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DEVELOPMENT OF A MODIFIED EMPIRICAL MODEL FOR NEW MOBILE RADIO NETWORK AT 28 GHZ MILLIMETER WAVE SPECTRUM

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ABSTRACT

Quality of received signal depends partly on the degree of loss the signal experiences along its path. Different models are available for network path loss (PL) prediction. The issues of poor network in some urban area need special attention especially during the deployment of 5G new radio network. It is believed that 4G and 5G networks will coexist for a very long time. 5G network will work in conjunction with the existing 4G network, and 4Gnetwork is not going away any time soon. Hence, it is important to develop a suitable model to mitigate the outcome of signal attenuation and signal interference in 5G network. This paper presented a modified particle swarm algorithm model in 4G network at 28 GHz millimeter wave spectrum. Some existing PL models are unsuitable for PL prediction in certain environments necessitating the development of an appropriate model. To achieve this, existing models and measured data were compared to find out the closest model to the measured value. The environmental loss exponent was obtained to modify Okumura-Hata which is the closest model to the measured path loss (PL) data. A new modified model for the terrain was enhanced by the developed Autoregressive Particle Swarm Optimization (APSO) Algorithm. Root Mean Square Error (RMSE) results obtained are 4.499 dB, 1.050 dB and 0.872 dB for Okumura-Hata, Modified and Enhanced model, respectively. The corresponding values for Mean Absolute Percentage Error (MAPE) are 0.254 %, 0.058 % and 0.048 %. The result showed that Enhanced APSO is a suitable model for predicting 4G network in Abuja, Nigeria.

***Keywords**: APSO, Okumura-Hata, Modified Model, Path Loss, RMSE, ECC-33, Auto-regressive.*

1. Introduction

The ability to predict the quality of signal received at different locations and at a particular frequency in a mobile radio network is of paramount importance. As the number of subscribers continues to increase, additional base network equipment is being installed to meet up with the number of subscribers. Unfortunately, the number of infrastructures installed does not match the explosive growth in the number of mobile subscribers (Akande, Semire, and Adeyemo, 2017). This made communication with the existing infrastructure inadequate and frustrating. However, due to path obstruction in the mobile channel, path loss is a problem to be addressed in urban and suburban areas [Imoize and Dosunmu, 2018].

A communication system has three important components namely: the transmitter, the channel, and the receiver. The channel is a transmission distance between transmitter and mobile unit. The transmitter converts original message into a suitable form, radio wave, for transmission over the channel and the receiver converts radio waves into usable information. The mobile radio channel is a wireless communication link through which signal can be transmitted from transmitter to the receiver. Mobile radio channel has objects which are irregular in shape, and they make the propagated signal unpredictable (Aied, and Ahmed, 2012).

In wireless communication, signal is transmitted from transmitter to the receiver without physical connection or wires. This signal is attenuated by the obstacles along the path, this phenomenon is called path loss (PL). This PL analysis is very critical in the design of any communication system (Mardeni, and Kwan, 2010). PL is referred to the reduction in density or power of electromagnetic wave that is being propagated from base station to mobile station. This is influenced by terrain profile of the environment such as: vegetation, building height, tall trees, foliage, dry, and moist air, the height, and location of the antennas (Erceg and Hari, 2001). The accurate prediction of path loss is needed for successful mobile radio planning of an environment (Sachin, and Jadhav, 2013).

The communication network models are categorized into three namely: Stochastic, Deterministic and Empirical propagation models (Sachin and Jadhav, 2013),(Abiodun and Ojo, 2019).The most used Empirical models are Okumura, Hata, Egli, Ikegami, Lee and Bertoni-Walfisch models. These models were developed from series of measurement in different places, and because of this, most of the models reported as good in those environments may not be accurate in other environments(Rappaport, 2002). The 4G network is currently under deployment in Abuja, Nigeria, and many countries within Sub-Sahara Africa. The mobile radio stations in Nigeria are plannedmaking use of empirical model without due consideration of the geographical location terrain (Adeyemo and Akande, 2016). The deployed empirical models are not accurate for PL prediction in the study environment.

Millimeter waves are radio wave typically defined to occupy the frequency range of 30 GHz – 300 GHz (Ashikur., Salsabil., and Raqeebir, 2021), (Hossain, 2017), (Mayada, Salwa,and Bassant,2021).They are called millimeter wave because the wavelength varies from 1 mm to 10 mm. It should be noted that millimeter wave travels by line of sight and is obstructed by physical objects like trees and buildings (Fourati, Maaloul, and Chaari, 2021), (Jansen, and Beaton, 2021).It is designed to cover short distances with the deployment of massive Multi Input Multi Output (MIMO) antennal system in 5G new radio network. The Millimeter Wave Frequencies of 28 GHz and 60 GHz are the most suitable frequencies for 5G new radio network (Siddiqui *et. al.* 2021).

The existing model have some network issues such as: signal attenuation due to multipath effect, network congestion as a result of bandwidth issues, and poor network design.Others are path loss due to propagation distance from base station to mobile station, and signal interference which may be as a result of noise in the communication channel.

To avoid increasing network problem which can lead to increase in cost, a progressive maintenance, optimization in communication technology need to be adopted(Nadir and Touati, 2008), (Huo, Jiang, and Lv, 2018). This will improve the performance of the system and ensure good Quality of Service (QoS). It became necessary to modify existing model to mitigate the effect of path loss and network congestion, which improve the received signal quality. This paper aims at modifying existing model for the urban area using measured PL data obtained from 4G Long Term Evolution (LTE) network. The measured data was collected using drive test equipment for the selected location in Abuja, Nigeria. The developed model was further enhanced using Auto-regressive Particle Swarm Optimization (APSO) Algorithm for accurate estimation of LTE signal.

2. Related Work

The optimization of COST-231-Hata model was presented for PL prediction in hotspot area. The data was collected in 4G LTE network in Lagos, Nigeria (Adeyemo and Akande, 2016). The work focusedon the GSM/UMTS network at 1900 MHz and not on 4G LTE network which cannot support fast internet video streaming and multimedia services available in 4G LTE network.Empirical and Neural Network (NN) based models were analyzed and presented for PL Prediction in (Eichie and Aibinu, 2017).Parameters likedistance, antenna power and terrain elevation were used as input for the development of artificial Neural Network (NN). This work was also on GSM network at 1800 MHz, and not 4G LTE. The analysis of a PL model in LTE was presented for FESTAC Town, Lagos in (Omijeh and Naemeka, 2018). Five empirical propagation models such as Free Space (FS), Egli, ECC- 33, COST- 231, and Ericson 999 models for PL prediction in Lagos metropolis were considered. The result showed that Ericsson model best predict the PL in FESTAC Town Lagos with a minimum deviation. The work was on GSM which is for voice signal and not 4G LTE network as reported.

The comparative analysis of propagation model in LTE Network for a Lagoon Environment using drive test for data collection was presented by Imoize, and Ogunfuwa (2019). The study focused on the optimization of a best-fit propagation model to improve PL prediction at 1800 MHz which cannot provide support for data and fast internet browsing available in 4G LTE network. Elsewhere in (Abiodun and Ojo, 2019), determination of Probability Distribution Function (PDF) for Modeling PL in Wireless Channels in Ondo State, Nigeria was reported. This work was on modeling mobile radio signal at 900 and 1800 MHz frequency. The results show that normal distribution has the best PDF for modeling the Radio Frequency (RF) signal over different environments in Ondo State.

The papers discussed show that the authors concentrated on GSM frequency bands which are different from that of 4G LTE network. Therefore, the proposed models in previous works are not accurate in the prediction of PL in 4G LTE network at Abuja. There is a need to improve the existing models as a result of channel impairment in 3G and 4G networks. This is because the existing path loss models designed elsewhere are not suitable models for signal propagation in Abuja, Nigeria. The number of subscribers increases exponentially every day; this can lead to network congestion. Hence, the reasons for this work in obtaining a modified model for effective signal propagation in the study area.

A model was consequently developed using Auto-regressive Particle Swarm Optimization (APSO) Algorithm which showed better results when compared to existing model for 4G LTE network. This is the major contribution of this work.

3. Materials and Method

A. Data Collection

The data collection was carried out using drive test method at three different locations in Abuja as shown in Table 1.

Table 1: Drive Test Routes

Designation	**Location**
L1	ZubaGarki Road
L2	Aguiyi Ironsi Street
L3	Umaru-Musa Yar'Adua

Items 15.0 is a drive test software used to record the measured data stored as a log files on the computer system. The Sony-Ericsson W995 phone, portable inverter, mobile antenna and Actix are all connected to the computer system inside a Driving Test Vehicle (DTV). 4G LTE network transmission parameters used for data collection are tabulated in Table 2.

Table 2: 4G LTE transmission Parameters

Item	**Values**
Transmitter Power	43dBm
Antenna Height	35m
Mobile Station Height	1.6m
Transmitter Gain	18dBi
Receiver Gain	1.76dBi

The short calls were made, and the PL values are recorded at every 0.1 km from 4G station at 28 GHz millimeter wave frequency. The data obtained was analyzed using regression method. The developed optimized algorithm known as Autoregressive Particle Swarm Optimization (APSO) algorithm was used to enhance the modified model for better network prediction in the study area. The measured data at 0.1 km is taken as the reference path loss $L_P(d_0)$ up to the maximum of 1.5 km as contained in Table 3.

Table 3: Measured PL Values against Distance for L1, L2 & L3.

Dist (m)	Measured PL $L_P(d_0)\ dB$ (L1)	Measured PL $L_P(d_0)\ dB$ (L2)	Measured PL $L_P(d_0)\ dB$ (L3)	Average Measured PL $L_{PM}(d_0)\ dB$
0.1	99	101	93.4	97.8
0.2	140	116	101.2	119.1
0.3	107	141	117.2	121.7
0.4	142	151	143.2	145.4
0.5	124	106	118.3	116.1
0.6	166	104	137.1	135.7
0.7	139	148	112.1	133.0
0.8	103	159	116.7	126.2
0.9	154	102	140.4	132.1
1.0	120	150	100.1	123.4
1.1	145	137	133.3	138.4
1.2	133	153	100.1	128.7
1.3	119	106	126.2	117.1
1.4	140	154	99.1	131.0
1.5	109	110	111.3	110.1

B. Regression method for L1

The regression analysis of the measured PL data for L1, the measured data at a distance of 0.1 km is taken and the reference path loss $(L_P d_0)$ is presented in Table 4.

Table 4: Regression Analysis of Measured and Predicted PL values for L1.

Dist (km)	Measured PL $L_{PM}(d_0)\ dB$, L1	Predicted PL $L_{PR}(d_i)\ dB$	$L_p(d_0) - L_{PR}(d_i)$	$[\ L_{PM}(d_0) - L_{PR}(d_i)\ ]^2$
0.1	99	99	0	0
0.2	140	099+3.01n	41−3.01n	1681−246.82n +09. 060n^2
0.3	107	099+4.77n	08−4.77n	64 − 76.32n+22.753n^2
0.4	142	099+6.02n	43−6.02n	1849 − 517.72n+36.240n^2
0.5	124	099+6.99n	25−6.99n	625−349.5n+48.86n^2
0.6	166	099+7.78n	67−7.78n	4489−1042.52n+60.528n^2
0.7	139	099+8.45n	40−8.45n	1600−676.0n+71.403n^2
0.8	103	099+9.03n	004−9.03	16−72.24n+81.541n^2
0.9	154	099+9.54n	55−9.54n	3025−1049.4n+91.012n^2
1.0	120	099+10.0n	21−10.0n	441 −420.0n+100.00n^2
1.1	145	99+10.41n	46−10.41n	2116−957.72n+108.368n^2
1.2	133	99+10.79n	34−10.79n	1156−733.72n+116.424n^2
1.3	119	99+11.14n	20−11.14n	400−445.60n+124.100n^2
1.4	140	99+11.46n	41−11.46n	1681−939.72n+131.332n^2
1.5	109	99+11.76n	10−11.76n	100−235.2n+138.298n^2
SUM				1139.919n^2 − 7762.48n + 19243

The received power decreases with distance as the signal is being propagated from Base Station to Mobile Station. The existing path loss model was developed using series of drive test data measured at different distance (Sanjay, 2012), (Santosh and K. Dinesh, 2015). The measurement-based propagation model for long distance is given as:

$$L_{PR}(d_i)\ dB = L_P(d_0) + 10(\mathrm{n})log\left(\frac{d_{1\ldots N}}{d_{Ref}}\right) \quad (1)$$

where:

n is the PL exponent,

$d_{1\ldots N}$ is the distance between the BS and MS.

d_{Ref} is the reference distance.

The modified predicted PL [$L_{PR}(d_i)$] was obtained by substituting reference path loss, exponent(n), distance and adding system modify factor (SMF) into equation (2) as:

$$\mathrm{L}_{\mathrm{PR}\,(d_i)} = \mathrm{L}_{\mathrm{PR}\,(d_o)} + [25.16 \log \mathrm{f_c} - 12.82 \log \mathrm{h_{bt}}] + 10(n) log(\frac{d_{1\ldots N}}{d_{Ref}}) \quad (2)$$

where:

$S\mathrm{MF_{sys}} = [25.16 \log \mathrm{f_c} - 12.82 \log \mathrm{h_{bt}}]$

$\mathrm{f_c} =$ the frequency (MHz) and $\mathrm{h_{bt}}$ the BS height (m).

The expression $\mathrm{L}_{\mathrm{P}\,(d_o)} - \mathrm{L}_{\mathrm{P}\,(d_i)}$ is an error term and, sum of the squared error $e(y)$, is given as:

$$e(y) = \sum_{i=1}^{N} [L_{PM}(d_0) - L_{PR}(d_i)]^2$$

(3)

where $L_{PM}(d_0)$ is the measured PL &$L_{PR}(d_i)$ the predicted PL.

The path loss exponent (n) is obtained from Table 2 by obtaining the differential of equation (3) and solving for (n):

$$e(y) = 1139.919n^2 - 7762.48\mathrm{n} + 19243$$

$$\frac{\partial e(y)}{\partial n} = 1139.919n^2 - 7762.48\mathrm{n} + 19243$$

$$= 2(1139.919n) - 7762.48$$

$$n = 3.41$$

The shadowing error because of obstruction in the terrain is the deviation. This deviation σ_{SD} is calculated from sum of mean square error $e(y)$ using equation (4) as:

$$\sigma_{SD} = \left(\frac{1}{N} \sum ([L_{PM}(d_0) - L_{PR}(d_i)]^2)^{\frac{1}{2}}\right) \quad (4)$$

Therefore, the shadowing error, $\sigma_{SD}(dB)$, about a mean value, is estimated from equation (4) as:

$$\sigma_{SD} = \left[\frac{1}{15}(1139.919)(3.41)^2 - 7762.48(3.41) + 19243\right]^{\frac{1}{2}}$$

$$\sigma_{SD} = 20.10\ dB$$

By substituting $L_{PM}(d_0)_{Ref}$, n and adding $\sigma_{SD}\ (dB)$ to compensate for the error into equation (2).The modified path loss model for L1 ZubaGarki**,** Abuja 4G LTE network is given as:

$$L_{PR}(d_i\,, 1) = 99.0 + [25.16 \log \mathrm{f_c} - 12.82 \log \mathrm{h_{bt}}] + 10(3.41) \log\left(\frac{d_{1\ldots N}}{d_{Ref}}\right) + 20.10\ dB \quad (5)$$

Thus, the reference measured path loss ($L_{PM}(d_0)$), loss exponent (n), shadowing deviation (σ_{SD}) and sum of square error [$L_{PM}(d_0) - L_{PR}(d_i)$ $]^2$ obtained for the locations considered in Abuja terrain is presented in Table 5.

Table 5: Measured PL, exponent, shadowing Deviation and Sum of Squared Error for Abuja.

Locations	Measured PL $L_{PM}(d_0)\ dB$	Exponent (n)	$\sigma_{SD}(dB)$	$[\,L_{PM}(d_0) - L_{PR}(d_i)\,]^2$
L1	99.0	3.41	20.10	$1139.919n^2 - 7762.48\mathrm{n} + 19243$
L2	101.0	3.27	21.75	$1139.919n^2 - 7443.56\mathrm{n} + 19249$
L3	93.4	2.60	16.62	$1139.919n^2 - 5927\mathrm{n} + 11849.13$
Modified Model for Abuja terrain	97.8	3.09	19.49	$1139.919n^2 - 7044.35\mathrm{n} + 16780.38$

The modified path loss model for L2 and L3 that was compared with existing models using simulation are presented in equations (6) and (7) as:

$$L_{PR}(d_i\,, 2) = 101 + [25.16 \log \mathrm{f_c} - 12.82 \log \mathrm{h_{bt}}] + 10(3.27) \log\left(\frac{d_{1\ldots N}}{d_{Ref}}\right) + 21.75\ dB \quad (6)$$

$$L_{PR}(d_i\,, 3) = 93.4 + [25.16 \log \mathrm{f_c} - 12.82 \log \mathrm{h_{bt}}] + 10(2.60) \log\left(\frac{d_{1\ldots N}}{d_{Ref}}\right) + 16.62\ dB \quad (7)$$

Therefore, the overall generalized PL model for Abuja terrain is presented in equation (8) as:

$$L_{PR}(d_i\,, 3) = 97.8 + [25.16 \log \mathrm{f_c} - 12.82 \log \mathrm{h_{bt}}] + 10(3.09) \log\left(\frac{d_{1\ldots N}}{d_{Ref}}\right) + 19.49\ dB \quad (8)$$

C. Modified Particle Swarm Optimization (APSO) Algorithm

The new Optimization Algorithm (OA) is obtained with the combination of Autoregressive (AR) process and particle swarm optimization (PSO) algorithm. The Autoregressive and PSO algorithm was hybridized to become Autoregressive Particle Swarm Optimization (APSO) which was deployed to enhance modified models for the study area. The linear autoregressive process from previous sample data $R(x_P)$ is of the form:

$$\mathrm{R}(x_P) = \mathrm{R}(x_P - 1) + \mathrm{R}(x_P - 2) + \mathrm{R}(x_P - 3) \ldots \ldots \mathrm{R}(x_P - \mathrm{n}) \quad (9)$$

Then, $\mathrm{R}(x_P)$ be the autoregressive process of order n , $\mathrm{k_i}$ is data point in the search space (channel).

$$R(x_P) = \frac{1}{2m} \sum_{i=1}^{m} k_i\, y(x_P - i) + z(m) \quad (10)$$

where:

$z(m)$ is the white noise.

$\frac{1}{2m}$ is a modified factor.

If $f(x_i)$ is the fitness function of the data in the channel (search space), therefore, the particles (data) in the search space are auto-regressed to eliminate error in the signal as:

$$f(x_i) = D_i + R(x_P) \quad (11)$$

Substituting equation (10) into equation (11), when $z(m)$ is equal to zero.

$$f(x_i) = D_i + \frac{1}{2m}\sum_{i=1}^{m} k_i\, R(x_P - i) \quad (12)$$

where $f(x_i)$ is the fitness function for each measured data, d_i represents each data point measured in the channel, m is the total number of measured data and k_i is the weight coefficient of AR filter for$i = 1, 2, 3, \ldots\ldots m$.

The inertia weight (IW_{Iw}) is deployed so that the signal can have good convergence at any distance:

$$IW_{Iw} = w_{max} - \left(\frac{w_{max}}{Maxiter}\right) iter \quad (13)$$

where,w_{max}isthe final weight, $Maxiter$is the maximum iteration and $iter$is the present iteration number:

$w_{max} = 1$,$Maxiter = 15$,$iter = 1, 2, \ldots m$.

The value of w_{max} is chosen to obtain highest convergence speed of data in the search space, the best value of $w_{max}$is always between 0.9 and 1.3 for maximum network performance (Zambrano-Bigia, and, Cleric, 2013). The velocity and position of PSO are given in equations (14) and (15) as:

$$V_i^{t+1} = [V_i^{t} + c_1.r_1(P_{i\,best}{}^{t} - X_i{}^{t}) + c_2.r_2(P_{g\,best}{}^{t} - X_i{}^{t})] \quad (14)$$

$$X_i^{t+1} = X_i^{t} + V_i^{t+1}.\Delta t \quad (15)$$

By multiplying equation (14) by equation (13) for better signal and good convergence. The new signal velocity is presented as:

$$\boldsymbol{V_{i(fx)}{}^{t+1} = IW_{Iw} * [V_i{}^{t} + c_1.r_1(P_{i\,best}{}^{t} - X_i{}^{t}) + c_2.r_2(P_{g\,best}{}^{t} - X_i{}^{t})]} \quad (16)$$

The newly developed APSO model was obtained by multiplying equation (12) with equation (16). This is the developed APSO model that was used to enhance modified empirical model. Therefore, the new velocity (V) and position (X) of the data (particle) in the channel is presented as given in equation (17) and (18) respectively. The simulation of these equations and the conventional modelswere done and the results compared.

$$V_{i(fx)}{}^{t+1} = \boldsymbol{f(x_i)\{IW_{Iw} * [V_i{}^{t} + c_1.r_1(B_{i\,best}{}^{t} - X_i{}^{t}) + c_2.r_2(B_{g\,best}{}^{t} - X_i{}^{t})]\}} \quad (17)$$

$$X_{i(fx)}{}^{t+1} = X_i{}^{t} - V_{i(fx)}{}^{t+1}.\Delta t \quad (18)$$

where $V_{i(fx)}{}^{t+1}$ is the new velocity, $V_i{}^{t}$ the initial velocity of the data, $X_{i(fx)}{}^{t+1}$ is the new position of the data, $X_i{}^{t}$ is the initial position of individual data, IW_{Iw} the inertial weight parameter, $c_1\, and\, c_2$ the cognitive and social acceleration factor, $r_1\, and\, r_2$ are random number [0,1], $B_{i\,best}{}^{t}$ the best position of of each data i until iteration t, $B_{g\,best}{}^{t}$ the global best position of the data until iteration t and Δt is the time step value; chosen to be 1s.

The parameter c_1 and c_2 are chosen to be$c_1 = 1, c_2 = 4 - c_1$ is the value that shows the best performance of the APSO algorithm.

The predicted path loss values for existing model, measured PL, modified model and enhanced APSO model for L1 (ZubaGarki road) is presented in Table 6.

Table 6: Measured PL, Predicted, Modified and Enhanced APSO Models for L1.

Dist (km)	Ok – Hata (dB).	COST-231(dB)	Erics (dB)	Egli (dB).	ECC (dB)	Measured PL (dB)	Modified (dB) (L1)	Enhanced (APSO) dB
0.1	100.3	102.8	135.5	190.1	300.5	99.0	113.5	112.7
0.2	110.8	116.2	144.6	202.1	309.5	140.0	115.7	116.0
0.3	116.9	122.4	149.9	209.2	314.7	107.0	118.7	119.0
0.4	121.2	126.7	153.7	214.2	318.4	142.0	121.0	121.3
0.5	124.6	130.1	156.7	218.1	321.3	124.0	123.3	123.6
0.6	127.4	132.8	159.1	221.2	323.7	166.0	126.0	126.3
0.7	129.7	135.2	161.1	223.9	325.7	139.0	128.3	128.6
0.8	131.7	137.2	162.9	226.2	327.4	103.0	130.3	130.5
0.9	133.5	138.9	164.4	228.3	328.9	154.0	132.0	132.3
1.0	135.1	140.5	165.8	230.1	330.3	120.0	133.6	133.8
1.1	136.5	142.0	167.1	231.8	331.5	145.0	135.0	135.2
1.2	137.8	143.3	168.2	233.3	332.7	133.0	136.3	136.5
1.3	139.0	144.5	169.3	234.7	333.7	119.0	137.5	137.7
1.4	140.2	145.6	170.2	236.0	334.7	140.0	138.6	138.8
1.5	141.2	146.7	171.2	237.9	335.6	109.0	139.6	139.8

D Performance Metrics of the Developed Model.

Performances of the enhanced and conventional models were evaluated to find out the most suitable model for the terrain. RMSE and MAPE were estimated to determine the best agreed models given in equation (19) and (20) respectively (Ekeocha and Ononiwu (2016), Parsons (2000)), (Zhang., Arunaba and Rias (2011)). The computation of error analysis for the existing, the modified and the enhanced APSO values are presented in Tables 7 – 8.

$$RMSE = [\frac{1}{n}\sum_{i=1}^{n}(p_{iml} - p_{irl})^2]^{\frac{1}{2}} \quad (19)$$

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{p_{im} - pi_{rl}}{p_{iml}}\right| x100$$
(20)

Table 7: RMSE Analysis of the Existing, Modified and Enhanced Models.

Location	Error Metric	Ok-Hata (dB	COST -231 (dB)	Ericsson (dB)	Egli (dB)	ECC-33 (dB)	Modified Model (dB)	E
L1	RMSE	0.940	4.33	30.65	93.14	195.24	0.707	
L2	RMSE	0.807	4.460	30.78	93.27	195.4	0.693	
L3	RMSE	11.75	17.01	43.33	105.8	207.9	1.750	
Average	RMSE	4.499	8.600	34.92	97.40	199.5	1.050	

Table 8: RMSE Analysis of the Existing, Modified and Enhanced Models.

Location	Error Metric	Ok-Hata (%)	COST -231 (%)	Ericsson (%)	Egli (%)	ECC-33 (%)	Modified Model (%)	E
L1	MAPE	0.049	0.223	1.580	4.801	10.06	0.0364	
L2	MAPE	0.042	0.230	1.588	4.813	10.08	0.036	
L3	MAPE	0.671	0.972	2.477	6.048	11.88	0.101	
Average	MAPE	0.254	0.475	1.882	5.221	10.67	0.058	

4. Results and Discussion.

The PL has been predicted using five conventional models. RMSE and MAPE values were obtained to determine the best and most suitable model for Abuja, Nigeria. The best model was selected and enhanced using APSO algorithm. The results obtained are presented in figure 1-3.

Figure 1 shows the path loss for L1 against distance for the measured, existing, modified, and enhanced APSO models. It can be observed that ECC-33 model has the highest path loss value among other models and not good for predicting path loss in L1 (ZubaGarki Road, Abuja). This is because of high population density and many tall buildings in the environment. The enhanced model performed better than all other models in Abuja environment. This shows that the enhanced model is a good model for the prediction of PL in 4G LTE network. The comparative analysis of the PL, RMSE and MAPE results for conventional and modified models in L1 are presented in Table 9.

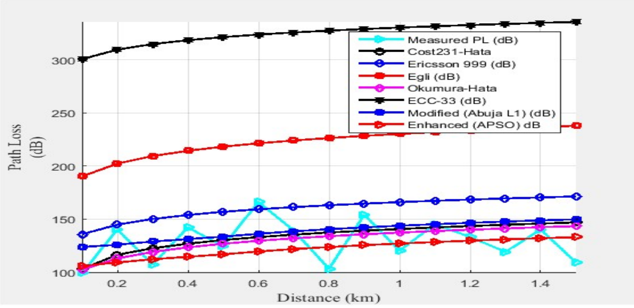

Figure 1: Plot of Path Loss against Distance with Measured PL for L1

Table 9: PL, RMSE and MAPE for conventional models at L1.

Models	PL (dB) at 0.2 km	RMSE (%)	MAPE (%)
Okum-Hata	110.8	0.940	0.049
COST-231	116.2	4.33	0.233
Ericsson	144.6	30.65	1.580
Egli	202.1	93.14	4.801
ECC	309.5	195.24	10.06
Modified	115.7	0.707	0.0364
Enhanced APSO	116.0	0.527	0.0272

Figure 2 shows the plot of PL values for L2 against distance for conventional, modified, and enhanced APSO models. It can be observed that the enhanced model gives the best result in L2 (Aguiyi Ironsi Street, Maitama Abuja) 4G network due to its closeness to the measured data. It means that the enhanced APSO is better model for signal prediction within the area under study compared to the conventional models. The Path Loss, RMSE and MAPE results for both exiting and modified models as obtained for L2 are presented in Table 10.

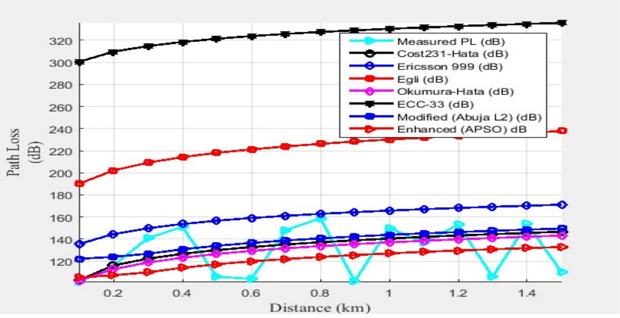

Figure 2: Plot of Path Loss Values against Distance with Measured for L2

Table 10: PL, RMSE and MAPE for conventional models at L2.

Models	PL (dB) at 0.2 km	RMSE (%)	MAPE (%)
Okum-Hata	110.8	0.807	0.042
COST-231	116.2	4.460	0.230
Ericsson	144.6	30.78	1.588
Egli	202.1	93.27	4.813
ECC	309.5	195.4	10.08
Modified	114.0	0.693	0.036
Enhanced APSO	114.3	0.440	0.023

Figure 3 shows the plot of path loss values for location 3 against distance for conventional, modified, and enhanced APSO models. It can be observed that ECC-33 over-estimates path loss prediction. This is because of high population density and many tall buildings in the terrain. The enhanced APSO model performs better than all other conventional models in L3 (Umaru-Musa Yar'Adua Road, Abuja). Therefore, enhanced APSO model is good for signal propagation in Abuja 4G network. The PL, RMSE and MAPE results for conventional, modified, and enhanced models as obtained for L3 are presented in Table 11.

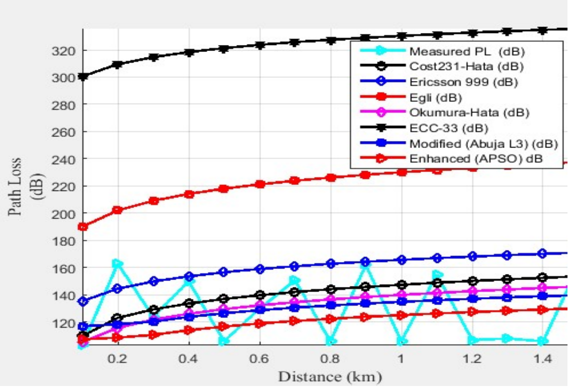

Figure 3: Plot of Path Loss against Distance with Measured PL for L3

Table 11: PL, RMSE and MAPE for conventional models at L3

Models	PL (dB) at 0.2 km	RMSE (%)	MAPE (%)
Okum-Hata	110.8	11.75	0.671
COST-231	116.2	17.01	0.972
Ericsson	144.6	43.33	2.471
Egli	202.1	105.8	6.048
ECC	309.5	207.9	11.88
Modified	116.5	1.750	0.101
Enhanced APSO	116.7	1.650	0.094

5. CONCLUSION

The PL data has been obtained through Drive Test Method (DTM) from 4G LTE station at three different locations in Abuja, Nigeria. Five conventional models were also used to predict the PL values for the terrain. The loss exponent which is one of the important components of network operations has been obtained for Abuja 4G network. The shadowing deviation for the terrain has been obtained and included in the modified model to cushion the effect of multipath fading. This will compensate for signal loss due to obstruction in the channel. The modified model was also obtained using measured PL and standard 4G LTE network parameters. The modified model outperforms all other conventional model considered in the PL prediction. The developed Autoregressive Particle Swarm Optimization (APSO) algorithm is capable of mitigating PL in mobile radio channel. Also, the modified model has the potential to solve the problem of network interference in 5G millimeter wave spectrum. The results obtained through RMSE and MAPE show that the enhanced APSO gives better results compared to conventional model in 4G LTE network at 28 GHz. Therefore, the enhanced APSO is suitable for 4G LTE network planning in Abuja, Nigeria.

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