Development of a modified propagation model of a wireless mobile communication system in a 4G network

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ABSTRACT

Pathloss is a key element that causes signal deterioration in the channel as the signal power reduces inversely with propagation distance, this deterioration experienced by the channel is majorly as a result of reflection, absorption, and scattering of the signal. This study however takes into consideration the radio path loss for precise base station (BS), frequency, and power adjustment prediction evaluated over a frequency of 2.3 GHz. With a distance range between 0.1 and 1.5 km for collection of data on the measured received signal strength (MRSS), five empirical models and a modified model were used to validate the measured data to determine their suitability for pathloss prediction at Federal University of Technology, Owerri (FUTO), Imo state, Nigeria. The results shows that the root mean square error (RMSE) for the Okumura-Hata, COST 231-Hata, Ericsson model, Lee, Stanford University Interim (SUI), ECC-33, and modified models are 14.33, 9.73, 25.79, 48.4, 33.76, and 8.31 dB respectively. Additionally, the Ericsson model provided 0.498 dB, the COST 231-Hata recorded 0.733 dB, and the modified model provided 0.453 dB for mean absolute percentage error (MAPE). Therefore, the improved model produces the best results, consequently, be deployed to approximately predict path loss for mobile radio coverage in Owerri, Nigeria.

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1. INTRODUCTION

Deploying wireless mobile communication networks require a critical review of pathloss prediction technologies. It is critical because cellular mobile communication signal losses differ from one location to another. Therefore, cellular mobile system advancements and their future applications necessitate a comprehensive site location plan, a good line of sight along the channel and a high data transfer rate. For high mobility applications like mobile access, the peak data transfer rate of a 4G cellular mobile system is anticipated to be around 100 Mbit/s. The 4G network's quick data transfer has the ability to give users of the network access to a wide range of services. Electromagnetic waves are used in wireless communication networks to transport data between a transmitter and a receiver [1]. Due to obstructions in the channel caused by high buildings, dense vegetation, sharp edges, and hilltops, this transmitted signal is therefore vulnerable to attenuation, resulting in reflection, diffraction, scattering, and absorption of the signal [2].

Several factors have been identified to have significant effects on the received signal strength (RSS), some of which are the environment in which the cellular network is placed, the operating frequency, and the radius of the cell. Additionally, pathloss has been discovered to vary directly with separation between the transmitter and the receiver [3]. The qualities of the received radio signal are influenced, in brief, by three fundamental occurrences. There are several of these, including losses in the radio wave path, multiple path (small-scale) fading, and large-scale shadow fading. Pathloss can therefore be referred to as signal attenuation in the communication channel as it travels from source to base station (BS) [2]. A crucial stage in building up a wireless communication system is path loss prediction in mobile radio channels. It is necessary to develop exact mathematical tools for adjusting power and radio characteristics that will ensure adequate network coverage of a given area [4]. A number of models that can be used in a system of mobile radio communication have been reported in the literature.

Several models, which were created for a specific terrain, suffer when used in another terrain [5], [6]. The performance of various path loss models was also shown to be poor when compared to the observed data in several investigations carried out in Nigeria and other tropical countries [7]. As a result, it is necessary to assess the situation and choose a model that is appropriate for the Federal University of Technology, Owerri (FUTO) environment. This study uses data from a drive test to examine the performance of the Okumura-Hata, Stanford University Interim (SUI), ECC-33 model with measured data in the South-East suburbs of Nigeria, near FUTO. An updated shadowing empirical model was also created based on the current models, and the path loss in (dB) was compared with the information from the drive test.

2. LITERATURE REVIEW

Recent research on path loss prediction models has emphasized the need to critically assess the environment at hand before deploying the best model for that environment. In evaluating the model with optimum performance, several studies have been done in various places. The predictions of the SUI, COST-231, and ECC-33 models were contrasted with the path-loss data acquired at Cambridge at a frequency of 3.5 GHz, Roslee and Kwan [8]. The result in the chosen area was overestimated by SUI and COST-231. The ECC-33 model provided the closest fit and was thus suggested for use in urban settings.

By utilizing a least-squares method, Halifa *et al.* [9] optimized the Hata model for Malaysian sub-urban area to produce a more precise prediction. Frequency measurements were taken outside between 400 and 1,800 MHz, Hata model produced the best results. The optimized model was deployed, verified in a different but similar environment to identify the relative error for evaluating the Hata model's effectiveness. A minute mean relative error was gotten which indicates a successful optimization.

In a similar manner, Ghana's worldwide interoperability for microwave access (WiMAX) network in the 2,500 to 2,530 MHz frequency was the focus of the work presented Gadze *et al.* [10]. A WiMAX site near the University of Ghana was used as a focus for measurement. Four empirical models were considered applicable for predictions and they were compared with the measured data. COST-231 extended model, had a greater correlation coefficient and the lowest root mean square error (RMSE). Therefore, being the most appropriate for the measured data, it was suggested in Ghana and the sub-regions for effective radio network planning. Another study was conducted to address the difficulties in radio transmission that network professionals face in choosing the most accurate and appropriate propagation model for Ghana. Faruk *et al.* [11] evaluated a wide range of long-term evolution (LTE) path-loss metrics for frequencies of 800 MHz and 2,600 MHz in urban and suburban locations. When the scientists compared the data to six widely used propagation models, it was found that the enhanced versions of the Ericson, ECC-33, and SUI models produced in the study accurately predicted the path-loss.

In Nigeria, measurement validation was presented using the modified Hata model for pathloss evaluation at 1.8 GHz in a rural environment of the Niger Delta region [12]. A modified pathloss model was developed to predict signal strength received at a reasonable accuracy. A mean prediction error value that was less than 10.4 dB and a standard deviation error value less than 18 dB was achieved for the network considered in the study area. Another path loss variation was also studied in the South-South region at 876 MHz, the loss increased by 35.5 and 25.7 dB/decade in the urban and Sub-urban regions respectively [13]. The modified Hata model was recommended to be applicable for path loss prediction in the area. The shortfall of the study was that it does not consider rural areas as a part of the coverage.

Five experimental models were taken into account while examining the performance of path loss for LTE network Emeruwa and Iwuji [14]. The actual field data on the network was captured at a frequency of 700 MHz using drive test. The forecast employing test mobile system (TEMS) research and discovery network planning tools provided the best prediction with the Ericsson model among the models used.

An optimized cost 231 model was developed Sharma *et al.* [15] to estimate path-loss in Jaipur, India over a 4G wireless communication link operating at 1,800 MHz. The measurement supports the distinction between anticipated and measured path-loss using the measured field strength as basis. Findings in the study revealed that COST-231 model is best for the studied environment. There also exists a mean error (ME) of -5 dB between measured values and the COST-231 model.

A tangent activation function and 48 hidden neurons were implemented in the feedforward neural networks (FNNs) algorithm [16] to create an ideal model. On eleven distinct base stations, each running at 1,800 MHz frequency, drive test readings were frequently taken. When the effectiveness of the suggested model was evaluated using common measures, little prediction error was discovered.

A signal attenuation prediction model for global system for mobile (GSM) operation at frequency of 1,800 MHz for several GSM networks at the chosen location of University of Nigeria Campus was proposed in [17]. At that frequency, measurements were taken in the field depending on the signal's strength. Regression analysis was used to assess field measurements in order to create the desired model. Based on its least error value, the proposed attenuation model outperformed other existing models in comparison.

Ibhaze *et al*. [18] used data gathered in a few Nigerian urban areas to develop new models while examining the efficacy of heuristic, empirical, and geographical methodologies. To compare the derived models to the empirical models, data were measured. It was noted that the ECC-33 and Egli models failed to produce RMSE values that were acceptable. The authors' work suggests that empirical models be improved in the future for the best accurate prediction. The authors suggested combining empirical and heuristic models for prediction in order to reduce the inaccuracy that is frequently associated with empirical models.

Imoize *et al.* [19] created a 2,100 MHz version of the Ericson model for the Alagbado neighborhood of Lagos, Nigeria. A sophisticated polynomial was fitted for data measurement. The measurement was correlated with various existing empirical models. There was a lesser likelihood of error in the prediction employed in the analyzed wireless channel, even if the model had previously been applied in the prediction of lower range frequencies different from the frequency spectrum considered.

Path-loss models for a 4G LTE network in urban and suburban areas of Lagos were described in [20]. At 3.4 GHz, the reference signal received power (RSRP) was noticed. The obtained models were connected to the observed data. The COST 231-Hata and Ericson models performed remarkably well in the chosen settings. The least square regression algorithm was used by the authors to create the model that performed the best. The generated models provided a good probability result with RMSES of 6.20 and 5.90 dB in the urban and sub-urban area that was chosen. When the results of propagation measurements in comparable surroundings were compared, it was found that the models would accurately represent radio coverage, increasing the value of mobile services in the same terrain.

The design of LTE networks in respect to the performance metrics it gives is crucial given the rising demand for cellular communication in terms of throughputs and adequate connectivity. In order to improve the performance of cellular networks for voice communication as well as data transmission, several studies have been reviewed to find propagation models that accurately give forecast of path-loss in continents throughout the world. However, the successful operation of current propagation models in wireless environments other than the locations where they were first intended to be deployed may present a different ideal. However, numerous studies show that when modified to the data collected from the experimental location, many widely used path-loss models perform better. This means that in order to understand the peculiarities of the environment and the elements that may cause signal losses along the course of radio propagation, a critical study and in-depth investigation of a specific terrain must be conducted. The wireless network planner will then be able to design or adapt an appropriate propagation model for a specific environment by thoroughly evaluating the elements that can result in signal loss.

A consideration for different terrains such as Rural, Suburban and urban were implemented in the research carried out in [21]–[23]. Other studies carried out considered special measuring field such as the study by [24] which focused on vegetation area and pathloss prediction for indoor environment by [25]. Braga *et al.* [26] focuses on a mixed city-river area and made it clear that only few studies have been carried out on mixed city-river area,

In the study, the development of a modified shadowing empirical model for the study area was carried out by modification of the log distance shadowing model, the derivative of the path loss exponent obtained and the standard deviation about a mean value substituted in the log distance shadowing model established the modified path loss model for FUTO University environment. Performance analysis based on the model's accuracy was carried out by utilizing statistical performance metrics like RMSE and mean absolute percentage error (MAPE). The amount of variation and error in the measured data determines how effective the proposed model is.

2.1. Empirical propagation models

There are theoretical empirical propagation models for predicting path loss over various topographies and specific environmental conditions. However, this study covers the location-specific and the generally employed empirical path loss model to predict the attenuation of the signal power from the mobile radio station to the BS transceiver. Okumura-Hata model is a globally acceptable model and had been adjudged as a good model to benchmark new approaches by the International Telecommunications Union [7]. Its only limitation is that it does not incorporate tropospheric parameters.

2.1.1. Okumura-Hata model

This model is appropriate for propagation in metropolitan areas [27]. The model's frequency range is restricted to 150 to 1,500 MHz, and BS antenna height, $\mathrm{h_{bt}}$, varies depending on the topography from 30 m to 200 m. According to [28], [29], the typical calculation for median path loss in metropolitan areas is as (1).

$$PL_P(urban)dB = 69.55 + 26.16\, log\, f_c - 13.82\, log\, h_{bt} - a(h_{mts}) \\ +[44.9 - 6.55\, log\, h_{bt}]\, log\, d \quad (1)$$

f_c represent the carrier frequency (in MHz) and d is distance (km) between BS and mobile station, h_{bt} and h_{mts} are the height (in meters) of base station antenna and mobile antenna respectively, $a(h_{mts})$ is the correction factor for active mobile antenna height. The mobile antenna correction factor for major cities is written as (2) and (3).

$$\text{For } f_c\ less\ than\ 300\ MHz, a(h_{mts}) = 8.29\ [log(1.54h_{mts})]^2 - 1.1\ dB \quad (2)$$

$$\text{For } f_c\ greater\ or\ equals\ to\ 300\ MHZ, a(h_{mbs}) = 3.201\ [log(11.75h_{mts})]^2 - 4.97\ dB \quad (3)$$

The mobile antenna correction factor $a(h_{mts})$ for small; medium size city is (4).

$$a(h_{mts}) = 1.11[log(f_c) - 0.7]h_{mts} - [1.56\, log(f_c) - 0.8]dB \quad (4)$$

The standard Okumura-Hata formulation for path loss calculation in suburban area [30], [31] is expressed in (5).

$$PL_P(suburan)\ (dB) = L_P(urban)dB - 2[log\frac{f_c}{28}]^2 - 5.4 \quad (5)$$

2.1.2. COST 231-Hata model

The European Co-operative for Scientific and Technical research created and developed the COST-231-Hata model (EURO-COST). The model is limited to a frequency between of 1,500 and 2,000 MHz, 30 to 200 m for base station antenna height, and separations of 1 to 20 km between the transmitter antenna and receiving antenna [32] provides the formula for the model as (6).

$$PL_{P(COST)}\ dB = 46.3 + 33.9\, log\, f_c - 13.82\, log\, h_{bt} - a(h_{mts}) \\ +[44.9 - 6.55\, log\, h_{mah}]\, log\, d + C_{ACF} \quad (6)$$

C_{ACF} defines the correction factor of the area, PL_P is path loss in (dB), f_c is the carrier frequency (in MHz), $h_{bt}\ i$ is the height (in meters) of BS antenna, h_{mah} is height (in meters) of mobile antenna, $a(h_{mts})$ is the correction factor for effective mobile antenna height, d is distance (km) between base station and mobile station. $C_{ACF} = 0$ dB for average sized environs and sub-urban environ, and 3 dB for urban areas. The mobile antenna correction factor for a large city is expressed for frequency less than or equal to 300 Mhz in (7).

$$a(h_{mb}) = 8.29\ [log(1.54h_m b)]^2 - 1.1\ dB \quad (7)$$

while for a small or medium sized city, it is given as (8).

$$a(h_{mb}) = 1.1[log(f_c) - 0.7]h_m - [1.56\, log(f_c) - 0.8] \quad (8)$$

2.1.3. Ericsson 9999 model

Ericsson model [33] was established on modified model of Okumura-Hata thereby giving opportunity for variation in parameters relative to propagation arena. The model is utilized up to frequency value of 1,900 MHz. Path-loss based on this model is estimated by [34] as (9) and (10).

$$L_{P\,(ERIC)}(dB) = a_0 + a_1\,log(d) + a_2\,log\,h_b$$
$$+[a_3\,log(h_{bsh})\,log(d)] - 3.2\ [log(11.75\,h_{rh})^2] + g(f_c) \quad (9)$$

$$g(f_c) = 44.49\,log(f) - 4.78[log(f)^2] \quad (10)$$

f is frequency in MHz, h_{bsh} is height in (m) of transmitter antenna, h_{rh} is receiver antenna height (m). Each of a_0, a_1, a_2, and a_3 has default standards for diverse environment [35]

2.1.4. Lee model

This model was established for use in United State of America at 900 MHz [28]. With additional field calibration measurement (drive tests), Lee model parameters can easily be adapted to the local surroundings. The model can be adapted to the remote environment easily compared to other path loss models. L_0, depends on the environment.

$$L_{P\,(Lee)}(dB) = L_0 + \beta\,log(d) + 10\,n\,log\left(\frac{f}{f_0}\right) - Z_0 \quad (11)$$

L_0 is reference median path loss, f_0 is the benchmark frequency, n is the exponent variations with the frequency, d is the distance in km, β is the slope of the path loss curve, Z_0 is the correction factor. The value of n and y are based on empirical data given as (12).

$$n = \begin{cases} 2 & for\ \ f_c < 450\ MHz\ and\ in\ suburban/Open\ area \\ 3 & for\ f_c > 450\ MHz\ and\ in\ Urban\ area \end{cases}$$

$$y = \begin{cases} 1 & for\ \ h_m < 3\ m \\ 2 & for\ h_m < 10\ m \end{cases} \quad (12)$$

2.1.5. SUI model

This is a recognized model for IEEE 802.16 by Stanford University [33]. The Hata model extension with correction parameters for frequencies beyond 1,900 MHz served as the foundation for this model. This model may be extended up to a 3.5 GHz frequency band using the SUI model with correction parameter [36]. Terrain A is ideal for a hilly landscape with moderate to heavy foliage densities and reflects a densely populated area. Ground B is an example of a suburban setting, with generally flat terrain and moderate to dense tree cover. Landscape C, or a rural setting, refers to flat terrain with moderate tree coverage [36].

$$L_{P\,(SUI)}(dB) = FS + 10\,v\,log\left(\frac{d}{d_0}\right) + X_{Cf} + X_{bsh} + S_{sf} \qquad for\ \ d > d_0 \quad (13)$$

$L_{P\,(SUI)}$ is path loss in dB, A is free space path loss, d is the distance from the transmitter to the receiver, d_0 is the reference distance, X_{fcf} is the frequency correction factor above 2 GHz (in MHz), X_{bsh} is correction factor base station height (m), S_{sf} is correction for shadowing (dB), v is path propagation exponent. The value of parameter $v = 2$ is for free space propagation in an urban area, $3 < v < 5$ is for urban non-line-of-sight (NLOS) environment and $v > 5$ is for indoor propagation.

The range of parameters involved are base station (transmitter) antenna height is (10 to 80 m), mobile station antenna height between 2 to 10 m, Cell Radius of (0.1 to 8 km). The log normally distributed factor (S_{sf}), for shadow fading because of trees and other clutter on mobile radio path and its value is between 8.2 and 10.6 dB [36].

The free space path loss (*FS*) is given as (14).

$$\mathrm{FS} = 20\log\left(\frac{4\pi d_0}{\lambda}\right) \quad (14)$$

where d_0 is the distance between transmitter and receiver, and λ is the wavelength. The path loss exponent *v* is given by (15).

$$\mathrm{v} = \mathrm{a} - \mathrm{bh_b} + \left(\frac{\mathrm{c}}{\mathrm{h_{bsh}}}\right) \quad (15)$$

The parameter h_{bsh} is approximately 10 to 80 meters for the height of the base station antenna. The constants: a, $b(m^{-1})$, and $c(m)$ rely on terrain-specific characteristics.

2.1.6. ECC-33 models

ECC-33 model, extrapolated from the actual measurements by Okumura and modified its assumptions to obtain similar values on models. The path loss model [31], [37] is given as (20).

$$L_{P(ECC-33)}(dB) = A_{FSA} + A_{MPL} - G_{tx} - G_{rx} \quad (20)$$

A_{FSA} is free space attenuation, A_{MPL} is basic median path loss, G_{tx} represents transmitter antenna height gain factor, G_{rx} is the gain factor of the receiving antenna height. Each of those specifications in (20) is defined by [31] as in (21) to (23).

$$A_{FSA} = 92.4 + 20\,log(d) + 20\,log(f) \quad (21)$$

$$A_{MPL} = 20.41 + 9.83\,log(d) + 7.894\,log(f) + 9.56\,[log(f)]^2 \quad (22)$$

$$G_{tx} = log\left(\frac{h_{bst}}{200}\right)\,[13.98 + 5.8(log\,d)^2] \quad (23)$$

For medium sized cities

$$\mathrm{G_{rx}} = [42.57 + 13.7\ \log\ (f)\ ]\ [\ \log(h_{mst}) - 0.585] \quad (24)$$

for large cities

$$\mathrm{G_{rx}} = 0.759\ (h_r) - 1.862 \quad (25)$$

where, *d* is the distance between base station and mobile station in (kilometer), h_{bst} is the height of transmitter antenna in meters, h_{mst} is the height of mobile antenna in meters.

2.1.7. Log-distance shadowing model

An empirical method for constructing a mobile radio propagation model based on analytical equations that replicate a measured data set is the log-distance shadowing model. Signal propagation in terrestrial wireless communication is characterized by a number of characteristics, including path loss, shadowing, and fading. The weakening of signal power as it travels from the base station to the mobile station is known as path loss. The average received signal power in a mobile radio channel drops logarithmically with distance, according to experimental and theoretical propagation models [30]. As a result, [38] provides the path loss model as a function of distance.

$$L_{P\,(d_i)}\,\alpha\,(\frac{d}{d_0})^v \quad (26)$$

$$L_{P\,(d_i)} = L_{P\,(d_o)}\,(\frac{d}{d_0})^v \quad (27)$$

$$L_{P\,(d_i)} = L_{P\,(d_o)} + 10v\log(\frac{d}{d_0}) \quad (28)$$

where, *v* is path loss exponent, *d* is the distance that exists between the BS and cellular mobile stations, and d_0 is the reference distance.

$$v = \frac{L_{P\,(d_i)} - L_{P\,(d_o)}}{10\log(\frac{d}{d_0})} \quad (29)$$

In balancing the effect of random shadowing due to clutter, the modified power path loss model [30] can be written as (30).

$$L_{P\,(d_i)} = L_{P\,(d_o)} + 10v\log\left(\frac{d}{d_0}\right) + \beta_\sigma \quad (30)$$

β_σ defines the zero-mean gaussian distributed random variable in (dB) and standard deviation σ in (dB). Using regression analysis in a mean square approach, path loss exponent *v*, can be determined as (31).

$$v = \frac{\sum_{i=1}^{N}[L_{P\,(d_o)} - L_{P\,(d_i)}]^2}{\sum_{i=1}^{N} 10\log\,(d_i/d_0)} \quad (31)$$

$L_{P\,(d_o)}$ is the path loss measured and $L_{P\,(d_i)}$ defines the path-loss predicted at any distance d_i, N represents the number of data points. The standard deviation is expressed as (32).

$$\sigma = (\frac{1}{N}\sum_{i=1}^{N}[L_{P\,(d_o)} - L_{P\,(d_i)}]^2)^{\frac{1}{2}} \quad (32)$$

The expression $L_{P\,(d_o)} - L_{P\,(d_i)}$ gives an error term relative to v, from (31) and the summation of the MSE, $e(v)$ is defined as (33).

$$e(v) = \sum_{i=1}^{N}[L_{P\,(d_o)} - L_{P\,(d_i)}]^2 \quad (33)$$

The derivative of (33) can be equated to zero while the mean square error is placed at minimal value to solve for v.

$$\frac{\partial e(v)}{\partial e} = 0 \quad (34)$$

3. METHOD

Using laptop-installed TEMS 11.0 research software, the received signal power was measured on a network of base transceiver stations located inside the Federal University of Technology, Owerri campus. The receiving antenna was mounted via the open rooftop of the Toyota Camry car and the height of the antenna from the ground was measured to be 1.5 m. A google earth software was also connected live to guide in the drive test path. The Sony Ericsson W995 TEMS phone, a global positioning system (GPS) unit, an HP Compaq laptop, and a drive test vehicle make up the drive test equipment as shown in Figure 1.

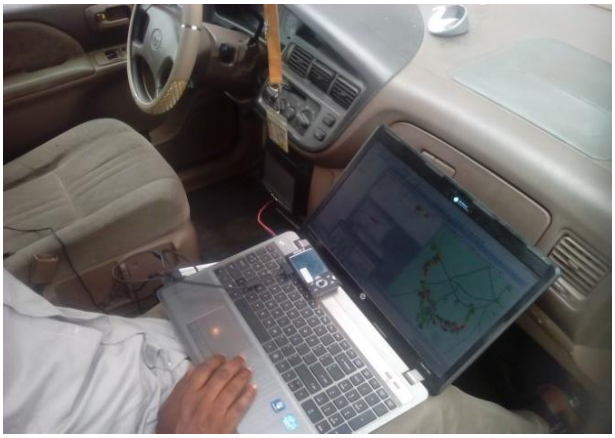

Figure 1. Experimental setup

The driving test path was originally planned for measurements and is motor-capable. The cabin of the driving car is outfitted with every piece of equipment as it should be. The Ericsson handset was used to measure the signal strength that was received during a brief call and upload it to the laptop's TEMS log file. Every 100 m, the following data were recorded: voice signal, coordinates, RSS, call loss, and call establishment. The GPS receiver provides the (longitude and latitude) coordinates. Additionally, the GPS offers the route taken and a Google map of the area. The base station for those experiments has an antennae height of 35 m operates at a frequency of 2.3 GHz while the height of the mobile station was chosen to be 1.5 m.

It was possible to forecast the path loss as measured on the FUTO University Campus with the aid of the empirical models discussed earlier. The models were chosen based on their ability to forecast mean route loss as a function of many characteristics, including operational frequency, mobile antenna heights, and distance. Table 1 shows the results of the regression analysis between the measured data and the anticipated path-loss data. The path loss exponent (v) is calculated by equating the derivatives of (33) to zero as:

$$e(v) = 1139.919n^2 - 5857.738n + 9259.05 = 0$$
$$\frac{\partial e(v)}{\partial e} = 2(1139.919n) - 5857.738 = 0$$
$$v = 2.57$$

Thus, from (32), the standard deviation, σ (dB), about a mean value, can be estimated as:

$$\sigma = \left(\frac{1}{15}(1139.919(2.57)^2 - 5857.738(2.57) + 9259.05\right)^{\frac{1}{2}}$$

$$\sigma = 10.75 \text{ dB}$$

By substituting for $L_P(d_0)_{Ref}$, v and adding σ to compensate for the error into (30), this will lead to the development of a modified shadowing empirical model for the investigation area. Therefore, the modified path loss model for Owerri FUTO University Campus suburban environment is presented as (34).

$$L_{PR}(d_i) = 107.2 + 10(2.57)\log\left(\frac{d_{1\ldots N}}{d_{ref}}\right) + 10.75 \text{ d B} \quad (34)$$

Table 1. Depicts FUTO University Campus regression analysis

Distance (m)	RSS (dBm)	Measured PL $L_p(d_0)$ dB	Predicted PL $L_p(d_i)$ dB
100	-76.21	107.2	107.2
200	-80.44	128.0	107.2+3.01n
300	-93.36	124.4	107.2+4.77n
400	-99.21	134.2	107.2+6.02n
500	-107.3	138.0	107.2+6.99n
600	-100.3	132.3	107.2+7.78n
700	-89.45	120.4	107.2+8.45n
800	-107.3	138.3	107.2+9.03n
900	-95.21	126.2	107.2+9.54n
1,000	-100.2	148.0	107.2+10.00n
1,100	-104.0	131.0	107.2+10.41n
1,200	-98.33	133.8	107.2+10.79n
1,300	-101.2	132.3	107.2+11.14n
1,400	-95.89	126.9	107.2+11.46n
1,500	-106.0	135.1	107.2+11.76n

4. RESULTS AND DISCUSSION

The measured path loss, the modified path loss model five other existing models: Okumura-Hata, Cost 231-Hata, Ericsson 999, Lee, SUI and ECC-33 model were examined at regular intervals of 0.1 km and the results were recorded and presented in Table 2. Figure 2 compares the measured Path loss and some existing empirical models considered in this work.

Table 2. The path loss measured, existing models and modified model for FUTO University suburban environment

Distance (km)	Measured PL (dB)	Okumura-Hata (dB)	Cost231-Hata (dB)	Ericsson 999 (dB)	Lee (dB)	SUI (dB)	ECC-33 (dB)	Modified model (dB)
0.1	107.2	87.96	102.85	74.80	78.89	121.19	332.16	117.95
0.2	128.0	98.43	113.33	105.13	80.05	137.2	338.89	125.69
0.3	124.4	104.6	119.45	122.87	80.73	146.57	343.2	130.21
0.4	134.2	108.9	123.8	135.46	81.21	153.21	346.42	133.42
0.5	138.0	112.3	127.17	145.23	81.58	158.37	349.01	135.91
0.6	132.3	115	129.92	153.20	81.89	162.58	351.19	137.95
0.7	120.4	117.4	132.25	159.95	82.14	166.14	353.08	139.67
0.8	138.3	119.4	134.27	165.79	82.37	169.23	354.75	141.16
0.9	126.2	121.2	136.05	170.95	82.56	171.95	356.24	142.47
1.0	148.0	122.7	137.64	175.56	82.74	174.39	357.6	143.65
1.1	131.0	124.2	139.08	179.73	82.9	176.59	358.84	144.71
1.2	133.8	125.5	140.39	183.53	83.04	178.6	359.99	145.68
1.3	132.3	126.7	141.6	187.04	83.18	180.45	361.05	146.58
1.4	126.9	127.8	142.72	190.28	83.3	182.16	362.05	147.41
1.5	135.1	128.9	143.77	193.30	83.42	183.75	362.98	148.18

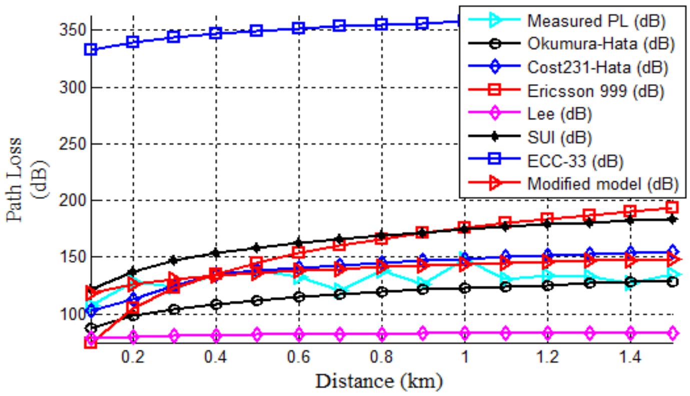

Figure 2. Path loss (dB) versus distance (km) for Okumura-Hata, COST-231-Hata, Ericsson 999, Lee, SUI, ECC-33, and modified model for FUTO University campus MTN network

Figure 2 was generated from the data presented in Table 2 The pathloss values at a distance of 0.10 km from the base station is 87.96, 102.85, 74.80, 78.89, 121.19, 332.16, and 117.95 dB. Additionally, the route losses measurements at a 1.5 km distance were 128.9, 143.77, 193.297, 83.42, 183.75, 362.98, and 148.18 dB. As a result of the towering trees, structures, and topography, the ECC-33 model overestimates the propagation path loss numbers, whereas Lee model did really poorly. The results demonstrate that the current path loss models under consideration are not appropriate for predicting propagation in the environment. The results from the modified model are most in line with the measurements. As a result, the modified model is appropriate for network planning and can be used to calculate the path loss coverage in Nigeria's FUTO University campus.

4.1. Validation of the propagation model

This section provides a description of the performance analysis based on the model's accuracy by utilizing statistical analysis methods such as: RMSE and MAPE. The amount of variation and error in the measured data determines how effective the proposed model is. In terms of the error rate between measured and anticipated values, these performance metrics will compare and validate the original and changed models. The MAPE and RMSE were calculated between the output of the existing models and the measured path loss data. As shown in (35), and (36) contain the following expressions by [1], [12].

$$\text{RMSE (dB)} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(pp_m - pp_r)^2} \quad (35)$$

$$\text{MAPE (dB)} = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{pp_m - pp_r}{pp_m}\right| x100 \quad (36)$$

where pp_m is the mean of measured data, pp_r is the mean value of predicted path loss, and n is the number of data points.

Apart from ECC-33 model which overestimates the propagation path loss numbers, according to the performance evaluation, the Ericsson model, SUI model and Lee model have a comparably large RMSE and MAPE values. Modified model and COST-231 are the models with closest value to the measured value, with RMSE and MAPE values of 8.31; 0.453 dB and 9.73; 0.498 dB respectively. Table 3 contains information on the performance evaluation.

Table 3. Shows the results of error computation from existing and modified models

	Okumura-Hata (dB)	COST-231 (dB)	Ericsson (dB)	Lee (dB)	SUI (dB)	ECC-33 (dB)	Modified (dB)
RMSE	14.33	9.73	25.79	48.4	33.76	222.1	8.31
MAPE	0.733	0.498	1.317	2.474	1.725	11.35	0.453

5. CONCLUSION

The path loss has been evaluated in the study using six existing models: The Okumura-Hata, COST-231, Ericsson 999, Lee, SUI, and ECC-33 models. Although there are various propagation models to forecast route loss, the findings of this paper support the idea that they are not accurate in predicting the coverage of the network in locations other than those for which it was intended. This study used a 2.3 GHz MTN base station to conduct measurements at various sites on the FUTO University campus in Owerri. An estimated value of the path loss was determined using the measured received signal strength (MRSS) of data gathered at various distances from mobile station to base station. By modification of the log distance shadowing model, the derivative of the path loss exponent obtained as $v = 2.57$ and the standard deviation σ=10.75 dB about a mean value were substituted in the log distance shadowing model to establish the modified path loss model for FUTO University environment. The addition of Standard deviation σ in the modified path loss model compensated for the error in the measured pathloss. Based on the amount of error on the exiting and improved model, utilizing RMSE and MAPE, the performance analysis and validation of the models were estimated. The improved model's performance estimation yielded the best result, demonstrating its applicability for path attenuation prediction in network coverage in the study area. It is recommended that this research is extended to other study area and machine learning prediction methods is adopted in future study.

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