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Modeling the Traffic Load of Selected Key Parameters for GSM Networks in Nigeria

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ABSTRACT

Global System for Mobile Communications (GSM) enabled voice traffic to go wireless, with the number of mobile phones tripled the number of landline ones, and the mobile phone penetration going beyond 100% in several markets, the subscribers' satisfaction and service quality delivery in some part of the country is far from expectation, service interruptions are perceived negatively by end-users, thus aggressively calls for the effective management to meet the expectations by adopting suitable resource management techniques. This paper summarized 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, thus the work established statistically using the Minitab statistical software package the following facts: (1) the weekly peak traffic in Kano metropolis of the three GSM networks in consideration (2) festive periods traffics are different from normal weekly traffic (3) Two-sample-means comparisons were statistically evaluated. And also using regression analysis here, a traffic model over some key parameters were developed. The proposed model could be served as decision making tools.

Keywords: GSM, Traffic, TCH, SDCCH, Minitab, Equation Modeling.

1. INTRODUCTION

Mobile communication today is available in a broad spectrum of technological and service-specific forms. Among the existing mobile communication networks, global system for mobile (GSM) communications is the most popular cellular communication system all around the globe [1]. In Nigeria like in all other developing countries the mobile phone has been instrumental to the rapid increase in telecommunications accessibility with the tele density ratio tripling, telephone lines in the country now put at more than 100 million [2]. GSM network still accounted for more than 70% of the voice calls and other voice telephony services in Nigeria, GSM subscribers making the country one of the fastest growing GSM market in the World, with just four fully functional GSM carriers in Nigeria; MTN, Airtel, Glo and 9mobile. Sixteen years after the start in Nigeria, the focus is drastically shifting from providing coverage to providing quality service. The euphoria of owning a mobile phone set has given way to complaints by subscribers on poor service quality, frequent call drops, echo during radio conversation, poor interconnectivity to and from licensed networks, distortions, network congestions, among other factors. These factors have left many mobile subscribers with no other alternative than to subscribe to more than one network and patronage of multiple Subscriber Identity Modules (SIMs) phone in order to maintain good connection.

The GSM radio network as shown in Figure 1.0, incorporates Base Station Subsystem (BSS), the BSS comprises of the Base Station Controller (BSC) and the Base Transceiver Station (BTS) which provide the mobile phone's interface to the network. A BTS is usually located in the center of a cell. The BTS provides the radio channels for signaling and user data traffic in the cells. Besides the high frequency part (the transmitter and receiver component) it contains only a few components for signal and protocol processing. A BSS has between 1 and 16 transceivers, each of which represents a separate radio frequency channel. Next in the hierarchy is the BSC may be located at the same site as the BTS, at its own stand-alone site, or at the site of the Mobile Switching Centre (MSC). BSC can control anywhere between 5-20 BTSs [3]. The main functions of the BSC include frequency administration, control of the BTS and exchange functions [4].

The Mobile Switching Subsystem (MSS/NSS) consists of Mobile Switching Centers and databases, which store the data required for routing and service provisions. The switching node of a mobile network is called the Mobile Switching Centre (MSC). It performs all the switching functions of a fixed network switching node, e.g. routing path search and signal routing. A public land mobile network can have several Mobile Switching Centers with each one being responsible for a part of the service area. The MSC normally houses the Home Location Register (HLR), Visitor Location Register (VLR), Authentication center (AuC) and the Equipment Identity Register (EIR). The BSCs of a base subsystem are subordinated to a single MSC [4]. There are three dominant interfaces to the network [3]:-

(i) A interface; provides connection between MSC and BSC.
(ii) A-bis Interface; provides connection between BSC and BTS.
(iii) Um interface; provides connection between the BTS and mobile station (MS).

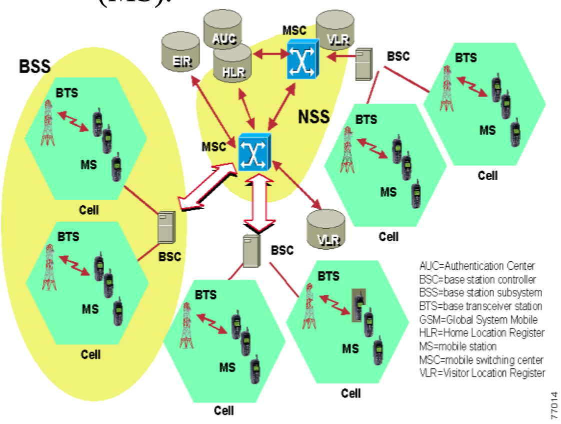

Figure 1: The GSM Networks [5].

In GSM network, a new call cannot be initiated if Standalone Dedicated Control Channel (SDCCH) channels are not available and the same happens when SDCCHs are available but all Traffic Channels (TCHs) are blocked [6].

1.1 Key GSM Network Traffic and other Concerned Parameters Definitions

1) Standalone Dedicated Control Channel (SDCCH): This channel is always used when a traffic channel has not been assigned, and is allocated to a mobile station only as long as control information is being transmitted. SDCCH access success rate: account for percentage of all SDCCH accesses received in the Base Station Controller (BSC) [7]. It measures the ease with which a call can be setup, the ease to recharge an account, send SMS, location update, paging etc. [8]. Reasons for poor SDCCH were too high timing advance, congestion, low signal strength on downlink or uplink, false accesses due to high noise floor. This can be found using [8]:

$$SDCCH\ Cong. = \frac{1-CSSR}{TCH\ assignment\ rate} \times 100 \quad (1)$$

Where CSSR is the call setup success rate and TCH is the Traffic Channel assignment rate.

2) Hand over Success Rate (HOSR): gives the percentage of successful handovers of all handover attempts. A handover attempt is when a handover command is sent to the mobile [7]. Large number of handovers will increase handover blocking probability, thus it is expected to be successful, imperceptible and less frequent [9]. The possible reasons for poor HOSR are congestion, link connection, incorrect handover relations, incorrect locating parameter setting, bad radio coverage, high interference, co-channel or adjacent etc. HOSR can be found using [10]:

$$HOSR = \frac{[(CC7 + CC8)]}{[(CC9 + CC10)]} \times 100\% \quad (2)$$

Where CC7 counts number of incoming successful handovers, and CC8 counts number of outgoing successful handovers. CC9 counts number of outgoing HO requests while CC10 counts number of incoming HO requests.

3) Mobile phone traffic is defined as the aggregate of phone calls over a group of circuits or switches with regard to the duration

of calls as well as their number, thus, traffic flow (A) is expressed as [11]:

$$A = C\ X\ T \qquad (3)$$

Where C designates the number of calls originated during a period of 1 h and T is the average holding time, usually given in hours. A is a dimensionless unit because we are multiplying calls/hour by hour/call. The preferred unit of traffic intensity is the erlang, named after the Danish mathematician A. K. Erlang [12].

1.2 Other Definitions

(a) Ramadan: According to [13]is one of the five pillars of Islam and also ninth month of the Islamic calendar, during which strict fasting is observed by Muslims worldwide from dawn to sunset, to commemorate the first revelation of the holy Quran according to Islamic belief. During the horizon of this study the fasting hours in Kano was 19hours (from 5:05 AM to 6:57 PM). The fasting was started on the 27th of May, 2017 and ended 26th of June, 2017. During this period in Kano people are exchanging greetings and reminders to their siblings and loved ones, through phone conversations and SMS messages. This however increases the network traffic and most of the times even difficult to establish calls and other related services throughout the period. Ramadan1 for the purpose of this study was taken as the first week of Ramadan followed by it succeeding weeks.

(b) Sallah: is a special occasion by followers of Islamic belief, which was categorize into Eid el-Fitr (known as Small Sallah as in Nigerian version or festival of breaking fast) [13] and Eid al-Adha (also known as Big Sallah or the festival of sacrifice). The difference was that the former is conducting at the end of each Ramadan, while the latter is conducting on the 10th of every month of Dhul Hijjah and it also incorporate sacrifice of animals. In Nigeria during both the two festivals, the government is declaring public holidays which lasts for two to three days. The traffic during these festivities were high as depicted in Figure 4.1 to 4.3. For the purpose of this study Sallah1 means Eid el-Fitr, while Sallah2 means Eid al-Adha.

(c) Minitab: is a statistics package software developed by three group of researchers (Ryan, B.F., Ryan, T.A. & Joiner, B.L.) at the State University of Pennsylvania in 1972 [14]. It is a set of comprehensive powerful tools to do; Basic Statistics, Regression and ANOVA, Quality Tools, Design of experiments, control charts, Reliability and Survival, and many more with great capabilities [14]. Forecasting is the technique of predicting the future. It is an integral part of almost all disciplines and mobile communication is not an exception. The quantitative forecasting techniques include but not limited to Regression and Time series (using Trend Analysis) [15]., as adopted in this research. Regression analysis is one of the traditional ways of identifying the relationships between output variables and input variables of a system. And also gives insights of the strengths and weaknesses of the output variables via moderating the input variables [16].

2. LITERATURE REVIEW

In [17] developed a traffic model that predicted a blocking probability for new voice and handover calls blocking probability in mobile communication networks (GSM), which is based on NCC recommended value of 2%. According to the authors' the high number of block calls experience in mobile network, especially during the busy- hour leads to poor Quality of Service (QOS) delivering in mobile network. These traffic models are used to manage, a balance relationship between cost incurred in mobile communication by operators and service render to the mobile subscribers. This traffic model shows the relationship between these components, channels resource (n), traffic load in erlang (A) and Grade of Service (GOS) or blocking probabilities. The relationship between traffic loads and services, state that as traffic load increases and the service decline in a constant capacity.

The traditional traffic models (like Erlang B formula) are not adequate to this presence mobile communication network, without the inclusions of mobility and data service into the mobile network. Therefore, the traditional models should incorporate the subscriber handover calls (mobility) and data service into the voice call framework [17]. In [6] proposed a formula that the RF engineers can use it to calculate the number of calls or Erlangs:

$$ErlangB = \frac{Established\_callsX\ MHT}{3600} \quad (4)$$

The work also focused on the hourly duration of calls that statistically established the peak hours in a typical North American GSM network, depicted the increase in traffic through the week, the significant different between weekday and weekend traffic and also developed a regression-based forecasting model for the traffic. But the work specifically considered only one carrier and also festive periods were not included on the traffic. Likewise, in [18] analyzed the comprehensive data were obtained from the NCC of CSSR, DCR, SDCCH congestion, and TCH congestion for Airtel, Etisalat, Glo and MTN using ANOVA, thus the values of the KPIs were plotted against the months of the year for better visualization and understanding of data trends across the four quarters. Multiple comparisons of the mean-quarterly differences of the KPIs were also presented using Tukey's Post Hoc test. Public availability and interpretation and discussion of these useful information will assist the network providers, Nigerian government, local and international regulatory bodies, etc. in ensuring access of people, machines and things to high quality telecommunications services, these according to the authors. [19] Presented an in-depth analysis of 3G networks from major cities in China and Southeast country and accurately identify high RTT/losses using a combination metrics of channel quality, traffic load and the number of soft handovers. The work explored that most of the traffic are limited by applications or opportunities, thus complemented the existing work by providing valuable data points about cellular network traffic and performance in Asia and performing a fine-grained diagnosis to pinpoint the root cause for performance issues. [20] Surveyed the literature on mobile traffic analysis run on operator-collected data. It proposed a hierarchical classification of studies on the research field, and categorized a large body f relevant works accordingly. And also summarized the main features of research activities, as well as of the datasets employed, and provides a comprehensive overview of the state of the art in the usage of cellular mobile traffic data for scientific research, and allows outlining open research directions. Similarly, [21] in their survey explored the following three research gaps that all the existing literatures failed to address: congestion at the three basic elements (BTS, BSC & MSC) of GSM network to characterize end-to-end connection. Use busy hour traffic data to dimension GSM network elements. Properly establish the statistical basis of the cause(s) of the identified congestion. Use sufficient data in their analysis to improve statistical quality of their results. [22] Performed the training of Levenberg-Marquardt Algorithms (LMA) that developed a model, which predicted traffic congestion on a BSC to MSC link in Bauchi Metropolis of Nigeria using twelve month hourly traffic data. And also correlation coefficient of 0.986 between predicted and actual corresponding traffic congestion volumes using regression analysis is realized, thus demonstrated the accuracy of the prediction. However, the causes of congestion were not identified and solutions were not proffer to resolve the congestion.

From the literature reviewed above, some researchers had suggested several approaches to construct mobile cellular traffic models considering one carrier only, while others suggested techniques to improve the available KPIs. However, most of these approaches were not evaluated for a live GSM networks. And also causes of traffic congestions during festive periods were not readily identified. Therefore, this work selected some key parameters from the active three GSM networks in Kano after drive test, the causes of traffic congestions during festive periods were readily identified and proper solutions to address the problems also provided. The work constructed traffic models using Minitab Software and to add more weight to the statistical analysis, comparison test analysis between the festive periods was performed.

3. MATERIALS AND METHODS

Ericson test phone with built-in TEMS Professional Investigation Software (TP) is a convenient and powerful tool for verification, monitoring and troubleshooting of cellular mobile networks and also for basic cell-planning tasks [23][10]. TP collects measurements and event data for immediate monitoring or for processing by other tools at a later time. It can capture data in areas that are difficult to cover during traditional drive-testing. The tool provides options to perform indoor-environment measurements quickly and easily. Another valuable option that was added to TP professional is a powerful scanner that places extensive data-gathering capabilities on the palm of the user's hand, that present detailed information about the surrounding networks.

Traffic have been used to develop an analytical model for traffic performance analysis of a system. Statistics of dwell times are important for teletraffic performance evaluation [3]. A good handover design will maximize quality of service (QoS) and capacity by providing high communication quality and retainability, it ensures proper cell borders and load balancing [11]. Mobile traffic conveys information concerning the movement, interactions, and mobile service consumption of individuals at unprecedented scales. The works dealt with the data collected by TP over a period of seven months from March to October, 2017, the recorded log files for both intra and inter calls of the network traffic parameters at different locations using the network architecture as outlined in Fig.3 were recorded and exported into the post analysis tool. Weekly averages of the various data were computed and recorded in a designed research form using Microsoft Excel Package 2016. The traffic performance and comparison of the three type of networks are done by calculating the mean averages of the considered KPIs.

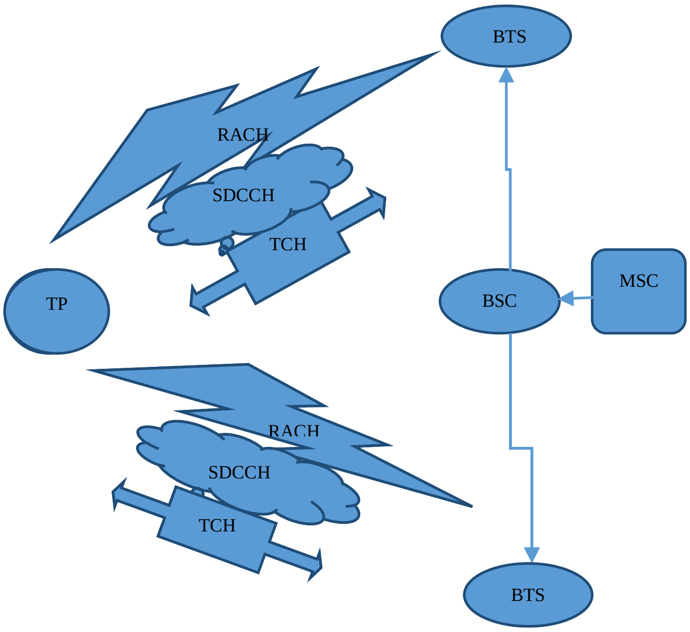

Figure 3: The Experimental Set up.

4. RESULTS AND DISCUSSIONS

A model is a mathematical expression or diagram or algorithms that represent traffic characteristics [17]. This paper formulated an experimental model from the theoretical and practical point of view and studied the traffic behaviors of SDCCH and HOSR as a function of network parameters (Traffic load and call duration), henceforth the contribution of each parameter were predicted. The main contribution of this work was the design of a regression-based forecasting model for the traffic base on some key parameters, and statistically established the weekly peak periods within the case study areas. Finally, the proposed model could be served as a decision making tools. The performance of the model was tested and the result was recorded as shown in Table 1.1 to 1.3 respectively.

The TCH blocking rate are higher than the NCC threshold of $\leq 2\%$. At this situation there are number of successive call blockings, thus the carriers are losing huge amount of revenue. Network utilization is the KPI that indicates the magnitude of network congestion and this KPI is independent with the situation. Call blocking rate provides to the carriers' identification and characterization of congestion. Spectrum utilization is also important factor in determining the efficient network utilization, as in [6] "extensive measurements have claimed the under-utilization of the allocated spectrum at 2.4GHz. The under-utilization has arisen due to the static allocation policies. The advantages of static spectrum allocation policies are interference reduction and simple system hardware. But the major disadvantage of these static policies is the inefficient utilization of radio spectral resources". Furthermore, high consistent (> 40%) utilization indicates points of network slow down (failure) and a need for changes or upgrades in network infrastructure. Utilization can be calculated using:

$$Utilization\ \% = \frac{(data\ bits \times 100)}{(bandwidth \times interval)} \quad (5)$$

4.1 Time Series Plot of Peak Weeks in Kano Metropolis of the Considered Carriers

Figure 3.1 depicted the measured durations of calls for every single week, starting from 23/03/2017 to 14/10/2017. For consistency, the weeks over the months will be referred to as week 1 to week 29 in the reminder. Thus the weekly durations of calls are computed over the 29 weeks, 5 days that constituted the time horizon of the study. The duration of calls picks up from the low point achieved at week 1 and increased sharply to reached week 2, the increasing trend continues at high rates until it reached 17.9E at week 2 also, the duration of the calls then started decreasing, sharply until it reached week 3 (24/03/2017) at 8.5E, then at a sharper rate over the week 4 (31/03/2017) at 12E, this indicated there was increased in traffic at the last week of month-ending (call durations are increasing), this can be seen at Figure. Looking at Figure 3.2, the call durations over the first week started at 8.9E (high traffic) and continue decreasing slowly to week 2 (09/04/2017) at 8.3E, duration of the calls pick up slowly while reaching 9.5E increases sharply to week 3 and continued to month-ending at 12.1E, it also indicated that durations of calls are increasing over month-ending as depicted in MTN. Considering Figure 3.3, also the duration of calls started at 20.4E at week 1 (which shows high congestion on this network with series of block calls over the week), the trend started decreasing slowly over week 2, the decreasing trend continued until it reached week 3 at 10.1E, then sharply increased over the week 4 (this call durations also increases towards month-ending) as previously observed on the last two networks. In a nutshell, 17.6E, 12.7E and 21.2E respectively are the highest traffic of the MTN, Glo and Airtel over the time horizon of the study, which shows that all the three carriers are operating below the NCC minimum target for the GSM network traffics.

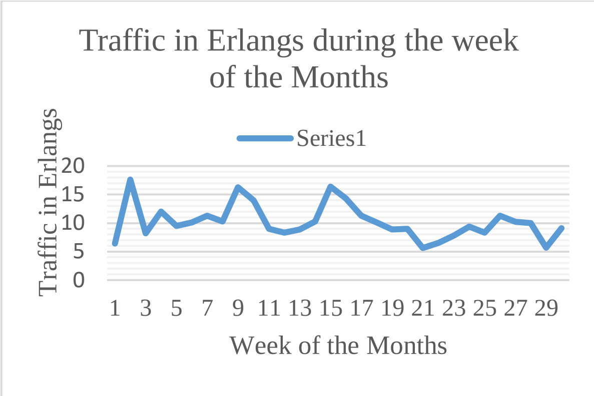

Figure 3.1: A time series plot of MTN weekly Traffic over the time horizon

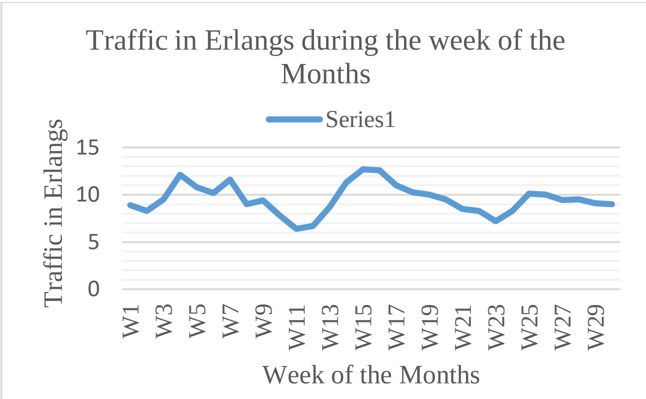

Figure 3.2: A time series plot of GLO weekly Traffic over the time horizon

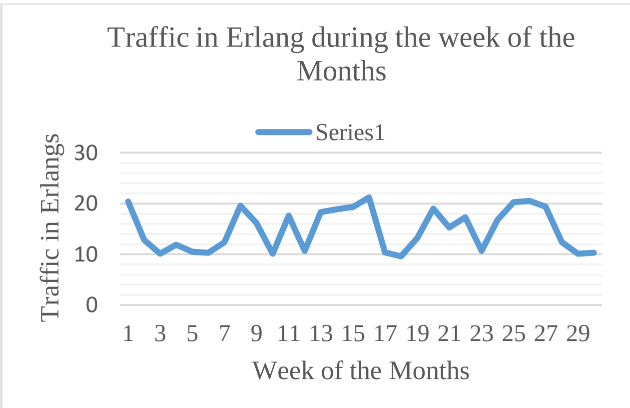

Figure 3.3: A time series plot of Airtel weekly Traffic over the time horizon

4.2 Using Regression Analysis Traffic was forecasted over two variables

Given the seasonal differences observed between weekly traffic, a multiple linear regression models were applied for the three carriers, where the two carriers (Glo and Airtel) had chances to displayed good fit.

$$Y = \{\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n + \varepsilon_i\},\ \ i = 1,2, \ldots .n \qquad (6)$$

Where Y and X are dependent and independent variable respectively. $\beta_0, \beta_1, \beta_2, \beta_n$ and ε_i are regression parameters and an error term respectively.

While linear regression model, when tested displayed poor fit for MTN data, thus a logarithmic transformation was employed and the transformed model is given as

$$\log Y = \log \beta_0 + x_1 \log \beta_1 + x_2 \log \beta_2 + x_3 \log \beta_3 + \cdots + x_n \log \beta_n \ \ (7)$$

The model has been developed with the help of Minitab statistical package. In terms of estimation error, the regression model has good fit, with an unadjusted R^2 of 20.8% and an adjusted R^2 of 14.9%, all predictors were globally and individually significant with no serious violation of the linearity, independence, normality, and equality of the variance conditions. The corresponding prediction equation to be used for forecasting the **MTN** Traffic data can be written as:

$$lny = -0.94 + 0.187\, x_1 + 0.942\, lnx_2 \ (8)$$

Where:
Y: Weekly Traffic load (Erlang)
x_1: Weekly blocking rate.
x_2: Weekly HOSR.

The equations (9) and (10) below shows the remaining two models that follows simple linear regression model. In terms of estimation error, the models had very good fit, with the adjusted R^2 of 43.60% and 77.1% for **Glo** and **Airtel** respectively, all predictors were globally and individually significant without any serious violation of the linearity, independence, normality, and equality of the variance conditions. The corresponding prediction equations to be used for forecasting the Glo and Airtel Traffic data can be written as:

$$Y = 28.9 - 0.012x_1 - 0.216\, x_2 \qquad (9)$$

$$Y = -13.9 + 1.79x_1 + 0.183x_2 \qquad (10)$$

4.3 Time Series Plots of Weekly Traffic during the Festive Periods

The representation in Figures 4.1 to 4.3 of the weekly festive period (Ramadan1 through Sallah2) traffic clearly indicated the significant differences between the weekly traffic. The equivalent time series trend lines were formulated in equations (11) through (13) for the Glo, MTN and Airtel respectively.

$$T_t = 6.1467+1.1086t \qquad (11)$$

$$T_t = 8.04+1.1457t \qquad (12)$$

$$T_t = 13.127+0.7114t \qquad (13)$$

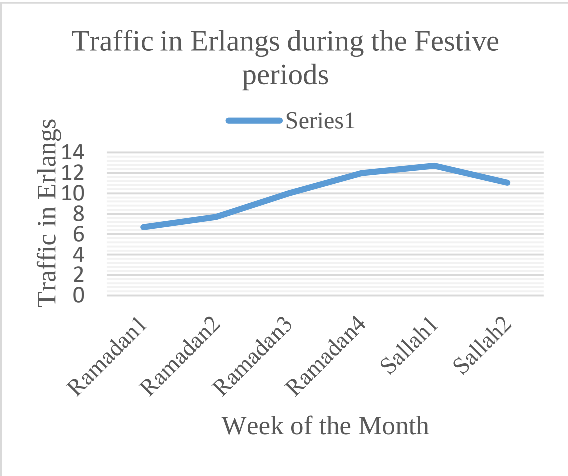

Figure 4.1: A time series plot of GLO Festive Periods Traffic over the months

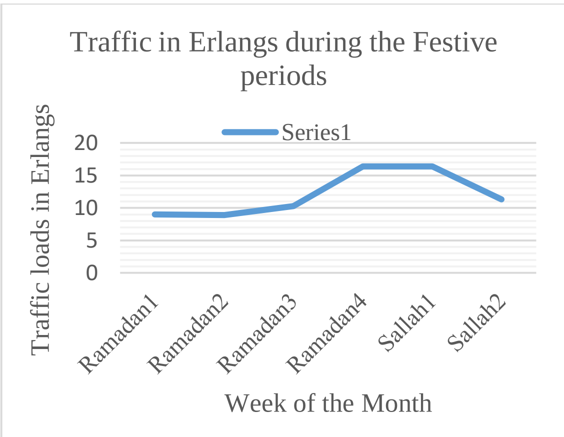

Figure 4.2: A time series plot of MTN Festive Periods Traffic over the months

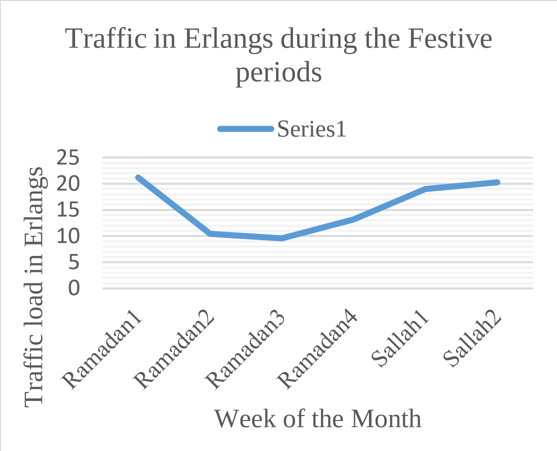

Figure 4.3: A time series plot of Airtel Festive Period Traffic over the months

4.4 Testing the Performance of the Trend

The developed trend models were statistically analyzed using Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE), to compare the performance of the forecasting techniques and consider the effect of the magnitude of the actual values and to under- or overestimate the accuracy of the model (to judge the model). The forecast error is given by the difference between the actual value and the forecast value as shown in equation (14). 0.924, 1.951 and 2.021 were the MAPE of MTN, Glo and Airtel respectively, as computed using equation (16). Moreover, the RMSE of 4.902, 19.811 and 27.563 for MTN, Glo and Airtel respectively were computed using equation (15).

$$Forecast\ error = Yt - Ft \qquad (14)$$

$$RMSE = \frac{\sum(\dot{x} - \ddot{x})(\dot{y} - \ddot{y})}{\sum(\dot{x} - \ddot{x})^2(\dot{y} - \ddot{y})^2} \qquad (15)$$

Where n = number of inputs

$\dot{x}$= actual output

$\ddot{x}$= mean of the actual output

$\dot{y}$= predicted output

$\ddot{y}$= mean of the predicted output

Y_t= actual value

F_t= forecasted value

$$MAPE = \frac{\sum \frac{|Y_t - F_t|}{Y_t}}{n} \qquad (16)$$

4.5 Hypothesis Testing of the Continuous Data

To add more weight in terms of statistical significance and to look deep over the weekly festive periods, this work conducted hypothesis tests for two sample comparison of successive weekly festive duration of calls. The statistical decisions from the hypothesis test were directed toward the festive periods, which compared the population mean durations of calls over successive weeks (1-week lag). It was assumed that μ_k was the mean duration of calls over the week k, k=1, 2,…., 6. (k=1 being Ramadan1). Festive hypothesis test can be performed as:

$$W_0: M_k \leq 0 \qquad (17)$$

$$W_1: M_k > 0 \qquad (18)$$

Where $M_k = \mu_{k+1} - \mu_k$, k=1, 2, 3,…6.

The significance level α of 0.05 was applied for the corresponding population t-tests, to reject or do not reject. The results tabulated in Table 1.1 through 1.3, statistically showed the existence of significant differences between all pairs of successive weeks from Ramadan through Sallah weeks.

Table 1.1: Two-Sample hypothesis testing of Traffic over Successive Festive Weeks of Airtel Network

Test	**Month Compared**	**p-value**	**Reject at α=0.05**
M_1	Ramadan1 Vs. Ramadan2	0.0265732	Approved
M_2	Ramadan2 Vs. Ramadan3	0.0436171	Approved
M_3	Ramadan3 Vs. Ramadan4	0.0361011	Approved

Test	Month Compared	p-value	Reject at α=0.05
M_4	Ramadan4 Vs. Sallah1	0.0271132	Approved
M_5	Sallah1 Vs. Sallah2	0.0447234	Approved

Table 1.2: Two-Sample hypothesis testing of Traffic over Successive Festive Weeks of GLO Network

Test	Month Compared	p-value	Reject at α=0.05
M_1	Ramadan1 Vs. Ramadan2	0.0400385	Approved
M_2	Ramadan2 Vs. Ramadan3	0.0363121	Approved
M_3	Ramadan3 Vs. Ramadan4	0.0413022	Approved
M_4	Ramadan4 Vs. Sallah1	0.0333643	Approved
M_5	Sallah1 Vs. Sallah2	0.0212122	Approved

Table 1.3: Two-Sample hypothesis testing of Traffic over Successive Festive Weeks of MTN Network

Test	Month Compared	p-value	Reject at α=0.05
M_1	Ramadan1 Vs. Ramadan2	0.0241421	Approved
M_2	Ramadan2 Vs. Ramadan3	0.0432710	Approved
M_3	Ramadan3 Vs. Ramadan4	0.0311313	Approved
M_4	Ramadan4 Vs. Sallah1	0.0421400	Approved
M_5	Sallah1 Vs. Sallah2	0.0317171	Approved

5. CONCLUSION

The data generated and computed were used in the construction of regression models for the traffic load. Each performance of the constructed models was assessed, as the models performed well, therefore it can be used as decision making tools that help FSE/Telecom engineers to decide on time and adequately deploy the necessary infrastructure. The research also focused on two particular metrics; the duration of calls during the weeks of the month and the weekly traffic during festive periods over the horizon of the study, and statistically provided that peak weeks in Kano Metropolis were most the last week of the month-ending of each particular month; and the traffic increases through the month. The work also deduced that there is statistically significant differences between the weekly festive periods and the normal weeks in terms of volume. The paper recommend that the same techniques could be adopted to parameters in 3G and beyond.

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