Path Loss Prediction for Some GSM Networks for Akwa Ibom State, Nigeria

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Abstract

Path loss prediction for some Global System of Mobile Communication (GSM) networks for Akwa Ibom State in the Federal Republic of Nigeria was undertaken in this study in order to obtain a suitable path loss model for path loss prediction for the State. Received Signal Strength (RSS) and path loss were obtained from MTN and GLO base stations (networks) located in Uyo, Eket, Ikot-Ekpene, Onna, Etinan and Oruk-Anam which are some major towns in Akwa Ibom State. Path loss plots from theoretical models and experimental data against Basic Transceiver System (BTS), mobile device distance, gave positive linear relationships resulting in the proposed path loss model for Akwa Ibom State. Comparative analysis of Mean Square Error (MSE) obtained showed Hata model to be the most reliable and suitable path loss prediction model for Akwa Ibom State. The MSE value for each town was 5.9dB, 4.09dB, 5.93dB and 4.03dB for Uyo, Eket, Onna and Etinan, respectively. It was found that Egli model with MSE value of 5.97dB is suitable for path loss prediction in Ikot- Ekpene due to its irregular terrain. Results also showed that none of the models being considered gave acceptable MSE value for Oruk-Anam. In this case, the proposed path loss prediction model for Akwa Ibom State should be used for Oruk-Anam. The results of this investigation therefore lend credence to the fact that terrain and infrastructural development affect not only path loss, but also the suitability of a given path loss model for a particular environment.

Index terms— path loss, global system of mobile communication (GSM), base transceiver station (BTS), received signal strength (RSS), networks and akwa ibom state.

1 Introduction a) Overview

ince the advent of telecommunication, there have been researches on how to improve and enhance communication between people at various locations. This resulted in Global System for Mobile Communication (GSM) which is a wireless form of communication that propagates information (voice and data) in the form of an electromagnetic (EM) wave.

It is a fact that cellular phones have revolutionized personal communications for millions of people around the globe. Like any mobile radio, a cellular phone transmits and receives electromagnetic reflection and absorption of radio energy by buildings is high, thus loss in power density will be high.

According to Mawjoud [6], networking planning is vital in the prediction of path loss and hence the coverage area, frequency assignment and interference which are the main concerns in mobile network planning. The available empirical formulae cannot be generalized to different environments (urban, sub-urban, rural). In general, suitability of these models differ for different environment.

Several propagation models have been formulated for prediction of path loss, but due to difference in terrain and level of development of a particular environment, appropriate model for a particular environment differs.

This study is aimed at obtaining a propagation model that is suitable, reliable and most accurate for path loss prediction in an environment and terrain like Akwa Ibom State in the Federal Republic of Nigeria.

2 II.

3 Review Of Previous Works

Path loss is the gradual reduction in power density of an electromagnetic wave as it propagates through the space from a source. Electromagnetic wave propagates through space from one region to another even when there is no matter in the intervening region. Electromagnetic wave, when traveling through an unguided medium, undergoes different kinds of propagation effects such as reflection, diffraction, free space loss, absorption, aperture medium, coupling loss and scattering. These propagation effects are the causes of reduction in power density (path loss). Path loss is as a result of received signal becoming weaker due to increasing distance between the base station and the transceiver system. This occurs even when there are no obstacles between the transmitting antenna and the receiving antenna. Radio wave propagation through a city is greatly affected depending on whether there is line-of-sight (LOS) between transmitting and receiving antennae or not. This is because propagation characteristics of the radio wave, such as path loss, fading and attenuation do not only depend on the distance and frequency, but also on the scatter angle that depends on what is causing the obstruction to the propagated wave [13].

A number of researchers have worked on path loss prediction which is of vital importance in GSM network design, planning, location of BTS, coverage area, frequency assignment and interference for effective cellular networks aimed at achieving effective signal values and levels between a transceiver and a mobile device.

Mawjoud [6] in his work on path loss propagation model prediction for GSM network planning studied the outdoor path loss behavior in Mosul city in Iraq to predict a suitable propagation model at the frequencies of 900MHz and 1800MHz in urban and sub-urban environments. After comparing the empirical models such as Hata, costs-231 Hata, International Telecommunication Union -Radio (ITU-R), Ericson and Stanford University Interim (SUI) with the experimental measured path loss for urban areas in Mosul city, the result showed that at 900MHz frequency, the best fit model for urban and sub-urban is Hata and Ericson models and for 1800MHz frequency, the best fit model for industrial and sub-urban areas is the Costa-Hata model. This shows that every environment has its distinctive characteristic factors and features that affect the propagation of wave differently. This, thus, precludes the generalization of a particular model for different environment. Various works [10,11] also showed that a path loss model cannot be generalized for different environment.

Also Isabona and Konyeha [5] in their study on urban area path loss propagation prediction and optimization using Hata model at 800MHz showed how Okumura Hata model is chosen and optimized for urban outdoor coverage in the Code Division Multiple Access (CDMA) system operating in 800MHz UHF frequency band in South South Nigeria. They compared measured path loss with theoretical path loss obtained from Hata, SUI, Lee and Egli models. In their result, Hata model was the nearest in agreement with the measured values. Based on these, they developed an optimized Hata model for the prediction of path loss experienced by CDMA 2000 signal in 800MHz band.

4 a) Reasons and causes of path loss

The reduction in power density (path loss) of a signal as it propagates from a source is caused by various factors which includes free space loss, diffraction, multipath fading, buildings and vegetation, terrain and atmosphere.

5 b) Theoretical path loss models

Theoretical models were derived based on the physical laws of wave propagation [10]. The theoretical path loss prediction models are divided into two basic types, namely; free space path loss model and plane earth propagation model.

6 i. Free space propagation model

In free space, the wave is not reflected or absorbed. Ideal propagation implies equal radiation in all direction from the radiating source and propagates to an infinite distance with no degradation. The free space path loss model is used to predict received signal strength when the transmitter and receiver have a clear unobstructed line-of-sight, LOS, path between them [10]. In satellite communication, microwave in LOS radio links typically undergo free propagation. According to [2,8,10], the power flux is given by f d dB L P + + = 2.6

where f is the carrier frequency in MHz, d is the T-R distance in km.

7 ii. The plane earth model

According to [14, ??8], path loss experience is worse in terrestrial environment than in free space. The most significant difference between terrestrial environment and free space is the presence of ground (and ground reflection) in a terrestrial environment. The plane earth loss increases far more rapidly than the free space loss and it is independent of carrier frequency. In plane earth model [14, ??8] The plane earth loss is rarely an accurate model of real-world propagation when taken in isolation. It only holds for long distance and for cases where the amplitude and phase of the reflected wave is very close to the idealized in case a equals 1.

8 c) Empirical Models

Empirical models, also known as stochastic models, are models obtained from experimental observation. There are of various types and their suitability differs with respect to terrain. In this work, Okumura model, Hata model, Cost-231 model and Egli model will be discuss.

i. Okumura Model According to [10], the Okumura's model is an empirical model based on extensive drive test measurements made in Japan at several frequencies within the range of 150 to 1920 MHz, but is extrapolated to 3000 MHz. For Okumura model, the prediction area is divided into terrain categories; open areas, suburban area and urban area [15]. Nadir and Ahmad showed that the signal strength decreases at much greater rate with distance than that predicted by free space model [7].

Okumura developed a set of curves giving the median attenuation relation to free space (?? ????), in an urban area over a quasi-smooth terrain with a base station effective antenna height The empirical path loss formula of Okumura is expressed as [10,15] ( ) ii. Hata Model The Hata model is an empirical formulation of the graphical path loss data provided by Okumura model (Hata, 1980). It is valid over roughly the same range of frequencies 150MHz to 1500MHz. This empirical formula simplifies the calculation of path loss because it is closed form formula and it is not based on empirical curves for different parameters. Two forms of the Okumura-Hata model are available **??**20]. In the first form, the path loss (in dB) is written as The more common form is a curve fitting of Okumura's original result. In that implementation, the path loss is written as **??** AREA m b mu F G h G h G d f A L dB L ? ? ? + =) ( ) ( ) , ( ) (m h m h h G b b b 1000 30 : 200 log 20) (10 < < = 2.11a ( ) m h h h G m m m 3 : 3 log 10) (10 < = 2.11b ( ) m h m h h G m m m 10 3 : 3 log 20) (10 ? ? = 2.11ccm cb exc space free H H A PL PL ? ? + = 2.12m b c h a h f A ? ? + = 2.14a ( ) ( ) ? ? ? = ? ? ? = 0 8 . 0) log(56 . 1 7 . 0) (log 1 . 1) (C f h f h a c m c m 2.14c

For metropolitan areas or large cities Path Loss Prediction for Some GSM Networks for Akwa Ibom State, Nigeria © 2017 Global Journals Inc. (US) ? ? ? ? ? = ? ? ? ? ? ? ? ? ? ? = 0 400 97 **.4**? ? ? ? = m b h h d L 2.20 III.

9 Cell, BTS And Mobile Device

Global system for mobile communication (GSM) is made up of a BTS and a mobile device enclosed within a cell.

In GSM, a cell is the geographical area covered by radio frequency from BTS which a mobile device located within that range can connect reliably is the transceiver (Figure **??**.1). The size of a cell is not fixed, it depends on several factors such as line-of-sight, reflection and absorption of radio frequency by obstacles and vegetation, height of the antenna, transmitters rate power, the required uplink/down link data rate of the subscribers device and the terrain.

10 iv. Egli Model

Egli model is an irregular terrain model for radio frequency propagation [10,15]. Egli model provides the median path loss due to terrain loss. It predicts the total path loss for point-to-point link (link-of-sight transmission). Typically, it is suitable for cellular communication scenarios where one antenna is fixed and another is mobile. Egli model is expressed as [15] ? 2 2 50 ? ? ? ? ? ? = d h h G G L m b m b 2.18 2 40 ? ? ? ? ? ? ? ? = f ? 2.19

where f is the frequency in MHz combing equation 2.18 and 2.19, Egli model is given by2 2 2 50 40 ? ? ? ? ? ? ? ? ? ? ? ? ? ? = f d h h G G L m b m b

The gain for mobile station, m

11 D

Sharma and Singh showed that these cells joined together to provide radio coverage over a large geographical area [16]. Path loss determines the cell range. For GSM, there are three cell ranges. Table **??**.4. Hamad-ameen from his research showed that the accuracy of cell planning depends on several factors and accuracy of propagation model is one of them [3]. Base Transceiver Station (BTS) in mobile communications holds the radio transceiver that defines a cell and co-ordinate the radio-link protocols with the mobile device. The BTS is the networking component of a mobile communications system from which all signals are sent and received. Thus it facilitates wireless communication between a device and network thereby creating the cell in a cellular network. A BTS consist of the following: antennas that relay radio message, transceivers, duplexers and amplifiers while a mobile device is a portable, wireless computing device that is small enough to be used while held in the hand; a handheld. These include mobile phones, PDA, computers.

12 Fig. 2.1: cell

A mobile phone operates on a cellular network which is composed of cells. If a subscriber (user) is located outside the cell belonging to the cellular network provider the user subscribed to, such a user cannot place or receive calls in that location.

13 a) Experimental Design

The methods employed in this study include physical site survey, collection of data, GPS measurement and analysis (graphs and regression). A detailed field study exercise for collection of data was carried out in selected cities of Akwa Ibom State using a mobile phone.

A NET monitor software installed in a Samsung galaxy phone was used to obtain the received signal strength from a fixed BTS at selected locations while GPS was used to measure the BTS -mobile device distance while a Personal Computer (PC) was used to save the collected data.

This study was conducted in December, 2015 in selected cities of Akwa Ibom State at a temperature of 27 o C. The Local Government Areas in which the investigation was carried out were Uyo, Eket, Ikot-Ekpene, Onna, Etinan and Oruk-Anam (Table **??**.1

14 c) Receiver Signal Strength (RSS)

In telecommunications, Received Signal Strength is the power present in a received radio signal and it is express in decibel (dB).

Below is a range of signal strength and its effect on quality of service.

15 Results And Discussion

The empirical path loss result was evaluated using four different path loss models, namely, free space model, **??**ata V.

16 Experimental Result

The collected measurement for MTN and GLO bass stations for the selected cities are shown below.

17 3.3

The proposed path loss model will be given by ?? ?? = ?? + ?? 0 ?? ???? + ?? 3.

18 4.7

The Mean Square Error (MSE) compares the measured data with the data obtained from each of the empirical models to determine the minimum MSE. The model that gives the least MSE and also not greater than 6dB, the minimum value of Mean Square Error for good signal propagation is suitable for prediction of path loss in the area in consideration. The Mean Square Error is expressed as?????? = ? (?? ?? ? ?? ??) 2 ??

where P M is the measured value, P E is the empirical value and N is the values of data taken.

For Uyo

19 Discussion

The results of path loss obtained from four empirical models are shown in table 4.1.The data shows that free space model has least path loss followed by Egli model and then Hata and COST-231 model which has close values.

The experimental results of received signal strength and path loss measured are shown in table 4.2 to 4.7. Regression analysis carried out on the results of Path Loss Prediction for Some GSM Networks for Akwa Ibom State, Nigeria each location gives equation 4.1 to 4.6. Figure **??**.1 to 4.6 show plots of path loss in decibel against distance in kilometres for the six study area. The graph shows a linear relationship between path loss and distance, increase in distance led to increase in path loss.

The MSE compares the measured data with the data obtained from each of the empirical model to determine the minimum MSE. The model that gives the least MSE and also not greater than 6dB, the minimum value of MSE for good signal propagation is suitable for prediction of path loss in the area in consideration. From the evaluation, MSE value obtained for Hata model (5. 9dB, 4.09dB, 5.93dB, 4.03dB) for Uyo, Eket, Onna and Etinan LGA respectively falls within the acceptable values of MSE for good signal propagation while Egli model (5.97) for Ikot-Ekpene is the acceptable value. From the evaluation, the least MSE value for Oruk-© 2017 Global Journals Inc. (US) Anam, Hata model (7.44) is above the minimum MSE value of 6db for a good signal propagation.

20 VII.

21 Conclusion

From the investigation, Hata model has the minimum means square error (MSE) of 5.9dB, 4.09dB, 5.93dB and 4.03dB for Uyo, Eket, Onna and Etinan, respectively. These values fall within the acceptable value of minimum MSE of 6dB for a good signal propagation. Hata model is more reliable and suitable for accurate path loss prediction in these areas while Egli model with MSE value of 5.97db for Ikot-Ekpene is suitable for path loss prediction for Ikot-Ekpene. This investigation also shows that the least MSE value of 7.44db for Oruk-Anam was obtained from Hata model but it is greater than the minimum MSE of 6dB for a good signed propagation. In these cases the proposed model (???? = 116.38 + 6.3?? ????) obtained from this study can be used Oruk-Anam.

From this study, Hata model gives a fairer result for path loss prediction for Akwa Ibom State. The study also shows that no generic model is suitable for generalized used since each model differs in their applicability over different terrain. For effective path loss prediction in Akwa Ibom State and network coverage performance, the proposed path loss model in equation 4.7 obtained from the experimental results from the state is reliable, suitable and more accurate. [1] [2]

Figure 1:

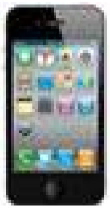

Figure 2:

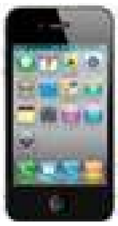

Figure 3:

[1] Path Loss Prediction for Some GSM Networks for Akwa Ibom State, Nigeria © 2017 Global Journals Inc. (US)

[2] © 2017 Global Journals Inc. (US)

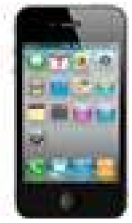

Figure 4: G

Figure 5:

where d is the distance (in metres) between the transmitter and receiver, t h is the height (in metres) of the transmitter antenna and r h is the height (in metres) of the receiver antenna.

In practice, a cor

equation 2.7 to yield

The correction fa

frequency of the carrier. Converting equation 2.8 to decibel gives.

L p = 10 log(a) + 20 log(h t) + 20 log(

Figure 6:

21

Carrier frequency	F	150 to 1920 MHz
Base station antenna height	b h	30 to 1000m
Mobile antenna height	m h	1 to 10m
Distance	D	1km to 100km

Figure 7: Table 2 . 1 :

23

B

where c f is given in MHz and d in km,

The function a ( ) and C depend on the environment for small and medium-size cities
m
h
a (h m)

C
For suburban environment The func- tion

C = [log(2 f c /) 28] 4 . 5 2 ?

For rural area f c) 2 ? 33 . 18 log (f log(78 . 4 = C

Figure 8: Table 2 . 3

24

Cell	Cell Radius
Large cells	1km ? r ? 30km
Small cells	1km to 30km
Micro cells	200m to 300m

Figure 9: Table 2 . 4 :

31

Signal Strength (dB)	Quality of
?105 ???? ? 100	Bad/drop call
? 99 ???? ? 90	Getting bad/signal may break up
? 89 ???? ? 80 Quality of service should not have problem	
? 79 ???? ? 65	Quality of service is good
???????????? ? 65	Quality of service is excellent
IV.	

Figure 10: Table 3 . 1 :

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Figure 11: Table 3 . 1

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Distance (km)	Free space (dB)	Hata (dB)	Cost-231 (dB)	Egli (dB)
1.0	91.58	123.97	123.59	110.46
2.0	97.61	133.95	133.84	122.50
3.0	101.13	139.79	139.84	129.35
4.0	103.63	143.65	144.10	134.54
5.0	105.56	146.86	146.86	138.42

Figure 12: Table 4 . 1 :

42

Network	Distance (km)	RSS (dB)	Path loss (dB)
MTN	1.0	-71	118
	2.0	-78	125
	3.0	-81	128
	4.0	-89	136
	5.0	-97	144
GLO	1.0	-79	126
	2.0	-85	132
	3.0	-89	136
	4.0	-95	142
	5.0	-101	148

Figure 13: Table 4 . 2 :

46

Network	Distance (km)	RSS (dB)	Path loss(dB)
MTN	1.0	-83	130
	2.0	-91	138
	3.0	-97	144
	4.0	-99	146
	5.0	-107	154
GLO	1.0	-79	126
	2.0	-83	130
	3.0	-91	138
	4.0	-95	142
	5.0	-97	144

Table 4.7: Measurement for Oruk Anam

Network	Distance (km)	RSS (dB)	Path loss (dB)
MTN	1.0	-83	131
	2.0	-92	140
	3.0	-98	146
	4.0	-107	155
	5.0	-113	161
GLO	1.0	-75	122
	2.0	-81	128
	3.0	-87	134
	4.0	-91	138
	5.0	-99	144

Figure 14: Table 4 . 6 :

Path Loss Prediction for Some GSM Networks for Akwa Ibom State, Nigeria

For Ikot-Ekpene

?? ?? = 10 (4060) 10(110)

?? ?? = 7.25

?? = 1305 10 ? 7.25

?? = 108.75

???? = 108. 75 + 7. 25?? ????

For Onna

?? ?? = 10 ?? ?? = 6.8 10(110) (4099)

?? = 1321 10 ? 6.8

?? = 111.7 ???? = 111. 7 + 6. 8?? ???? ?? ?? = 10 10(4280) 10(110) ? 30 ?? ?? = 5.2 ?? = 1392

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?? ?? = 6.34

?? = 8124 60

?? = 116.34

???? = 116. 38 + 6. 34?? ????

???? = 120. 5 + 5. 8 ?? ????

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