$$A_1 = \frac{\lambda^2}{4\pi} \quad (3)$$

Where λ is the wavelength of the propagation, combining (1), (2) and (3) gives us (4)

$$P_1 = P_0 \left(\frac{\lambda}{4\pi d} \right)^2 \quad (4)$$

Path loss is usually determine by the difference between the power transmitted by the BS and power received by the MU as given by (5)

$$L_0(dB) = P_0 - P_1 \quad (5)$$

Substituting (4) into (5); we will yield

$$L_0 = 20\log(4\pi) + 20\log(d) - 20\log(\lambda) \quad (6)$$

Simplifying (6) with respect to the frequency, the generic free space path loss equation is obtained as in (7)

$$L_0 = 32.4 + 20\log(d) + 20\log(f) \quad (7)$$

As we know path loss is the function of distance as given in (8)

$$P_l(dB)d^{\alpha} \quad (8)$$

Simplifying the (8) in logarithmic form, we will have (9).

$$P_i(dB) = L_0 + \alpha\log(d) \quad (9)$$

Where P_i is the path loss between the BS and the MU, L_0 is the propagation constant known as free space loss and α is the propagation index, d is the distance between the BS and the MU.

1.2 COST 231- Hata Model

The COST-231-Hata model is an extension of the Hata model which is developed to address the shortcomings that Hata model is not capable of addressing [2]. This model has similar characteristics with Okumura-Hata model, but differs bythe following; frequency 1500 MHz to 2000 MHz, and the link distance, 1km to 20km [2][3]. COST 231-Hata model is given by

$$L_i = 46.3 + 33.9\log f_c - 13.82\log h_B - a(h_m) + \log d \, (44.9 - 6.55\log h_m) + C_H \quad (6)$$

Where $a(h_m) = 3.20(\log 11.75 h_m)^2$ - 4.97, for f > 400 MHz and C_H is the correction factor usually given by 3dB for urban environments.

2. Study Area and Method of Data Collection

The data is collected in a day time with MU in Mubi town, Nigeria at different locations for three GSM operators which includes AIRTEL, MTN and GLO. The city is typically a sub-urban area which consists of buildings approximately 15-25m, significant number of trees;Tamarin, Shear butter, Locust bean, Barasusaethiopus "Giginya", Neem, Mahogany, Date palm"Dipino" cashew and Guava; their height range between 7m – 12m, river Yazaram that divides the city into two and usual human activities like vehicle movements during the time of the day. On the MU, there are 0 to 5bars signifying the signal strength received at the destination. The network bars on the MU range from 0 to 5 bars, the lowest bar is 0 and is the weakest signal while the signal strength increases as the number of the bars increases, which means that the strongest signal is 5 bars. On each location at least 100 samples of those bars were taken making a total of 2,000 observations for each GSM operator. Usually, GSM signal strength is measured in -dBm; that is, the power measured (dB) multiple by the distance between the transmitter and MU receiver. The useful range is from -50dBm to -110dBm in a frequency range of 900MHz to 1800MHz or 1900MHz depending on the environmental requirements. The smaller the number of the dB received by the MU the worse the reception or QoS. Therefore, -50dB is much better than -110dB. In this work, we assigned 0 (no bar) to -105dB, subsequently, 1bar = -95dB, 2bars = -85dB, 3bars = -75dB, 4bars = -65dB and 5bars = -55dB. The MU from transmitter is located in different positions. Starting, from; 500m to 10,000m.

3. Neural Network Prediction

The sample of the signal received is thenanalyzed using the ARNN in order to obtain a weight that could give us desired output. In the process, we trained the network several times so that the network will learn about the data and predict the error that could be responsible for the signal attenuation, as the training continues; we noticed that the successive training pairs negate the change in each stage of training to a reasonable point, that is up to the stage that the error is minimal. This now confirms the degree of the attenuation on the propagation, at that point the neural network (NN) tend to recognize and differentiate between the actual propagation energy (power) as well as the amount of the attenuation (error). Fig. 4 to 6 shows the overall outcomes of NN prediction after the training, validation and test. The accuracy of the NN prediction is validated by R-square and the MSE, each prediction is also noted.

MSE gives us the difference between values predicted by the model and the data observed which provides a good measure of accuracy. R - square sometimes refers to coefficient of determination or coefficient of multi determination for multiple regression, as mentioned earlier, this parameter shows how close the data fits the model, low value of R-square signifies poor prediction and high value give better prediction which is usually from 0 to 1, the performance of the prediction increases when R - square gets closer to 1.

A. Neural Network Clustering

Clustering simply means grouping elements together based on their properties, appearance, contexts and other features. We trained the experimental data collected using neural network clustering, the network learned about the data and produced clusters of the power measured. Figure 1, is the clusters of the path loss measured for the AIRTEL GSM operator.

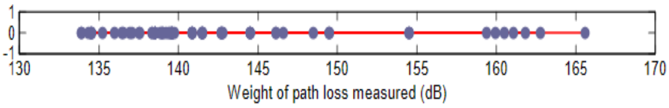

Figure1: SOM of weight positions path loss for the AIRTEL

As we can see, the path loss measured is mostly $135 \leq P_i \leq 140$. Figure 2, shows the clusters of the path loss measured for the MTN GSM operator.

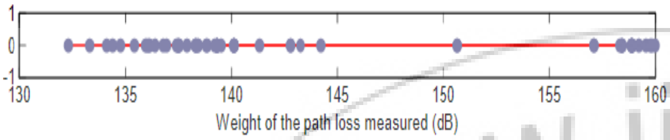

Figure 2: SOM of weight positions path loss for the MTN

Here also the path loss measured is almost similar to that of the AIRTEL mostly from $135 \leq P_i \leq 140$. Figure 3, gives the path loss measured for the GLO GSM operator.

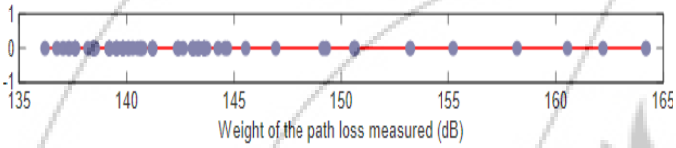

Figure 3: SOM of weight positions path loss for the GLO

In this case, it seems GLO operators experienced more path loss than the two other GSM operators; the path loss here is mostly $136 \leq P_i \leq 145$.

4. Results and Discussion

The NN path loss predictive models for each of the GSM operators are given in (10) to (12).

$$P_{airtel} = 1.04 * target + 0.32 \qquad (10)$$

Where α corresponds to 1.04in (10), this seems to have a good propagation index. In literature the best propagation index is between 0 to 1, [11] target corresponds to the log (d), 0.32 corresponds to the L_0 and $P_{airtel}$is the path loss experienced by the AIRTEL GSM operator. Figure4, presents the NNautoregressive model.

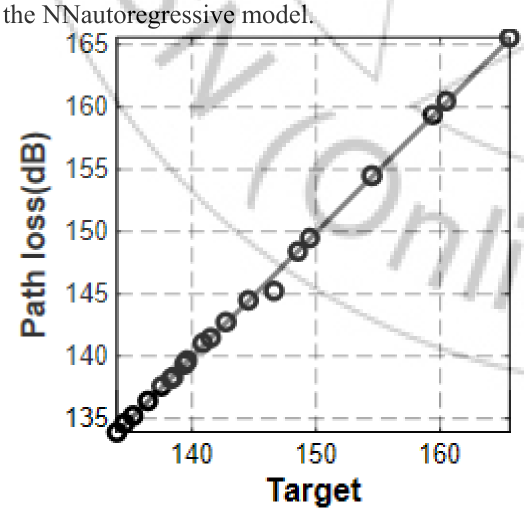

Figure 4: NN autoregressive prediction for AIRTEL operator

NN predictive model for the MTN GSM network operator is given in (11).

$$P_{mtn} = 1 * target + 0.077 \qquad (11)$$

Parameter α=1, L_0=0.077

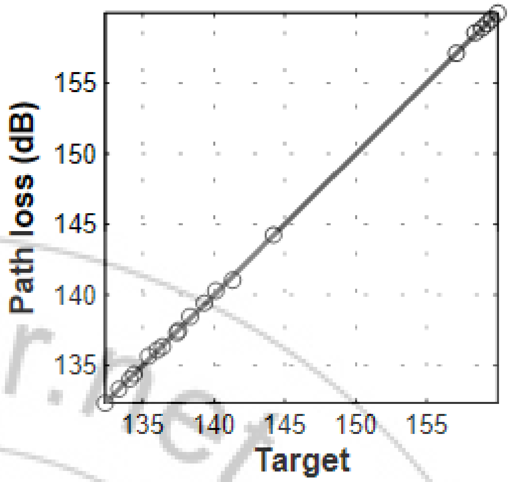

Figure 5:.NN autoregressive model for MTN operator

NN path loss predictive model for the GLO network operator is given in (11).

$$P_{glo} = 1.1 * target + 6.9 \qquad (12)$$

Parameter α=1.1, L_0=6.9

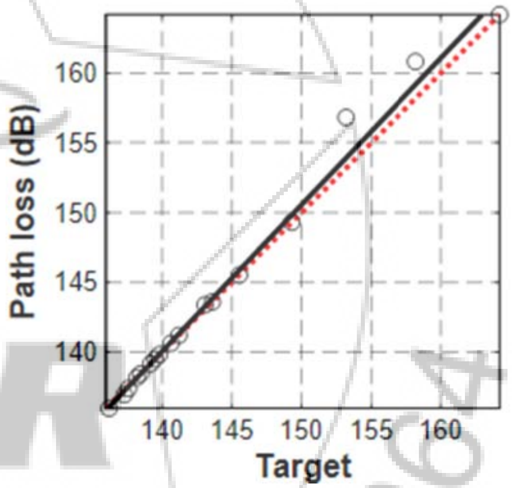

Figure 6: NN autoregressive model for GLO operator

Table 1, shows the R-square, MSE values predicted usingthe models (10) to (12). This gives the average path loss for the entire GSM operator.

Table 1:. R-square, MSE and P_l values

Operators	R-square	MSE (dB)	P_l(dB)
AIRTEL	0.99628	1.76329	16.9600
MTN	0.99945	1.29580	16.0770
GLO	0.99454	2.37112	24.5000

The COST 231 Hata model is then modified using the values of MSE in Table 1 for each GSM operator as given in (13), (14) and (15) for AIRTEL, MTN and GLO respectively.

$$L_{airtel} = 44.54 + 33.9 \log f_c - 13.82 \log h_B - a(h_m) + \log d \,(44.9 - 6.55 \log h_m) + C_H \qquad (13)$$

$$L_{mtn} = 45.01 + 33.9 \log f_c - 13.82 \log h_B - a(h_m) + \log d \,(44.9 - 6.55 \log h_m) + C_H \qquad (14)$$

$$L_{glo} = 43.93 + 33.9\log f_c - 13.82\log h_B - a(h_m) + \log d\ (44.9 - 6.55\log h_m) + C_H \quad (15)$$

The modified models and COST 231 are shown in Figure 7, the blue color graph represents the COST 231-Hata model, red color represents the MTN modified model, green represents the AIRTEL modified model and the brown color represents the GLO modified model, as we can see the GLO operator experienced more losses followed by AIRTEL operator then MTN is the least. The reason may be features of the environment studied is different from where COST 231-Hata is modeled and the variation of the losses among the three GSM operators in the same city may be due to the fact that the BSs are not located in the same area.

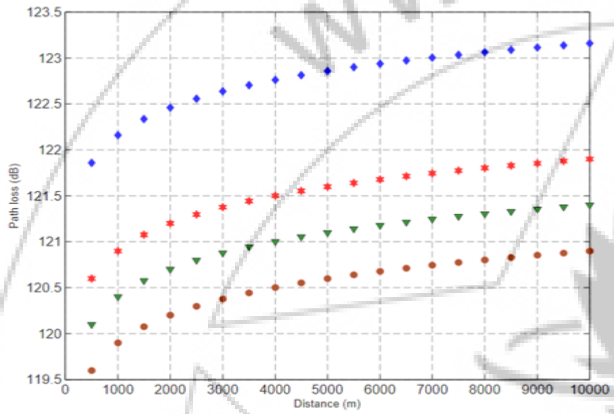

Figure 7: The COST 231 and the modified models

5. Conclusion

Path loss is an important parameter that one needs to know before undertaking the design or improving the existing radio frequency communication path. In this work, we used the autoregressive neural network to the predict path loss for three GSM operators in Mubi town. The neural network predicted that the average GSM signal strength is attenuated at 16.96dB, 16.077dB and 24.5dB with the corresponding MSE of 1.76329dB, 1.2958dB and 2.37112dB for AIRTEL, MTN and GLO respectively. Then each MSE value is used to modify the reference model adopted and neural network clustering determined the weight position of the power received. This work demonstrated that autoregressive neural network is a good tool for path loss prediction with precision.

Reference

[1] [1] Sami A. Mawjoud "Path Loss Propagation Model Prediction for GSM network planning", International Journal of Computer Applications, Vol. 84, No. 7, December, 2013.

[2] [2] European Cooperation in the Field of Scientific and Technical Research Euro- Cost 231 urban Transmission loss Model for Mobile Radio in the 900 MHz and 1800MHz Bands. Revision 2, The Hague, September, 1991

[3] [3] Goldsmith A., "Wireless Communication", USA, Cambridge University Press, 2005.

[4] [4] J. Wu and D. Yuan, "Propagation Measurements and Modeling in Jinan City", IEEE International Symposium on Personal, Indoor and Mobile Radio Communications, Boston, MA, USA, Vol. 3, pp. 1157- 1159, 8-11 September 1998.

[5] [5] Z. Nadir, I. Aeng, N. Flfadhil, and F. Touati," Path Loss Determination Using Okumura-Hata Model and Spline Interpolation for Missing Data for Oman", Proceedings of the World Congress on Engineering, Vol. 1,pp. 2-4,UK, July, 2008.

[6] [6] Hata M., "Empirical Formula for Propagation Loss in Land Mobile Radio Services", IEEE Transaction on Vehicular Technology Vol. 29, No. 3, 1980.

[7] [7] Y. Okumura et al., "Field Strength and Its Variability in VHF and UHF Land-Mobile Radio Service", Review of the Electrical Communications Laboratory, Vol. 16, no. 9-10, September-October 1968.

[8] [8] V. Erceg, L. Greenstein, "An Empirical Based Path Loss Model for Wireless Channels in Suburban Environments", IEEE Journal on Selected Areas of Communication", Vol. 17, pp/ 1205-1211, July 1999.

[9] [9] S. R. Saunders M. Hata, "Empirical Formula for Propagation Loss in Land Mobile Radio Services", IEEE Transactions on Vehicular Technology, vol VT 29 August 1980.

[10] [10] A. Medeisis and A. Kajackas, "On the Use of the Universal Okumura-Hata Propagation Predication Model in Rural Areas", Vehicular Technology Conference Proceedings, VTC Tokyo, Vol.3, pp. 1815-1818, May, 2000.

[11] [11]Ham Radio operator in Florence. Understanding propagation numbers, iw5edi.com

[12] .[12] Yuvraj Singh, "Comparison of Okumura, Hata and COST-231 on the bases of the path loss and signal strength" International Journal of Computer and Application, Vol. 59 No. 11, December, 2012.

[13] [13] Danladi Ali and Vlada N.Y. Wavelet based path loss modeling for global system for mobile communication in an urban environment International Journal of Science and Research 3(7): 1929-1932

[14] [14] Shalangwa D. A. Measurement and Modeling of Path Loss for GSM Signal in a Sub Urban Environment over Irregular Terrain. International Journal of computer science and network security. 10(8):268-274

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