PREDICTING FIFTH GENERATION (5G) NETWORK COVERAGE USING LEAST-SQUARES OPTIMIZATION METHOD IN URBAN AREAS OF OYO AND OGBOMOSO, NIGERIA

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Abstract
Propagation path loss modelling plays an important role in the design of cellular systems. A good number of researchers have worked to investigate and predict suitable propagation models for 5G network in Nigeria, but, none of such works have been targeted to cover Oyo and Ogbomoso towns in Oyo state. This research aimed at providing suitable transmission models, to drive the implementation and deployment of 5G technology in these two major towns. To achieve this, four existing models, namely; Ericsson, Egli, Cost-231 and Okumura-Hata were used to investigate the performances of the selected three networks, namely GLO, MTN and AIRTEL in six different locations of the two towns. Drive test was carried out using Test Mobile System (TEMS). The models' accuracy and suitability were statistically evaluated with Agilent 89600B VSA software. The average RMSE was 53.87 dB for the Ericson model and 29.33 dB for the Okumura model. The higher Root Mean Square Error (RMSE) values, exceeding the desirable 6 dB threshold across all tested models, indicates that no single model can effectively predict signal strength across all scenarios. To achieve accurate predictions, Ericsson model and Okumura-Hata model having lowest RMSE in most sites leading to the conclusion that they offer better signal prediction were optimized, for improved performance.

Keywords
Path loss,
5G Network,
Received Signal Strength,
Least Squares Optimization,
TEMS

1. INTRODUCTION

The fifth generation (5G) mobile network, the latest global wireless standard succeeding 1G, 2G, 3G, and 4G, is designed to deliver unprecedented levels of connectivity. This advancement in mobile communications marks a significant departure from current networks, aiming to provide consistently high-speed connections and a seamless user experience (Yushan et al., 2021). Characterized by rapid speeds, outstanding reliability, and minimal delays, 5G is expected to transform industries and empower real-time communication in security, remote medical care, precise agriculture, digital supply chains, and many other areas. This impact is greater than the previous network generations (Nigerian Communications Act, 2003; Mollel and Kisangiri, 2014).

In order to accelerate the development of 5G networks in Nigeria, and to expand 5G network coverage to both rural and urban areas, it is pertinent to focus on the technical aspects which will make the development of the 5G technology have the greatest level of impact and significantly reduce any extraneous influences that may affect, deployment plan, network roll-out, coverage and capacity. One of the goals is to make Nigeria one of the leading nations in the deployment and utilization of 5G, in a manner that is beneficial to all the stakeholders and contribute maximally to the building of Nigeria's digital economy.

2. MATERIALS AND METHOD

2.1 Materials Selection

2.1.1 Experimental Sites

The two different towns which have been chosen in Oyo State are Ogbomoso and Oyo; South West part of Nigeria. The base Transceiver Stations (BTSs) in this research are referenced with respect to which mast they were mounted, and these BTSs in the two towns were chosen because of their hardware specifications and service availability. Ogbomoso is located on Latitude 8.1227º N, Longitude 4.2436º E and Oyo is located on latitude 7.8430 ºN, Longitude 3.9368 º E The two towns in Oyo state are next to each other, but Ogbomoso shares boundary with Ilorin, the Capital of Kwara state which is in the North Central part of Nigeria and is located on Latitude 8.5373 º N, Longitude 4.5444 º E of Greenwich meridian (Oseni and Ojo, 2022).

2.1.2 The measurement routes

The areas that were investigated in Oyo town are the MTN base station at Federal School of Surveying (Route 1), the GLO base station along Emmanuel Alayande College of Education (Route 2), and the AIRTEL base station at Alaafin palace (Route 3), all in Oyo town. At Ogbomoso, the MTN base station at Sabo (Route 4), the GLO base station at Odo Oru area (Route 5), and the AIRTEL base station at LAUTECH Main Gate (Route 6), were investigated. The base stations used in this study are referenced with respect to which mast they were mounted, and these base stations were chosen because of their hardware specifications and service availability.

2.1.3 Research set up

All the measurements were conducted using the already available network. The base stations are located at different heights and the mobile station's antenna was positioned on top of a vehicle with a GPS receiver. An Omni-directional antenna was used. The spectrum analyzer with a frequency range of 100 Hz to 7 GHz was used to measure the strength and frequency of each radio signal over a set frequency range. The spectrum analyzer, functioning as a sophisticated radio receiver, analyzes each received radio signal to accurately determine its magnitude and frequency (Reshma and Chaitanya, 2012). The spectrum analyzer's data was saved to a laptop's hard drive through a PCMIA-GPIB card for later processing. The PC controlled the analyzer and also recorded location details.

2.2 Methods

2.2.1 Data Acquisition

Test Mobile System (TEMS) 16.00 software was used for investigation and collection of data while TEMS 10.09 was used for analysis and reporting of data. The complete process of data collection involves careful setting up of GPS and TEMS enabled hand-set for the purpose of data acquisition.

2.2.2 Selected Model

The selected models are Ericsson, Egli, COST-231 Hata, Okumura-Hata Models. Among numerous models, these are the most significant ones, they are the basic tools for signal prediction, providing the foundation of mobile communication service. The operating frequency and other related parameters such as distance between transmitter and receiver and height of the antenna were considered before selection of the following models.

a) Ericson Model

Ericsson's software for path loss prediction is called the Ericsson model. This model is a modification of the Okumura-Hata model, allowing parameter changes to suit various propagation environments (Imoize and Kaddi, 2022). The path loss according to this model is calculated with Eq.1:

$$P_L = a_0 + a_1 . log_{10}(d) + a_2 log_{10}(h_b) + a_3 . log_{10} h_b . log_{10}(d) - 3.2(log_{10}(11.75 h_r)^2) + g(f)$$

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(1)

where

$$g(t) = 44.49 log_{10}(f) - 4.78(log_{10}(f))^2$$

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The default values of these parameters (a_0, a_1, a_2, and a_3) vary with different terrains (Enughwure et al., 2024). The values of parameters a_0 and a_1 are based on the least square (LS) method.

b) Egli Model

The Egli model is a terrain-based model designed to predict radio wave propagation, particularly for mobile systems operating between 3 MHz and 3 GHz. This model accounts for factors like frequency, antenna height, and polarization. It employs correction factors to ensure its predictions align with measurements taken over flat ground, considering all the aforementioned elements (Imranullar et al, 2012). Consequently, it can estimate the total signal loss between two points, making it well-suited for cellular communication scenarios involving a fixed base station and a mobile unit, as well as transmissions across uneven terrain (Medeisis and Kajackas, 2000). The Egli expression for path loss in dB is given as Eq . 2:

$$P_L = \begin{cases} 20\log_{10} f_C + P_0 + 76.3 .... h_r \le 10 \\ 20\log_{10} f_C + P_0 + 83.9 .... h_r \ge 10 \end{cases} \quad (2)$$

Where:

$$P_0 = 40\log_{10} d - 20\log_{10} h_t - 10\log_{10} h_r$$

f_C =frequency of transmission in MHz, h_t is height of the base station antenna in meter. h_r is the height of the mobile station antenna in meters and d is the distance from the base station antenna in km.

c) COST 231 Hata Model

The COST 231 Hata model, an extension of the Hata model, is used for frequencies in the 1500-2000 MHz range. It is employed for path loss predictions at these frequencies for rural and urban areas (Chebil et al., 2013). Its simplicity and available correction factors have led to its widespread adoption for path loss prediction at these frequencies (Miah et al., 2012) .The basic path loss equation for COST 231 Hata Model can be expressed as Eq.3:

$$P_L = 46.3 + 33.9.\, log_{10}(f) - 13.82 log_{10} h_b - ah_m + 44.9 - 6.55 log_{10}(h_b)) log_{10}(d) + C_m$$

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(3)

Where:

h_b is the transmitter antenna height in meter and the correction parameter (c_m), c_m has different values for different environments.

d) Okumura- Hata Model

The most widely adopted propagation data for mobile networks are still Okumura's measurements from 1968, which also contributed to the Hata model (Folaponmile and Sani, 2011). These Japanese tests, covering diverse environmental scenarios and transmitter parameters, showed that signal strength decreases with distance at a considerably higher rate than the predicted free space loss (Diawuo et al., 2013). The path loss in *Okumura-Hata's notation reads Hata Model was based on Okumura's test measurements and predicted various equations for path loss with different types of environments as given in Eq. 4*

$$P_L(dB) = 69.5 + 26.16\log f_C - 13.82\log h_b - a(h_m) + (44.9 - 6.55\log h_b)\log R \quad (4)$$

where carrier frequency f_c is in MHz, base station height h_b is in m and range R is in km.

2.2.3 Development of 5G Path Loss Model using Least-Square Optimization Method

Radio propagation models are built on practical observation rather than theory. This means they are created by analyzing extensive datasets gathered from the specific environment they aim to represent (Singh, 2012). For a model to be dependable, this data must be broad enough to encompass the diverse range of situations that could arise in that context. Consequently, like all models derived from real-world data, radio propagation models do not give precise link behavior; instead, they forecast the most probable performance under particular circumstances (Alam and Khan, 2013).

a) Calculation of Optimum Path loss Prediction

The parameter for each equation of the model was modified to accommodate the least square error function Q_1 Q_1 and Q_2 Q_2, this is used to minimize the sum of the square differences between the measured values and predicted values which is given in equation (5) which is the least squared error function that was reduced for the condition of an optimum path loss prediction model for the suburban area to be met as presented in Eq. 5.

$$Error(Q_1, Q_2) = \frac{1}{N}\sum_{K=1}^{N}(L_{Mk} - L_{Pk})$$

$$Error(Q_1, Q_2) = \frac{1}{N}\sum_{K=1}^{N}(L_{Mk} - L_{Pk})$$

(5)

where, N= number of data points

In order to minimize $Error(Q_1, Q_2)$ $Error(Q_1, Q_2)$, the error function equation is differentiated partially with respect to Q_1 Q_1 and Q_2 Q_2, and to meet the Least Square criteria that enhances Q_1 Q_1 and Q_2 Q_2, the whole set of partial differential equations of the Error function must be equivalent to zero thus, N equations are obtained which are given as Eqs 6-9;

$$Eq1: Q_1 + Q_2 L_{MK,1} + L_{PK,1} = L_{Optimized,1}$$
$$Eq2: Q_1 + Q_2 L_{MK,2} + L_{PK,2} = L_{Optimized,2}$$
$$\vdots$$
$$EqN: Q_1 + Q_2 L_{MK,N} + L_{PK,N} = L_{Optimized,N}$$

(6)

These equations can be represented in the form of matrices:

$$\begin{bmatrix} 1 & L_{Mk,\ 1} \\ 1 & L_{Mk,\ 2} \\ : & : \\ : & : \\ 1 & L_{Mk,\ N} \end{bmatrix} X \begin{bmatrix} Q_1 \\ Q_2 \end{bmatrix} = \begin{bmatrix} L_{Optimized,\ 1} - L_{Pk,\ 1} \\ L_{Optimized,\ 2} - L_{Pk,\ 2} \\ : \\ : \\ L_{Optimized,\ N} - L_{Pk,\ N} \end{bmatrix}$$

$$\begin{bmatrix} 1 & L_{Mk,\ 1} \\ 1 & L_{Mk,\ 2} \\ : & : \\ : & : \\ 1 & L_{Mk,\ N} \end{bmatrix} X \begin{bmatrix} Q_1 \\ Q_2 \end{bmatrix} = \begin{bmatrix} L_{Optimized,\ 1} - L_{Pk,\ 1} \\ L_{Optimized,\ 2} - L_{Pk,\ 2} \\ : \\ : \\ L_{Optimized,\ N} - L_{Pk,\ N} \end{bmatrix}$$

(7)

This system of equations can now be set out as given in the following equation:

$$V \times K = J$$

$$V \times K = J$$

(8)

Where V = matrix of constraints coefficients

K = Enhanced variables = $[Q_1 Q_2]^T$ $[Q_1 Q_2]^T$

J = Right hand constraints

Thus, the finest tuned coefficients Q_1 Q_1 and Q_2 Q_2 that meet the least square criteria are obtained from the solution of the given matrix equation:

$$K = [V^T V]^{-1} V^T J$$

$$K = [V^T V]^{-1} V^T J$$

(9)

b) Root Mean Squared Error

Root Mean Squared Error (RMSE) is the square root of the average of the squares of all the errors. RMSE is good for measuring accuracy when it comes to comparing forecast errors of different models or model configurations for a particular variable and not between variables, as it is scale-dependent] corroborates that RMSE is sensitive to change of scale and data transformations (Juan et al., 2021; Kwubeghary et al., 2024). RMSE does not provide the direction of overall error as expressed in equation (10). Therefore, the RMSE is expressed as eq.10.

$$\text{RMSE} = \left[\frac{1}{n}\sum_{i=1}^{n}[(p_{ml} - p_{rl})^2]\right]^{\frac{1}{2}}$$

$$\left[\frac{1}{n}\sum_{i=1}^{n}[(p_{ml} - p_{rl})^2]\right]^{\frac{1}{2}}$$

(10)

c) Standard Deviation

The Standard Deviation (SD) is a measure of shadowing as a result of obstructions such as tall building, foliage and trees in the channel. This made the signal to attenuate due to blockage of Line-of-Sight (LOS) between the transmitter and the receiver (Imianvan et al., 2024). The standard deviation is given by eq.11.

$$\delta = \left[\frac{1}{n-1}\sum_{i=1}^{n}\left[(p_{ml}-p_{rl})^2\right]\right]^{\frac{1}{2}} \quad \left[\frac{1}{n-1}\sum_{i=1}^{n}\left[(p_{ml}-p_{rl})^2\right]\right]^{\frac{1}{2}} \tag{11}$$

where,

δ is the Standard Deviation (SD), p_{ml} p_{ml} is the Measured Path loss, p_{rl} p_{rl} is the Predicted Path loss. Equations (10) and (11) are the mathematical equations of the statistical performance metrics.

3. RESULTS AND DISCUSSION

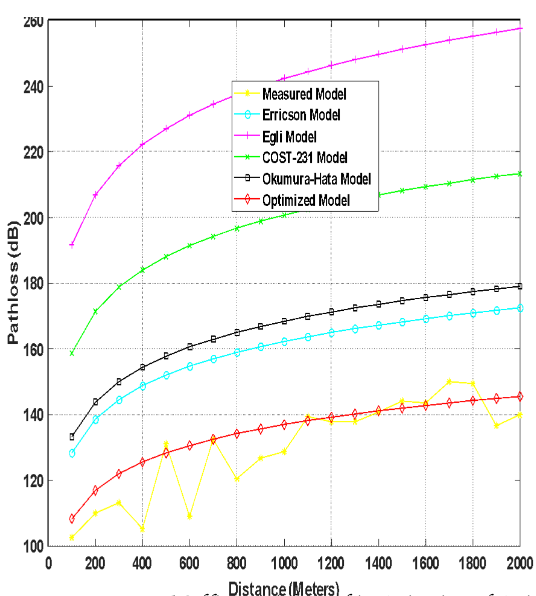
3.1 The Results of the Optimized Model

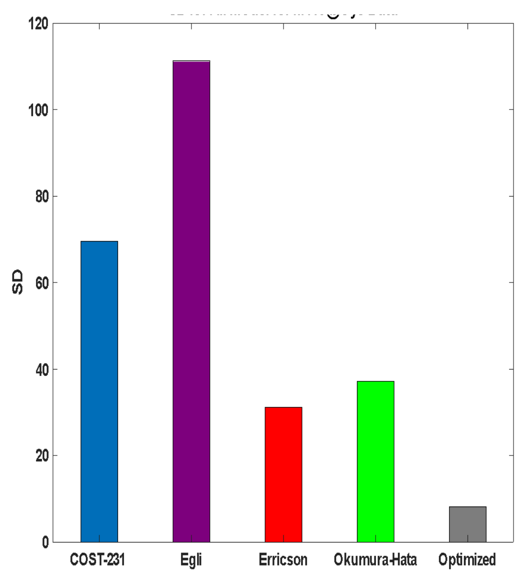
The results of the optimized models in comparison with the existing models are hereby presented based on measured data obtained from different routes. A total number of six routes, three in each suburban area were investigated. In Oyo town, the MTN base station located at Federal School of Surveying is taken as route 1, the GLO base station located along Emmanuel Alayande College of Education Oyo being route 2, and the AIRTEL base station located close to the National Museum at Alaafin of Oyo's palace as route 3. In Ogbomoso, the MTN base station at Sabo area is taken as route 4, the GLO base station at Odo Oru area as route 5, and the AIRTEL base station at Ladoke Akintola University main gate being route 6.

3.1.1 Path Loss Values Obtained for Federal School of Surveying MTN Base Station (Route 1)

Figure 1a shows the path loss values against distance for Measured, Ericsson, Egli, COST-231, Okumura-Hata and the optimized Ericsson model. At a distance of 500 m from the base station, the path loss values obtained were 131.1 dB, 152.05 dB, 227.01 dB, 188.11 dB, 157.80 dB and 128.31 dB. At a distance of 1000 m, for Measured, Ericsson, Egli, COST-231, Okumura-Hata and the optimized Ericsson model, the path loss values obtained equally were 128.70 dB, 162.27 dB, 242.26 dB 200. dB, 168.40 dB and 136.93 dB, respectively. Also, at a distance of 1500 m from the 75 base station as well, for Measured, Ericsson, Egli, COST-231, Okumura-Hata and the optimized Ericsson model. the path loss values obtained were 144.10 dB, 168.24 dB, 251.18 dB, 208,14 dB, 174.60 dB and 141.97dB respectively. Obviously, it can be observed that Egli model has the highest path loss value among other models. This shows that the Egli model is not good for predicting path loss in Oyo route 1. The Ericsson model performed fairly while the Optimized-Ericsson model version gave a better result.

Figure 1b presents the Standard Deviation (SD) results for the Federal School of Surveying Oyo MTN Base Station. The results obtained showed that the SD were 31.17, 111.36, 69.54, 37.21 and 8.24 in the same sequence respectively. Also, the Root Mean Square Errors (RMSE) obtained, as presented in Figure 1c, were 30.39, 108.54, 67.78, 36.27 and 8.03 accordingly. It can be seen that the Ericsson model gave better results and would be good for analyzing signal attenuation for networks in Oyo.





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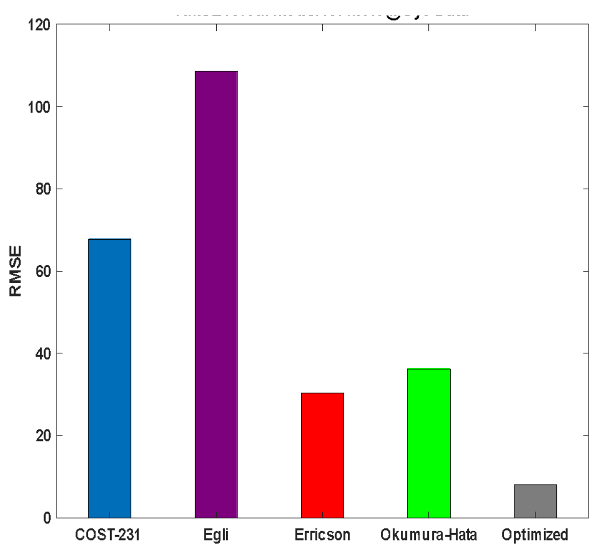

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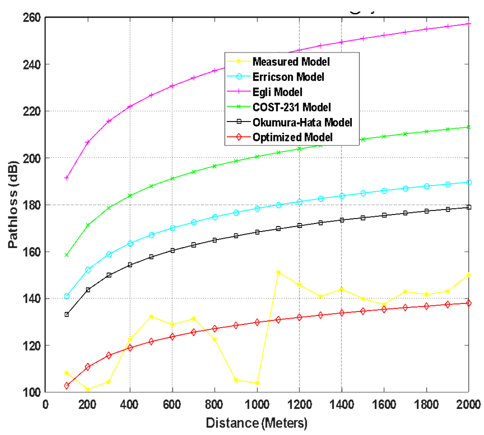
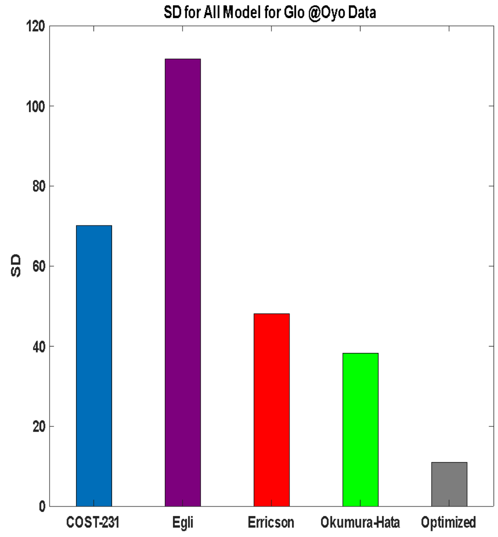
Figure 1: (a) Path Loss against Distance for Federal School of Surveying MTN Base Station (b) Standard Deviation graph (c) Root Mean Square Error (RMSE) graph.

3.1.2 Path Loss Values Obtained for GLO Base Station along Emmanuel Alayande College of Education, Oyo (Route 2)

The path loss values against distance for different models are shown in Figure 2. At a distance of 500 m from the base station, the path loss values obtained were 132.20 dB, 167.17 dB, 226.83 dB, 187.96 dB, 157.67 dB and 121.62 dB for Measured Path Loss, Ericsson, Egli, COST-231, Okumura-Hata and Optimized models respectively. Also, at a distance of 1000 m, the path loss values were 103.80 dB, 178.40 dB, 242.06 dB, 200.59 dB, 168.26 dB and 129.79 dB for the same sequence respectively. A distance of 1500 m from the base station gave path loss values of 139.90 dB, 185.00dB, 250.98 dB, 207.97 dB, 174.46 dB and 134.57 dB also for the same sequence respectively. Obviously, the Egli model performed poorly while the Okumura-Hata model performed fairly and the optimized Okumura-Hata model gave a better result in Oyo route 2 for Glo network.

The results obtained as shown in Figure 2b using SD were 48.10, 111.66, 70.07, 38.24 and 10.91 for the same sequence of models respectively. Also, the RMSE values obtained as plotted in Figure 2c were 46.88, 108.83, 68.30, 37.27 and 10.64 also for the same sequence of models respectively. The results showed that the optimized Okumura-Hata model is the best for path loss prediction for the Glo network in Oyo town.





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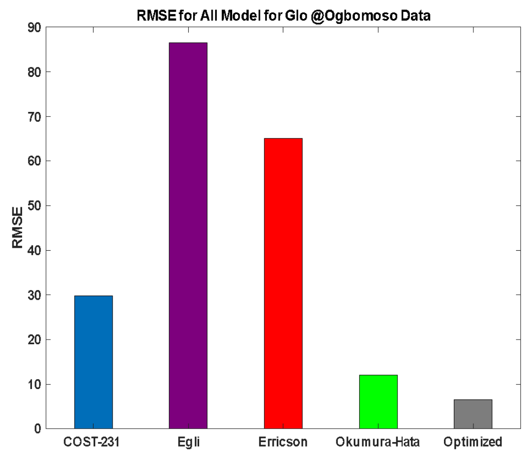

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Figure 2: (a) Path Loss against Distance for Emmanuel Alayande Area, Oyo GLO Base Station (b) Standard Deviation graph (c) Root Mean Square Error (RMSE) graph.

3.1.3 Path Loss Values Obtained for AIRTEL Base Station at Alaafin of Oyo's Palace (Route 3)

The Airtel base Station is located beside Oyo palace, right in front of the National Museum. The path loss values obtained against distance for the same sequence of models for Location 3 in Oyo are shown in Figure 3. At a distance of 500 m from the base station, the path loss values obtained were 121.40 dB, 168.02 dB, 224.77 dB, 186.26 dB, 156.24 dB and 138.60 dB for the same sequence of models respectively. Also, at a distance of 1000 m, the path loss values obtained were 127.80 dB, 179.32 dB, 239.87 dB, 198.77dB, 166.74 dB, and 147.91 dB for the same sequence of models respectively. At a distance of 1500 m, the path loss values obtained were 140.80 dB, 186.97 dB, 250.11 dB, 207.26 dB, 173.86 dB and 154.22 dB for the same sequence of models respectively.

As shown in Figure 3b, the results obtained using standard deviation (SD) were 53.43, 112.28, 71.90, 42.07 and 24.92 for the same sequence of models respectively. Also, Figure 5c presents the RMSE values as 52.07, 109.43, 70.08, 41.01 and 24.29 for the same sequence of models respectively. It can be observed from Figure 3c that the Ericson model performed fairly well out of the existing models considered, however, the optimized Okumura-Hata model showed a better performance with the lowest RMSE value of 24.29. Hence, it is the best model for signal prediction for Palace Area, Airtel network in Oyo town.

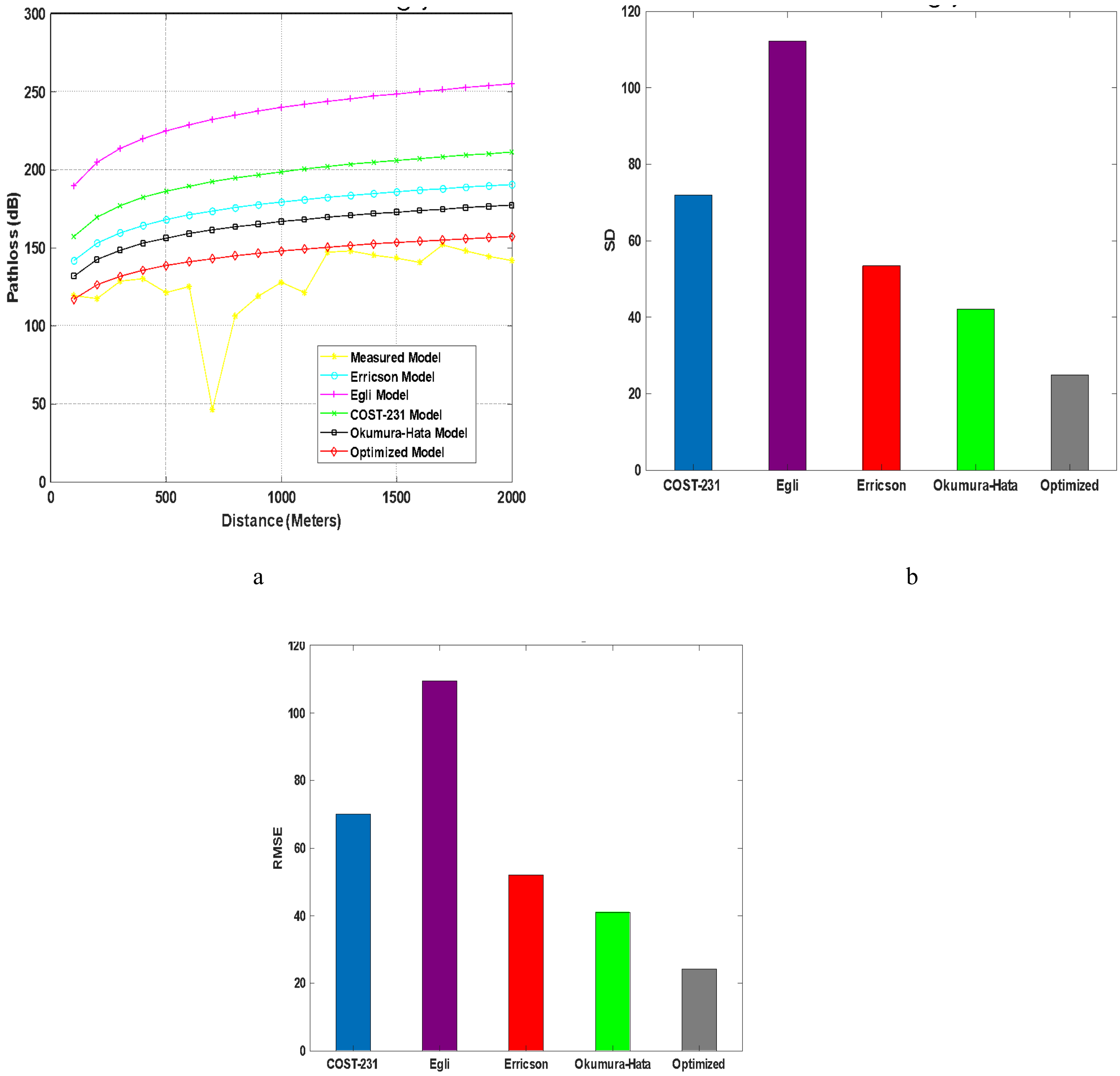

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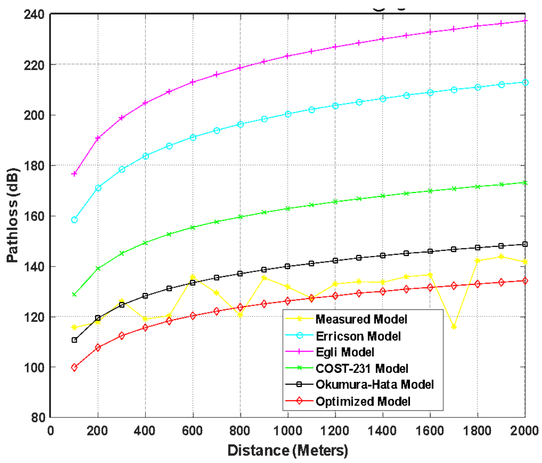
Figure 3: (a) Path loss against Distance for Palace Area, Oyo Airtel Base Station (b) Standard Deviation graph (c) Root Mean Square Error (RMSE) graph.

3.1.4 Path Loss Values Obtained for MTN Base Station at Sabo Area Ogbomoso (Route 4)

Figure 4(a) shows the path loss against distance for Measured Path Loss, Ericsson, COST-231, Egli, Okumura-Hata and Optimized Okumura-Hata models for MTN base station at Sabo area in Ogbomoso. At a distance of 500 m from the base station, the path loss values obtained were 120.20 dB, 187.75 dB, 209.21 dB, 152.59 dB, 131.06 dB and 118.25 dB for measured path loss, Ericsson, Egli, COST-231, Okumura-Hata and the Optimized Okumura-Hata models, respectively. At a distance of 1000 m, the path loss values obtained were 131.80 dB, 200.36 dB, 223,26 dB, 162.84 dB, 139.86 dB and 126.19 dB respectively. Also at a distance of 1500 m, the path loss values obtained were 135.80 dB, 207.74 dB, 231.49 dB, 168.84 dB, 145.01 dB and 130.84 dB in the same sequence respectively. Okumura-Hata performed reasonably, Egli model performed poorly while the optimized Okumura-Hata model gave a better result.

Figure 4b shows the results obtained using standard deviation (SD) for the same sequence of models were 69.81, 92.87, 32.32, 11.02 and 7.28 respectively. Also, in Figure 4c, the RMSE values obtained for the same sequence were 68.04 dB, 90.52 dB, 31.50 dB, 10.74 dB and 7.10 respectively. It can be seen from this result that the optimized Okumura-Hata model gave the better result, hence it is a good model for signal prediction for networks in MTN Sabo Area, Ogbomoso.



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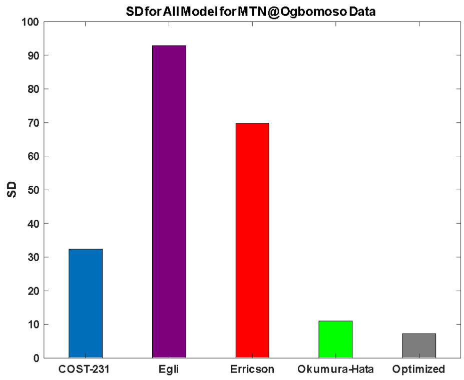

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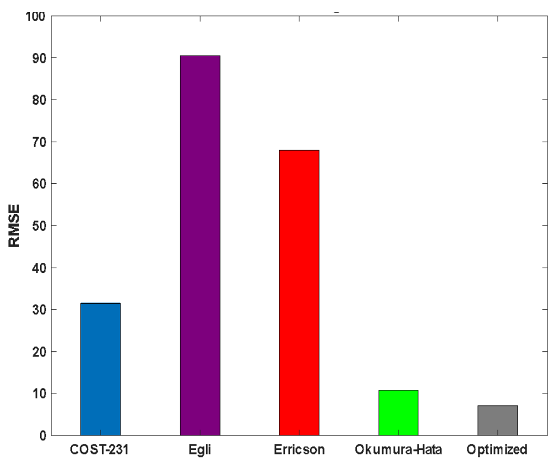

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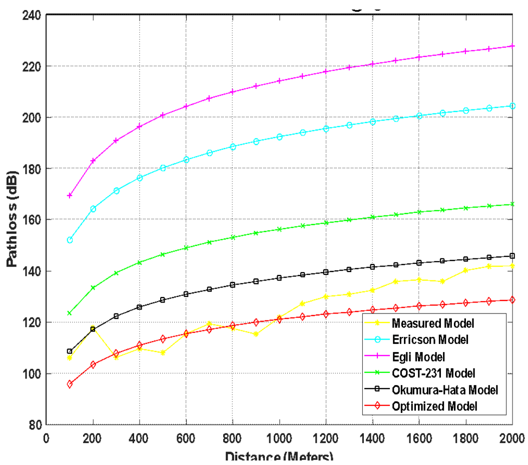
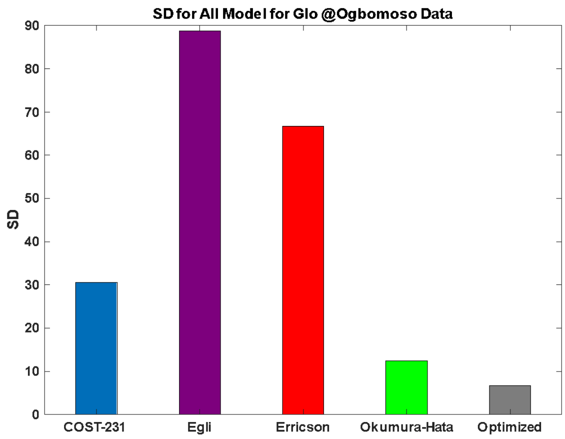
Figure 4: (a) Path Loss against Distance for Sabo Area, Ogbomoso MTN Base Station (b) Standard Deviation graph (c) Root Mean Square Error (RMSE) graph.

3.1.5 Path Loss Values Obtained for GLO Base Station at Odo Oru Ogbomoso (Route 5)

The path loss values against distance for Measured Path Loss, Ericsson, Egli, COST-231, Okumura-Hata and the Optimized Okumura-Hata models for GLO base station at Odo Oru Area in Ogbomoso are shown in Figure 5a. At a distance of 500 m from the base station, the path loss values obtained were 108.00 dB, 180.26 dB, 200.68 dB, 146.37 dB, 128.57 dB and 113.43 dB for the same sequence of models respectively. Also, at a distance of 1000 m, the path loss values obtained were 121.80 dB, 192.36 dB, 214.16 dB, 156.20 dB, 137.20 dB and 121.05 dB also for the same sequence of models respectively. At a distance of 1500 m, the path loss values obtained were 135.80 dB, 199.45 dB, 222.05 dB, 161.96 dB, 142.26 dB and 125.51 dB for the same sequence of models, respectively.

In like manner, Figure 5b shows the results obtained using standard deviation (SD) for the same sequence of models. The SD results obtained were 66.73, 88.70, 30.51, 12.36 and 6.71 respectively. In Figure 5c the RMSE values obtained are presented. The following values 65.04, 86.45, 29.74, 12.05 and 6.54 correspond to the same sequence of models, respectively. Therefore, it can be seen from the results obtained that the Okumura-Hata model showed a fairly improved result while the optimized Okumura-Hata model outperformed others. Hence, the optimized Okumura-Hata model is recommended for signal prediction for Odo oru in Ogbomoso.





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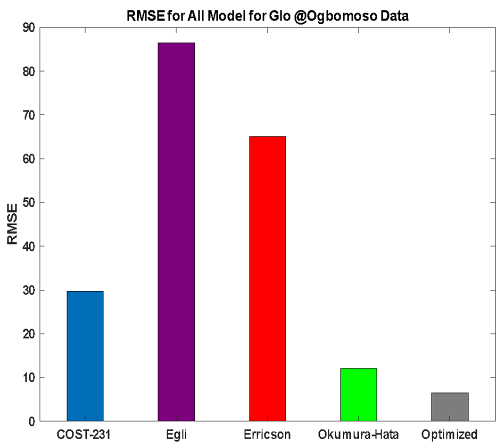

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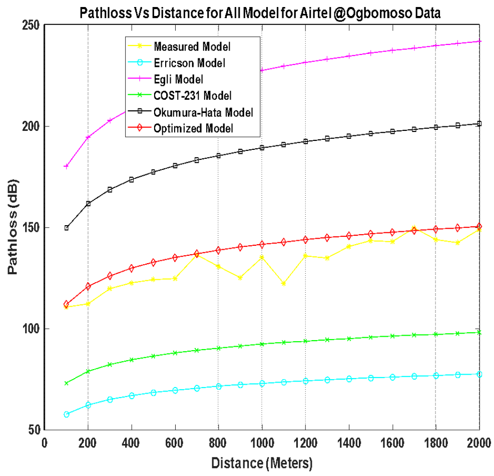
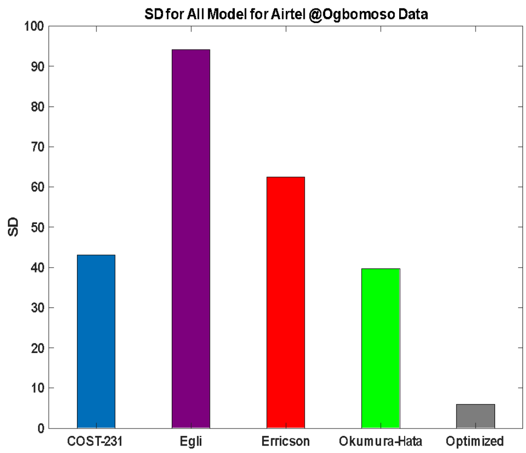
Figure 5: (a) Path Loss against Distance for Odo Oru, Ogbomoso GLO Base Station (b) Standard Deviation graph (c) Root Mean Square Error (RMSE) graph.

3.1.6 Path Loss Values Obtained for AIRTEL Base Station at LAUTECH Main Gate (Route 6)

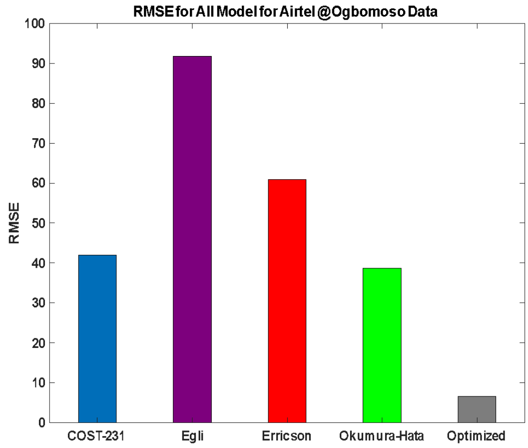
Figure 6a shows the path loss against distance for Measured Path Loss, Ericsson, Egli, COST-231, Okumura-Hata and Optimized Okumura-Hata models for Airtel 4G LTE Network in Ogbomoso. At a distance of 500 m from the 4G LTE base station, the path loss values obtained were 124.20 dB, 68.30 dB, 213.18 dB, 86.38 dB, 177.25 dB, and 132.55 dB for the same sequence of models respectively. At a distance of 1000m, the path loss of 135.00 dB, 72.89 dB, 227.51 dB, 92.19 dB, 189.16 dB and 141.45 dB were also obtained for the same sequence of models respectively. A distance of 1500m away from the base station gave the path loss values of 143.30 dB, 75.57 dB, 235.89 dB, 95.58 dB, 196.12 dB and 146.66 dB were also obtained for the same sequence of models, respectively

The results obtained using standard deviation (SD) in figure 6b for the same sequence of models were 62.53, 94.18, 43.10, 39.63 and 5.92 respectively. The values 60.95, 91.79, 42.01, 38.63 and 6.54 were obtained as the RMSE values in figure 6c for the same sequence of models, respectively. The optimized Okumura-Hata model gave better results and is good for analyzing signal attenuation for the Airtel network at LAUTECH Main gate, Ogbomoso.





b



c

Figure 6: (a) Path Loss against Distance for LAUTECH Main gate, Ogbomoso Airtel Base Station (b) Standard Deviation graph (c) Root Mean Square Error (RMSE) graph.

The quality and accuracy of the model were quantitatively evaluated using the Standard Deviation (SD) and the Root Mean Square Error (RMSE), derived from the measured data. Notably, if a model generates substantial prediction errors at a particular distance between the Base Station and the Mobile Station, it is considered unsuitable for that environment (Imianvan and Robinson, 2024).

4. CONCLUSION

In this research, four existing models were used to investigate the performances of the selected routes. The data collected were analyzed and the different radio frequency (RF) parameters of the networks considered were evaluated, measured data have been compared with the performances of some selected existing models. The models' accuracy and suitability were statistically evaluated by determining their prediction error relative to actual network measurements. The prediction error was expressed as the Standard Deviation of Error (SD) and Root Mean Square Error (RMSE). The average RMSE was 53.87 dB for the Ericson model and 29.33 dB for the Okumura model. The higher Root Mean Square Error (RMSE) values, exceeding the desirable 6 dB threshold across all tested models, indicates that no single model can effectively predict signal strength across all scenarios. To achieve accurate predictions, Ericsson model that most closely matched the measured data across all sites and Okumura-Hata model having lowest RMSE in most sites leading to the conclusion that it offers better signal prediction were optimized, not just for the studied sites and comparable cellular environments in the two towns, but also likely for most sparsely developed regions for improved performance.

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