Computer Simulation of Path Loss Characterization of a Wireless Propagation Model in Kwara State, Nigeria

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Abstract— **Propagation models are used extensively in network planning, particularly for conducting feasibility studies and during initial deployment. Accurate characterization of radio propagation channel through important parameters and a mathematical model is important for predicting signal coverage, achievable data rates, specific performances attributes of signaling and reception schemes. Hence, this work sets out to determine the propagation model that is suitable in Kwara state, Nigeria. The model is to modify the Okumura-Hata model which has wide acceptability and currently in use for mobile radio propagation to suit the terrain of Kwara state, Nigeria. The Okumura- Hata's equation for predicting signal path loss was modified and simulated in C++ Programming language. The results were compared with the Empirical method results from the Okumura-Hata's model.**

From the results obtained, necessary adjustments to the model are proposed for use in mobile communications system designed to improve the Quality of Service in the system. The simulation method of this research proves to be more efficient, faster and accurate than the Physical and Empirical methods that are mostly used. The simulated average propagation path loss of this research work is lower than that of the Okumura-Hata's average propagation path loss for urban area (medium size city) and suburban areas. This implies that the simulation method of this research will improve the Quality of Services of the research areas if employed.

***Keywords*— Path-loss, Propagation model, Quality of Service, Okumura-Hata model, C++, Kwara State**

I. INTRODUCTION

With the rapid growth in wireless telecommunications services due to increasing desire for next generation services by mobile subscribers, there has been an increasing need for proper network coverage predictions. This planning requires a good understanding of the fundamental limitations caused by environment specific conditions to radio signal propagation, (Ubom et al., 2011,)

Propagation models have traditionally focused on predicting the received signal strength at a given distance from the transmitter, as well as the variability of the signal strength in a close spatial proximity to a particular location. Propagation models that predict the signal strength for an arbitrary transmitter-receiver (T-R) separation distance are useful in estimating the radio coverage area of a transmitter. Propagation models are useful for predicting signal attenuation or path loss. This path loss information may be used as a controlling factor for system performance or coverage so as to achieve perfect reception. (Ayyappan et al., 2008)

Although path loss characteristics have been modeled by many technical researchers, research has shown that existing models suffer differences when deployed at areas that were not initially was designed for (Ubom et al., 2011). Therefore, to determine the actual effect of propagation path loss in Kwara State, Nigeria, a modified radio propagation path loss model is simulated using C++ to solve the problems of wireless network design in Kwara state, Nigeria.

II. MOBILE RADIO PROPAGATION MODELS

Propagation models are used extensively in network planning, particularly for conducting feasibility studies and during initial deployment (Edeko, 2010). Accurate characterization of radio propagation channel through important parameters and a mathematical model is important for predicting signal coverage, achievable data rates, specific performances attributes of signalling and reception schemes. (Ayyappan et al., 2008)

There are various propagation prediction models for mobile radio communications systems. Such as Long-Rice model, Okumura-Hata's model, Lee's model, Durin's model, Walfisch and Bertoni's model, cost-123 model, ECC 33 model etc. In this work, particular attention is given to prediction model by Okumura-Hata.

This is because the model has been widely accepted and as such, it will be used to evaluate the simulated results.

III. OKUMURA-HATA MODEL

The Okumura-Hata's model was first described by Yoshihisa Okumura and then modified by Hata. This model is based on propagation measurements conducted in Kanto, Tokyo in Japan (Shoewu et al., 2010). The initial model by Okumura presents signal strength prediction curves over a distance in a quasi-smooth urban area. From these prediction curves, Hata developed a mathematical formulation for simple computational applications. Hata presented the urban area propagation loss as a standard formula, along with additional correction factors for application in other situations such as suburban, rural, among others, therefore this model is called Okumura-Hata's model.

The Okumura-Hata model is expressed as:

$$L_P = x + y \log_{10}(f_c) - 13.82\log_{10}(h_t) - a(h_r) + (44.9 - 6.55\log_{10}(ht)) \log_{10}(d) \text{ ---- } (1)$$

Where x and y are frequency dependent parameters and are given as 69.55 and 26.16 respectively within the frequency range.

H_t =transmitter antenna height in meters,
H_r =receiver antenna height in meters
$a(h_r)$ =receiver correction factor,
$a(h_r) = [1.1\log_{10}(f) - 0.7)\, h_r - (1.56\log_{10}(f_c) - 0.8]$ ----(2)
The specification ranges for the model are:
$150 \leq f_c \leq 1500$ (f_c in MHz)
F_c = the carrier frequency
$30 \leq h_t \leq 200$ (h t in m)
h_t = transmitting antenna height
$1 \leq d \leq 20$ (d in km),
d = distance between transmitter and receiver

IV. METHODS USED TO DETERMINE PATH LOSS

i) Physical method: This method is used mostly for feasibility studies. A transmitter will be placed on the highest building in the area; the transmitter will transmit at a given frequency i.e. 900MHz, A radio frequency analyzer will be synchronized to the transmitter frequency and when this is done, the RF analyzer distances will be varied and the results for distances will be recorded, this will now be computed using the Okumura-Hata equation, and it will be compared with the Okumura-Hata's model result.

ii) Measurement method (Empirical Method): This involves field measurement by using an existing base station and the distance from the station will be varied at a distance of 500 meters. The receiving signal will now be used to calculate the path loss. The Equipment set up is placed inside a vehicle that maintains at an average speed of 30km/h; data collection is done starting from a distance of 500m from the base station. The vehicle then moves along the direction of the main lobe of the directional antenna away from the site until it gets to the coverage border. This process is repeated for the site under which the experiment is performed.

iii) Simulation method (Theoretical method): This is done by physical site survey to the selected sites. During the sites survey, any obstacle such as buildings, structures or trees capable of causing obstruction of radio signal along the line of sight are identified and measured. The average height of the building is noted, also the vegetation of the site and any physical structure like mountain, hills, valley etc are noted and their heights also noted.

The Simulation method is more efficient, faster and accurate than the Physical and Empirical methods. It is flexible and it can be used for different terrains; the method is not cumbersome like the Physical and the Empirical method. The distances simulated are the true distances but in the other methods, this is not possible because the distances will follow the road path and this may not be the accurate distance between the transmitter and the receiver. The Simulated method can be used to cover large distance which will be difficult for the other two methods to cover.

The simulated method can be used for both feasibility studies and during initial deployment while the other two methods cannot be used for the two tasks. For this reasons, l will make use of the simulation method using C++ will be employed because of it's flexibility.

V. SITES USED

Offa town was chosen for this research work as a suburban, as an area with terrain features such as dense vegetation mostly of tall trees, classrooms, Administrative blocks, students' hostels, residential buildings and few tall buildings in the town. The measurements were taken from Federal Polytechnic Offa towards Owode and towards Ijagbo. By this, the entire town (Offa) was covered.

As a town, it is expected that the building will be at most two-storey building, but Offa is a Polytechnic town, where there are four to five-storey buildings, which is calculated to be between 40meters to 45meters, this is not common with suburban towns. To model for a town like Offa which has unexpected tall building, the height of the buildings and the trees must be taken into consideration.
The expected height for a mask in a town is 30-35 meters, but a height of 50 meters will be simulated for Offa, having in mind that the institution may build high-rise in future.

Ilorin was chosen as a medium city. As a medium city, we expect it to have high-rise and to be highly populated. The high rise is not common from Maraba to

Muritala towards A-division, then towards Ganmo. This is unusual for a big city as Ilorin is highly populated and the flow of traffic is very high both in the morning and evening, and this will definately increase the inflow of calls in this area apart from the rush hour which is supposed to be in the afternoon. The terrain is a flat surface with trees having an average height of 45meters, with big canopies that can cause attenuation of the signal, also buildings in the sites have an average height of 50 meters. The high population must be put into consideration when planning for this axis, also the tall trees and the building must be considered. The simulated height for the site will be 60 meters, so as to cut off the attenuation in the site

The research followed the following procedures

- Identify the site
- Survey the town, to know the height of the building and vegetation that can affect path loss
- Identify the parameters to be used (Those to be constant and those to be varied)
- Modify the Okumura-Hata's model to suit the cities
- Slot the variable into the equation (height and distance)
- Simulate the equation using C++
- Simulated results
- The simulated result will be compared with Okumura-Hata for Suburban

VI. MODEL EQUATIONS

The equations for urban areas (i.e. Medium or Mega cities) are expressed in equation (3) and the equation for Suburban areas i.e. Towns is expressed in equation (5). The a(hr) which is the correction factor for the receiving antenna is expressed for a medium size city in equation (4), while for the Suburban areas i.e. Towns, the a(hr) which is the correction factor for the receiving antenna is expressed in equation 4(the same with medium city).

In carrying out this work, Hata's equation for predicting propagation path loss (L_p) is expressed below:

For urban areas (i.e. Medium or Mega cities) L_p (in dBm) is expressed as follows:

$$L_p = 69.55+26.16\log_{10}(fc) - 13.82\log_{10} h_t - a(hr) + (44.9 - 6.55 \log_{10}(h_t)\log_{10} d \text{ ------------(3)}$$

L_p is in dBm

Where

$150 \leq f_c \leq 1500$ (f_c in MHz)

F_c = the carrier frequency

$30 \leq h_t \leq 200$ (h_t in m)

h_t = transmitting antenna height

$1 \leq d \leq 20$ (d in km),

D = distance between transmitter and receiver

a (hr) = the correction factor for the receiving antenna and is computed as follows:

i) For a medium-size city:

$$a(h_r) = (1.1 \log_{10} f_c - 0.7)\, h_r - (1.56\log_{10} f_c - 0.8) \quad \text{---- (4)}$$

Where

$1 \leq h_r \leq 10$ (h_r in m)

iii) **For Suburban areas i.e. Towns**

$$L_{ps} = L_p(\text{urban}) - 2\,[\log_{10} (\frac{f_c}{28}]^2 - 5.4 \quad \text{----------------(5)}$$

For a medium-size city (Ilorin):

$$Lp = 69.55+26.16\log_{10}(900) - 13.82\log_{10} (60m) - a(hr) + (44.9 - 6.55 \log_{10}(60m)\log_{10} d \text{ ------------(6)}$$

Where

a (hr) = the correction factor for the receiving antenna and is computed as follows:

For a medium-size city:

$$a(hr) = (1.1 \log_{10} fc - 0.7)\, hr - (1.56\log_{10} fc - 0.8)$$

Where

$1 \leq hr \leq 10$ (hr in m)

For Suburban areas i.e. Towns (Offa)

$$Lp = 69.55+26.16\log_{10}(fc) - 13.82\log_{10} (50m) - a(hr) + (44.9 - 6.55 \log_{10}(50m)\log_{10} d - 2\,[\log_{10} (\frac{f_c}{28}]^2 - 5.4 \text{ --(7)}$$

Where

a (hr) = the correction factor for the receiving antenna is expressed as:

$a(hr) = (1.1 \log_{10} fc - 0.7)\, hr - (1.56\log_{10} fc - 0.8$ (i.e. the a(hr) for suburban is the same as that for medium city).

VII. MODIFIED HATA'S EQUATIONS

The modifications were done based on the theoretical method. Okumura-Hata model neglects terrain profile between transmitter and receiver i.e. hills and other obstacles between transmitter and receiver were not considered (Ayyappan et al., 2008) .This is because both Hata and Okumura made the assumption that transmitter would normally be located on hills (Ayyappan et al., 2008), the assumptions are corrected by taking the terrains of the research sites into consideration and the heights were predicted based on the terrains

VIII. ANALYSIS OF THE SIMULATION RESULTS AND DISCUSSION

The simulated results for Ilorin (city) and Offa (Suburban) are shown in Table 1. Table 2 shows the comparison of urban simulated path loss result with Okumura-Hata's model result for urban area. Table 3 shows the comparison of suburban simulated path loss result with Okumura-Hata's model for suburban.

Figure1 is a graphical representation of the comparison of the urban simulated path loss results with the Okumura-Hata's model results for urban area; Figure 2 shows the graphical representation of the comparison of suburban simulated path loss result with Okumura-Hata's model for suburban. All the graphical representations were done using Microsoft Excel

Table1. The Simulated Results for Ilorin and Offa

T_X/R_X DISTANCES (KM)	ILORIN	OFFA
O.5KM	103.22	93.94
1.OKM	112.39	102.56
1.5KM	117.75	107.61
2.0KM	121.60	111.19
2.5KM	124.52	113.97
3.0KM	126.94	116.25
3.5KM	128.98	118.16
4.0KM	130.75	119.82
4.5KM	132.31	121.29
5.0KM	133.71	122.60
5.5KM	134.96	123.79
6.0KM	136.12	124.87
6.5KM	136.71	125.86
7.0KM	138.16	126.79
7.5KM	139.07	127.65
8.0KM	139.93	128.46
8.5KM	140.73	129.21
9.0KM	141.49	129.92
9.5KM	142.20	130.59
10.0KM	142.88	131.23

Table 2 Comparison of Urban (Ilorin) Simulated Path Loss Results with Okumura-Hata's Model

T_X/R_X DISTANCES	ILORIN	OKUMURA-HATA MODEL FOR URBAN
O.5KM	103.22	123.66
1.OKM	112.39	134.26
1.5KM	117.75	140.46
2.0KM	121.60	144.86
2.5KM	124.52	148.28
3.0KM	126.94	151.06
3.5KM	128.98	153.42
4.0KM	130.75	155.47
4.5KM	132.31	157.27
5.0KM	133.71	158.88
5.5KM	134.96	160.34
6.0KM	136.12	161.60
6.5KM	136.71	162.89
7.0KM	138.16	164.04
7.5KM	139.07	165.08
8.0KM	139.93	166.07
8.5KM	140.73	166.99
9.0KM	141.49	167.87
9.5KM	142.20	168.70
10.0KM	142.88	169.48

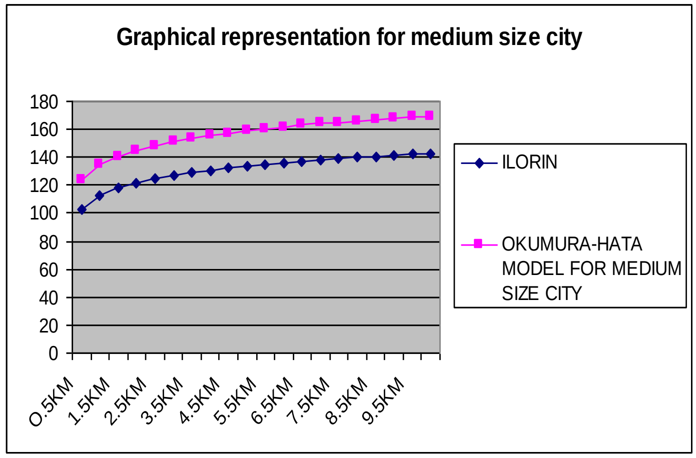

Figure 1 Graphical Representation of the Path Loss for Ilorin and Okumura-Hata Path Loss (Urban Area)

In Table 2, the urban simulated path loss results were compared with that of Okumura-Hata's model for urban area. It shows that the simulated result have low path loss compared with that of Okumura-Hata's model for urban. The average path loss for Ilorin is 131.22dBm while the average path loss for Okumura-Hata's urban area is 156.03dBm.This implies that the simulation method have considered the terrain problem of the urban area in Nigeria and the result can be used to resolve the path loss caused by the terrain.

The graph in figure 2 shows that for the same distances, the simulated path loss for the urban areas are lower when compared to that of Hata for suburban area. This implies that the simulation method can be used to reduce path loss that affect the Quality of Services (QoS), the simulation method have taken the terrain of the urban area into consideration.

The differences in the simulated path loss results and the Okumura-Hata's path loss results are certainly due to the differences in the topology and the differences in the terrain between Ilorin, Kwara State, Nigeria and Tokyo.

Table 3 Comparison of Suburban (Offa) Simulated Path Loss Results with Okumura-Hata's Model

T_X/R_X DISTANCES	OFFA	OKUMURA-HATA MODEL (SUBURBAN AREA)
0.5KM	93.94	122.52
1.0KM	102.56	133.12
1.5KM	107.61	139.32
2.0KM	111.19	143.72

2.5KM	113.97	147.14
3.0KM	116.25	149.92
3.5KM	118.16	152.28
4.0KM	119.82	154.33
4.5KM	121.29	156.13
5.0KM	122.60	157.74
5.5KM	123.79	159.20
6.0KM	124.87	160.53
6.5KM	125.86	161.75
7.0KM	126.79	162.90
7.5KM	127.65	164.66
8.0KM	128.46	164.93
8.5KM	129.21	165.85
9.0KM	129.92	166.73
9.5KM	130.59	167.56
10.0KM	131.23	168.34

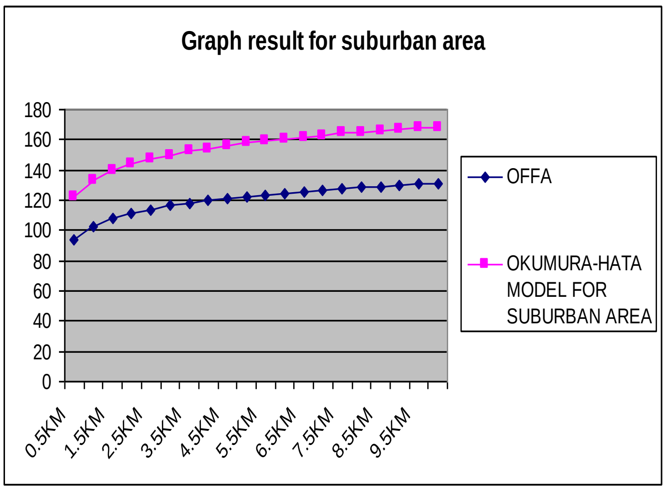

Figure 2 Graphical Representations of the Path Loss for Offa and Okumura-Hata path loss (suburban Area)

In Table 3, the Suburban simulated path loss result was compared with that of Okumura-Hata's model for Suburban. It shows that the simulated result have low path loss compared with that of Okumura-Hata's model for Suburban. The average path loss for Offa is 120.29dBm while the average path loss for Okumura-Hata's suburban area is 154.93dBm. This implies that the simulation method has conceded the terrain problem of the Suburban area in Nigeria and the result can be used to resolve the path loss caused by the terrain.

The graph in figure 2 shows that for the same distances, the simulated path loss for the suburban area is lower compared to that of Hata for suburban area, this implies that the simulation method can be used to reduce path loss that affect the Quality of Services (QoS), the simulation method have taken the terrain of the suburban area into consideration. The differences in the simulated path loss results and the Okumura-Hata's path loss results is certainly due to the differences in the topology and the differences in the terrain of Offa-town in Kwara State, Nigeria and Tokyo.

IX. CONCLUSION

Radio transmission in a mobile communication system often takes place over irregular terrain. The terrain profile of a particular area needs to be taken into account for estimating the path loss. The terrain profile may vary from a simple curvature of the earth surface profile to a highly curved mountainous profile. From this research, it was established that all radio system suffer path loss, which are influenced either by the distance between transmitter and receiver, motion and terrain.

The results from this research show that path loss in Kwara State can be reduced if the different terrains are taken into consideration during network planning, particularly when conducting feasibility studies, initial deployment and during deployment. Since, the objective of this research is to develop a model that can help in planning better mobile wireless network and to address the poor quality of mobile network services in Offa-town and Ilorin in Kwara State, Nigeria.

The simulated results from the modified Hata-Okumura model will help in the planning and in the optimization of the networks of the investigated environment as the simulated method has been proved to be better and faster than the Empirical method. Furthermore, the simulation method of this research can be used during network planning for conducting feasibility studies and during initial deployment, this will save time and cost.

The major reasons for poor QoS is bad planning during initial development, all these can be solved by using the simulation modelling technique discussed in this research. The Simulation method of this research is more efficient, faster and accurate than the physical and empirical methods. It is flexible and can be used for different terrains; the method is not cumbersome like the Physical and the Empirical method. The distances simulated are the true distances but in the other methods, this is not possible because the distance measurement follows the road path and this may not be the accurate distances between the transmitter and the receiver. The Simulated method can be used to cover large distance which will be difficult for the other two methods to cover. Lastly, the simulated method can be used for both feasibility studies and during initial deployment, while the other two methods cannot be employed for the two tasks.

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