MIDLANDS STATE UNIVERSITY

Quality of Service measurement and evaluation in Telecommunications: A case study of Africom (Private) Limited

By

Sakhile Ndlovu

R115517V

Submitted in partial fulfilment of the requirement of the degree of

Telecommunications Honours

Department of Physics and Telecommunications in the

Faculty of Science and Technology at the

Midlands State University

GWERU

May, 2014

Supervisor: A Nechibvute

Co-supervisor: F Mazunga

Abstract

This research work studied the behaviour of Africom's converged network, measured and evaluated the QoS of service of the network with the various traffic streams. Its objective was to identify and measure the different metrics that affect the delivery of QoS in the network. Parameters for measuring QoS were be identified and measured and the overall performance of the network evaluated. The approach that was adopted was guided by the subscriber concerns as well as the technical parameters that support conformance to networking standards. The measurement process made use of three methods to measure and evaluate the service: live tests, customer satisfaction surveys, as well as mobile switching centre statistics and monitoring. A conclusion was drawn on whether the different approaches used complement or work against each other in evaluating the QoS of the network under study.

DECLARATION

I, Sakhile Ndlovu student registration number **R115517V,** hereby declare that I am the sole author of this thesis. I authorize the Midlands State University to lend this thesis to other institutions or individuals for the purpose of scholarly research.

Signature ______________________________ Date __________________________

APPROVAL

This dissertation entitled "Quality of service measurements and evaluation in Telecommunications: A case study of Africom (Private) Limited" by Sakhile Ndlovu meets the regulations governing the award of the degree of Telecommunications of the Midlands State University, and is approved for its contribution to knowledge and literal presentation.

Supervisor……………………………………………………..

Date………………………………………………………….

Acknowledgements

I would like to extend my profound gratitude to my family, friends and colleagues for their support throughout the time that I was carrying out the research. Most importantly, I would like to acknowledge my husband and daughter who has been my pillar of support and for encouraging me to pursue my studies in this field. Their support and patience kept me inspired and motivated throughout the project.

I would also like to express my sincere gratitude to my supervisors and lectures for the support and guidance. Their input into my academic career has been invaluable. I would also like to thank the members of staff in the Department of Physics and Telecommunications for their contribution throughout the three year period of my studies. The input they have contributed shall forever be treasured.

My thanks also go to Africom personnel in different departments who helped me gather all relevant data that saw this work a success. Special mention will go to Progress Nyahuma in the Service Management Centre department, Fine Jakata, the Network Planning Engineer, Joshua Tayengwa in IP Services, Fungayi Mashayanyika in the Operations department, Chad Gorerokufa Brand Experience department and the Bulawayo team.

My sincere thanks and gratitude goes to Ms. Sibonginkosi Muteyiwa from the Post and Telecommunications Regulatory Authority in Zimbabwe and Mr Comfort Muchekedza from the Consumer Council in Zimbabwe based in their Bulawayo office. I appreciate the time they took off their busy schedules to assist with my project.

Above all I would like to thank God for giving me hope and faith that saw the completion of this work. His grace has kept me afloat and inspired.

List of acronyms

3GPP2	3rd Generation Partnership Project 2
AAA	Authentication, Authorization and Accounting
ACSI	American Customer Satisfaction Index
BCR	Base-Centric Routing
BSC	Base Station Controller
BTS	Base Transceiver Station
CCBS	Completion of Calls to Busy Subscriber
CCZ	Consumer Council of Zimbabwe
CDMA	Code Division Multiple Access
CNPs	Calling Party Numbers
COS	Class of Service
CSC3300	Call Session Controller 3300
Diffserv	Differentiated Services model
DS	Differentiated Service field
DSCP	Differentiated Service Code Point
FCS	Frame Check Sequence
FCT	Fixed Cellular Terminals
FER	Frame Erasure Rate
FIFO	Fist In First Out
GPS	Global Positioning System
HLR	Home Location Register
HSS	Home Subscriber Server
IAD	Integrated Access device
IETF	Internet Engineering task Force
Intserv	Integrated Services
IP	Internet Protocol
IPSA/DA	IP Source Address/Destination Address
IPv4	Internet Protocol Version 4
IPv6	Internet Protocol Version 6
ISUP	ISDN *User Part*
ITU-T	Telecommunication Standardization Sector of the International Telecommunications Union
KPI	Key Performance Indicators
LDP	label distribution protocol
LEN	Length
LSP	Label Switch Path
LSR	Label Switch Router
MAP	Mobile Application Part
MGW	Media Gateway
MOS	Mean Opinion Score
MPLS	MultiProtocol Label Switching

MRFP	Media Resource Function Processor
MSC	Mobile Switching Centre
MSCe	Mobile Switching Centre emulation
MTTR	Mean Time to Repair
MWRR	Modified Weighted Round Robin
NE40E	NetEngine40E series router
PDD	post dial delay
PDN	Public Data Network
PDSM	Position Determination Service Module
PHB	Per Hop Based
PLMN	Public Land Mobile Network
POTRAZ	Post and Telecommunications Regulatory Authority of Zimbabwe
PSTN	Public Switched Telephone Network
QoS	Quality of Service
RED	Random Early Detection
RF	Radio Frequency
ROI	Return on Investment
SBC	Session Boarder Controller
SCP	Service Control Point
SIP	Session Initiation Protocol
SMS	Short Message Service
SPSS	Statistical Package for Social Sciences
TCB	Traffic Conditioner Block
TOS	Type of Service
VDSL	Very high bit rate Digital Subscriber Line
VoIP	Voice over Internet Protocol
WCDMA	Wideband Code Division Multiple Access
WFQ	Weighted Fair Queuing
WMS	Wireless Media Server
WRED	Weighted Random Early Detection

Contents

List of Figures

List of Tables

CHAPTER 1: INTRODUCTION

1.1 Problem statement

End to end quality of service (QoS) in telecommunications is defined as the ability of a service to deliver the implied and stated user requirements as well as conformance to standards. It is the telecommunications network's ability to meet the consumers' implied and stated needs in its totality [1]. Measuring quality of service provides the basis on which key decision with regards to network pre-planning; re-engineering; optimisation and purchase decisions are based. The measurement process provides the basis for the evaluation of the network service.
In measuring quality of service three parties have been identified as the key stakeholders and beneficiaries to the QoS information, that is, the service provider, the user and the regulatory authority or consumer support groups. The measurement of QoS provides the different users with the tools required to evaluate the performance of the networking systems and support the QoS audit and assessment processes.

For the service provider, QoS information provides the information required in network planning, pre- and post-implementation and during network expansion. It gives an indication of the overall network performance and supports sound decision making processes required in the acquisition of additional networking infrastructure equipment and in communicating to the subscribers the proper information on the level of QoS that the network is able to deliver. The methods used in measuring QoS provide results that can be readily used in network optimisation which may involve network reengineering and reconfiguration. It provides the basis for benchmarking network performance against that of competitors and identifying areas of weakness that need to be improved on. It helps in identifying future needs in terms of infrastructure and resources. Service providers are able to carry out their own performance evaluation and implement corrective measures required to provide a competitive service to their consumers. The service provider is also able to identify the critical customer concerns that they need to meet in order to retain their existing customer base and gain a competitive advantage over its competitors.

From the perspective of the user, one is able to make a comparison on available service options and make an informed choice on the best service that meets their QoS requirements. A user's decision is affected by expectations and the decision to maintain a specific service is largely dependent on the perceived QoS, that is, on whether the service has met the customer expectations. The results of this research should enable consumers to be able to make decisions on which service provider to take up based on the impact of each promised level of QoS on their operations and they should be able to evaluate for themselves if the service provider's claims are realistic if they are already using the service.

For the Post and Telecommunications Regulatory Authority of Zimbabwe (POTRAZ), the work will seek to identify the most objective method that can be used across all competing services. A benchmark QoS level will be defined for the measurement of QoS and this provides POTRAZ with the basis upon which QoS can be regulated and monitored objectively across all service providers. The measurement of QoS also provides the regulatory authority with the actual information of the QoS of each service provider which can be used in enforcing compliance to predefined or preset standards according to individual licensing agreements. POTRAZ will be able to identify key performance indicators for QoS monitoring as well as classification of services according to QoS characteristics. With specified and standardised quantifiers, POTRAZ in conjunction with the Consumer Council of Zimbabwe (CCZ) will also able to implement suitable strategies of consumer protection.

Since the technical skills of these users of the QoS information vary it is imperative that information presented to them on QoS should consider their degree of expertise in the field. Information on the measures which will be used to quantify the QoS characteristics of network should be related to the expectation of the concerned parties in a language they are conversant in.

1.2 Motivation and background

Growth and evolution in the telecommunications industry has seen movements from the traditional, predominantly analogue systems to digital technology which allows the integration of multiple services onto a single platform [2]. The growth in multimedia applications requiring network infrastructure as backbones and the huge investment cost in setting up the network has motivated convergence of applications into one network. Multimedia applications have complex bandwidth and QoS requirements which have to be supported on the single networking platform [3]. The various demands of the applications require the network to be capable of supporting real time and non real time applications as well as video and audio streaming on the same network infrastructure with differing QoS requirements. QoS policy implementation provides the means of optimizing bandwidth utilization; the policies further support the QoS management which is a necessity in order to provide usable and reliable network services. QoS enables efficient utilization of network capacity meeting traffic performance requirements and achieving high throughput.

When subscribers use a telecommunications service they are concerned with the end to end experience and as such their evaluation is based on the quality of service from the point of service initiation or request and connection right through to the termination of the connection [4]. The main objective in implementing and measuring QoS therefore is to ensure end to end reliability of the service while at the same time conforming to standards.

To maintain the integrity of traffic being transmitted, the network needs to be cognisant of the different traffic streams that it is transmitting and transmit within specified QoS parameters of each individual traffic stream. Reliability and performance of applications that require enhanced network performance characteristics on an end to end basis is improved through frequent measurement, network optimisation and management of QoS by the service providers. As such, quality of service within the network needs to be measured and monitored in order to support the various support departments in making the appropriate decision with regards to maintaining a specified QoS level.

1.3 Literature Review

A lot of work has been done in the field of measuring QoS in telecommunications. Systems and models [5]; [6]; [7]; [8]; [9] have also been designed and used to measures quality of service of telecommunications networks. Other methods focus on the technical characteristics of the network and their measurement in order to determine the level of QoS delivered by the network under specific traffic characteristics and conditions [10]. Some of the approaches that have been adopted focus on measuring QoS based on predefined key performance indicators specified by recognised bodies like Internet Engineering task Force (IETF) , International Telecommunications Union (ITU-T) and Third Generation Partnership Project 2 (3GPP2) [11]; [12].

A system was developed by Beuran et al [5] to measure quality of service for purposes of identifying application requirements. The designed system is able to objectively measure quality of service in a network. Parameters such as latency, jitter, packet loss and throughput were identified as the indicators of the level of QoS delivered. The system monitors traffic to measure the above parameters and simultaneously measured the user perceived QoS to enable correlation of the two. The method of measuring quality of service monitors the device behaviour as well as suitability of the network in delivering the quality of service required by the different applications.

Roberts [6] did an analysis of the statistical nature of IP traffic and the way it impacts QoS. His work looks at the different classes of IP traffic in a converged network to identify individual requirements. QoS models are looked into at length with critical analysis of past congestion control mechanisms. A flow aware networking architecture is proposed in the form of a cross protect router. He focused on the means of achieving QoS with consideration to pricing and the return on investment (ROI) of the chosen QoS policy. Traffic is classified according to different bandwidth and flow characteristics which impact the QoS guarantee as well as looking at the relationship between demand, capacity and performance in implementing QoS in a cost effective manner. Issues that affect the various traffic types are identified and proposed as suitable quantifiers for measuring quality of service for example jitter in packet traffic. He further looks at how each quantifier can be improved using the available QoS guarantees for the different traffic priority classes using Diffserv, Intserv and MPLS. Advantages and disadvantages are looked into in detail and it is clearly specified that each traffic classification requirements is based on the customer specifications.

An American Customer satisfaction index (ACSI) model was developed in America to measure customer satisfaction and was applied to the Macedonian mobile market in previous work [7].The ACSI model gives an indication of the value and quality of service and goods across industries based on the customer views and experience. This is a cause-effect model with satisfaction in the centre and indices for drivers of satisfaction situated on the left. The outcome of the satisfaction is located on the right hand side. The implementation of the ACSI model is shown in figure 1.1 below:

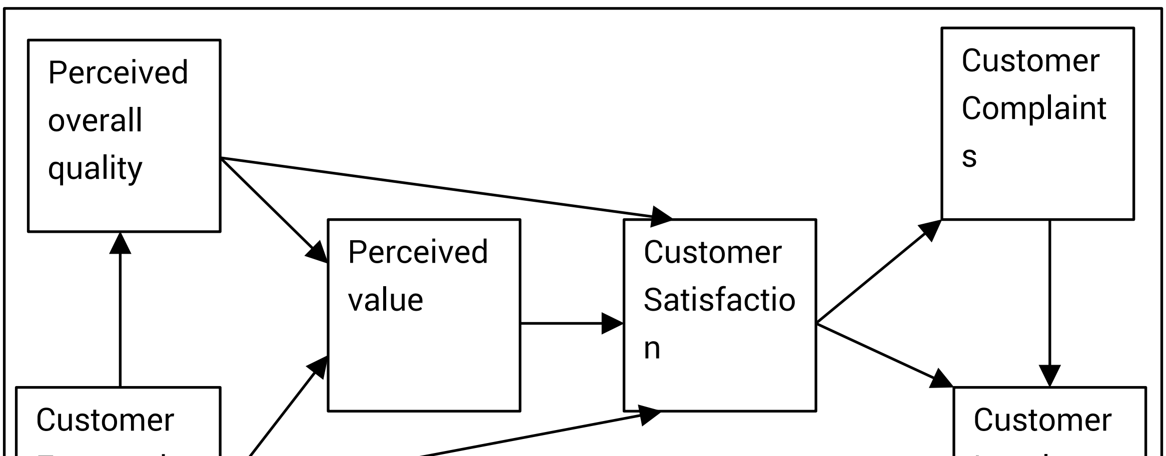


Figure 1.1 ACSI customer satisfaction model [7]

The ACSI model identifies three factors or indices that contribute to customer satisfaction as being the perceived quality, the perceived value and the customer expectation. The outcome of customer satisfaction is identified to be customer complaints and customer loyalty. The methodology adopted in the ACSI model is to ask users a number of questions which assess the three input indices and each response is weighted on a scale of 0-100.The overall strength of each indices on the outcome is quantified by the ACSI model. The ACSI model gives the service provider an indication on the impact of each index and enables the service provider to identify areas of weakness that need to be improved on.

Angelova [7] emphasizes that measuring QoS for services is not easy as there are no tangibles to measure unlike goods and as such quality of services are based on the users comparison of the service performance to their expectations. QoS is further affected by the user’s experience in relation to the service provider’s service delivery process. The user satisfaction measurement on the quality of service from the major telecommunication service providers in Macedonia was done using the ACSI model with a 95% confidence level.

Gronroos [8] developed a model known as the functional and technical quality model which identified technical quality, functional quality and corporate image as being the three dimensions of quality. Technical quality was identified as the quality of the service that the subscriber gets after interaction with the service provider while functional QoS is how the user gets the technical outcome. His work placed emphasis on the fact that a good QoS is achievable if a service provider can successfully manage the perceived service quality. This is achievable by matching the perceived QoS to the expected QoS. The measure of quality of service in [8] looks at the gap between the perceived and the expected quality which are highly dependent on the subscriber.

Do Young [9] worked on a measurement analytic framework for estimating the overflow probability at a multiplexing point within the network. The thrust of the work was with measuring QoS at a network point where resources like bandwidth and network buffers are sharing and the probability of overflows is high. The framework uses statistical theories and principles to determine and measure the overflow probability which is then used as an indication of network congestion. The overflow probability is used in guiding decision making for network optimization. The framework acknowledges the long range dependence model as being most suited to measuring network bursts. A time scale is identified, called a dominant time scale, during which traffic is to be characterized in order to estimate the required QoS measures which typically include the buffer overflows and delay distribution. The goal of the framework was to develop a measurements analytic framework which is based on the dominant time scale to measure buffer overflow with a Gaussian process.

Khattar [10] carried out research work on QoS from the customer perspective. The work identifies eight primary dimensions of product quality as performance, features, reliability, conformance, durability, serviceability, aesthetics and the perceived quality as the key performance indicators. Dimensions of service quality on the other hand are identified as reliability, responsiveness, accuracy, employee knowledge, consistency courtesy and speed. Khattar further goes on to identify the QoS parameters which most telecommunications operator's measure and the sub parameters of the measurements. He discusses the different methods that have been adopted by the majority of the service providers to measure quality of service and these are identified as drive tests, measurements carried out from the mobile switching centre (MSC) as well as the use of the customer satisfaction index. The latter measurement method compares the user's perceived QoS to the user's expectations. Three aspects are identified as being the main contributors in determining the expected and perceived satisfaction levels and these are the actual delivered QoS, the perceived QoS delivered by competitors and the QoS in other markets. Key factors highlighted in [10] been adopted in the past by the various service providers and benchmarking the different service providers against their competition.

Pitas et al [11] carried out work on measuring quality of service of a mobile network that is based on wideband code division multiple access (WCDMA) technology. The focus of the work was to study the performance of a real life mobile network assessing the QoS performance of the radio access network, carrying out the audit of the network and benchmarking. The parameters under study were guided by the key performance indicators as identified by IETF [11]. Parameters studied include the network accessibility, throughput, latency and post dial delay and each of these parameters were measured using drive tests.

More research work has been done to determine suitable quantifies that are customer oriented to measure quality of service [12]. The work is based on research work carried out in over 130 network carriers, service providers, research companies and vendors across the world guided by ITU-T recommendations. Hardy looked at the means of measuring and evaluation QoS from the perspective of the consumer and relates it to that of the service provider. He evaluates each identified user concerns and tries to relate the user concern to a QoS that is relevant in the service provider's perspective. Various quantifiers are identified and network acceptable standard defined in the valuation process.

1.4 Aim

The aim of this research is to identify suitable measures and evaluate the QoS of a converged network. Three different approaches will be used to measure the QoS and a conclusion will be made on whether the approaches can work together to evaluate a service or against each other. The outcome of this research will report on the QoS level offered by the converged network as well as recommendations on how the methods of measurements can be improved where need be.

1.5 Objectives

The objectives of this work are:-

- Identification of the Africom network and application users for fixed and mobile broadband services, VoIP, fixed and mobile voice.
- Identification of suitable parameters and key performance indicators of measuring QoS for the various platforms and application services.
- Determination of suitable measures for the identified parameters and QoS measurement for each parameter.
- Data collection, compilation , manipulation and processing
- Evaluation of results and conclusion

- Recommendations on future work.

1.6 Conclusion

In this work suitable measurement parameters will be identified and evaluated to help the consumer, the service provider and POTRAZ to make the best decisions under the prevailing conditions. The results of the measurement process will be used to support decision making on the best service, required improvements on the service offered as well as monitoring and evaluation.

This work will combine a number of approaches adopted by some of the scholars [7]; [11]; [12]. Using the identified concerns it will look at the means of measuring quality of service based on the identified concerns using 3 methods; the customer satisfaction surveys, the live tests as well as the measurements from the MSC. Each approach will be explained in detail in the next chapter which covers the theoretical aspects of measuring QoS and evaluating it.

Chapter two will look at the theoretical aspects of QoS and its implementation in a converged network. It will detail the models that have been adopted in implementing QoS and the key concerns of QoS that are addressed by these models. Existing methods of measuring QoS will be explained in detail as well the key parameters that they measure will be defined.

Chapter three will look at the methodology adopted in carrying out the research work, this chapter will provide the information on how the actual information was collected. It will explain the systems and the equipment that was used in accessing the required data

Chapter four will provide details of the results and explanation of the data manipulation techniques adopted in this work. Conclusions based on the results will be drawn up in Chapter five.

CHAPTER 2: THEORETICAL ASPECTS

2.1 Introduction

This chapter gives a background on the theory of implementation of quality of service policies in a converged network .It looks at how the technical parameters that measure quality of service are measured and the calculations of each .The parameters of interest are in relation to a network that is under study and how they have implemented their QoS policies and what governs their measurement process.

2.2 Network topology

Africom is a network service provider operating a Converged IP based network. Their services include fixed and mobile data service on the wimax platform which is a wireless solution. They also offer VoIP services and have extended their service to include a Session Initiation Protocol(SIP) solution for voice .Their network combines a number of technologies that includes fixed wimax, fibre, CDMA2000 1x EV-DO Rev A , Very high bit rate digital subscriber line(VDSL) and Very small aperture terminal (VSAT) solution. The core network topology is as shown in figure 2.1 below.

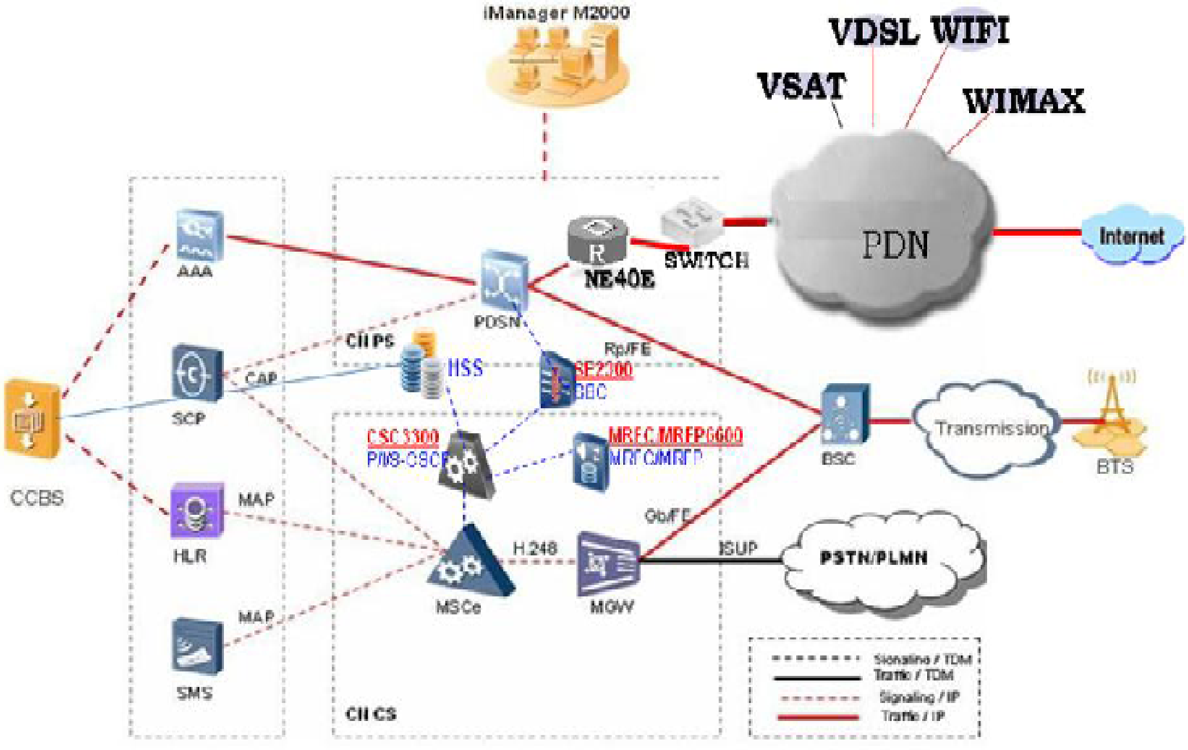


Figure 2.1 The Africom network topology [13].

The nature of the traffic transmitted within the Africom network is such that it varies in terms of their QoS requirements. The services they offer are IP based and since different applications respond differently to latency with varying bandwidth requirements , the organisation have adopted one of the QoS models in order to meet the QoS needs of each application. In order to deliver end to end QoS guarantee the policies adopted by the converged network should be able to perform traffic classification and marking, queuing, policing and shaping. It should be able to perform traffic prioritization of delay sensitive traffic. Classification and marking, queuing, congestion management, traffic shaping and policing are explained below.

With traffic classification and marking, packets are organised or classified according to priority on the inbound direction of the port [14]. Classification is concerned with how traffic is identified and marked in the network. Priority classes are configured based on IP precedence DSCP value of IP packets and COS value of 802.1p packets. It is predefined or configured in the Type of Service field (TOS) in a packet header indicated in the packet below.

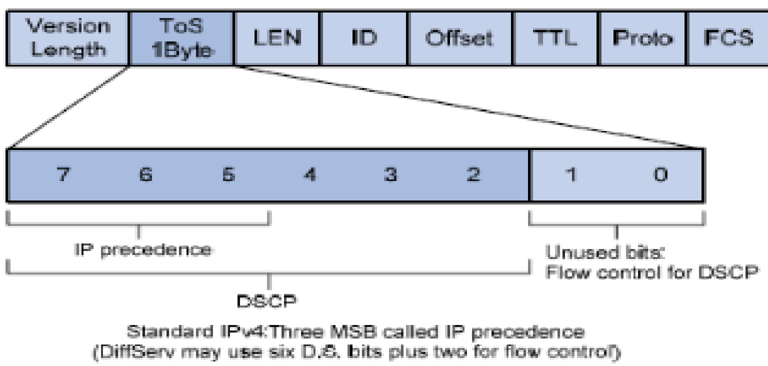


Figure 2.2 IP Level QoS classification: -DSCP/IP [14]

At frame level the Virtual Local Area Network identification (VLAN) ID defines the COS priorities used in forwarding the frame.

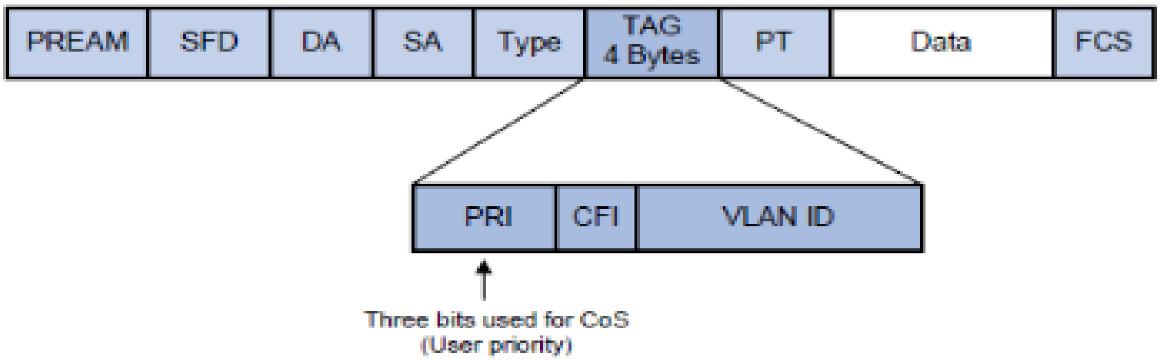


Figure 2.3 Frame level QoS classification 802.1Q COS [14]

Queuing mechanisms make use of high performance memory buffers to hold data before it is processed. This enables temporary storage of packets to accommodate slow packets before they are forwarded to the intended destination as well as avoiding overwhelming the receiver in areas of bottlenecks or shared resources like multiplexers.

Congestion management implements measures for handling resource competition in the event of congestion, usually applied in the outbound direction. It buffers packets and makes use of a scheduling algorithm to arrange the forwarding sequence of the packets. Congestion avoidance, usually applied on the outbound interface, monitors the usage status of the available network resources and reduces the amount of traffic by dropping packets in the queue when there is excessive congestion.

Traffic shaping is applied in the outbound port direction of the downstream device and adapts the output traffic rate to the available network resources to reduce the incidence of dropped packets and network congestion. Policing implements policies that follow flow configurations specified in the inbound port direction. When there is congestion or excessive flows it imposes restrictions and penalties to reduce the excessive use of network resources.

The mechanisms above are employed by the various QoS models in order to deliver end to end QoS as per application requirements. There are three models that have been adopted over the years that are the Intserv, Diffserv and the MPLS. Traditionally the internet service have been offered on a best effort QoS policy which has no traffic classification and traffic prioritization mechanisms using the First In First Out (FIFO) principle.

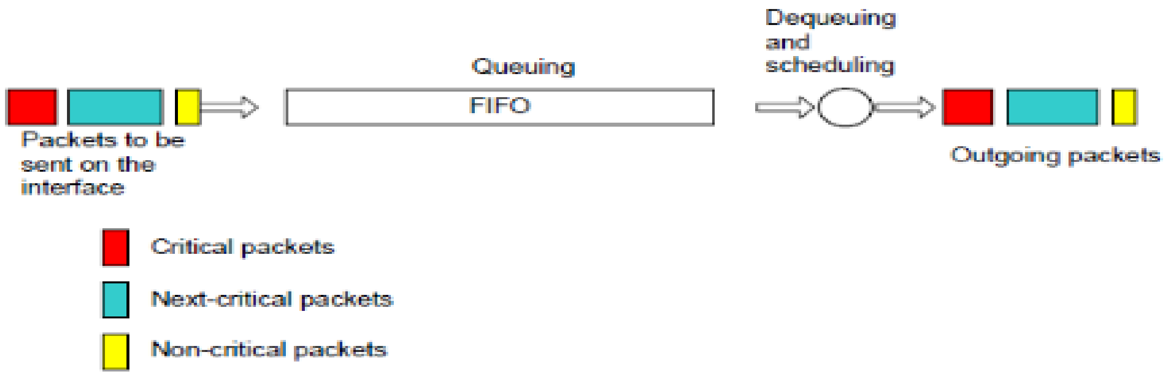


Figure 2.4 FIFO Queuing [14]

Best effort does not provide any traffic guarantees on jitter, delay, packet loss ratios and reliability. In best effort the application does not request for permission to transmit or make a reservation to the network it simple sends its traffic and the network forwards it with no guarantees.

2.3 QoS implementation models

2.3.1 Integrated Service (Intserv)

It was the initial effort in the implementation of QoS by IETF. Intserv [15] accommodates traffic of various classes. It makes use of out-of-band signalling protocol called resource Reservation Protocol (RSVP) .Applications request for a specific service from the network ,that is ,traffic parameters like jitter, delay and bandwidth are requested before sending their transmissions and these are reserved on each router along the path. After checking that it has resources, the network maintains a state for each traffic flow and keeps traffic classification, policing, queuing and scheduling for each state which is identified with session identifier that uniquely maps to a <source-destination address, protocol>pair. Once the application gets the network acknowledgement on its request it starts to transmit and the negotiated parameters are maintained for as long as the traffic is being transmitted. Intserv provides guaranteed service with assured bandwidth and limited delays as well as the controlled load service which guarantees some applications low delay and high priority to reduce the impact of overloads when they occur. The weakness of Intserv is that due to its traffic negotiation process it is not scalable over the internet which would require a large number of sessions.

2.3.2 Differentiated services model (Diffserv)

Diffserv was developed to overcome the shortcomings of Intserv, which is, that of scalability of multiple sessions existing on a single backbone [15]. This model was adopted as it was taking less processor powers through computation and maintaining of session on the router and hence the model was noted to be cheaper to implement. Allocation of resources in Diffserv is on a per hop basis on each router .With Diffserv, traffic flows are classified according to predetermined rules resulting in a few sets of class flows. Traffic is classified at the border router for consistent treatments at each transit or core along the network. The classification is based on IPV4/IPV6 'Types of Service' (TOS) field also known as the Differentiated Service field (DS). It makes use of 2 bits with the remaining six being reserved for future use. The code points of the DS field determines the standard code point .Each router along the path reads the code point and uses it to determine the traffic class used in the classification process. Diffserv makes use of per hob based forwarding (PHB) and because of this the behaviour of traffic along the route is unpredictable.

All traffic classification and traffic conditioning is performed by the border router. Packets are forwarded based on the content so the packet header and checked by the meter for compliance to traffic conditions .The results of the meter are forwarded to the marker or dropper for decision making. The markers simply write or rewrite the DSCP while the shaper delays the packets to make the flow compliant with the profile. The role of the dropper in the traffic conditioning process is to drop or discard some packets in the traffic stream to bring traffic in compliance with the traffic profile. Diffserv makes use of FIFO, Weighted Fair Queuing (WFQ), Modified Weighted Round Robin (MWRR) and Modified Deficit Round Robin (MDRR) queuing policies to manage the queuing process. For congestion avoidance it makes use of Random early detection (RED) and Weighted Random Early detection (WRED) algorithms which minimise packet delay by controlling queues.

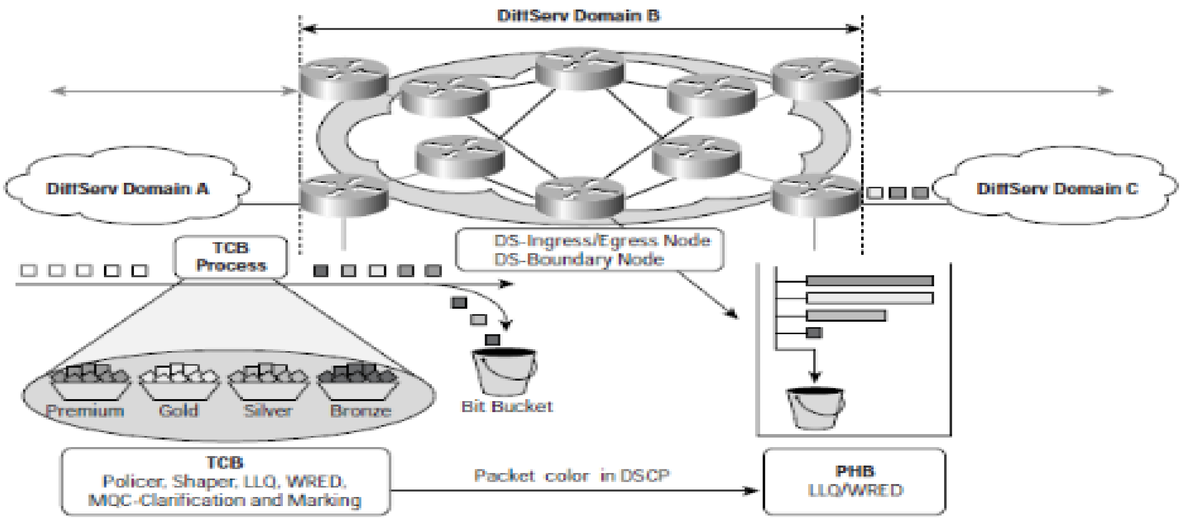


Figure 2.5 Implementation of Diffserv QoS model [16]

2.3.3 Multiprotocol Label Switching (MPLS)

MPLS is based on the Diffserv QoS model and hence interoperation of network operating with Diffserv and MPLS is not very difficult. In MPLS the forwarding of packet is done by the Label switched router (LSR) which matches the label on the MPLS domain. MPLS makes use of the label distribution protocol (LDP) to distribute label switch paths (LSP) which are then used as tunnels between the layer 2 and 3 of the OSI model; packets are classified at the border router with an MPLS header. The header comprises of a 20 bit label with 3 bits for the class of service (COS) field, 1 bit stack indicator and 8 bit Time-To-Live (TTL) field. The label is used as an index to search through the forwarding table .After the LSR finishes processing a packet it discards the incoming label and it is then replaced with an outgoing label before the packet is forwarded to the next LSR. Multiple traffic streams are then aggregated into a single traffic trunk (LSP) of the given class of service .The implementation of MPLS enables faster classification and forwarding of packets and efficient tunnelling [17].

The network under study implements the MPLS QoS model in order to deliver end to end Quality of service for all traffic streams within network. The core of the network is based on the MPLS internetworking with the Diffserv architecture. The delivery of QoS is guaranteed within the network although some of the end user routing terminals may be based on a best effort model with no QoS guarantees.

2.4 Methods of measuring QoS

Methods that have been identified as being regularly used to measure quality of service performance are highlighted in this section. These include measuring customer satisfaction through customer surveys, the use of monitoring and measurement software from the centralised Mobile Switching Centre (MSC) as well as measuring the identified key quality indicators of a given network service using live tests or drive tests.

2.4.1 Customer Satisfaction Surveys

Consumer surveys provide the service provider with subjective customer feedback. They give an indication of the perceived quality of [18] by pinpointing points of weakness of a the service whose QoS is being measured. Perceived quality of service is the quality of service that is experienced by the user of the service. Customer surveys give an indication of the gap between expected quality of service to the actual perceived QoS [6]. When users subscribe for a service a number of factors determine their choice of service and these contribute largely to their expected QoS. These include the technical and operational characteristics, the mood, the environment and prevailing promotions at the time of purchase. These build the user's expectation on the performance of the service and eventually affect the way the level of satisfaction once the service has been used. The user's expectation gives an indication of some of the key quality indicators of the service that will be expected during its operation. The gap between the expected and the perceived QoS give an indication of the level of user satisfaction and is an indication of the quality of service from the user's perspective.

2.4.2 Live Tests

2.4.2.1 Drive test

Drive tests are used to give an indication of the quality of service of a mobile network as experienced by the mobile user [18].They duplicate the challenges that subscribers face as they travel along the network coverage zone from sector to sector. Typical problems that can be experienced by users include blocked calls, poor voice quality and poor coverage. The drive test provides the information of these based on time, location as well as the Forward link Frame Erasure rate (FER) which gives an indication of the link quality. This method is usually adopted by mobile communications services and provides information on QoS at a given time instance and location. The test is carried out using a customised testing vehicle or device. Drive tests support network optimisation and troubleshooting and addresses issues to do with coverage and network performance issues. They can be used to investigate QoS concerns through tests carried out on the same route for a given period at the same time of the day usually peak periods over an agreed time period.

CDMA networks are prone to interference and fluctuating coverage due to the cell breathing phenomenon as network traffic increases. This affects network coverage of each sector resulting in poor delivery of QoS in previously covered sections. Drive tests collect data on radio frequency coverage area and makes use of post processing tools to identify the causes of the RF issues. A phone based driver test makes use of a mobile phone, a GPS locator, licensed drive test software and a laptop. The drive test system measures the pilot channels which is the unaltered CDMA's short code .The timing offset of the pilot channel's short code is measured by the receiver. Pilot scanning provides an idea of the coverage and the results of the test drive give an indication of the Ec/Io of the Pilot channel. The Ec/Io gives a measure of the amplitude of the power of each received channel. The Ec is a signal strength measurement of the pilot dBm while the Io is the total power in dB within the 1, 25 bandwidth channel. Ec/Io therefore gives an indication of the power of an individual base station or sector to the total power in the channel or the overall interference. This ratio provides comparison information of the power level of the different base station in each channel.

The phone based system [19] is preconfigured to measure specific parameters of the pilot and the threshold values are specified before the test is carried out. The system measures the preconfigured pilots and categorises them into active, candidate, and neighbour with the rest classified as remainder pilots. Active pilots are those that are currently involved in processing the call reception and transmission. Pilots transitioning either to or from being active pilots are called candidates while the neighbours are those whose probability of qualifying the active set is very high. During handover the neighbours list comprises of neighbour associated with each sector involved in the handoff. Pilots are displayed in different colour that is red for active, yellow for candidate and blue for neighbours.

2.4.2.2. Native live testing

Native tests include testing the audio quality of a line by making actual test calls to different destinations and asking call recipients to rate the quality of the call using a MOS rating scale. The MOS gives an indication of the quality of voice from the connection. This method is used to quantitatively express the quality of speech within a communications network .This gives as an indication of the perceived voice quality after reception. MOS is measured on a scale of 1 - 5 with 5 being the best perceived quality sound and 1 being poorest perceived what sound quality , the ratings are indicated in table 2.1

Table 2.1 Mean Opinion Score ratings [20]

MOS Rating	Quality	Impairment
1	Bad	Very Annoying
2	Poor	Annoying
3	Fair	Slightly annoying
4	Good	Perceptible but not annoying
5	Excellen t	Imperceptible

2.4.3 MSC statistics and tests.

Tests can also be carried out from MSC by monitoring network performance during a specified time domain during which certain traffic conditions persist; for example during peak traffic period. Various networks monitoring software can be configured to monitor and analyse specific network characteristics like jitter, latency, MOS, packet losses, packet discards and bandwidth utilisation.

2.5 Key Quality indicators

QoS models guarantee a certain level of QoS in terms of jitter, latency, bandwidth and prioritisation of packet and ultimately the performance of traffic along the network. These are the key technical characteristics that affect packet traffic as it is being routed through a network. Additional characteristics include the access speed, that is, the data throughput that a network is able to deliver measures in bits per second (bps) as well as the network congestion.
Indicators of quality of service include latency, jitter and network availability [21]; [22]. 3GPP2 [23] define KPIs based on the end to end delivery of QoS. KPIs test the QoS across different networks over a period of time using specified and agreed on key performance indicators. Comparisons made with this approach are objective. The regulating authority in consultation with service providers agree on the acceptable indicators for the services and measurements are carried out within the scope of the measurement guidelines and expected QoS [18].

Typical examples of indicators that are measured include latency, jitter, network availability and dropped call ratio (DCR) just to mention a few. The different indicators are explained in detail below

2.5.1 Latency

Latency is defined as the end to end delay. For a packet n it is calculated as

Eqn 2.1

Where
Arrival $_n$ is the arrival time of packet n
Departure $_n$ is the departure time of packet n at the source.

2.5.2 Jitter

Jitter is the delay variation between consecutive packets in the same traffic streams. Jitter is calculated in milliseconds (ms) as:-

Eqn 2.2

Where

L_{max} is minimum latency

L_{min} is minimum latency

Another method for calculating jitter using the packet arrival time is shown below:-

Eqn 2.3

Measurements of jitter can also be computed using centralised network monitoring software enabling measurements of the behaviour of the network in real life situation. Additional technical concerns when measuring QoS include the packet losses which can be measured through telnet sessions and accessing of traffic performance statistics at interface level.

2.5.3 Network availability

Network availability is the probability that service will be offered to the user when needed. Availability is measured as a percentage (%) and it gives an indication of the number of times that the broadband service is accessible. It is calculated as follows:-

Eqn 2.4

Where

A is availability

F number of failed attempts

T number of successful connections

Alternatively it can be calculated as:-

X100 Eqn 2.5

Where:-

MTBF is the mean time between failures

MTTR is the mean time to repair

2.5.4 Dropped call ratio

Dropped call ratio is the proportion of calls that are dropped due to network problems or failure after being successfully connected before the user terminates the call. This is expressed as

Eqn 2.6

2.5.5 Blocked Call rate

Blocked call rate (BCR) it is a measure of the probability that a call will be blocked as a result of unavailability of resources to process that call. It is calculated as:-

Eqn 2.7

2.5.6 Call setup success rate (CSSR)

CSSR is the percentage of calls successfully setup; it is an indication of the probability of success in setting up a call calculated as:-

Eqn 2.8

2.5.7 Session setup success rate (SSSR)

This is used to evaluate the accessibility performance of a network; it is a ratio of the successful originating session establishments to all the session origination attempts

SSSR= Eqn 2.9

2.5.8 Dropped call rate (DCR)

This gives an indication of the number of calls that are disconnected prematurely before the user completes their conversation. These are due to handover failures, network congestion and radio loss.DCR is calculated as:-

DCR= Eqn 2.10

2.5.9 Handoff success rate (HSR)

It is a measure of the probability of success of the handover process as the user is mobile within a network cell. Calls are transferred or handed over from one cell to the next as the user moves and the degree of success is calculated using the following formula:-

HSR= *Eqn 2.11*

2.5.10 Service activation time (SA)

Service activation or provisioning time is the total time it takes for a customer to get a service from the time they have provided all the obligations. This is calculated as:-

SA

Eqn

2.12

2.5.11 Traffic channel congestion ratio (TCH)

It is a measure of the probability that a call will not be successful due to congestion on the network or unavailability of the radio network.

2.5.12 Mean time to repair (MTTR)

Mean time to repair is the minimum time it takes from the time the service is reported or noticed to be down to the time that full functionality of the service is restored. This is also known as Service restoration time.

2.5.13 Post Dial delay (PDD)

PDD is the total time taken from the time a caller dials the last digit to the time to of getting acknowledgement of call request in the form of either a number busy tone or ringing. It is also known as the call setup time also known as the post dial delay

2.5.14 Operator response time

It is the time taken from initiating an online or telephone query to the time it takes to get an answer or acknowledgement.

2.5.15 Bill correctness

Bill correctness is a measure of the bill correctness and complaints per 100 bills issued within a single billing period.

2.5.16 Audio quality

Audio quality tests the listening quality. It gives an indication audio sound quality during a call measured using the Speech Quality Index Mean Opinion Score (SQI MOS) of the call.

2.5.17 Network coverage

Coverage which is the percentage coverage of the network

2.6 Summary of KPI Characteristics adopted by Africom

According to telecommunications licensing requirements in Zimbabwe all service providers are required to submit copies of the service level contract to POTRAZ specifying the adopted KQIs upon application for a licence. Table 2.2 below provides a summary of the KQIs adopted by Africom for their Mobile services and table 2.3 for their wireless broadband and fixed services.

Table 2.2: Africom KPIs for Mobile services [24]

QoS Network performance	**Target level**
Supply time for connections	Prepaid:- 5 minutes

	Post paid:- Within 3 hours
Network coverage	100% coverage
Average time to respond to customer call	85% of calls within 35 seconds
Call setup time(PDD)	5 seconds on net, 10 seconds international during busy hour
SMS mobile originated/terminated Success	95% Delivered within 24 hour
Audio quality	SQI MOS score of (3.5
Fault repair time	95% within business hours
Call setup success ratio	>98%
Call drop ratio	<2%
Billing accuracy	<= 3 complaints per 1000 bills
EVDO Content Activation ratio	>=90%
Traffic channel congestion factor	<2%
1x Packet CSSR	>90%
Radio network availability	99.9%
MSC Availability	99.9%
Handover success rate	>90%

Table 2.3 Africom KPI for fixed and wireless broadband services [24]

QoS Network performance	**Target level**
Supply time for connection	90% completed within agreed schedule
Fault repair time	95% within 24 hours
Service Availability	>99.9%

Ratio of packet loss	<5% packet loss
Round trip delay	<<95 milliseconds national reference <250 milliseconds international reference
Jitter	<50 milliseconds

CHAPTER 3: METHODOLOGY

3.1 Introduction

The objective of this research work is to determine appropriate parameters that can be used to measure and evaluate Africom's Quality of service. This chapter will provide and account of the methodology that was adopted in carrying out the research work to meet the already stated objectives. It will detail the processes and the techniques determining which data to source as well as determining the sources of the desired data. It will further look at the data acquisition and manipulation of the sourced data.

3.2 Methodology formulation

Prior to any work being done the strategy formulation stage was done to determine the different processes that would be done and which resources would have to be allocated to each process or stage of the research process. The first step was to identify the stakeholders who would benefit from the measurements of QoS and to identify which QoS concerns they had. Each stakeholder had specific concerns that needed to be addressed and this determined the methods that would be adopted in measuring the QoS. This also involved determining the sample size, the sample period as well as determining the primary and secondary data sources. Decisions on how the measurement process would be carried out based on the data sources were defined.

3.2.1 Identifying stakeholders

The identified stakeholders were the different network users for the different fixed and mobile services; Africom Private limited, the service provider; POTRAZ and CCZ.

3.2.2 Identifying stakeholder concerns

The approach adopted was to initially get the opinions and input of the consumers through surveys and questionnaires. Methods adopted in carrying out the survey included telephone interviews, one of one interviews and email interviews. One on one interviews were carried out through routine customer visits as well as walk in clients.

Once consumer input was collected the information was used as a guideline in determining which operational and technical characteristics of the Telecommunications service had to be measured and the appropriate means of measuring them. To determine the appropriate key performance to measure; user concerns along with the regulatory requirements that the network based on its licensing agreement was supposed to meet. This approach was so that QoS was measured based on its ability to meets its user's need as well as conforming to standards.

3.2.3 Determining sample size and data to be collected

The network under observation spans multiple towns and data needed to be collected in all the towns. For the mobile voice and data services the customer base currently is 75 387 and the OMC statistics were able to fully capture the usage statistics of all active subscribers for the 28 day period.

For questionnaires and surveys, the cost of acquiring data through surveys in the entire country was too high so an assumption had to be made that the outcome of the feedback from Bulawayo and Harare was a true reflection of every user including the other smaller towns. The samples were taken out for five groups of service users, that are, the fixed broadband service users, with the second group being made up of mobile users and the third group comprising of users of both fixed and mobile services. A fourth group was made up of the members of the customer interfacing and support departments comprising of customer care agents, service maintenance engineers and the Customer relationship managers. The fifth group was made of the POTRAZ and CCZ. The total sample size was 62 and this was split into:-

- 21 fixed broadband users
- 18 mobile service users
- 13 fixed and mobile users
- 8 members of the customer interfacing departments

- 1 member of the regulating authority, and 1 consumer support group

The decision to include a higher percentage of fixed broadband subscribers was based on the ease of access to the sampling population. Fixed subscribers have a fixed location making it easy to contact them while the location of mobile subscribers is unpredictable. The demographic composition of the sample population further detailed below

3.2.3.1 Demographic composition of sample population

The demographic composition of the sample population can confidently support the findings as being a true reflection of the perceived QoS of the total population. It is comprised of people who make decisions to subscribe for the service, use, support or regulate it and have an appreciation of the meaning of QoS and how it impacts the service.

The educational qualification of the sample comprised of 48% with a maximum qualification of ordinary level and the remaining 52% having a tertiary qualification or higher. Table 3.1 gives the breakdown according to age and sex.

Table 3.1 Demographic composition of the sample size by age and sex

Class	**Percentage total**
Males	36%
Females	64%
17-20 Years	15%
21-30 years	57%
31-40 years	22%
Above 40 years	6%

Users were also observed to be using more than one service provider for Telecommunications services and the percentage composition of based on the number of service providers being used in shown in Table 3.2

Table 3.2 Demographic composition of the sample size by the number of Service providers being used

Service providers used	**Percentage Total**
1	19%
2	69%
3	12%
4 and above	0%

Different questionnaires were used for the different categories (See appendix 1- 4)

3.3 Data acquisition

With the strategy specified, data sources specified, the data acquisition stage involves the actual collection of both quantitative and qualitative data. The data sources were defined as the primary data sources, that is , first hand information specifically collected by the researcher and secondary sources which is information within access of the researches which could be from previous records and external sources. Method of acquiring such data is specified in the methodology formulation stage which defies the best method of accessing the appropriate data using affordable methods

The methods adopted in the data acquisition process were classified into primary and secondary data sourced and are detailed as follows:-

3.3.1 Primary Data Sources

3.3.1.1 Surveys and Interviews

A survey was used to measure the level of customer satisfaction, customer expectation and to determine customer's QoS expectations on the service that they are subscribing for. Part of the questionnaire process involved identifying the types of services used by the different subscribers. What made them opt for certain service providers – the decision criteria used and expected QoS from the chosen service provider was also researched on . The survey was done in three forms, that is, through one on one interviews, emails and telephone interviews. Samples of the questionnaires are attached in appendix 1-4

3.3.1.2 Live tests

Using the key quality indicators identified from the surveys live tests targeted at measuring the network performance were selected and carried out .Africom implemented the MPLS model with the objective to conform to the 3GPP2 [23] standards and to deliver quality of service to all application on a application to application basis end to end.

The live tests involved carrying out drive test on the CDMA portion of the network which offers mobile voice and data services. Before carrying out the drive tests the first objective was to identify a time slot during which peak traffic was observed along the route which was between 0800 hours till 1630 hours when the traffic would reduce. A single route was adopted and 5 tests were carried out on the same route. Equipment used in the drive test included 4 HTC mobile handsets operated in the idle and dedicated mode acting as probes, GPS as well computer running licensed TEMS investigation software version 15.3.3.

3.3.1.3 Statistics and Monitoring from MSC

IManager m2000 and SolarWinds open NMS were used to monitor and extract statistics not provided by the drive test to determine call attempts of all call connections initiated within the Africom network. Connection attempts as well as the data usage statistics on the mobile devices were used as an indication of the usage patterns and as a means of determining network availability for the test subjects for a period of 28 days.

For the fixed wimax platform lives tests involved the use of network monitoring software (NMS) and base station logon. The NMS gives state information of each node connected to the network whether it is up or down giving an indication of how long the node has been down. Backbone throughput and capacity was also monitored against the individual node demands to check the effectiveness of the traffic shaping. Logon into the different nodes provided statistics on the interface behaviour; these were done under extreme load conditions to observe the behaviour of router in terms of latency, transmitted packets, jitter, packet discards. On the radio network statistics like the radio network utilisation were extracted for comparison with the results of the drive tests

3.3.2 Secondary Data sources

OTRS software system was used to keep track of faults and progress status update on faults. The system was used to monitor repeat faults and the nature of faults. Target faults were faults regarding degradation of service like slow speeds and the resolution times which gave an indication of the availability of the network. Nodes with a history of repeat network degradation faults were further checked at interface level for packet discards, the link performance in terms of latency as well as implementing configuration of QoS on the end router and further testing for latency, throughput packet losses and discards. Mean time to repair was also extracted from the system

For Fixed Cellular Terminals (FCTs) and Integrated Access device (IAD) records of tests from surveys carried out to determine the MOS, Jitter and latency done by the Enterprise implementations department were used. Pre implementations test records gave an indication of post dial delay (PDD) for 5 customer sites. The distribution of the implementations was spilt into 1 Gwanda, 3 Bulawayo installations, 1 Gweru installation and 1 Victoria Falls installation. Calls were initiated by the implementation engineer to the following destinations and in each case the PDD, MOS, latency and jitter were observed and recorded:-

On net calls to Africom Contact centre and Africom Bulawayo Table 3.3 shows the destination test list.

Table 3.3: MOS Test Calls

Called network/ country	**Call destination**	**ON NET**	**OFF NET**	**REGIONAL**	**INTERNATIONAL**
Africom	Contact centre	X			
TELONE	Gwanda, Bulawayo, Beitbridge, Kariba, Harare		X		
Econet	2 Econet subscribers		X		
Netone	2 Netone subscribers		X		
Telecel	2 Telecel subscribers		X		
South Africa	Any 2 different networks			X	
Namibia	Any 2 different networks			X	
UK	1 Fixed and 1 Mobile				X
USA	2 Fixed and 1 Mobile				X

The outcome of the analysis was evaluated based on the arithmetic mean as well as the standard deviation of the perceived KPIs being measured.

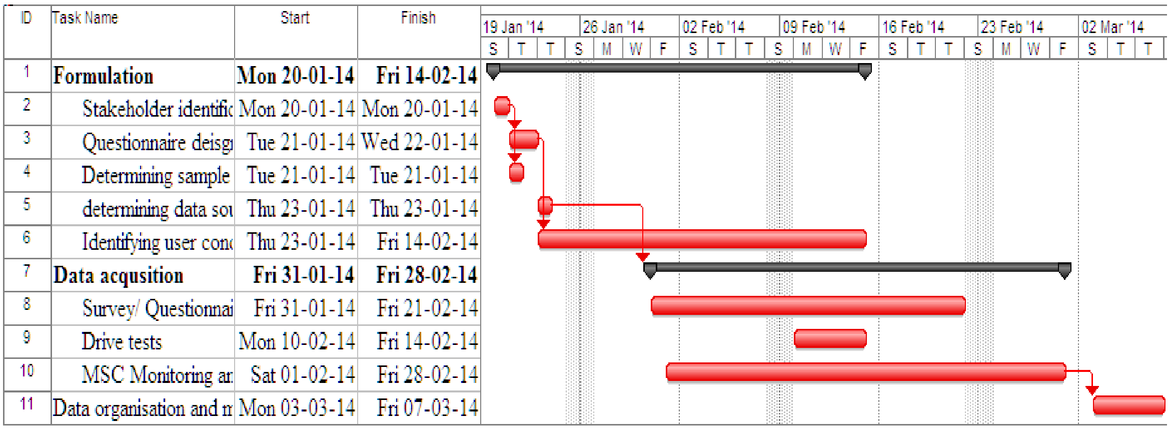
3.4 Data organising and manipulation

The process involved the formatting of data to formats that are easy to understand that support easier evaluation of the data. This involved the use of statistical software and graphs and visual aids.

From the MSC, Network monitoring software was also used to collect and carry out the required data manipulation techniques before evaluation of the results of each individual node connected on the network. Results of the surveys and questionnaires were collected, managed and analysed using Statistical Package for Social Science 16.0 (SPSS) for quantitative data. The outcome of the analysis was evaluated based on the arithmetic mean as well as the standard deviation of the perceived KPIs being measured.

The work breakdown is detailed in the Gantt chart below

Project Name	QoS Measurement



ID	Task Name	Start	Finish
1	**Formulation**	**Mon 20-01-14**	**Fri 14-02-14**
2	Stakeholder identific	Mon 20-01-14	Mon 20-01-14
3	Questionnaire deisgi	Tue 21-01-14	Wed 22-01-14
4	Determining sample	Tue 21-01-14	Tue 21-01-14
5	determining data sou	Thu 23-01-14	Thu 23-01-14
6	Identifying user conc	Thu 23-01-14	Fri 14-02-14
7	**Data acqusition**	**Fri 31-01-14**	**Fri 28-02-14**
8	Survey/ Questionnai	Fri 31-01-14	Fri 21-02-14
9	Drive tests	Mon 10-02-14	Fri 14-02-14
10	MSC Monitoring ar	Sat 01-02-14	Fri 28-02-14
11	Data organisation and m	Mon 03-03-14	Fri 07-03-14

Figure 3.1: Gantt chart of project tasks

CHAPTER 4: RESULTS AND ANALYSIS

4.1 Introduction

This chapter presents and analyses the results acquired during the data acquisition stage. The approaches adopted in acquiring the data involved customer satisfaction surveys, live and drive tests, and OMC monitoring statistics and tests. The results were solicited on a platform by platform and service by service basis. The objective was to evaluate the end to end reliability of the network within and right through to the border router, on the various platforms. All acquired data was extracted, organised, manipulated and analysed using NMS, OTRS, VX view, Excel, SPSS and presented using frequency tables, pie charts and graphs. Conclusions on the overall network performance evaluation will be drawn after individual evaluation of all nodes on the network.

4.2 Customer Satisfaction Results and Analysis

The customer satisfaction survey made use of a three part survey. The first part of the survey used structured questionnaires to get the user view on their major concerns on the service being delivered to them. The objective of the first survey was to determine the QoS concerns of the users and ultimately translate them to KPIs. The second survey determined the QoS level delivered by Africom based on the key quality indicators identified determined by the structured survey. The third survey used a single closed ended question to determine customer loyalty and their willingness to recommend the service and to determine customer which were used as an indicator of the perceived QoS.

The questionnaire used rated 10 individual KQIs of the service and which were derived from the user concerns. The ratings from the responses on each individual question are as indicated in table 4.3

Table 4.1: Customer Satisfaction Surveys Results

On a scale of 1 to 5 please rate Africom's quality of service on the parameters stated below					
1 being poor and 5 being excellent quality					
	1	**2**	**3**	**4**	**5**
Bill correctness	2	5	10	41	3

Operator response time	1	0	53	7	0
Supply time during initial connection	0	0	5	7	49
Audio quality	3	5	10	42	1
Coverage	10	49	2	0	0
Accessibility	2	3	7	49	0
Call setup time	1	8	52	0	0
Access speeds(Download and uploads)	0	2	3	3	53
Mean Time To Repair	3	12	18	23	5
Parameter	**1**	**2**	**3**	**4**	**5**
Congestion	0	0	4	8	49
Total	**23**	**86**	**167**	**184**	**165**
Average	**2.3**	**8.6**	**16.7**	**18.4**	**16.5**

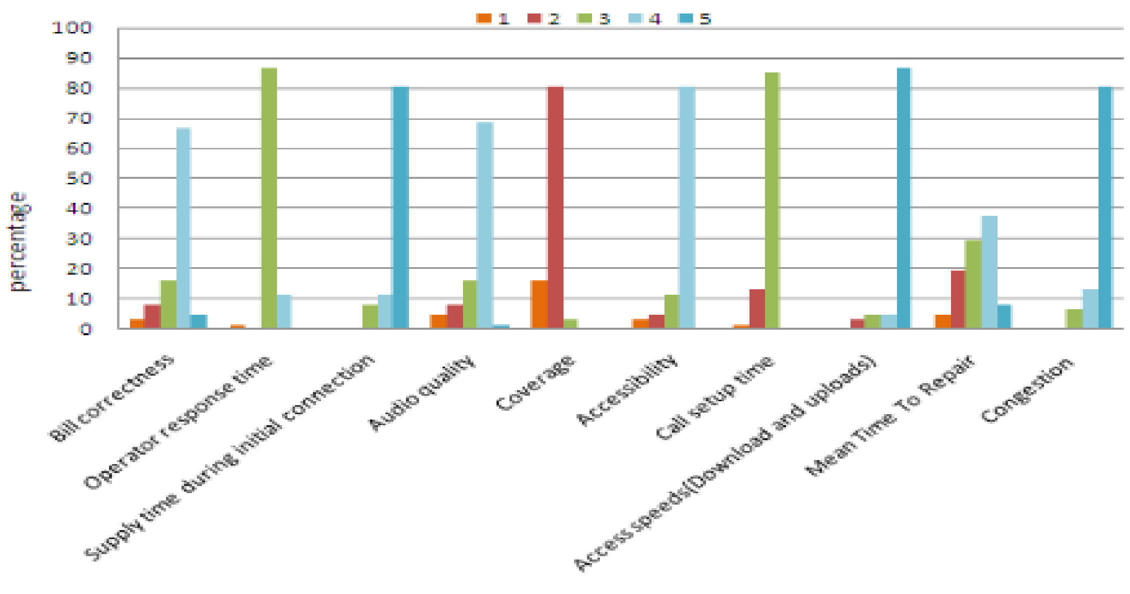


Figure 4.1: The results of the Customer satisfaction survey

From the graph above, it is clear that quality of service for Africom needs to be improved as shown by all parameters that failed to get over 90% of respondents rating a score of 5.

Of a major concern is the network coverage that received ratings showing perceived poor service by customers: 16% giving a rating 1 and 80% giving it a rating of 2 which are the least ratings. The low rating indicates that the level of QoS being delivered by Africom reflects a weakness in coverage which requires the organisation to look at optimisation methods that will improve coverage in areas with poor coverage or intermittent connectivity. This could also mean that the organisation needs to invest in additional infrastructure targeting areas that currently do not have coverage.

From the above results it can be seen that Africom's performance in the remainder of the characteristics show that it is managing to minimise the gap between the expected and perceived QoS in the areas of bill correctness, operator response time, supply time to initial connection, audio quality, service accessibility, call setup time, access speeds and congestions. The MTTR shows a normal distribution with 75% giving a score of 3 and above. This also indicates a need to improve as 28 % the population has given them an average rating on the delivered QoS. Africom therefore needs to work on its MTTR as their customers expectation seems to be higher than what they are delivering.

According to the ACSI model satisfied customers are loyal and willing to refer or recommend a service. The results in Figure 4.2 below gives an indication of the survey carried out to determine the overall percentages from the sample population of the uses who were willing to recommend Africom to others.

Table 4.2: Customer referrals

			Y	N
Would you recommend the Africom service to anyone else			53	8

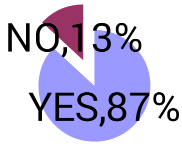


Figure 4.2 Current potential customer's referrals

The results of the part of customer satisfaction survey pertaining to customer loyalty and their potential to refer potential customers to Africom services showed that 87% of the sampling population get considerable satisfaction from using Africom services. Considering their low rating of network coverage KQI which is seen as the major contributing factor why users were using multiple service providers, this reflects that the customers seek improvement of quality of services provided but are not willing to abandon Africom services for services of competing service providers. This can imply that the entire Telecommunication industry is not offering services with quality that meet customers' satisfaction levels.

4.3 Live and Drive Test Results and Analysis

4.3.1 Live LAN to WAN MOS tests

Pre and post installation tests were carried out on the PDN to determine suitability for fixed voice solutions.IAD provides the routing functionality to the Africom CDMA via existing PDN infrastructure. Table 4.4 shows the average performance statistics of the 5 link tests.

Table 4.3 Live MOS tests

	0800	**0900**	**1000**	**1100**	**1200**	**1300**	**1400**	**1500**
MOS	4	3	3	2	2	3	4	4

Figure 4.3 shows that an acceptable MOS score is achieved during the day except for the period between 1100 hours and 12 hours. This could be attributed to the network's QoS policy implementation failure as it fails to priorities voice packets under extreme load conditions.

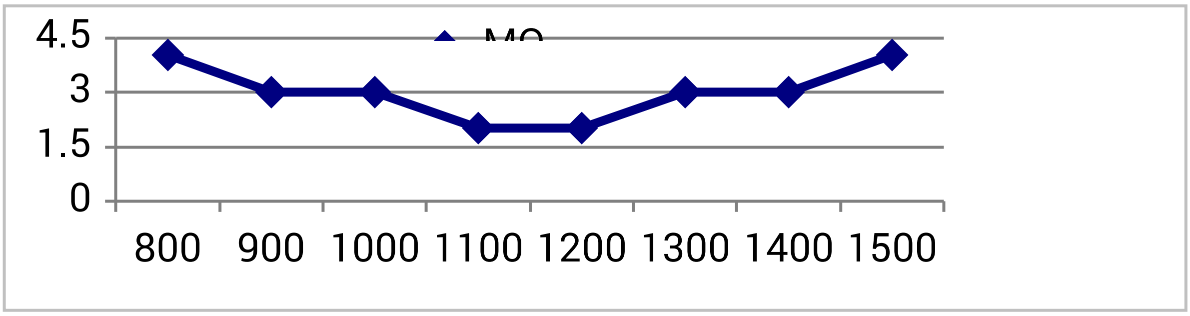


Figure 4.3 Daily MOS score

4.3.2 Drive tests

Drive tests were carried out over a 5 day period along the Montrose - Belmont route which has a number of fixed and mobile service users in the industrial area. Threshold values were predefined and preset for the parameters being measured, the route be followed defined .Tests were carried out between 0800 hours and 1600 hours following the same route. Calls were generated and the KQIs measured for further processing later. Table 4.3 details the results of the drive test carried out during the test period.

Table 4.4: Drive test results

Drive tests	**Target**	**Mean**	**Test 1**	**Test 2**	**Test 3**	**Test 4**	**Test 5**
Blocked calls	< 2%	4%	1	3	3	1	2
Call attempts	-	100%	50	50	50	50	50
Call setup	98%	96%	49	47	47	49	48
Active set Ec/Io	-2dBm<Ec/Io<-32 dbm	-5.33	-5	-5.75	-4.54	-5.35	-6
SQI MOS	>3.5	3.78	3.2	3.8	3.7	4.2	4

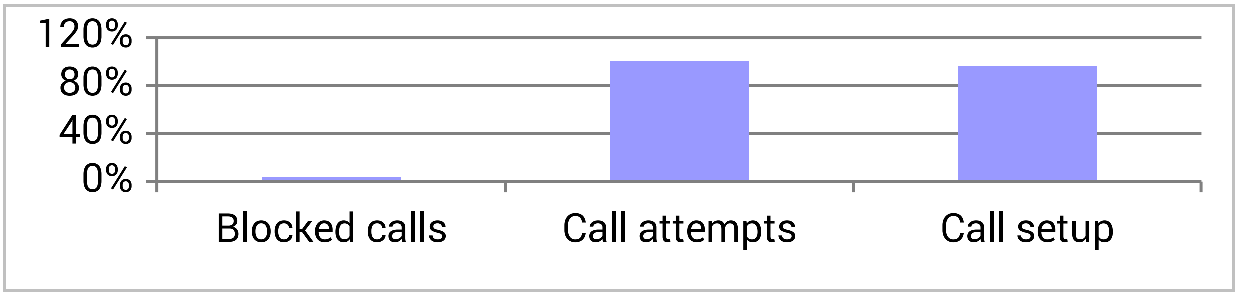


Figure 4.4: Drive tests results

The drive tests were based on a sample of 50 test calls giving a CCSR of 96% and CBR of 4%.The targeted values for the CSSR and the CBR 98% and 2% respectively this indicates that the network underperformed in terms of its accessibility KPI. Africom is falling short by 2%.The resultant QoS being delivered by Africom falls short of their licensing requirements and the Service level agreements. In terms of the Speech quality index MOS (SQI MOS) it was noted that the CDMA network performed well above the targeted 3.5 with a mean of 3.78. Since transmission in CDMA network is over a single transmission frequency, power is measured with consideration of the noise and interference existing within the same channel in terms of the ratio Ec/Io. The measurement obtained in the drive tests gave a mean of -5,33dBm indicating good usable power level in relation to the interference. Acceptable and good quality network should give and Ec/Io that goes up to -18dBm figure above may allow acceptable communication but with a lot of noise and poor speech quality.

4.4 OMC Statistics and Monitoring Data Analysis

This section presents and analyses secondary data that was collected from the monitoring and test activities at Africom Mobile Switching Centre. Because of the security policy, some of the data could not be presented with details that may compromise the security of the network. Statistics were extracted from the system using IManager m2000 Mobile services, SolarWinds open NMS software was for wireless broadband and fixed solutions.

4.4.1 Fixed services

4.4.1.1 Node Availability

It is a measure of the availability of the Point-of-Presences (PoPs), the BTS, the VSAT hub enabling fixed service user access to the public data network (PDN) connectivity. The different network nodes were monitored using SolarWinds Open NMS. The results on node availability are in Table 4.5 below further analysed into Figure 4.5

Table 4.5 Fixed services node availability

All applications and Fixed services					
	Outage counter	**MTTR(hrs)**	**Outage(hrs)**	**Outage percent**	**Availability percentage**
Average	19.00	1.11	23.75	3.535	96.465
Maximu m	93.00	15.04	472.12	70.256	100.00
Minimum	0.00	0.00	0.00	0.00	29.744

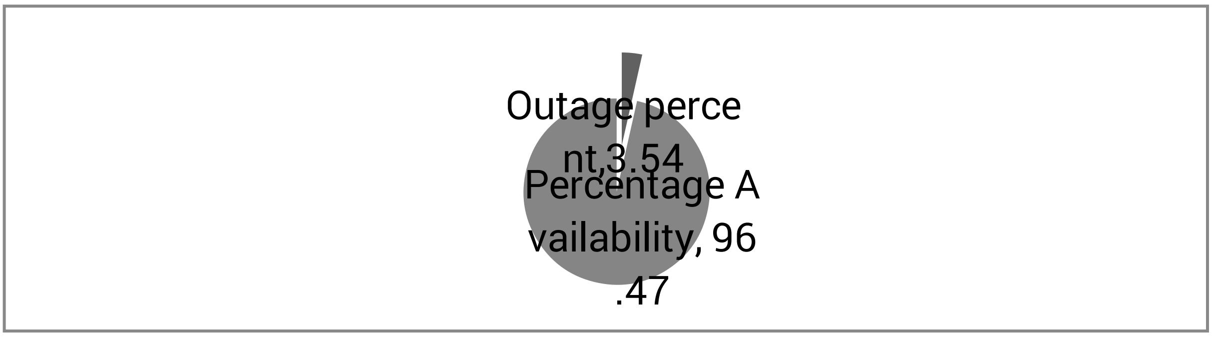


Figure 4.5 Fixed services node availability

An analysis of the results of the fixed services node availability report shows that Africom performed poorly. They missed their target 99, 9 % target by 3, 43 % despite having managed a maximum availability of 100 % on some of their fixed nodes. From network observations it was noted that another contribution to the poor node availability was the power outages which affected nodes located outside the central business districts.

4.4.1.2 Internet services

Table 4.6 shows the network statistics extracted using openNMS. These were extracted targeting the performance of the PDN at different times of the day and to determine the overall QoS and potential bottlenecks, congestions during peak periods

Table 4.6 OMC statistics on internet services

	0800	**0900**	**1000**	**1100**	**1200**	**1300**	**1400**	**1500**
Latency	87.6	336.2	454	443.17	455.5	184.67	158.33	123.4
Packet loss	0%	1%	1%	1%	1%	0%	1%	1%
Jitter	7.45	4.88	7.12	4.12	6.13	8.16	10.18	9.80

4.4.1.2.1 Latency

The network was observed to be having huge latencies from 0900 hours up to 1300 hours this indicated that although the network had an MPLS QoS it its core it was falling to maintain a steady level of QoS. It was behaving like a network operating under the best effort model with no guarantees on latency under conditions of congestion. This is the trend observed in Figure 4.6 below.

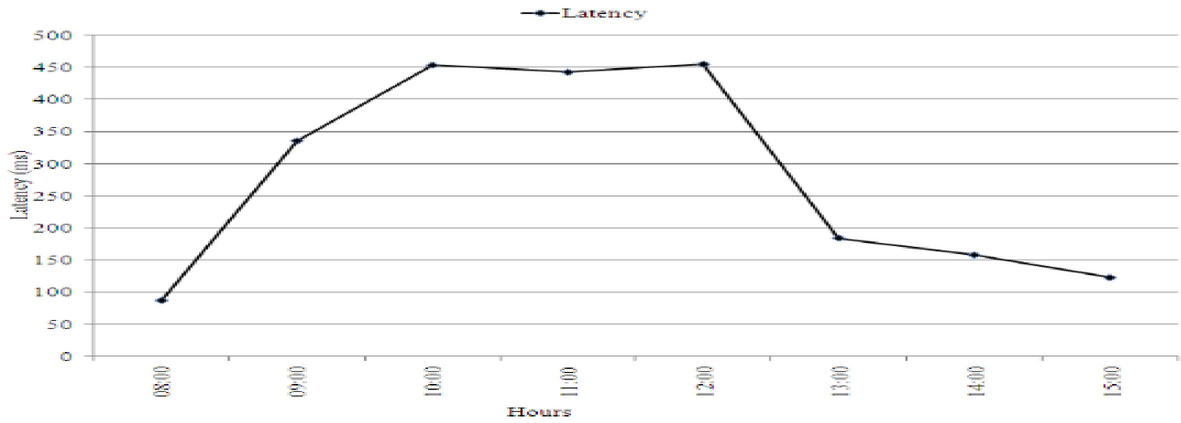


Figure 4.6 Africom Internet latency

4.4.1.2.2 Packet loss

According to the internet services KPIs target for Africom, the target acceptable level of packet loss before the service is said to be degraded is 5%. Basing on the network's performance in Figure 4.7 below it can be seen that in terms of the Africom managed to excel in the service delivery in as far as packet losses were concerned.

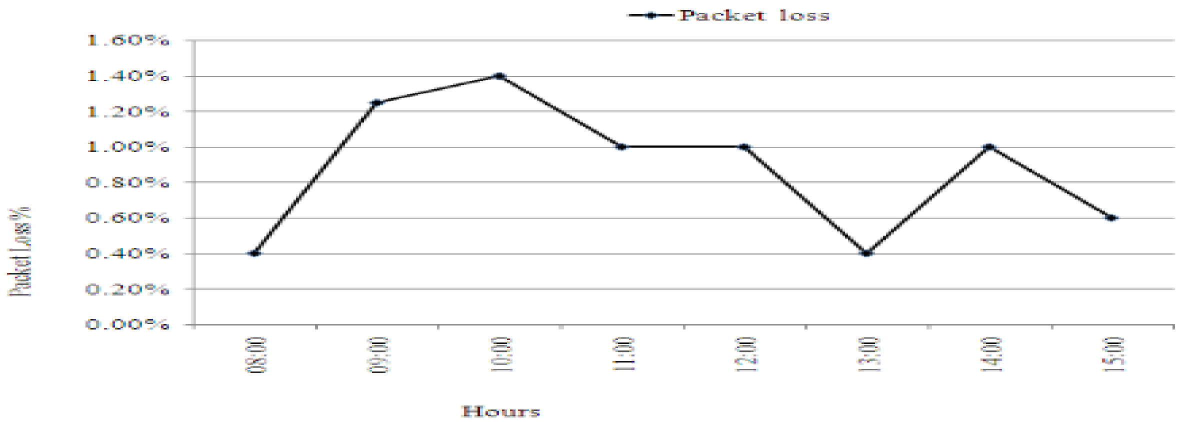


Figure 4.7 Internet network packet losses

4.4.1.2.3 Jitter

Africom offers a service called Guroo which is a SIP based service that relies on the internet connection to deliver telephone services to users .To ensure reliability of the connection and VoIP service support jitter should be below 10 milliseconds. Figure 4.8 shows that the Africom's internet platform did perform well on the Jitter KPI

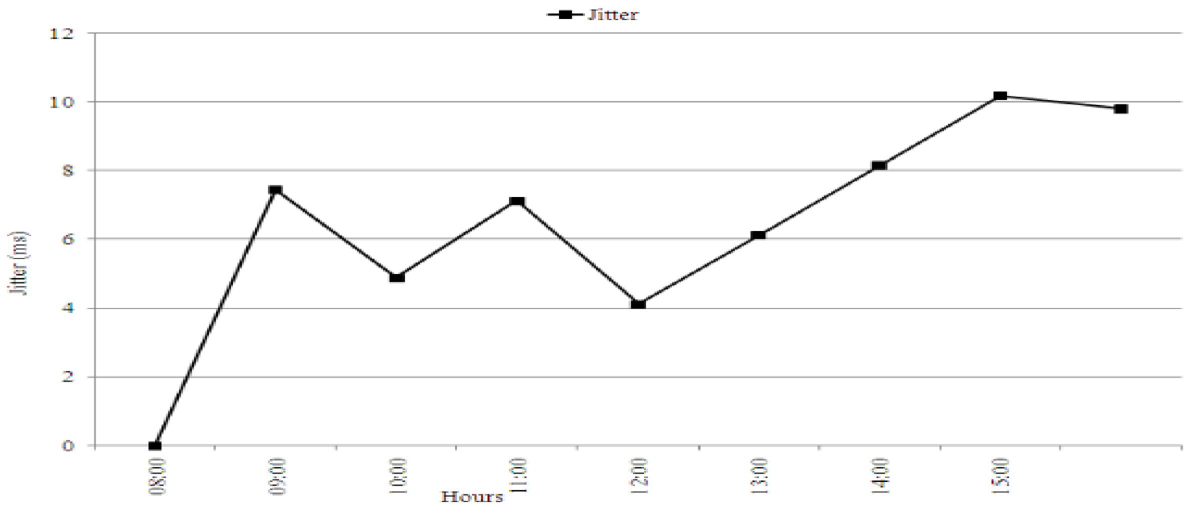


Figure 4.8 Africom internet jitter

4.4.2 Mobile services

The network availability of the all CDMA infrastructure from the MSC, BTS, and the radio network were monitored over one month and the statistics collected. Table 4.6 and Figure 4.9 shows the outcome of the results

Table 4.7 Results of the mobile service node availability

	Outage counter	**MTTR(hrs)**	**Outage(hrs)**	**Outage percent**	**Availability percentage**
Average	19.50	0.29	5.34	0.79	99.21%
Maximum	20.00	0.28	5.37	0.80	99.21%
Minimum	20.00	0.27	5.37	0.79	99.20%

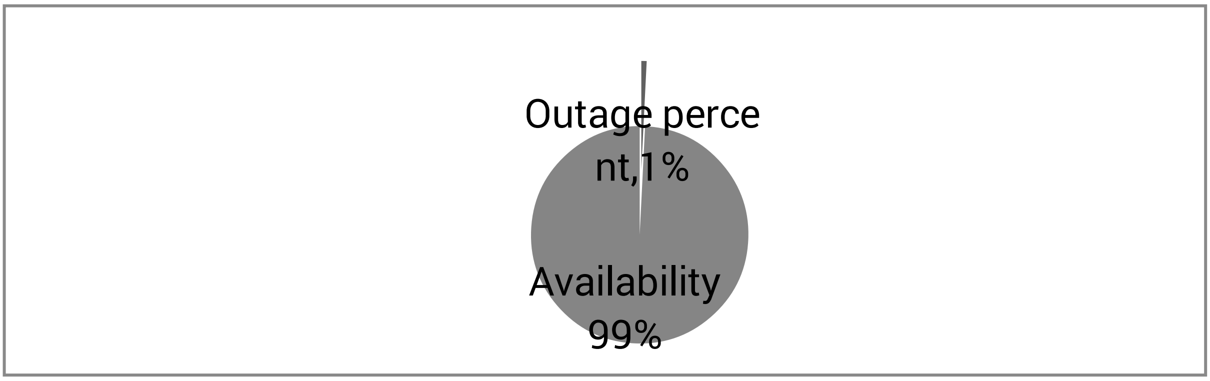
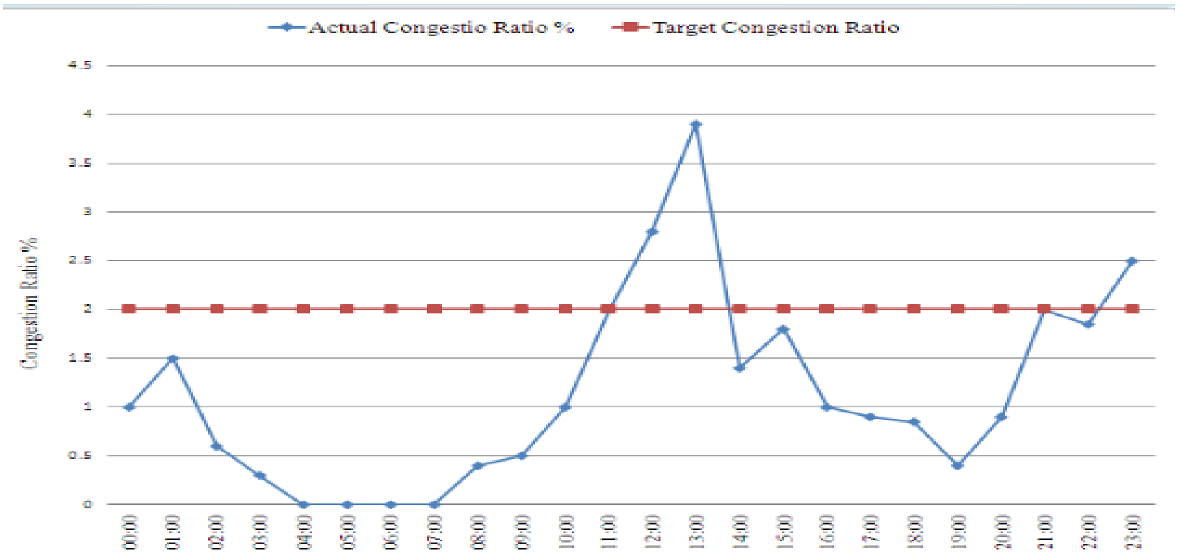


Figure 4.9 Mobile node availability

Based on the above node availability report, the average node availability for Africom's service delivery for the month of February fell short of the target 99.9% by 0.8% with the worst case being 29.74% for mobile services. This indicates a near miss of their target 99, 9 % target by a mere 0.8 %.

Figures 4.10, 4.11, and 4.12 show the Congestion Ratio, Call Drop Ratio and Call Setup Success Ratio, respectively. These parameters reflect the probability of a successful connection and directly contribute to the perceived QoS .From 0000hrs till 1100 hrs Africom is able to meet the acceptable target TCH. Its then rises to unacceptable levels between 11hrs to 1330hrs and falls within target after 1500 hours and up to 2200 hrs where there is a slight increase in congestion till 2300 hours which later drops again. This is probably due to increase traffic on the network due to connectivity demand for purposes of business communications by companies located in the Montrose, Belmont area between 0800 hours peaking at 1300 hours before declining toward day end. The increase is attributed to home users in the residential suburbs surrounding Montrose, Belmont, Burnside areas. As the congestion ratio increases so does the number of dropped calls while the call success ratio has an inverse ratio to the two. On the three parameters Africom was noted to meet its target for the greater part of the day with momentary peaks out of the target range. Overall Africom was noted to be meeting its QoS for the greater part of the day.



,

Figure 4.10 Africom CDMA Congestion ratio

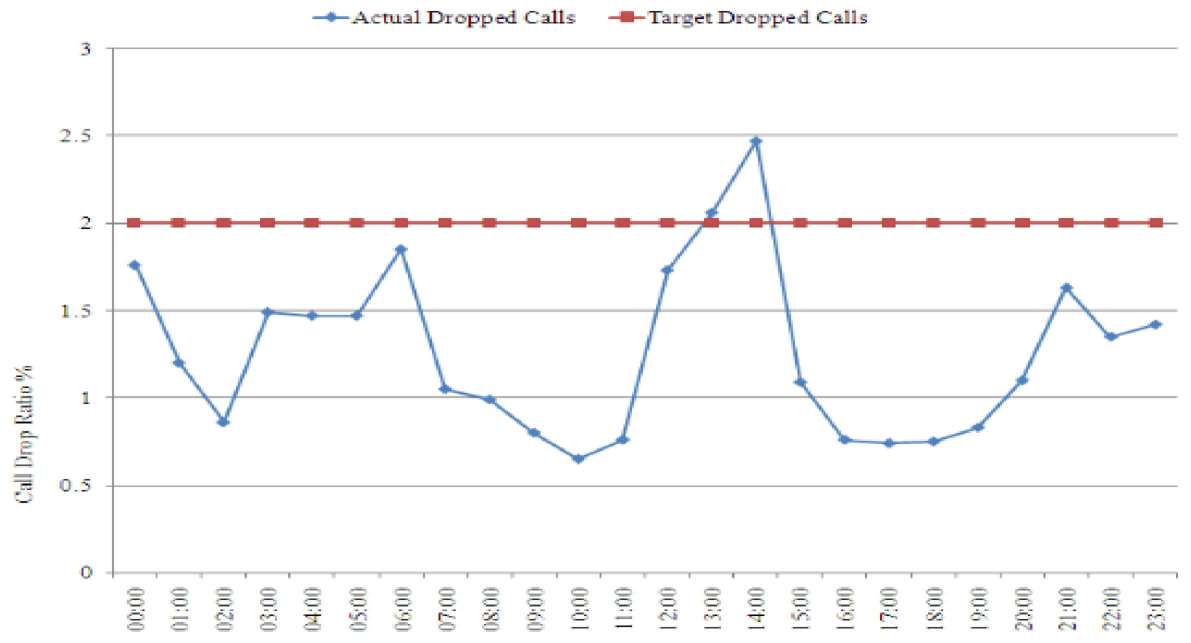


Figure 4.11 Africom CDMA CDR

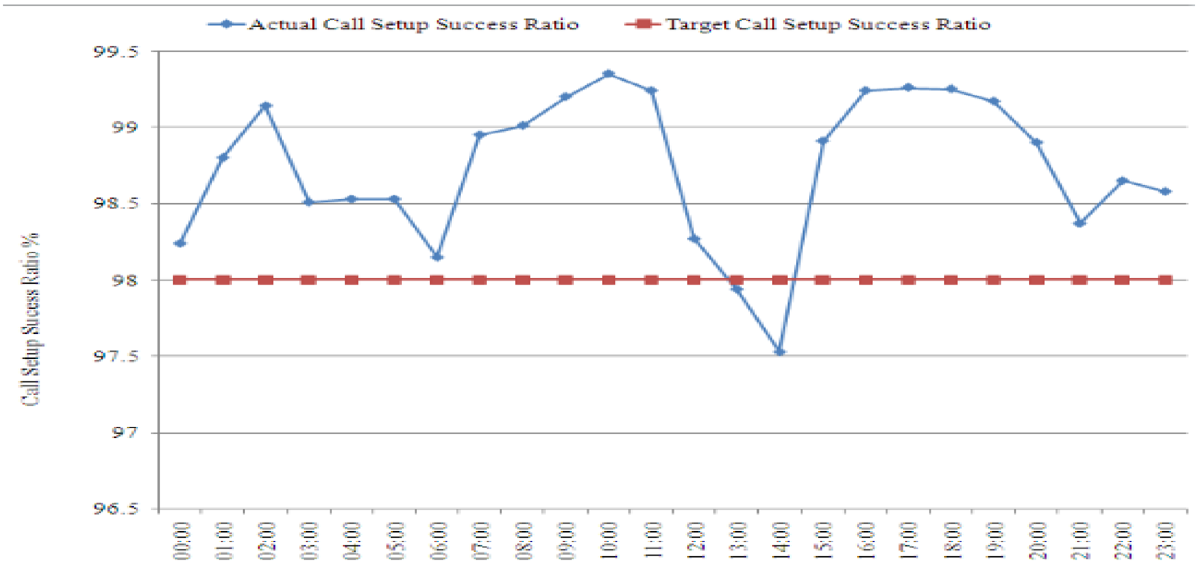


Figure 4.12 Africom CDMA CSSR

Handover success impacts the call maintenance phase of the communications cycle. As the mobile equipment moves from one cell to another handover success determines the probability that the call will be transferred to the next cell without interference or call drop. This therefore contributes also to the call drop ratio. During the test period it was observed that Africom was meeting its targeting QoS level in as far as handovers were concerned with moments of troughs falling below the acceptable 90% at 0700 hours, 1300 hours and 2000 hours. It was also observed that the whenever the handover ratio was degraded the TCH was also poor leading to an increase in dropped calls. Figure 4.13 show the graphs of the average daily handover success ratio.

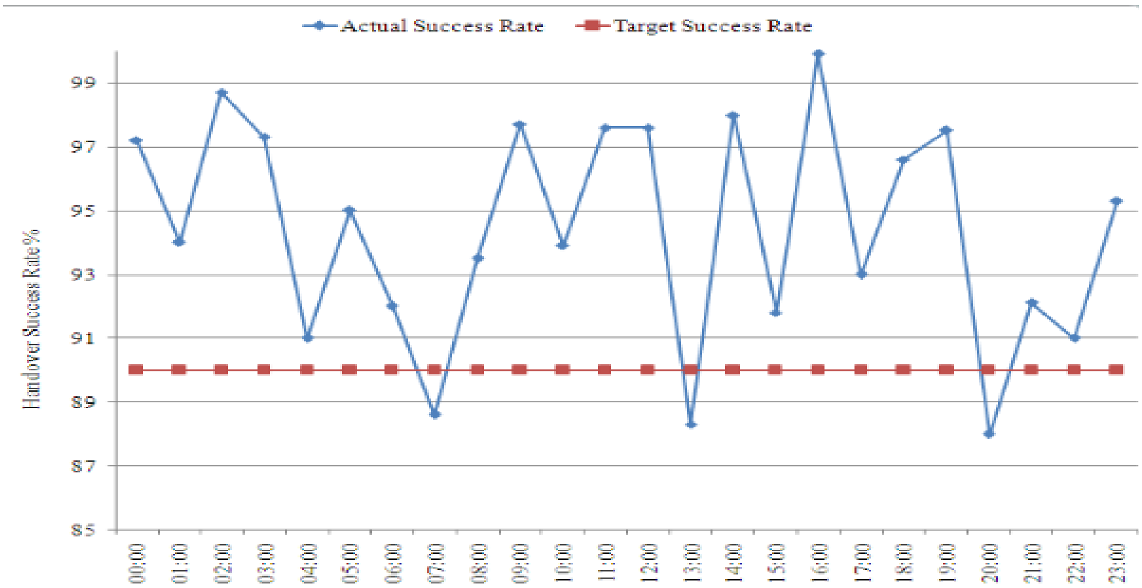


Figure 4.13 Africom CDMA Handover success

From the SMS statistics it was noted that Africom was meeting its target success rate. Basing on the customers interactions it was however noted that the SMS service was no longer popular with most subscribers who had adopted instant messenger services like whatsapp, viber, and Skype. This then meant that there was a high probability that the statistics acquired on the SMS success ratio where not indicative of the network performance under intense SMS traffic conditions. The findings on the SMS success rate are below on Figure 4.14

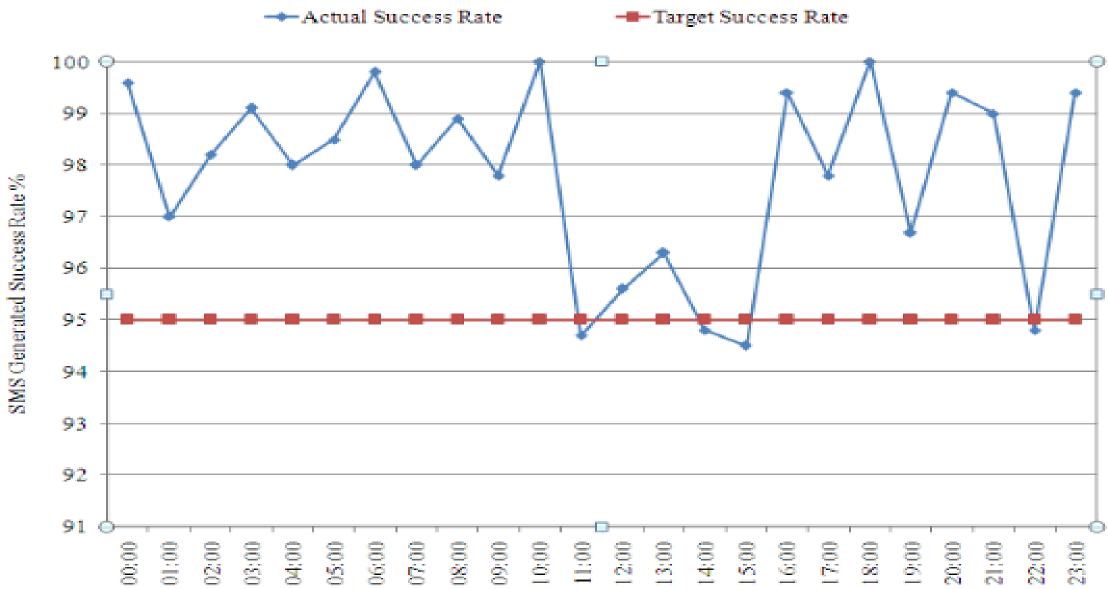


Figure 4.14 Africom CDMA SMS success rate

The CDMA network is optimised for higher throughput and access speeds for both voice on 1x and data on EVDO. The behaviour of the network is such that given an increase in the demand for the data services part of the 1x channel is allocated to the data services at slower speeds slower than 3,1Mbps.To analyse the QoS delivered for data services results extracted on the EVDO contents success ratio and the 1x packet success ratio were extracted and used. Figures 4.15 and 4.16 show the results of the EVDO Content Activation ratio and the packet setup ratio against the targets. It was noted that the EVDO content activation met its target falling below its target at 1300 hours and 2300 hours. The two graphs show that there is a relationship between the two in that whenever EVDO activation was poor it also led to poor 1x packet success rate. This can be attributed to the fact that the failure of the EVD activation led to an increase in the demand for 1X services resulting in congestion and poor performance.

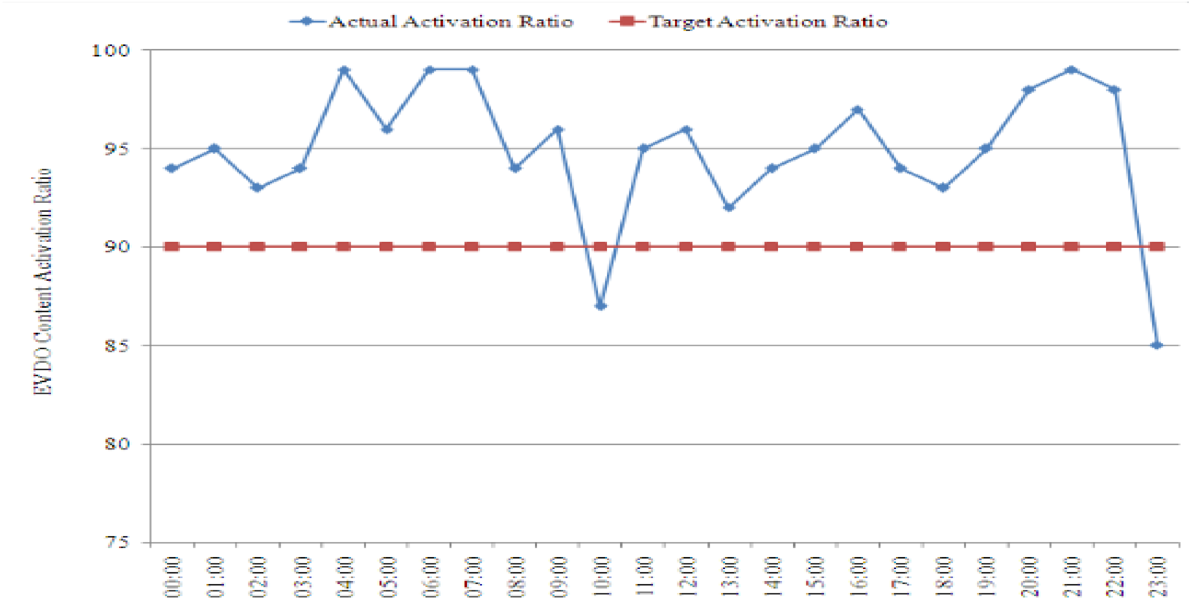


Figure 4.15 EVDO content activation ratio

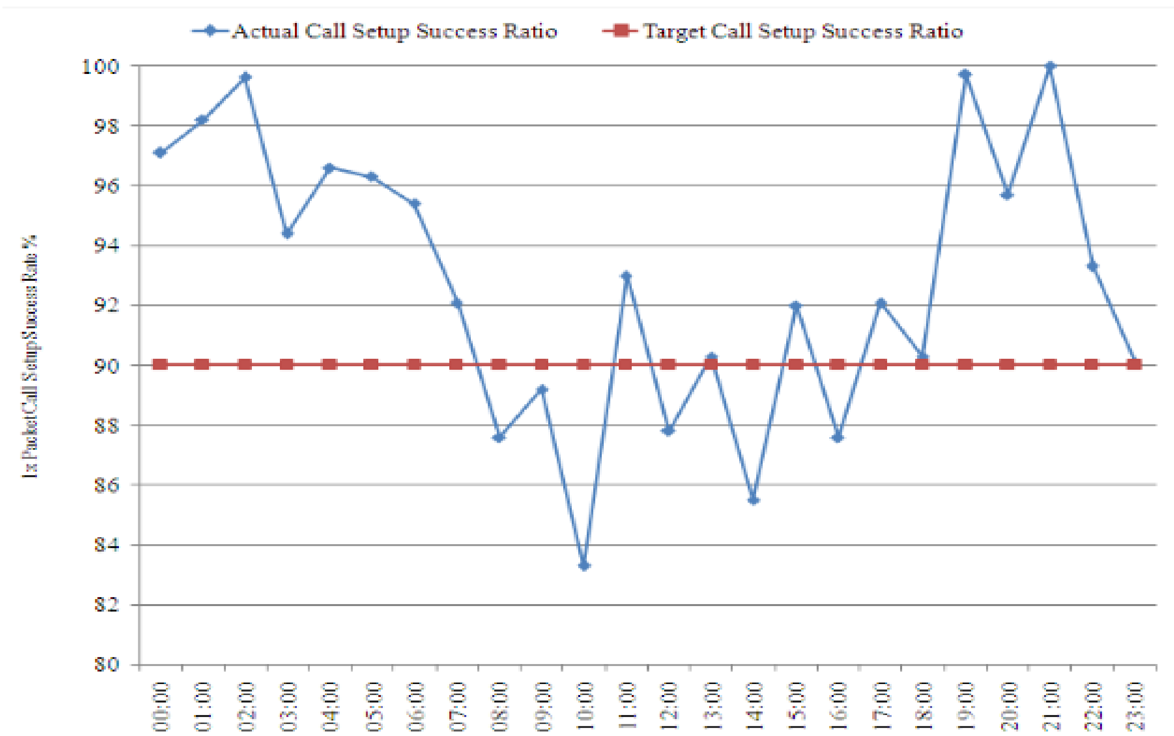


Figure 4.16 1x Packet setup success ratio

Figures 4.17 and 4.18 show the Radio Network availability and MSC Network availability, respectively. The MSC is the core of the network with nodes that span the distance between different switching centres. The Radio network is at access layer of mobile network infrastructure characterised by wireless interfaces between base stations and mobile devices. MSC is important for enabling the signalling functions of the network to control call setup and tear-down while Radio network provides the gateway for access of mobile devices to mobile cellular network and its services. The results of the two parameters show that the target 99, 9% availability is being achieved most of the times. Results also show that availability is generally poor between 0900 hours and 1800 hours. Some of the factors that may be causing this trend include power cuts and congestion.

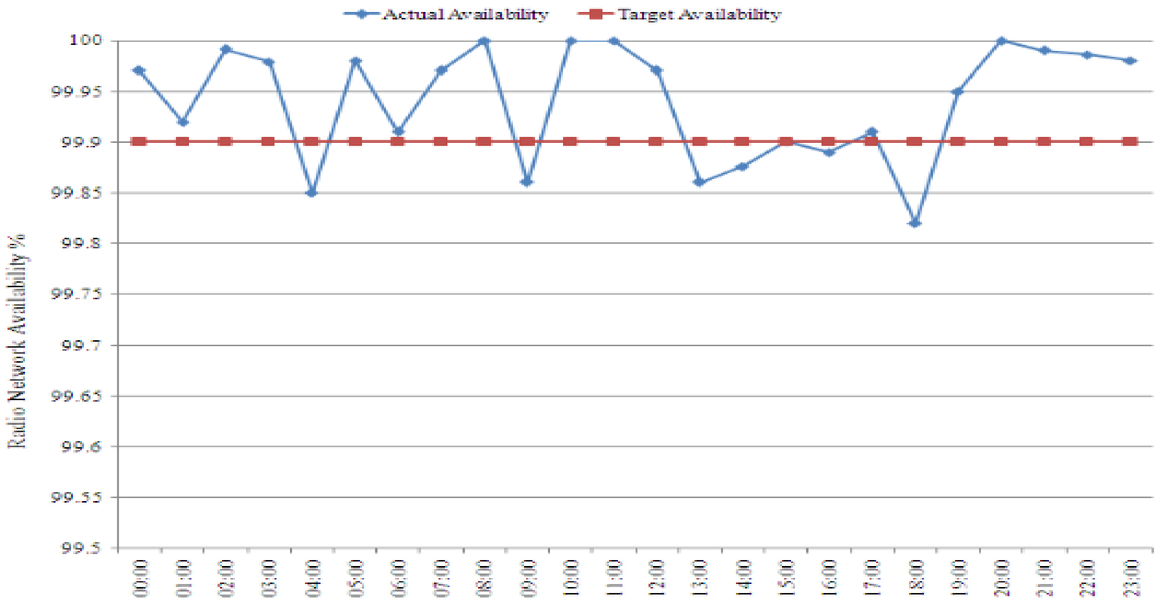


Figure 4.17 Radio network availability

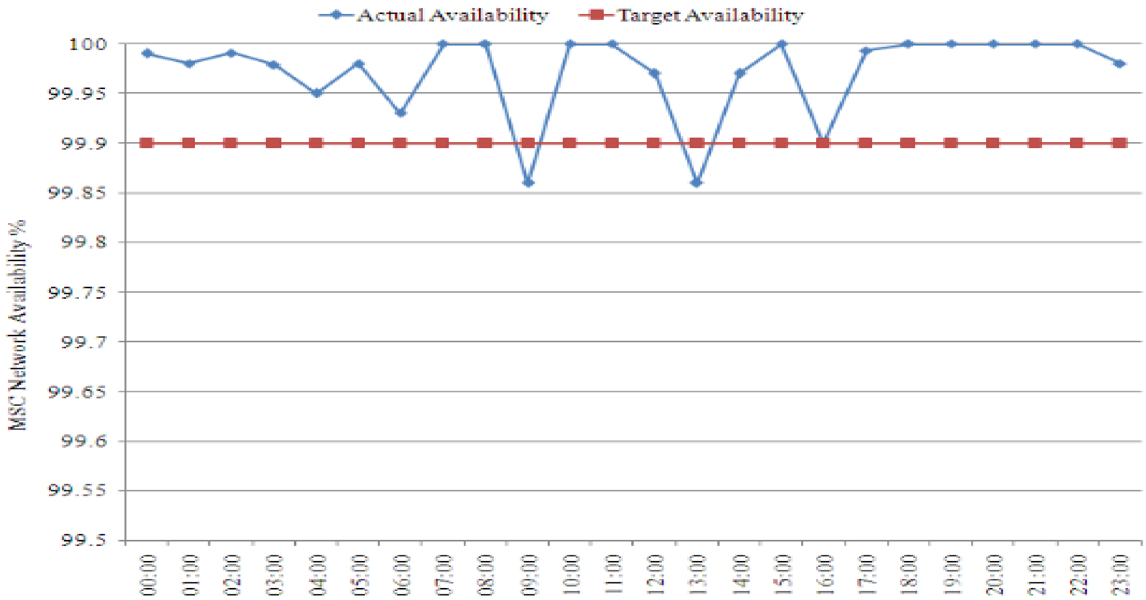


Figure 4.18 MSC network availability

In conclusion the analysis of the results of Africom indicated that it is delivering and intrinsic QoS that is meeting its target .The analysis on a platform by platform gave the researcher and opportunity to identify individual weaknesses according on an application basis. It was also observed the decision to use the preferred methods for accessing data allowed the researcher to acquire all the data that affected considered the technical elements of QoS as well as the technical QoS of the service.

CHAPTER 5: CONCLUSIONS

5.0 Introduction

This chapter gives and overall conclusions on measurements and evaluation process. It provides a summary of the findings and the evaluation process; it will also carry out a check against the initial objectives of the research to determine if the initial objectives were met and the recommendations to improve the research process. Recommendations will also be made on how Africom can improve their service as well as proposal for future work in the similar field of study

5.1 Summary of findings

There were three methods adopted in the research process and the works sought to evaluate QoS and determine if the three methods worked for or against each other. It was observed that overall findings from all the three method adopted complemented each other. Weaknesses of one method were compensated for by the other methods. The drive tests gave a feel of the perceived QoS and network functionality while the OMC statistics gave an indication of the intrinsic QoS performance of the network. These two put together gave an indication that Africom is delivering good quality of service for the measured KPIs. The customer satisfaction survey gave the subjective opinion of the user and this gave an indication that Africom needs to work on certain parameters but was performing well in terms of delivering QoS as indicated by the 87% customers who are satisfied and willing to recommend Africom services.

It was noted that Africom's major weaknesses lie in its poor network coverage as can be seen from the poor score they got from the customer satisfactions survey. As was observed by Angelova [6] the customer expectation usually exceeds the perceived QoS. Customers are generally not satisfied with the service being delivered by Africom although its intrinsic QoS indicated that it is performing well. Since the parameters for measuring QoS were based on the input of the different stakeholders it was noted that their expectations are very different and the understating of each other expectation on the QoS to be delivered is very different.

Conclusions were drawn that the different platforms on the Africom network were optimised for the services there were designed to deliver implying that the models adopted in managing QoS were effective.

5.2 Recommendations

5.2.1 Recommendations to Africom

It was noted that Africom needs to implements congestion managements mechanisms targeting peak periods. In most cases it was observed that the blocked call ratio, the overall network availability was below target performance during peak periods.

Africom also needs to invest in more network infrastructure to as well as optimising their network to cover areas currently not covered by their network. Through the use of drive test it was actually observed that certain areas within 1 km of the base station were not getting a good reception indicating that the tilt and orientation of the antennas needed to be adjusted.

For fixed broadband it was observed that deterioration of the QoS was as a result of the network topology implemented. The core network engaged MPLS to manage QoS while end nodes were configured on a best effort resulting in poor QoS. Africom needs to ensure that QoS policies are implemented on an end to end basis if it is to deliver quality of service acceptable to its users and within the regulatory requirements

Another factor that was noted to be contributing to low node availability on both the fixed and mobile platforms was the outages due vandalism or fibre backbone break. There is a need for Africom to include some redundancy on major backbone links especially for fibre links spanning towns through the use of microwave links to reduce service outages and interruptions.

5.2.2 Recommendations for further study

This research work focused on measuring and evaluation QoS from the perspective of the different stakeholders. It revealed that the different stakeholder have different views in as far as QoS is concerned. As a result of this it was concluded that future research work should focus on identifying the parameters of measurements that should capture on encapsulate the different views into one such that the outcomes of the findings are agreeable to all parties concerned.

It was also observed that QoS degraded under congestion and peak periods; future research can also look at the means of implementing QoS policies that are capable of focusing on the shared resources like multiplexers, the radio network, the MSC and how traffic can be managed to control QoS degradation during peak periods.

5.3 Conclusion

In conclusion it was noted that Africom needs to move towards a more customer's centric approach in it delivery of QoS .Its technical performance is on target but it was observed that there was a gap between the delivered QoS and the customer's expectation which needed to be addressed. Africom needs to understand the extent of the impact of their limited coverage on the customer expectation and the overall QoS delivered affecting the perceived QoS.   There is a need to educate and manage the user expectations by ensuring that Africom's customer facing departments develop a deeper understating of the customer expectations and how these can be related to the intrinsic quality of service they deliver. It was observed that the Africom network was delivering poor QoS as far as network congestion during peak periods. It can be concluded that the research did manage to measure and evaluate the Africom network QoS and the findings can be used to improve the level of QoS being currently delivered and that the three methods adopted in this research were useful tools that complemented each other.

References

[1]	Study Group 2, Overall Network Operation, Telephone Service, Service Operation and Human Factors in E.800 Recommendation Series. 2008 pp3
[2]	European Commission, Towards and information society approach in Green paper on the convergence of Telecommunications media and information technology sector and implications for regulations, Brussels .1997, pp 2
[3]	Cisco systems , What is network convergence all about .2002 pp 3
[4]	P.Y. Hebert and ETSI, "End-to-end QoS in the users' point of view," in *ITU-T Workshop*, Geneva, 2003.
[5]	Mihail Ivanovici, Bob Dobinson Razvan Beuran, Network Quality of Service Measurement System for Application Requirements Evaluation, pp. 1-8.
[6]	Roberts J.W. And France Telecom Research and Development. Internet Traffic, QoS and Pricing.2001
[7]	Jusuf Zekiri Biljana Angelova, "Measuring Customer Satisfaction with Service Quality Using American Customer Satisfaction Model (ACSI Model)," in *International Journal of Academic Research in Business and Social Sciences*, vol. 1, no. 3,2011 pp. 232-258.
[8]	C. Gronroos, "A service quality model and its marketing implications," *European Journal of Marketing*, vol. 18, no. 4, pp. pp. 36-44, 1984.
[9]	N.B. Shroff D.Y. Eun, "A Measurement Analytical Framework for QoS Estimation based on dominant Time Scale," in *IEEE INFOCOM*, Anchorage, AK, 2001.
[10]	Vivek Khattar, IMRB International, "QoS and Customer Satisfaction:," *Pipeline Publication*, vol. 3, no. 2, pp. 1-5, July 2006. [Online]. Available "PipelinePub.com"
[11]	E D Avgeri, M P Kallenou, P Constantinou C N Pitas, "Measurements and QoS Analysis of Live-World Mobile Telecommunication Networks," in *3rd Pan-Hellenic Conference of Electrical and Computer Engineering Students*, Athens, 2009.
[12]	W. Hardy. QoS Measurement and Evaluation of Telecommunications Quality of Service. J Wiley and sons, West Sussex , England, 2001
[13]	Africom, Company Profile Document, pp. 19.
[14]	Hangzhou H3C Technologies Co. www.h3c.com. [Online].Available "http://www.h3c.com/portal/Products___Solutions/Technology/QoS/Technology_White_Paper/200812/623011_57_0.htm"
[15]	W. Zhao, et al Internet Quality of Service: an Overview, Columbia University, pp. 4.

[16]	Cisco Systems, Cisco IOS MPLS Quality of service whitepaper, pp. 2.
[17]	R. Chakravorty, et al End-to-End Internet Quality of Service (QoS): An Overview of Issues, Architectures and Frameworks, 2000, pp. 5.
[18]	Channel Island Competition and Regulatory Authorities. (2013, March) CICRA. [Online]. Available "http://www.cicra.gg/ pp. 14"
[19]	Agilent technologies, Optimizing your CDMA Network today and tomorrow using drive test solutions, Application note 1345. pp1-7
[20]	Department of MIIT, University of Kuala Lumpur Mohd Nazrii Ismaiill, Analyzing of MOS and Codec Sellection for Voice over IP Technollogy, Malaysia , 2009 pp 269
[21]	ETSI TS 102 024-5 V4.1.1, Telecommunications and Internet Protocol Harmonization Over Networks (TIPHON) Release 4; End-to-end Quality of Service in TIPHON Systems; Part 5: Quality of Service (QoS) measurement methodologies, 2003-09, pp. 9-16.
[22]	ETSI 3rd Generation Partnership Project (3GPP), Universal Mobile Telecommunications System (UMTS); Quality of Service (QoS) concept and architecture (3GPP TS 23.107 version 5.10.0 Release 5), 2003-09, pp. 8.
[23]	3GPP2, Recommended Minimum Performance Standards for cdma2000 Spread Spectrum Mobile Stations. 3GPP2 C.S011-E11 version 1.0, 2012 pp69
[24]	Africom Service Contract pp 5-8

APPENDICES

Appendix 1:- CCZ Questionnaire

Please note the survey is in relation to fixed and mobile voice and data services in Zimbabwe.

1. What is your definition of Quality of service in Telecommunications?

……………………………………………………………………………………………

2. What is your role in Telecommunications? (With regards to Telecoms Quality of service issues)

……………………………………………………………………………………………

3. How do you measure quality of service in Telecommunications?

……………………………………………………………………………………………

4. What do you think are the basic and critical quality of service concerns in telecommunication services for the consumer?

……………………………………………………………………………………………

5. Do you think consumer's needs are being met currently in telecommunications and why? ……………………………………………………………………………………………

b. If not what recommendations would you suggest to address the gap?

……………………………………………………………………………………………

6. Based on your experience how do you think consumers measure quality of service in Telecommunications?

……………………………………………………………………………………………

7. How do you think service providers measure their quality of service and which features do you think should be measured in order to evaluate if a service meets acceptable quality of service?

……………………………………………………………………………………………

8. Who do you think should measure Quality of service and how often? (eg Consumers, ISPs, The regulator Authority)

………………………………………………………………………………………………

9. Is Quality of service being regulated in Zimbabwe, and what consumer awareness activities are in place to support consumer education?

………………………………………………………………………………………………

10. Have you ever handled an Africom Customer Quality of service complaint in the past? If so what was the case?

………………………………………………………………………………………………

11. How often do you get Telecommunications QoS complaint? ...

12. How many Africom complaints have you handled in the past...

13.How would you rate Africom's Quality of service on a scale of 1-5..

(5 being the best and 1 being poor)

Appendix 2 POTRAZ Questionnaire

Please note the survey is in relation to fixed and mobile voice and data services in Zimbabwe.

1. What is your definition of Quality of service in Telecommunications?

……………………………………………………………………………………………

2. What is your role as POTRAZ in measuring, evaluation and enforcing Quality of service compliance in telecommunications?

……………………………………………………………………………………………

3. How do you measure quality of service in Telecommunications?

……………………………………………………………………………………………

4. What do you think are the basic and critical quality of service concerns in telecommunication services for the consumer?

……………………………………………………………………………………………

5. a) Do you think consumer's needs are being met currently in telecommunications and why? ……………………………………………………………………………………………

b. If not what recommendations would you suggest to address the gap?

……………………………………………………………………………………………

6. Based on your experience how do you think consumers measure quality of service in Telecommunications?

……………………………………………………………………………………………

7. a)How do you think service providers measure their quality of service and which features do you think should be measured in order to evaluate if a service meets acceptable quality of service?

……………………………………………………………………………………………

b. Please specify the recommended metrics for measuring each parameter identified in part **a** of the question

……………………………………………………………………………………………

8. Who do you think should measure Quality of service and how often? (Eg

Consumers, ISPs, The regulator Authority)

……………………………………………………………………………………………

9. Is Quality of service being regulated in Zimbabwe, and what consumer awareness activities are in place to support consumer education?

……………………………………………………………………………………………

10 Under what conditions do you measure quality of service in telecommunications and how often?

……………………………………………………………………………………………

11. Under what conditions do you recommend that Service providers measure their quality of service in telecommunications and how often?

……………………………………………………………………………………………

12. Is Quality of service being regulated in Zimbabwe, by who and what policies are there to regulate it?

If not are there any plans to do so?

……………………………………………………………………………………………

……………………………………………………………………………………………

13. What penalties are in place for failure to meet basic Quality of service requirements?

……………………………………………………………………………………………

14. What is the general conclusion that can be drawn from the overall performance of the different service providers on Quality of service performance?

……………………………………………………………………………………………

b) Which areas do you feel need improvement

……………………………………………………………………………………………

Thank you

Appendix 3 Quality of service measurement and evaluation Questionnaire: - Individuals

Questionnaire applies to mobile and fixed voice and data services
1. How do you determine (characteristics) which service is the best?
2. What is your definition of Quality of Service in telecommunications?
3.What are your expectations from the current service you are using?(Specify services being used)
4. What are your critical Quality of Service needs for the service you wish to access or are using?
5. What do you feel should be improved?
6.Why do you keep your current service provider?(Specifying service used)
7. Why would you move from your current ISP?
8.Why did you move from your previous ISP?(Where applicable)
9. How responsive has your ISP been to your Quality of Service concerns and queries?
10.What support systems do you need form your service provider to address your Quality of Service needs/concerns?
11. Which service do you use, which ISP?
b. Specify requirements for each service?
12. Do you know who to approach with a Quality of service within your ISPs organisation, outside (regulatory authorities etc)?
13. Have you ever had a Quality of service issue that was poorly addressed, how

do you feel it should have been addressed?
14. Have you ever had a Quality of service issue that was addressed in a way that you appreciated and how was it addressed?
15. Do you think Quality of service should be regulated , and why?
16. Who do you think should do that and at the moment do you think there is anyone doing the regulation?
17. How do you think the regulatory authority should enforce Quality of service regulation?
18. What is your opinion on Quality of service measurement?
19. How do you measure an ISP's Quality of service?
20. How do you think ISP'S measure their Quality of service?
21. How do you think they should measure their QoS?
Any further comments:-

Appendix 4:- Customer satisfaction survey

On a scale of 1 to 5 please rate Africom's quality of service on the parameters stated below					
1 being poor and 5 being excellent quality					
	1	**2**	**3**	**4**	**5**
Bill correctness					
Operator response time					
Supply time during initial connection					
Audio quality					
Coverage					
Accessibility					
Call setup time					

Access speeds(Download and uploads)					
Mean time to repair					
Congestion					
			Y	**N**	
Would you recommend the Africom service to anyone else					

Appendix 5: LAN TO WAN TESTS

LAN to WAN tests							
Time	**Packet loss**	**Jitter(ms)**	**Latency(ms)**	**Time**	**Packet loss**	**Jitter(ms)**	**Latency(ms)**
03-Feb							
08:30	1%	11	87	12:30	1%	1.7	550
09:30	1%	5.8	395	13:30	0%	1.8	185
10:30	0%	16	636	16:39	1%	2.1	102
11:30	0%	1.7	522	17:00	1%	8.9	66
12:30	2%	1.6	953				
13:30	0%	12	57				
16:49	1%	15	91				
16:51	1%	8.9	66				
04-Feb				06-Feb			
08:30	1%	13	88	08:30	0%	9	87
09:30	1%	6.3	541	09:30	0%	1	103
10:3	2%	1.6	636	10:3	2%	9.4	636

0				0			
11:30	2%	2	522	11:30	1%	8	522
12:30	1%	17.3	683	12:30	1%	2.2	521
13:30	0%	11	246	13:30	0%	10	133
16:30	0%	11.1	220	16:30	1%	8	102
05-Feb				07-Feb			
08:30	0%	9	88	08:31	0%	1	88
09:30	1%	6.3	541	09:20	3%	5	541
10:30	2%	1.58	636	10:35	1%	7	636
11:30	2%	2	465	11:30	0%	9.3	465
				12:30	0%	12	550
				13:30	0%	6	185
				16:28	0%	11	102

Appendix 6: Availability report

Fixed wimax (16d) wimax platform					
	Outage counter	MTTR(hrs)	Outage(hrs)	Outage percent	Availability percentage
Average	29	0.28	9.09	1.3252	98.684
Maximum	89	0.57	39.84	5.929	99.709
Minimum	10	0.14	1.96	0.291	94.071
All CDMA sites					
	Outage counter	MTTR(hrs)	Outage(hrs)	Outage percent	Availability percentage
Average	18	3.87	52.81	7.858	92.142
Maximum	68	61.24	472.12	70.256	99.976
Minimum	1	0.07	0.16	0.024	29.744
All Core nodes					
	Outage counter	MTTR(hrs)	Outage(hrs)	Outage percent	Availability percentage
Average	12	0.35	3.1	0.461	99.539
Maximum	35	2.05	9.53	1.418	99.976
Minimum	1	0.12	0.16	0.024	98.582
Internet fibre					
	Outage counter	MTTR(hrs)	Outage(hrs)	Outage percent	Availability percentage
Average	35	0.12	4.04	0.601	99.399
Maximum	35	0.12	4.04	0.601	99.399
Minimum	35	0.12	4.04	0.601	99.399
Mobile services					
	Outage counter	MTTR(hrs)	Outage(hrs)	Outage percent	Availability percentage
Average	15	3.17	33.94	5.05	94.95
Maximum	68	61.24	464.98	69.194	100
Minimum	0	0	0	0	30.806

All applications and services					
	Outage counter	**MTTR(hrs)**	**Outage(hrs)**	**Outage percent**	**Availability percentage**
Average	19	1.11	23.75	3.535	96.465
Maximum	93	15.04	472.12	70.256	100
Minimum	0	0	0	0	29.744