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Assessment of the Reliability of Global Services Mobile Communication Networks on Quality of Services (QoS): A Comparative Study of Four Major Giants

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Abstract:
This paper is an overview assessment of the availability (A) of Global Services Mobile Communications (GSM) of the six geopolitical zones (North West, North East, North Central, South West, South East and South South) of Nigeria in the Sub-Saharan African Continent. We approach the problem of Quality of Services (QOS) with Unavailable Second (UAS) constraint from the network operator's perspectives. The ratio of measured availability to unavailable seconds (UAS) assessment method measures the network installed capacity, base stations and active voice subscription, range of operation of the packet optimized optical transport network solutions. The choice of a hybrid network gives us a bird-eye view of the IP only End-to-End Transport layer due to its complete transparency. The five-year assessment on the coverage range with special consideration given to factors like zones of the country, environment and base stations where it is deployed, active voice subscription and internet services. The results reveals that the operations of the major giants are in order [MTN, GLOBACOM, ETISALAT and AIRTEL] over the past five years within a Sub-Saharan African Environment.

Keywords: *Global Services Mobile Communications (GSM), Reliability, Sub-Saharan, Quality of Services (QOS), Base Stations*

1. Introduction

Over the years, Global Services Mobile Communications (GSM) network coverage and services have improved tremendously from the perspective of network installed capacity, base stations and active voice subscription, internet services with the objective of delivering great quality of services. The last decade after the start of the GSM era in Nigeria witnessed a stiff competition, as operators have to compete for the same potential subscribers and the focus is now gradually shifting from providing coverage to providing quality service therefore the euphoria of owning a phone set is gradually giving way to complaints of dropped calls and congestion among subscribers.

Global Services Mobile Communications (GSM) have had great impact on globalization of the Nigeria economy since its inception in 2001. But the tremendous growth in subscription have brought some challenges to the operators. Issues on how to tackle the occurring congestion in the mobile wireless communication posed in their services and have caused a lot of inconveniences to the subscribers. A network operators' goal is to provide good quality services to the end users (subscribers) with respect to speech, effective roaming globally and lesser tariffs. Global Services Mobile Communications (GSM) has become more advanced and handles more subscribers than analog systems [1].

In this research work, we assume well over 150 million users of GSM contending for access almost at the same time in Nigeria, making the country one of the fastest growing GSM markets in Africa and the world at large [2]. The Nigeria telecommunication market is looking forward to achieve a tele density of 100% by the year 2020 which is driven by the massive telephone and mobile communication improvements thereby requesting for a great increase in the information and communication technology (ICT).

Currently, Nigeria with the population density of over 170 million people are being serviced by five major Global System for Mobile (GSM) Telecommunication operators which are MTN, AIRTEL, GLOMOBILE, ETISALAT and MTEL. [3] But among the various operators MTN has the greatest customer base with over 57.2 million subscribers although the competition as it gets fierce.

Our goal in this paper is to compare and contrast the reliability and efficiency of network operators' system in Nigerian telecommunication. Landscape and present a proposal similar to the part stress method as a preferable assessment method for reliability of an existing system based on the possibilities of considering various stresses peculiar to the network equipment on a specific area of application. Our network availability which is the ratio of measured time to Unavailable Second (UAS) is utilized in the assessment method.

The remainder of the paper is arranged as follows;

We begin section 1 with a hindsight view of the telecommunication environment in Nigeria and network operator system description, section 2 discusses the background of this topic, assessment criteria and methods, we focus on the method used in assessing the reliability of the four players that dominate in the telecommunication network operators.

The Mean Time to Failure, Mean Time Before Failure, network equipment failure statistics Section 3 gives a bird-eye view of our work and contribution to this research work. We present the reliability assessment of the four major network operator giants based on their network installed capacity, base stations and active voice subscription. This leads us to discuss the results in Section 4 and the final section 5 gives us a further direction to this research work and conditions where this justification is acceptable and otherwise stated.

2. Network System Description

An easy way to describe the four network systems with the ITU's requirements is to follow ITU-T Standard G.826. Section 2 provides insight to this research work with the view of authors 0. Akinsanmi and K. Adebusuyi in their text [5] on reliability of engineering systems where the definition of reliability and availability of engineering systems can be assessed based on their Mean Time before Failure (MTBF) of equipment and Mean Time to Repair (MTTR) of reactive available networks. Global Services Mobile Communications (GSM) operational efficiency and reliability can assessed based on availability of the communication infrastructure for service delivery.

We discuss from the perspective of the provider with underlying technologies for optical buffering and fast switching. For the purpose of this work, we base our assessment on all optical packet switching network with all packets processed in optical domain and transparent to the service delivered.

From the provider's point of presence (P0P), we have a holistic approach to gather basic information and data for any operator. This covers the Base Transceiver Stations (BTS) Sites: its layout and design for the purpose of business operation. The various Base Transceiver Stations (BTS) Sites on the network has installed capacities based on level of network coverage, time and conditions of business.

The conditions of business are regulated by the Nigerian Communication Commission (NCC). This market is highly deregulated with the NCC licensing a wide variety of telecoms operators. This market has moved from zero to hero over the years of existence in Nigeria and is now considered a leading opportunity for both telecom operators and equipment suppliers. As at December 2014, [16] the installed capacities for (MTN, GLO, AIRTEL and EMTS) were 80,000,000; 38,631,800; 51,012,668 and 40,000,000 respectively. Active voice subscriptions increased from the year 2012, 59,893,093; 28,219,089; 27,556,544 and 21,103,749 for MTN, GLO, Airtel and EMTS respectively. MTN, GLO, Airtel and EMTS had 12,557; 6,677; 6,186 and 4,756 base stations. Mobile [GSM] operators owned a total of 30,176 base stations which is an increase from 28,289 base stations recorded by Mobile [GSM] in December, 2013 thereby indicating an increase of 6.6%. [ ]

2.1. Network Characteristics

1. Full Redundancy: Full Redundancy can be demarcated as the provision of a mode of setting an equipment or system to perform a generic function. It is a method of improving equipment or system reliability. Application of redundancy in reliability implies that a system will continue to function satisfactorily in spite of failure of some items from which it is built up. Redundancy offers advantage when primitive maintenance is planned. The existence of a redundant element can allow for repair in some cases with no system downtime.

Sometimes, it prolongs the operating time significantly in a situation whereby the equipment cannot be maintained. However, the application of redundancy is without limitations, it increases weight, space complexity, cost and time to design. Redundancy is classified into Active and passive [stand by] redundancy.

2. Fast restoration:
3. High availability (99.999 %):
4. Low latency:
5. High bandwidth:
6. Dynamic allocation and high bandwidth efficiency:
7. Quality of services

Our goal is to adhere to ITU's requirements for five nines' operational efficiency in this paper as closely as possible.

3. Related Work

The GSM revolution in the Nigerian Telecommunication sector has its history dated back in the year 2001 amidst various Quality of Services challenges. According to R.O Ijawoye [1] in their paper designed to address Nigeria's mobile revolution journey in the last decade, identified various intricacies, challenges, gains and point the roadmap of reduction in the price tariffs, favourable government policy and proper network infrastructure planning to the future of GSM.

In Adekitan study of GSM networks co-location in Benue State, [2] a state in the Central zone of the county, he identified telecommunications infrastructure sharing and cost optimization as a solution to proper network infrastructure planning and recommended that the regulating body like Nigerian Communication Commission (NCC) should eliminate the issues of non-harmonization of standards in specifications among telecom operators that are open to sharing network infrastructure through issuing colocation licenses to third party companies telecommunications infrastructure. He further stated that the improvement in the power sector will reduce tariffs charged on services by operators and hence improvement in quality of Services.

However, the authors in [3] discussed Quality the service from the perspective of both the service provider and the subscriber. Poor network traffic Congestion and Control on GSM network contributed to high unavailability of the Network services. They recommended the International Telecommunication Union (ITU) bench mark on key performance indicators (KPI) for network operations vs operators to NCC. There result reveals that Etisalat (94.72%) had the highest Average call set-up success rate (CSSR) for operation, Airtel (96.47%), GLOBACOM (72.88%) and MTN (69.15%). The average call set-up failure rate ratio for operation was high for MTN (30.82%), GLOBACOM (27.10%), Etisalat (5.30 %) and Airtel (3.70 %). The various network operators Quality of experience (QoE) was different as well. The Average call success rate (%) ratio for Airtel was the highest (92.03%), Etisalat (92.00%), GLOBACOM (48.57%), and lowest for MTN (45.17%). The Average call set up failure rate (%) ratio for operators was high for MTN (25.40%), GLOBACOM (21.12%), Airtel (4.42 %) and Etisalat (2.22 %) respectively.

C. F. Chidozie et.al [4] argue that the deregulation of the Nigerian Telecommunication Sector that led to the creation of the Nigerian communication commission (NCC) contributed to development in the nation but with new challenges. The issue of ensuring conformity to best quality of service delivery; upgrading of infrastructures to meet international standard; security and maintenance of facilities, especially in the remote areas; ensuring the framework of broadband that can be accommodated by the ecosystem; and security of data in this digital world all affect the reliability of networks from deviating from the five nine's concept.

This is similar to the view of authors in [1], [2] [3] where foreign mobile operators in Nigeria dominated the telecommunication landscape while neglecting the promotion of indigenous operators of the telecommunication services in the country. A concept also similar to the part stress method.

This is significantly different from that for the part count method and may be reflected in the established reliability design philosophy. The part stress method is one of two methods used in assessing the reliability of network equipment. In the part stress method, the effect of the various stresses on the actual hardware are put into consideration; alongside with the environmental factor and the quality of the utility, whereas the count method of assessing the reliability of systems is based on the number of different parts, quality level and application environment.

Our aim in both cases is to determine the failure rate for a given network system operating in a specific environment such as the case study in this Paper.

In the ITU-T Recommendation E.800, QoS is defined as the collective effect of service performance, which determines the degree of satisfaction of a user of the service. In [5] and [6], customer's Quality of experience (QoE) or satisfaction was used as a yard stick of measurement to help service firms improve service quality and help prospective customers make informed choice (s) of a service provider. Performance metrics such as availability, reliability, retain ability and accessibility were measured as a desired quality level. In an attempt to find an alternative to the issue of poor quality of service (QoS) from a single service provider, a trend in subscriber's behaviour reveals the desire to acquire multiple GSM lines.

In [7] they arguably conclude that most subscriber' acquire multiple GSM subscriptions because of poor quality of services from network operators. A factor that led to the creation of number portability.

Another issue of concern in relation to poor quality of service is that of cross connections and dropped calls that resulted into a temporary measure of number portability. This was addressed by O. M. Onyema and O. M. Ogechi [8], in their research work and effort to measuring the motivating factors behind subscriber's willingness to paying for Mobile Telecommunications Services in Nigeria. A problem statement identified that mobile lines are increasingly becoming inactive as subscribers abandon their lines to switch from one network to the other in the quest for quality service which opposes the design concept of global roaming. This was supported by Nigerian communication commission (NCC) as the growth rate of total active lines declined from 53.2% in 2008 to about 8.5% in 2011. [8] and [9]

In addition, O. M. Onyema and O. M. Ogechi recommended a policy whereby operators pay fines for welfare loss in terms of wrongly routed calls, drop calls, over network congestions arising from wrongly timed promotional sales, non-competitive prices that increases demand for telecoms services without commensurate improvements in quality services etc.

In this paper we approach the problem of quality of service with Unavailable Second (UAS) constraint from the network operator's perspectives. Our contributions are the following in contrast to most papers addressing similar perspective of quality of service, we provide a proposal similar to the part stress method as a preferable assessment method for reliability of an existing system based on the possibilities of considering various stresses peculiar to the network equipment on a specific area of application. Our network availability which is the ratio of measured time to Unavailable Second (UAS) is utilized in the assessment method.

3.1. Internet Services

Scores for internet speed were highest among Etisalat subscribers (57.4), and lowest among MTN subscribers (46.9). Table I shows the spread of scores for quality of voice calls and video streaming was much smaller, but scores registered by Etisalat subscribers were still highest 58.5 and 58.6 respectively.

The lowest scores for voice and video streaming were registered by MTN and 56.2 respectively. The spread of network reliability scores across ISPs was small. Etisalat registered the highest score in respect of the loss of service and getting cut off at 61.2 and 60.6 respectively. [10], [11] MTN scored the lowest when it came to getting cut off and loss of services, scoring 58.1 and 57.9 respectively. Although the spread of scores across ISPs for complaints handling was small, they were highest among Globacom subscribers. Perceived internet speed appeared to be relatively high in the South West zone, and slow in North West zone.

However, at the same time, perceived quality of voice calling through the Internet was highest in North West zone. Perceived frequency of getting cut off was also highest in North West zone with high network down time due to social-political glitches.

Availability (in Times of second)				
Network subscribers	Percentage (%) Voice	Percentage (%) Video	loss of service	Cut off
ETMS	58.5	58.6	61.2	60.6
MTN	56.2	56.2	57.9	58.1
GLOBACOM	57.1	57.2	50.2	51.5
AIRTEL	57.3	58.0	51.2	52.5

Table 1: Speed Scores in bps and % for Internet Services

3.2. Mobile Telephony

The differences between Nigeria's four major mobile operators were modest across all indicators for mobile telephony. MTN registered lower scores on quality of calls to other mobile and fixed networks; it scored 58.5, compared to Etisalat's score of 63.1, which was the highest for that indicator. Etisalat also scored highest on issues concerning network reliability, but differences were modest again. [10] For example, Etisalat scored 62.8 on the loss of service indicator, the lowest score of 60.9 was registered by MTN, closely followed by Airtel's score of 61.

On the issue of charging, Globacom and Etisalat registered higher scores; Etisalat had the highest scores for the correct charging of calls 65.5, closely followed by Globacom with 65.2. On the issue of whether rates aligned with service providers' advertised rates, Etisalat scored highest with 60.9, closely followed by Globacom on 59.1. [12, 13, 14] MTN was the lowest on both issues of charging; it scored 60.4 for the correctness of charging and 55.3 for the whether the rates it charged agreed with advertised.

Although the differences were modest, Etisalat subscribers rated VAS services highly (57.2) and MTN subscribers rated those relatively poorly (55.5). Etisalat subscribers rated all aspects of complaints handling highly. It received the highest scores for all complaints handling indicators, apart from the effectiveness of the IVR service; its score of 63.2 was ahead of Airtel's score of 63.3. [15], [16], [17]

When looking at differences between zones, mobile services appeared to be better in the North Central & FCT and South West zones. Views on the charging for SMS and VAS services were poorer in North West zone, and respondents in South zone appeared to have greater technical difficulty in using these services.

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3.3. Unavailable Second (UAS)

This is a period of unavailable time begins at the onset of ten consecutive Severely Encoded Seconds (SES) events. These ten seconds are considered to be part of unavailable time. A new period of available time begins at the onset of ten consecutive non-SES events. These ten seconds are considered to be part of available time. (ITU-T G.826,) [20]

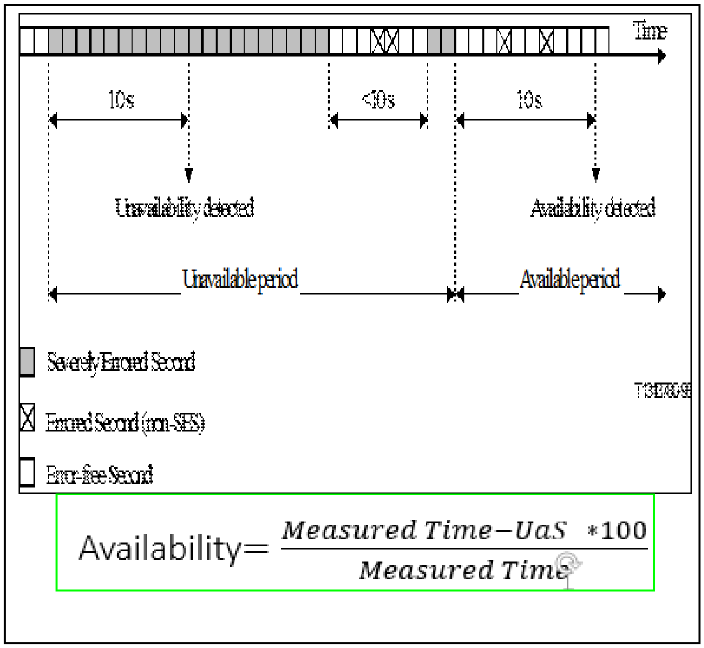

Figure 1: Unavailable Second (UAS) Description

<u>3.3.1. Equipment Availability</u>

Equipment Availability is the probability that an equipment will perform its required function at a steady instant of time or over a stated period of time.

Availability is a function of the utilization factor of a unit or system is defined as the ratio of the operating time (top) to the sum of the maintenance time (TM), Idle time (tid), (which may occur between completion of maintenance and use due to administrative reasons) and the operating time. Mathematically, the utilization factor, U can be expressed as

$\mu = top/(tm+tid+top)$ --------------------------------- (1),

From equation (1) above, if the idle link is equal to zero (i.e. tid =0) and the maintenance time becomes as small as possible, then utilization factor will approach its maximum value and can now be called availability of a unit or system.

Mathematically, time can be expressed as

$A = top/(top+tm+tm(min),)$ -------------- μ max (2),

However, the mean time before failure (MTBF) =top and the mean time to repair (MTTR) =tm (min).

Then;

$A = MTBF/(MTBF+MTTR,)$ ------------------------ (3),

If the availability of an equipment is given as 0.90, this means that the equipment is working satisfactory for 90 percent of the time, and under repair for the remaining 10 percent.

There are three forms of system availability, namely; steady –state availability, instantaneous availability and mission availability.

A= MTBF/
(MTBF+MTTR,)

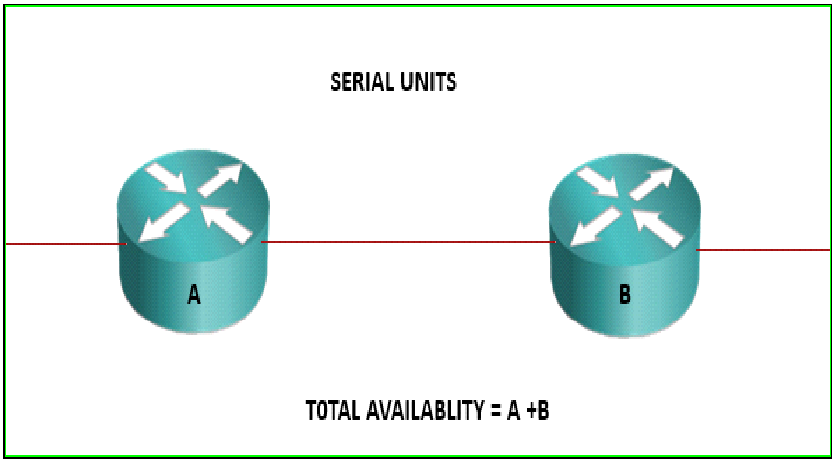

Figure 2: Serial Units

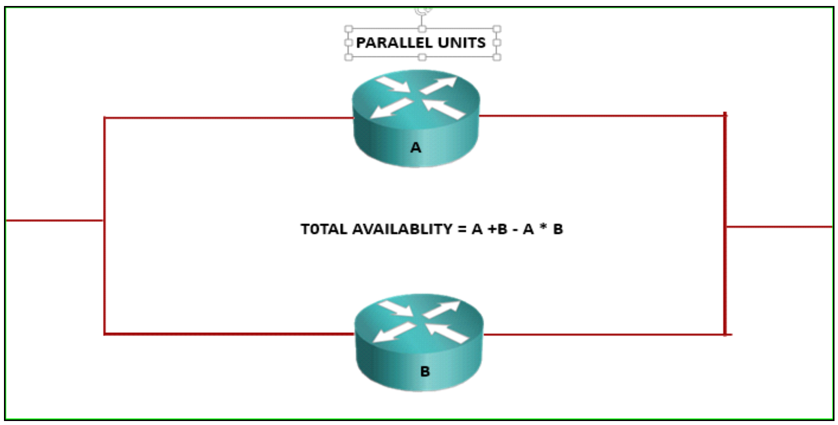

Figure 3: Parallel Units

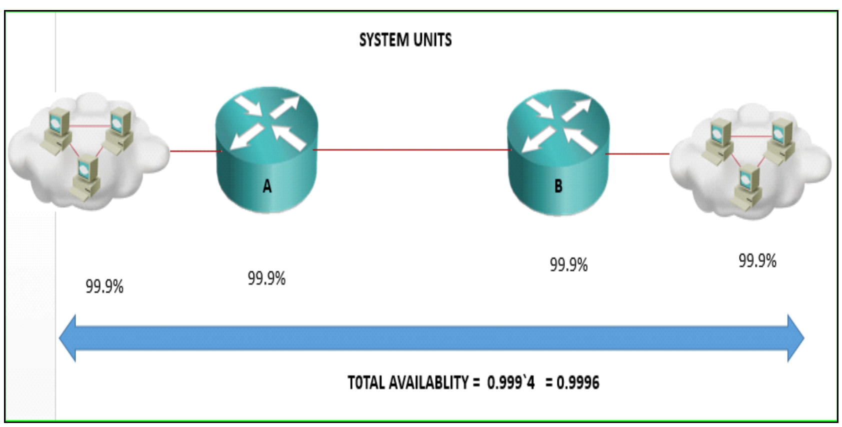

Figure 4: Total Available System Units

3.3.2. Network Availability

The reliability of network services is a function of availability of prompt service provisioning with respect to the conditions of network operation within a specified environmental conditions at a given period of time.

In the next generational network, availability is presumed to be a principal selling point in the telecommunication market. This is also known as Theoretic Availability in real terms. Percentage value of network uptime for a given time period such 2400 hrs in a day, 7 days in a week and 52 days in a month and 365 days in a year of continuous network operation under specified conditions.

The popularly defined terminology for availability is the "Five-nines" 99,999%. This is viewed as desired uptime in network core-level of any net-work operation. [Fig 1.0] a week and 52 days in a month and 365 days in a year of continuous network operation under specified conditions as shown in Table 1.

Availability	Downtime per year
99,9999%	32s
99,999%	5min 15s
99,99%	52min 36s
99,9%	8h 46min
99%	3 days 15h 40min

Table 3: availability is the "Five-nines"

3.4. Gateways in Use

A total of 110 Gateways were in use by Mobile GSM, CDMA & operators in 2014 compared to 107 in use in 2013[ ] (13) Number of gateways in use as at December, 2014 which was an increase from (11) Number of gateways in use recorded in 2013. Similarly, GTS Infotel reported (2) Number of gateways in use as at December, 2014 which was an increase from (1) Number of gateway in use as at December, 2013 Cross Connection and Dropped Calls

4. Availability Measurement Model

We establish constraints based on three statements with the use of three simple rules to design comments in fuzzy logic toolbox. Fuzzy logic is a good solution here because it is easy to formulate the answer using basic rules as follows:

1. If service is poor transmission is bad, quality is Low.
2. If service is good or quality is average
3. If service is excellent or transmission is great, quality is high.

Fuzzy logic was useful for designing the four network systems models and system controls where precise definitions and boundaries do not exist or are too rigid.

In building fuzzy logic system to solve the quality of service (QOS) problem in the four network, we assume quality of transmission (QoT) is around 15% but based on the Quality of transmission in real time.

We created a margin between two inputs: quality of transmission and quality of service (QOS)

```
%Establish constriants
Low Tip=0.05; aver Tip=0.15; highTip=0.25
tip Range=high Tip-LlowTip;
bad service=0; okay service=3;
good service=7'greatservice=10
service Range=great Service-bad service
poor Transm=0; great Transm=10;
Transm Range=great Transm-bad Transm;

% If service is poor or Transm is noisy, tip is cheap
if service<okayService,
tip= ((( averTip-lowTip)/(okay Service-bad Service))..
* Service+lowTip) *ServRatio + ...
(1-servRatio)* (tipRange/Transm Range*Transm+lowTip);

% If service is good, tip is average
elseif service<good Service,
tip=averTip*servRatio + (1-servRatio) * ...
(tipRange/TransmRange *Transm+lowTip);

% If service is execellent or Transm is noiseless, tip is HIGH
else
tip=(((highTip-averTip)/ ...
(greatService-goodService))*....
(service-goodService)+averTip) *servRatio + ...
(1-servRatio)*tipRange/TransmRange*Transm+lowTip);
End
```

5. Numerical Results

5.1. Results on the Availability of Services of operators

We simulated this problem with non-fuzzy logic tool,

Since we can easily change our definitions of good and bad, transmission and service. Poor and great in numerical terms. From the graphical representation in figure 5.0 and 6.0, the tip or axes y -transmission should be high, service and transmission should be great and noiseless. Fuzzy logic is a good solution here because it is easy to formulate the answer using basic rules shown below without using mat lab command codes is difficult because it hard to understand, maintain and change

We design and simulate the fuzzy logic system from scratch and we implemented the four basic steps in building and simulating

First, we defined input and output functions. Second we created membership functions and created rules. We then simulated the resulting fuzzy logic system. This is more convenient to use due to its graphical user Interface.

Fuzzy logic tool box does not limit the number of inputs or output allowed. We define the input function as service and one output function as quality.

By default we have one input and one output variable

and we added one input more.

input=service

input=transmission

output=quality

The system diagram shows name of the system and type of inference used.

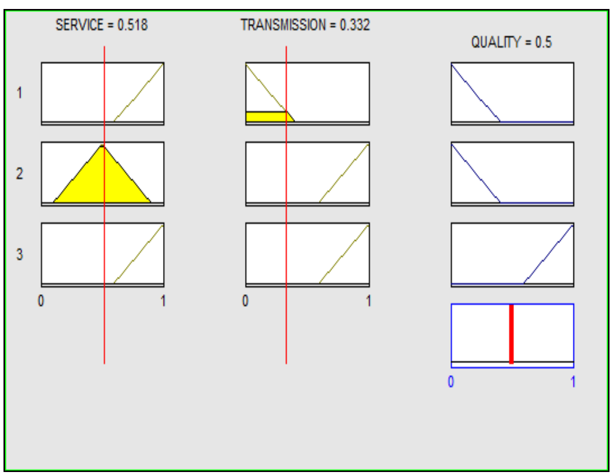

Figure 5: The membership function for service, transmission and quality

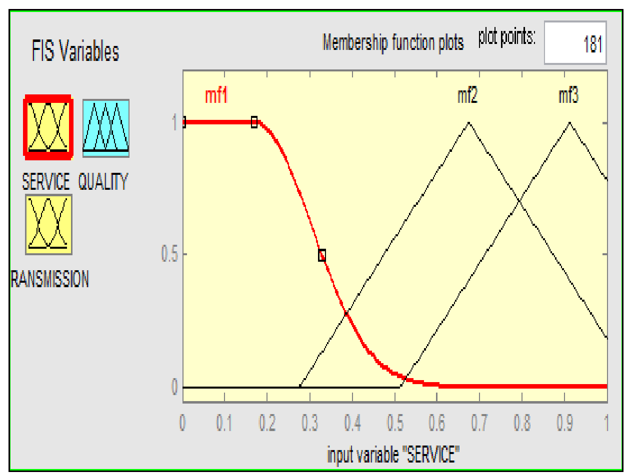

Figure 6: The membership function for transmission and quality

Figure 2. Example of an image with

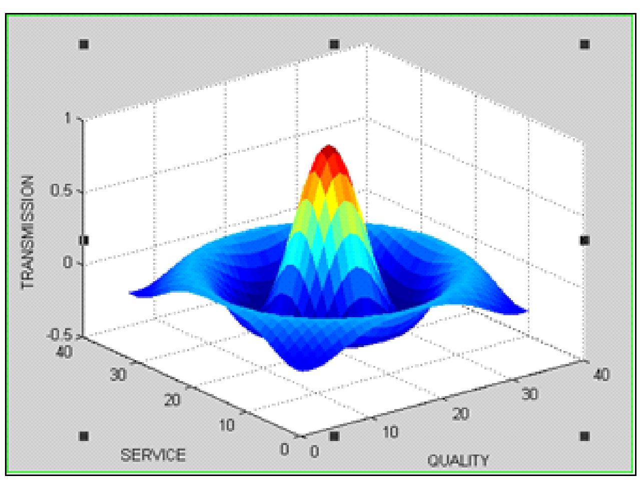

Figure 7: Relationship between service, transmission and quality.

AVAILABILITY/LINK Year 2007-2009 ,	**MT (sec)**	**Av1**	**Av2**	**Av3**	**AV4**	**AVr1**	**AVr2**	**UAS**	**%UAS**	**Avg UAS**
MTN	0.007	0.029	0.070	0.130	0.093	0.091	0.110	0.200	0.120	0.21
GL0	0.020	0.062	0.120	0.210	0.170	0.160	0.200	0.330	0.230	0.34
AIRTEL	0.032	0.094	0.180	0.290	0.240	0.230	0.280	0.450	0.340	0.47
EMTS	0.010	0.059	0.119	0.200	0.168	0.150	0.190	0.310	0.220	0.30
Year 2010-2012,										
MTN	0.079	0.220	0.370	0.560	0.490	0.450	0.610	0.890	0.710	0.85
Gl0	0.130	0.340	0.560	0.820	0.730	0.670	0.920	1.300	1.100	1.20
Airtel	0.290	0.780	1.300	1.800	1.700	1.500	2.100	2.900	2.500	2.70
EMTS	0.120	0.320	0.520	0.720	0.700	0.650	0.900	1.250	1.000	1.15
Year 2013-2015										
MTN	0.810	2.100	3.500	5.100	4.500	4.100	5.800	8.100	6.700	7.30
Gl0	2.200	5.700	9.600	14.000	12.000	11.000	16.000	22.000	18.000	20.00
Airtel	5.900	16.000	26.000	38.000	13.000	30.000	43.000	60.000	49.000	54.00
EMTS	2.150	5.690	9.500	13.000	11.000	10.000	15.000	21.000	17.000	19.00

Table 4: Results on the Quality factor of Equipment Availability

MT: Measured Time
Av1: Available Link 1
Av2: Available Link 2
Av3: Available Ring 3
AV4: Available Ring 4
AVr1: Available Ring 1
AVr2: Available Ring 2
UAS: Unavailable Second (UAS)
%UAS: Percentage Unavailable Second (UAS)
Avg UAS: Average Unavailable Second (UAS)

5.2. Results of Failure Rate of Network Vis-a Vis Environment of operation

NETWORK	Quality level
EMTS-SS	0.5
AIRTEL-SE	1.0
GLO-NW	2.5
MTN-NC	5.0
EMTS-SW	8.0
GLO-NE	45.0
AIRTEL-NW	75.0
MTN-NE	150.0

Table 5: Factors for Availability and QOS

FAILURE RATE LEVEL	$*\pi_Q$
MTN	1.5
GLO	1.0
AIRTEL	0.3
EMTS	0.1

Table 6: Failure Rate of Network vs Environment

	Year 1	Year 2	Year 3	Year 4	Year 5
Design	0.9915	0.98314	0.9748	0.9666	0.9584
MTN	0.83954	0.7048	0.5917	0.4968	0.4171
GLO	0.83953	0.7046	0.5912	0.4960	0.4170
AIRTEL	0.7804	0.6900	0.4500	0.4600	0.4144
EMTS	0.83845	0.7000	0.5500	0.4900	0.4160

Table 7: Reliability Result

	Year 1	Year 2	Year 3	Year 4	Year 5
Design	99.15%	99.31%	99.48%	96.66%	99.84%
MTN	83.95%	70.48%	59.17%	49.68%	41.71%
GLO	83.45%	70.47%	59.01%	49.52%	40.70%
AIRTEL	82.01%	70.01%	58.38%	46.48%	39.48%
EMTS	83.00%	70.45%	58.40%	49.44%	40.59%

Table 8: Percentage of Reliability

6. Conclusion

In this paper, we have identified the criteria for availability, unavailable seconds, Mean Time to Repair on a network operation. We approached the problem of quality of service with Unavailable Second (UAS) constraint from the network operator's perspectives. This results shows that MTN has the lowest UAS in the Central Central and South South Zone, and EMTS has the highest UAS in the North East and North West Zone of the country. The reliability of a network is strongly influenced by decision made during the design process. Deficiencies in network design affect all phases of network operation and are progressively more expensive to correct as provisioning proceeds. Also worth mentioning is the constraints of shortage supply of power to telephone infrastructure, lack of basic modern digital telephone infrastructure, vandalism, theft of network infrastructure, insecurity in certain parts of the country, multiple taxation and over-regulation which are issues in further research

7. Acknowledgement

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