



EFFECTS OF PATHLOSS ON CAPACITY OF WIRELESS LTE NETWORK IN FUPRE, EFFURUN, NIGERIA

D.U. Onyishi¹ and V.E. Oweh²

¹Department of Electrical and Electronics, Federal University of Petroleum Resources, Effurun, Delta State, Nigeria

²Department of Computer Engineering, Delta State Polytechnic, Otefe Oghara. Delta State, Nigeria

*Corresponding author's email address: owehvictor12@gmail.com

ARTICLE INFORMATION

Submitted 11 July, 2023
Revised 2 September, 2023
Accepted 9 Sept., 2023

Keywords:

Path loss
GSM
Propagation models
log-normal

ABSTRACT

The impact of path loss has significant implications for the pricing strategies adopted by mobile communication companies. Accurate determination of path loss is crucial for effectively planning and operating high-capacity networks that deliver reliable services. Although previous researchers have devised various system designs, these models cannot be universally applied across all environments. The ongoing signal deterioration due to urbanization and industrialization presents a challenge to network capacity. This study aims to develop an Average path loss system specifically tailored for the planning of Worldwide System for Mobile Communication networks in the vicinity of the Federal University of Petroleum Resources Effurun (FUPRE) and its surrounding areas. The methodology employed involves instrumentation and measurement techniques. Distances in meters are measured using a digital wheel meter, while a handheld Android device equipped with G-MoN Pro software captures data including reference signal strength indicator (RSSI), latitude, and longitude during driving tests conducted along predefined routes. The collected data were subjected to regression analysis. The results indicated that the exponent path loss value (n) is 3.07, suggesting a cellular radio network environment typical of a metropolitan area. The root mean square error (RMSE) of 4.91 dB falls within an acceptable range for the reference measurement environment in the region. The average network models demonstrated greater precision than all other models, producing outputs with a smaller margin of error. Therefore, providers of GSM network infrastructure can leverage this practical model, based on the Log-Normal shadowing principle, to enhance and optimize their services in the FUPRE area and its surroundings.

1.0 Introduction

Path loss is the decrease in electromagnetic wave power density as it propagates through space, caused by various phenomena like diffraction, reflection, and absorption. The signal received from the base station weakens as the distance from the transceiver system to the mobile station increases (Ibhaze et al., 2017). The disparity between the power from the source and the power received is termed path loss. The performance of cellular network depends on the propagation model deployed during planning stage. Due to the complex and diverse nature of the radio propagation environment, the power of a propagation signal fluctuates with respect to time and space.

Path loss is a critical factor that impacts the quality of service in mobile communication systems. Accurately assessing path loss is essential for designing and operating reliable networks. To achieve precise estimation, different propagation models have been formulated.

Afolayan et al. (2017), their studied reviewed that Propagation prediction is vital tool for GSM networks planning. It determines factors like Base Trans-receive Stations location, coverage area, frequency assignment, and interference management, ensuring reliable and strong signal connections between transceivers and mobile devices.

Path loss, which can curtail signal range and lead to interference, has a major impact on the capacity of a mobile network, ultimately affecting its overall performance (Rana et al., 2014). Long Term Evolution (LTE) is a standard for high-speed data connectivity in cellular networks, providing faster data transfer speeds compared to 3G networks (Imoize et al., 2019).

Path loss can be determined using theoretical models, modeling software, empirical models, or field observations. The best approaches used typically combined field measurements with principally beneficial models. Poor path loss planning, which generally results from disregarding urbanization and relying on methods that don't incorporate actual field measurements, limits the capacity of wireless LTE networks. This study aims to implement a path loss model from four existing GSM network providers which includes MTN, Globacom, 9mobile, and Airtel within FUPRE and its environs to build an Average network model specifically for this environment.

In addition, this research examined some specific parameters such as exponent path loss, shadowing factor, measured path loss, and Root mean square error (RMSE) that can use create practical average network model using accurate field measurement data. Likewise, our research strives to create highly accurate and computationally effective models. The use of log distance and Log-normal shadowing modelling can be used in determining the said parameters mentioned above and emphasis will be laid equally on considering the effects and relationship of distance on measured path loss, predicted path loss, network capacity and average path loss.

Ifesinachi et al. (2021), had shown that a practical model for path loss propagation specifically for an LTE network in Onitsha, Nigeria. Measurement data from various locations in the city was collected to developed the model. The study found an exponent path loss is 3.5 and shadowing factors of 8.7 dB. Comparing the model with existing ones, it demonstrated superior accuracy in forecasting path loss in the Onitsha region.

Ikechukwu (2020), similarly emphasizes the significance of bandwidth and signal power in LTE wireless communication. The study identifies limitations due to government restrictions on bandwidth and low-powered devices. To overcome these constraints, the study proposes implementing channel coding and equalization techniques. By employing these strategies, wireless LTE communication capacities can be enhanced, improving performance and overall system capability.

In the research conducted by Faruk et al. (2019), to evaluate the effectiveness of a path loss concept using empirical data, geospatial data and heuristic data for Path Loss Estimates in Urban Environments The model accurately predicted signal strength within the limit of 1500 meters but showed reduced accuracy beyond that range. The study identified terrain, building

materials, and vegetation as factors influencing path loss. The results indicate that the inclusion of geospatial information has the potential to enhance the precision and efficiency of path loss model.

According to Benmus et al. (2016), who carried out a study aimed at creating a practical model utilizing Synthetic neural systems (SNS) for the purpose of forecasting the deterioration of signal strength across varying frequencies in Tripoli. The objective was to assess the accuracy of SNS in path loss prediction and compare it with existing models. The findings revealed that the SNS model outperformed existing models, achieving high correlation coefficients of 0.93 for the training dataset and 0.99 for the testing dataset. Based on these results, the study came to the conclusion that SNS is a useful tool for predicting route loss in mobile phone networks.

Armoogum et al. (2015) investigated the influence of topography on Loss of path in Yola, Nigeria's village and city regions. Radio frequency measurements were taken, revealing that topography had a weighty influence on signal attenuation. In city areas, buildings and structures were the main contributors to path loss, while in village areas, vegetation and terrain played a decisive role. The study emphasizes the prominence of understanding the influence of topography on path loss for effective network development and optimization.

According to Adeyemi et al. (2014), examined the effects of path loss on lowlands and mountainous areas of Bida, Niger State. The analysis showed that areas with obstacles like hills and mountains had higher path loss. These obstacles obstruct or reflect the signal, leading to reduced signal strength, coverage, and lower network capacity. In contrast, valley areas with flat terrain had lower path loss as the signal travelled more easily.

Austins et al. (2014) also conducted work on utilizing traffic engineering to enhance LTE network capacity in dense urban areas. They proposed an algorithm that can increase network capacity by up to 20% and is robust to changes in traffic load and cell configuration. The algorithm was executed with minimal modifications to existing LTE networks, offering a practical solution for improving capacity in urban settings. capacity.

Berkeley et al (2012) conducted a study to enhance LTE network capacity through interference management and resource allocation. Proposed techniques like interference cancellation and advanced signal processing algorithms to mitigate interference and enhance network performance. Dynamic resource allocation based on real-time network conditions was employed to fulfil the needs of high-speed users, resulting in increased network capacity by dynamically shared frequencies maximizing reuse while minimizing clashes as users and base station adjust power to maintain good signal while minimize interference and overall capacity of LTE is boosted.

2.0 Materials and Methods

The research methodology employed in this investigation involved the application of instrumentation and measurement techniques. The investigation was conducted in the neighbourhood of the Federal University of Petroleum Resources Effurun and its surrounding areas. Two test handsets equipped with G-MoN Pro software on an Android device were used. Similarly, a digital wheel meter attached to a car for measuring the distance covered from the base transceiver station was used. The Received Signal Strength Indicator (RSSI) measurements

were acquired from LTE Base Trans-receive Stations of GSM service providers located along designated routes such as Ugbomro road, DSC Expressway, DSC Roundabout, Okuokoko, Federal junction, and FUPRE. These service providers included MTN, Globacom, 9mobile, and Airtel, utilizing frequencies ranging from 800MHz to 2600MHz and transmitter power levels of 40, 40, 35, and 38 Watts respectively (Shoewu et al.,2014). The antennas were mounted on steel towers with an average height of 42 meters, and their spatial separation was measured horizontally. The field experimental data consisted of the RSSI values were collected up to a distance of 1500 meters. Figure 1 also showed an illustration of the measurement sites. In the end, the gathered data was subjected to regression analysis, which is a robust statistical method employed to assess the correlation between the desired independent variables. The measurement of Received Signal Strength Indicator (RSSI) over a specific distance at the respective service providers and their angular displacement as shown in Table I. The intention was to verify the signal strength received by various users in relationship with different service providers in the said location.



Figure 1: Google Map of the measurement area. Available online @www.mdpi.com/journal/map

2.1 Mathematical modelling of log distance and Log-normal shadowing model of path loss

2.1.1 Estimating Path Loss using a Log-distance concept

By incorporating variables such as distance and environmental conditions, the model utilizes the logarithmic decay with distance to make predictions about signal strength. The exponent path loss (n) represents the specific path loss characteristic for varying distances between the transmitter and receiver. The concept is represented by equation according to (Murdock et al., 2013).

$$L_p(d_i) = L_p(d_0) + 10n \log\left(\frac{d_i}{d_0}\right) \tag{1}$$

where

d_0 is the initial distance, d_i is the variable distance from initial point
n exponent path loss

$L_p(d_0)$ is the Path loss measured, $L_p(d_i)$ is the path loss predicted.

The exponent path loss (n) is a constant derived empirically and is influenced by the characteristics of the propagation environment. It is determined using equation (1) and can be mathematically represented as follows.

$$n = \frac{\{L_p(d_i) - L_p(d_0)\}}{10 \log_{10} \left(\frac{d_i}{d_0} \right)} \quad (2)$$

The exponent path loss can be statistically determined using linear regression analysis, Equation (2) which represents the summation of the mean square error in this context.

$$n = \frac{\sum_{i=1}^{N_i} \{L_p(d_i) - L_p(d_0)\}}{\sum_{i=1}^{N_i} 10 \log_{10} \left(\frac{d_i}{d_0} \right)} \quad (3)$$

Where the term $L_p(d_i)$ represents Path Loss Predicted, $L_p(d_0)$ represents Path Loss measured and N_i is the number of measured data or sample points. The expression, $L_p(d_i) - L_p(d_0)$, is an error term with respect to n, and the sum of the mean squared error, $e(n)$, is expressed as

$$e(n) = \sum_{i=1}^{N_i} [L_p(d_i) - L_p(d_0)]^2 \quad (4)$$

The optimal value of the exponent path loss (n), which minimizes the Mean Square Error (MSE), is obtained by setting the derivative of equation (4) to zero and solving for n.

$$\frac{\partial e(n)}{\partial n} = 0 \quad (5)$$

2.1.2 Log-normal shadowing concept of Path Loss

The model predicts signal attenuation for mobile communication, considering random shadowing effects from obstacles. It assumes a log-normal distribution for received signal power, indicating signal strength fluctuations with shadowing factors ($\sigma\rho$). The model is represented by equation (Hata, 1980).

$$L_p(d) = L_p(d_0) + 10n \log \left(\frac{d_i}{d_0} \right) + \sigma\rho \quad (6)$$

where

$L_p(d)$ Path loss is derived from the log-normal shadowing concept.

$\sigma\rho$ is the shadowing factor

The equation provided above establishes the derived model when the value is accurately measured. The shadowing factor ($\sigma\rho$) is also expressed as (Hata, 1980).

$$\sigma\rho = \sqrt{\sum \frac{[(L_p(d_i) - L_p(d_0))]^2}{N_i}} \quad (7)$$

Where

N_i = Sum of measured statistics points.

$L_p(d_0)$ is the Measured path loss, $L_p(d_i)$ is the Predicted path loss

2.1.3 The Concept of Data Analysis

Data collection for the study started 100 meters from the primary transmitter station, followed by a 100-meter drive along the designated route. This process was repeated twice daily for three months. Average of RSSI values were recorded. To ensure accuracy, the test car maintained a constant speed of 20 Km/h, with a highest speed of 30 Km/h to consider the Doppler Effect (Shoewu et al., 2014).

2.1.4 Power Transmitted P_t for each the Networks

Power Transmitted P_t for MTN = 40 Watts.

Power Received in RSSI is $P_r(\text{dBm}) = -41 \text{ dBm}$.

$d_o = 100$ metres $d_i = 100$ metres

Power transmitted in dBm is expressed as $10\log\left(\frac{\text{power.in.watts}}{1mW}\right)$ (8)

(i). Power Transmitted P_t for MTN = 40 Watts

$P_t = 40$ watts, in Decibel milliwatts (dBm)

$$10\log\left(\frac{40}{1 \times 10^{-3}}\right) = 46.02 \text{ dBm}$$

(ii). Power Received in RSSI in is $P_r(\text{dBm}) = -41 \text{ dBm}$

$$P_r = \text{Antilog}\left(\frac{\text{RSSI}}{10}\right) \quad (9)$$

$$P_r = 10^{-4.1} = 7.94 \times 10^{-5}$$

2.1.5 Measured path loss = $L_p(d_o)$

$$L_p(d_o) = 10\log\left(\frac{P_t}{P_r}\right) \quad (10)$$

$$L_p(d_o)_{MTN} = 10\log\left(\frac{46.02}{7.94 \times 10^{-5}}\right) = 58 \text{ dB}$$

2.1.6 The predicted Path Loss $L_p(d_i)$ value can be obtained

Recalled equation (1) from section 2.1.1

$$L_p(d_i) = L_p(d_o) + 10n \log\left(\frac{d_i}{d_o}\right)$$

For $L_p(d_o) = 58 \text{ dB}$, $d_o = 100$ metres $d_i = 100$ metres

$$L_p(d_i) = 58 \text{ dB}$$

For $L_p(d_o) = 58 \text{ dB}$, $d_o = 100$ metres, $d_i = 200$ metres

$$L_p(d_i) = 58 + 3.01n$$

2.1.7 Determination of Exponent Path Loss (n)

The optimal value of n, which minimizes the $[L_p(d_i) - L_p(d_0)]^2$, can be resolve by setting the derivative to zero and solving for n utilizing the values from Table 2. Substituting into equation (6), we obtain the derivative as follows:

$$e(n) = \sum_{i=1}^{Ni} [L_p(d_i) - L_p(d_0)]^2$$

$$= 1138.151 n^2 - 7813.12n + 13797$$

$$\frac{\partial e(n)}{\partial n} = 0$$

$$2(1138.151) n - 7831.12 = 0$$

$$\text{Hence, } 2276.302n - 7831.12 = 0$$

$$\text{Therefore, } n = \frac{7831.12}{2276.302} = 3.44$$

The value of exponent Path Loss n, MTN network is 3.44

Now, setting the same conditions as applied to MTN in Table 2, the value of exponent Path Loss in other networks can be calculated for Globacom, 9Mobile, Airtel and Average network are 3.12, 3.06, 3.00 and 3.08 respectively.

2.1.8 The shadowing factor $\sigma\rho$ (dB)

The shadowing factor, which indicates location variability, is calculated as the range of values around a mean value. By substituting the values of n and Mean Error Deviation Square from Table 2 into equation (7), the following result is obtained.

$$\sigma\rho = \sqrt{\sum \frac{[(L_p(d_i) - L_p(d_o))]^2}{Ni}}$$

For MTN network, where n = 3.44 and Ni = 15

$$= \left[\frac{1138.151 n^2 - 7813.12n + 13797}{15} \right]^{\frac{1}{2}} = \left[\frac{1138.151 \times 3.44^2 - 7813.12 \times 3.44 + 13797}{15} \right]^{\frac{1}{2}} = 5.09 \text{ dB.}$$

The process of measuring and computing the shadowing factor ($\sigma\rho$) for MTN was replicated for other chosen network service providers. By utilizing equation (7) and referencing Table 2, the resulting values for Globacom, 9mobile, Airtel, and Average Network, under the same conditions, were 4.53 dB, 4.88 dB, 5.60 dB, and 5.13 dB, respectively.

Therefore, by substituting the values for $L_p(d_0)$, n, and $\sigma\rho$ specific to the MTN network into Equation (6), we obtain the Log-Normal Shadowing Empirical model tailored for the Federal

University of Petroleum Resources (FUPRE) and its surrounding areas.

$$L_p(d) = L_p(d_0) + 10n \log\left(\frac{d_i}{d_0}\right) + \sigma\rho$$

$$L_p(d) = 58 + 10(3.44) \log\left(\frac{d_i}{d_0}\right) + 5.09(dB) \tag{11}$$

By substituting various parameters values into equation (6), the Log-Normal Shadowing model for each network was modified as follows:

$$L_p(d)_{GLOBACOM} = 62 + 10(3.12) \log\left(\frac{d_i}{d_0}\right) + 4.53(dB) \tag{12}$$

$$L_p(d)_{9MOBILE} = 60 + 10(3.06) \log\left(\frac{d_i}{d_0}\right) + 4.88(dB) \tag{13}$$

$$L_p(d)_{AIRTEL} = 66 + 10(3.00) \log\left(\frac{d_i}{d_0}\right) + 5.6.0(dB) \tag{14}$$

$$L_p(d)_{AVERAGE} = 62 + 10(3.07) \log\left(\frac{d_i}{d_0}\right) + 5.13(dB) \tag{15}$$

3. Results and Discussion

The experimental results obtained from measurement taken from various service providers in the field. The measured results were tested in Log-normal shadowing concept of Path Loss for MTN, Globacom, 9mobile and Airtel which yielded Average Network shown in table I according to Equations (3), (4) and Shadowing factor in Equations (6), (7) respectively. Table I results clearly evaluate all others service providers parameters such RSSI and Angular displacement of all available base stations in order to create highly accurate and computationally effective models. This indicated that the Log-normal shadowing concept result are in consonance with the Information Handling Service measured data.

Table I The values of RSSI for sites measured

S/N	FIELD MEASURED RSSI					AVERAGE	ANGULUR	
	DISTAN CE meters	RSSI (dBm) MTN	RSSI (dBm) GLOBAC OM	RSSI (dBm) 9MOBILE	RSSI (dBm) AIRTEL	RSSI (dBm) AVERAGE Network	Latitude (Degree)	Longitude (Degree)
1	100	-41	-45	-43	-49	- 45	5.54984	5.82589
2	200	-47	-49	-46	-52	-49	5.54964	5.82589
3	300	-52	-54	-50	-55	- 53	5.56314	5.81879
4	400	-55	-54	-53	-59	-55	5.56431	5.81989
5	500	-58	-62	-56	-63	- 60	5.56435	5.8201
6	600	-61	-65	-59	-66	- 63	5.56472	5.8216
7	700	-64	-68	-62	-69	- 66	5.56547	5.82516
8	800	-68	-72	-65	-73	- 70	5.56661	5.82698
9	900	-71	-74	-69	-76	- 73	5.56778	5.82366
10	1000	-75	-76	-71	-78	- 75	5.56836	5.83051
11	1100	-81	-79	-74	-81	- 79	5.56807	5.83398
12	1200	-83	-82	-76	-84	- 81	5.56983	5.83409
13	1300	-85	-84	-79	-87	- 84	5.57167	5.83404
14	1400	-86	-87	-81	-89	- 86	5.57404	5.83672
15	1500	-87	-92	-85	-95	- 90	5.57187	5.83972

Again, when the measured results in Table 2 where are the evaluated, the Measured path loss, the Predicated path loss, Mean error deviation and Mean error deviation square were obtained. It was also realized that the Exponent Path Loss and Shadowing factor is in agreement with the Information Handling Service measured data.

Table 2: Measured path loss, predicted path loss and mean square Error for MTN

S/N	DIST. (Metre)	RSSI (dBm) MTN	Measured path loss $L_p(d_0)$	Predicted path loss $L_p(d_i)$	mean error deviation $[L_p(d_i)-L_p(d_0)]$	Mean error deviation Square $[L_p(d_i) - L_p(d_0)]^2$
1	100	-41	58	58	0	0
2	200	-47	64	$58 + 3.01n$	$3.01n - 6$	$9.0601n^2 - 36.12n + 36$
3	300	-52	69	$58 + 4.77n$	$4.77n - 11$	$22.7529n^2 - 104.94n + 121$
4	400	-55	72	$58 + 6.02n$	$6.02n - 14$	$36.240n^2 - 168.56n + 196$
5	500	-58	75	$58 + 6.99n$	$6.99n - 17$	$48.860n^2 - 237.66n + 289$
6	600	-61	78	$58 + 7.78n$	$7.78n - 20$	$60.528 n^2 - 311.20n + 400$
7	700	-64	81	$58 + 8.45n$	$8.45n - 23$	$71.402 n^2 - 388.70n + 529$
8	800	-68	85	$58 + 9.03n$	$9.03n - 27$	$81.540 n^2 - 487.62n + 729$
9	900	-71	88	$58 + 9.54n$	$9.54n - 30$	$91.011 n^2 - 572.40n + 900$
10	1000	-75	92	$58 + 10.0n$	$10.0n - 34$	$100 n^2 - 680.0n + 1156$
11	1100	-81	98	$58 + 10.41n$	$10.41n - 40$	$108.368n^2 - 832.80n + 1600$
12	1200	-83	100	$58 + 10.75n$	$10.75n - 42$	$115.56 n^2 - 903.0n + 1764$
13	1300	-85	102	$58 + 11.14n$	$11.1n - 44$	$123.21 n^2 - 976.8n + 1936$
14	1400	-86	103	$58 + 11.46n$	$11.46n - 45$	$131.10 n^2 - 1031.4n + 2025$
15	1500	-87	104	$58 + 11.76n$	$11.76n - 46$	$138.06 n^2 - 1081.92n + 2116$
Σ						$1138.151 n^2 - 7813.12n + 13797$

Therefore, Equations (11), (12), (13), (14) and (15) were employed to generate the data presented in Table 3 given below. The table demonstrates the established path losses at several distances from 100 meters from the base station to 1500 meters for a network capacity covered area in the examined regions and allowing a comparison of mean path losses for each network as presented below.

Table 3: Established path losses derived from the proposed modified model.

S/N	Distance in (m)	Path loss in (dB) MTN network	Path loss in (dB) Globacom network	Path loss in (dB) 9mobile network	Path loss in (dB) Airtel network	Path loss in (dB) Average network
1	100	63.09	66.53	64.88	71.60	67.13
2	200	73.44	75.92	74.09	80.63	76.37
3	300	79.50	81.41	79.47	85.91	81.77
4	400	83.80	85.31	83.30	89.66	85.61
5	500	87.13	88.33	86.26	92.56	88.58
6	600	89.85	90.80	88.69	94.94	91.01
7	700	92.16	92.89	90.74	96.95	93.07
8	800	94.15	94.70	92.51	98.69	94.85
9	900	95.91	96.30	94.07	100.22	96.42
10	1000	97.46	97.73	95.48	101.60	97.83
11	1100	98.91	99.02	96.74	102.84	99.10
12	1200	100.21	100.20	97.90	103.97	100.26
13	1300	101.40	101.28	98.96	105.01	101.32
14	1400	102.31	102.28	99.95	105.98	102.31
15	1500	103.64	103.02	100.86	106.88	103.23
MEAN		90.86	91.72	89.59	95.82	91.52

These values obtained as a result operating similar conditions maintained for different networks, namely MTN, Globacom, 9mobile, Airtel, and Average network, the results is presented in Table 4 shown below.

Table 4: Different values of the exponent path loss, shadowing factor, $L_p(d_0)$, RMSE

S/N	Parameters	MTN	Globacom	9Mobile	Airtel	Average network
1	n	3.44	3.12	3.06	3.00	3.07
2	$\sigma\rho$ (dB)	5.09	4.53	4.88	5.60	5.13
3	$L_p(d_0)$ (dB)	58.0	62.0	60.0	66.0	62.0
4	RMSE(dB)	5.15	4.41	4.89	5.65	4.91

Figure 2 shows the typical established path loss experienced by GSM operators. The Airtel network exhibits the highest path loss compared to MTN, Globacom, 9mobile, and Average networks, with values of 4.96 dB, 4.09 dB, 6.23 dB, and 4.29 dB respectively. The figure also demonstrates a strong correlation connecting the Average network model and other networks. Therefore, the Average network model is positioned centrally, avoiding overspill path loss, and strikes a balance between underestimating and overestimating path loss. Considering these factors, it can enhance signal strength, expand coverage area, reduce interference, and increase network capacity.

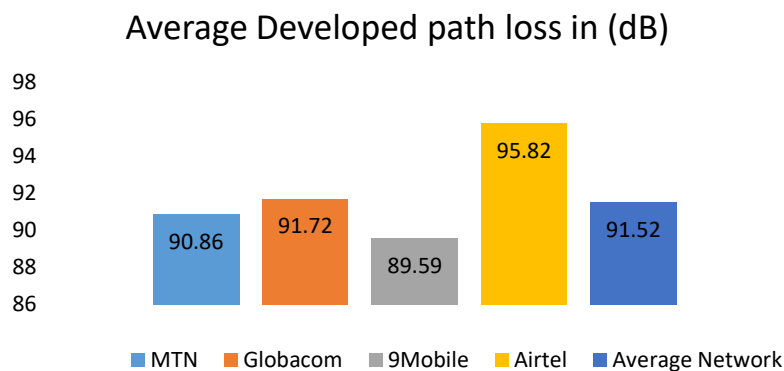


Figure 2: The Path Losses of All Typical Networks

Figure 3 demonstrates the measured path losses at a distance of 500 meters for different network providers. The measured path losses are as follows: 75 dB for MTN, 75 dB for 9mobile, 77 dB for Average, 79 dB for Globacom, and 80 dB for Airtel. This suggests that MTN has the smallest observed path loss, whereas Airtel exhibits the highest path loss. The MTN network offers a substantially better capacity while the Airtel network only delivers the bare minimum. The graph suggests that the Average network has a moderate network capacity due to its central location.

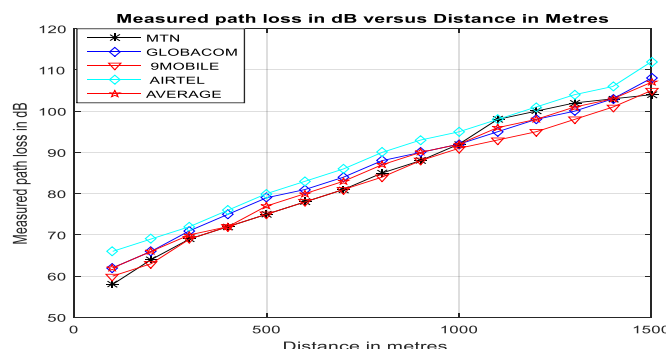


Figure 3: Depicts the relationship between measured path loss in (dB) and distance(m)

The expected path loss estimates for several networks at a measurement distance of 1000 meters are shown in Figure 4. The values for 9mobile, MTN, Average, Globacom, and Airtel are recorded as 92dB, 93dB, 94dB, 94dB, and 97dB, respectively. The graph clearly demonstrates that network capacity falls as expected path loss rises. Conversely, the graph portrays that the Average network demonstrates relatively reduced predicted path loss and accommodates more users in the network.

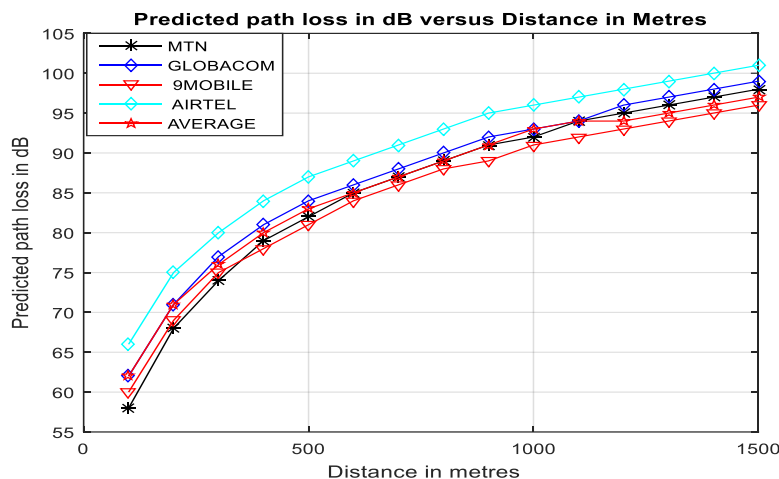


Figure 4: Displays the predicted route losses in (dB) plotted against distance (m).

At 500-meter distance away (Figure 5) from the starting point, the 9mobile network exhibits a favourable performance factor of 86.26 dB, while the Airtel network experiences the highest degradation factor of 92.56 dB. This indicates that the 9mobile network can accommodate more customers than the Airtel network. The results indicate that path loss varies among the different GSM operators and increases at different rates over the measured distance. Additionally, the graph shows that the MTN and Airtel networks tend to overestimate their path losses, while 9mobile and Globacom networks underestimate theirs. There is no significant path loss in the average network., allowing for moderate user capacity without exceeding its limits. This also highlights the improvement in service quality and increased network capacity as credited to the average network.

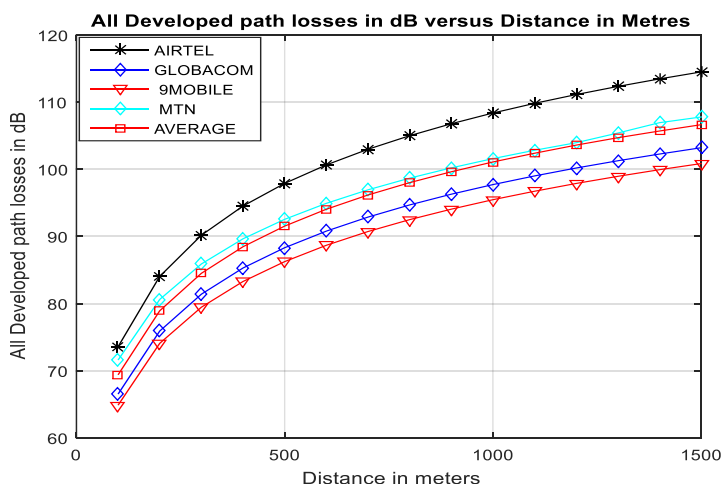


Figure 5: illustrates the system capacity models in terms of dB versus distance in meters.

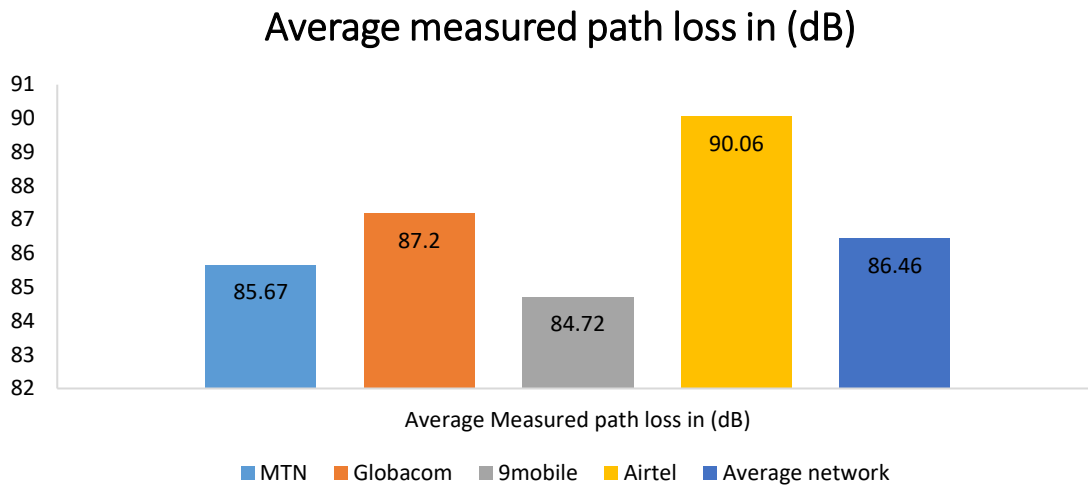


Figure 6: Average Measured path loss in (dB)

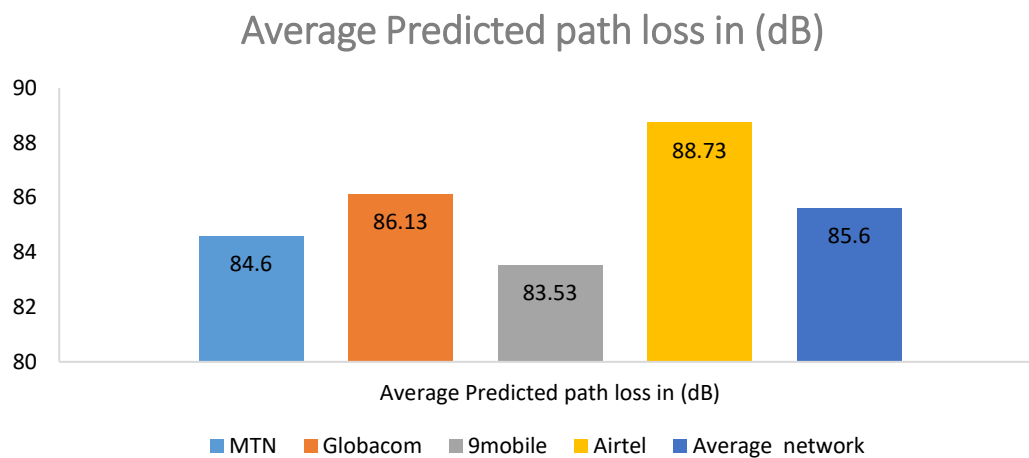


Figure 7: Average Predicted path loss in (dB)

4. Conclusion

In this study, an average network model derived from four existing GSM networks operating at 2600 MHz within the Federal University of Petroleum Resources, Effurun, Delta State was introduced. These networks include MTN, Glo, Airtel, and 9mobile. The proposed models were developed using the Log-normal shadowing model, based on data collected from various locations within the specified area. The resulting path loss models are as follows:

The analysis revealed that among the four GSM network models considered, the Average network model provided the best fit for the selected locations. Specifically, the predicted path loss for the Average network was 85.60 dB, while MTN, Glo, 9mobile, and Airtel networks recorded path loss values of 84.60 dB, 86.43 dB, 83.53 dB, and 88.73 dB, respectively.

Furthermore, the Average network model exhibited a moderate root mean square error and shadowing factor compared to any of the standard network path loss models examined. When applied within the University environment and its surrounding areas, this model has the potential to reduce path loss, thereby addressing the frequent network fluctuations experienced by subscribers in the region.

References

Adebayo, TL. and Edeko, FO. 2006. Characterizations of analysis of Path Loss at 1.8GHz: A case investigation of Benin City. *Research Journal of Applied Sciences*, 41(04): 23 – 34.

Adeyemi, A. and Adu, O. 2014. An Evaluation of Viability of a variety of Path Loss Designs for LTE Network Panning. *World Congress on Engineering*, London U.K., July 6-8, 23(1): 150 - 161.

Afoayan, J., Obot, A. and Simeon, O. 2017. Prediction Path loss model for Macrocellular settings in cities. *Nigerian Journal of Technology*, 30(1): 120 – 131.

Armoogum, OT. and Konyeha, SR. 2015. Models of Wave Propagation for the Development of Mobile Communication Systems, *GAAS Munich*, 3(2): 23 -31.

Benmus, TA., Abboud, R. and Shatter, MS. 2016. Neutral Network at 1000, 1600, and 2100 MHz bands: method to simulate path loss propagation for the greater Tripoli area in *Sciences and Technology of Control System and Computer Engineering 16th International Conference*, held in Jaipur, India on December 15th -16th, 3(12):793-798.

Enyi I, VS., Val, UE., Ugwu, FC. and Chidubem, CO. 2021. Path Loss Model Predictions for Different GSM Networks in the University of Nigeria, Nsukka Campus Environment for Estimation of Propagation Loss. *International Journal of Advanced Research in Computer and Communication Engineering*, 10(8): 108 – 115.

Faruk, N., Popoola, SI., Surajudeen-Bakinde, NT. and Oloyede O. 2019. An Experimental Study of Geospatial, Empirical, and Heuristic models for Path Loss Estimates in Urban Environments. *IEEE ACCESS*, 7: 77293 - 77307.

Hata, M. 1980. Propagation loss empirical approach for land mobile radio services. *Journal of Vehicular Technology*, IEEE, 29(3): 317-325.

Ibhaze, AE., Imoize, AL., Ajose, SO., John, SN., Ndujiuba, CU. and Idachaba, FE. 2017. A model of empirical propagation for path loss prediction at 2100 MHz in a metropolis setting. *Journal of Technologies and Science in India*, 10(5): 1-9.

Ifesinachi, EO., Idigo, VE., Ohaneme, CO. and Obioma, PC. 2021. Implementation of an Empirical model for Path Loss propagation in an LTE Network in Onitsha, *Journal of Engineering and Applied Sciences*, 19(1): 23 – 34.

Imoize, AL., Ibhaze, AE., Nwosu, PO. and Ajose, SO. 2019. Finding a 4G LTE Network's Best-Fit Propagation Models in Lagos, Nigeria's. *Engineering Journal of the West Indies*, 3(12): 44-52.

Murdock, JN., Junior, RW., and Daniels, RC. 2013. *Millimeter wave wireless communications*. Prentice Hall.

Rana, SB., Pardeep, P. and Parveen K. 2014. Modified Formulation of Algorithms for Path Loss Broadcasting Applications. *International Journal of Recent Technology and Engineering*, 23(03): 56 – 63.

Rahman, M., Imran, K. and Mohammed, T. 2020. A Survey of Algorithms for Path Loss Wireless Communication Systems. *International Journal of Electronics and Telecommunications*, 24(04): 56 – 63.

Shoewu, O. and Edeko, FO. 2014. Investigating Signal Attenuation in Cluster-Based GSM Base Stations in the Area of Lagos, *Publication on Electrical and Computer Engineering Systems in the International Transactions*, 2(1):28 – 33.