBeans IDE is an open-source integrated development environment which supports the development of all Java application types (Java SE including JavaFX, (Java ME, web, EJB and mobile applications). Among its other features are: an Ant-based project system, Maven support, refactorings, and version control (supporting CVS, Subversion, Mercurial and Clear case). The MNVSim is written with JAVA programming language in NetBeans 7.0 with MySQL XAMP control panel for the database integration. It was developed as a client in middle tier server application with the respective network service provider's integration on the computing platform.

Fuzzy logic was used to extend this research on the trusted computing platform while showing the respective surface diagrams for the network integration process variables. In this case, both the migration pattern as well as the enhancement factors for the MNP using fuzzy trusted computing engine based on JAVA virtual machine, JVM were shown

The application is made to be very portable since the approach of implementation ignored the usage of database like MYSQL, Sybase or Oracle , as such there is no drain on the system resources when deployed. As shown in figure 4.28, the proposed system by default supports the four key networks while only supporting one active migration at any time leveraging the centralized database as shown in figure 4.23. In figure 4.20, a valid network user at t migrates to ETISALAT.

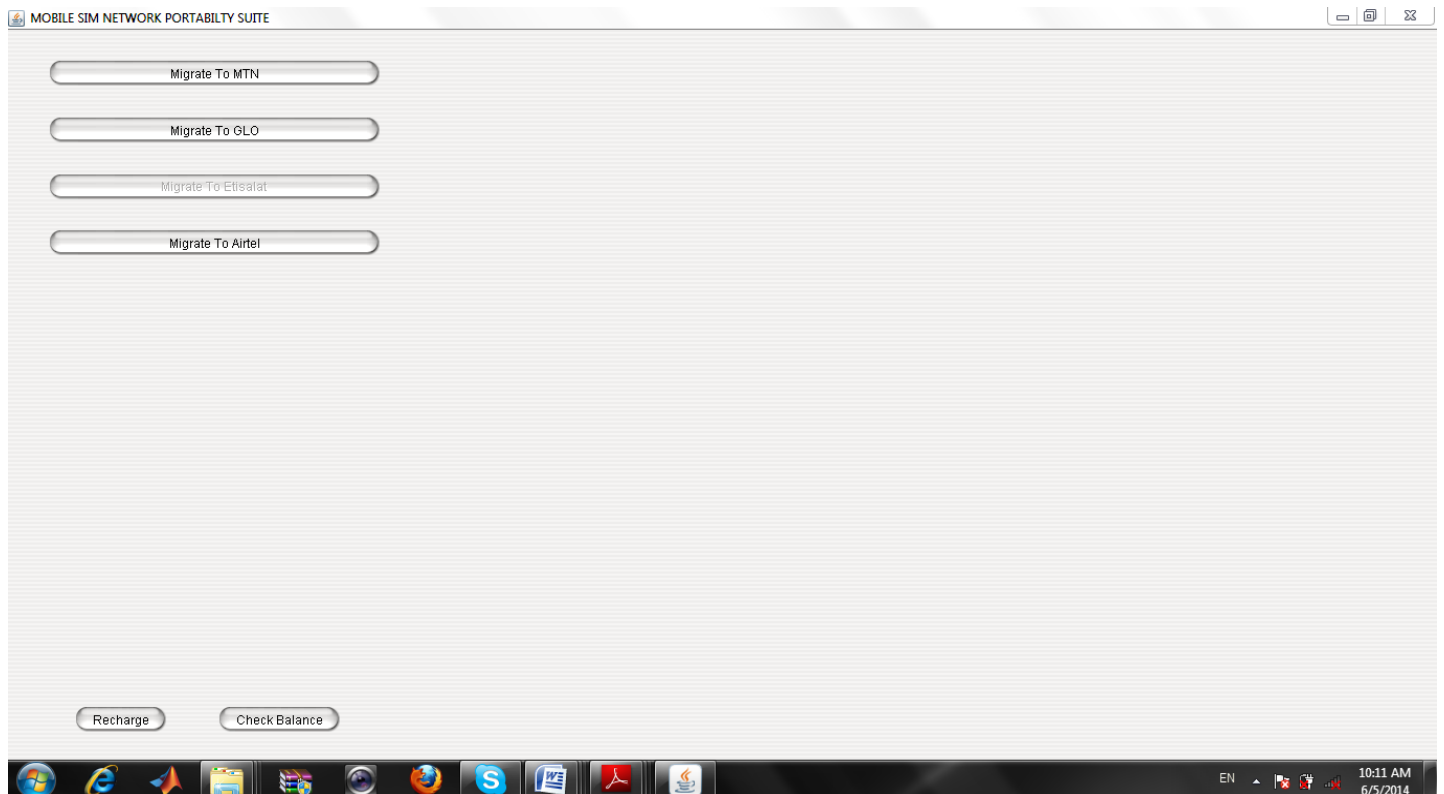


Figure 4.20: A valid user migration to ETISALAT

Figure 4.21 shows how as valid user that have migrated to ETISALAT can explore the MNPSim suite account checking capabilities in figure 4.22.

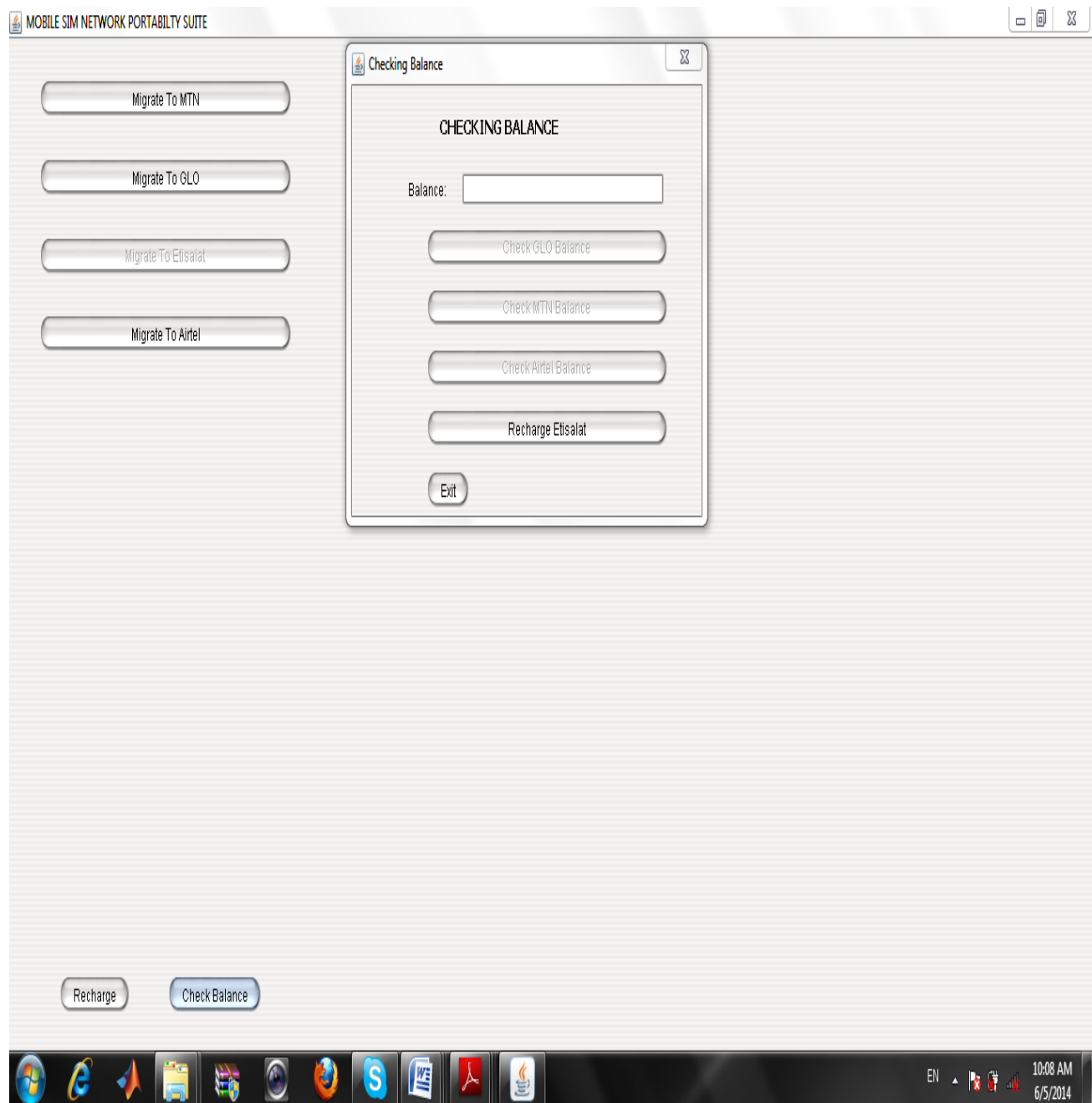


Figure 4.21: A valid user migration to ETISALAT with account checking capabilities

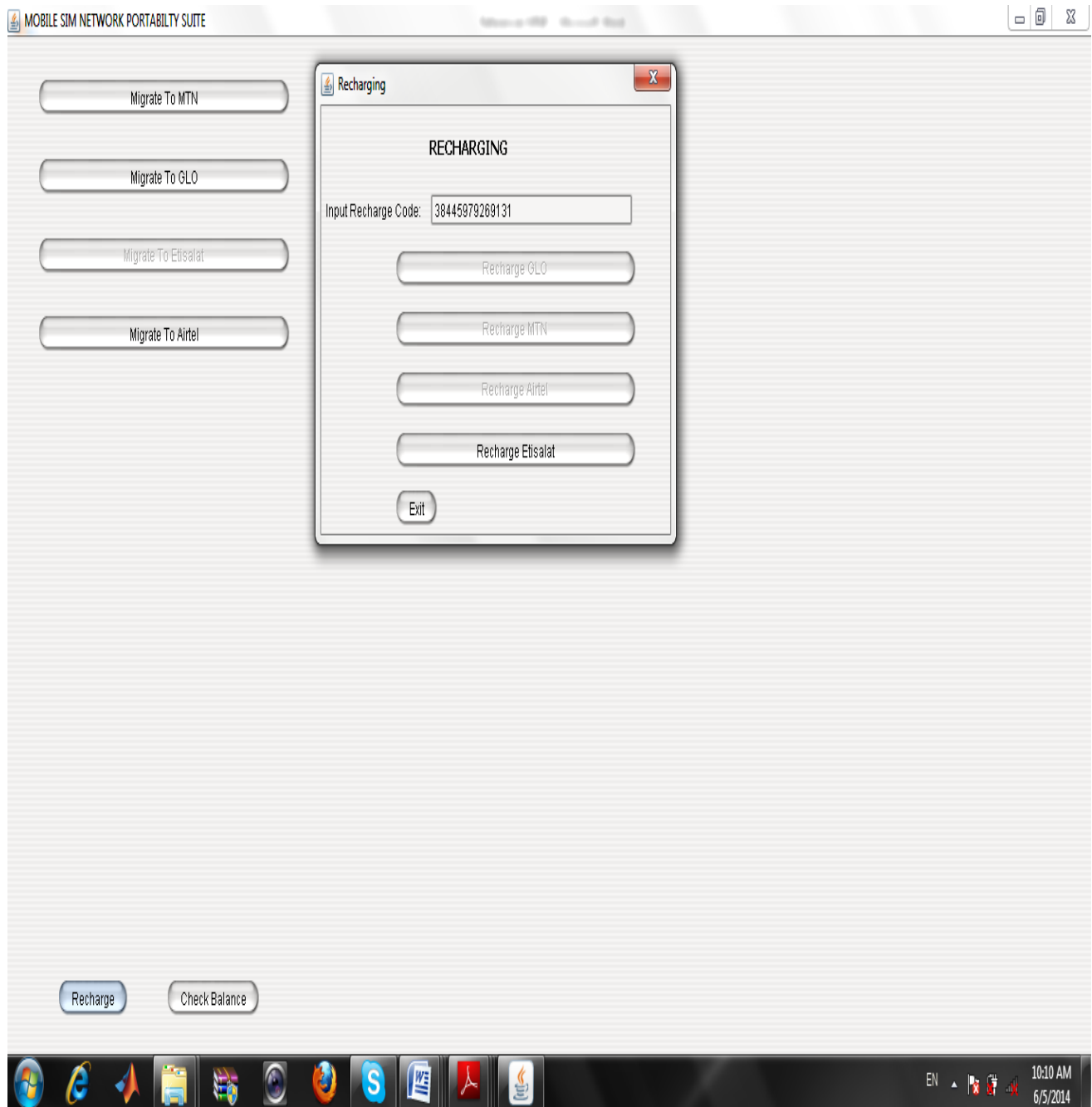


Figure 4.22: A valid user migration to ETISALAT with account recharging capabilities

Figure 4.23 shows an implementation of a valid user SIMcard registration with the migration log interface. By submitting the registration details, the user have by default accepted the service level agreement without much bureaucracies. Figure 4.24 shows the details of a migration log interface, while figure 4.27 shows the Simcard Network Migration audit log trails.

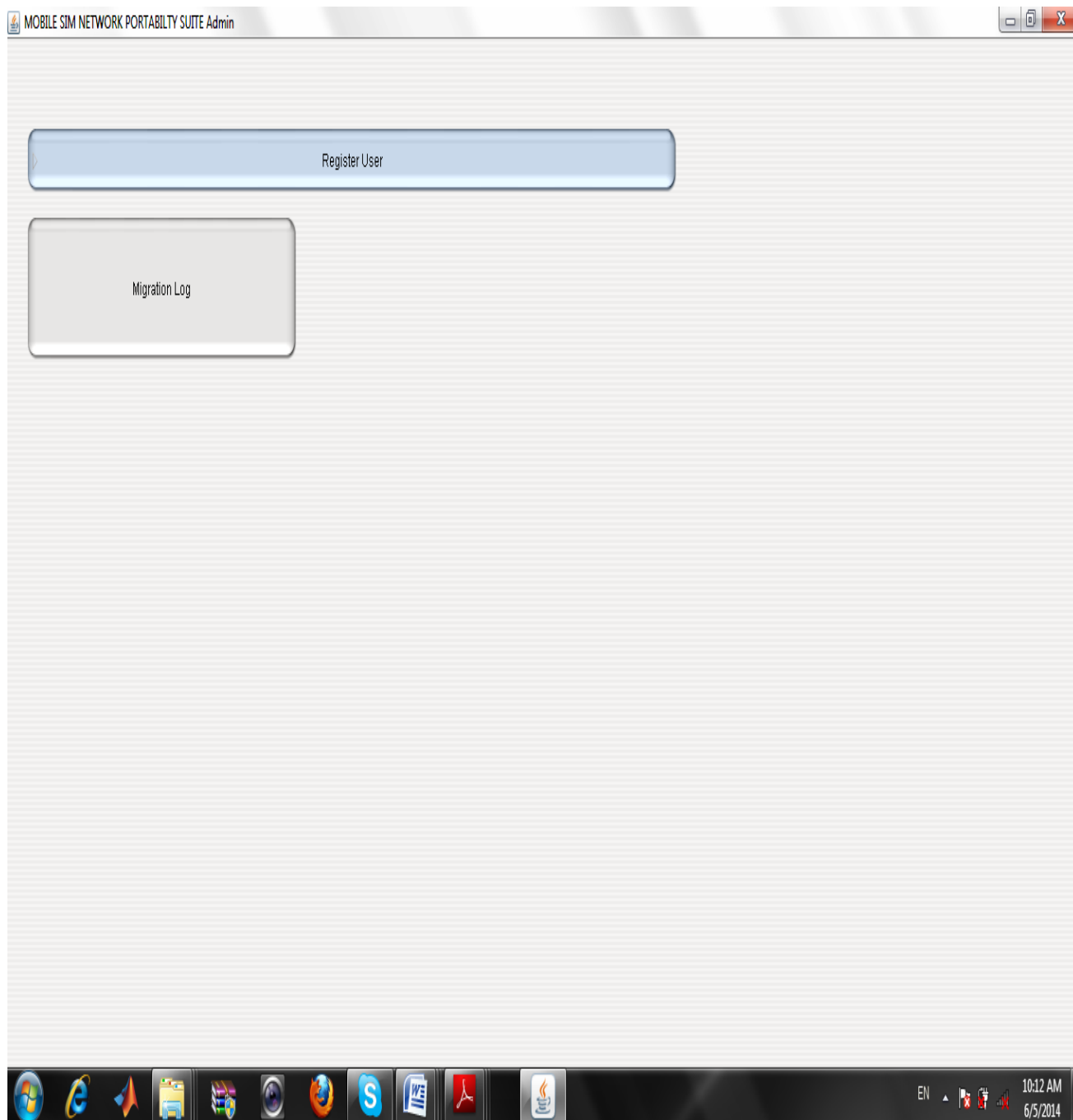


Figure 4.23: A valid user SIMcard registration with the migration log interface

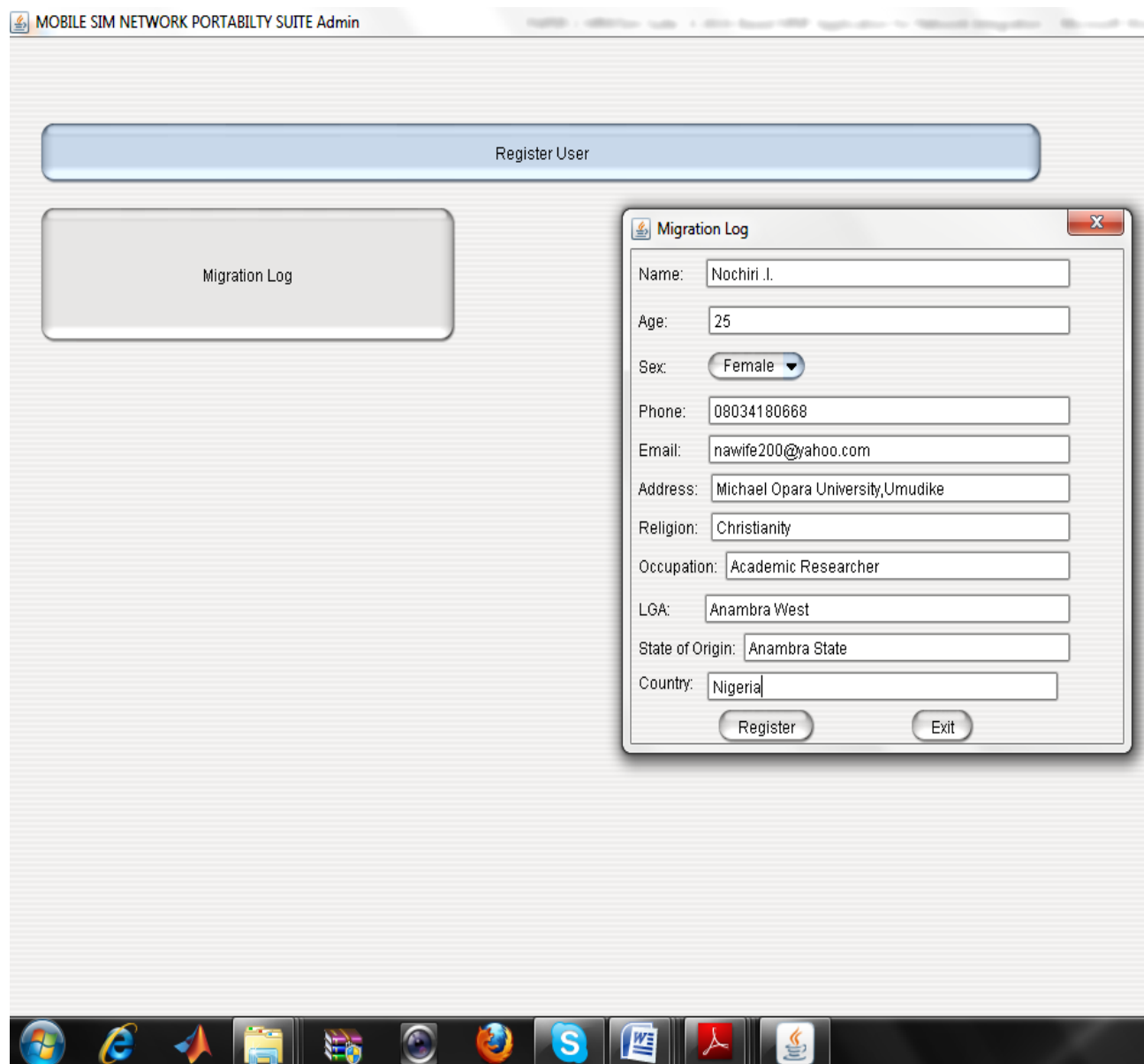


Figure 4.24: A valid user SIMcard Migration log interface

Firefox | localhost / localhost / networkmigration... | localhost/phpmyadmin/index.php?db=networkmigration&token=714ae2f15df1e9c2d3bfa40a0714685a

phpMyAdmin

Database: networkmigration (2)

networkmigration (2)

migrationdetails
simreg

Sort by key: None

+ Options

	sn	name	age	sex	phone	email	address	religion	occupation	lga	state	country
☐	1	f	fds	Female	fdsf	sf	dfdf	ff	dsfdfsdf	dsfdfsdf	fdsf	fdsfd
☐	2	f	fds	Female	fdsf	sf	dfdf	ff	dsfdfsdf	dsfdfsdf	fdsf	fdsfd
☐	3	Dr. Kennedy C.O	30	Male	08034180668	arissyncline@yahoo.com	26Emmannemeka Street	Christianity	Engineering Consults-R&D	Ihitte Uboma	IMO	Nigeria
☐	4	Dr. Kennedy C.O	30	Male	08034180668	arissyncline@yahoo.com	26Emmannemeka Street	Christianity	Engineering Consults-R&D	Ihitte Uboma	IMO	Nigeria
☐	5	Dr. Kennedy C.O	30	Male	08034180668	arissyncline@yahoo.com	26Emmannemeka Street	Christianity	Engineering Consults-R&D	Ihitte Uboma	IMO	Nigeria
☐	6	Dr. Kennedy C.O	30	Male	08034180668	arissyncline@yahoo.com	26Emmannemeka Street	Christianity	Engineering Consults-R&D	Ihitte Uboma	IMO	Nigeria
☐	7	Dr. Kennedy C.O	30	Male	08034180668	arissyncline@yahoo.com	26Emmannemeka Street	Christianity	Engineering Consults-R&D	Ihitte Uboma	IMO	Nigeria
☐	8	Dr. Kennedy C.O	30	Male	08034180668	arissyncline@yahoo.com	26Emmannemeka Street	Christianity	Engineering Consults-R&D	Ihitte Uboma	IMO	Nigeria
☐	9	Dr. Kennedy C.O	30	Male	08034180668	arissyncline@yahoo.com	26Emmannemeka Street	Christianity	Engineering Consults-R&D	Ihitte Uboma	IMO	Nigeria
☐	10	Dr. Kennedy C.O	30	Male	08034180668	arissyncline@yahoo.com	26Emmannemeka Street	Christianity	Engineering Consults-R&D	Ihitte Uboma	IMO	Nigeria
☐	11	Dr. Kennedy C.O	30	Male	08034180668	arissyncline@yahoo.com	26Emmannemeka Street	Christianity	Engineering Consults-R&D	Ihitte Uboma	IMO	Nigeria
☐	12	Dr. Kennedy C.O	30	Male	08034180668	arissyncline@yahoo.com	26Emmannemeka Street	Christianity	Engineering Consults-R&D	Ihitte Uboma	IMO	Nigeria
☐	13	Dr. Kennedy C.O	30	Male	08034180668	arissyncline@yahoo.com	26Emmannemeka Street	Christianity	Engineering Consults-R&D	Ihitte Uboma	IMO	Nigeria
☐	14	Dr. Kennedy C.O	30	Male	08034180668	arissyncline@yahoo.com	26Emmannemeka Street	Christianity	Engineering Consults-R&D	Ihitte Uboma	IMO	Nigeria
☐	15	Dr. Kennedy C.O	30	Male	08034180668	arissyncline@yahoo.com	26Emmannemeka Street	Christianity	Engineering Consults-R&D	Ihitte Uboma	IMO	Nigeria
☐	16	Dr. Kennedy C.O	30	Male	08034180668	arissyncline@yahoo.com	26Emmannemeka Street	Christianity	Engineering Consults-R&D	Ihitte Uboma	IMO	Nigeria
☐	17	Dr. Kennedy C.O	30	Male	08034180668	arissyncline@yahoo.com	26Emmannemeka Street	Christianity	Engineering Consults-R&D	Ihitte Uboma	IMO	Nigeria
☐	18	Dr. Kennedy C.O	30	Male	08034180668	arissyncline@yahoo.com	26Emmannemeka Street	Christianity	Engineering Consults-R&D	Ihitte Uboma	IMO	Nigeria

6:08 PM 6/5/2014

Figure 4.25: SimCard Registration details in the network integration Server backend

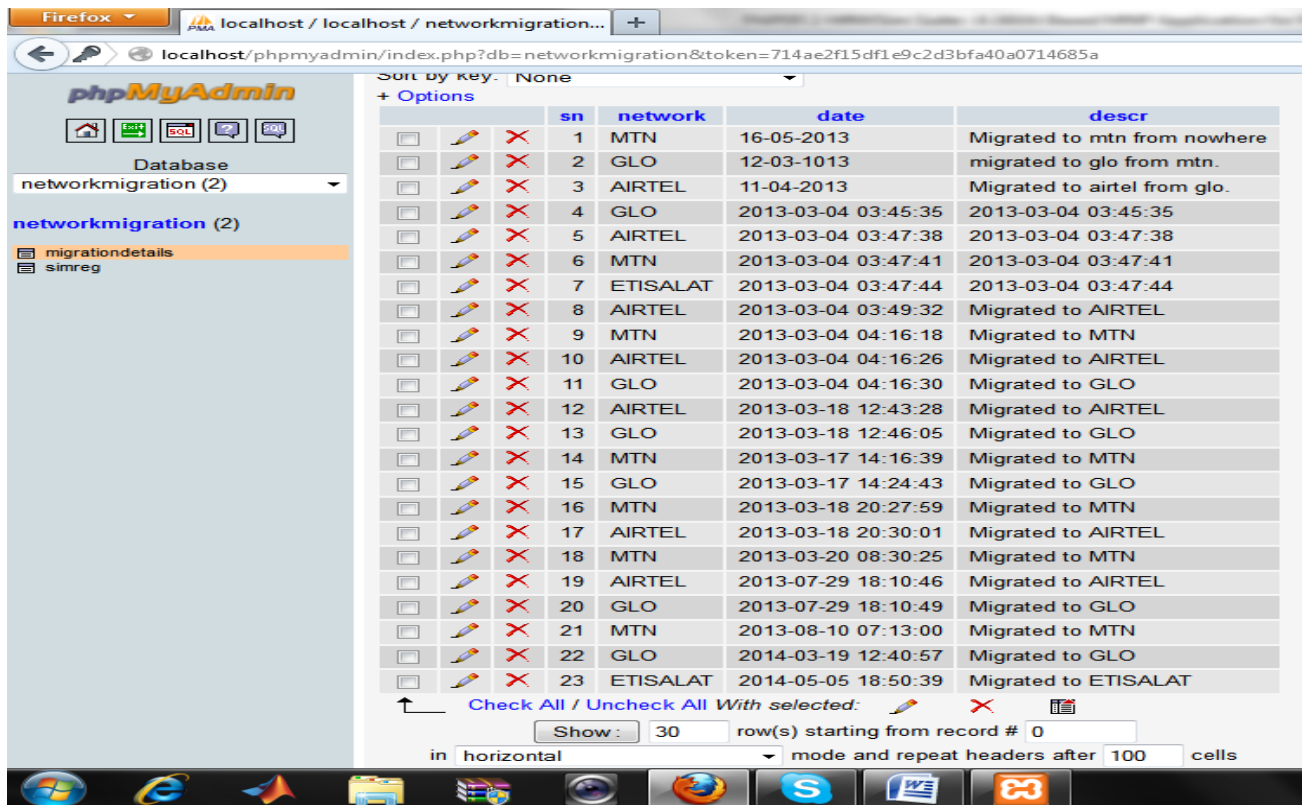


Figure 4.27: A valid user SIMcard Network Migration log interface

Figure 4.26 and figure 4.27 shows the database capture of the network migrations specifying the id, network, time stamp with its descriptions.

Table 4.1: GSM Model Interface Specifications

Simulation Parameters	Specifications
Channel Type	Forward fundamental radio configuration 3
Data rates	4.Kps
Propagation Model	Space Diversity:
Transmit diversity Mode	Non-TD
Channel Profile	Multipath fading

Channel bandwidth	3.5MHz
Receiver Type	Rake Receiver
Number of Simulations	100
Traffic Model	Infinite Buffer

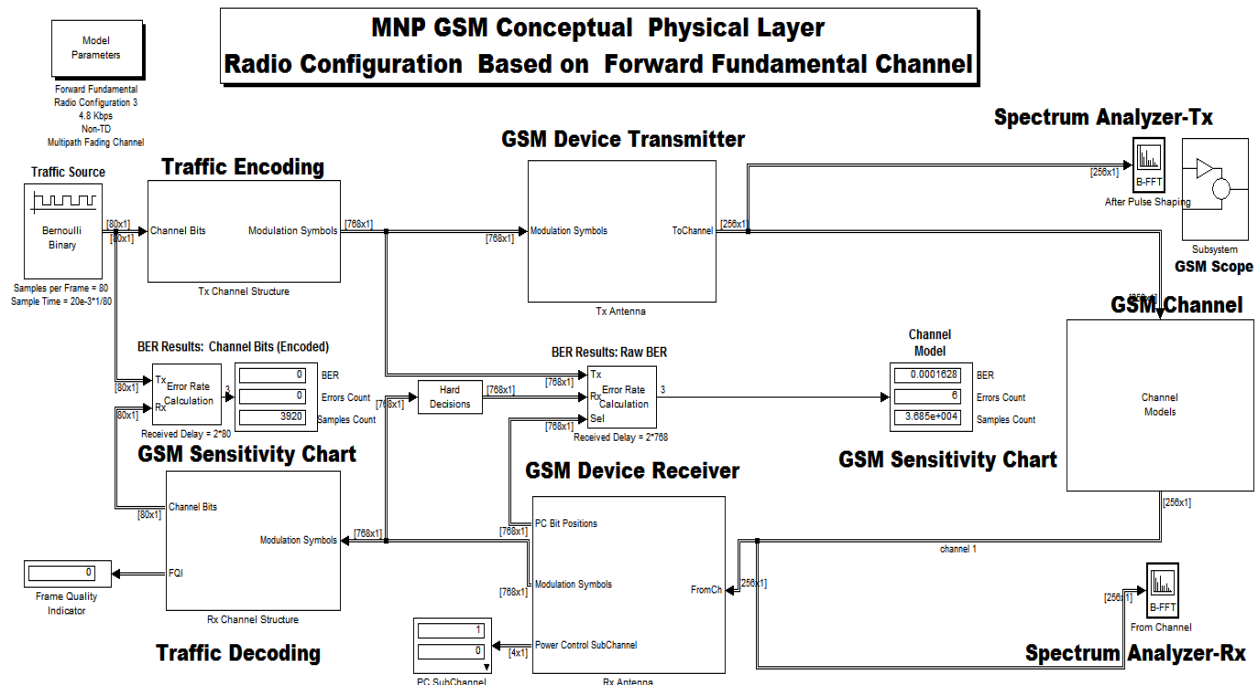


Figure 4.28: MATLAB Implementation for GSM Model

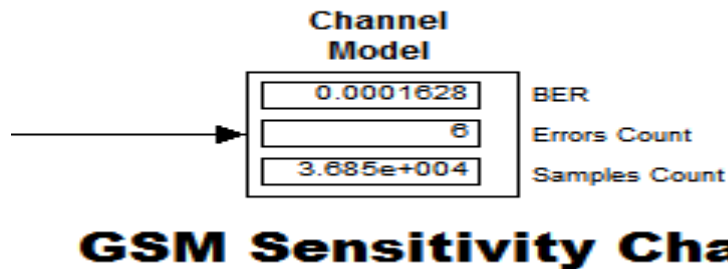


Figure 4.29: GSM BER Sensitivity Response

Figure 4.28 shows the implementation input in the MATLAB environment. The input to the source encoder in context is the voice stream. The output of the source encoder is a stream of bits mapped into the channel encoder. This streams of bits was passed through different blocks shown in figure 4.28. Some output was obtained at the output of the channel decoder block. The input and output was compared in order to check the validity of the results via BER monitor.

The model ends the receiver interface with a BER/Error estimator. The BER is computed by adding the source generated data with the demodulator output.

Finally, the BER, Error counts and sample counts are monitored. For a simulation of 1sec, this work showed a BER of 0.00162 which is very satisfactory for call drop analysis. In realizing a stable but sensitive system, the base BER of 0.00162 which is less than 1 achieves a good reliability. with table 4.1 showing the simulation parameters.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 RESULTS

Figures 5.1 and 5.2 show the behaviour of the three networks, MTN, ETISALAT, GLO and AIRTEL in April, 2012.

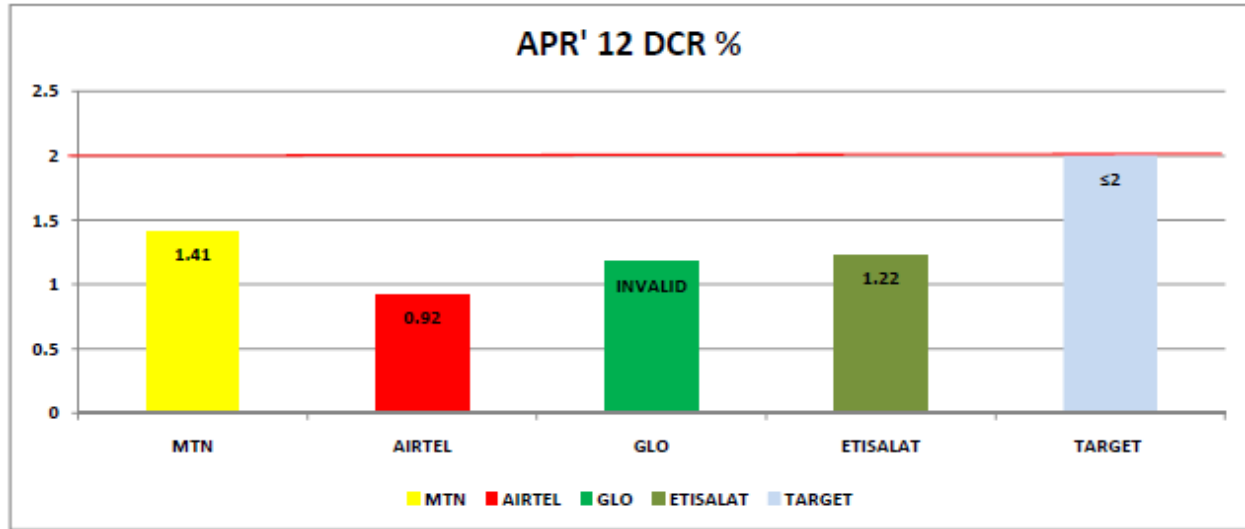


Figure 5.1: A plot of DCR against Network Operator

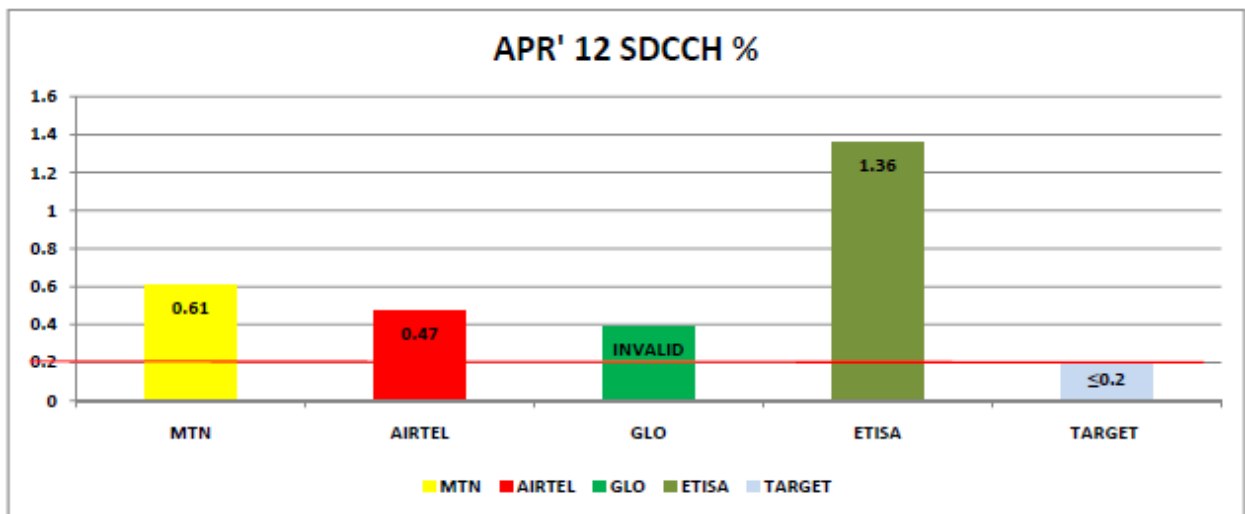


Figure 5.2: A plot of SDCCH KPI against Network Operators, (April,2012)

From figure 5.1 to 5.2, given that the NCC DCR target of 2%, It was observed that MTN, ETISALAT and AIRTEL met and superseded the Commission minimum threshold in the period under review.

Figures 5.3, 5.4, 5.5 and 5.7 show the behaviour of the three networks, MTN, ETISALAT, GLOBACOM and AIRTEL in March, 2013.

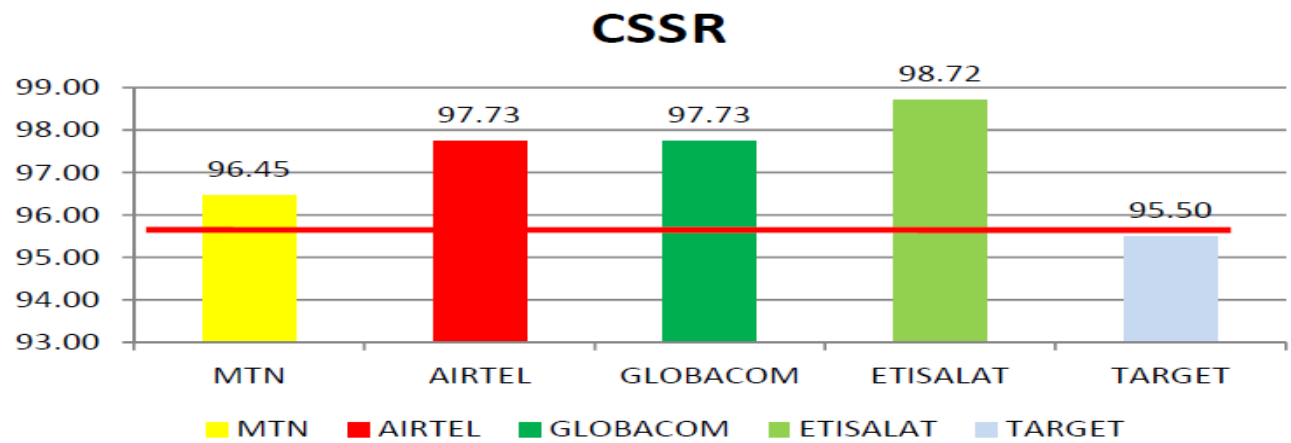


Figure 5.3: A Plot of CSSR KPI against Network Operators, (March, 2013)

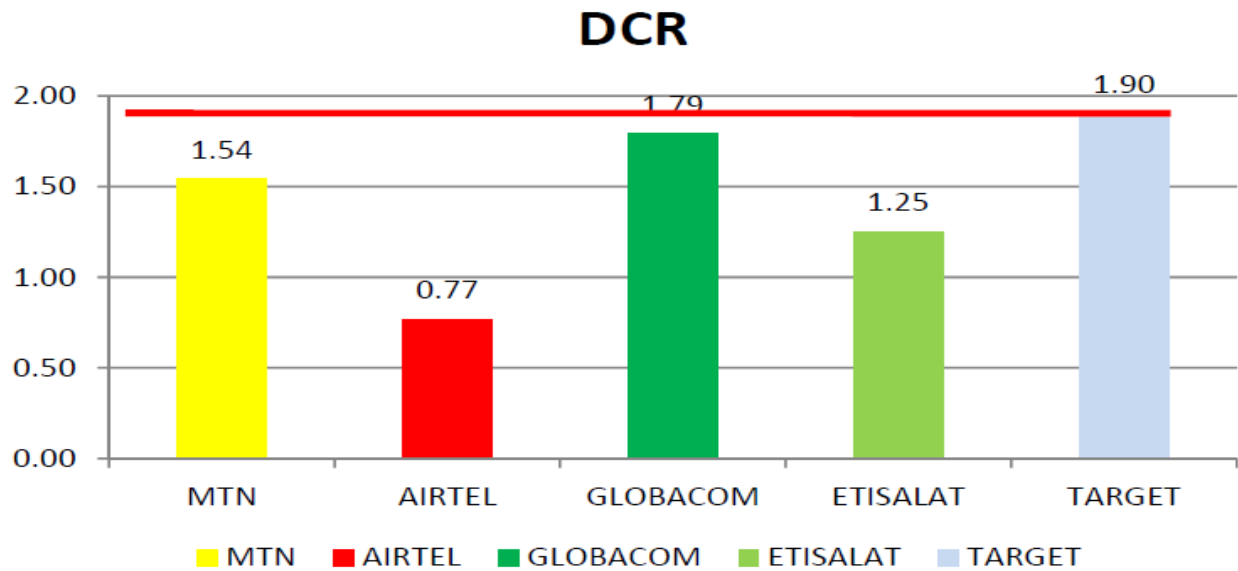


Figure5.4: A Plot of DCR KPI against Network Operators, (March, 2013)

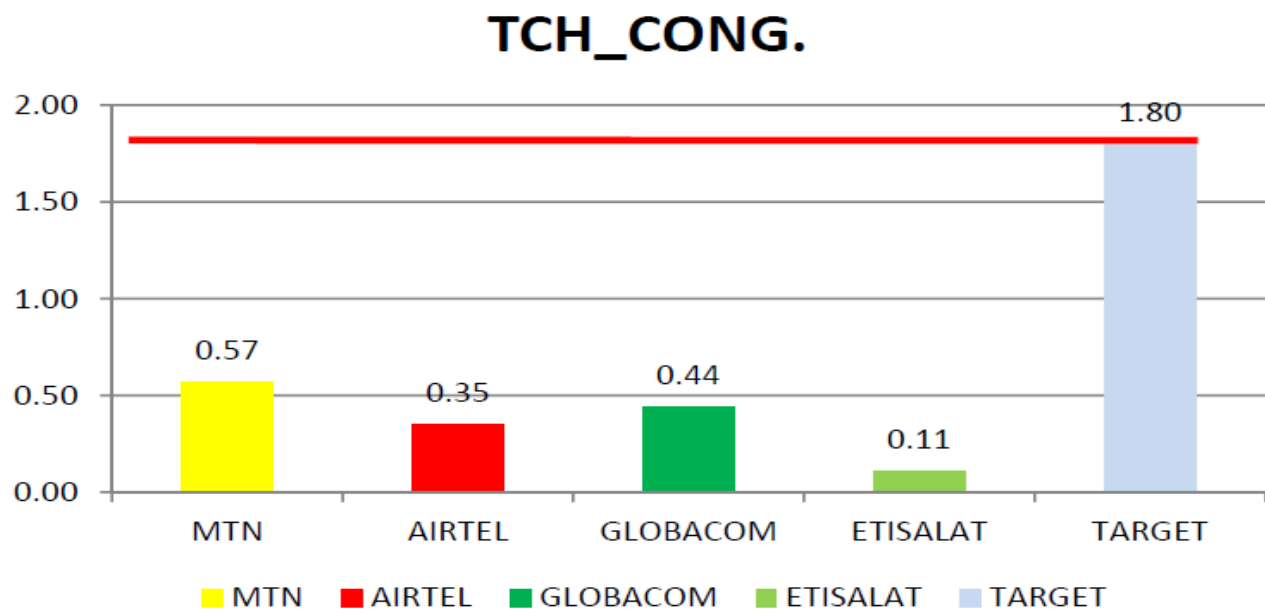


Figure 5.5: A Plot of TCH_CONG KPI against Network Operators, (March, 2013)

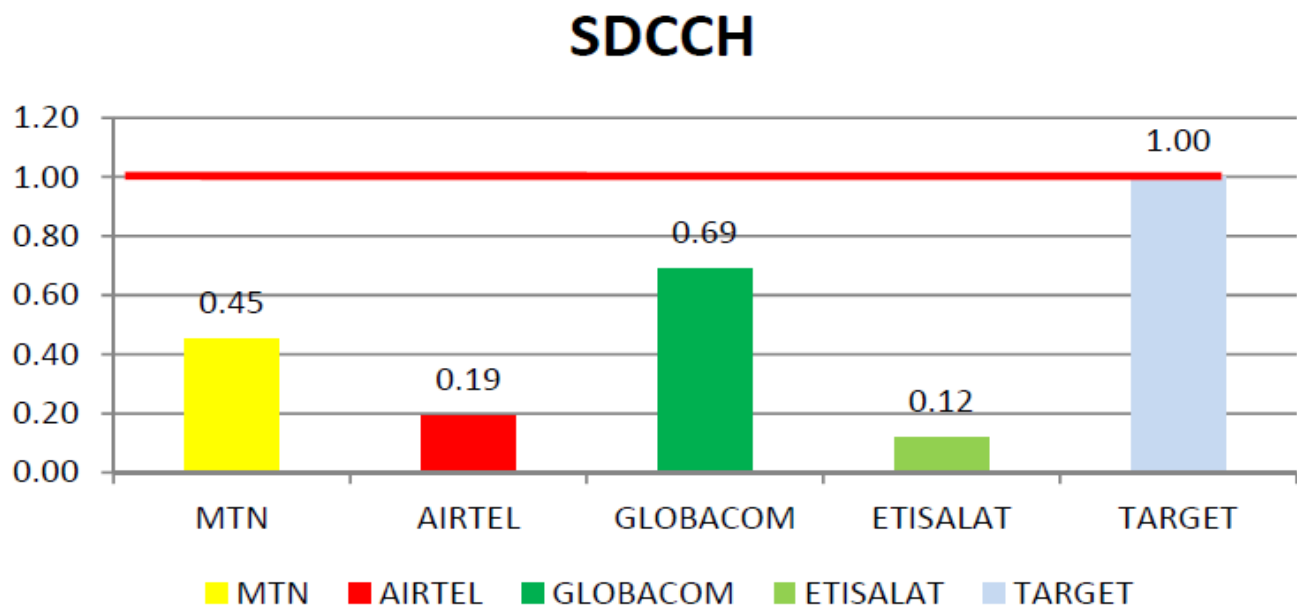


Figure 5.6: A Plot of SDCCH KPI against Network Operators, (March, 2013)

This proves that there was a minimal call drops for Etisalat and Airtel networks as at the period of March, 2013 The Avg TCH_CON showed a fair result for all the operators in March 2013.

Also, AIRTEL offered the best (lowest) call drop rate compared to other networks in March, 2013. This showed a good compliance to NCC requirements.

Figures 5.7, 5.8, 5.9 and 5.10 show the behaviour of the three networks, MTN, ETISALAT, GLOBACOM and AIRTEL in April, 2013.

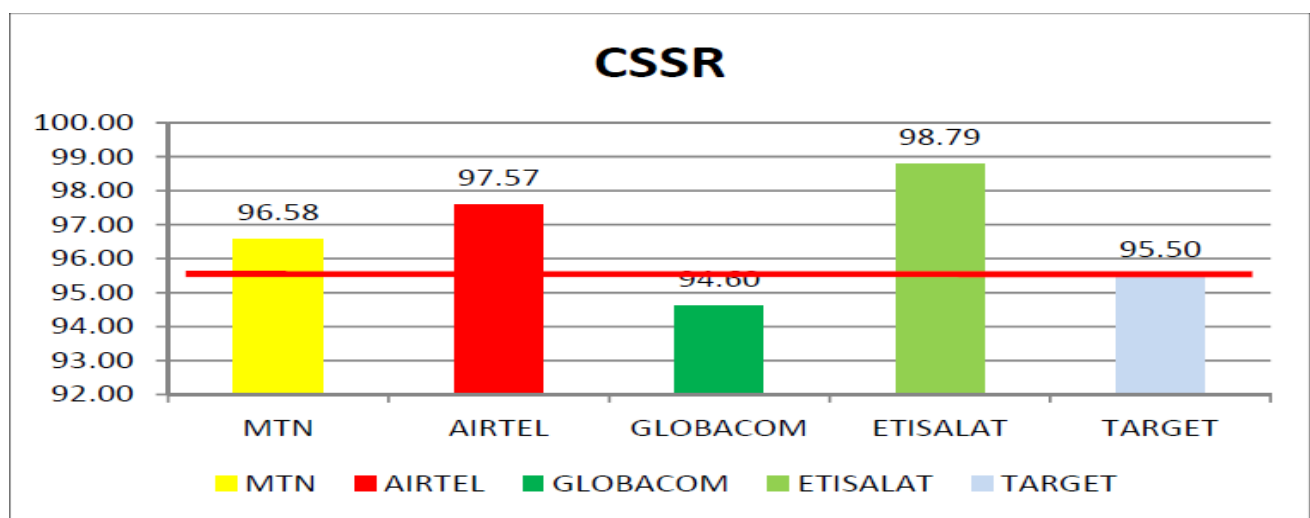


Figure 5.7: A Plot of CSSR KPI against Network Operators, (April, 2013)

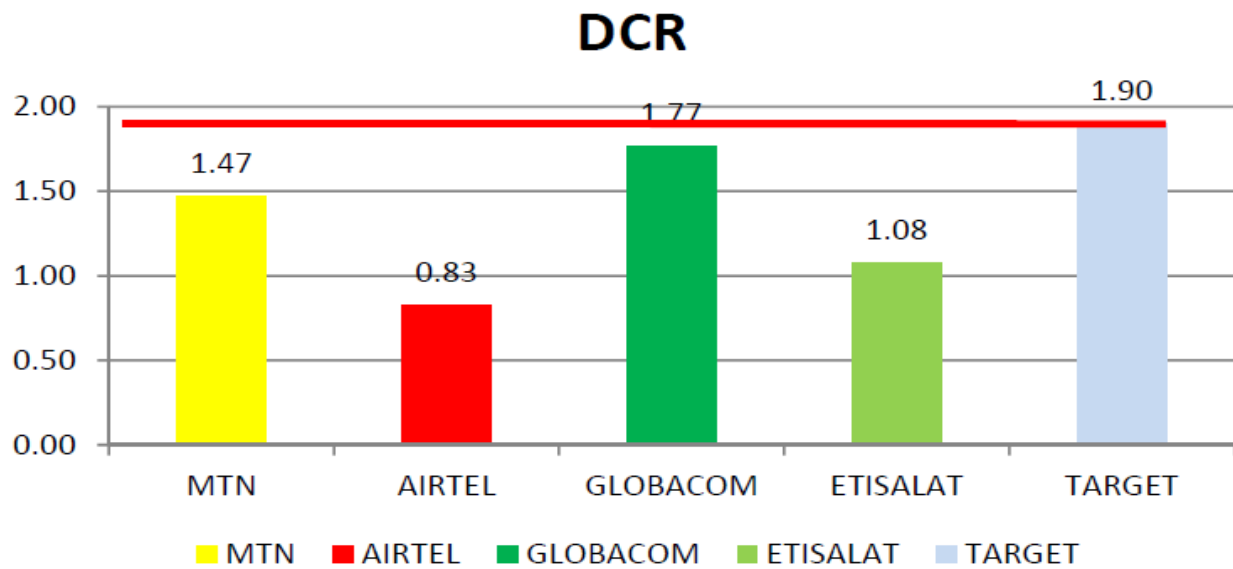


Figure 5.8: A Plot of DCR KPI against Network Operators, (April, 2013)

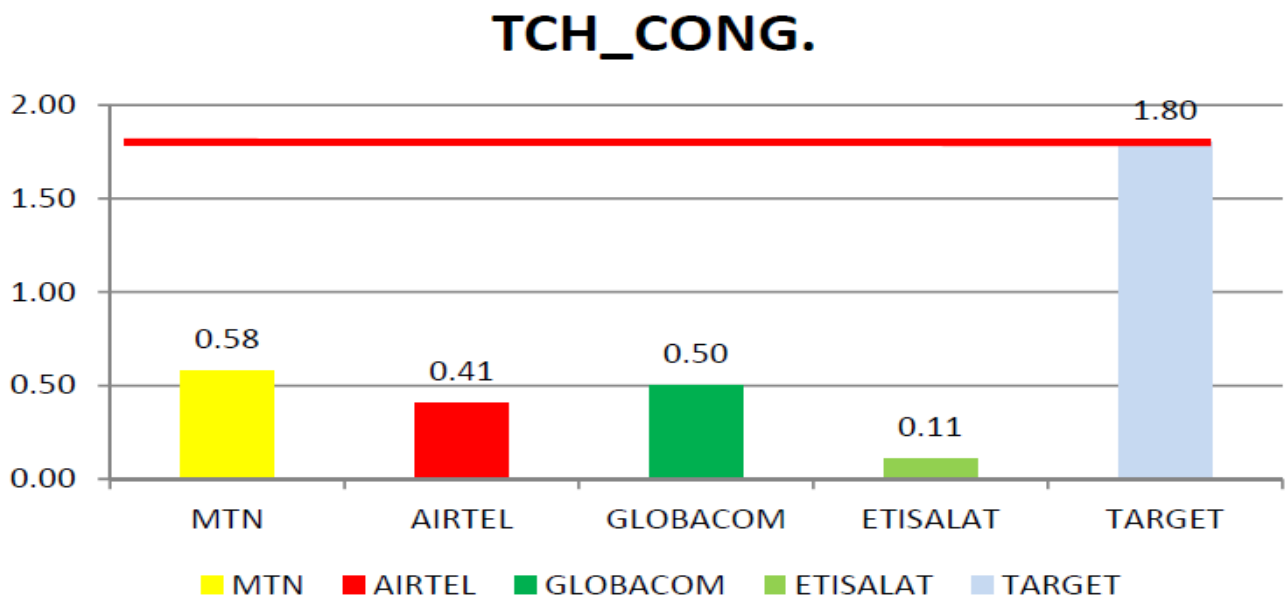


Figure 5.9: A Plot of TCH_CONG KPI against Network Operators, (April, 2013)

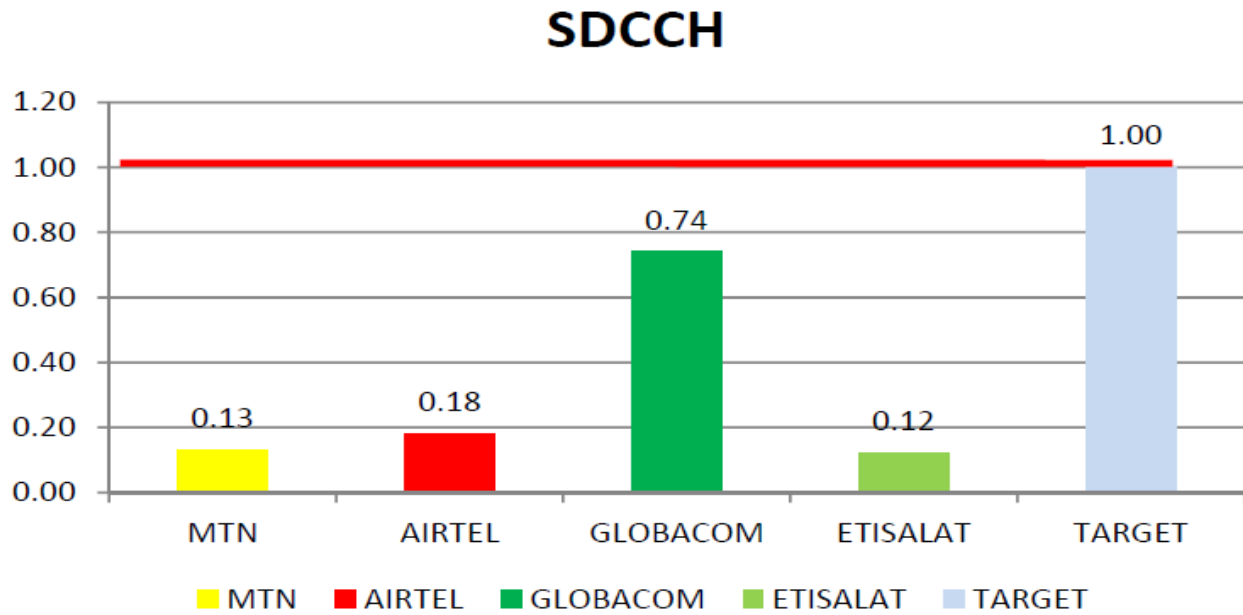


Figure 5.10: A Plot of SDCCH KPI against Network Operators, (April, 2013)

In the month of April the average of the KPI values were evaluated and it was found that the overall performance of GLO was the best on CSSR.

Figures 5.11, 5.12, 5.13 and 5.14 show the behaviour of the three networks, MTN, ETISALAT and AIRTEL in May, 2013.

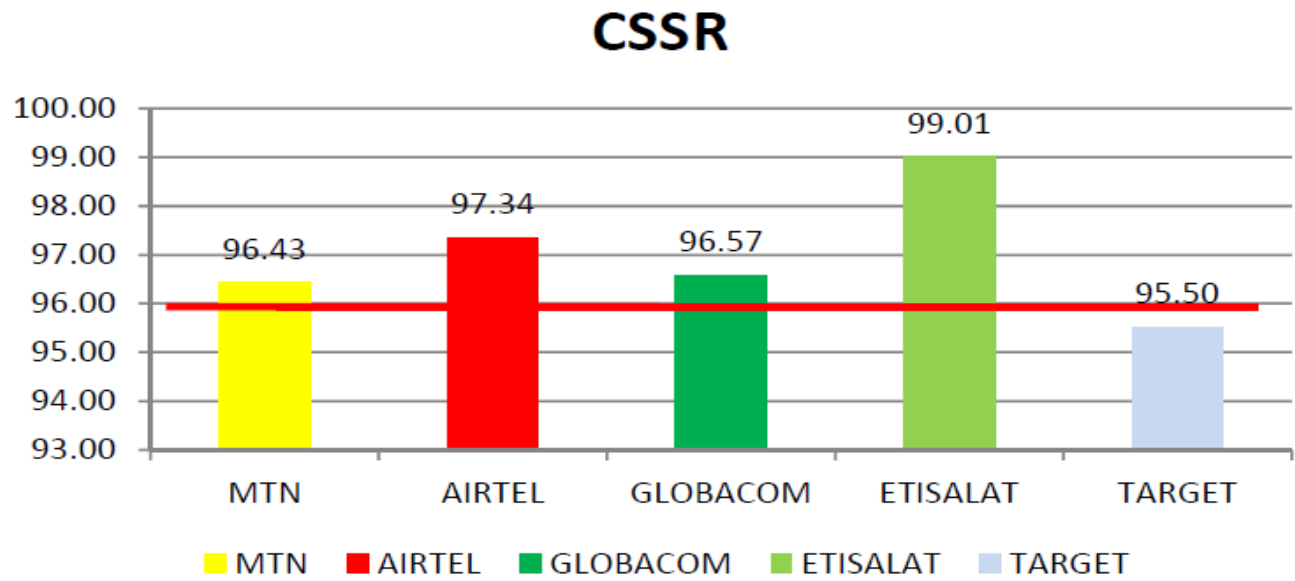


Figure 5.11: A Plot of CSSR KPI against Network Operators, (May,2013)

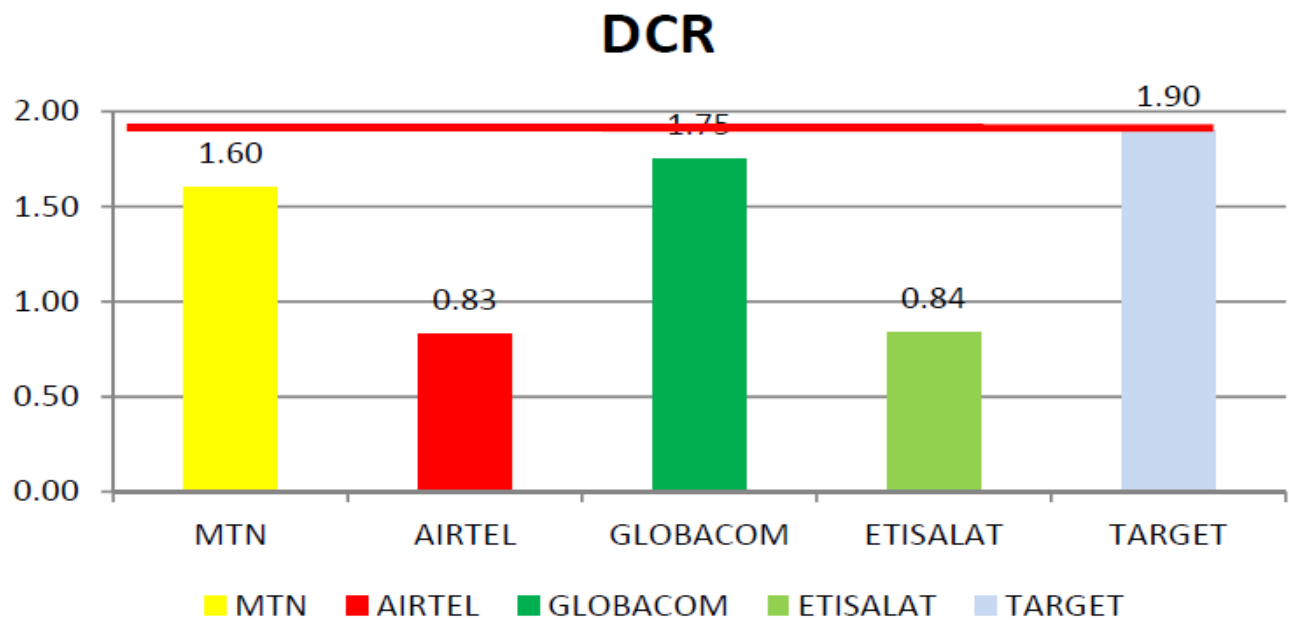


Figure 5.12: A Plot of DCR KPI against Network Operators, (May, 2013)

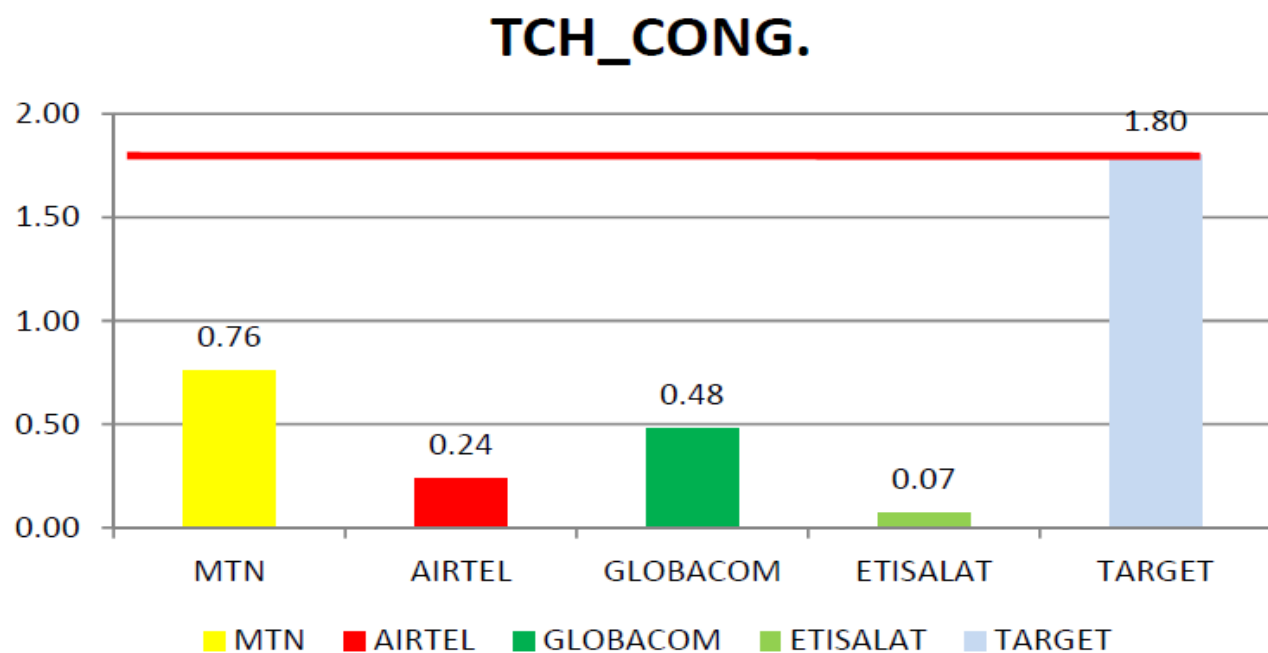


Figure 5.13: A Plot of TCH_CONG KPI against Network Operators, (May, 2013)

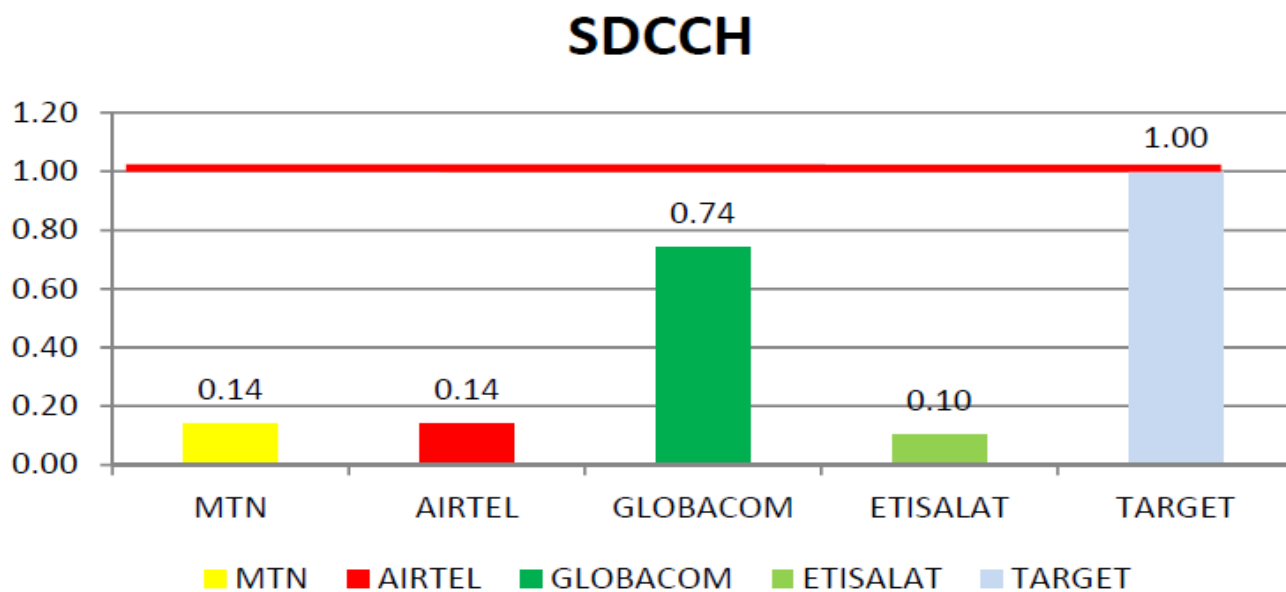


Figure 5.14: A Plot of SDCCH KPI against Network Operators, (May, 2013)

The result gotten from our comparison in May 2013 shows that there was a minimal call drops for Etisalat and Airtel networks as at the period of May, 2013

Figures 5.15, 5.16, 5.17 and 5.18 show the behaviour of the three networks, MTN, ETISALAT and AIRTEL, GLOBACOM in June, 2013.

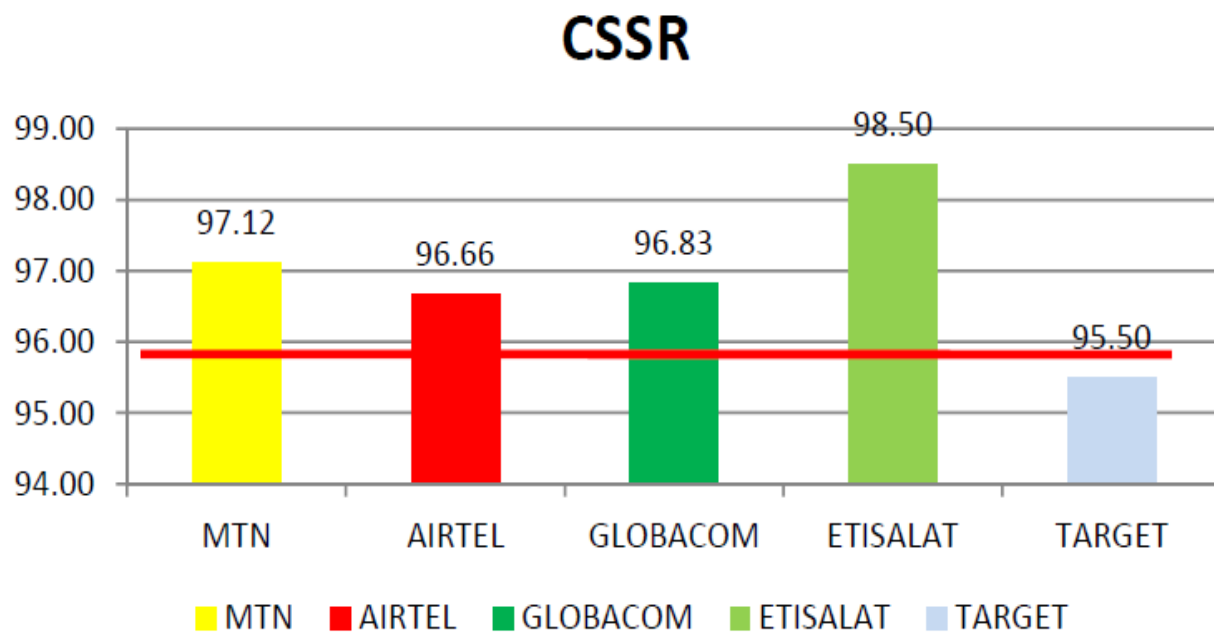


Figure 5.15: A Plot of CSSR KPI against Network Operators, (June,2013)

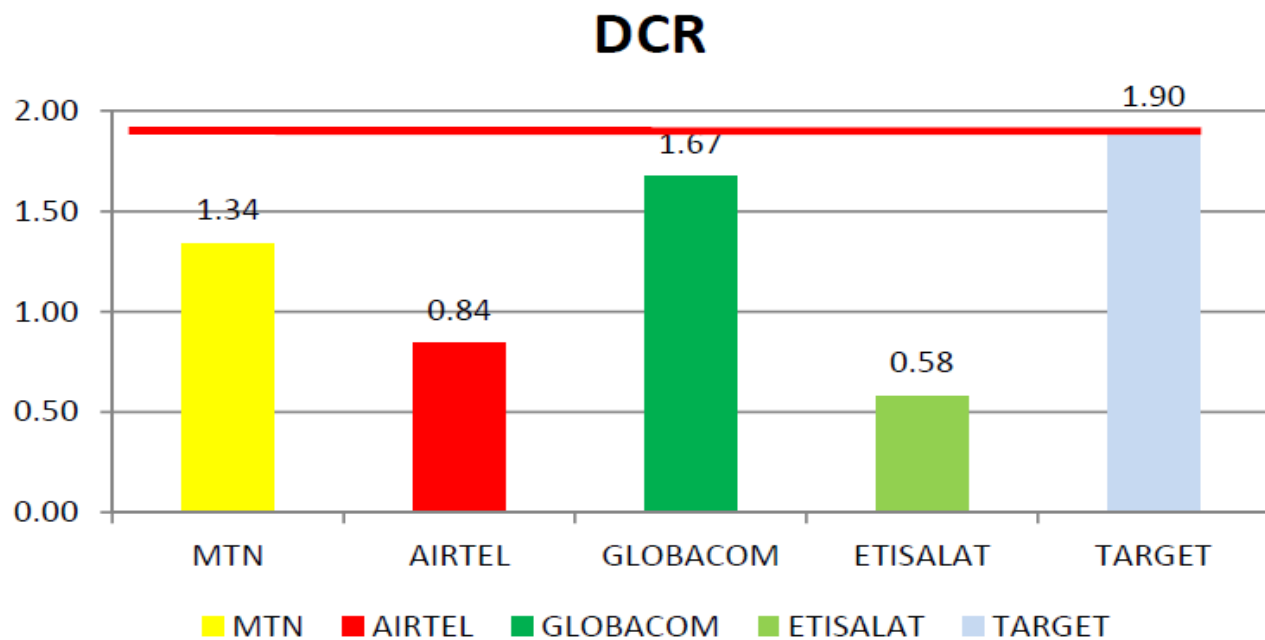


Figure 5.16: A Plot of DCR KPI against Network Operators, (June,2013)

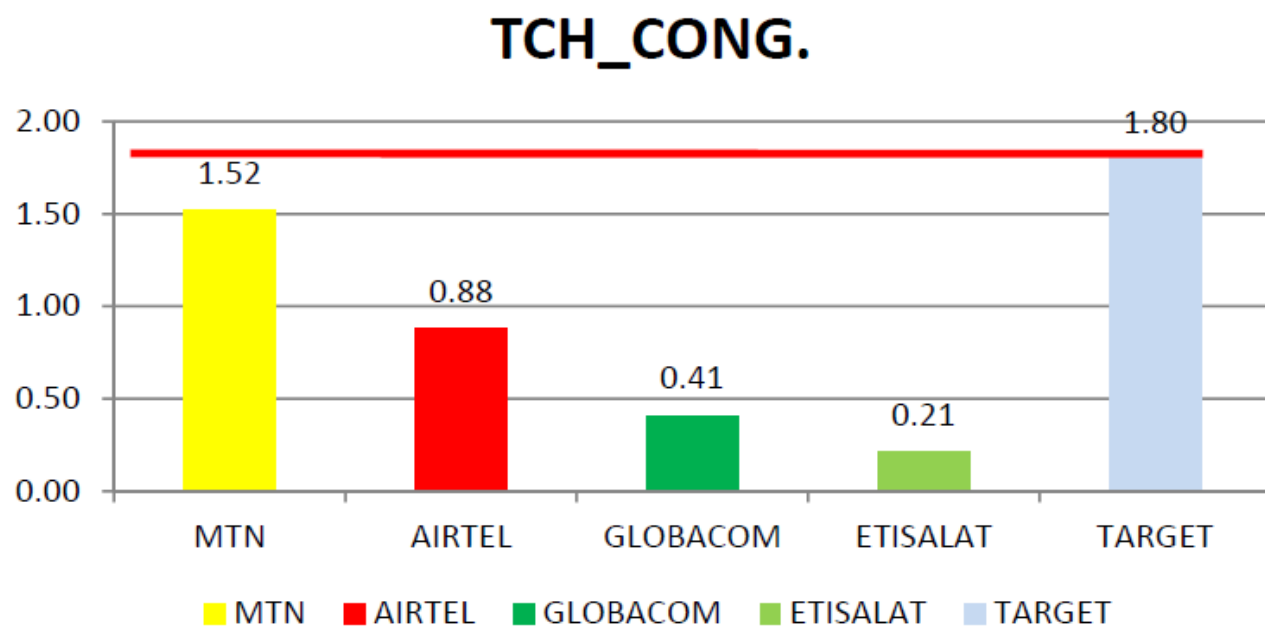


Figure 5.17: A Plot of TCH_CONG KPI against Network Operators, (June,2013)

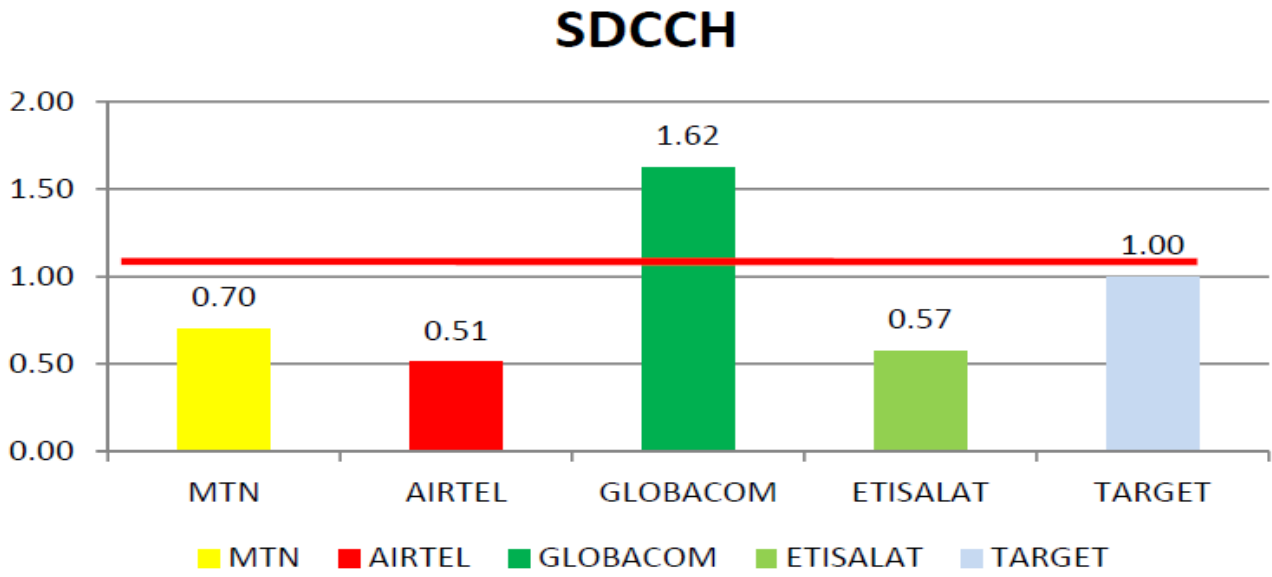


Figure 5.18: A Plot of SDCCH KPI against Network Operators, (June,2013)

In June 2013, it was observed that Airtel offered the best CDR compared with others, while all the networks failed in SDCC. Airtel having the best TCHCON.

Figures 5.10 to 5.38 show the behaviour of the three networks, MTN, ETISALAT, GLOBACOM and AIRTEL in some selected months of 2013 and 2014.

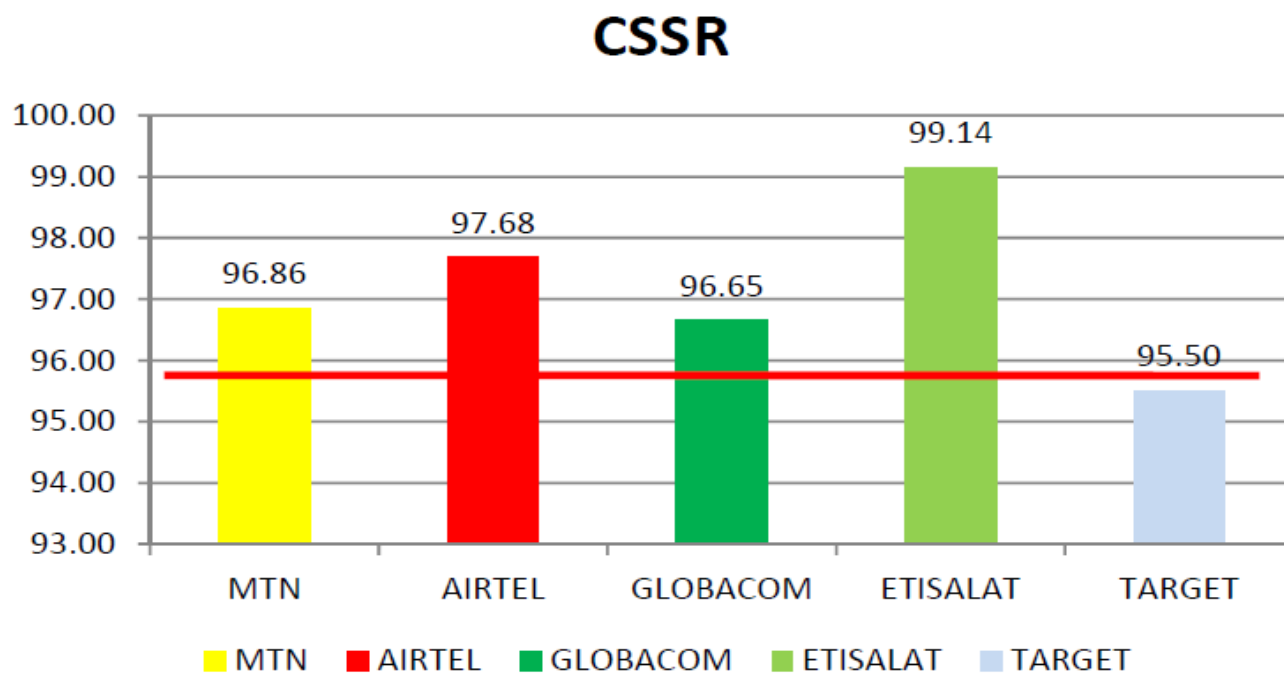


Figure 5.19: A Plot of CSSR KPI against Network Operators, (July, 2013)

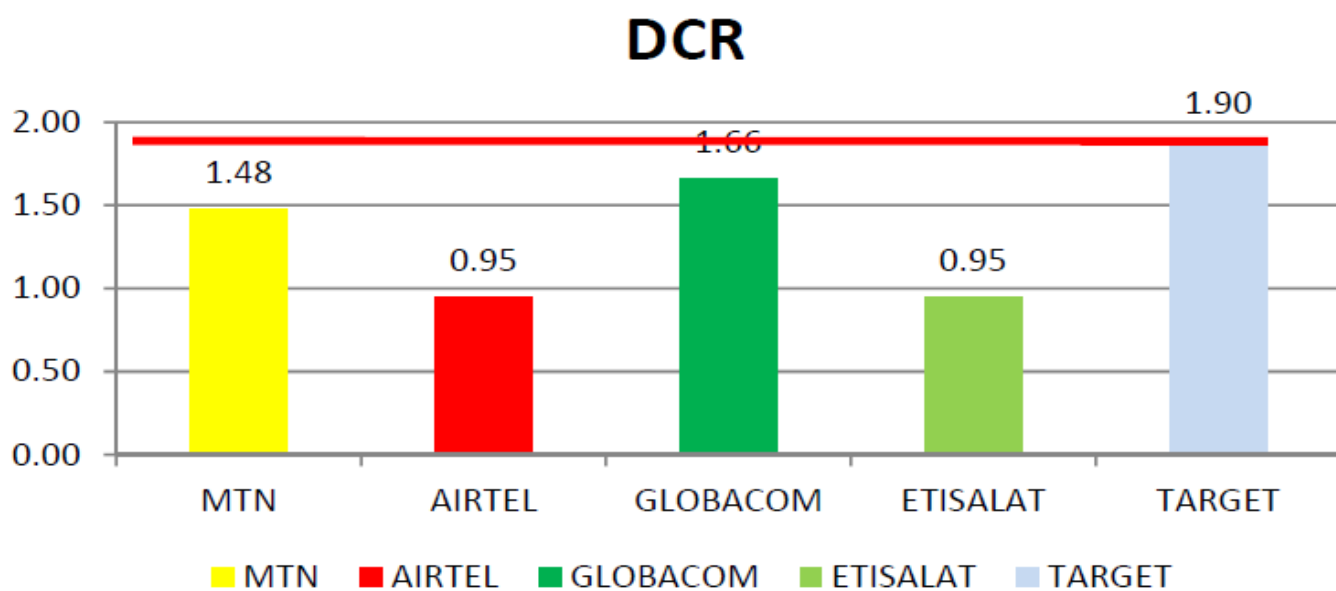


Figure 5.20: A Plot of DCR KPI against Network Operators, (July, 2013)

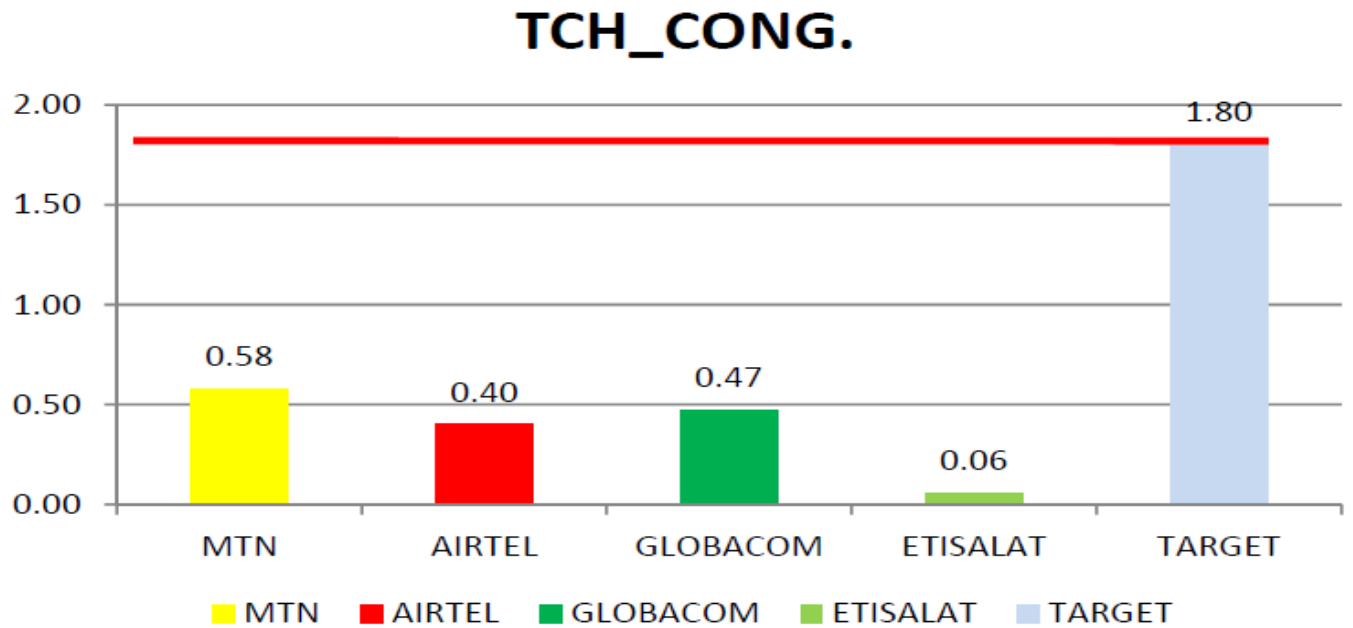


Figure 5.21: A Plot of TCH_CONG KPI against Network Operators, (July, 2013)

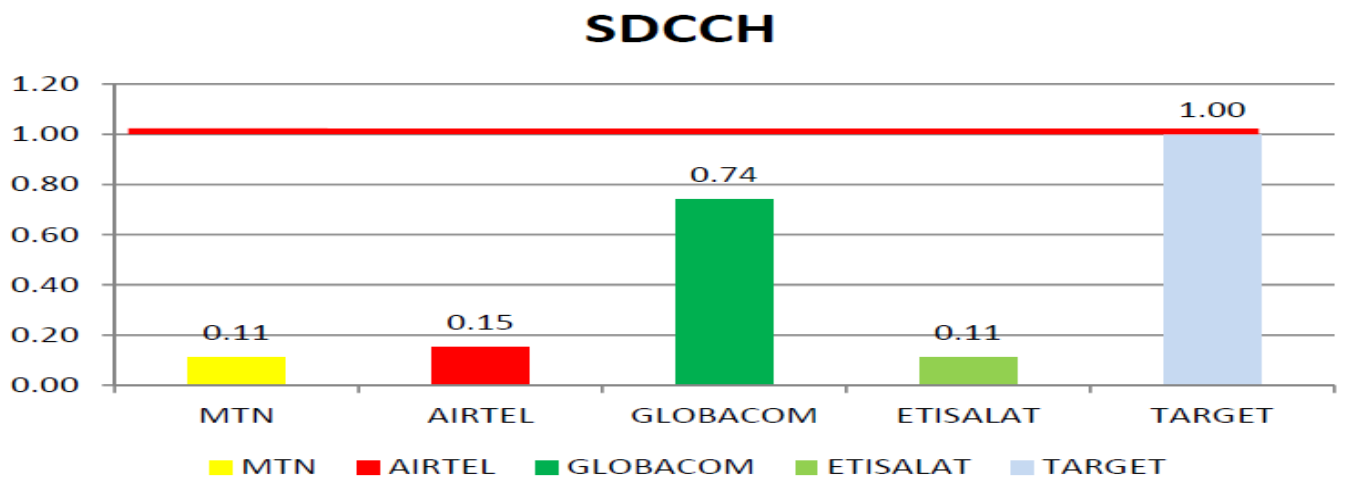


Figure 5.22: A Plot of SDCCH KPI against Network Operators, (July, 2013)

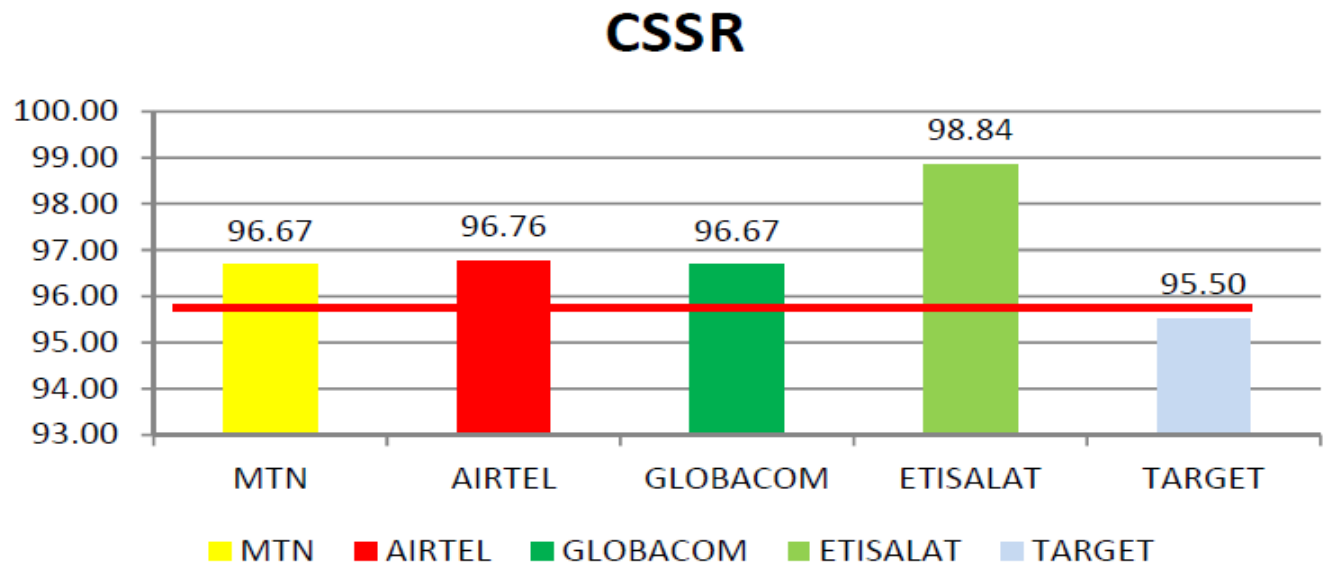


Figure 5.23: A Plot of CSSR KPI against Network Operators, (August, 2013)

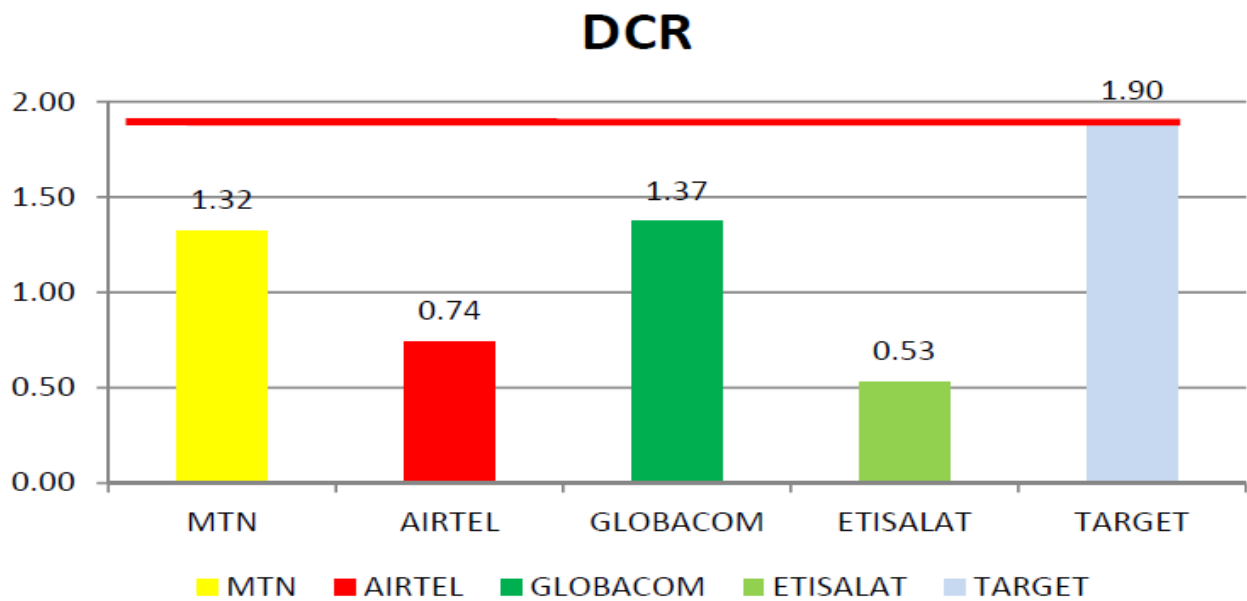


Figure 5.24: A Plot of DCR KPI against Network Operators, (August, 2013)

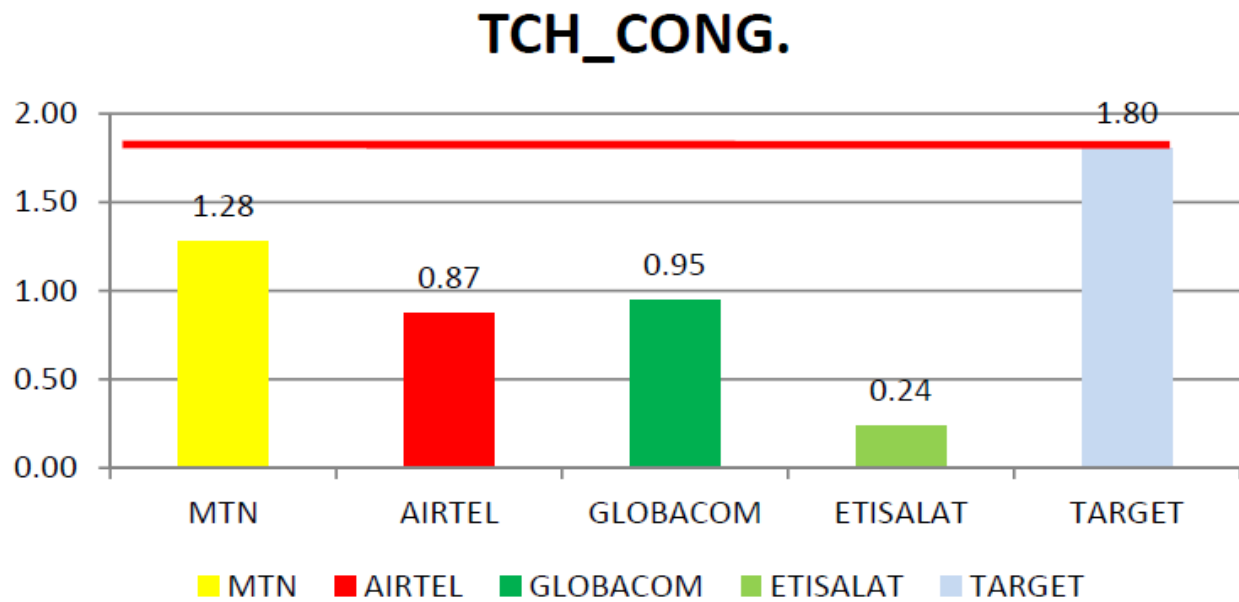


Figure 5.25: A Plot of TCH_CONG KPI against Network Operators, (August, 2013)

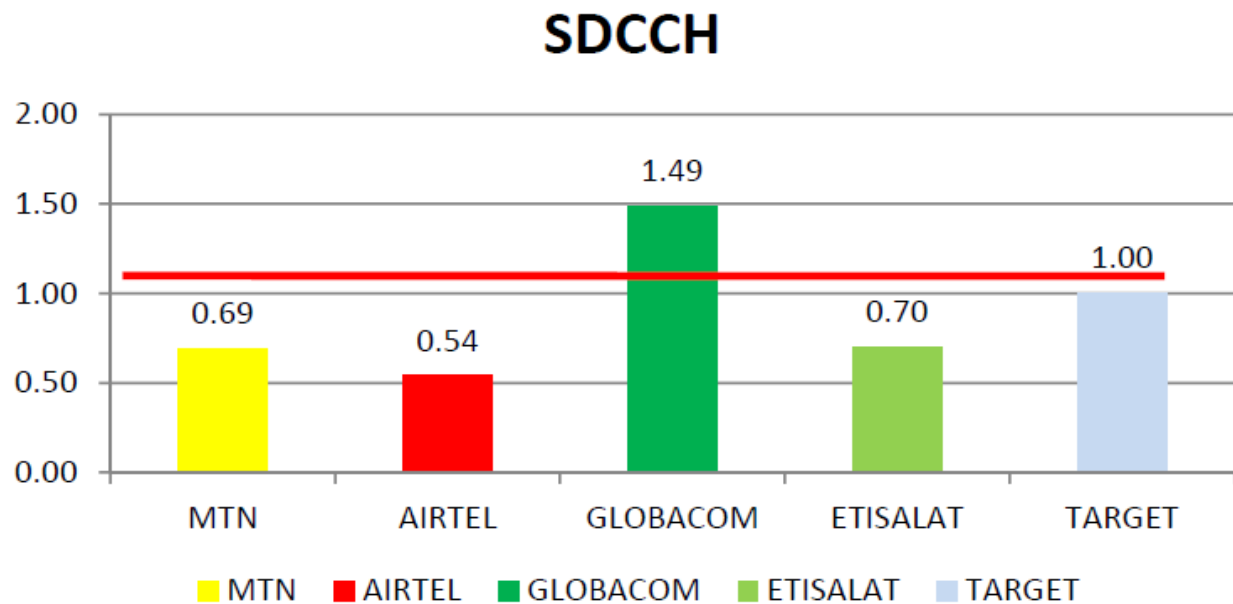


Figure 5.26: A Plot of SDCCH KPI against Network Operators, (August, 2013)

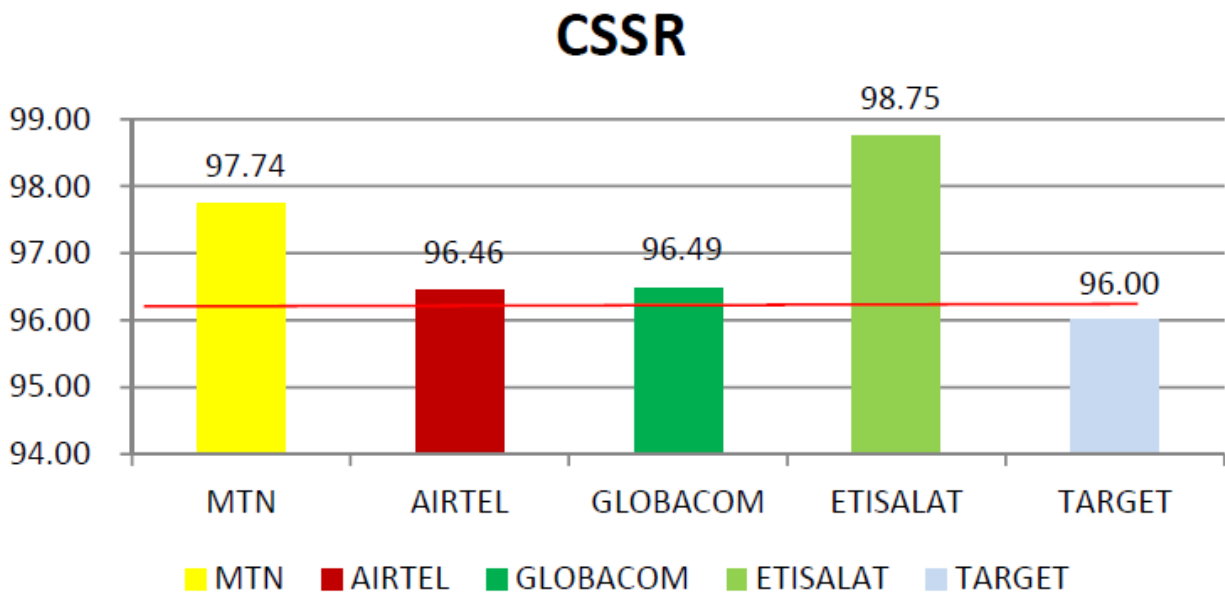


Figure 5.27: A Plot of CSSR KPI against Network Operator, (September, 2013)

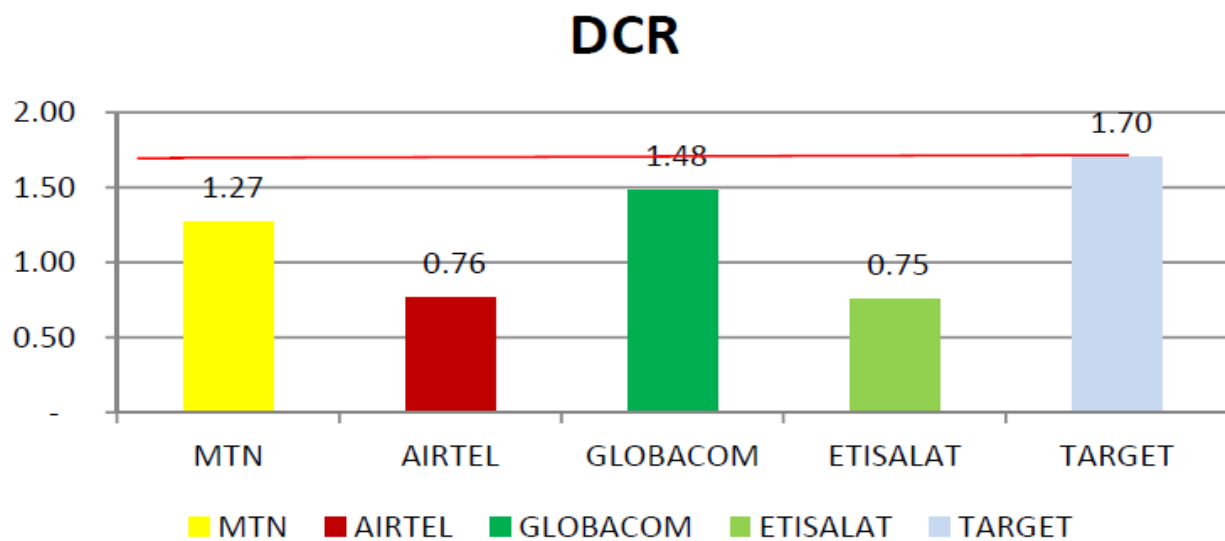


Figure 5.28: A Plot of DCR KPI against Network Operator, (September, 2013)

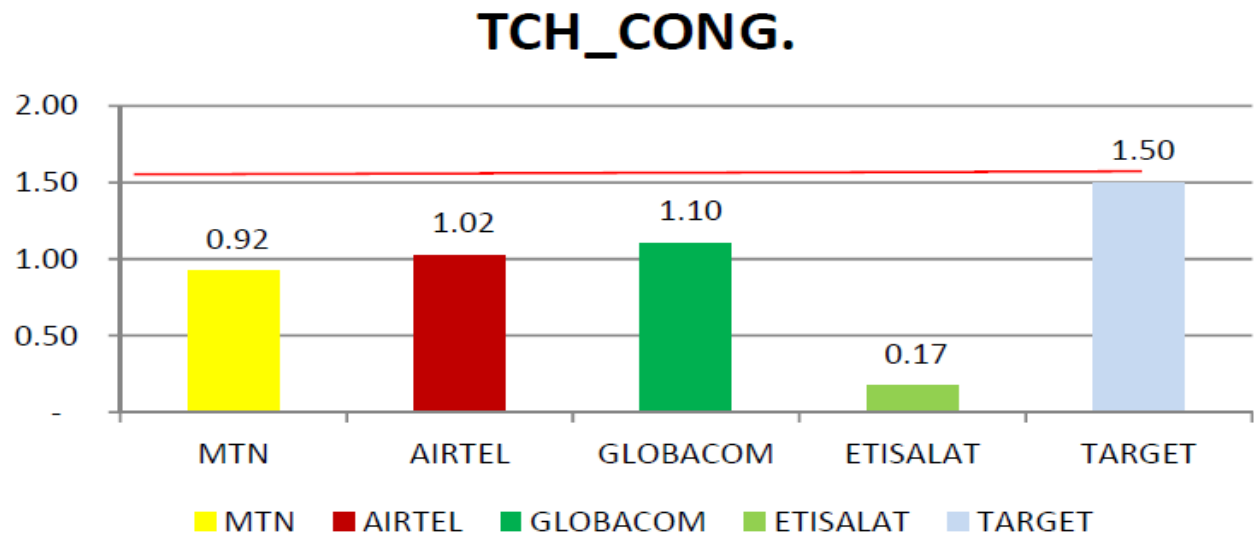


Figure 5.29: A Plot of TCH_CONG KPI against Network Operator, (September, 2013)

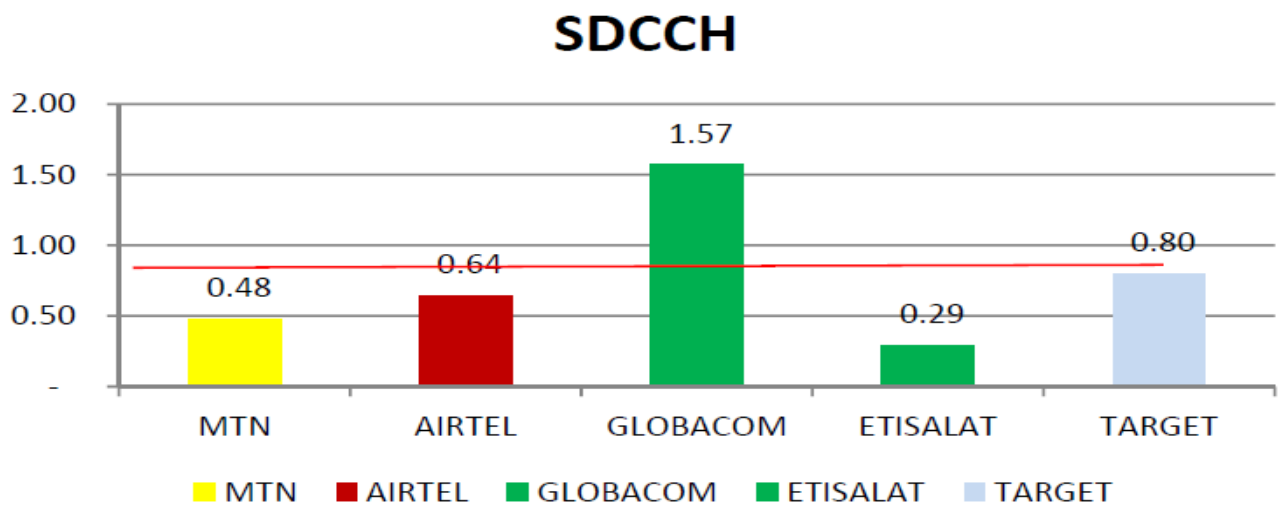


Figure 5.30: A Plot of SDCCH KPI against Network Operator, (September, 2013)

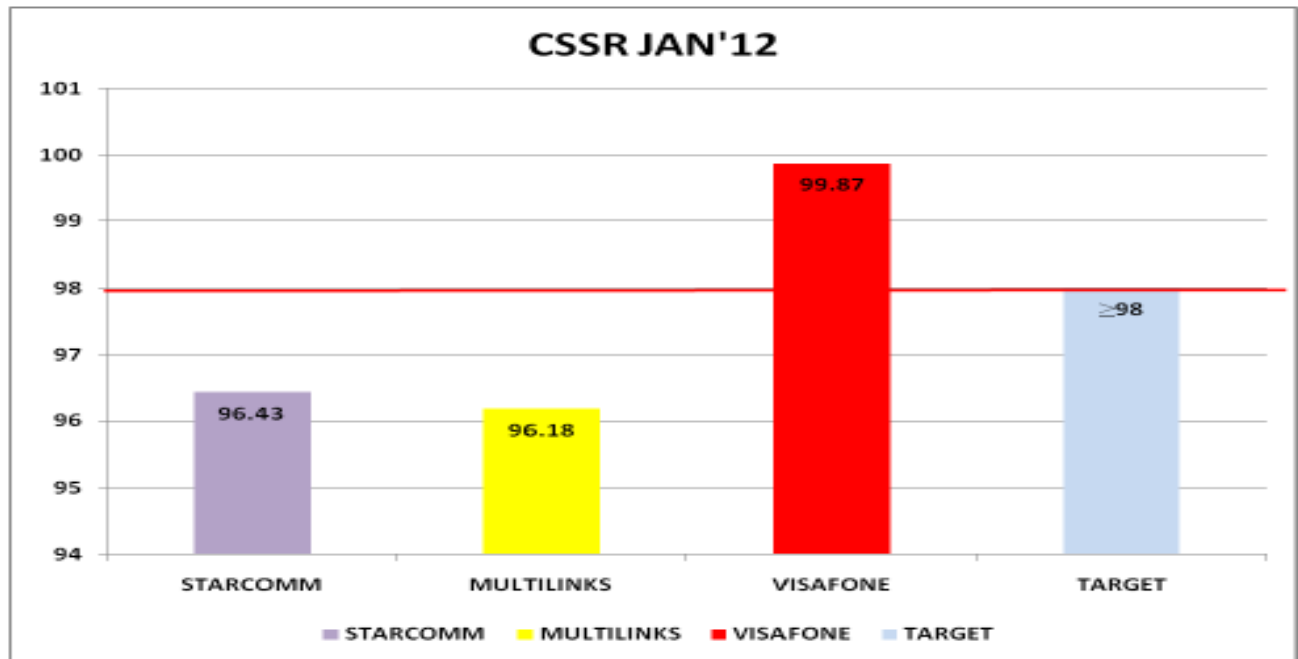


Figure 5.31: A Plot of CSSR KPI against Network Operator, (Jan, 2012)

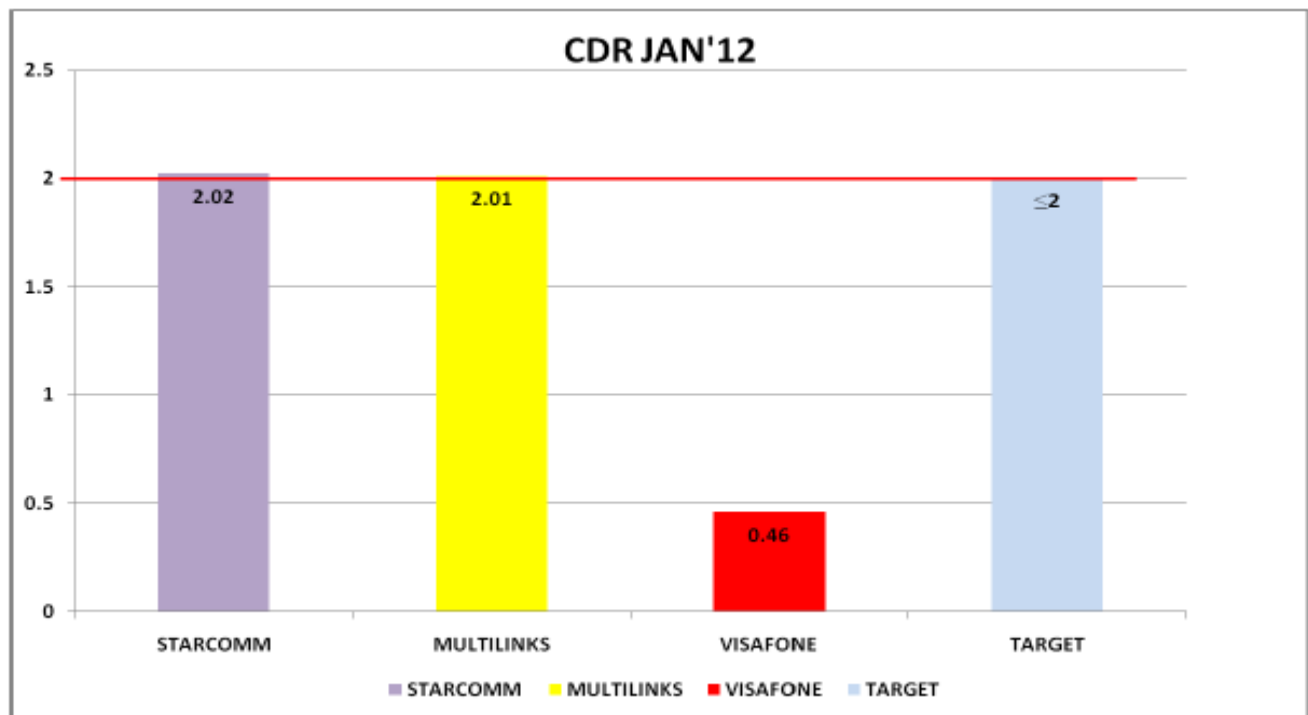


Figure 5.32: A Plot of CDR KPI against Network Operator, (Jan, 2012)

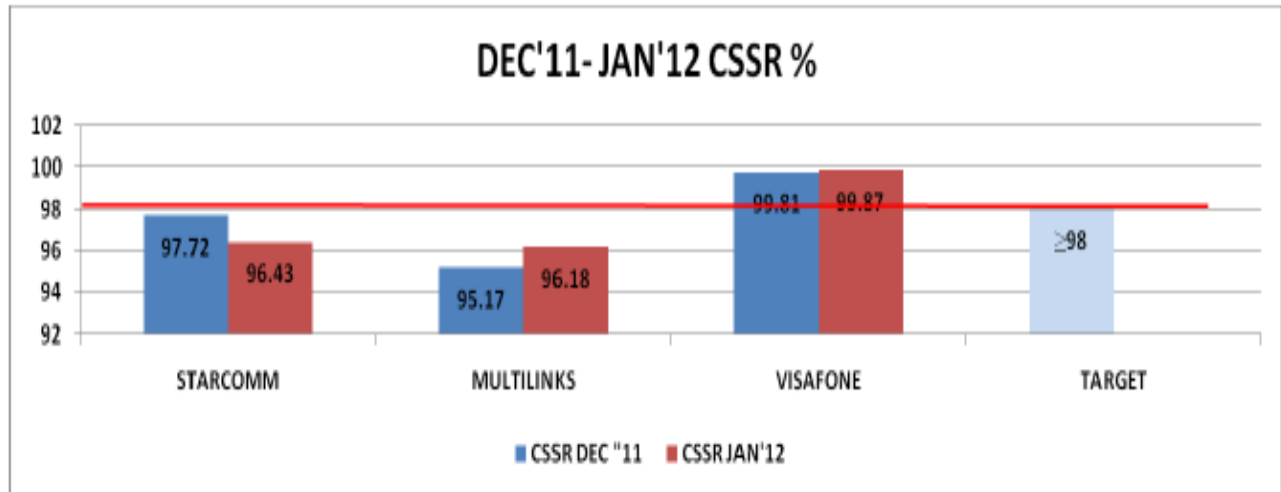


Figure 5.33: A Plot of CSSR KPI against Network Operator, (Dec 2011-Jan, 2012)

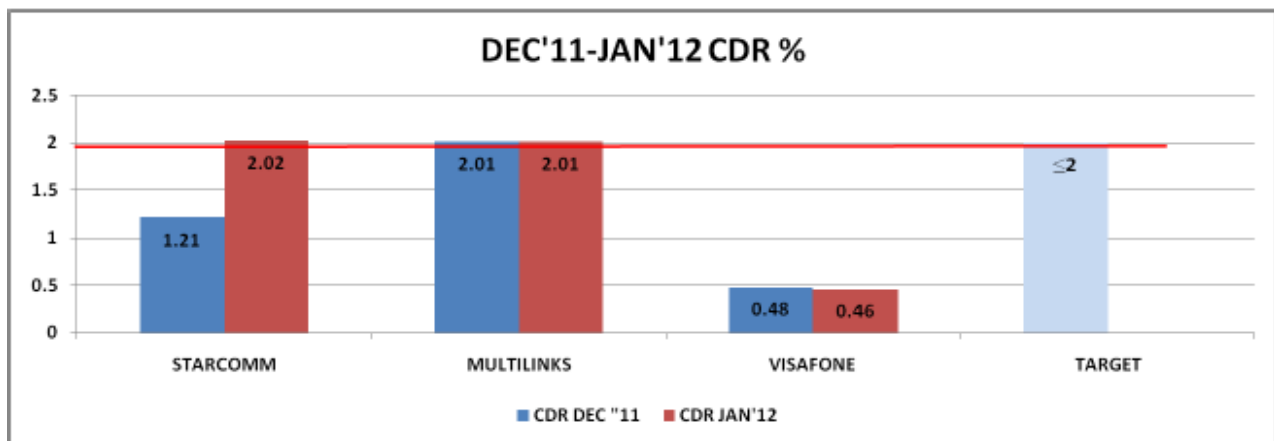


Figure 5.34: A Plot of CDR KPI against Network Operator, (Dec 2011-Jan, 2012)

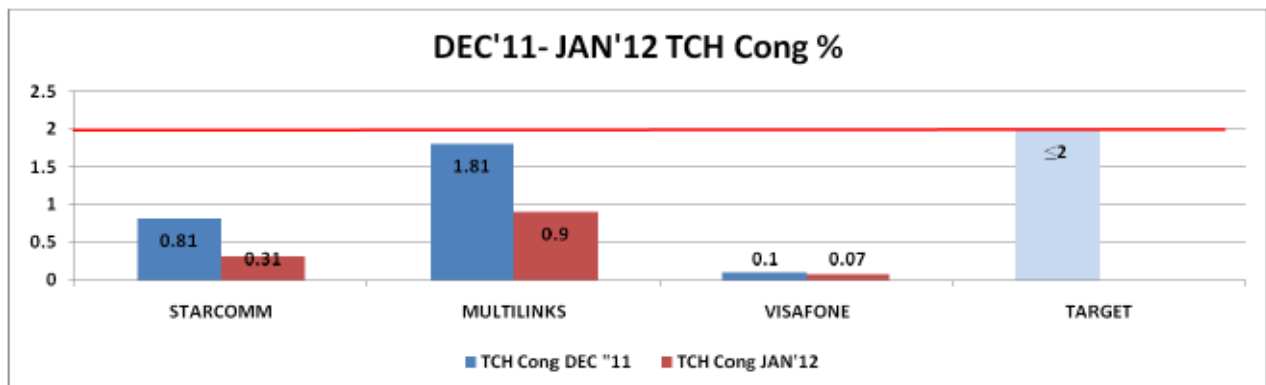


Figure 5.35: A Plot of TCH_Cong KPI against Network Operator, (Dec 2011-Jan, 2012)

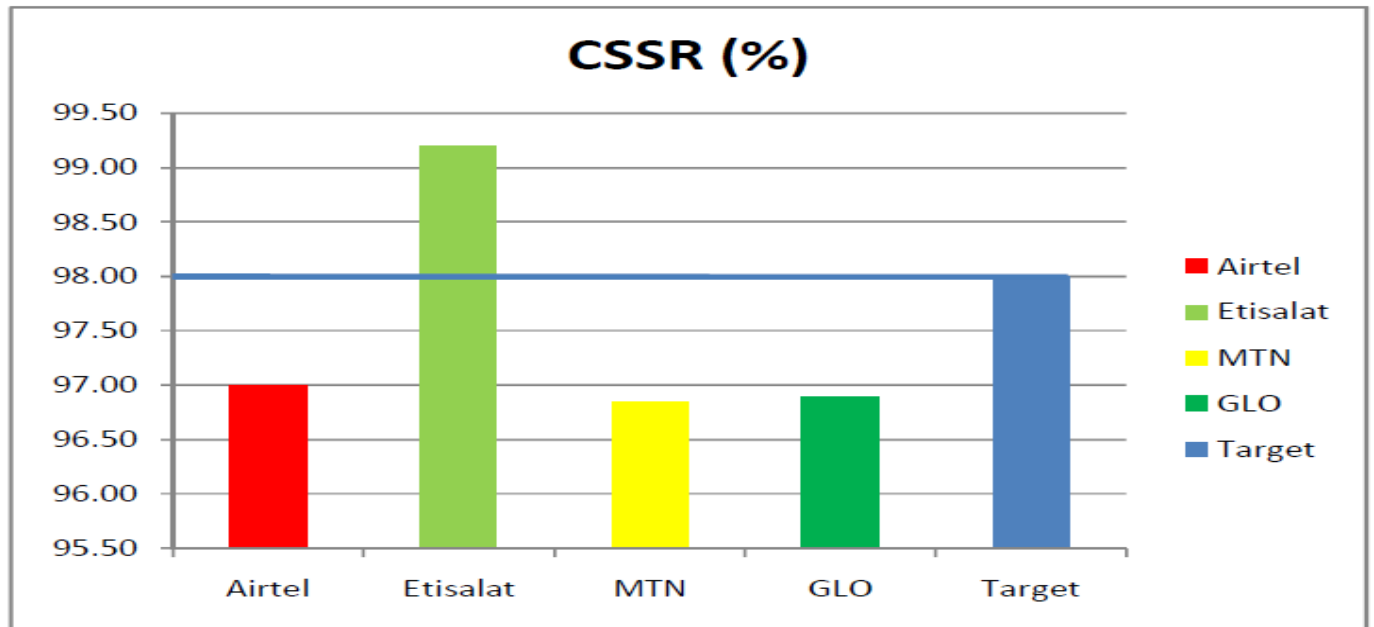


Figure 5.36: A Plot of CSSR KPI against Network Operator, (Jan, 2014)

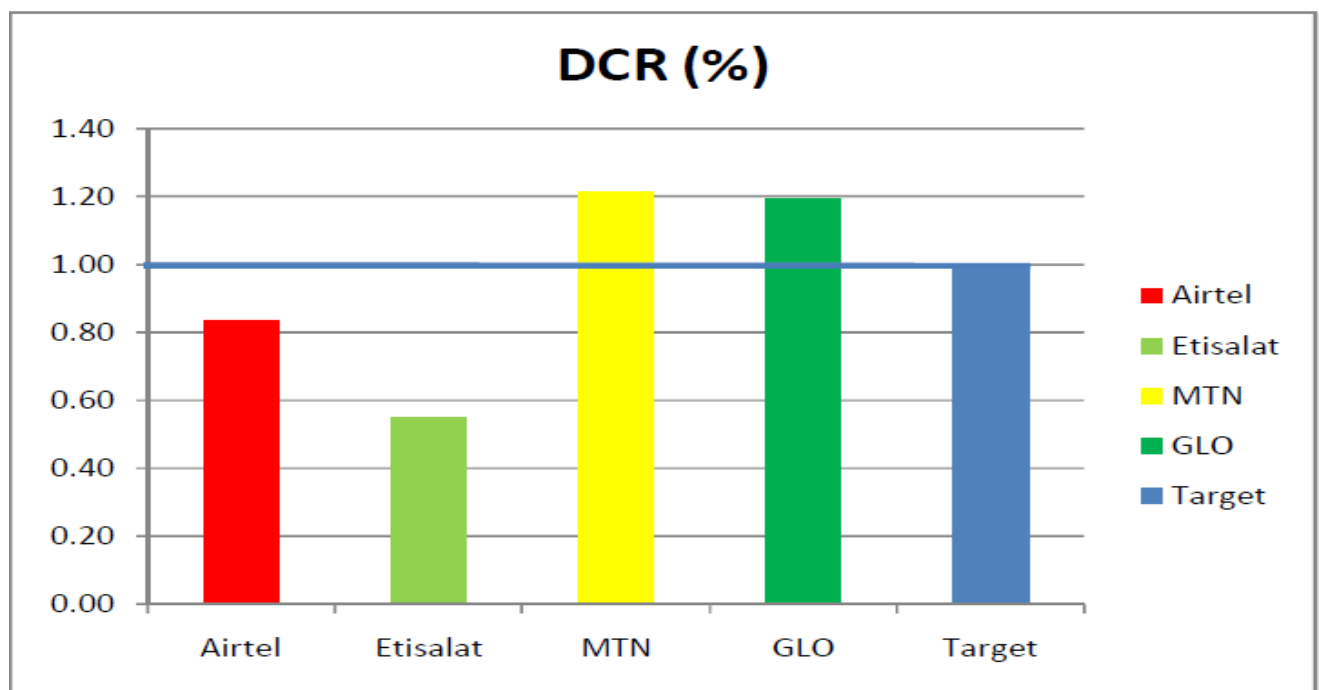


Figure 5.37: A Plot of DCR KPI against Network Operator, (Jan 2014)

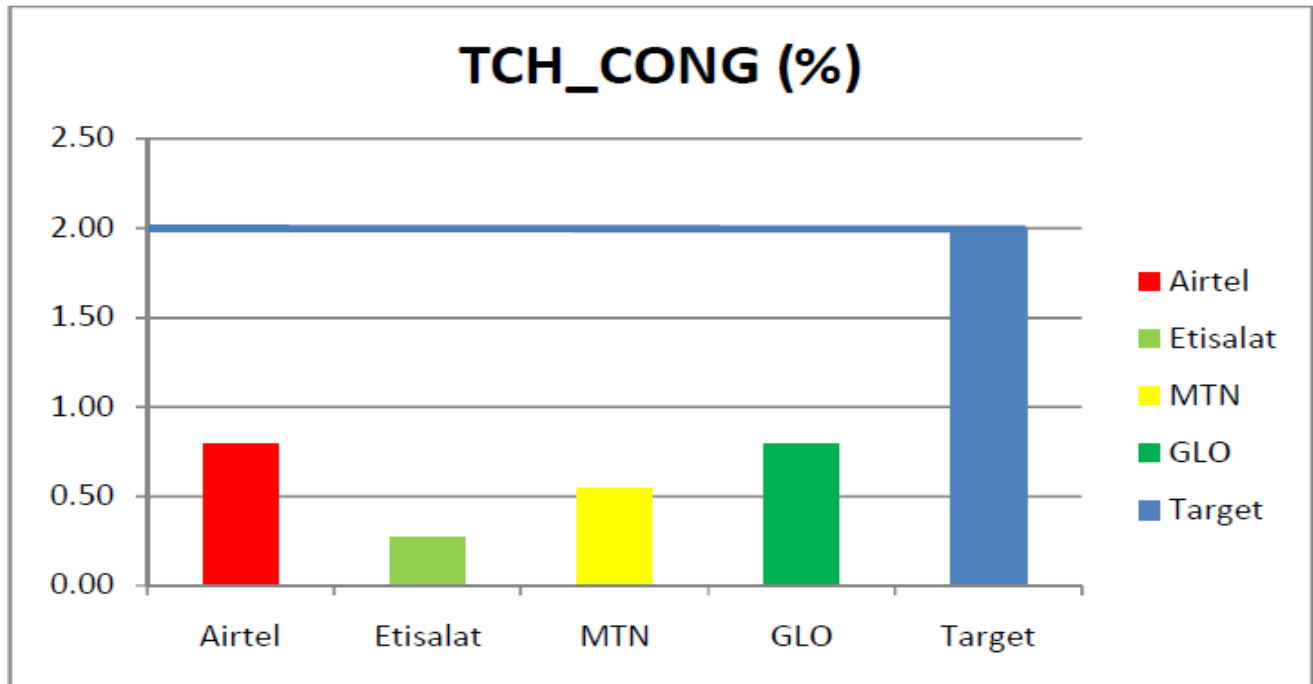


Figure 5.38: A Plot of TCH_CONG KPI against Network Operator, (Jan, 2014)

It was observed that all the Operators failed to meet the Commission target within the period under review.

- GLO value cannot be validated and does not reflect actual network performance in the period under review.
- An average of 15% of GLO data were not available (N/A)
- ETISALAT consistently recorded worst performance when compared with other operators' performance and the Commission's target of 0.2%.

The dataset derived from KPI of March, 2013 is shown in table 3.6.

From figure 5.1, it was shown that Etisalat has the best Avg. CSSR threshold of 98.72% ahead of other networks in march, 2013.

From the results of figures 5.19 to 5.38, it was deduced that there are factors that contributes to GSM operators not meeting the exact expectation of the QoS specified by NCC even though some networks showed improvement over others with respect to some KPIs.

Figures 5.39 to 5.43 shows the results of the simulation of a GSM network in MATLAB software. The simulation seeks to show a sensitivity profile of the end user GSM node via BER strategy to obtain QoS dataset.

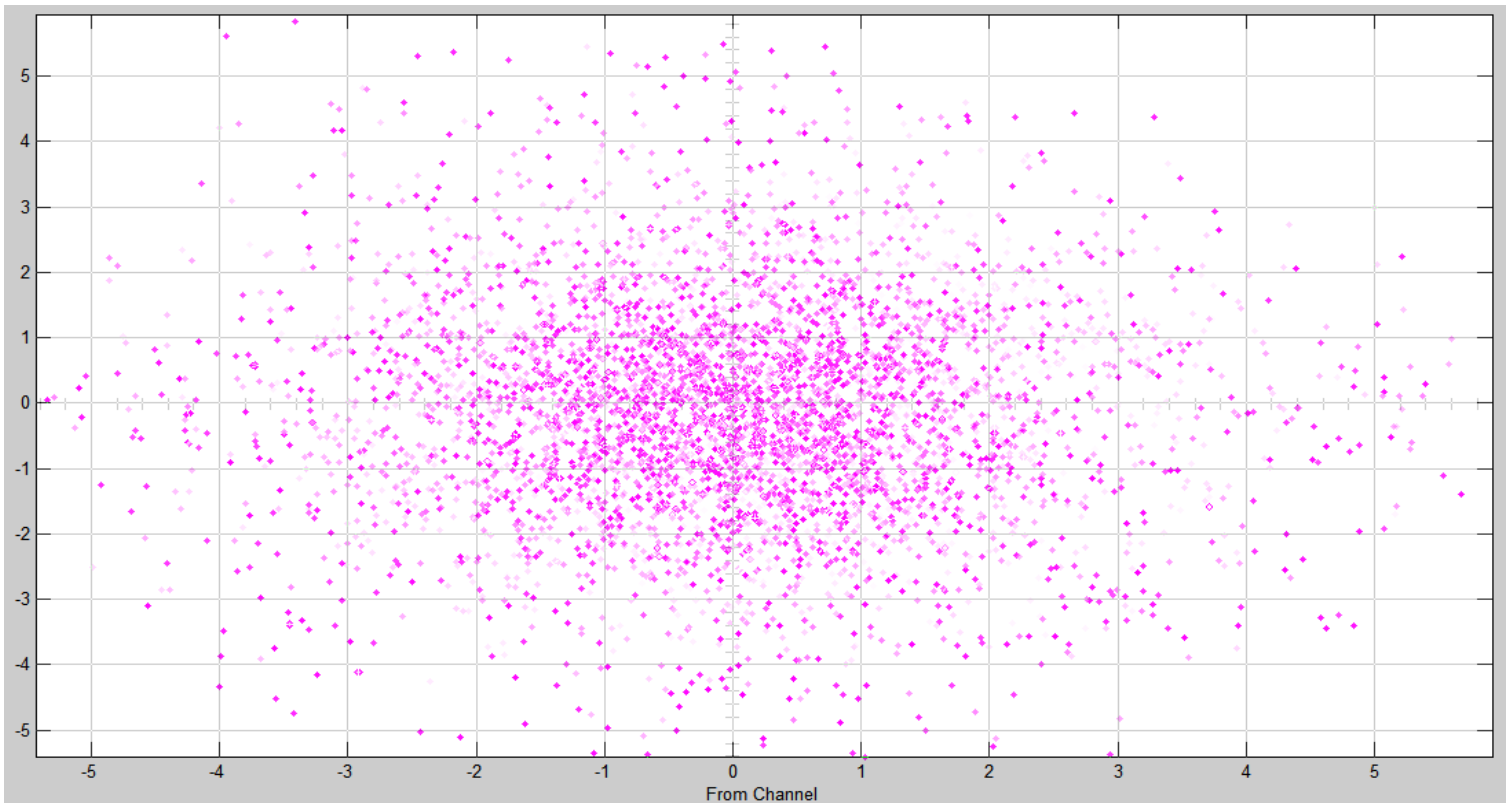


Figure 5.39: A plot of Channel fading response before the Receiver

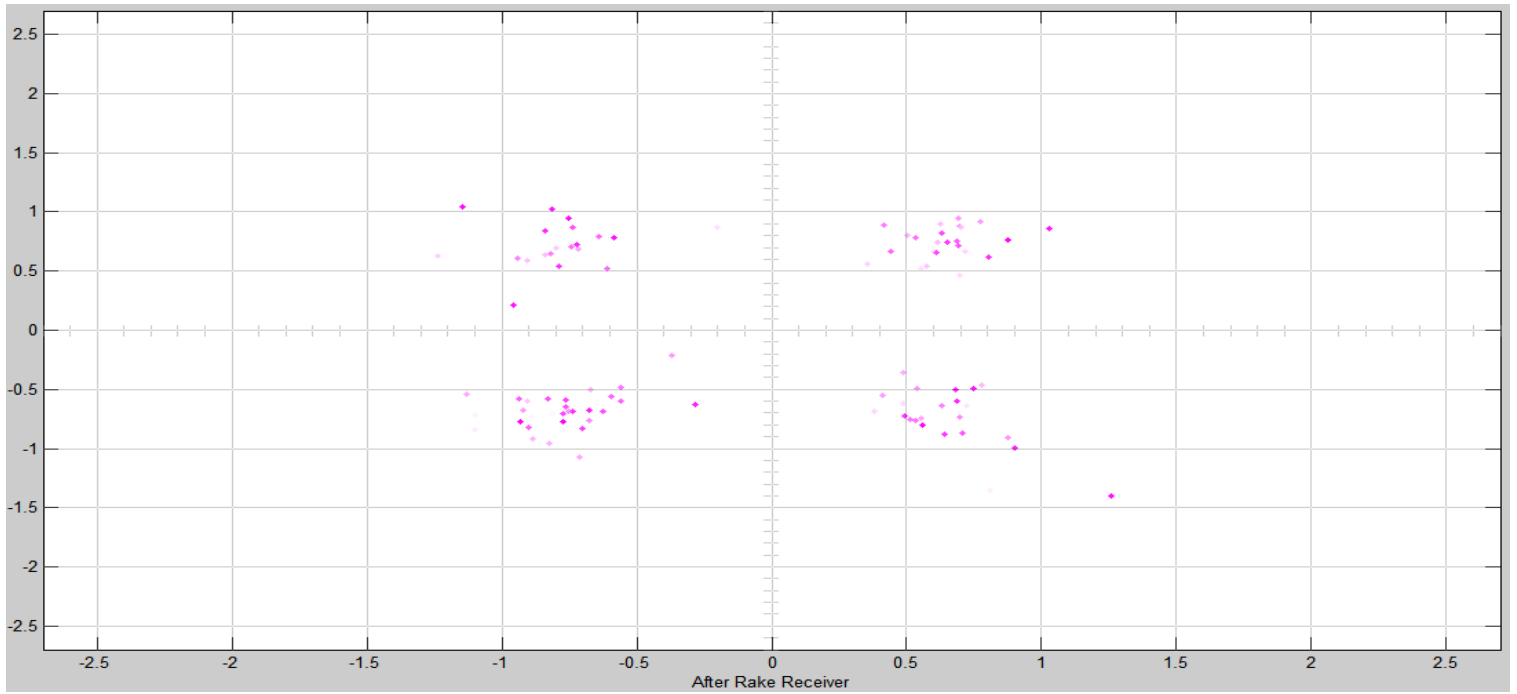


Figure 5.40: A plot of Channel fading response after the Receiver

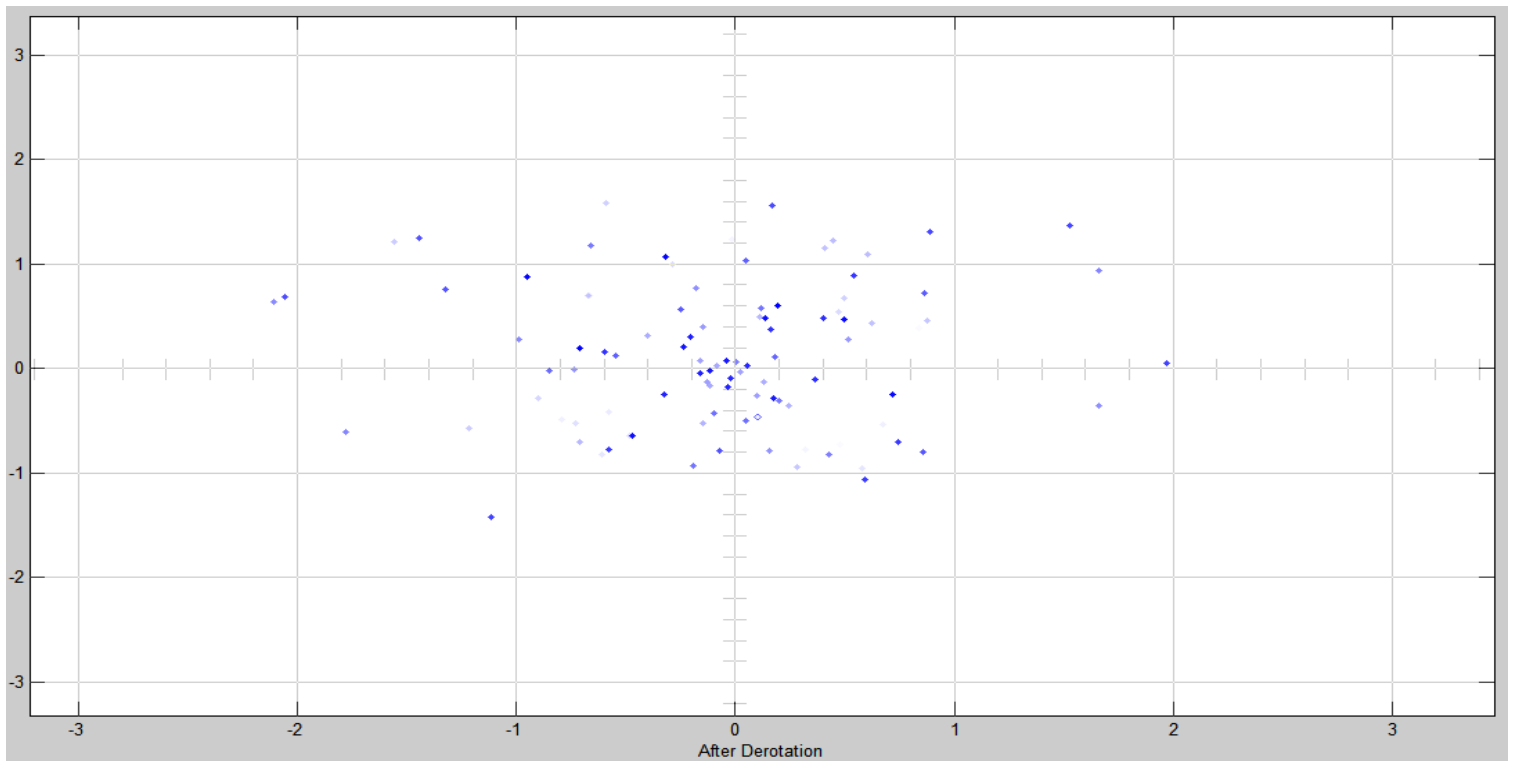


Figure 5.41: A plot of Channel fading response after deterioration at the receiver

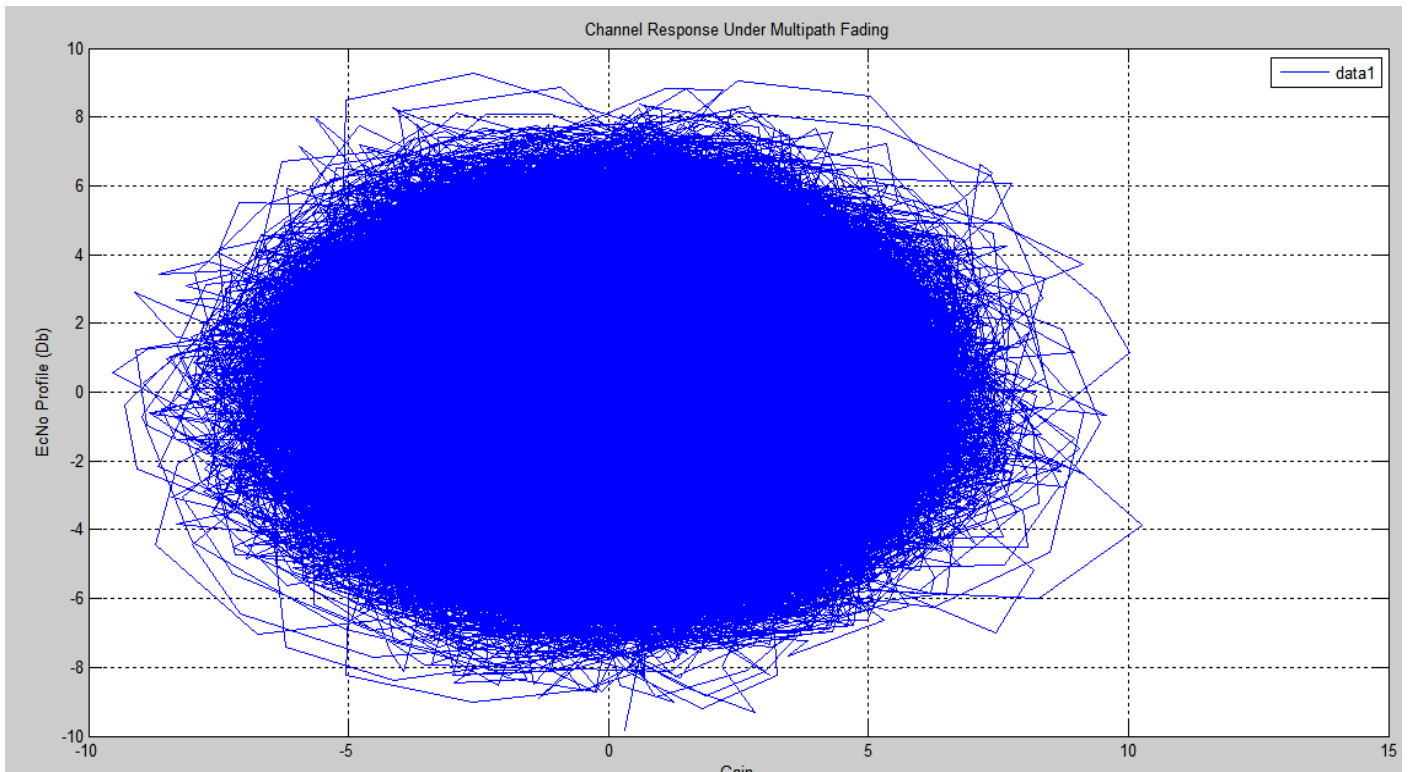


Figure 5.42: A plot of Channel response under multipath fading

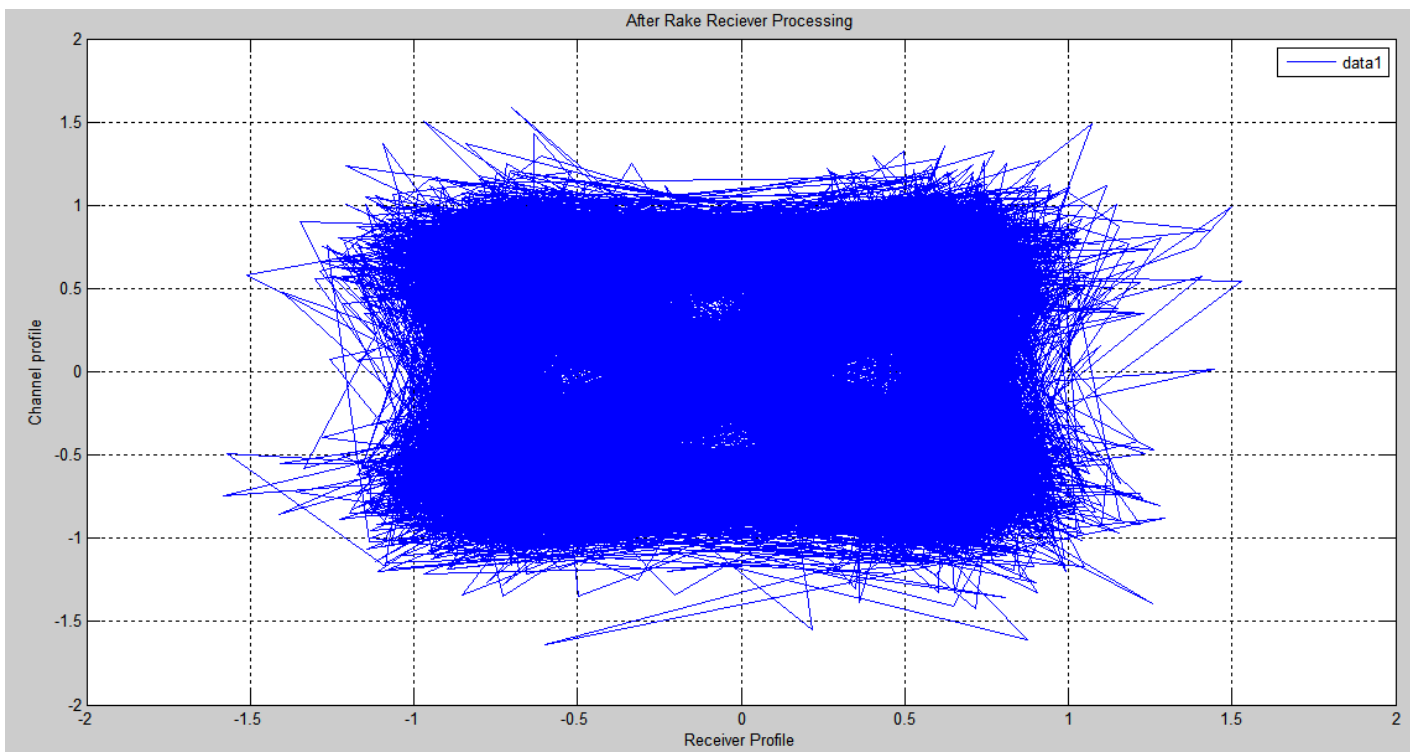


Figure 5.43: A plot of Channel fading response after rake receiver processing.

From the results of figures 5.39 to 5.43, it can be said that the GSM module that is compliant with the proposed QoS model was achieved showing a satisfactory BER results. And also that a low Bit Error Rate model with a call drop rate of <1 was achieved in the integration framework.

5.2 DISCUSSION

The optimal points for the process variables were found to be 0.5. Mobile SIM Network Portability Suite developed showed the capability of the fuzzy block set of MATLAB/Simlink and Java programming language with Netbean 7.0 and XAMP Control panel to integrate different network SIM card. This approach demonstrates the replaceability of existing SIM card. This approach demonstrates the replaceability of existing SIM card GSM architecture with an adequate trusted software module proposed to demonstrate the functionalities of the network integration. MNP Java VSIM Suite was suggested to all mobile network operators and the migration of subscriber to adopt. For simulation of 1sec, a BER of 0.00162 was found; in realizing a stable but sensitive system, the BER of 0.00162 which is less than 1 signifying a very good and satisfactory BER for call drop analysis.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

In this research, Key Performance Indices of network providers (KPI) which causes poor service quality in Nigeria were examined. The four network operators in Nigeria were analyzed in the context of their KPI data which NCC regulates. The application of drive test and deductive reasoning was exploited to show the non uniformity of the operators in terms of QoS delivery to its end customers. The review findings now lead to a novel method of subscriber migration in mobile cellular networks and its implementation framework in future mobile phones and devices. A novel QoS framework was presented which seeks to enforce expedite action on the part of the network operators for improved QoS demand.

An improved platform for MNP vis-à-vis Subscriber Identity Module (SIM) proposed by Trusted Computing Group Mobile Phone Work Group (TCG MPWG) Reference Architecture was developed and analysed. A Java VSIM portability Suite for Mobile Number Portability (MNP) parametric SIM network algorithm using fuzzy logic where implemented. The approach demonstrates the replacability of the existing MNP SIM card GSM architecture with an adequate trusted software module proposed to demonstrates the functionalities of the network integrations. Furthermore, the proposed method for SIM MNP (Mobile SIM Network Portability Suite-MSimNPS) for all mobile network operator and the migration of subscriber credentials between devices was analysed considering its integration techniques, and the parameters on which it depends. MSimNPS decision using fuzzy logic framework was developed showing the customer parameters while focusing its evaluation based on a set of benchmarks which are considered as crucial for deployment while taking cognizance of user's requirements of mobile devices.

Contributions to Knowledge

Throughout this research, this work has made following contributions viz:

1. Carried out an exhaustive literature survey on GSM QoS and KPI target analysis for possible improvements.
2. Developed simplified QoS management framework for GSM operators in Nigeria

3. Developed a fuzzy integrated GSM network for decision rule management, using Mamdani Inference engine.
4. To develop a MNSuite showing the scenario migration processes for end users.
5. Developed a GSM model for BER sensitivity with MATLAB Simulink.

Problems Encountered and Solutions

- i. The inability to locate a viable testbed environment to make preliminary investigations was a major constraint to this work. However, this was finally solved with the availability of simulation rich MATLAB Simulink which was used for the various implementations.
- ii. Further, poor background on network softwares as well as simulation softwares was a big setback, but via the help of experts, researchers and other professionals, a light was shed in this direction.

Recommendations

This work recommends that the regulators must actively encourage the use of improved MNP scheme to avoid subscriber exploitation while compelling service providers to come up with innovative scheme that will improve QoS. Also, the concept of infrastructure sharing among the operators to reduce their cost of infrastructural deployment, maintenance, etc, allowing them to focus on QoS is highly recommended.

- The integration framework should be re-examined by the network regulator i NCC while seek possible interfacing considerations among the operators systems
- There should be an infrastructure sharing mechanism between the operators for cost reduction in CAPEX so as to improve on other areas.
- The NCC and the four GSM operators should increase efforts to educate Nigerian Subscribers on the Mobile Number Portability Scheme.

- Adequate information such as requirements, guidelines and turnaround time for switching GSM operators should be made public
- GSM operators should focus mainly on reducing their current rate of dropped calls, and also strive to improve the quality and coverage of data services, customer care and tariff plan as these are identified as the highest sources of attraction by customers who want to switch to new networks

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Appendices

Appendix I: Paper Publications

1. **Nnochiri Ifeoma.U**, K.C. Okafor, C.C Osuagwu, C.U, Nwamuo, ñ***MNVSim Suite: A JAVA Based MNP Application for GSM Network Integration in Nigeria***, *International Journal of Research in Electronics & Communication Technology(IJRECT)*, Volume-2, Issue-3, May-June, 2014, Pp. 68-83, IASTER 2014, www.iaster.com.ISSN Online: 2347-6109, Print: 2348-0017, India.
2. **Nnochiri.I.U**, C.C.Osuagwu, K.C.Okafor, ñ***Empirical Analysis on the GSM Network KPIs Using Real Time Methodology For a Novel network Integration***. *Progress in Science and Engineering Research Journal*, ISSN 2347-6680 (E) PISER 13, Vol.02,Pp. 092-107, 2014,India. <http://.piserjournal.org/>
3. Iroegbu Chibuisi and **Nnochiri, Ifeoma U.**, “***Design and Implementation of Amplitude Modulation Channels Using Matlab/ Simulink***”, *Journal of Research in Physical Science*, ISSN: 1577-7994 Vol.10, Pp. 19-26, 2014.
4. **Nnochiri, I.U.**, “***Virtual Private Network Security***”, *International Journal for Research in Applied Science & Engineering Technology*, ISSN: 2321-9653 Vol.2, Pp 175-179, 2014.
5. **Nnochiri I.U** and Okafor Kennedy Chinedu, “***A Conceptual Framework on User Prospection on factors of quality of service (QoS) for mobile Sim Network***”, *International Journal of Wireless Communication, Networking and Mobile Computing*, Vol. 3 Pp 29-42, 2014.
6. **Nnochiri I.U** and Okafor Kennedy Chinedu, “***Sensitivity Profile of a Prototype Mobile Number Portability GSM design Using Bit Error Rate (BER)***”, *American Society for Science and Technology*, Vol. 2, Pp 59-68, 2015.
7. **Nnochiri I.U** and Nweke Chisom B., “***Comparison Study between Fuzzy Logic Controller (FLC)and Proportional-Integral-Derivative(PID) in Controlling of liquid Flow***”, *International Journal of Engineering and Technical Research*, ISSN: 2321-0869 Vol.2, Pp 53-56, 2014.

Appendix II: Fuzzy logic M-file

```
[System]
Name='FNI_DecisionRule'
Type='mamdani'
Version=2.0
NumInputs=3
NumOutputs=1
NumRules=0
AndMethod='min'
OrMethod='max'
ImpMethod='min'
AggMethod='max'
DefuzzMethod='centroid'
[Input1]
Name='NetCoverg_1'
Range=[0 1]
NumMFs=3
MF1='mf1': 'trimf',[-0.4 0 0.4]
MF2='mf2': 'trimf',[0.1 0.5 0.9]
MF3='mf3': 'trimf',[0.6 1 1.4]
[Input2]
Name='Tariff_Plan_2'
Range=[0 1]
NumMFs=3
MF1='mf1': 'trimf',[-0.4 0 0.4]
MF2='mf2': 'trimf',[0.1 0.5 0.9]
MF3='mf3': 'trimf',[0.6 1 1.4]
[Input3]
Name='CustomerCare_Mgmt'
Range=[0 1]
NumMFs=3
MF1='mf1': 'trimf',[-0.4 0 0.4]
MF2='mf2': 'trimf',[0.1 0.5 0.9]
MF3='mf3': 'trimf',[0.6 1 1.4]
[Output1]
Name='FNI_Decision_Rule'
Range=[0 1]
NumMFs=3
MF1='mf1': 'trimf',[-0.4 0 0.4]
MF2='mf2': 'trimf',[0.1 0.5 0.9]
MF3='mf3': 'trimf',[0.6 1 1.4]
[Rules]
```

Appendix III: JAVA Codelings for MNSim Suite

```
/*  
  
 * MyDBConnection.java  
  
 *  
  
 * Created on August 29, 2012, 4:54 AM  
  
 * * To change this template, choose Tools | Template Manager  
 * and open the template in the editor.  
  
 */  
  
import java.awt.event.ActionEvent;  
import java.awt.event.ActionListener;  
import java.sql.Connection;  
import java.sql.DriverManager;  
import java.sql.ResultSet;  
import java.awt.*;  
import javax.swing.*;  
  
/**  
  
 *  
  
 * @author ICTUO  
  
 */  
  
public class MyDBConnection implements ActionListener{  
    private Connection myConnection;  
  
    /** Creates a new instance of MyDBConnection */  
  
    public void init(){  
        try{  
            Class.forName("com.mysql.jdbc.Driver");
```

```

myConnection=DriverManager.getConnection("jdbc:mysql://localhost:3306/networkmigration"
,"root", "nbuser");

    }

    catch(Exception e){

        System.out.println("Failed to get connection");

        e.printStackTrace();

    }

}

public Connection getMyConnection(){

    return myConnection;

}

public void close(ResultSet rs){

    if(rs !=null){

        try{

            rs.close();

        }

        catch(Exception e){}

    }

}

public void close(java.sql.Statement stmt){

    if(stmt !=null){

        try{

            stmt.close();

        }

        catch(Exception e){}

    }

}

```

```

    }
}

public void destroy(){
    if(myConnection !=null){
        try{
            myConnection.close();
        }
        Catch (Exception e){}
    }
}

public void actionPerformed(ActionEvent e) {
}
}

import java.awt.Dimension;
import java.awt.Toolkit;
import java.awt.event.ActionEvent;
import java.awt.event.ActionListener;
import java.sql.*;

/*
 * To change this template, choose Tools | Templates
 * and open the template in the editor.
 */

/**
 *
 * @author Onwe
 */
public class registerSim extends javax.swing.JDialog implements ActionListener{

    MyDBConnection mdbc;
    Connection conn;
    Statement stmt;
    ResultSet rs = null;
    PreparedStatement pS;

```

```

/** Creates new form NewJDialog */
public registerSim(java.awt.Frame parent, boolean modal) {
    super(parent, modal);
    initComponents();
}

/** This method is called from within the constructor to
 * initialize the form.
 * WARNING: Do NOT modify this code. The content of this method is
 * always regenerated by the Form Editor.
 */
@SuppressWarnings("unchecked")
// <editor-fold defaultstate="collapsed" desc="Generated Code">
private void initComponents() {

    jPanel1 = new javax.swing.JPanel();
    jLabel1 = new javax.swing.JLabel();
    jLabel2 = new javax.swing.JLabel();
    jLabel3 = new javax.swing.JLabel();
    jLabel4 = new javax.swing.JLabel();
    jLabel5 = new javax.swing.JLabel();
    jLabel6 = new javax.swing.JLabel();
    jLabel7 = new javax.swing.JLabel();
    jLabel8 = new javax.swing.JLabel();
    jLabel9 = new javax.swing.JLabel();
    jLabel10 = new javax.swing.JLabel();
    jLabel11 = new javax.swing.JLabel();
    jButton1 = new javax.swing.JButton();
    jButton2 = new javax.swing.JButton();
    jTextField1 = new javax.swing.JTextField();
    jTextField2 = new javax.swing.JTextField();
    jTextField4 = new javax.swing.JTextField();
    jTextField5 = new javax.swing.JTextField();
    jTextField6 = new javax.swing.JTextField();
    jTextField7 = new javax.swing.JTextField();
    jTextField8 = new javax.swing.JTextField();
    jTextField9 = new javax.swing.JTextField();
    jTextField10 = new javax.swing.JTextField();
    jTextField11 = new javax.swing.JTextField();
    jComboBox1 = new javax.swing.JComboBox();

    int width = 200;

    int height = 200;

```

```

setSize(width, height);
setTitle("Migration Log");

// Get the size of the screen
Dimension dim = Toolkit.getDefaultToolkit().getScreenSize();

// Determine the new location of the frame

int x = (dim.width-width)/2;
int y = (dim.height-height)/2;

// Move the frame

setLocation(x, y);

setDefaultCloseOperation(javax.swing.WindowConstants.DISPOSE_ON_CLOSE);

jLabel1.setText("Name:");

jLabel2.setText("Age:");

jLabel3.setText("Sex:");

jLabel4.setText("Phone:");

jLabel5.setText("Email:");

jLabel6.setText("Address:");

jLabel7.setText("Religion:");

jLabel8.setText("Occupation:");

jLabel9.setText("LGA:");

jLabel10.setText("State of Origin:");

jLabel11.setText("Country:");

jButton1.setText("Register");
jButton1.addActionListener(this);

jButton2.setText("Exit");
jButton2.addActionListener(this);

```

```

jComboBox1.setModel(new javax.swing.DefaultComboBoxModel(new String[] { "-----",
"Female", "Male" }));

javax.swing.GroupLayout jPanel1Layout = new javax.swing.GroupLayout(jPanel1);
jPanel1.setLayout(jPanel1Layout);
jPanel1Layout.setHorizontalGroup(
    jPanel1Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
        .addGroup(javax.swing.GroupLayout.Alignment.TRAILING,
jPanel1Layout.createSequentialGroup()
            .addContainerGap()
            .addGroup(jPanel1Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.TRAILING)
                .addGroup(jPanel1Layout.createSequentialGroup()
                    .addComponent(jLabel5, javax.swing.GroupLayout.Alignment.LEADING)
                    .addGroup(javax.swing.GroupLayout.Alignment.LEADING,
jPanel1Layout.createSequentialGroup()
                        .addComponent(jLabel6)
                        .addGap(10, 10, 10)
                        .addComponent(jTextField6, javax.swing.GroupLayout.DEFAULT_SIZE, 294,
Short.MAX_VALUE))
                    .addGroup(javax.swing.GroupLayout.Alignment.LEADING,
jPanel1Layout.createSequentialGroup()
                        .addComponent(jLabel7)
                        .addGap(10, 10, 10)
                        .addComponent(jTextField7, javax.swing.GroupLayout.DEFAULT_SIZE, 296,
Short.MAX_VALUE))
                    .addGroup(javax.swing.GroupLayout.Alignment.LEADING,
jPanel1Layout.createSequentialGroup()
                        .addComponent(jLabel8)
                        .addPreferredGap(javax.swing.LayoutStyle.ComponentPlacement.RELATED)
                        .addComponent(jTextField8, javax.swing.GroupLayout.DEFAULT_SIZE, 285,
Short.MAX_VALUE))
                    .addGroup(javax.swing.GroupLayout.Alignment.LEADING,
jPanel1Layout.createSequentialGroup()
                        .addComponent(jLabel9)
                        .addGap(28, 28, 28)
                        .addComponent(jTextField9, javax.swing.GroupLayout.DEFAULT_SIZE, 296,
Short.MAX_VALUE))
                    .addGroup(javax.swing.GroupLayout.Alignment.LEADING,
jPanel1Layout.createSequentialGroup()
                        .addComponent(jLabel10)
                        .addPreferredGap(javax.swing.LayoutStyle.ComponentPlacement.RELATED)
                        .addComponent(jTextField10, javax.swing.GroupLayout.DEFAULT_SIZE, 269,
Short.MAX_VALUE))
                .addGap(10, 10, 10))
            .addContainerGap(10, true))

```

```

        .addGroup(javax.swing.GroupLayout.Alignment.LEADING,
jPanel1Layout.createSequentialGroup())

    .addGroup(jPanel1Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING
    )
        .addComponent(jLabel4)
        .addComponent(jLabel3))
    .addGap(18, 18, 18)

    .addGroup(jPanel1Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING
    )
        .addComponent(jTextField5, javax.swing.GroupLayout.DEFAULT_SIZE, 295,
Short.MAX_VALUE)
        .addComponent(jTextField4, javax.swing.GroupLayout.DEFAULT_SIZE, 295,
Short.MAX_VALUE)))
    .addGroup(javax.swing.GroupLayout.Alignment.LEADING,
jPanel1Layout.createSequentialGroup())

    .addGroup(jPanel1Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING
    )
        .addComponent(jLabel1)
        .addComponent(jLabel2))

    .addGroup(jPanel1Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING
    )
        .addGroup(jPanel1Layout.createSequentialGroup())
        .addGap(18, 18, 18)
        .addComponent(jTextField1, javax.swing.GroupLayout.DEFAULT_SIZE,
298, Short.MAX_VALUE))
        .addGroup(jPanel1Layout.createSequentialGroup())
        .addGap(20, 20, 20)

    .addGroup(jPanel1Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING
    )
        .addComponent(jComboBox1,
javax.swing.GroupLayout.PREFERRED_SIZE, javax.swing.GroupLayout.DEFAULT_SIZE,
javax.swing.GroupLayout.PREFERRED_SIZE)
        .addComponent(jTextField2, javax.swing.GroupLayout.DEFAULT_SIZE,
296, Short.MAX_VALUE))))
    .addGroup(jPanel1Layout.createSequentialGroup())
        .addComponent(jLabel11)
        .addPreferredGap(javax.swing.LayoutStyle.ComponentPlacement.RELATED, 4,
Short.MAX_VALUE)

```

```

.addGroup(jPanel1Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING
)
    .addGroup(jPanel1Layout.createSequentialGroup()
        .addGap(10, 10, 10)
        .addComponent(jButton1)
        .addGap(80, 80, 80)
        .addComponent(jButton2))
        .addComponent(jTextField11, javax.swing.GroupLayout.PREFERRED_SIZE,
290, javax.swing.GroupLayout.PREFERRED_SIZE))
        .addGap(10, 10, 10)))
    .addContainerGap(43, javax.swing.GroupLayout.PREFERRED_SIZE))
);
jPanel1Layout.setVerticalGroup(
    jPanel1Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
        .addGroup(jPanel1Layout.createSequentialGroup()
            .addContainerGap()

```

```

.addGroup(jPanel1Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.BASELINE
E)
    .addComponent(jLabel1)
    .addComponent(jTextField1, javax.swing.GroupLayout.PREFERRED_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, javax.swing.GroupLayout.PREFERRED_SIZE))
    .addPreferredGap(javax.swing.LayoutStyle.ComponentPlacement.UNRELATED)

```

```

.addGroup(jPanel1Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.BASELINE
E)
    .addComponent(jLabel2)
    .addComponent(jTextField2, javax.swing.GroupLayout.PREFERRED_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, javax.swing.GroupLayout.PREFERRED_SIZE))
    .addPreferredGap(javax.swing.LayoutStyle.ComponentPlacement.UNRELATED)

```

```

.addGroup(jPanel1Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.BASELINE
E)
    .addComponent(jLabel3)
    .addComponent(jComboBox1, javax.swing.GroupLayout.PREFERRED_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, javax.swing.GroupLayout.PREFERRED_SIZE))
    .addGap(10, 10, 10)

```

```

.addGroup(jPanel1Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.BASELINE
E)
    .addComponent(jLabel4)
    .addComponent(jTextField4, javax.swing.GroupLayout.PREFERRED_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, javax.swing.GroupLayout.PREFERRED_SIZE))
    .addPreferredGap(javax.swing.LayoutStyle.ComponentPlacement.RELATED)

```

```

.addGroup(jPanel1Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.BASELINE)
.addComponent(jLabel5)
.addComponent(jTextField5, javax.swing.GroupLayout.PREFERRED_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, javax.swing.GroupLayout.PREFERRED_SIZE))
.addPreferredGap(javax.swing.LayoutStyle.ComponentPlacement.RELATED)
.addGroup(jPanel1Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.BASELINE)
.addComponent(jTextField6, javax.swing.GroupLayout.PREFERRED_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, javax.swing.GroupLayout.PREFERRED_SIZE)
.addComponent(jLabel6))
.addPreferredGap(javax.swing.LayoutStyle.ComponentPlacement.RELATED)
.addGroup(jPanel1Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.BASELINE)
.addComponent(jTextField7, javax.swing.GroupLayout.PREFERRED_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, javax.swing.GroupLayout.PREFERRED_SIZE)
.addComponent(jLabel7)
.addPreferredGap(javax.swing.LayoutStyle.ComponentPlacement.RELATED)

.addGroup(jPanel1Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.BASELINE)
.addComponent(jTextField8, javax.swing.GroupLayout.PREFERRED_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, javax.swing.GroupLayout.PREFERRED_SIZE)
.addComponent(jLabel8))
.addGap(9, 9, 9)

.addGroup(jPanel1Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.BASELINE)
.addComponent(jLabel9)
.addComponent(jTextField9, javax.swing.GroupLayout.PREFERRED_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, javax.swing.GroupLayout.PREFERRED_SIZE))
.addPreferredGap(javax.swing.LayoutStyle.ComponentPlacement.RELATED)

.addGroup(jPanel1Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.BASELINE)
.addComponent(jLabel10)
.addComponent(jTextField10, javax.swing.GroupLayout.PREFERRED_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, javax.swing.GroupLayout.PREFERRED_SIZE))

.addGroup(jPanel1Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
)
.addGroup(jPanel1Layout.createSequentialGroup())
.addGap(6, 6, 6)
.addComponent(jTextField11, javax.swing.GroupLayout.PREFERRED_SIZE,

```

```

        javax.swing.GroupLayout.DEFAULT_SIZE, javax.swing.GroupLayout.PREFERRED_SIZE)
        .addPreferredGap(javax.swing.LayoutStyle.ComponentPlacement.RELATED)

.addGroup(jPanel1Layout.createParallelGroup(javax.swing.GroupLayout.Alignment.BASELINE)
E)
        .addComponent(jButton1)
        .addComponent(jButton2)))
        .addGroup(jPanel1Layout.createSequentialGroup()
        .addPreferredGap(javax.swing.LayoutStyle.ComponentPlacement.RELATED)
        .addComponent(jLabel11)))
    );

    javax.swing.GroupLayout layout = new javax.swing.GroupLayout(getContentPane());
    getContentPane().setLayout(layout);
    layout.setHorizontalGroup(
        layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
        .addComponent(jPanel1, javax.swing.GroupLayout.DEFAULT_SIZE,
javax.swing.GroupLayout.DEFAULT_SIZE, Short.MAX_VALUE)
    );
    layout.setVerticalGroup(
        layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
        .addComponent(jPanel1, javax.swing.GroupLayout.DEFAULT_SIZE,
Short.MAX_VALUE)
    );

    pack();
} // </editor-fold>

// Variables declaration - do not modify
private javax.swing.JButton jButton1;
private javax.swing.JButton jButton2;
private javax.swing.JComboBox jComboBox1;
private javax.swing.JLabel jLabel1;
private javax.swing.JLabel jLabel10;
private javax.swing.JLabel jLabel11;
private javax.swing.JLabel jLabel2;
private javax.swing.JLabel jLabel3;
private javax.swing.JLabel jLabel4;
private javax.swing.JLabel jLabel5;
private javax.swing.JLabel jLabel6;
private javax.swing.JLabel jLabel7;
private javax.swing.JLabel jLabel8;
private javax.swing.JLabel jLabel9;

```

344,

```

private javax.swing.JPanel jPanel1;
private javax.swing.JTextField jTextField1;
private javax.swing.JTextField jTextField10;
private javax.swing.JTextField jTextField11;
private javax.swing.JTextField jTextField2;
private javax.swing.JTextField jTextField4;
private javax.swing.JTextField jTextField5;
private javax.swing.JTextField jTextField6;
private javax.swing.JTextField jTextField7;
private javax.swing.JTextField jTextField8;
private javax.swing.JTextField jTextField9;
// End of variables declaration

@Override
public void actionPerformed(ActionEvent e) {

    if(e.getSource() == jButton1){

        try{

            String name = jTextField1.getText();
            String age = jTextField2.getText();
            String sex = jComboBox1.getSelectedItem().toString();
            String phone = jTextField4.getText();
            String email = jTextField5.getText();
            String address = jTextField6.getText();
            String religion = jTextField7.getText();
            String occupation = jTextField8.getText();
            String lga = jTextField9.getText();
            String state = jTextField10.getText();
            String country = jTextField11.getText();

            int x = 0;

            mdbc=new MyDBConnection();
            mdbc.init();
            conn=mdbc.getMyConnection();
            stmt = conn.createStatement();
            //pS = conn.prepareStatement("SELECT network FROM migrationdetails where url
=?");
            pS = conn.prepareStatement("insert into simreg values(?,?,?,?,?,?,?,?,?,?,?)");

            pS.setInt(1, x);
            pS.setString(2, name);
            pS.setString(3, age);

```

```

        pS.setString(4, sex);
        pS.setString(5, phone);
        pS.setString(6, email);
        pS.setString(7, address);
        pS.setString(8, religion);
        pS.setString(9, occupation);
        pS.setString(10, lga);
        pS.setString(11, state);
        pS.setString(12, country);

        pS.executeUpdate();
        conn.close();

    }
    catch(Exception exx){

        exx.printStackTrace();
    }

}

if(e.getSource() == jButton2){

    dispose();

}

}
}

import java.awt.Dimension;
import java.awt.Toolkit;
import java.sql.*;
import java.util.*;
import javax.swing.*;
import javax.swing.table.TableColumn;
public class JTableResultSet {
    public void resultOnTable() {
        Vector columnNames = new Vector();
        Vector data = new Vector();
        JPanel panel = new JPanel(); //
        try {
            Class.forName("com.mysql.jdbc.Driver").newInstance();

```

```

Connection con = DriverManager.getConnection(
    "jdbc:mysql://localhost:3306/networkmigration", "root", "nbuser");
String sql = "Select date,descr from migrationdetails";
Statement statement = con.createStatement();
ResultSet resultSet = statement.executeQuery(sql);
ResultSetMetaData metaData = resultSet.getMetaData();
int columns = metaData.getColumnCount();
for (int i = 1; i <= columns; i++) {
    columnNames.addElement(metaData.getColumnName(i));
}
while (resultSet.next()) {
    Vector row = new Vector(columns);
    for (int i = 1; i <= columns; i++) {
        row.addElement(resultSet.getObject(i));
    }
    data.addElement(row);
}
resultSet.close();
statement.close();
} catch (Exception e) {
    System.out.println(e);
}
JTable table = new JTable(data, columnNames);
TableColumn column;
for (int i = 0; i < table.getColumnCount(); i++) {
    column = table.getColumnModel().getColumn(i);
    column.setMaxWidth(250);
}
JScrollPane scrollPane = new JScrollPane(table);
panel.add(scrollPane);
JDialog frame = new JDialog();
frame.setModal(true);
frame.add(panel);    //adding panel to the frame

int width = 200;

int height = 200;

frame.setSize(width, height);
frame.setTitle("Migration Log");

// Get the size of the screen
Dimension dim = Toolkit.getDefaultToolkit().getScreenSize();

// Determine the new location of the frame

```

```

        int x = (dim.width-width)/2;
        int y = (dim.height-height)/2;

        // Move the frame

        frame.setLocation(x, y);
        frame.setSize(600, 400); //setting frame size
        frame.setDefaultCloseOperation(JDialog.DISPOSE_ON_CLOSE);
        frame.setVisible(true); //setting visibility true
    }
}

import java.awt.Dimension;
import java.awt.Toolkit;
import java.awt.event.*;

/*
 * To change this template, choose Tools | Templates
 * and open the template in the editor.
 */

/**
 *
 */
/
public class adminPage extends javax.swing.JFrame implements ActionListener{

    /** Creates new form NewJFrame */
    public adminPage() {
        initComponents();
    }

    /** This method is called from within the constructor to
     * initialize the form.
     * WARNING: Do NOT modify this code. The content of this method is
     * always regenerated by the Form Editor.
     */
    @SuppressWarnings("unchecked")
    // <editor-fold defaultstate="collapsed" desc="Generated Code">
    private void initComponents() {

        jButton1 = new javax.swing.JButton();
        jButton2 = new javax.swing.JButton();
        setTitle("MOBILE SIM NETWORK PORTABILTY SUITE Admin");
        int width = 200;

```

```

int height = 200;

setSize(width, height);

// Get the size of the screen
Dimension dim = Toolkit.getDefaultToolkit().getScreenSize();

// Determine the new location of the frame

int x = (dim.width-width)/2;
int y = (dim.height-height)/2;

// Move the frame

setLocation(x, y);

setDefaultCloseOperation(javax.swing.WindowConstants.EXIT_ON_CLOSE);

jButton1.setText("Register User");
jButton1.addActionListener(this);

jButton2.setText("Migration Log");
jButton2.addActionListener(this);

javax.swing.GroupLayout layout = new javax.swing.GroupLayout(getContentPane());
getContentPane().setLayout(layout);
layout.setHorizontalGroup(
    layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
        .addGroup(layout.createSequentialGroup()
            .add(layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
                .add(layout.createSequentialGroup()
                    .addGap(26, 26, 26)
                    .addGroup(layout.createParallelGroup(javax.swing.GroupLayout.Alignment.LEADING)
                        .add(layout.createSequentialGroup()
                            .addComponent(jButton1, javax.swing.GroupLayout.Alignment.TRAILING,
                                javax.swing.GroupLayout.DEFAULT_SIZE, 341, Short.MAX_VALUE)
                            .addComponent(jButton2, javax.swing.GroupLayout.PREFERRED_SIZE, 341,
                                javax.swing.GroupLayout.PREFERRED_SIZE)
                            .addContainerGap(33, Short.MAX_VALUE))
                        .add(layout.createSequentialGroup()
                            .addGap(62, 62, 62)
                            .addComponent(jButton1, javax.swing.GroupLayout.PREFERRED_SIZE, 43,
                                javax.swing.GroupLayout.PREFERRED_SIZE)

```

```

        .addGap(18, 18, 18)
        .addComponent(jButton2,      javax.swing.GroupLayout.PREFERRED_SIZE,      97,
javax.swing.GroupLayout.PREFERRED_SIZE)
        .addContainerGap(80, Short.MAX_VALUE))
    );

    pack();
} // </editor-fold>

/**
 * @param args the command line arguments
 */
public static void main(String args[]) {

    try {

        javax.swing.UIManager.setLookAndFeel("com.birosoft.liquid.LiquidLookAndFeel");

    } catch (Exception ex) {

    }

} //</editor-fold>
}
/* Create and display the form */
java.awt.EventQueue.invokeLater(new Runnable() {

    public void run() {
        new adminPage().setVisible(true);
    }
});
}
// Variables declaration - do not modify
private javax.swing.JButton jButton1;
private javax.swing.JButton jButton2;
// End of variables declaration

@Override
public void actionPerformed(ActionEvent e) {

    if(e.getSource() == jButton2){

        new JTableResultSet().resultOnTable();
    }

    if(e.getSource() == jButton1){

```

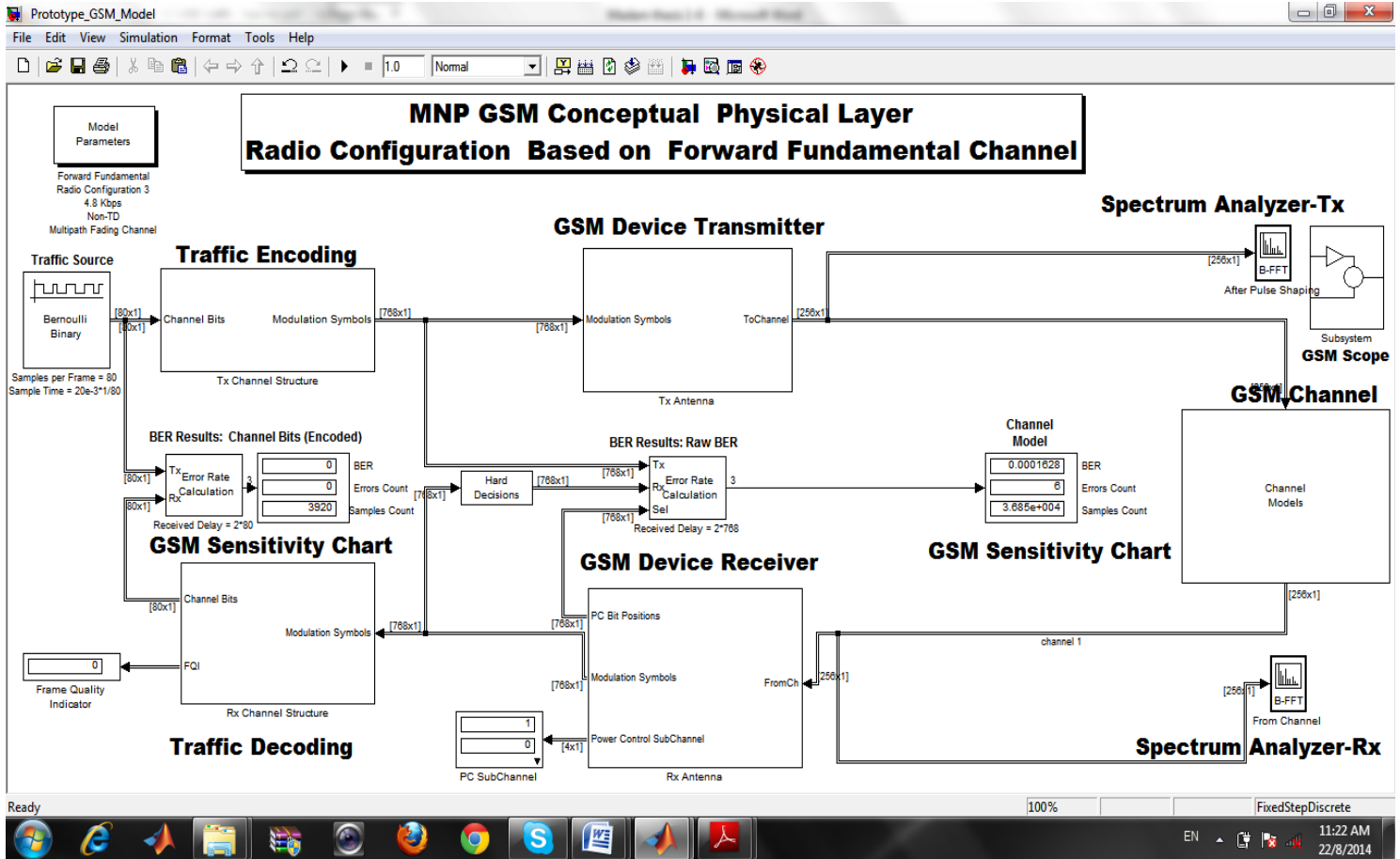
```

registerSim dialog = new registerSim(new javax.swing.JFrame(), true);
    dialog.addWindowListener(new java.awt.event.WindowAdapter() {

        });
    dialog.setVisible(true);
}
}
}

```

Appendix IV: MATLAB Environment Snapshots



MATLAB 7.9.0 (R2009b)

File Edit Debug Parallel Desktop Window Help

Current Folder: D:\Thesis -MENG,PHD\PHD_ Fuzzy Gsm QoS-SIM INTEGRATIO

Shortcuts How to Add What's New

Command Window

```
>> New to MATLAB? Watch this Video, see Demos, or read Getting Started.
>> plot(FQI,'DisplayName','FQI','YDataSource','FQI');figure(gcf)
>> plot(Viterbi_decoder,'DisplayName','Viterbi_decoder','YDataSource','FQI');figure(gcf)
>> plot(FQI,'DisplayName','FQI','YDataSource','FQI');figure(gcf)
>> plot(Encoder,'DisplayName','Encoder','YDataSource','Encoder');figure(gcf)
>> plot(Viterbi_decoder,'DisplayName','Viterbi_decoder','YDataSource','FQI');figure(gcf)
>> plot(Channel_Response_1,'YDataSource','Channel_Response_1');figure(gcf)
>> plot(Channel_Response,'YDataSource','Channel_Response');figure(gcf)
>> plot(After_Rake_Receiver,'YDataSource','After_Rake_Receiver');figure(gcf)
>> grid on
>> plot(After_Rake_Receiver,'YDataSource','After_Rake_Receiver');figure(gcf)
>> grid on
```

Workspace

Name	Value	Min	Max
After_Derotation	<19201x1 double>	0	-3.907...
After_Rake_Receiver	<19201x1 double>	0	1.2568...
Channel_Response	<4915456x1 double>	<Too ...	<Too ...
Channel_Response...	<4915456x1 double>	<Too ...	<Too ...
Encoder	<19584x1 logical>		
FQI	<4896x1 logical>		
Viterbi_decoder	<51x1 logical>		
ans	<1x1 struct>		
str1	'Rx Antenna'		
str2	'From Channel'		
str3	'After Rake'		
str5	'After Derotation'		
str6	'After Pulse Shaping'		
str7	'From Channel'		

Stack: Base plot(After_Rake_Receiver)

Command History

Start

EN

4:38 AM
23/8/2014

Appendix v: List of Abbreviation

AKA: -	Also Known As
AUC: -	Authentication Centre
BSC: -	Base Station Controller
BSS: -	Base Station Subsystem
BTS: -	Base Transceiver Station
CCR: -	Call Completion Rate
CDR: -	Call Drop Rate
CHSR: -	Call Handover Success Rate.
CSSR: -	Call Setup Success Rate
EDGE: -	Enhanced Data Rates for GSM Evolution
EIR: -	Equipment Identity Register
ETSI: -	European Telecommunications Standard Institute
GOS: -	Grade of Service
GPP: -	Generation Partnership Project
GPRS: -	General Packet Radio Services
GSM: -	Global System for Mobile Communication
HLR: -	Home Location Register
HOD: -	Head of Department
HSPA: -	High Speed Packet Access
IMEL: -	International Mobile Equipment Identity
IMSI: -	International Mobile Subscriber Identity
IMT: -	International Mobile Telecommunications
ISO: -	International Organization for Standardization
ITU: -	International Telecommunication Union
KPI: -	Key Performance Index
LTE: -	Long Term Evolution
LTE-A: -	Long Term Evolution Advanced
MCN: -	Mobile Cellular Networks
ME:-	Mobile Equipment.

MNP: -	Mobile Number Portability
MS: -	Mobile Station
MSC: -	Mobile Switching Center
MTP: -	Mobile Trusted Platform
MWBA: -	Mobile Wireless Broadband Access
N.C.C:-	Nigeria Communication Commission
NSSS: -	Network-and Switching Subsystem
OMC: -	Operation and Maintenance Center
OMSS: -	Operation and Maintenance Subsystem
PNL: -	Private Network Links
QOS: -	Quality of Service
RAN: -	Radio Access Network
RSS: -	Radio Subsystem
SC-FDE: -	Single-Carrier Frequency-Domain-Equalization
SDCCH: -	Standalone Dedicated Control Channel
SIM: -	Subscriber Identity Module
UMTS: -	Universal Mobile Telecommunication System
VLR: -	Visitor Location Register