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PERFORMANCE EVALUATION OF A CDMA 1XEV-DO WIRELESS NETWORK OPERATING AT A FREQUENCY OF 876.76MHz IN PORT-HARCOURT NIGERIA

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ABSTRACT

The performance of a CDMA1xEV-DO wireless network operating at a frequency of 876.76MHz in the city of Port Harcourt, Nigeria was evaluated in his work. Several network performance challenges ranging from poor network coverage to overall quality of service degradation have been recently experienced by the network users. These obvious challenges attributed to finding the efficient method for the system upgrade. Field measurements were conducted in some selected urban areas in Port Harcourt such as Aba road, Ikwerre road and Liozu roadusing Agilent tool E6474 and ZTE 302 test phone at vehicular speed. The received signal strength (RSS) was gathered from the transceiver stations of Visafone with transmitting power of 27W, mounted on a steel tower with average height of 40m and mobile height of 1.5m.The measurements were conducted within the range of 100 to 1200 meters at an interval of 100m apart. The computed pathloss exponent and the standard deviation were obtained as 3.24 and 5.11dB respectively. The propagation pathloss model for the environment of study was developed as $Lp = 62.11 \text{ dB} + 32.4\log(D)$which was compared with the existing models. The result obtained showed that the developed pathloss model was best suited for the environment

KEYWORDS: Wireless network, CDMA 1x EV-DO, quality of service, drive test, path loss

I. INTRODUCTION

With the rapid growth in wireless communication due to enabling technologies and increase desire for next generation's services by mobile subscribers, the need for high quality, high capacity network and proper network coverage prediction has become extremely important. The planning requires a good understanding of coverage design in modern mobile networks. This is heavily site specific and can vary significantly depending on the terrain and frequency of operation, velocity of mobile terminal, antenna height etc. Accurate characterization of radio channel through key parameters and a mathematical model is important for predicting signal coverage [1].

The mechanisms of electromagnetic wave propagation are diverse and are characterized by certain occurrences such as reflection, refraction and diffraction of wave[2, 3].These result to signal scattering, fading and shadowing along the signal path result causing service degradation. This service degradation is termed as path loss which is the reduction in power of an electromagnetic wave as it propagates through space and is a major component in analysis and design of link budget of a communication system [4].

Code Division Multiple Access Evolution Data Optimized (CDMA1x EV-DO) comes under wireless communication, which depends on the propagation of waves infree space and providing transmission of data. CDMA1x EV-DOnetwork has been facing different challenges ranging from drop calls, network outage, slow data service and inefficient signal handover, among others which lead to poor coverage of signals in some selected urban areas in Port Harcourt. These areas are Aba road, Ikwerre road and Liozu road. The consequence of this is enormous as it has caused a lot of financial loss to the CDMA1x EV-DO Operator due to rapid migration of subscribers to other networks in search of good quality of service.

This study is therefore to carry out performance evaluation of CDMA 1x EV-DO coverage in Port Harcourt using the selected areas as case study.

Path loss (PL) at destination is generally determined by the use of different models which is broadly categorized into three types; empirical, deterministic and stochastic. Empirical models are those based on observations and measurements alone. The deterministic models make use of the laws governing electromagnetic wave propagation to determine the received signal power at a particular location. Deterministic models often require a complete 3-D map of the propagation environment. Stochastic models, on the other hand, model the environment as a series of random variables[5,6].

According to [7],macro cells are generally large, providing a coverage range in kilometers and used for outdoor communication. Several empirical path loss models have been determined for macro cells. Among numerous propagation models, the following are the most significant ones, providing the foundation of mobile communication services. The models include;

II. HATA MODEL

The Hata model Hatais an empirical formulation of the graphical path loss data provided by Okumura and is valid over roughly the same range of frequencies, 150-1500MHz. This empirical model simplifies calculation of path loss since it is a closed form formula and is not based on empirical curves for the different parameters.
The standard formula for median path loss in urban areas under the Hata model is:

Situation1: Urban Hata pathloss

$$PL = 69.55 + 26.16 log_{10}(f) - 13.82 log_{10}(hb) + (44.9 - 6.55 log_{10}(hb)) log_{10}(d) - a(hm) \quad (1)$$

Situation 2: Surban Hata pathloss

$$PL = PLUrban - 2((log_{10} f/28))^2 - 5.4 \quad (2)$$

Situation 3: Rural Hata pathloss

$$PL = PLUrban - 4.78(log_{10}(f)^2) + 18.33 log_{10}(f) - 40.98 \quad (3)$$

Where the MS (Mobile station) antenna correction factor for the entire above situation is:

$$a(h_m) = 1.11 log_{10}(f) - 0.7)h_m - (1.56 log_{10}(f) - 0.8) \text{ in dB} \quad (4)$$

f is the frequency in MHZ
h_m is the height of the mobile antenna in meters
h_b is the height of the base station antenna in meters

COST 231 extension to Hata Model

The COST-231 Hata model is widely used for predicting path loss in mobile wireless system. The cost-231 Hata model is designed to be used in the frequency band from 500MHz to2000MHz. It also contains corrections for urban, suburban and rural (flat) environments. Although its frequency range is outside that of the measurements, its simplicity and the availability of correction factors have made it widely used for path loss prediction at this frequency band. The basic equation for path loss in dB is:

$$PL(dB) = 46.3 + 33.9 log(f_c) - 13.82 log(h_b) - a(h_m) + (44.9 - 6.55 log(h_b)) log_{10}(d) + c_M \quad (5)$$

Where, *fc* is the frequency in MHz, *d is the distance* between access point (AP) and customer premises equipment (CPE) antennas in km, and hb is the AP antenna height above ground level in meters. The parameter Cm is defined as OdB for suburban or open environments and 3dB for urban environments. The parameter *a(hm)* is defined for urban environments as:

$$a(h_m) = 3.20(log_{10}(11.75 h_r))^2 - 4.97, f > 400 MHz \quad (6)$$

For suburban or rural (flat) environments,

$$a(h_m) = 1.11 log_{10}(f) - 0.7)h_r - (1.56 log_{10}(f) - 0.8) \quad (7)$$

Where, hr is the CPE antenna height above ground level. The path loss exponent of the predictions made by COST-231 Hata mode is given by:

$$n_{cost} = (44.9 - 6.55 \log(h_b))/10 \quad (8)$$

To evaluate the applicability of the cost-231 model for the 3.5GHz band, the model predictions are compared against measurements for three different environments, namely, rural (flat), suburban and urban [7, 8]

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III. METHODOLOGY

In this work, the received signal strength (RSS) measurements was gathered from the transceiver stations of Visafonewith a transmitting frequency of 876.87MHz and transmitting power of 27W, mounted on a steel tower with average height of 40m and mobile height of 1.5m.Method adopted for this work is summarized below:

1) **Single site verification exercise**: This is a process used to verify the status of the base stations within the cluster. In this exercise, individual sites are verified to ensure they are free of critical hardware problems before the drive process is started. Engineering parameters like antenna height, transmit power and the pseudorandom-noise(PN) configured for each cell of the sites are properly checked for errors and inconsistency with that site data obtained before the drive exercise
2) **Drive test:** drive test refers to the data collection exercise. Tools used are tabulated in Table 1.
3) **Drive test report or log-file analysis:** After drive test, raw data collected are processed using the actix analyzer.

Table 1: Drive Test Tools

Name	Function	Set	Provider
Agilent E6474 /Navigator/Actix sportlight	Drive Test/ Post-Processing Tool	3	HUAWEI/VISAFONE
ZTE S100/EVDO modem	Test Mobile	3	VISAFONE
Car	For Drive Test	1	VISAFONE
GPS	For Drive Test	1	VISAFONE
Laptop	For Drive Test	1	VISAFONE

The forward coverage (RX_level) of the network in Port Harcourt Town shows that the receive signal strength is not too good in the area of study.

Table 2 shows the average received signal strength across the routes. The result shown in Table 2 clearly illustrated the received signal strength degradation performance relative to increase in distance. At 0.10 km, the average receive signal strength is -45dBm.

Table 2: Average Received Signal Strength across the routes

Distance(km)	Average RSS(dBm)
0.10	-45
0.20	-56
0.30	-58
0.40	-61
0.50	-63
0.60	-75
0.70	-72
0.80	-80
0.90	-84
1.00	-78
1.10	-81
1.20	-68

The Transmission Parameters used in the drive test are itemized in Table 3.

Table 3: Transmission Parameters for the CDMA 1xEVDONetwork

S/N	Transmission parameters	Values
1	Frequency of operation	876.87MHz
2	Transmitter power	27W
3	Transmitter height	40m
4	Mobile Station height	1.5m

Derivation of the path loss model within the area requires the following steps;
Calculation of the average power received at this closest distance (0.1Km).
Power Received, $P_{r_{av}}(dBm) = -45dBm$ (9)
Converting the power to dB,
$10logP_r = -45$
$P_r = 10^{-4.5} = 3.16X10^{-5}dB$
The CDMA 1xEVDOTransmitter power P_t is 27W.
Thus; $P_t = 10\log 27w \approx 14.31dB$

Measured Path Loss:
According to [9], the standard equation used for this calculation is shown in equation 10 below:

$$P_m(dB_{in}) = 10\log\left(\frac{p_t}{p_r}\right) \quad (10)$$

Where$P_m$is the measured path loss, $dB_{in}$is close-in distance, $P_t$is the CDMA 1xEVDOtransmitting power, $P_r$is the received Signal strength.

Hence,the measured path loss is computed as represented in Table 4 below;

Table 4: Measured path loss computation

Distance(km)	Average RSS (dBm)	Measured Path loss, Pm (dB)
0.10	-45	57
0.20	-56	68
0.30	-58	70
0.40	-61	73
0.50	-63	75
0.60	-75	87
0.70	-72	84
0.80	-80	92
0.90	-84	96
1.00	-78	90
1.10	-81	93
1.20	-68	80

Table 4contains the generated measured path loss values. To determine the proposed model, the values for the predicted path loss should be obtained alongside the path loss exponent.

Estimation of the Predicted Path Loss:
The predicted path loss values are obtained by substituting the measured path loss values of Table 4 into equation 11[10].

$$Lp(d) = Lp(d_{in}) + 10n\log\left(\frac{di}{d0}\right) + X\sigma \quad (11)$$

Where;$Lp(d)$ = predicted path loss, d_{in} = close-in distance, n = pathlossexponent, σ = Standard Deviation, X=constant.

From Table 4, the path loss, $Lp(d_{in})$at a close-in distance of 0.10km is,
$Lp(d_{in})$= 57dB

The predicted path losses at various distances were obtained as shown in table 5.

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Table 5:The measured path loss, Predicted Path Loss with path loss exponent (n)

Distance(km)	**Average RSS (dBm)**	**Measured Path loss, Pm (dB)**	**Predicted Path loss(dB)**
0.10	-45	57	57
0.20	-56	68	57+3.0n
0.30	-58	70	57+4.8n
0.40	-61	73	57+6.0n
0.50	-63	75	57+7.0n
0.60	-75	87	57+7.8n
0.70	-72	84	57+8.5n
0.80	-80	92	57+9.0n
0.90	-84	96	57+9.5n
1.00	-78	90	57+10.0n
1.10	-81	93	57+10.4n
1.20	-68	80	57+10.8n

The fourth column of Table 5 is the predicted path losses for the CDMA 1xEVDOnetwork. The values obtained have an 'n' coefficient which stands for the path loss exponent. The value for the path loss exponent could then be derived via the sum of the Mean Squared Error formula using equation 12 below.

Estimation of the Path Loss Exponent via Sum of the Mean Squared Error: The sum of mean squared error, $e(n)$, is given as;[10].

$$e(n) = \sum_{i=1}^{k}\left[P_m(d_{in}) - L_p(d\ \ )\right]^2 \tag{12}$$

Where Pm = measured path loss, Lp = path loss at close-in distance of d_{in}
Substituting the values in column 3 and 4 of table 5 into equation 12 generated the values shown in Table 6.

Table 6: The Mean Squared Error computation

Distance(km)	**Average RSS (dBm)**	**Measured Path loss, Pm (dB)**	**Predicted Path loss(dB)**	$\left[\mathbf{P_m(d_{in}) - L_p(d\ \ )}\right]^2$
0.10	-45	57	57	0
0.20	-56	68	57+3.0n	$9n^2 - 66n + 121$
0.30	-58	70	57+4.8n	$23n^2 - 125n + 169$
0.40	-61	73	57+6.0n	$36n^2 - 192n + 256$
0.50	-63	75	57+7.0n	$49n^2 - 252n + 324$
0.60	-75	87	57+7.8n	$60.8n^2 - 468n + 900$
0.70	-72	84	57+8.5n	$72.3n^2 - 459n + 729$
0.80	-80	92	57+9.0n	$81n^2 - 630n + 1225$
0.90	-84	96	57+9.5n	$90.3n^2 - 741n + 1521$
1.00	-78	90	57+10.0n	$100n^2 - 660n + 1089$
1.10	-81	93	57+10.4n	$108.2n^2 - 749n + 1296$
1.20	-68	80	57+10.8n	$116.6n^2 - 497n + 529$

The sum of mean squared error, $e(n) = 746.2(n)^2 - 4839n + 8159$
Differentiating both sides after equating to zero helps to minimize the Mean Squared Error at a particular exponent value. Thus;

$$\frac{\partial\, e(n)}{\partial n} = 0 \tag{13}$$

Where n is the Path loss exponent

$$\frac{\partial\, e(n)}{\partial n} = 2[746.2n] - 4839 = 0$$

$$1492.4n = 4839$$

pathloss exponent, $n = 3.24$
The path loss exponent is 3.24. So, substituting this value of n into equation 11 results to equation 14 shown below,

$$Lp = Lp(d_0) + 10\,(3.24)\log\left(\frac{d_i}{d_0}\right) + X\delta \quad (14)$$

$$Lp = Lp(d_0) + 32.4\log\left(\frac{d_i}{d_0}\right) + X\delta \quad (15)$$

The sum of mean squared error is computed as;
Sum of mean squared error, $e(n) = 746.2(3.24)^2 - 4839(3.24) + 8159$
Sum of mean squared error, $e(n) = 323.67$

To obtain the standard deviation, equation 16[7]is employed.

$$\delta = \sqrt{\sum \frac{[(P_m) - (L_p)]^2}{N}} \quad (16)$$

Where δ = Standard deviation, P_m= measured path loss, L_p= predicted path loss, N=Number of data points (12)

$$\delta = \left[\sum \frac{[(P_m) - (L_p)]^2}{N}\right]^{\frac{1}{2}} \quad (17)$$

$\delta = 5.1149$dB or 5.11dB

The path loss model for the CDMA 1xEVDOnetwork in Port-Harcourt city is computed as;

$$Lp = 57\text{ dB} + 10 * 3.24\log\left(\frac{d_i}{d_0}\right) + 5.11\text{ dB} \quad (18)$$

$$Lp = 62.11\text{ dB} + 32.4\log(D) \quad (19)$$

Where, $D = \frac{d_i}{d_0}$

Calculation of Hata path loss for Port-Harcourt
Using equation (1) and Table 2, the Hata equation is written thus;

$$PL = 124.34 - 34.407 log_{10}(d) \quad (20)$$

COST 231 Model for Port-Harcourt Urban Centre:
Also, using equation (5) and Table 2, the COST 231 equation is written thus;

$$L_{COST231}(port) = 126.91 + 34.41\log_{10}(d) \quad (21)$$

IV. RESULTS AND DISCUSSION

The plot of the proposed CDMA 1xEVDOnetwork model in Port-Harcourt is plotted as represented in Figure 1 using MatLab.

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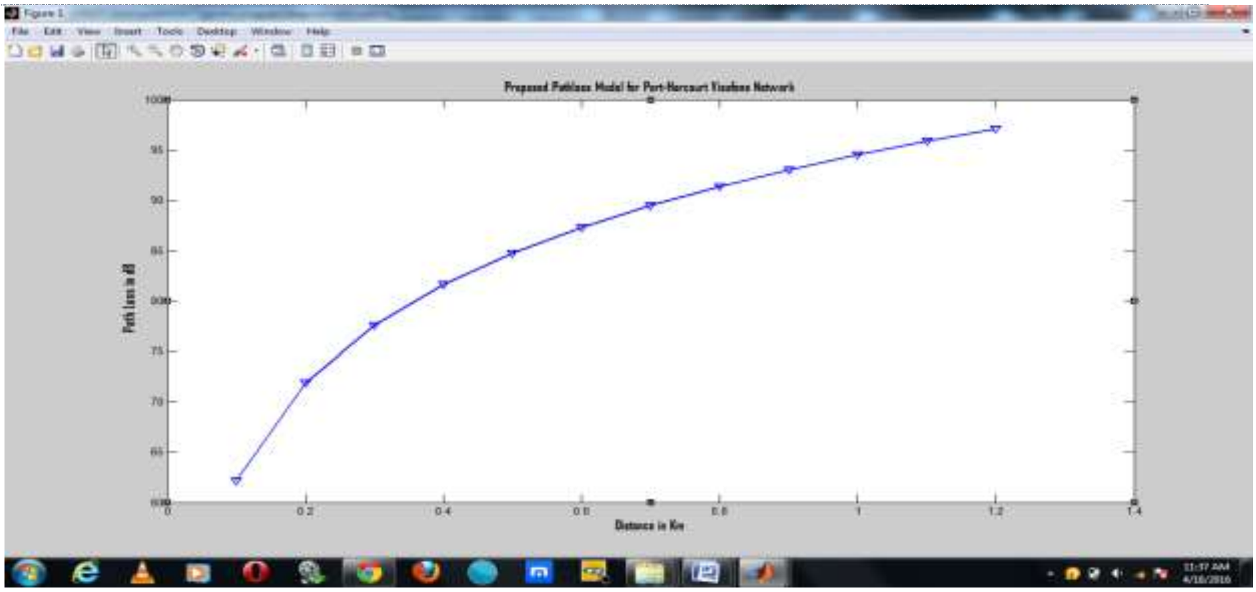

Fig. 1: Plot of distance (km) against proposed Model.

From the plot of the proposed model shown in figure 1, the path loss varies directly with the distance. At a distance of 0.10km (close-in distance), 0.6km and 1.2km, the path loss obtained was 62.12 dB, 87.3319 dB and 97.0852dB respectively.

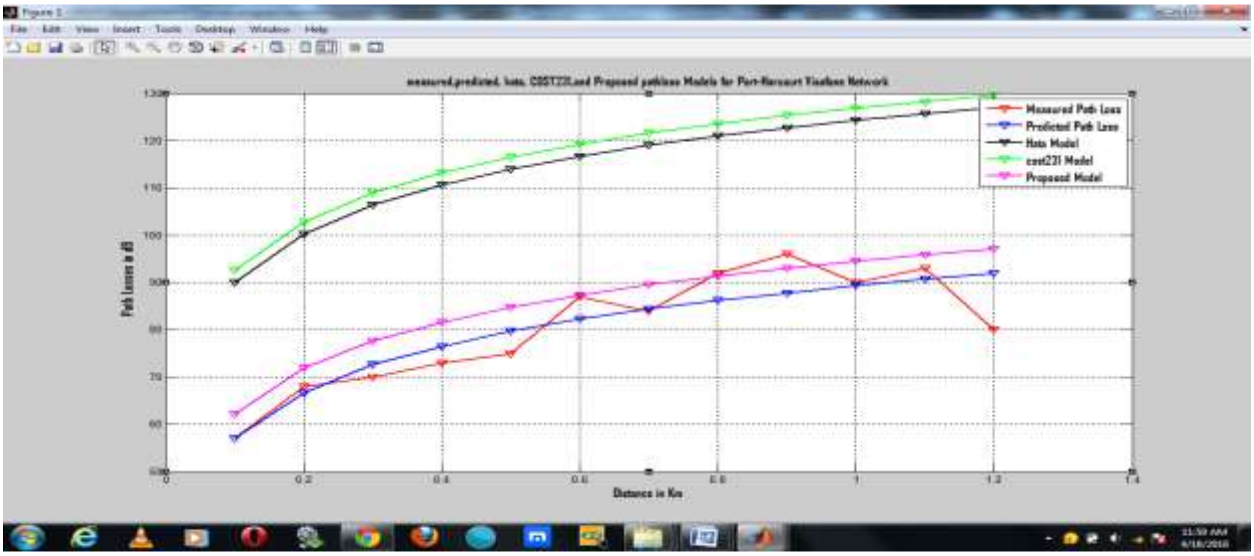

Fig. 2: Comparison of measured, predicted, Hata, COST231, and proposed path loss models.

The plot in Fig. 2 compares the proposed CDMA 1xEVDOnetwork model with the measured path loss, predicted path loss, standard Cost 231 and Hata models. Their comparison is tabulated in Table 7

Table 7. Comparison of path loss models

Distance (Km)	Path loss models (dB)				
	Measured	Predicted	Hata	Cost 231	Proposed
0.10	57	57	89.93	92.50	62.12
1.2	80	92	127.66	129.64	97.085

It could be keenly observed that both standard models (Hata model and COST 231 model) are not good enough for analyzing the signal losses in Port-Harcourt CDMA 1x EVDO network as their values have much deviation from the proposed model which if optimized will be able to solve the issue of coverage. The proposed model is best suited for analyzing the path loss within the area in question as it is uniquely designed for the environment.

V. CONCLUSION

This research work has shown the outdoor path loss model obtained for CDMA 1x EVDO network in Port Harcourt urban using the mean squared error approach. A drive test was carried out using the Agilent installed laptop and mobile phone. The outcome of the test was analyzed to ascertain the measured path losses, predicted path losses and sum of mean squared error method. The pathloss exponent was obtained as 3.24 while the standard deviation was computed as 5.1dB. An efficient and reliable path loss model for study area was eventually developed for the CDMA 1x EVDO network. It was observed that both standard models (Hata model and COST 231 model) were not good for analyzing the signal losses in port-Harcourt CDMA1XEVDO network as their values have much deviation from the proposed model. Thus, the proposed model is best suited for analyzing the path loss within the area in question as it is uniquely designed for the environment.

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