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# A real time series forcasting for a signal loss in a multipath antenna system using convolutionary networks

## Adegbenjo A and Adekunle Y

**Abstract**
This study presents propagation measurements of the fifth generation long-term evolution (5G LTE) network using Huawei Technologies drive test equipment. Measurements were taken from five transmitting evolved node base stations (eNodeBs) located along five major routes in Osogbo, Nigeria, at an operating frequency of 1800MHz. An empirical model was developed for planning and optimizing Global System for Mobile Communication (GSM) networks which address the poor quality of services provided by GSM service providers in Osogbo town. The average path losses predicted are 80.10dB, 74.27dB, 80.89, 80.65dB and 82.30dB, while the measured are 75.70, 70.20, 78.30, 79.12 and 76.10, respectively. However, according to R. Rakesh 2012, the acceptable range between measure and predicted result lies between 1 ≤ PL≤ 20dB. Therefore, the average values obtained vary between 2 to 7dB, within the acceptable range. Therefore, it can be concluded that the modified model developed from the Log-Normal shadowing model can be useful to GSM network service providers for planning and optimization their services in Osogbo, Nigeria. The study recommends that Nigerian Communication Commission (NCC), which is the regulatory body, mandate the GSM service providers in the country to experimentally test their desired scientific model to ascertain its practicability at the planning stage before the release of the operating license.

**Keywords:** Pathloss, mobile networks, prediction, machine learning

## 1. Introduction
Several wireless network operators have used COST 231-Hata and Okumura-Hata models in Nigeria to construct radio networks, which are based on the European Cooperation in Science and Technology. These models, however, were created for environments other than Nigeria's, and a model that works well in one context may not function as well in another with distinct geographical features. Existing models are limited in their effectiveness and accuracy when employed in a setting that varies geographically from the one intended. The validity of the model used in the design has a significant impact on network performance, as should be noted. An essential goal in a wireless network planning phase is to anticipate signal strength loss in a geographic region and ensure that handoff sites match prediction in the optimization phase and coverage meets design standards such as on-street received signal intensity (RSS). In practice, measuring signal strength and other network key performance indicators (KPIs) is seen as a critical necessity for delivering effective network design and dependable coverage for a given region (Bavarva *et al*., 2015) [1]. Wireless communication systems employ path loss statistics as factors to achieve maximum performance and efficient network design (Rappaport, 1996; Molisch, 2012) [5, 6]. Sasaki *et al*. Using unique attenuation coefficient prediction algorithms in a residential neighborhood with a curved road, mobile terminals may be predicted (2012) [7]. For a more precise assessment, the additional loss caused by road angles along the curving route was computed. The model was validated by a measuring experiment in a separate residential neighborhood.
From the late 2000s forward, there has been a rapid expansion of GSM coverage across Africa. From 2004 until the present, it has been Nigeria's most active industry. Major firms in the market have a reputation for providing poor customer service. Due to a variety of issues, the quality of network service providers' offerings remains poor. As a result, the Nigerian Communication Commission (NCC) must move quickly to rein in the operations of these network service providers and address the problems that prevent them from providing quality service to their teaming clients (Sasaki *et al*., 2012) [7]. Investigation and identification of probable elements, as well as suitable remedies based on scientific results,

become important to solve client concerns. According to a survey conducted by Sewalker *et al*. (2019) [8], GSM customers in the tested regions reported problems with different network service providers. Network congestion, frequent call failures, an echo, poor inter and intra connection, cross talk interference during conservation, and signal fading are just a few of the challenges faced by subscribers. Weather conditions, propagation mechanisms such as reflection and diffraction as well as other variables such as vegetation and free space loss may all affect GSM signal strength in the examined area (Shi *et al*., 2015) [9]. It is difficult to predict wireless radio channels because, unlike a fixed line of sight channels, mobile radio channels are unpredictable. All elements must be considered when examining wireless radio channels, including whether the transmission route is in line of sight or is blocked by obstacles such as buildings or mountains. When examining wave propagation in an urban context, we encounter many reflections from high-rise buildings and other objects. Multipath fading is caused by electromagnetic waves traveling on several pathways with varying lengths and interacting at a spot. This causes a fluctuation in the received wave's strength, which in turn affects its distance from the transmitter.

## 2. Materials and Method

### 2.1 Investigated environments

Osogbo, Nigeria, is one of Africa's most populous cities, with an estimated population of more than 4 million people. It is situated in Nigeria's South-West geopolitical zone, which has a tropical climate with an average annual rainfall of 1693mm. The huge population of Osogbo is partially to blame for the city's clogged roads during peak hours.

### 2.2 Experimental setup and measurements

On three separate routes in Osogbo, five eNodeBs were installed, and Huawei drive test equipment was used to evaluate each eNodeB's Reference Signal Received Power (RSRP). These measurements were made at 1800MHz. UE, a Genex probe, a GPS module, an LTE modem, and a personal computer system are included. On the PC, LTE software was loaded for post-drive analysis of user equipment readings. High-speed packet access mobile hotspot, Huawei E57765-601 mobile Wi-Fi, which supports 1800MHz, 2600MHz FDD, and 2300MHz TDD is the user equipment (TDD). Table 1 shows the coordinates of the eNodeBs as a result of the GPS module being linked to the PC.

Maps input characteristics to output values (observations of path loss) in the path loss model. Modeling a predictor that can make accurate predictions is essential, but constructing a more generic model that fluctuates in response to particular conditional inputs. Using nonlinear regression models and variance analysis in combination, Figure 1 illustrates a three-step method for forecasting route loss in a suburban setting. A PCA and variance analysis balances the ANN-MLP-based nonlinear model to create a more generic model.

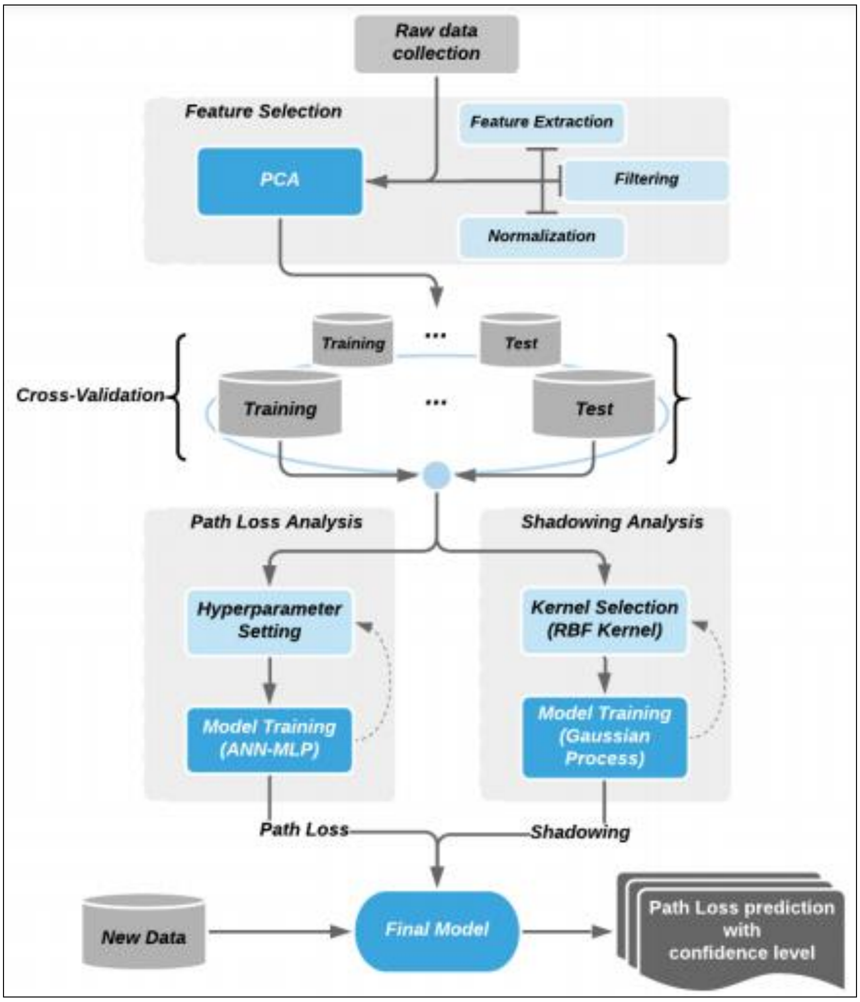


**Fig 1:** Machine-learning-based route loss analysis method.

Based on current deterministic regression analysis, a basic long-distance model requires predefined variables PL0 and N and experimentally observed log-normal shadowing $\boldsymbol{X_\sigma}$.

$$PL = PL_0 + 10n\ log_{10}(d) + X_\sigma,\ for\ d \geq 1km, \quad (1)$$

PL0 is the loss of one kilometer of track. Whereas a model based on learning may predict target values based on training data distribution, regression models incorporating nonlinear features can be created with greater precision. Due to the nonlinear nature of this model, steep slopes and complicated data distributions may be correctly predicted. By analyzing the co-distribution of input characteristics, PCA determines the important variables. Analyzing two variables, the suggested model consists of a Gaussian process-based shadowing model and an ANN-MLP-based route loss model.

$$PL = PL\_ANN(d) + GP_\sigma,\ for\ d \geq 1\ km \quad (2)$$

As shown in Figure 1 and Table 1, we assess the prediction cover, which measures how well the predicted values of a model correspond with the actual test data in the standard deviation. In addition, the preview coverage is the measured data ratio inside a range of α to β divided by the entire quantity of measured data where α and β are given in the following formula:

$$\alpha = \begin{cases} PL_0 + 10n\, log_{10}(d) - r\sigma_1 \\ PL\_ANN(d) - r\sigma_2 f \end{cases} \quad (3)$$

$$\beta = \begin{cases} PL_0 + 10n\, log_{10}(d) + r\sigma_1 \\ PL\_ANN(d) + r\sigma_2 f \end{cases} \quad (4)$$

**Table 1:** Proposed Algorithm

**Algorithm 1** Algorithm used to train a GAN.

1: Inputs:
Batch size *m*.
The number of steps for the discriminator *K*.
Learning rate λ and an optimizer Opt(·)
Noise vector $z \sim p_g(z)$.
Target data set $x \sim p_{data}(x)$.
2: **Initialise:**
Models G and D for generating and discriminating data, where $\Theta_G$ and $\Theta_D$.
3: **while** $\Theta_G$ and $\Theta_D$ have not converged **do**
4: **for** k = 1 to K **do**
5: Noise vector with m-elements $\{z^{(1)}, \cdots, z^{(m)}\}$ from the noise prior pg(z)
6: Sample m data points $\{x^{(1)}, \cdots, x^{(m)}\}$ from the target data distribution $p_{data}(x)$
7: $g_D \leftarrow \Delta_{\Theta_D}\left[\frac{1}{m}\sum_{i=1}^{m} log\, D\left(x^{(i)}\right) + \frac{1}{m}\sum_{i=1}^{m} log\left(1 - D\left(G\left(z^{(i)}\right)\right)\right)\right]$
8: $\Theta_D \leftarrow \Theta_D + \lambda \cdot Opt(\Theta_D, g_D)$.
9: **end for**
10: Sample m-element noise vector $\{z^{(1)}, \cdots, z^{(m)}\}$ from the noise prior $p_g(z)$
11: $g_D \leftarrow \frac{1}{m}\sum_{i=1}^{m} log\left(1 - D\left(G\left(z^{(1)}\right)\right)\right)$
12: $\Theta_G \leftarrow \Theta_G - \lambda \cdot Opt(\Theta_G, g_G)$.
13: **end while**

As shown in Algorithm 1, a basic GAN may be trained using a standard training procedure. Both the generators and the discriminator are taught throughout each iteration. Finally, G may give data that is close to the intended distribution if the model converges. Table 3 shows the GAN's overall structure (g). A noise vector, z, is input into generator G, generating G(z) output following the desired distribution. D attempts to determine whether or not G(z) is a genuine sample or an object.

### Experimental Result

Signal strength will be assessed and gathered across a variety of distances using a driving test. Evaluation of a radio mobile communication network's service and coverage quality. Driving and testing a car while connected to a wireless network is mandatory. A region with low-rise buildings and greenery around it will be used to gather data from Nigerian driving exams. A GPS receiver antenna, a mobile phone, and a laptop with map information software will be used for the driving test. A 900/1800 MHz frequency and 120 measurements per minute will be utilized for the measurements. It was necessary to repeat the measurement and derivation process for each of the other network service providers included in this study to arrive at the empirical model developed for Airtel. MTN, Globacom, and Etisalat's results for the Oke unit are shown in Table 4.

**Table 2:** Reference path loss and standard deviation for oke oniti

| Parameter | Airtel | MTN | Globacom | Etisalat |
|---|---|---|---|---|
| N | 1.9 | 2.0 | 1.9 | 2.4 |
| $\sigma$ in (db) | 3.9 | 3.4 | 2.7 | 5.5 |
| Path loss(do) in (dB) | 70 | 63 | 71 | 66 |

In the Log-Normal Shadowing Model and the modified Log-Normal Shadowing model, the route loss values were replaced.

PL (Airtel) (di) = 70+ 10(1.9) Log (di/do) + 3.9 (dB) (5)
PL (MTN) (di) = 63 + 10(2.0) Log (di/do) + 3.4 (dB) (6)
PL (Globacom) = 71+ 10(1.9) Log (di/do) + 2.7 (dB) (7)
PL (Etisalat) = 66 + 10(2.4) Log (di/do) + 5.5 (dB) (8)

Table 3 shows the results of the equations 5-8 discussed before. The data shows the measured route losses for GSM providers in the research region at various distances. For each service, the average route loss is presented and compared.

**Table 3:** Measured path losses from the proposed modified for oke oniti

| Model Distance in (m) | Path loss in (dB) Airtel Network | Path loss in(dB) MTN Network | Path loss in (dB) Globacom Network | Path loss in (dB) Etisalat Network |
|---|---|---|---|---|
| 50 | 89.85 | 84.15 | 91.45 | 89.25 |
| 100 | 94.67 | 89.27 | 96.27 | 95.57 |
| 150 | 97.48 | 92.26 | 99.08 | 99.27 |
| 200 | 99.48 | 94.37 | 101.08 | 101.89 |
| 250 | 100.45 | 96.13 | 102.63 | 103.93 |
| 300 | 102.30 | 97.38 | 103.90 | 105.59 |
| 350 | 103.37 | 98.72 | 104.97 | 107.00 |
| 400 | 104.30 | 99.50 | 105.90 | 108.21 |
| 450 | 105.21 | 100.37 | 106.73 | 109.29 |
| 500 | 105.95 | 101.15 | 107.45 | 110.35 |

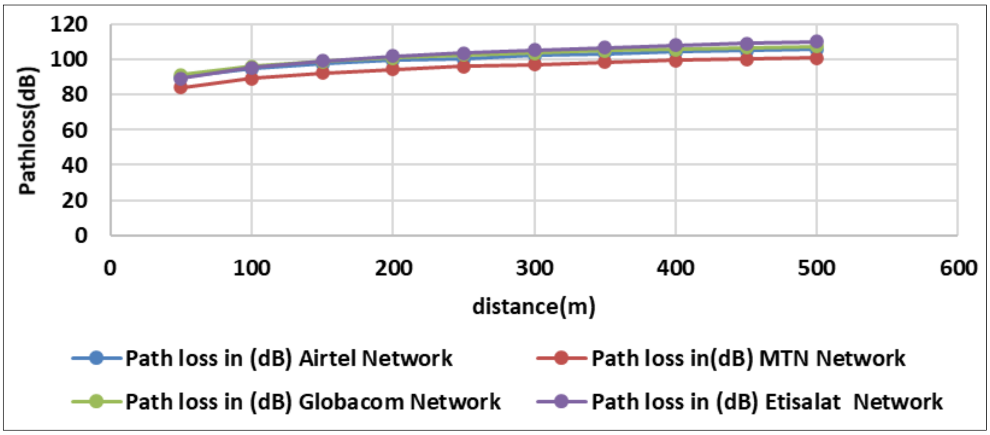


**Fig 2:** Measured path losses from the proposed modified for oke oniti

**Table 4:** Measured and Predicted path losses for oke oniti

| | Airtel | MTN | Globacom | Etisalat |
|---|---|---|---|---|
| Average measured path loss in (db) | 76.80 | 71.30 | 79.40 | 77.20 |
| Average predicted path loss in (db) | 81.20 | 75.37 | 81.99 | 83.50 |

Graphic representations of measured route loss versus distance and average propagation path loss are shown in Figure 3.

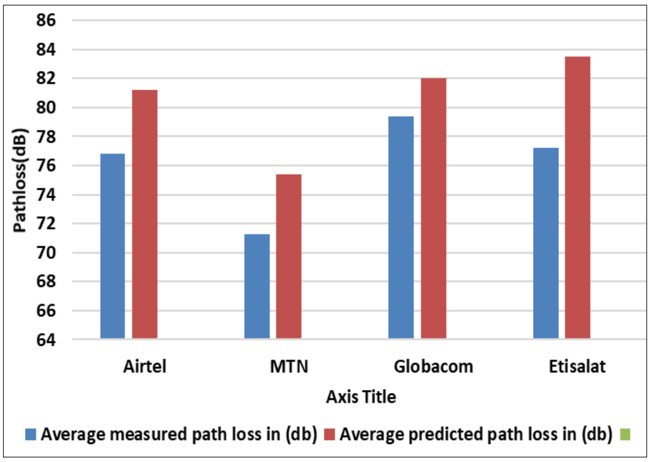


**Fig 3:** Measured and Predicted path losses for oke oniti

It was necessary to repeat the measurement and derivation process for each of the other network service providers included in this study to arrive at the empirical model developed for Airtel. MTN, Globacom, and Etisalat's results for Ita olokan are shown in Table 5 below

**Table 5:** the standard deviation of Ita olokan's reference route loss

| Parameter | Airtel | MTN | Globacom | Etisalat |
|---|---|---|---|---|
| N | 1.4 | 1.5 | 1.4 | 1.9 |
| $\sigma$ in (db) | 3.4 | 2.9 | 2.2 | 5.0 |
| Path loss(do) in (dB) | 60 | 54 | 62 | 57 |

For the Log-Normal Shadowing model, the path loss values were replaced, and the amended Log-Normal Shadowing model for the respective becomes:

PL (Airtel) (di) = 60 + 10(1.4) Log (di/do) + 3.4 (dB) (9)
PL (MTN) (di) = 54 + 10(1.5) Log (di/do) + 2.9 (dB) (10)
PL (Globacom) = 62 + 10(1.4) Log (di/do) + 2.2 (dB) (11)
PL (Etisalat) = 57 + 10(1.9) Log (di/do) + 5.0 (dB) (12)

The data in Table 6 was obtained by solving equations 9-12 above. The data shows the measured route losses for the GSM providers in the research region at various distances. The average route losses for the various network services are also shown and contrasted.

**Table 6:** Measured path losses from the proposed modified for Ita olokan

| Model Distance in (m) | Path loss in (dB) Airtel Network | Path loss in(dB) MTN Network | Path loss in (dB) Globacom Network | Path loss in (dB) Etisalat Network |
|---|---|---|---|---|
| 50 | 93.45 | 93.25 | 100.55 | 98.35 |
| 100 | 104.57 | 98.37 | 105.37 | 10467 |
| 150 | 107.38 | 101.36 | 108.18 | 108.37 |
| 200 | 109.38 | 103.49 | 110.18 | 110.99 |
| 250 | 110.93 | 104.11 | 111.73 | 113.98 |
| 300 | 112.20 | 106.48 | 113.00 | 114.69 |
| 350 | 113.27 | 107.72 | 114.23 | 116.13 |
| 400 | 114.20 | 108.60 | 115.00 | 117.31 |
| 450 | 114.97 | 109.47 | 115.92 | 118.39 |
| 500 | 115.75 | 110.25 | 116.55 | 119.35 |

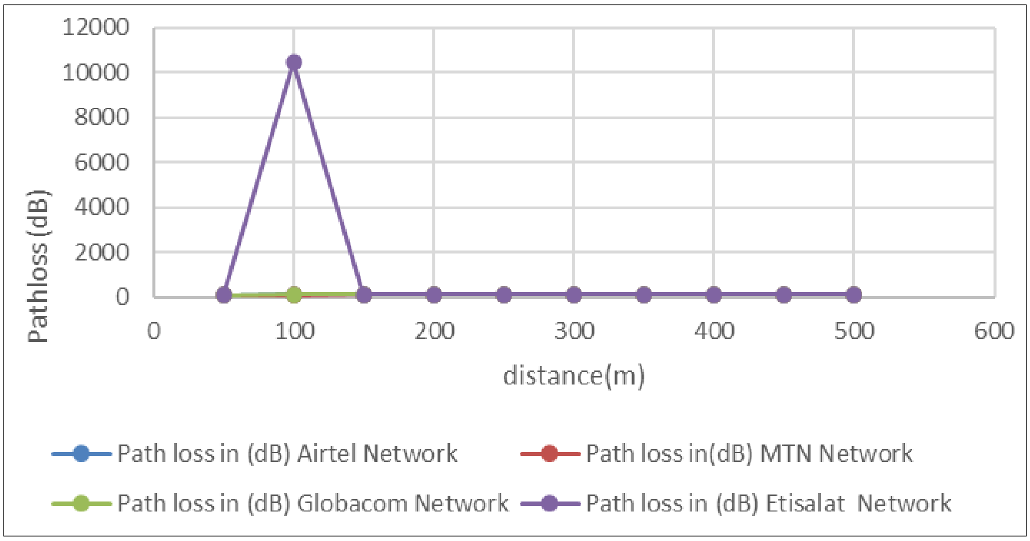


**Fig 4:** Measured path losses from the proposed modified for Ita olokan

**Table 7:** Measured and Predicted path losses for Ita olokan

| | Airtel | MTN | Globacom | Etisalat |
|---|---|---|---|---|
| Average measured path loss in (db) | 105.85 | 100.35 | 108.45 | 106.25 |
| Average predicted path loss in (db) | 110.25 | 104.41 | 110.95 | 102.45 |

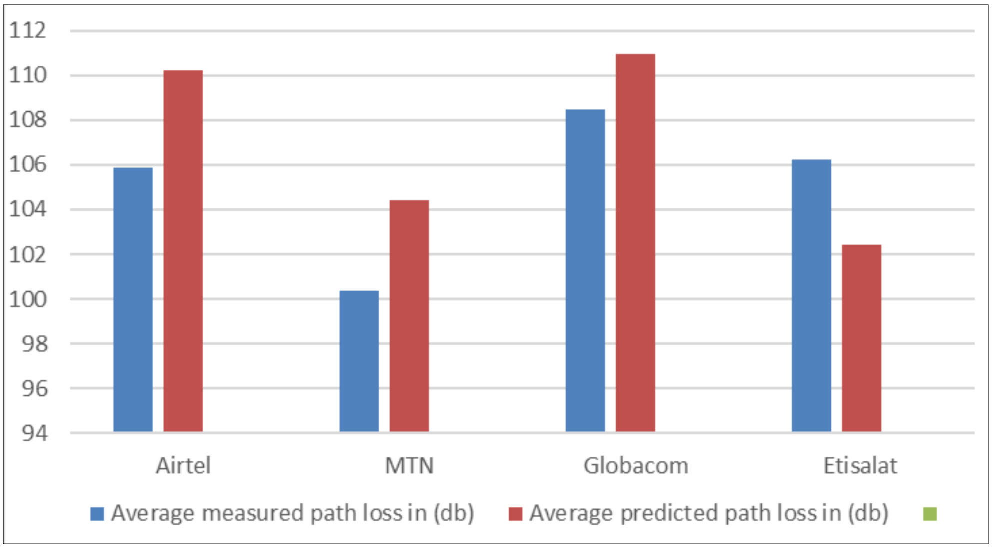


**Fig 5:** Measured and Predicted path losses for Ita olokan

Graphical representations of measured path loss versus distance and average path loss are shown in Figure 4 and Figure 5, correspondingly. To get at the empirical model created for Airtel, it was essential to repeat the measurement and derivation procedure for each of the other network service providers included in this research. Table 8 below shows MTN, Globacom, and Etisalat's Odiolowo results.

**Table 8:** Reference path loss and standard deviation for Odiolowo

| Parameter | Airtel | MTN | Globacom | Etisalat |
|---|---|---|---|---|
| N | 2.0 | 2.1 | 2.0 | 2.5 |
| $\sigma$ in (db) | 4.0 | 3.5 | 2.8 | 5.6 |
| Path loss(do) in (dB) | 56 | 50 | 58 | 53 |

For the Log-Normal Shadowing model, the path loss values were replaced, and the amended Log-Normal Shadowing model for the respective becomes:

PL (Airtel) (di) = 56 + 10(2.0) Log (di/do) + 4.0 (dB) (13)
PL (MTN) (di) = 50 + 10(2.1) Log (di/do) + 3.5 (dB) (14)
PL (Globacom) = 58 + 10(2.0) Log (di/do) + 2.8 (dB) (15)
PL (Etisalat) = 53 + 10(2.5) Log (di/do) + 5.6 (dB) (16)

As a result, the information in Table 9 was derived from equations 13 to 16 above.

The data shows the measured route losses for the GSM providers in the research region at various distances. The average route losses for the various network services are also shown and contrasted.

**Table 9:** Measured path losses from the proposed modified for Odiolowo

| Model Distance in (m) | Path loss in (dB) Airtel Network | Path loss in(dB) MTN Network | Path loss in (dB) Globacom Network | Path loss in (dB) Etisalat Network |
|---|---|---|---|---|
| 50 | 74.70 | 68.20 | 75.50 | 73.30 |
| 100 | 79.52 | 73.32 | 80.32 | 79.62 |
| 150 | 82.73 | 76.31 | 83.13 | 83.32 |
| 200 | 84.33 | 78.44 | 85.13 | 85.94 |
| 250 | 85.88 | 80.15 | 86.68 | 87.98 |
| 300 | 87.15 | 81.43 | 87.95 | 89.64 |
| 350 | 88.22 | 82.77 | 88.34 | 90.05 |
| 400 | 89.15 | 83.55 | 89.95 | 92.26 |
| 450 | 89.97 | 84.42 | 90.78 | 93.24 |
| 500 | 90.70 | 85.20 | 91.50 | 94.20 |

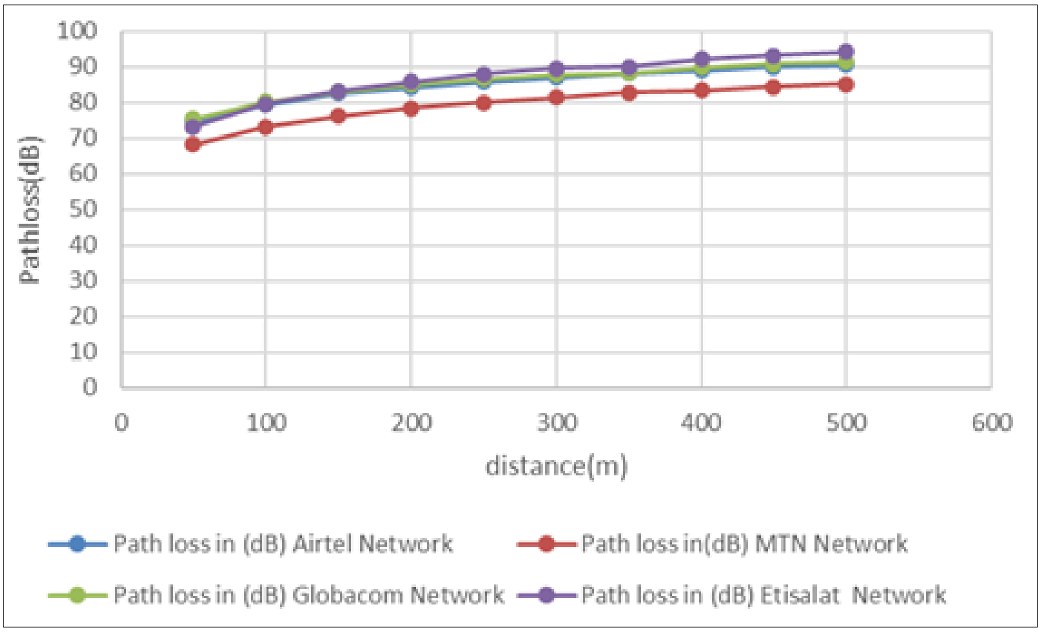


**Fig 6:** Measured path losses from the proposed modified for Odiolowo

**Table 10:** Measured and Predicted path losses for Odiolowo

| | Airtel | MTN | Globacom | Etisalat |
|---|---|---|---|---|
| Average measured path loss in (db) | 95.90 | 90.30 | 98.40 | 96.20 |
| Average predicted path loss in (db) | 100.20 | 94.37 | 100.99 | 102.40 |

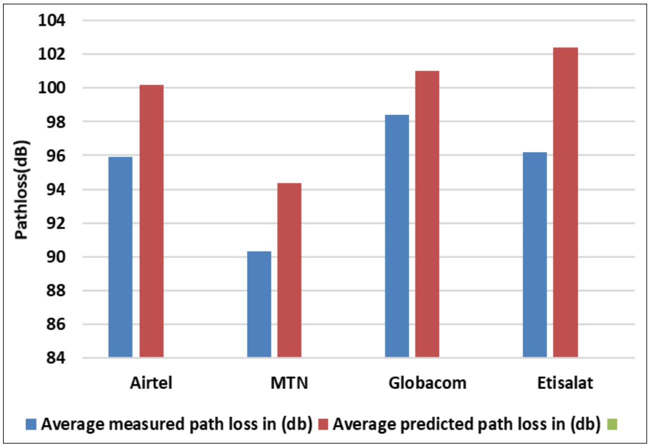


**Fig 7:** Measured and Predicted path losses for Odiolowo

Graphical representations of measured path loss versus distance and average path loss are shown in Figures 6 and 7 above. It was necessary to repeat the measurement and derivation process for each of the other network service providers included in this study to arrive at the empirical model developed for Airtel. Ota efun results for MTN, Globacom, and Etisalat are all in the same ballpark, as seen in Table 11 below.

**Table 11:** Reference path loss and standard deviation

| Parameter | Airtel | MTN | Globacom | Etisalat |
|---|---|---|---|---|
| N | 1.00 | 1.10 | 1.00 | 1.50 |
| $\sigma$ in (db) | 3.00 | 2.50 | 1.80 | 4.60 |
| Path loss(do) in (dB) | 36 | 30 | 38 | 33 |

The route loss parameters for the Log-Normal Shadowing model were modified, and the revised Log-Normal Shadowing model for the respective is:

PL (Airtel) (di) = 36 + 10(1.0) Log (di/do) + 3.0 (dB) (17)

PL (MTN) (di) = 30 + 10(1.1) Log (di/do) + 2.5 (dB) (18)

PL (Globacom) = 38 + 10(1.0) Log (di/do) + 1.8 (dB) (19)

PL (Etisalat) =33 + 10(1.5) Log (di/do) + 4.6 (dB) (20)

As a result, the information in Table 12 was derived using equations 17-20. Measured route losses for GSM service providers in the study area are shown for different distances in the data. For each service, the average route loss is presented and compared.

**Table 12:** Measured path losses from the proposed modified for Ota efun

| Model Distance in (m) | Path loss in (dB) Airtel Network | Path loss in(dB) MTN Network | Path loss in (dB) Globacom Network | Path loss in (dB) Etisalat Network |
|---|---|---|---|---|
| 50 | 81.71 | 74.21 | 81.51 | 79.31 |
| 100 | 85.53 | 79.33 | 86.33 | 85.63 |
| 150 | 88.34 | 82.32 | 89.14 | 89.33 |
| 200 | 90.34 | 84.45 | 91.14 | 91.95 |
| 250 | 91.89 | 86.12 | 92.69 | 93.99 |
| 300 | 93.16 | 87.44 | 93.96 | 95.65 |
| 350 | 94.23 | 88.78 | 94.12 | 96.02 |
| 400 | 95.16 | 89.56 | 95.96 | 98.27 |
| 450 | 95.98 | 90.43 | 96.78 | 99.35 |
| 500 | 96.71 | 90.21 | 97.51 | 100.31 |

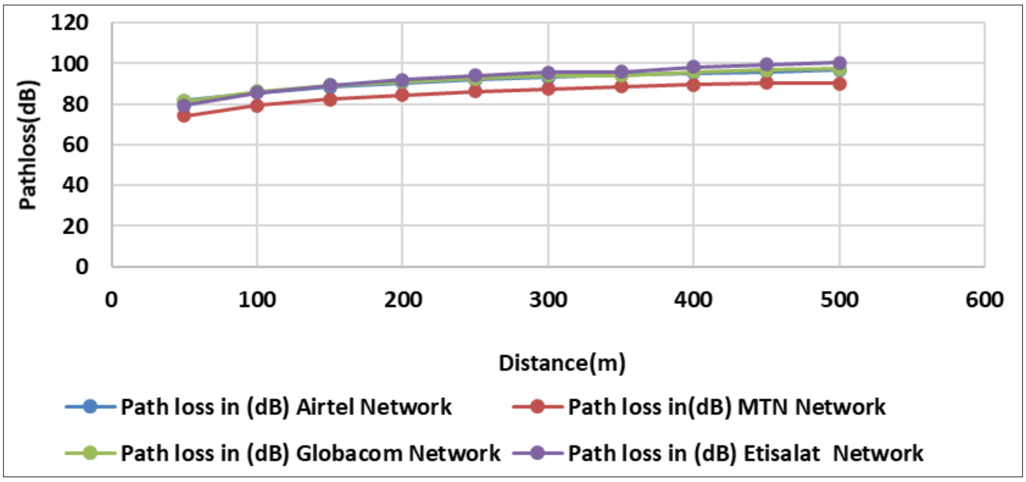


**Fig 8:** Measured path losses from the proposed modified for Ota EFUN

**Table 13:** Measured and Predicted path losses for Ota efun

| | Airtel | MTN | Globacom | Etisalat |
|---|---|---|---|---|
| Average measured path loss in (Db) | 78.81 | 73.31 | 81.41 | 79.21 |
| Average predicted path loss in (Db) | 83.21 | 74.27 | 83.00 | 85.41 |

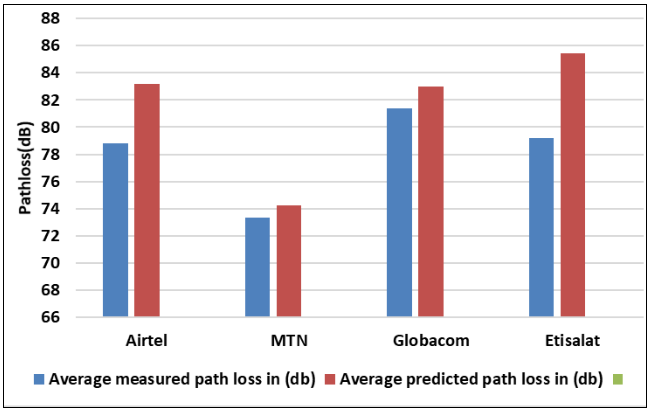


**Fig 9:** Measured and Predicted path losses for Ota efun

Figure 8 and Figure 9 exhibit graphical representations of measured path loss vs distance and average path loss. It was necessary to repeat the measurement and derivation process for each of the other network service providers included in this study to arrive at the empirical model developed for Airtel. MTN, Globacom, and Etisalat's results for Dada Estate are shown in Table 14.

**Table 14:** Reference path loss and standard deviation for Dada Estate

| Parameter | Airtel | MTN | Globacom | Etisalat |
|---|---|---|---|---|
| N | 3.0 | 3.1 | 3.0 | 3.5 |
| $\sigma$ in (db) | 5.0 | 4.5 | 3.8 | 6.6 |
| Path loss(Do) in (Db) | 26 | 20 | 28 | 23 |

The improved Log-Normal Shadowing model that results from include the route loss values in Equation (5) is as follows:

PL (Airtel) (di) = 26 + 10(3.0) Log (di/do) + 5.0 (dB) (21)

PL (MTN) (di) = 20 + 10(3.1) Log (di/do) + 4.5(dB) (22)

PL (Globacom) = 28 + 10(3.0) Log (di/do) + 3.8 (dB) (23)

PL (Etisalat) = 23 + 10(3.5) Log (di/do) + 56.6 (dB) (24)

Thus, the data shown in Table 15 below was generated using equations 21-24 above. Measured route losses for GSM service providers in the study area are shown for different distances in the data. For each service, the average route loss is presented and compared.

**Table 15:** Measured path losses from the proposed modified for Dada Estate

| Model Distance in (m) | Path loss in (dB) Airtel Network | Path loss in(dB) MTN Network | Path loss in (dB) Globacom Network | Path loss in (dB) Etisalat Network |
|---|---|---|---|---|
| 50 | 70.70 | 64.20 | 80.50 | 69.30 |
| 100 | 75.52 | 69.32 | 76.32 | 75.62 |
| 150 | 78.33 | 72.31 | 79.13 | 79.32 |
| 200 | 80.33 | 74.44 | 81.13 | 81.94 |
| 250 | 81.80 | 75.18 | 82.68 | 83.98 |
| 300 | 83.15 | 77.43 | 83.95 | 85.64 |
| 350 | 84.22 | 78.77 | 84.71 | 86.51 |
| 400 | 85.15 | 79.55 | 85.95 | 88.26 |
| 450 | 85.97 | 80.42 | 86.77 | 89.34 |
| 500 | 86.70 | 81.20 | 87.50 | 90.30 |

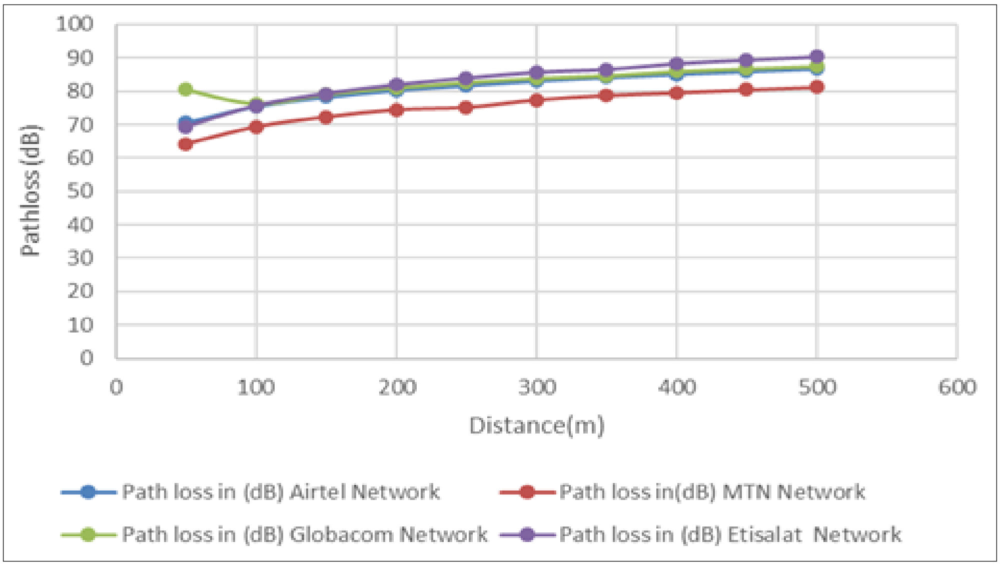


**Fig 10:** Measured path losses from the proposed modified for Dada Estate

**Table 16:** Measured and Predicted path losses for Dada Estate

| | Airtel | MTN | Globacom | Etisalat |
|---|---|---|---|---|
| Average measured path loss in (db) | 85.90 | 90.40 | 88.50 | 86.30 |
| Average predicted path loss in (db) | 100.30 | 84.47 | 90.99 | 92.50 |

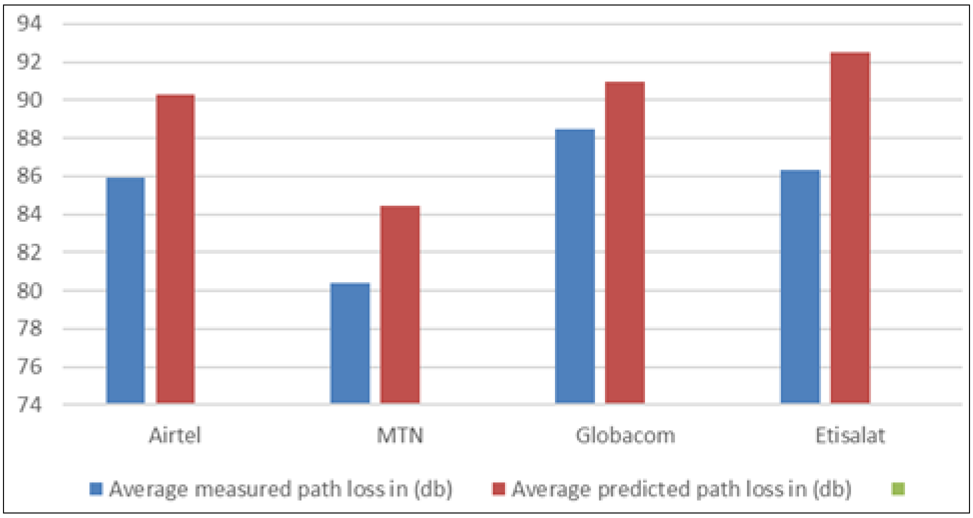


**Fig 11:** Measured and Predicted path losses for Dada Estate

Path loss is shown against distance in Figures 10 and 11, while average path loss is plotted in Figures 12 and 13.

## Conclusion

To better design GSM networks in Osogbo, Nigeria's Osun state, this study tries to forecast the propagation route loss model and use that information. The measuring and instrumentation approach is used. In Osogbo town, the digital wheel meter and the portable Spectrum analyzer were used to measure signal loss (AAronia AG HF 2025E spectrum). Outside fields were used to test the GSM service provided by Airtel, MTN, Glo, and Etisalat. A comparison of the observed and projected route losses was presented in both tabular and graphical modes. The variation of the average values was found to be between 2 and 7 dB, which is within the permissible range. This indicates a strong connection between the observed and expected models. In Osogbo, Nigeria, GSM network service providers may use the empirical model generated from the Log-Normal shadowing idea to plan and improve their services.

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