Comparative Analysis of Signal Strength of Some Cellular Networks in Port Harcourt, Nigeria.

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Abstract— This paper presents a comparative analysis of the Received Signal Strength (RSS) measurement of some cellular networks in Port Harcourt, Nigeria. Measurements were carried out using Radio Frequency Signal Tracker to determine received signal of three selected Global System for Mobile Communication networks (MTN, Airtel and Globalcom) at five strategic locations (Borokiri, Old Government Residential Area, Rivers State University, Ikwerre Road and Aba Road) in Port Harcourt, Rivers State. From the results obtained it shows that in Borokiri MTN has the highest received signal strength of -61.9dBm, Old GRA Airtel has the highest received signal strength of -61.3dBm, RSU and Ikwerre Road Globalcom has the highest received signal strength of -68.3dBm and -64.9dBm respectively while for Aba Road MTN has the highest received signal strength of -63.0dBm. In all the measurements, the results were analyzed using least square method and standard deviation to approximate the measurement data and path loss model was developed using ordinary least square regression technique.

Index Terms—Attenuation; Signal Tracker; Received Signal Strength, Transmitter.

I. INTRODUCTION

The wireless telephone system which is a major breakthrough in Communication comes either in fixed wireless lines or the Global System for Mobile communication (GSM) [1]. Statistics have shown that in many countries the use of mobile phone is already higher than the fixed one [2] and [3]. Communication is a major driver of any economy. Nigeria is not left out in the race of rapid development. However with the advent of GSM in Nigeria, telecommunication services have been brought closer to individuals in the country [4]. GSM has its own challenges in the area of signal reception.

GSM network in Nigeria is currently faced with the challenge of subscriber's dissatisfaction in the quality of services offered by the existing network providers. In this research work, the signal strength of some cellular networks (MTN, Globalcom and Airtel) operational in Port Harcourt were measured and compared to ascertain the network with better signal strength. The Signal strength measurement was carried out using Radio Frequency Signal Tracker.

The measurements were conducted at five strategic locations (Borokiri, Old Government Residential Area, Aba Road,

Ikwerre Road, and Rivers State University). Three networks (MTN, Globalcom and Airtel) were considered to determine the cellular network with the best received signal strength using Radio Frequency Signal Tracker (RFST).

The locations were chosen randomly based on the size of population. Borokiri lies between latitude $4^{\circ}47'24''$ North of the Equator and longitude $7^{\circ}2'6''$ East of the Greenwich Meridian line. Old Government Residential Area lies between latitude $4^{\circ}47'34.48''$ North of the Equator and longitude $7^{\circ}0'34.44''$ East of the Greenwich Meridian line, Aba Road lies between latitude $4^{\circ}49'4.44''$ North of the Equator and longitude $7^{\circ}0'37.44''$ East of the Greenwich Meridian line, Ikwerre Road lies between latitude $4^{\circ}49'17.16''$ East of the Equator and longitude $6^{\circ}59'2.4''$ of the Greenwich Meridian line while Rivers State University (RSU) lies between latitude $4^{\circ}49'34.68''$ North of the equator and longitude $6^{\circ}58'52.32''$ East of the Greenwich Meridian line. Figure 1 shows the Google Earth Map of the locations of measurement

Fig. 1. Google Earth Map showing the Locations of Measurement

II. PATH LOSS MODELS

When making an estimation of the possibilities for a radio system to function, it is a common practice to set up a link budget [5]. Simplified models are used frequently due to short coming of making an accurate estimate of all the parameters

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involved in the processing of the signal from the transmitter to the receiver.

The Frii's Free Space formula [5] is given as;

$$P_R = \frac{P_T G_T G_R \lambda^2}{L_T L_R (4\pi d)^2} \quad (1)$$

Where P_R = Received power, G_R = Receiver antenna gain, G_T = Transmitter antenna gain, L_R = Receiver losses, L_T = Transmitter losses, λ = Signal wavelength, d = Distance between the transmitter and the receiver antenna

There are many empirical propagation path loss models that are efficient and simple to use as it is obtained from in-depth field measurement. Site specification models are based on numerical methods and finite difference time domain (FDTD) technique and for the theoretical propagation path loss models are obtained from physical hypothetical assumptions while the diffraction models is obtained by using physical optics with the assumption of constant height and building spacing [6]. These models include the Free Space Model, Hata Propagation Model, Stanford University Interim (SUI) Model, Longley- Rice Model, Electronic Communication Committee-33 (ECC-33) Model, Cooperative for Scientific Research (COST-231) Model, LEE Model, Regression Model, Least Square Formulation Model, Path Loss Exponent Model with Aggregate penetration Loss (APL), Partition-Based Out Door-In Door Model etc. This paper emphasized on the Free Space Model, ECC-33 Model, COST-231 and Hata Models [6].

A. Free Space Propagation Path Loss Model

This model assumes that there is no obstacle between the transmitter and the receiver during signal propagation. In this case the transmitter radiates signal to an infinite distance with a situation of signal absorption or reflection [6]. In a case where the transmitter propagates signal at 360 using a fixed power with an ever increasing sphere, the transmitter will have a power flux of;

$$P_d = \frac{P_t}{4\pi d^2} \quad (2)$$

Where P_t is the power of the transmitter and P_d is the power obtained when the distance is from the antenna.

Free Space Propagation shows that the signal received by the receiver decays with distance between the transmitter and the receiver at a rate of 20dB/decade. It is also between the transmitter and the receiver.

B. ECC-33 Model

This model stands for Electronic Communication Committee-33 model. This model extrapolates the Okumura measurements and amended its assumptions to closely depict a fixed wireless access system. This model is commonly suitable for Suburban small areas [6]. The equation for this model is given as;

$$PL = PL_{F3} + PL_{bm} - G_b - G_m \quad (3)$$

Where PL_{F3} is the free space path loss given as:

$$PL_{F3} = 92.4 + 20\log_{10}(d) + 20\log_{10}(f) \quad (4)$$

PL_{bm} is the basic median path loss given as;

$$PL_{bm} = 20.41 + 9.83\log_{10}(d) + 7.994\log_{10}(f) + 9.56(\log_{10}(f))^2 \quad (5)$$

F is the frequency in MHZ and d is the distance between the transmitter and the receiver in Km.

$$G_b = \log_{10} \left(\frac{hb}{200} \right) \{ 13.98 + 5.8 [\log_{10}(d)]^2 \} \quad (6)$$

$$G_m = [42.57 + 13.7 \log_{10}(f)] [\log_{10}(hm) - 0.585] \quad (7)$$

C. COST-231 Propagation Model

This model stands for co-operative for Scientific and Technical Research. It is an enhanced version of the Hata Propagation Model. It uses four variables in predicting propagation loss which includes frequency, height of base station antenna, height of receiving antenna and distance between base stations and receiving antenna. The path loss equation for COST-231 propagation model is given as;

$$PL(db) = 46.3 + 33.9\log_{10}(fc) - 13.82\log_{10}(hb) - a(hm) + (44.9 - 6.5 - S\log_{10}(hb))\log_{10}(d) + CM \quad (8)$$

Where CM may be 0 for Suburban City or 3 for Metropolitan City

D. Hata Propagation Model

This is a set of equation obtained on measurements and extrapolations taken from curves derived by Okumura. It is fully empirical prediction method formulated for graphical path loss. The model is appropriate for frequency range of 150MHZ-1500MHZ (UHF) and for distance of 1Km-20Km. The model does not consider terrain profiles like hills that are found between the transmitter and the receiver. Three cases are used to calculate path loss associated with this model [6].

Case 1: Urban Hata Path Loss

$$PL = 69.55 + 26.16\log_{10}(fc) - 13.82\log_{10}(hb) + (44.9 - 6.55\log_{10}(d) + MS - a(hm)) \quad (9)$$

Case 2: Suburban Hata Path Loss

$$PL = PL_{Urban} - 2((\log_{10} \frac{fc}{28})^2 - 5.4) \quad (10)$$

Case 3: Rural Hata Path Loss

$$PL = PL_{Urban} - 4.78 ((\log_{10}(fc))^2 + 18.33 \log_{10}(fc) - 40.98) \quad (11)$$

Where MS is the Mobile Station antenna correction factor

$$a(hm) = 1.11\log_{10}(fc) - 0.7hm(1.56\log_{10}(fc) - 0.5) \text{ (dB)} \quad (12)$$

Where hb is the transmitter height, hm is the receiver height and fc is the transmitting frequency.

III. MATERIALS AND METHODS

A. Measurements

Signal Strength measurements were conducted at five strategic locations (Borokiri, Old Government Residential Area, Aba Road, Ikwerre Road, and Rivers State University) in Port Harcourt.. Three networks (MTN, Globalcom and Airtel) were considered to determine the cellular network with the best received signal strength using Radio Frequency Signal Tracker (RFST). The Radio Frequency Signal Tracker is an Application installed in a Techno Y4 mobile device which measures and displays the generated signal strength for each of the cellular network operators. The measurements of the signal strength for each of the mobile networks at the strategic location were recorded on daily basis. Measurements were conducted in the months of March 2017, April 2017 and May 2017 at each of the locations under consideration

The measurements were recorded at every distance of 100m for a given route of 2000m. A total of twenty seven

thousand six hundred (27,600) Signal Strength data were recorded for the three cellular networks at the five locations. Table I, Table II and Table III shows the specification of the Base Transceiver Stations for the three cellular networks at the five locations.

The measurement tool employed for the measurement was a Techno Y4 with Radio Frequency Signal Tracker (RFST) version 1.3.2 installed in it. The software is an engineering application tool for performing hand-held drive test. It is basically used to monitor and record Signal Strength and Serving Cell Location (describing the cell site's zones of coverage) and save or play back the data. The software gives information such as Base Transceiver Station (BTS) over the air interface. It also identifies the network operators Mobile Network Code (MNC).

The software program is an engineering application for performing Ad-hoc drive tests. It allows for the monitoring and recording of Signal Strength and Serving Cell location as drive test is conducted. It displays the cell phone's number, the device phone type (None or GSM), the unique device ID, the serial number of the SIM card, the SIM state, software version, the unique subscriber identity and the current Signal Strength of the phone in dBm. Network; here it gives the alphabetic name of the current registered operator, current network connection state, the radio technology currently being used, the Mobile Country Code as well as the Mobile Network Code used by the carrier, the Location Area Code and Cell ID, the current state of data traffic (IN, OUT, NONE, INOUT), the current data connection state, the current call state (Idle, Ringing or Off hook) and the number of neighbors being considered for selection as well as their individual Received Signal Strength Indicators (RSSI). Location; this service indicates weather you are using Google, Open Cell ID, or personal local site database to determine site location, displays current latitude and longitude in DMS (Degree Minutes and Seconds). The software program operates with the use of Geographic Position System. In course of the measurement, the Local Area Code, Cell Identity and Reception Transmission Level were constant while the Received Signal Strength in dB/m, Transmitting power and Reception Quality were changing. Mobile Country Code (MCC) and Mobile Network Code (MNC) were fixed for all networks. MCC for all networks is 621, while MNC is 50 for Globalcom, 30 for MTN and 20 for Airtel as shown in the table below

TABLE I: THE SPECIFICATION OF MTN BTS

Network	Locations	Specifications
MTN	Borokiri	Site No: T21472, Mcc: 621, Mnc: 30, Lac: 10283, Cell ID: 21479
	Old G.R.A	Site No: T2098, Mnc: 30, Mcc: 621, Lac:10283, Cell ID: 16009
	RSU	Site No: T188, Mnc:30, Mcc:621, Lac:10283, Mcc: 621, Cell ID: 16279
	Ikwerre Road	Site No: T0341, Mcc: 621, MNC: 30, Lac:10283, Cell ID: 3410
	Aba Road	Site No: Nil, Mcc: 621, Mnc: 30, Lac: 60224, Cell ID: 1313

TABLE II: THE SPECIFICATION OF AIRTEL BTS

Network	Locations	Specifications
AIRTEL	Borokiri	Site No: RV114, Mcc: 621, Mnc:20, Lac: 453, Cell ID: 15542
	Old G.R.A	Site No: RV121, Mnc: 20, Cell ID: 9321, Lac: 453, Mcc: 621
	RSU	Site No: RV121, Mcc:621, Mnc:20, Lac:10283, Cell ID: 7826
	Ikwerre Road	Site No: 2299, Mnc: 20, Mcc: 621, Lac:10283 Cell ID: 7826
	Aba Road	Site No: RV0023, Mcc: 621, Lac: 538, Mnc: 20, Cell ID:40023

TABLE III: THE SPECIFICATION OF GLOBALCOM BTS

Network	Locations	Specifications
GLOBAL COM	Borokiri	Site No: PAR028, Mcc: 621, Mnc:50, Lac: 9500, Cell ID:35281
	Old G.R.A	Site No: Nil, Mnc:50, Mcc: 621, Lac: 9500, Cell ID: 36842
	RSU	Site No: NC-00148, Mcc: 621, Mnc: 50, Cell ID: 35072
	Ikwerre Road	Site No: POT-002, Mcc: 621, Mnc: 50, Cell ID: 35072,
	Aba Road	Site No: Nil, Mnc: 50, Mcc: 621, Cell ID: 23109, Lac: 3040

B. Data Presentations

TABLE IV: AVERAGE MEASUREMENTS FOR BOROKIRI

DISTANCE (M)	MTN RSS(dBm)	Airtel RSS(dBm)	Globalcom RSS(dBm)
200	-55.9	-55.3	-59.1
400	-56.6	-61.6	-61.2
600	-58.0	-62.9	-63.3
800	-60.3	-63.8	-65.5
1000	-58.7	-66.0	-66.6
1200	-63.2	-67.9	-69.2
1400	-64.6	-69.8	-69.9
1600	-66.3	-73.5	-73.3
1800	70.8	-77.3	-77.0
2000	-74.2	-81.1	-79.9

TABLE V: AVERAGE MEASUREMENTS FOR OLD GRA

Distance (m)	MTN RSS(dBm)	Airtel RSS(dBm)	Globalcom RSS(dBm)
200	-57.2	-59.7	-63.3
400	-58.7	-61.9	-65.2
600	-60.7	-64.8	-64.4
800	-61.7	-65.9	-68.5
1000	-62.5	-67.5	-71.4
1200	-65.5	-70.4	-71.9
1400	-66.8	-73.5	-73.0
1600	-68.9	-75.3	-75.5
1800	-70.9	-77.8	-79.9
2000	-76.7	-80.9	-82.8

TABLE VI: AVERAGE MEASUREMENTS FOR RSU

Distance (m)	MTN RSS(dBm)	Airtel RSS(dBm)	Globalcom RSS(dBm)
200	-62.6	-57.5	-59.2
400	-63.2	-60.7	-60.5

600	-64.8	-68.8	-62.6
800	-66.9	-66.0	-65.3
1000	-68.1	-69.5	-67.2
1200	-70.2	-72.0	-68.7
1400	-71.4	-73.3	-70.9
1600	-74.0	-74.8	-62.4
1800	-77.1	-76.7	-73.1
2000	-78.9	-78.4	-78.5

TABLE VII: AVERAGE MEASUREMENTS FOR IKWERRE ROAD

Distance (m)	MTN RSS(dBm)	Airtel RSS(dBm)	Globalcom RSS(dBm)
200	-59.0	-59.6	-60.3
400	-62.8	-62.5	-60.9
600	-64.3	-63.8	-64.2
800	-66.6	-66.7	-66.5
1000	-68.9	-68.4	-68.4
1200	-70.5	-69.9	-68.6
1400	-72.9	-71.3	-71.7
1600	-74.8	-73.2	-72.7
1800	-79.2	-76.4	-75.6
2000	-82.4	-79.1	-78.5

TABLE VIII: AVERAGE MEASUREMENTS FOR ABA ROAD

Distance (m)	MTN RSS(dBm)	Airtel RSS(dBm)	Globalcom RSS(dBm)
200	-56.5	-60.4	-62.9
400	-59.1	-61.4	-64.4
600	-60.9	-64.9	-66.4
800	-63.3	-66.8	-67.3
1000	-66.4	-70.9	-69.2
1200	-68.5	-72.9	-70.6
1400	-69.7	-74.8	-71.8
1600	-72.5	-76.8	-73.8
1800	-73.9	-79.5	-72.5
2000	-77.4	-81.7	-80.3

TABLE IX: AVERAGE MEASUREMENT OF ALL THE NETWORK

Location	Network	RSS(dBm)
Borokiri	MTN	-61.9
	Airtel	-67.3
	Globalcom	-65.5
Old GRA	MTN	-63.4
	Airtel	-61.3
	Globalcom	-62.3
RSU	MTN	-68.6
	Airtel	-70.1
	Globalcom	-68.3
Ikwerre Road	MTN	-69.7
	Airtel	-67.5
	Globalcom	-64.9
Aba Road	MTN	-63.0
	Airtel	-69.3
	Globalcom	-69.3

IV. RESULTS AND DISCUSSIONS

A. Signal strength Analysis

To determine path loss for the conducted measurements at various distances free space propagation path loss model was used.

Path loss for free space is given as;

$$PL(d) (dB) = 32.45 + 20 \log(d) + 20 \log(f) \quad (13)$$

If frequency is given as 900MHZ and d is the distance between the transmitter and the receiver in km

Considering free space log normal law

$$PL = 20 \log\left(\frac{4\pi d}{\lambda}\right) + 10 \log\left(\frac{d}{d_0}\right) \quad (14)$$

Where λ is the wavelength, C is the speed of light and f is the frequency, while the operating frequency is 900MHZ.

$$\text{Therefore } \lambda = \frac{3 \times 10^8}{900 \times 10^6}$$

$$\lambda = 0.33 \quad (15)$$

For reference of 100m

$$PL = 20 \log\left(\frac{4\pi d}{\lambda}\right) \quad (16)$$

$$PL = 20 \log\left(\frac{4 \times 3.142 \times 100}{0.33}\right) \quad (17)$$

$$PL = 71.6 \text{ dB} \quad (18)$$

The path loss estimated from the measurement data with corresponding distance from the BTS for each of the networks were analyzed using Microsoft Excel. The path loss was observed to increase with corresponding increase in distance while conducting measurements as shown in Table X. Path loss for the three networks is shown in figure 2, Figure 3 and Figure 4.

Fig.2. Path loss for MTN

Figure 2 shows a plot of estimated average path loss(dB) against distance(m) for MTN network at the selected locations. The plot showed that path loss increases with distance.

Fig. 3. Path loss for Airtel

Figure 3 shows a plot of estimated average path loss(dB) against distance(m) for Airtel network at the selected locations. The plot showed that path loss increases with distance.

Fig. 4. Path loss for Globalcom

Figure 4 shows a plot of estimated average path loss(dB) against distance(m) for Globalcom network at the selected locations. The plot showed that path loss increases with distance.

B. Model Development

The measured data of the cellular networks at the five strategic locations based on the received signal strength were analyzed using Ordinary Least Square (OLS) regression in Microsoft Excel 2013. The results are shown in Tables X through XII for each network considered; a regression line was used to develop an equation as a developed model for predicting the path loss over distance. The table consist of the distance from the Base Transceiver Station to receiver (mobile device) while the coefficient of x-variable are the slope of the regression line which is an indication of the rate at which the path loss increases with the distance from the BTS.

TABLE X: OLS REGRESSION RESULT FOR MTN

SUMMARY OUTPUT						
Regression Statistics						
Multiple R	0.959417					
R Square	0.920481					
Adjusted R Square	0.910541					
Standard Error	1.561672					
Observations	10					
ANOVA						
	df	SS	MS	F	Significance F	
Regression	1	225.8455	225.8455	92.60447	1.13E-05	
Residual	8	19.51055	2.438818			
Total	9	245.356				
Coefficients, Standard Error, t Stat, P-value, Lower 95%, Upper 95%, Lower 95.0%, Upper 95.0%						
Intercept	76.38	1.066825	71.59564	1.61E-12	73.9199	78.8401
X Variable	0.008273	0.00086	9.623121	1.13E-05	0.00629	0.010255

Table X shows the Ordinary Least Square Regression Analysis of the received signal strength of MTN network over distance. The analysis indicated that the correlation coefficient of the regression line is approximately 0.96 while the coefficient of determination (R^2) is approximately 0.92. The coefficient of distance (x-variables) is 0.0083 while the intercept is 76.38dB.

Hence, the developed path loss model equation for MTN is given as:

$$PL \text{ (dB)} = 76.38 + 0.0083d \quad (19)$$

TABLE XI: OLS REGRESSION RESULT FOR AIRTEL

SUMMARY OUTPUT						
Regression Statistics						
Multiple R	0.959903					
R Square	0.921413					
Adjusted R Square	0.91159					
Standard Error	2.076324					
Observations	10					
ANOVA						
	df	SS	MS	F	Significance F	
Regression	1	404.376	404.376	93.79834	1.08E-05	
Residual	8	34.48897	4.311121			
Total	9	438.865				
Coefficients, Standard Error, t Stat, P-value, Lower 95%, Upper 95%, Lower 95.0%, Upper 95.0%						
Intercept	75.77333	1.418399	53.42172	1.67E-11	72.5025	79.04417
X Variable	0.01107	0.001143	9.684955	1.08E-05	0.008434	0.013705

Table XI shows the Ordinary Least Square Regression Analysis of the received signal strength of Airtel network over distance. The analysis indicated that the correlation

coefficient of the regression line is approximately 0.96 while the coefficient of determination (R^2) is approximately 0.92. The coefficient of distance (x-variables) is 0.0111 while the intercept is 75.77dB.

Hence, the developed path loss model equation for Airtel is given as:

$$PL \text{ (dB)} = 75.77 + 0.0111d \quad (20)$$

TABLE XII: OLS REGRESSION RESULT FOR GLOBALCOM

SUMMARY OUTPUT							
<i>Regression Statistics</i>							
Multiple R	0.956551						
R Square	0.914989						
Adjusted R Square	0.904363						
Standard Error	2.09056						
Observations	10						
<i>ANOVA</i>							
	df	SS	MS	F	Significance F		
Regression	1	376.3205	376.3205	86.10587	1.48E-05		
Residual	8	34.96352	4.370439				
Total	9	411.284					
<i>Coefficients, Standard Error, t Stat, P-value, Lower 95%, Upper 95%, Lower 95.0%, Upper 95.0%</i>							
Intercept	74.39333	1.428124	52.09165	2.04E-11	71.10007	77.68659	71.10007 77.68659
X Variable	0.010679	0.001151	9.279325	1.48E-05	0.008025	0.013333	0.008025 0.013333

Table XII shows the Ordinary Least Square Regression Analysis of the received signal strength of Globalcom network over distance. The analysis indicated that the correlation coefficient of the regression line is approximately 0.96 while the coefficient of determination (R^2) is approximately 0.91. The coefficient of distance (x-variables) is 0.0115 while the intercept is 74.39dB.

Hence, the developed path loss model equation for Globalcom is given as:

$$PL \text{ (dB)} = 74.39 + 0.0115d \quad (21)$$

Where d is the distance between the transmitter and the receiver in meters.

V. CONCLUSION

The Paper showed that as the mobile equipment (receiver) was moved away from the Base Transceiver Station the signal strength was observed to be reduced. In all the measurements, the results were analyzed to determine the path loss propagation model shown in equations (19), (20) and (21). This work has informed subscribers the network choice to use at various locations Port Harcourt in order to reduce the challenge of network failure or lack of signal for effective communication. In this research it has been established that transmitted signals gets weak as they are propagated through the air space, building and other physical obstructions. Also path loss increases with measurement distance from the BTS.

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