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Tropospheric Influence on Call Setup in Mobile Networks

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The dependency of mobile network operators on the troposphere for signal transmission without pre-evaluation and characterization of the region where the signals are transmitted is the reason for the poor Quality of Services (QoS) delivered to their network subscribers. To describe the reliability of networks, one needs to know which weather parameters affect the propagation of signals. This research investigates the effect of weather variables (relative humidity, wind speed, rainfall and temperature) on call setup for four mobile networks (MTN, Airtel, Globacom and 9mobile) in Cross River State, Nigeria. Six years data of weather variables collected from the Nigerian Meteorological Agency (NiMet) and six years Call Setup Success Rate (CSSR) data obtained from the telecommunications regulatory body, Nigerian Communication Commission (NCC), was used in this study, both spanning from January 2015 to December 2020. From the collected data, graphs were plotted and, in each case, the CSSR was the dependent variable while the tropospheric variables were the independent variables. Also, regression models were obtained to forecast the CSSR of each network, provided the tropospheric variable at each given period is known. Finally, the variables were correlated to give a picture of how each tropospheric variable related to the CSSR of the networks. For MTN network, a low negative correlation was obtained for temperature and relative humidity, a low positive correlation was obtained for rainfall while an increase in windspeed led to a corresponding decrease in CSSR. For Airtel network, a moderately positive correlation existed between CSSR and windspeed/rainfall while a low positive relationship existed between temperature and CSSR. However, an increase in relative humidity led to more

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successful call setups. For Globacom network an increase in relative humidity, windspeed, and temperature moderately led to a decrease in the number of successful call setups while rainfall had a very low effect on call setup. Finally, for 9mobile network, an increase in temperature led to a moderate increase in call setup. Relative humidity and windspeed had a negligible effect on call setup while a moderately negative relationship existed between rainfall and call setup. The result of this study will be very useful to mobile network planners and the network operators.

Keywords: Mobile networks; call setup; tropospheric influence; environments; MTN network.

1. INTRODUCTION

A call setup is an exchange of signaling information in the call process that leads to Traffic Channel (TCH) seizure [1]. In telecommunications, a call setup is evaluated using the Call Setup Success Rate (CSSR) which is the number of unblocked call attempts to the number of seizures resulting in a successfully established call [2]. CSSR depicts the percentage of attempts to initiate a call that results in a connection to the dialed number [3]. It is measured in percentage and given a threshold level of 98% by the Nigerian Communication Commission (NCC) [4,5].

A successful call setup consists of an immediate assignment procedure and an assignment procedure. The former is used in creating a signaling connection between the Mobile Station (MS) and the network while the latter is used to occupy a speech channel [6]. High CSSR depicts better cell performance and is obtainable when Traffic Channel (TCH) allocation and Standalone Dedicated Control Channel (SDCCH) seizures are accessed to setup a call [7]. When there is a call setup failure, it means that the user’s request is not served due to problems on the resource allocation of a signaling channel in which the negotiation for the actual traffic is performed [8]. A major cause of call setup failure or poor CSSR is low signal strength [3] which is sometimes caused by weather and this is one major reason for constant optimization [9].

The cellular network comprises of a Mobile Station (MS) that connects to the Base Transceiver Station (BTS) via air interface [10]. In addition to other hardware, BTS contains the equipment called Transceiver (TRX), which is responsible for the transmission and reception of several radio frequency (RF) signals to and fro the end user [11,12]. There are three main components that are required to setup a communication system; the transmitter, the receiver and the channel between the two. The signal which passes through this channel crosses the tropospheric layer of the earth [13]. In this region, signals, usually transmitted as radio waves [14,15], are affected by varying conditions during propagation and when a radio wave is interrupted by bad weather, signal quality reduces and this can cause signal losses [16-19].

Studies shows that when signals are transmitted, they interact with tropospheric variables like rainfall, wind speed, relative humidity, temperature, sand and dust storms [20-25]. When the transmitted signals interact with the tropospheric variables, the signals undergo absorption, interference, refraction, scattering, reflection, fading and attenuation [8,26-32]. This introduces distortions to communication systems [33], causing transmission error and affecting signal quality [34-35].

In Nigeria, network operators rely on transmitting signals through the troposphere without pre-evaluation and characterization of the troposphere and this is the reason for poor QoS [23]. To describe the reliability of networks, one needs to know which weather parameters affect the propagation of signal and the changing weather conditions, which may cause severe degradation in system performance [36]. To forecast, simulate, and design high performance communication systems, exact transmission characteristics of radio waves in various environments have to be known [22]. Mobile network providers need to plan and optimize of their networks. They need to find a compromise between the radio coverage in different environments, the QoS and the operation of the network [34].

The QoS of mobile networks can be improved by eliminating the factors that affect KPI performance both from external and internal sources [37], giving room for accurate prediction of radio frequency signal in a terrain [38].

Several researchers have investigated technical factors affecting poor QoS [39,40]. These has led to the frequent expansion of their base stations and capacities but the problem of poor call qualities persists [41].

The authors in [9] studied the impact of weather conditions on Wide Code Division Multiple Access (WCDMA) signals on the MTN network in Enugu State, Nigeria. Materials used for this research were a laptop, GPS, a power inverter, a Testing Equipment for Mobile System (TEMS) V13.0 software installed in the laptop and a TEMS mobile phone. A drive test was conducted and voice calls were made for 120 seconds on the mobile phone for five years, covering both rain and dry season. Log files for dropped and blocked calls were extracted and correlation test was performed to ascertain any relationship existing between them. Results show that during adverse weather conditions, Blocked Call Rate (BCR) and Dropped Call Rate (DCR) rose. Weather condition during dry season had a blocked call rate of 8.76% compared to the rainy season with 12.89%. From the outcome of the experiment, a model was developed for predicting an unknown network call statistics variable.

The authors in [29], in Benin City, on a Glo network operating in the 900 MHz band, investigated the impacts of weather and environment conditions on mobile communication signals. Research materials used was frequency signal tracker software, version 2.5.1, configured into an Intel palm top notebook. Relative parameters data were obtained from 200 meters from Glo BTS from 28th of July to 31st of August 2016, with data obtained hourly. Morning, afternoon and evening, dry weather, fog weather and raining conditions was based on the statistical central tendency parameters. An average refractivity gradient of 613N/km was obtained. Relative humidity and pressure had -0.50 and -0.44 while temperature and refractivity had 0.50 and 0.42 correlations. At dry weather, signal strength variation was within 32dBm, within 34dBm during fog, and a higher range within 38dBm during rain. The further the mobile station from the BTS, the higher the signal loss.

The authors in [42] accessed speech quality in GSM/UMTS networks and how it is affected by weather parameters. The meteorological station, Asterisk PBX, provided information about temperature, rain, humidity, dew point, wind speed and atmospheric pressure. A monitoring tool which carried out a call in every five minutes and about twenty thousand measurements were made. Transmitted calibrated speech samples were compared with that received by Perceptual Evaluation of Speech Quality (PESQ) method. Computed Mean Opinion Score (MOS) to every call stored in a database was analyzed using K-means clustering method and about fifty percent decrease of MOS during a heavy rain was observed.

The authors in [43] examined the dependence of weather parameters on GSM signal in Lagos. The research was carried out in the ITU regions of Lagos metropolitan area and was divided into seven sites being urban, suburban, ex-urban, rural, dense-urban, micro-urban and peri-urban transmission environment. A Lenovo Laptop with path loss software installed in it, alongside a licensed key called DONGLE, was used to collect rain outage of the annual availability of this region and a MATLAB computer program was used in analyzing the data. The measurement system consisted of live documented radio base stations (BS) data transmitting at 13GHz, 15GHz and 23GHz in the seven sites that constituted the metropolitan environment and this effort revealed that weather affects signal propagation.

The authors in [44] studied the effects of atmospheric temperature and wind speed on UHF radio signal. The experiment was carried out in the Automated Weather Station Signal Strength Meter (AWSSSM) in the Department of Industrial Physics, Enugu State University of Technology (ESUT), from a signal receiving system which was set up by connecting a high gain UHF antenna and spectrum analyzer coupled to a laptop system. The high gain UHF antenna transmitted at 519 MHz and Ku band signal of 11.7-12.7 GHz with a Global Positioning System (GPS) of longitude 7.5, latitude 6.3. Measurement was taken for a period of five months starting from the month of April to August 2017. The signal strength in the KU band spectrum was obtained every two seconds daily and simultaneously the meteorological components were observed. The curves for signal strength on temperature and wind speed were obtained. It was observed that temperature inversion in the tropospheric layer causes a ducting effect which affects radio signals which affects radio signals. Consequently, the speed of wind was found was found to have an effect on the bending capability of the wave.

The authors in [45] investigated the effect of relative humidity, rainfall, temperature and wind speed on dropped calls in mobile networks.

Tropospheric variables were seen to have weak, moderate and in most cases, strong correlation with dropped calls.

To the best of our knowledge, no researcher has studied the impact of weather on CSSR. Bearing in mind that weather parameters affect signals and one of the causes of poor CSSR is low signal strength, we may assume that weather affects CSSR, hence, this research. The crucial part of this research is to detect the dependencies of CSSR on rainfall, wind speed, temperature and relative humidity. This article is divided into sections; we shall start with an explanation of the materials and methods used in this study, followed by an analysis of the data, discussion of analyzed data and then go into a conclusion.

2. METHODOLOGY

This work investigates how relative humidity, wind speed, rainfall and temperature affect call setup in mobile networks. Four mobile networks are investigated in this study. They are MTN network, 9mobile network, Glo network and Airtel network. The research is carried out in Cross River State, Nigeria. 72 months radiosonde data for Cross River State, obtained from the Nigerian Meteorological Agency (NiMet) is used in this study. These data contain monthly data of relative humidity, windspeed, rainfall and temperature, spanning from January 2015 to December 2020.

Furthermore, 72 months data of CSSR was obtained from the Nigerian Communication Commission. These data spans from January 2015 to December 2020. The CSSR data were measured during busy hours across base stations in Cross River State.

The obtained tropospheric and CSSR data is then subjected to statistical analyses to obtain a relationship between both variables. A correlation analysis was done to obtain the degree of relationship between the variables investigated while a regression analysis was done to establish a relationship between the variables investigated, as well as to enable us predict and forecast when to expect call setup success or not.

3. RESULTS AND DISCUSSION

This section in divided into four parts. We shall first analyze the effect of relative humidity on call setup for the four networks, followed by the effect of windspeed, rainfall **and** finally, temperature.

3.1 Effects of Relative Humidity on Call Setup

In this part, Fig. 1 shows a graph of CSSR against relative humidity, plotted for MTN network. A weak negative correlation value of – 0.07 was obtained. A regression model to predict possible call setup was obtained as $C = - 0.01R + 100.13$ for MTN users. A graph of CSSR against relative humidity for Airtel network was revealed in Fig. 2. A strong positive correlation value of 0.82 was developed with a regression model $C = 0.05R + 94.70$ for Airtel users to forecast when it is accurate to make calls. Fig. 3 sets forth a graph of CSSR against rainfall for Globacom network. A regression equation, $C = - 0.09R + 105.75$ and a moderately negative correlation value, - 0.34 were obtained. A graph of CSSR against relative humidity for 9mobile network is presented in Fig. 4, with weak correlation value of – 0.14 and regression equation of $C = – 0.01R + 100.29$. In each regression model developed, C depicts CSSR while R stands for relative humidity. Therefore, at a known value of relative humidity, it is possible to predict the probability of having a successful call setup.

3.2 Effects of Wind Speed on Call Setup

In this section, figure 5 to 8 flaunt graphs of CSSR against windspeed for MTN, Airtel, Globacom and 9mobile network respectively. For MTN network, a high negative correlation of – 0.95 was obtained with regression equation $C = - 0.03W + 101.28$. A regression model $C = 0.01W + 98.68$ and a moderately positive correlation value of 0.33 was obtained for Airtel network. For Globacom network, a moderately negative correlation of – 0.69 was obtained with a derived regression equation $C = - 0.06W + 101.54$. For 9mobile network, a regression model $C = 0.01W + 99.09$ along with a weak correlation value of 0.22 was obtained. In each case, C represents CSSR while W represents the windspeed.

3.3 Effects of Rainfall on Call Setup

Here, figure 9 to 12 present graphs of CSSR against rainfall for MTN, Airtel, Globacom and 9mobile network respectively. A weak positive correlation of 0.10, a moderately positive correlation of 0.49, a weak positive correlation of 0.16 and a moderately negative correlation of –0.32 was obtained for MTN, Airtel, Globacom and 9mobile network, respectively. Furthermore, regression models were obtained for the four networks: C = 5.12RF + 99.41 for MTN network, C = 0.01RF + 98.66 for Airtel network, C = 0.01RF + 98.02 for Globacom network and C = 0.01RF + 99.69 for 9mobile network. Again, C represents CSSR while RF represents rainfall.

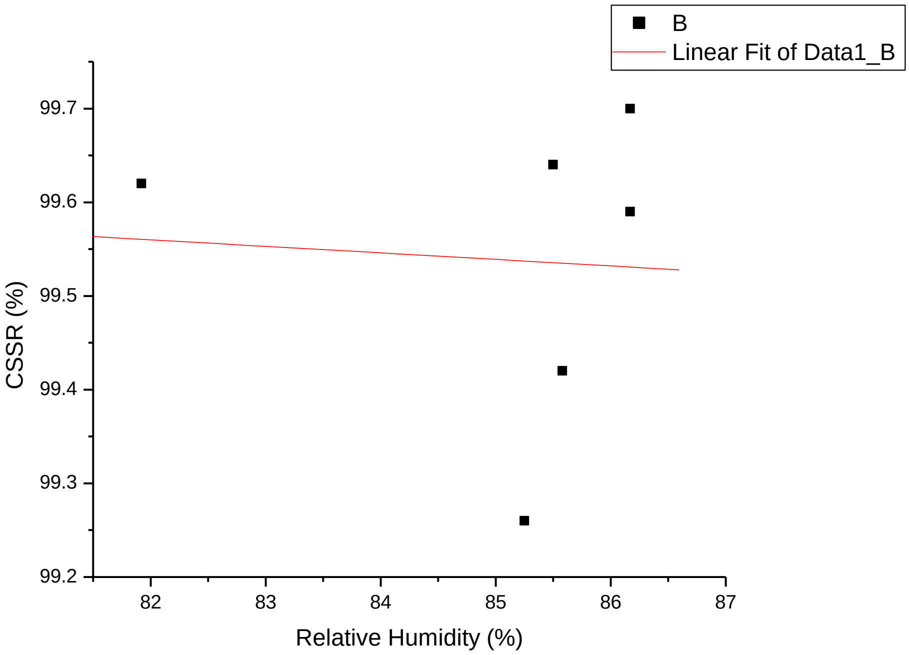

Fig. 1. Graph of CSSR against relative humidity for MTN Network

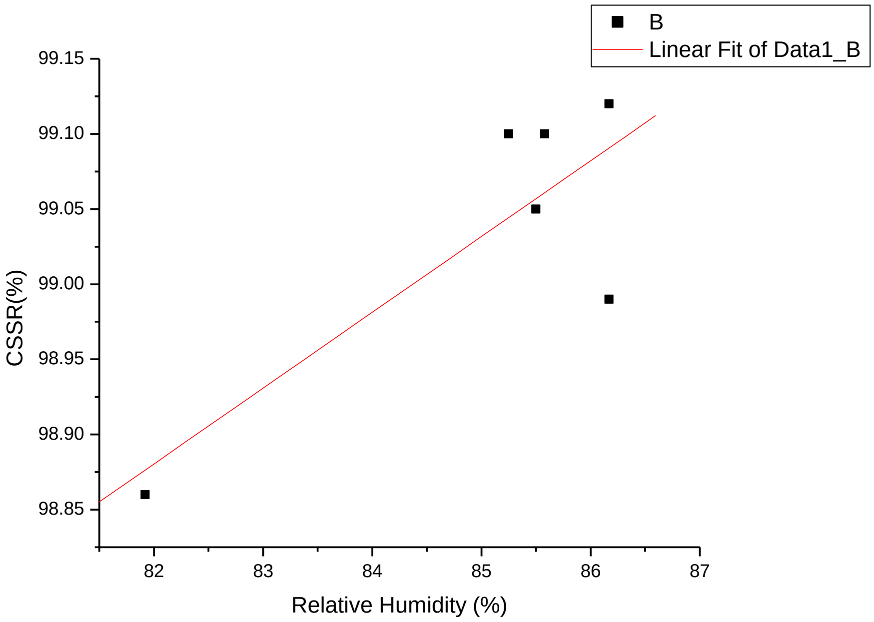

Fig. 2. Graph of CSSR against relative humidity for Airtel Network

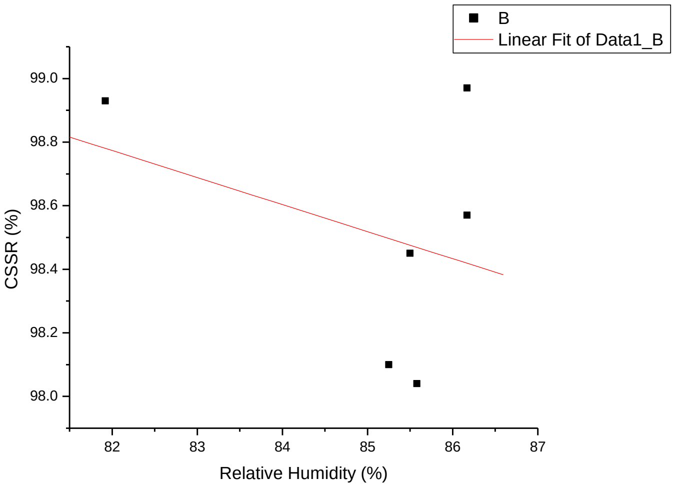

Fig. 3. Graph of CSSR against relative humidity for Globacom Network

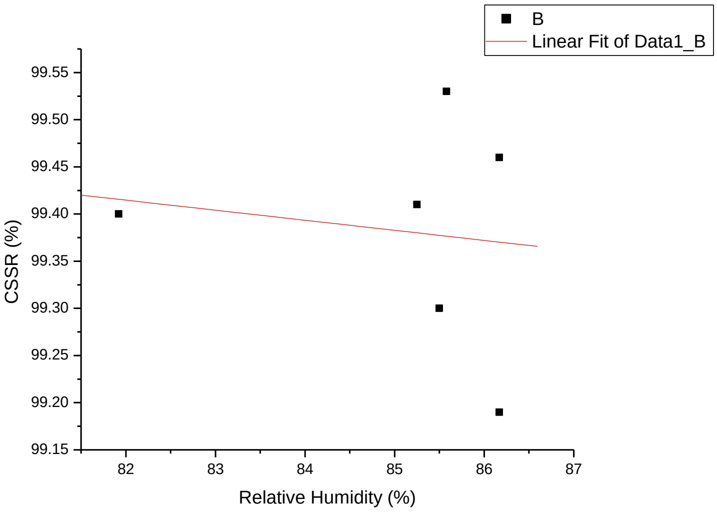

Fig. 4. Graph of CSSR against relative humidity for 9Mobile Network

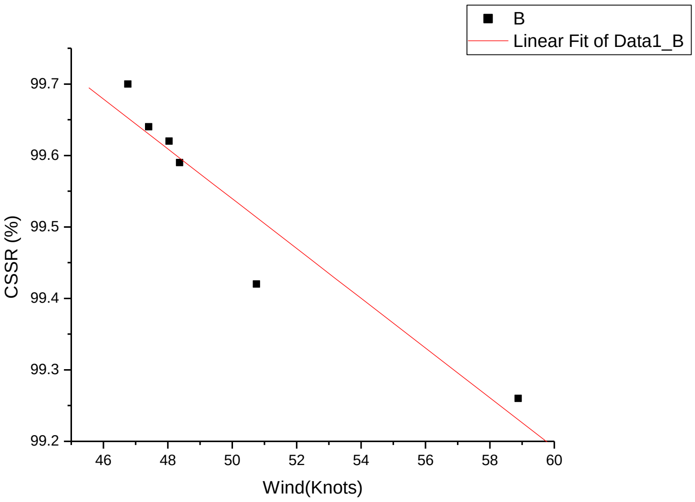

Fig. 5. Graph of CSSR against Wind Speed for MTN Network

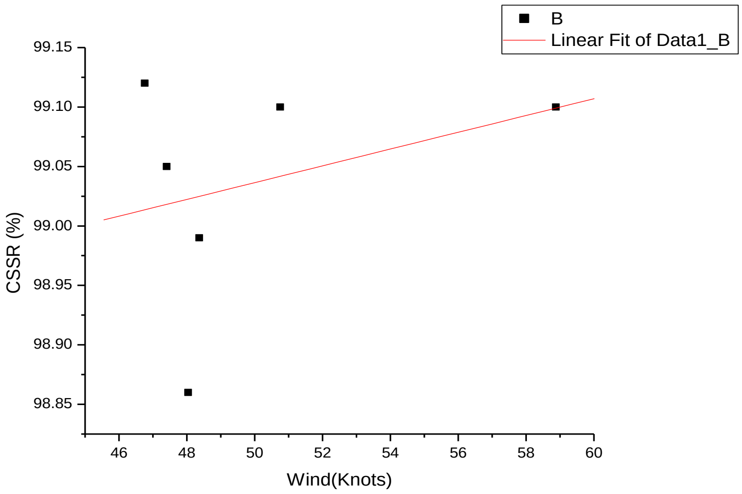

Fig. 6. Graph of CSSR against wind speed for Airtel Network

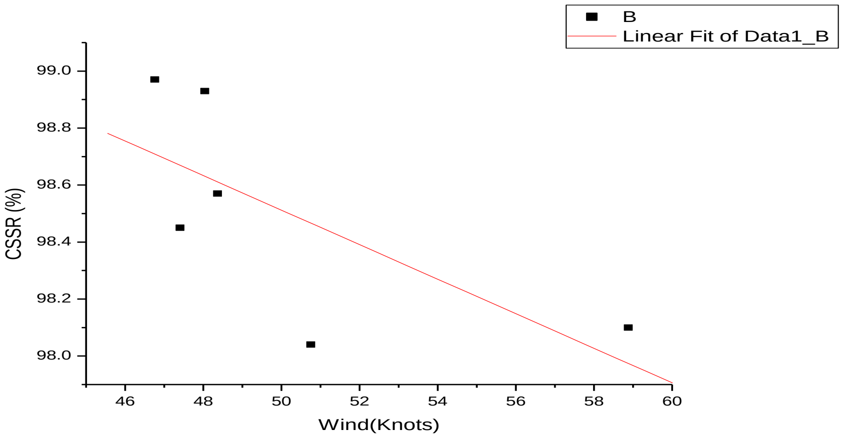

Fig. 7. Graph of CSSR against wind speed for Globacom Network

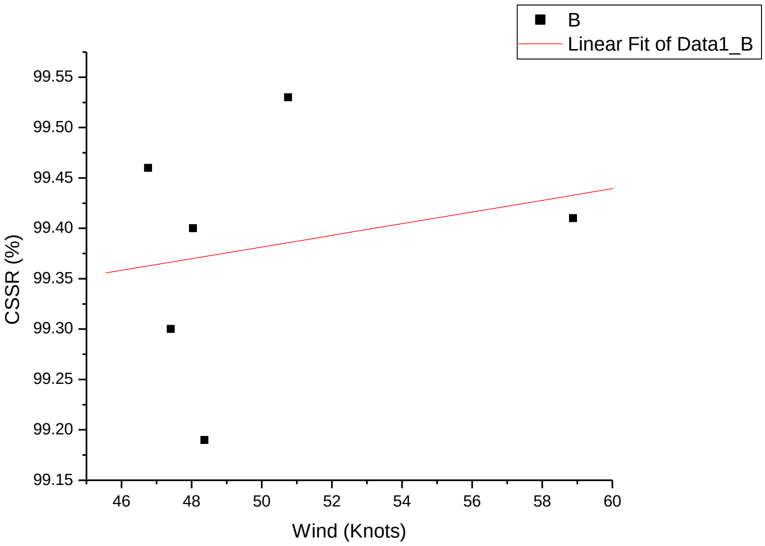

Fig. 8. Graph of CSSR against wind Speed for 9Mobile Network

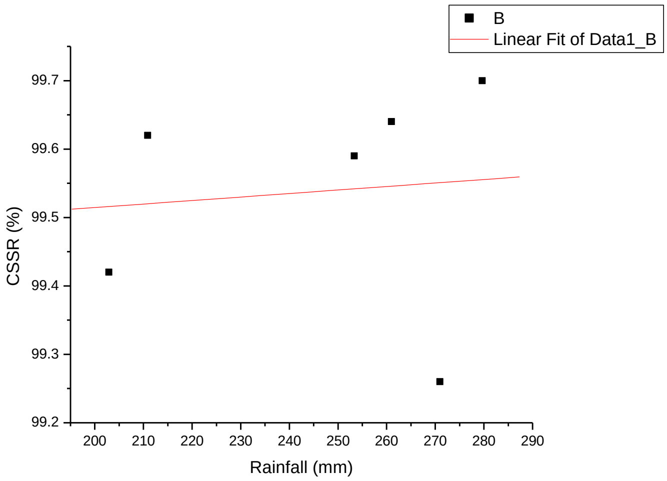

Fig. 9. Graph of CSSR against Rainfall for MTN Network

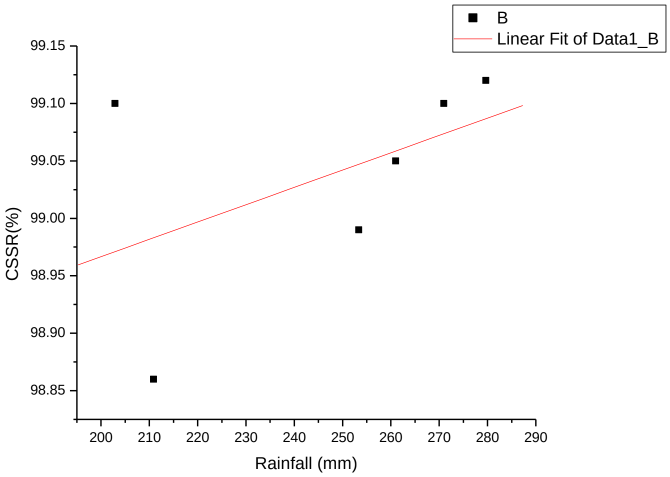

Fig. 10. Graph of CSSR against Rainfall for Airtel Network

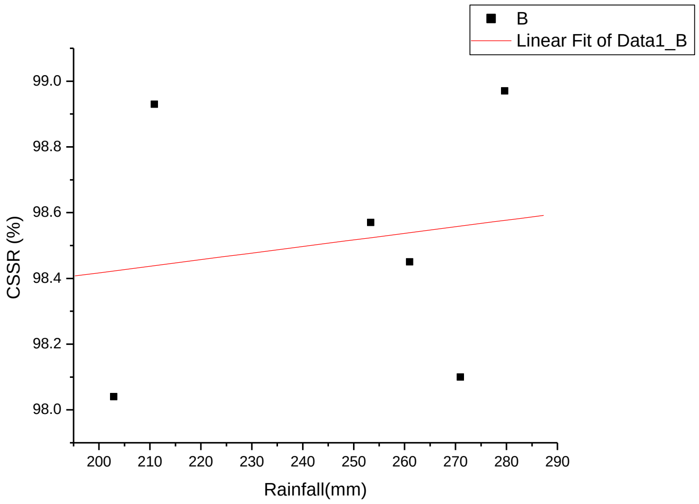

Fig. 11. Graph of CSSR against Rainfall for Globacom Network

3.4 Effects of Temperature on Call Setup

Lastly, Figs 13 to 16 unveil graphs of CSSR against temperature for the four networks under study. A low negative correlation value of – 0.10 was obtained for MTN network, a low positive correlation value of 0.14 was realized for Airtel network, a moderately negative correlation value of – 0.38 was obtained for Globacom network and a moderately positive correlation of 0.51 was obtained for 9mobile network. Again, regression equations C = - 0.02T + 100.14, C = 0.02T + 98.49, C = - 0.18T + 104.26 and C = 0.07T + 97.02 were obtained for MTN, Airtel, Globacom and 9mobile networks. Here, C stands for CSSR while T represents temperature.

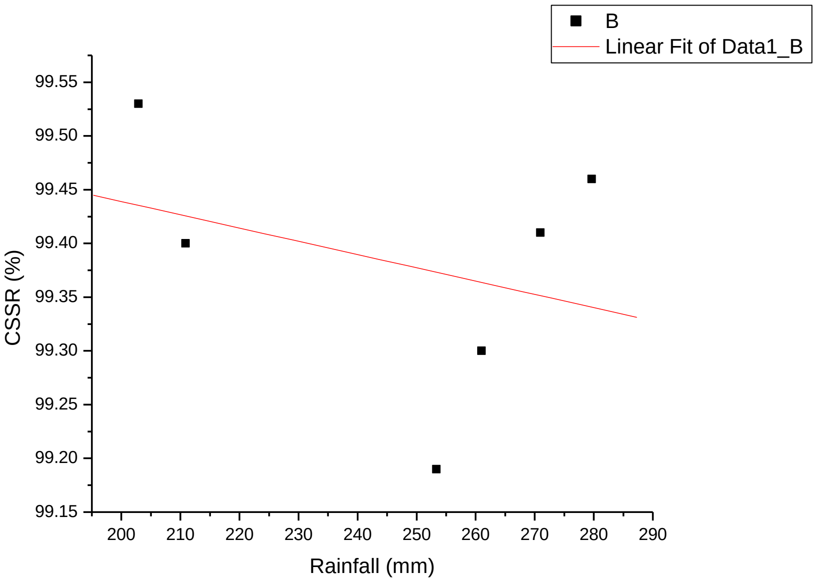

Fig. 12. Graph of CSSR against Rainfall for 9Mobile Network

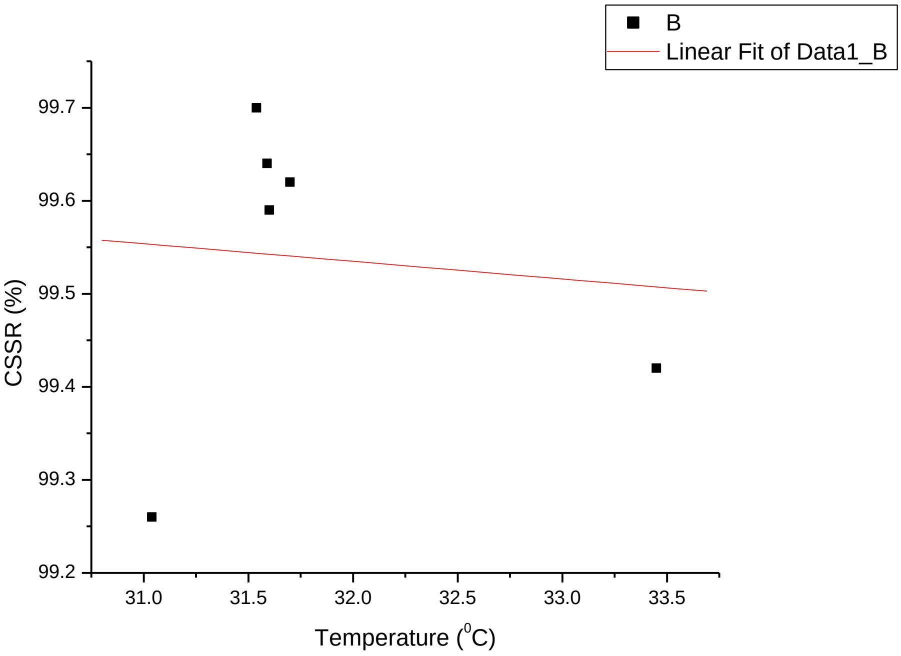

Fig. 13. Graph of CSSR against Temperature for MTN Network

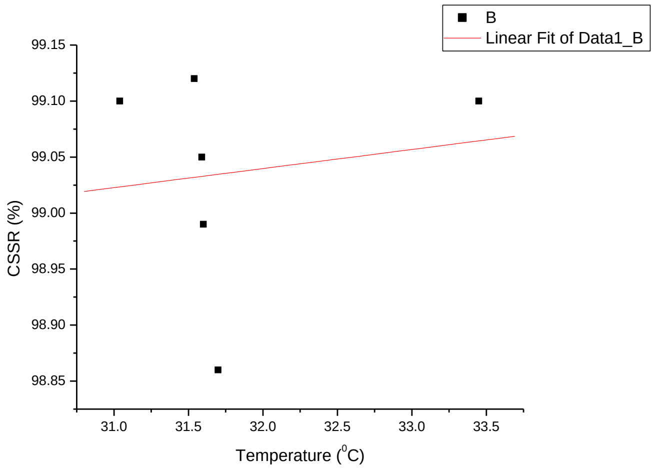

Fig. 14. Graph of CSSR against Temperature for Airtel Network

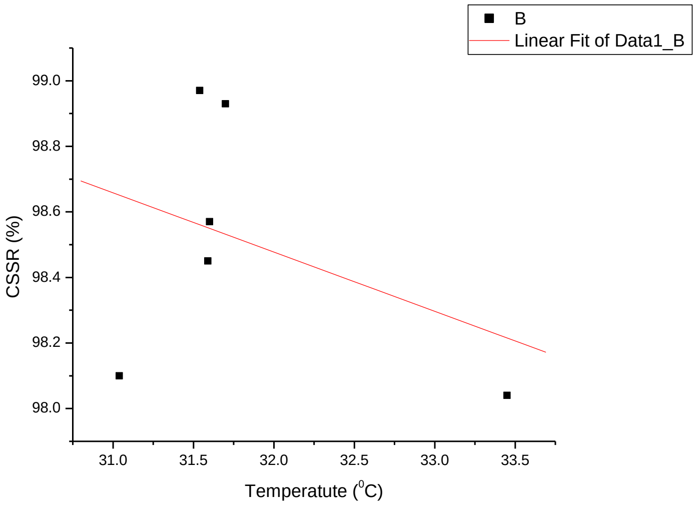

Fig. 15. Graph of CSSR against Temperature for Globacom Network

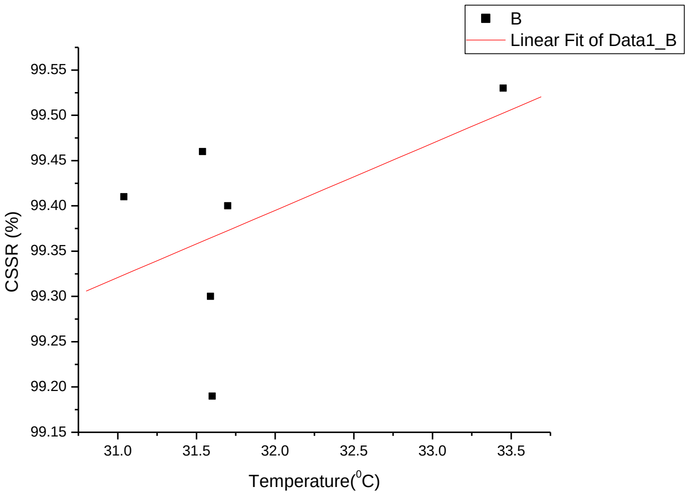

Fig. 16. Graph of CSSR against Temperature for Graph Network

4. CONCLUSION

The influence of relative humidity, windspeed, rainfall and temperature on call setup for four mobile networks operating in Calabar have been studied. The call setup of the four networks under study varied with tropospheric variables in an irregular pattern. This result will be useful to radio frequency planners, the mobile network operators, the NCC and those in academics.

DISCLAIMER

The products used for this research are commonly and predominantly used products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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