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OPTIMUM DIMENSIONING OF INTERCONNECTIONS BETWEEN SOME GSM OPERATORS IN NIGERIA USING ERLANG B MODEL

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ABSTRACT

In the research, development, design and operation of telecommunication and computer networks, the important problems are determining the optimum configuration and dimensions of the system's capacity for providing a given performance or Grade of Service (GoS). It would be uneconomical if exclusive resources such as switching and transmission facilities were dedicated to each customer. Therefore a pool of facilities is provided in common for a number of customers, and thus situations can arise in which a customer has to wait for connection, due to shortage of resources. Hence, it is required to evaluate such GoS quantitatively, and clarify relations between the GoS and the amount as well as configuration of the telecommunications facilities. In this paper, the Erlang B model coupled with Siemens Normal and High Load formulae are used to determine the optimum network capacity based on detailed user behavior and demanded quality of service parameters in an overall telecommunication system. As a benchmark, 18 months teletraffic data for interconnections between Networks A to F in Nigeria was utilized and Microsoft Excel was used for the analysis of the data. The performance level of the system has been calculated according to the International Telecommunications Union Standards (ITU-T) criteria. The results showed a Call Completion Rate (CCR) of 63% and the Answer Seizure Ratio (ASR) of 23% which were below the then standard values of 75% and 55% respectively. The result shows that the interconnections were not optimum. Some were over dimensioned and some were under dimensioned. Comparing with the Average current Industry statistics of CCR and ASR of 93% and 80% there is 30% and 40% improvement in CCR and ASR respectively. Recommendations were made to interconnecting service providers for optimum configuration.

Keywords: Call Completion Rate (CCR), Answer Seizure Ratio (ASR), Erlang and Grade of Service (GoS)

INTRODUCTION

Telecommunication systems have been evolving from the conventional telephone network that mainly deals with voice, to the integrated services digital network (ISDN) integrating, voice, data and video. Moreover, the asynchronous transfer mode (ATM) and optical switching technologies are being developed for the broadband ISDN, which can handle speedy video communications as well. In the design and development of such telecommunications and computer networks the important problems are determining the optimum configuration and dimensions of the system for providing a given performance or grade of services (GoS) (Melamed & Morris 1995, Cooper & Kawashima, 1989). Traffic theory is a mathematical description of the network and telecommunication systems in probabilistic categories. The aim of traffic theory is to construct analytical models of telecommunication networks and systems that enable their proper design and effective management. Basic principles of traffic theory were formulated by a Danish mathematician Agner Krarup Erlang (1879–1929) at the beginning of the twentieth century. From work originally devoted to telecommunication applications, a new branch of probability theory emerged, called queuing theory. Nowadays, traffic theory is classified as part of technical cybernetics, a branch of science that has been developing very rapidly over the past few decades and has been using an increasing range of mathematical methodologies such as probability theory, algebra, graph theory, stochastic processes theory and Markov process theory (Ozovehe1 et al., 2011). Researchers often rely on teletraffic theory for the solution of these problems (Melamed & Morris, 1995). The purpose of the teletraffic theory is to find relation between quality of services and equipment cost. This is very important for planning and controlling of telecommunication networks to the satisfaction of the user. This gives rise to the issues of Quality of Service (QoS) in telecommunication networks, which is defined in the ITU-T Recommendation E-800 as: "*The collective effect of service performance, which determines the degree of satisfaction of a user of the service*". QoS parameters are administratively specified in Service Level Agreement (SLA) between users and telecom operators. These QoS parameters (from a contract of SLA) are reflecting on GoS parameters. Based on a given set of QoS requirements, a set of GoS parameters are selected and determined as functions of human behavior characteristics (Danbatta, 2015). In telecommunications systems, it would be uneconomical if resources such as switching and transmission facilities were exclusively dedicated to each customer. Rather a pool of these facilities is provided for a number of customers to share. Thus situations can arise in which a customer is rejected or has to wait for connection because a resource was being used by another user. Hence, it is required to evaluate such grades of services (GoS) quantitatively, and clarify relations between the GoS and the amount as well as configuration of the telecommunications facilities (Danbatta 2004). The teletraffic theory analyses such GoS using probability theory since the demand of telephone data calls has stochastic characteristics.

A telephone network cannot be calculated exactly like an electronic circuit, as the behavior of the subscriber (which can only be examined with difficulty) determines the demands on the network. For this reason, suitable statistical procedures must be defined in order to record the network arithmetically. The specifications of the parameters necessary for statistical recordings are laid down by the International Telecommunications Union (ITU) in Recommendation E.600. These parameters are Call Completion Rate CCR and Answer Seizure Rate ASR.

This world of heterogeneous elements exerts a pressing and critical demand for the concept of interoperability and its variations (see Figure 1):

i. Interoperability of networks and of network management systems.
ii. Interworking of applications and transparency between services.
iii. Interfacing among operators and service providers, exchange of *Quality of Service* (QoS), *Service Level Agreement* (SLA) information and accounting rules.

Interoperability is one of the most critical issues in communications to be solved in the 21st century.

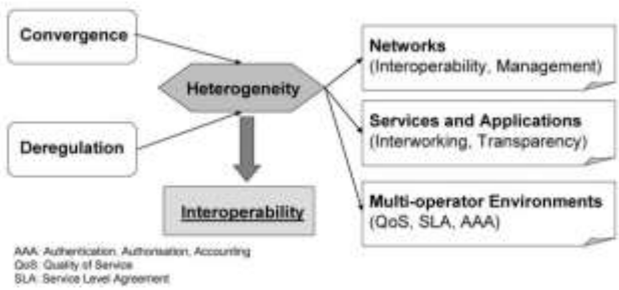

Figure 1: Interoperability between Networks in the convergence Industry (Stasiak et al., 2011)

Resource dimensioning is a performance requirement for the development of the effective network architecture. The customers' demand are met by utilizing randomly both the hardware or software resources like outgoing digital trunks, timeslots, tone detectors etc (Stasiak et al. 2011). There are three different traffic profiles (Fiche and Hebuterne, 2004): Normal day corresponds to usual activities during a day, High load condition corresponds to special days in a year. Exceptional conditions corresponds to unexpected happenings. To unravel the course (s) of the congestion, GSM network performance evaluation are done by network service providers, NSPs, consulting companies, Telecommunication Regulators and independent researchers using NMS measurements KPIs in order to bench mark the performance of the network in terms of GoS and QoS. Usually, extensive measurements from live network or simulation of network data are required to determine optimal cellular network dimension in order to reduce network congestion and improve QoS. We present in this work a review of such related works on the basis of network elements they have addressed.

LITERATURE REVIEW

Tom Waligo (2008) investigates teletraffic engineering issues in the design and development of next generation network systems. Comprehensive modelling of the operation of the systems under a variety of traffic flows has been done. Sani Man-Yahaya (2007) conducted a performance management studies in communication networks with specific interest on the Mobile Switching Centre of Celtel limited Lagos area. A traffic data was obtained on weekly basis for nine mobile switching centres located in three different locations in Lagos area, indicating subscriber's demands and responses for a period of six months were collected and studied. The entire network expansive control measures that actually lead to the establishment of more Mobile Switching Centers especially in Victoria Island is the lasting solution to ensure reasonable improvement in network performance.

Isabel Frostne (2011) studies the Network in Kulyab region. After collecting and analyzing the data, the new MSC was configured, so it meets the current traffic demands along with appropriate number of base stations it can support and the extent to which it improves the overall network performance in terms of increased reliability, capacity, and throughput. Osahenvemwen & Emagbetere (2011) analyzed some BSC performance using offered traffic, carried traffic, block traffic, call completion rate (CCR), busy hour call attempt (BHCA) and GOS as traffic performance indicators. The data was analyzed using excel package to determine the busy hour which was observed to be 18:00 GMT. The work of Mughele & Wole (2012) investigated the causes of congestion using a survey research design methodology, live data from MTN BTS and BSC, as well as customer feedback. The study showed that a major cause of MTN network congestion is lack of adequate network resources to cope with the demand of its teeming subscribers. Similarly, Ohaneme et al. (2012) simulated some traffic models in MATLAB environment for evaluating performance of GSM networks using Call Completion Ratio (CCR) and Answer Seizure Ratio (ASR) on four mobile network's BTS and BSC in Nigeria. The result showed that the QoS is not reliable as a result of network congestion. However, the work did not identify the cause or proffer solution to the congestion problem. Ozovehe1 et al (2011) addressed congestion during busy hour. Analyzed Real-time traffic user to predict the traffic demand pattern on network resources for proper prediction of network congestion so that resources can be provided to take care of rejected or diverted traffic. Nnamdi, Aneke and James (2017) have developed a control algorithm for the management of the congestion experienced in the GSM network in Nigeria. It explores the use of Erlang-B in determining the appropriate probability level for some range of subscribers, dynamic allocation with and without time slicing, coupled with signal sensing, frequently recent call allocation, and priority allocation algorithms were developed to manage the congestion. Furthermore, a hybrid algorithm was developed that integrates all the algorithms together, Galadanci and Abdullahi (2019) utilizes the log files data generated on three active GSM networks in Kano, and intensively evaluated the traffic performances of three key teletraffic parameters of GSM network, during the seven months' duration including the festive periods, statistically using the Minitab statistical software package And also using regression analysis here, a traffic model over some key parameters were developed.

MATERIALS AND METHODS

As a benchmark study, eighteen months daily teletraffic data for the outgoing traffic flow at the Network A was utilized. The data includes parameters such as traffic intensity, total number of calls completed, total number of calls attempted and total number of minutes of usage. Erlang formulae would be used for a statistical analysis of the network data using Microsoft Excel and Siemens Teletraf software.

This exchange was selected because it was connected to several public operators Network B to G in Nigeria. The exchange was also connected to *20 other exchanges spread across the country. The names of the Networks were omitted due to some regulatory rules and restrictions.*

Trunk group Size

To calculate the required trunk group size between two switching centers, the traffic characteristics must be considered. If the traffic sources (subscriber or PBX) are not influenced by external events, we speak of random traffic. There are two parameters for random traffic.

(*i*) The interval of incidence; i.e. the time from the start of one connection until the start of the next connection.

(*ii*) The call duration; i.e. the time from seizure until release.

A call is defined as a demand for connection in teletraffic systems, and it is also referred to as customer.

Telephone traffic means all users or employment, regardless of the origin and irrespective of whether this relates to a successful call or not. As the subscribers generate the telephone traffic, they are also called traffic sources. Mathematical models are used to describe the behavior of subscribers (Akimaru and Kawashima 1989). Traffic can be random or deterministic. Random traffic describes the behavior of a large group of traffic sources in a Mathematical model. Essentially, a distinction is drawn between random traffic of the first and second type. Random traffic of the first type (also called Erlang traffic) is a traffic generated by an infinite number of traffic sources. These sources are characterized by the probability of attaining a seizure irrespective of the number of already existing seizures. In practice, the number of traffic sources is always limited. If the ratio of subscriber numbers to traffic flow is greater than 10, then this is Erlang traffic. Statistical behavior of this sort is also characterized by two parameters: Interval of incidence and holding time. Both times are exponentially distributed negatively. In the case of random traffic of the second type (also called Engset traffic), the ratio of subscriber numbers to traffic flow is less than 10, and the number of traffic sources is limited. The seizure of any occurring call depends on the connections already in existence. However, this model is only suitable for original traffic sources, i.e. traffic coming straight from subscribers without additional concentration levels. The holding time is the time from seizure until release of a line. Suppose there are *n* attempted calls that have been answered with conversation times $t_1, t_2, \dots t_n$ respectively then the traffic volume T_V, is given as

$$T_V = t_1 + t_2 + \dots\dots t_n \text{ Erlang-s} \quad (1)$$

The traffic volume is the total holding time (usage time) of all the seizures in a serving trunk group observed during a specific observation period (usually 15mins.). It has the dimension of time. However, to identify it as a telephone traffic volume the unit is called Erlang- second (Erl-s) as indicated in equation (1). The mean holding time t_m is found as

$$t_m = T_V/n \quad (2)$$

A closely related quantity is the traffic flow, which is defined as

$$y = T_V/T \quad (3)$$

Where *T* is the observation period, usually given as 15 mins, 30 mins, 45mins, or 1 hour. The dimension of traffic flow is Erlang. Traffic flow is also equivalent to the average number of seizures existing simultaneously. That is to say

$$y = (C_C \times t_m)/T \quad (4)$$

Where C_C is the carried calls. For dimensioning of switching equipment, the traffic flow of the busy hour traffic (BHT) is used.

If the mean holding time or the number of seizures is not taken into account, the traffic flow itself does not provide any information about the seizure of the central equipment used for connection setup. Many seizures with a short holding time (e.g. Televoting) do not generate a higher trunk group load but load the central equipment much more heavily.

Traffic Offered (*A*)

The traffic offered corresponds to the traffic flow that would occur if the call attempts were successful; generally speaking, the traffic offered cannot be directly measured, but is calculated from the number of call attempts made per time unit, multiplied by the mean holding time of the successful call attempts of this traffic. In loss mode, the traffic offered is a theoretical quantity because it includes the rejected call attempts. In pure delay mode, the traffic offered is equivalent to the traffic carried.

$$A = \frac{C_A t_m}{T} \quad (5)$$

In pure delay systems $A = y$. However in practice there is always some loss traffic therefore $A > y$.

Traffic Rejected (R)

The traffic that cannot be accepted by a trunk group is called traffic rejected. In loss mode, this traffic is called loss traffic i.e. the subscriber is connected to a recorded announcement or hears the busy tone. For the quantitative evaluation of the quality of service in loss systems, the GoS parameters most frequently used are the loss coefficient (often called the call congestion) and the blocking coefficient (often called the time congestion) Stasiak et al. (2011). A rejected traffic flow is not a measurable quantity. It is calculated from the number of lost call attempts and the mean holding time of successful call attempts in the trunk group. In overflow mode this traffic corresponds to overflow traffic.

$$R = C_R \times t_m \quad (6)$$

Where C_R is the number of rejected calls and t_m is the mean holding time.

Blocking (B)

The state of a switching network or a trunk group in which the setup of a new connection is impossible because either no suitable path to free serving lines is available (internal blocking) or all serving lines are busy (external blocking) is called blocking. By design, the space time and space stages used in digital switching systems are individually free from blocking. This is the probability that a call attempt is rejected and lost as a result. An estimate for loss probability is the ratio of the number of rejected calls to the total number of calls. It can be distinguished in greater detail by the type of connection desired: point-trunk group loss probability, user-to-user loss probability etc. In most cases, loss probability B relating to traffic offered A is employed.

Erlang B Formula

The Erlang B formula is used to calculate the loss or overflow of a circuit group if the offered traffic is given. A trunk group consists of circuits each of which has the same probability of being selected. This means that any of these circuits may be seized when a request (call attempt) arrives Cooper Akimaru and Kawashima (1989).

$$B = \frac{\frac{A^N}{N!}}{\sum_{i=1}^{N} \frac{A^N}{i!}} \qquad (7)$$

N is the number of circuits available and A is the offered traffic. The Erlang B formula can be applied if the following conditions are given:

- Full availability, which means that all circuits can be seized by the switch without any restriction.
- An infinite number of sources (random traffic of first order, also called Erlang traffic).
- A loss system which means if no free circuit is available, the call is lost; no waiting for a second trial. In case of such systems the The Erlang B loss formula will give the probability that a call is being lost. Add details of implication of the result

There are certain Key Performance Indices (KPI) standardized by ITU by means of which user satisfaction is measured. These indices include Call Completion Rate and Answer Seizure Ratio. They are also used as indicators of revenue generation and network performance. They are defined as follows Siemens (1993):

ASR = (Answered Calls × 100)/Total Seizure

CCR = (Busy + Answered + Unanswered Calls)×100 / Total attempt

The parameters are measured in %, and the expected total average values of CCR and ASR are 75% and 55% respectively for effective network utilization.

RESULTS AND DISCUSSION

As a benchmark study, the data of Network A for 18-months period was used based on daily-busy hour (10:00am-11:00am) traffic analysis done by OMC (Operation and Maintenance Center) staff. The data and result of Network A to F route was selected as a reference for this discussion, as the same format was used in every other routes. The numbers of provided and available circuits within each trunk group are given. Hence the number of faulty circuits are given by their computed differences. The observation period T is 900 seconds. The Grade of Service B=83.306%, which is a function of N (number of circuits available) and the Offered traffic.

Sample Calculations

To calculate the value for "Normal / High load, Variance V of the individual days is crucial, however; how much do the "traffic flows" of the 30 days deviate from the average. The root of the variance then produces the standard deviated STD. This deviation is then included in the calculation of the "Normal load". The calculation for Network A to Network F route is given as follows:

Table 1: Results of performance analysis of interconnectivity between Network A to F number of trunks provided =122 period (busy hour) t =900secs

DAY	**NUMBER OF AVAILABLE CIRCUITS N**	OFFERED TRAFFIC A (ERL)	CARRIED TRAFFIC Y (ERL)	TRAFFIC VOLUME TV Y*T (ERL-s)	LOST TRAFFIC A-y (ERL)	CALLS CARRIED CC	ERL/CCT y/N (ERL)	GRADE OF SERVICE B=f(N,A) %	MEAN OLDING TIME Tm=TV/CC Sec
1.	122	729.6047	121.8	109620	607.8047	2693	0.998361	83.306	40.705533
2.	122	526.0749	121.7	109530	404.3749	3657	0.997541	76.866	29.950779
3.	122	322.1579	121.4	109260	200.7579	4060	0.995082	62.317	26.91133
4.	122	292.9178	121.3	109170	171.6178	2478	0.994262	50.589	44.05569
5.	122	141.8097	117.8	106020	! 24.0097	1850	0.965574	16.931	57.308108
6.	122	134.7144	117.4	105660	17.3144	1126	0.962295	15.366	93.83659
7.	122	136.6748	117.1	105390	I 19.5748	1069	0.959836	14.322	98.587465
8.	122	134.2553	116.7	105030	17.5553	1190	0.956557	13.076	88.260504
9.	122	133.1537	116.5	104850	16.6537	5484	0.954918	12.507	19.119256
10.	122	132.6267	116.4	104760	16.2267	955	0.954098	12.235	109.69634
11.	122	131.1315	116	104490	15.0315	1060	0.951639	11.463	98.575472
12.	122	130.6594	116	104400	14.6594	1075	0.95082	11.22	97.116279
13.	122	128.4702	115.5	103950	12.9702	991	0.946721	10.096	104.89405
14.	122	126.5232	115	103500	11.5232	930	0.942623	9.1076	111.29032
15.	122	123.4887	114.1	102690	9.3887	1255	0.935246	7.6028	81.824701
16.	122	119.873	112.8	101520	7.073	1036	0.92459	5.9004	97.992278
17.	122	118.896	112.4	101160	6.496	1178	0.921311	5.4636	85.874363
18.	122	117.5245	111.8	100620	5.7245	1149	0.916393	4.8709	87.571802
19.	122	116.8762	111.5	100350	5.3762	1171	0.913934	4.5999	85.695986
20.	122	116.2501	111.2	'100080'	5.0501	1146	0.911475	4.3442	87.329843
21.	122	116.0461	111.1	99990	4.9461	1074'	0.910656	4.2621	93.100559
22.	122	115.8442	111	99900	4.8442	1213	0.909836	4.1817	82.357791
23.	122	115.6446	110.9	99810	4.7446	1113	0.909016	4.1027	89.67655
24.	122	115.4471	110.8	99720	4.6471	1532	0.908197	4.0253	65.091384
25.	122	115.2516	110.7	99630	4.5516	1120	0.907377	3.9493	B8.955357
26.	122	115.0581	110.6	99540	4.4581	1127	0.906557	3.8747	88.322981
27.	122	114.8666	110.5	99450	4.3666	973	0.905738	3.8015	102.20966
28.	122	114.677	110.4	99360	4.277	1202	0.904918	3.7296	82.66223
29.	122	114.4893	110.3	99270	4.1893	1403	0.904098	3.6591	70.755524
30.	122	113.9368	110	99000	3.9368	1500	0.901639	3.4553	70.66542

The Normal load and High Load as given by Siemens, EWSD Switching: Network Planning, 1999 can be calculated as

NL = A_{mean} + correction factor *STD

HL = A_{mean} + correction factor *STD

METHOD A

B _GOS = 1%
A_{mean}= 168.83147 Erl
Variance = 18547.94 Erl^2
Standard Deviation = 136.1908128 Erl
Correction Factor 1.6
The Normal load as given by Siemens, EWSD Switching: Network Planning, 1999

NL = A_{mean} + correction factor *STD 427.594 Erl
N' TRUNKS NL = f(A,B)=f(427.59, 1) 453
N' TRUNKS MOD 480

HL

B_GOS= 3%
A_{mean} 5 = 402.513 Erl
Variance = 52172.696 Erl^2
Standard Deviation STD = 228.41343 Erl
Correction Factor 2.3
HL = A_{mean} + correction factor *STD 927.86389, Erl
N' TRUNKS HL = f (A,B)=f(927.86, 83.306) 922
N'TRUNKS MOD 930

METHOD B

HL = 2nd Highest Day = 526.075 Erl
N' TRUNKS HL = f (A, B) =f (526.07, 3) 530 Trunks
N' TRUNKS MOD 540 Trunks
NL = 4th Highest Day = 292.917 Erl
N' *TRUNKS NL = f (A, B) =f (292.92, 1)* 317 Trunks
N' TRUNKS MOD 330 Trunks

Where NL and HL indicate Normal Load and High Load respectively.
A comparison of the results of both methods showed that the values do not deviate from each other. In many cases, there is no difference in the number of trunks, as a result of the modularization of PCM 30 technology.

From Table 2, the analysis showed that for optimum traffic handling that would have met subscribers' expectation. Network B would have added 38 more outgoing circuits, Network C would have added 45 more circuits. Network F would have added 258 more circuits. 32 circuits would have being removed from outgoing trunk to Network D.11 circuits would have been removed from Network E outgoing trunk to Network A. 30 circuits would have been removed from Network A outgoing trunk to Network G.

Table 2: Summary of Results

Network A	A_{mean}	Standard Deviation (Erl)	Normal Load (Erl)	High Load (Erl)	No of Trunks available	No of Trunks Modularized	Difference	Remarks
Network B	77.9	5.3	86.4	102	82	120	-38	Under-Dimensioned
Network C	19.1	11	36.7	55.8	15	60	-45	Under-Dimensioned
Network D	50.9	5.2	59.2	70.3	122	90	+32	Over-Dimensioned
Network E	78.2	5.5	87	92.5	131	120	+11	Over-Dimensioned
Network F	169	136	427.6	927.8	122	480	-258	Under-Dimensioned
Network G	5.31	2.22	8.87	15.86	60	30	+30	Over-Dimensioned

CONCLUSIONS

After the data analysis of the network the CCR and ASR which are found to be 63% and 23% respectively, are below the expected values of 75% and 55%. The low CCRs and ASRs were as a result of Congestion during the high traffic at peak period and transmission problems due to fading and power failures at the terminal Exchanges. According to results obtained from this model, no any trunk group was optimally configured for all the Networks. Some Circuits were over dimensioned while some were under dimensioned. The results of this research shall therefore facilitate the implementation of network planning process, which comprises of network analysis, network design, and network optimization. The outcome would lead to the least operational cost of network implementation, high robustness for the network to adopt easily to changed conditions, high survivability or in-built redundancy of the network in case of partial network outages and excellent quality of service (QoS) experienced by the customer, e.g. as minimum number of blocked calls, minimum call setup delays.

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