Wireless Network Modelling and Analysis using Path Loss Models

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ABSTRACT

In this paper, the network modelling and analysis of some selected areas such as nonurban, urban, suburban, exurban, dense urban, microurban, and periurban have been carried out through the adoption of path loss models. The accuracy of the employed path loss models was determined using the Root Mean Square (RMS) error between the measured values and the estimated path loss of the applicable empirical models.

(Keywords: path loss, COST231 model, COST WI model, free space model)

INTRODUCTION

In wireless communications, path loss models are valuable tools employed to guarantee quality of service (QoS) provisioning in a network. Path loss can be described as the reduction in power density of an electromagnetic wave as it propagates through space [1]. It is used to determine the difference in the transmitting power and receiving power of the information transmitted from the source to the destination as it propagates in the form of electromagnetic (EM) waves.

All transmitted information incurs path loss as electromagnetic waves propagate from source to destination due to a number of factors that include reflection, diffraction, and scattering. The electromagnetic effects of parameters such as power attenuation and deep fading also contributes to reduction in signal quality, resulting in several issues in wireless networks such as dropped calls in cellular networks.

To address these drawbacks, accurate estimation of propagation path loss is essential for an efficient mobile network design. Propagation path loss models are mathematical tools employed in wireless communications to plan and optimize wireless network systems [2]. The design of an efficient wireless network involves several phases, these phases can be classified into various perspectives that include planning, optimization, and design [3].

The planning phase of a wireless network is used to predict the loss of signal strength (coverage) in an area of interest. The quality of coverage of any wireless network design depends on the accuracy of the propagation model. This implies that, the coverage reliability of a wireless network design depends on the accuracy of the propagation model.

The optimization phase is used to ensure that a network operates as close as possible to the original design by making sure handoff points are close to prediction, coverage is within design guidelines such as indoor, incar, and onstreet RSS, and co-channel interference is low at neighboring sites. Also, in the optimization phase, the measured data collected from a real network may be used to tune the propagation models employed in the design phase.

Advances in wireless communications have made embedded built-in error estimation possible in propagation models applied for cellular mobile systems, generally of the order of 7.0 dB standard deviation, a factor of ten in signal power. Any reduction in the estimated error value would increase the quality of service, reduce undesirable power losses, increase coverage area, and determine best arrangements of base stations [4]. Moreover, any reduction in the estimated error value would result in a significant impact on the size and performance of a network, thus, improving, QoS and user's satisfaction. To overcome the issues identified, the parameters of the adopted empirical models must be modified with reference to an area of interest towards achieving a minimal error between the predicted and measured signal strength.

In network planning, the predication of path loss, coverage area, frequency assignment and interference are key parameters. However, the existing empirical models cannot be generalized to different environments (nonurban, urban, suburban, exurban, dense urban, microurban, and periurban), this connotes that, the suitability of these models differ for different environments. Therefore, the data obtained through measurements in this study were compared with three empirical propagation models at 1800MHz in nonurban, urban, suburban, exurban, dense urban, microurban, and periurban, areas in Lagos.

The accuracy of the employed path loss model was determined using the Root Mean Square (RMS) error between the measured values and the estimated path loss of the applicable empirical models.

LITERATURE REVIEW

Path Loss Theory and Models

Radio transmission in mobile communication system often takes place over irregular terrain. Therefore, propagation models are employed to predict path loss over different types of terrains. This is important to achieving QoS provisioning in a wireless network. The models considered in this work are applicable to GSM bands (1800 MHz).

Free Space Path Loss Model

In telecommunication, free space path loss (FSPL) is the loss in signal strength of an electromagnetic wave resulted from a line of sight path through free space (usually air), with no obstacles nearby to cause reflection or diffraction [4]. It is defined in "Standard Definitions of Terms for Antennas", IEEE Std 1451983, as the loss between two isotropic radiators in free space, expressed as a power ratio [5]. Generally, it is expressed in dB. So, it is often assumed that the antenna gain is a power ratio of 1.0 or 0 dB. It does not include any loss associated with hardware imperfections, or the effects of any antennas gain. The FSPL is rarely used standalone, but rather as a part of the Friis transmission equation, which includes the gain of antennas. Free space path loss is proportional to the square of the distance between the transmitter and receiver, and also proportional to the square of the frequency of the radio signal.
Equation 1 is used to determine the free space path loss of an environment.

$$\mathrm{FSPL} = \left(\frac{4\pi d}{\lambda}\right)^2 = \left(\frac{4\pi df}{c}\right)^2 \quad \textbf{(1)}$$

where:
λ is the signal wavelength (in metres),
f is the signal frequency (in hertz),
d is the distance from the transmitter (in metres),
c is the speed of light in a vacuum, 2.99792458 × 108 metres per second.
This equation is only accurate in the far field where spherical spreading can be assumed; it does not hold close to the transmitter.

$$\begin{aligned}\mathrm{FSPL(dB)} &= 10\log_{10}\left(\left(\frac{4\pi}{c}df\right)^2\right) \\ &= 20\log_{10}\left(\frac{4\pi}{c}df\right) \\ &= 20\log_{10}(d) + 20\log_{10}(f) + 20\log_{10}\left(\frac{4\pi}{c}\right) \\ &= 20\log_{10}(d) + 20\log_{10}(f) - 147.55\end{aligned} \quad \textbf{(2)}$$

For typical radio applications, it is common to find f measured in units of MHz and d in km, in which case the FSPL equation becomes:

$$\mathrm{FSPL(dB)} = 20\log_{10}(d) + 20\log_{10}(f) + 32.45 \quad \textbf{(3)}$$

For d, f in meters and kilohertz, respectively, the constant becomes -87.55.

For d, f in meters and megahertz, respectively, the constant becomes -27.55.

For d, f in kilometers and megahertz, respectively, the constant becomes 32.45.

The FSPL expression above often leads to the erroneous belief that free space attenuates an electromagnetic wave according to its frequency. This is not the case, as there is no physical mechanism that could cause this. The expression for FSPL actually encapsulates two effects.

Dependency of the FSPL on distance is caused by the spreading out of electromagnetic energy in free space and is described by the inverse square law, that is:

$$S = P_t \frac{1}{4\pi d^2} \quad \textbf{(4)}$$

where:

- S is the power per unit area or power spatial density (in watts per meters-squared) at distance d,
- P_t is the equivalent isotropically radiated power (in watts).

This is not a frequency dependent effect. The frequency dependency is somewhat more confusing. The question is often asked: Why should path loss, which is just a geometric inverse square loss, be a function of frequency? The answer is that path loss is defined on the use of an isotropic receiving antenna ($G_r = 1$). This can be seen if we derive the Free Space Path Loss from the Friis transmission equation.

$$FSPL = \frac{P_t}{P_r} G_t G_r \quad \textbf{(5)}$$

Hence path loss is a convenient tool; it represents a hypothetical received power loss that would occur if the receiving antenna were isotropic. Therefore, the free space path loss can be viewed as a convenient collection of terms that have been assigned the unfortunate name path loss. This name calls up an image of purely geometric effect and fails to emphasize the requirement that $G_r = 1$.

A better choice of the name would have been unity gain propagation loss. Hence frequency dependency of the path loss is caused by the frequency dependency of the receiving antenna's aperture in case the antenna gain is fixed. Antenna aperture in turn determines how well an antenna can pick up power from an incoming electromagnetic wave. Dependency of antenna aperture from antenna gain is described by the formula:

$$A = G \frac{\lambda^2}{4\pi} \quad \textbf{(6)}$$

Equation 6 indicates that, the lower the frequency (the longer the wavelength), the bigger antenna is needed to achieve certain antenna gain. Therefore for a theoretical isotropic antenna ($G_r = 1$), the received power P_r is described in Equation 7:

$$P_r = S \frac{\lambda^2}{4\pi} \quad \textbf{(7)}$$

where S is a power density of an electromagnetic wave at a location of theoretical isotropic receiving antenna. Note that this is entirely dependent on wavelength, which is how the frequency dependent behavior arises.

In simple terms the frequency dependency of the path loss can be explained like this: with the increase of the frequency the requirement to keep the gain of the receiving antenna intact will cause an antenna aperture to be decreased, which will result in less energy being captured with the smaller antenna, which is similar to increasing the path loss in the situation when receiving antenna gain would not have been fixed.

Cost 231 Hata Model

The COST Hata model is a radio propagation model that extends the urban Hata model (which in turn is based on the Okumura model) to cover a more elaborated range of frequencies [5]. This model is applicable to urban areas.

To further evaluate Path Loss in Suburban or Rural Quasiopen/Open Areas, this path loss has to be substituted into Urban to Rural/Urban to Suburban Conversions. The COST Hata model is given in Equation 8.

$$L = 46.3 + 33.9 \log f - 13.82 \log h_B - a(h_R) + [44.9 - 6.55 \log h_B] \log d + C \quad \textbf{(8)}$$

For suburban or rural environments:

$$a(h_R) = (1.1 \log f - 0.7) h_R - (1.56 \log f - 0.8) \quad \textbf{(9)}$$

$$C = \begin{cases} 0\ dB \text{ for medium cities and suburban areas} \\ 3\ dB \text{ for metropolitan areas} \end{cases}$$

where:

L = Median path loss. Unit: decibel (dB)

f = Frequency of Transmission. Unit: megahertz (MHz)

hB = Base station antenna effective height. Unit: meter (m)

d = Link distance. Unit: Kilometer (km)

hR = Mobile station antenna effective height. Unit: meter (m)

a(hR) = Mobile station antenna height correction factor as described in the Hata model for urban areas.

The European Cooperative for Scientific and Technical research (EUROCOST) formed the COST231 working committee to develop an extended version of the Hata model. COST231 proposed the following equation to extend the Hata's model to 2 GHz. The proposed model for path loss is given in Equation (10).

L50 (urban) = 46.3 + 33.9 log fc – 13.82 log hte – a (hre) + (44.9 – 6.55 log hte) log d + Cm

(10)

where:

a(hre) is the correction factor for effective mobile antenna height which is a function of the size of the coverage area.

0 dB for medium sized city and suburban areas

Cm = 3 dB for metropolitan centers

The COST231 extension of the Hata model is restricted to the following range of parameters:

f : 1500–2000 MHz

hte : 30m to 200m

hre : lm to lOm

d : lkm to 20 km

The limitation of this model is that it requires that the base station antenna is higher than all adjacent rooftops.

COST Walfish Ikegami Model

This empirical model is a combination of the Walfisch and Ikegami models. It was enhanced by the COST 231 project [6], [7]. The model considers the buildings in the vertical plane between the transmitter and the receiver. Street widths, buildings heights as well as transmitter and receiver heights are considered.

The accuracy of this empirical model is quite high because in urban environments the propagation in the vertical plane and over the rooftops (multiple diffractions) is dominating. Especially if the transmitters are mounted above roof top levels. If the wave guiding effects due to multiple reflections in streets are dominating, the accuracy of the COST WalfischIkegami model is limited because it is focused on the multiple diffractions in the vertical plane [6].

The general parameters of the COST Walfisch – Ikegami model are frequency f (800...2000 MHz), height of the transmitter hTX (4...50 m), height of the receiver hRX (1...3 m), distance d between transmitter and receiver (20...5000 m), parameters depending on the buildings (mean value of building heights $h_{roof,}$, mean value of widths of streets w, and mean value of building separation b).

The classical COST Walfisch Ikegami model determines the mean street width, mean building height, mean building separation for the whole building database (i.e. the whole cell area). Due to the fact that some areas are not homogeneous such as a city such that in some regions the buildings are taller compared to other areas. WinProp increases the accuracy of the model because the three parameters depending on the buildings (street width, building heights, building separation) are not identical for all locations in the cell. They are actually analyzed individually for each receiver pixel based on the actual buildings in the vertical plane between Tx and Rx.

RESEARCH APPROACH

In this study, a driving test approach was employed for data collection and analysis purposes.

Drive Testing

Drive testing method is used for measuring and assessing the coverage, capacity and QoS of a mobile radio network [8], [9]. This technique consists of using a motor vehicle containing mobile radio network air interface measurement equipment that can detect and record a wide variety of the physical and virtual parameters of mobile cellular service in a given geographical area. By measuring what a wireless network subscriber would experience in any specific area, wireless carriers can make directed changes to their networks that provide better coverage and service to their customers.

Drive testing requires a mobile vehicle outfitted with drive testing measurement equipment. This equipment is usually highly specialized electronic devices that interface to OEM mobile handsets. This ensures measurements are realistic and comparable to actual user experiences.

Data Collected During Drive Testing

Drive test equipment typically collects data relating to the network itself, services running on the network such as voice or data services, radio frequency scanner information and GPS information to provide location logging [10], [11].

The data set collected during the drive testing field measurements includes signal intensity, signal quality, interference, dropped calls, blocked calls, anomalous events, call statistics, service level statistics, QoS information, handover information, neighboring cell information, and GPS location.

Drive Testing Techniques

Drive testing can be classified into different types that include network benchmarking, optimization and troubleshooting, and service quality monitoring [12], [13].

Network benchmarking

For benchmarking, a multichannel tool, namely TEMS was employed. This tool was used to measure several network technologies and service types in order to provide comparable information regarding competitive strengths and weaknesses.

Optimization and Troubleshooting

Optimization and troubleshooting information were used to aid the process of finding specific problems during the rollout phases of new networks or to observe specific problems reported by the network users' during the operational phase of the network lifecycle. In this phase, drive testing data was used to diagnose the cause of specific issues such as dropped calls and missing neighbor cell assignments.

Service Quality Monitoring

In this phase, service quality monitoring approach such as mean opinion score (MOS) was used to make test calls across the proposed network to a fixed test unit to assess the relative quality of various services. This was done with the view of assessing the experience of the end users in order any issues experienced that include QoS degradations. Service quality monitoring was carried out in an automated manner using devices that run largely without human intervention. This was achieved through driving testing on a live network.

RESULTS AND DISCUSSION

The results obtained in this study using the employed models are given in Tables 1, 2, 3, 4, and 5, while Figures 1 to 5 shows the analysis of the obtained results over a period of five months for the considered areas (nonurban, urban, suburban, exurban, dense urban, microurban, and periurban). Figure 6 shows the performance of the employed models in the considered areas.

Table 1: Mean Received Signal Level at 1800 MHz for January, 2017.

S/N	TX/RX	NONURBAN	URBAN	SubUrban	EXURBAN	DENSE URBAN	MICRO URBAN	PERIURBAN	FREE SPACE	COST 231	COST WI
	Distance (km)	dbm	dbm	Dbm	dbm	Dbm	dbm	Dbm			
1	0.5	-68	-62	-63	-62	-67	-78	-79	91.53	118.64	105.28
2	1	-69	-64	-66	-64	-69	-79	-80	97.56	129.24	111.31
3	1.5	-70	-66	-68	-66	-70	-80	-82	101.08	135.44	114.83
4	2	-71	-68	-70	-68	-72	-83	-84	103.58	139.84	117.33
5	2.5	-73	-69	-72	-70	-74	-85	-88	105.51	143.26	119.26
6	3	-75	-70	-74	-72	-76	-90	-90	107.10	146.04	120.85
7	3.5	-78	72	-76	-74	-79	-92	-92	108.44	148.40	122.19
8	4	-80	-74	-78	-76	-80	-94	-94	109.60	150.44	123.35
9	4.5	-81	-76	-80	-78	-81	-96	-96	110.62	152.25	124.37
10	5	-83	-78	-81	-80	-84	-98	-98	111.53	153.86	125.28
11	5.5	-85	-80	-84	-82	-86	-100	-100	112.36	155.32	126.11
12	6	-88	-81	-86	-86	-88	-102	-102	113.12	156.65	126.87
13	6.5	-89	-82	-88	-89	-90	-104	-104	113.81	157.87	127.56
14	7	-90	-84	-90	-90	-91	-106	-106	114.46	159.00	128.21
15	7.5	-91	-86	-94	-93	-94	-108	-108	115.06	160.06	128.81
16	8	-93	-88	-98	-97	-96	-110	-110	115.62	161.05	129.37
17	8.5	-95	-90	-100	-99	-98	-112	-112	116.14	161.97	129.89
18	9	-97	-92	-104	-100	-100	-113	-113	116.64	162.85	130.39
19	9.5	-98	-98	-110	-107	-103	-114	-114	117.11	163.68	1ju30.86
20	10	-101	-101	-119	-114	-108	-115	-115	117.56	164.46	131.31

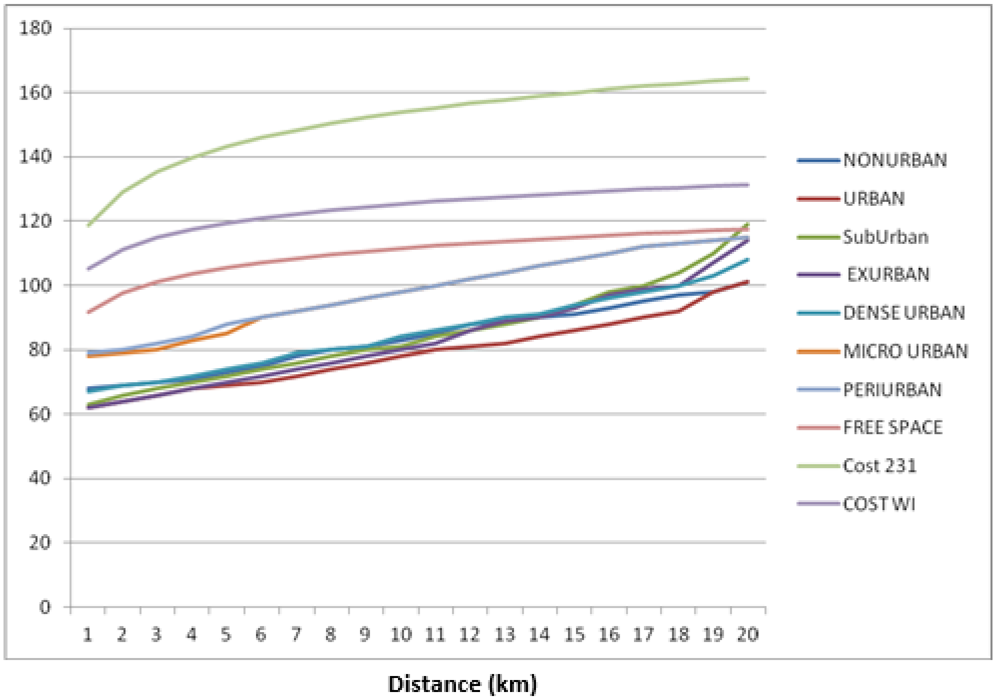

Figure 1: Analysis of Seven Base Stations at 1800 MHz for January, 2017.

Table 2: Mean Received Signal Level at 1800 MHz for February, 2017.

S/N	TX/RX	NONURBAN	URBAN	SubUrban	EXURBAN	DENSE URBAN	MICRO URBAN	PERIURBAN	FREE SPACE	COST 231	COST WI
	Distance (km)	dbm	dbm	Dbm	dbm	Dbm	dbm	Dbm			
1	0.5	-53	-72	-72	-72	-60	-72	-61	91.53	118.64	105.28
2	1	-55	-74	-78	-74	-64	-76	-64	97.56	129.24	111.31
3	1.5	-58	-76	-80	-76	-68	-78	-69	101.08	135.44	114.83
4	2	-60	-79	-84	-78	-70	-80	-70	103.58	139.84	117.33
5	2.5	-61	-80	-86	-80	-74	-82	-72	105.51	143.26	119.26
6	3	-63	-83	-88	-82	-76	-84	-74	107.10	146.04	120.85
7	3.5	-65	-85	-90	-84	-78	-86	-76	108.44	148.40	122.19
8	4	-68	-88	-94	-86	-80	-88	-78	109.60	150.44	123.35
9	4.5	-70	-90	-95	-88	-82	-90	-80	110.62	152.25	124.37
10	5	-72	-91	-97	-90	-86	-92	-82	111.53	153.86	125.28
11	5.5	-74	-93	-99	-92	-88	-94	-84	112.36	155.32	126.11
12	6	-76	-95	-100	-96	-90	-96	-86	113.12	156.65	126.87
13	6.5	-78	-98	-101	-98	-94	-98	-88	113.81	157.87	127.56
14	7	-80	-100	-102	-100	-96	-100	-90	114.46	159.00	128.21
15	7.5	-82	-101	-104	-102	-98	-101	-93	115.06	160.06	128.81
16	8	-86	-104	-106	-104	-100	-102	-96	115.62	161.05	129.37
17	8.5	-89	-106	-108	-106	-104	-103	-99	116.14	161.97	129.89
18	9	-90	-108	-110	-107	-108	-105	-100	116.64	162.85	130.39
19	9.5	-95	-111	-115	-108	-110	-106	-107	117.11	163.68	130.86
20	10	-100	-113	-119	-109	-118	-107	-115	117.56	164.46	131.31

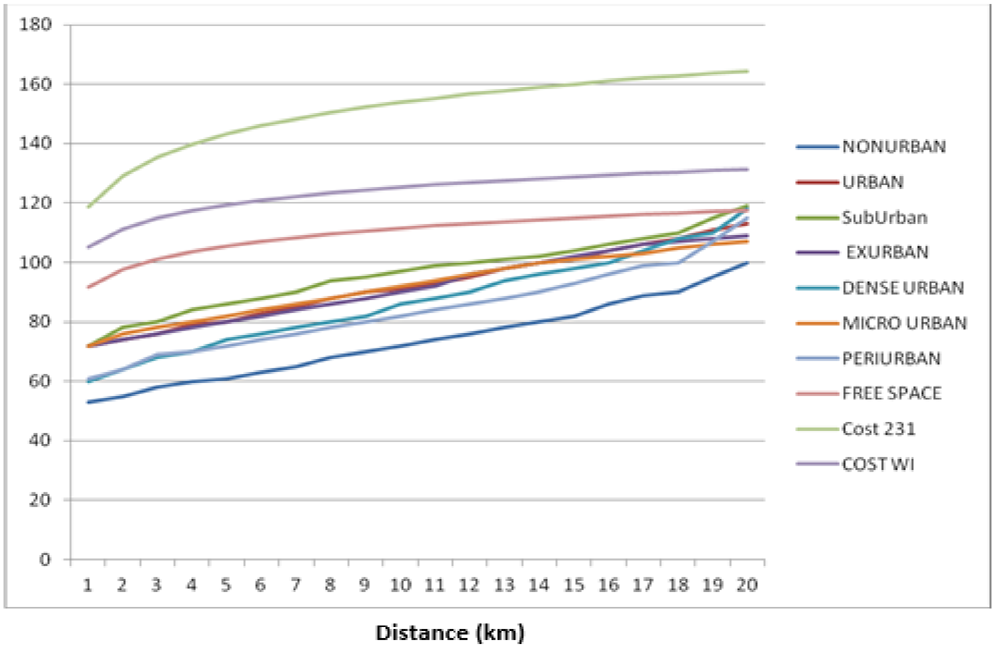

Figure 2: Analysis of Seven Base Stations at 1800 MHz for February, 2017.

Table 3: Mean Received Signal level at 1800 MHz for March, 2017.

S/N	TX/RX	NONURBAN	URBAN	SubUrban	EXURBAN	DENSE URBAN	MICRO URBAN	PERIURBAN	FREE SPACE	COST 231	COST WI
	Distance (km)	dbm	dbm	Dbm	dbm	dbm	dbm	Dbm			
1	0.5	-50	-53	-53	-57	-55	-50	-52	91.53	118.64	105.28
2	1	-53	-55	-55	-59	-56	-52	-55	97.56	129.24	111.31
3	1.5	-56	-57	-57	-60	-57	-54	-57	101.08	135.44	114.83
4	2	-58	-59	-59	-63	-58	-56	-59	103.58	139.84	117.33
5	2.5	-60	-60	-60	-65	-59	-58	-63	105.51	143.26	119.26
6	3	-63	-63	-63	-69	-60	-60	-68	107.10	146.04	120.85
7	3.5	-65	-65	-65	-70	-62	-63	-70	108.44	148.40	122.19
8	4	-68	-69	-69	-73	-64	-65	-73	109.60	150.44	123.35
9	4.5	-70	-70	-70	-75	-65	-69	-75	110.62	152.25	124.37
10	5	-73	-73	-73	-77	-67	-70	-79	111.53	153.86	125.28
11	5.5	-75	-75	-75	-79	-69	-73	-80	112.36	155.32	126.11
12	6	-77	-77	-77	-80	-70	-75	-83	113.12	156.65	126.87
13	6.5	-79	-80	-79	-82	-73	-77	-85	113.81	157.87	127.56
14	7	-80	-82	-80	-84	-75	-79	-88	114.46	159.00	128.21
15	7.5	-83	-85	-83	-86	-77	-80	-90	115.06	160.06	128.81
16	8	-85	-88	-85	-89	-79	-83	-93	115.62	161.05	129.37
17	8.5	-88	-90	-90	-90	-80	-85	-95	116.14	161.97	129.89
18	9	-90	-95	-95	-93	-85	-87	-100	116.64	162.85	130.39
19	9.5	-95	-100	-100	-97	-90	-90	-110	117.11	163.68	130.86
20	10	-100	-110	-`110	-100	-98	-100	-120	117.56	164.46	131.31

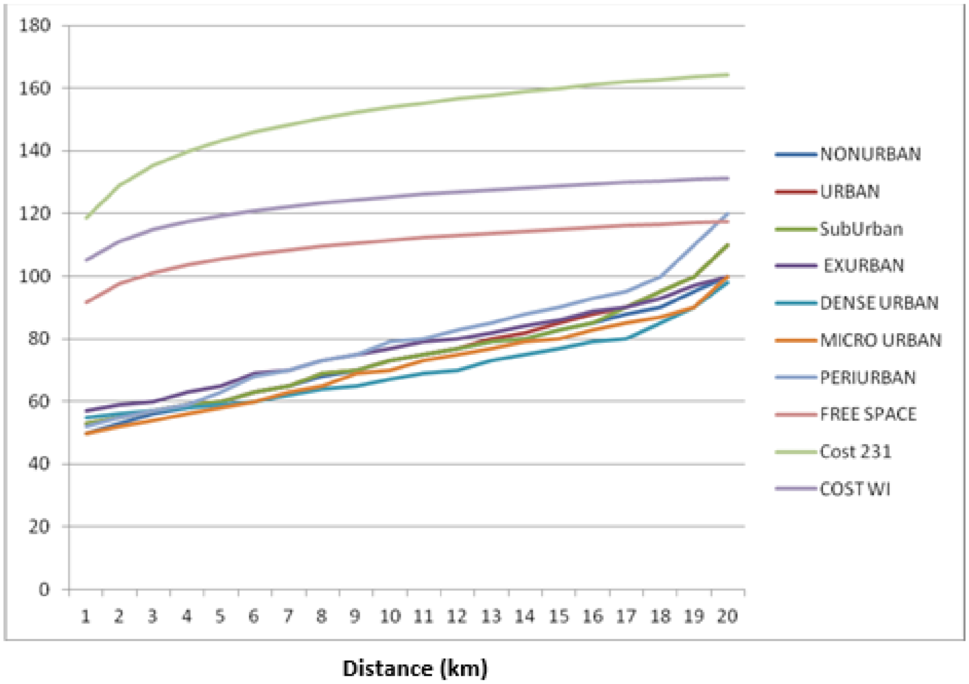

Figure 3: Analysis of Seven Base Stations at 1800 MHz for March, 2017.

Table 4: Mean Received Signal Level at 1800 MHz for April, 2017.

S/N	TX/RX	NONURBAN	URBAN	SubUrban	EXURBAN	DENSE URBAN	MICRO URBAN	PERIURBAN	FREE SPACE	COST 231	COST WI
	Distance (km)	dbm	dbm	Dbm	dbm	dbm	dbm	Dbm			
1	0.5	-62	-51	-69	-53	-78	-72	-61	91.53	118.64	105.28
2	1	-64	-54	-70	-54	-79	-73	-62	97.56	129.24	111.31
3	1.5	-68	-57	-71	56	-80	-74	-67	101.08	135.44	114.83
4	2	-70	-60	-72	-58	-81	-75	-70	103.58	139.84	117.33
5	2.5	-73	-63	-73	-59	-83	-78	-73	105.51	143.26	119.26
6	3	-75	-65	-74	-60	-85	-80	-75	107.10	146.04	120.85
7	3.5	-78	-67	-75	-63	-87	-84	-78	108.44	148.40	122.19
8	4	-80	-70	-76	-65	-90	-86	-80	109.60	150.44	123.35
9	4.5	-84	-73	-77	-70	-93	-88	-84	110.62	152.25	124.37
10	5	-86	-75	-78	-72	-97	-90	-86	111.53	153.86	125.28
11	5.5	-88	-79	-79	-74	-100	-92	-88	112.36	155.32	126.11
12	6	-90	-80	-80	-76	-102	-94	-90	113.12	156.65	126.87
13	6.5	-92	-85	-81	-78	-103	-96	-92	113.81	157.87	127.56
14	7	-94	-90	-83	-80	-105	-98	-94	114.46	159.00	128.21
15	7.5	-96	-95	-83	-84	-107	-100	-96	115.06	160.06	128.81
16	8	-98	-100	-84	-86	-110	-106	-98	115.62	161.05	129.37
17	8.5	-100	-105	-85	-90	-103	-110	-100	116.14	161.97	129.89
18	9	-106	-110	-86	-96	-105	-112	-106	116.64	162.85	130.39
19	9.5	-110	-115	-89	-100	-108	-114	-110	117.11	163.68	130.86
20	10	-112	-120	-90	-102	-114	-115	-111	117.56	164.46	131.31

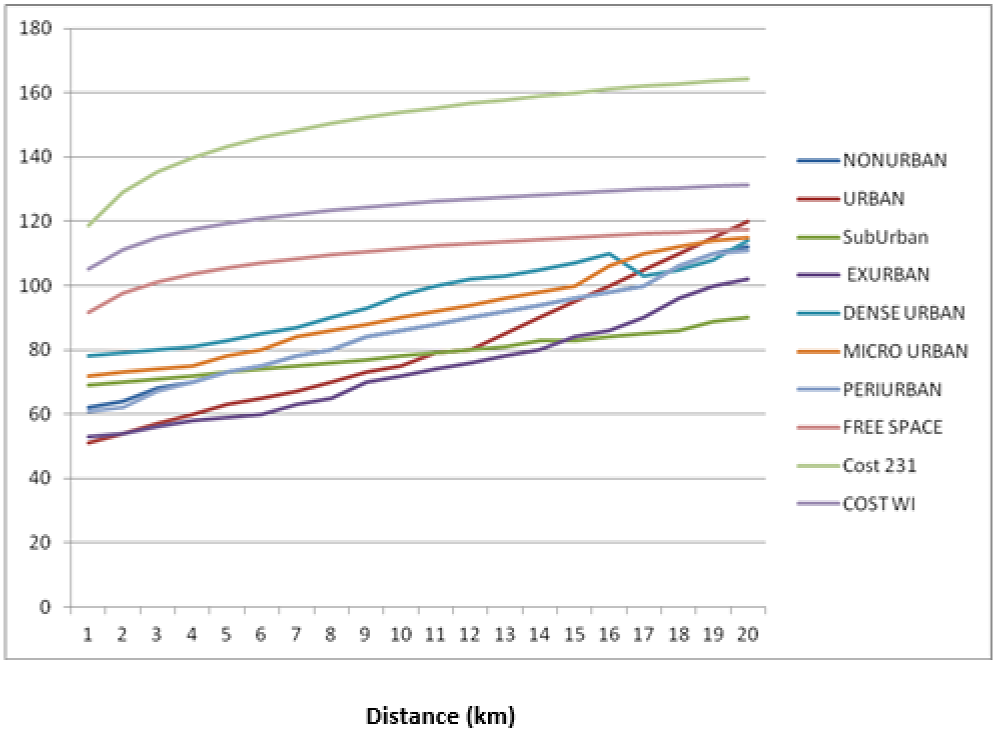

Figure 4: Analysis of Seven Base Stations at 1800 MHz for April, 2017.

Table 5: Mean Received Signal Level at 1800 MHz for May, 2017.

S/N	TX/RX	NONURBAN	URBAN	SubUrban	EXURBAN	DENSE URBAN	MICRO URBAN	PERIURBAN	FREE SPACE	COST 231	COST WI
	Distance (km)	Dbm	dbm	Dbm	dbm	dbm	dbm	Dbm			
1	0.5	-50	-52	-56	-68	-55	-50	-67	91.53	118.64	105.28
2	1	-53	-54	-70	-70	-56	-53	-70	97.56	129.24	111.31
3	1.5	-56	-68	-72	-71	-57	-56	-76	101.08	135.44	114.83
4	2	-58	-70	-76	-73	-58	-58	-78	103.58	139.84	117.33
5	2.5	-59	-73	-78	-75	-59	-60	-80	105.51	143.26	119.26
6	3	-60	-75	-80	-80	-60	-63	-82	107.10	146.04	120.85
7	3.5	-63	-78	-82	-83	-62	-65	-84	108.44	148.40	122.19
8	4	-65	-80	-84	-85	-64	-68	-86	109.60	150.44	123.35
9	4.5	-70	-84	-86	-87	-65	-70	-88	110.62	152.25	124.37
10	5	-72	-86	-88	-89	-67	-73	-90	111.53	153.86	125.28
11	5.5	-74	-88	-90	-90	-69	-75	-92	112.36	155.32	126.11
12	6	-76	-90	-92	-92	-70	-77	-94	113.12	156.65	126.87
13	6.5	-78	-92	-94	-94	-73	-79	-96	113.81	157.87	127.56
14	7	-80	-94	-96	-96	-75	-80	-98	114.46	159.00	128.21
15	7.5	-84	-96	-98	-98	-77	-83	-100	115.06	160.06	128.81
16	8	-86	-98	-100	-100	-79	-85	-101	115.62	161.05	129.37
17	8.5	-90	-100	-101	-106	-80	-88	-102	116.14	161.97	129.89
18	9	-96	-106	-102	-110	-85	-90	-103	116.64	162.85	130.39
19	9.5	-102	-110	-103	-112	-90	-95	-105	117.11	163.68	130.86
20	10	-108	-112	-105	-113	-98	-100	-106	117.56	164.46	131.31

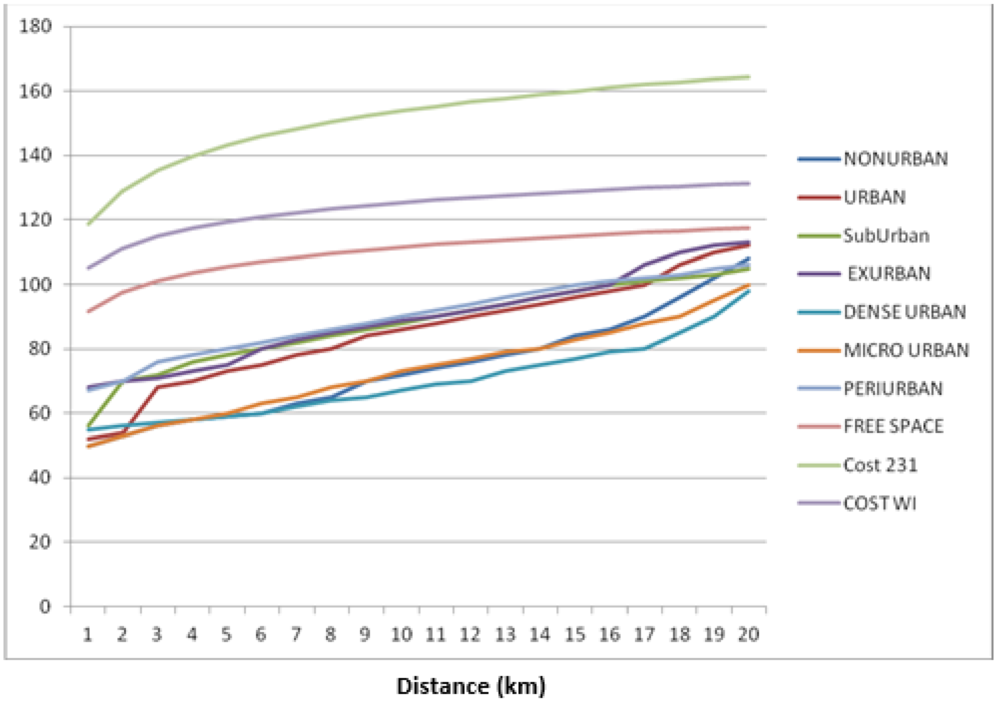

Figure 5: Analysis of Seven Base Stations at 1800 MHz for May, 2017.

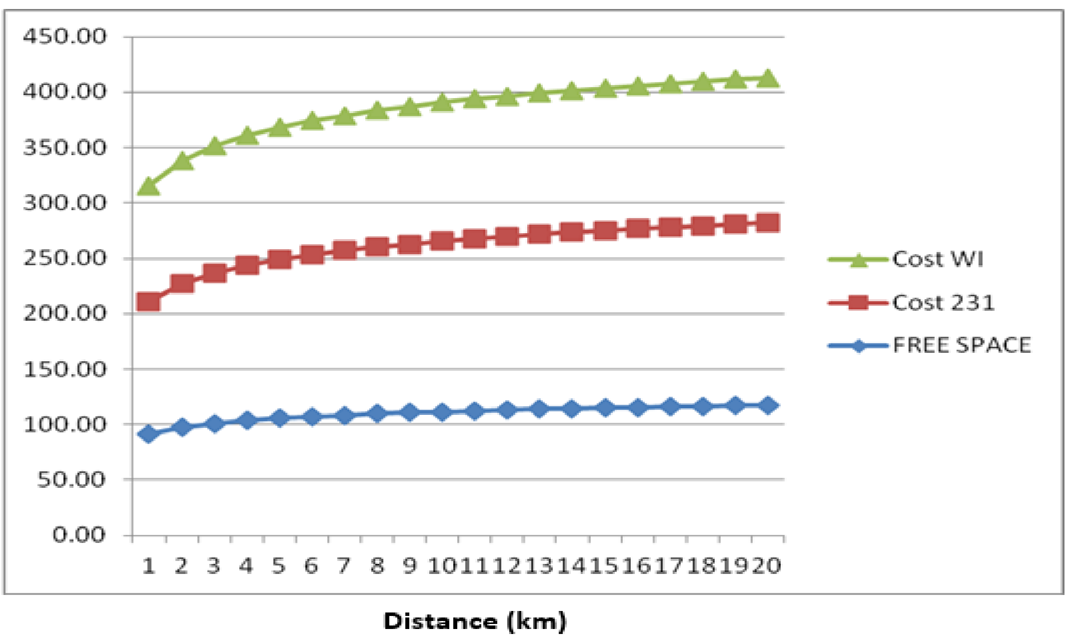

Figure 6: Performance of COST WI, COST 231 and Free Space Models.

CONCLUSION

In this study, the measured path losses in seven cells were compared with the theoretical path loss models: COST 231, Free Space, and COST Walfish Ikegami model. The measured path loss, when compared with theoretical values from the theoretical models, showed that, the closest agreement with the path loss predicted by the Hata model in terms of path loss exponent prediction and standard deviation error analysis. Based on this, an optimized Hata model for the prediction of path loss experienced by GSM signals in the 1800MHz band in seven stations of Lagos, Nigeria has been developed. The optimized model showed high accuracy and is able to predict path loss with smaller standard deviation errors as compared to the Hata model.

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