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Path Profile Modeling of Telecommunication Signals for a Telecomm Provider in the University of Benin

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Abstract

In this paper a path profile for the University of Benin based on field measurement data obtained from an existing telecom provider is provided and documented. The area of interest is the Faculty of Engineering and its environs. Measurements of received signal strength from the base station of the provider were obtained within the coverage area of 50m to 2km using handheld software: Signal strength© and Net monitor©. Measurement tape, sticks and chalks were used to mark distances on the soil and tarred road respectively. The measured path loss for 2G and 3G signals for the provider was obtained and a model was developed afterward to enable determination of signal path loss and exponent. These models can be used for simulation and planning of wireless and specifically telecommunication systems employing both 2G and 3G technology for the University of Benin especially in and around the area of the Faculty of Engineering. These models represent important properties of signal propagation that affect the transmission of electromagnetic signals. They also help the design engineer to make changes to deployment blueprints and analyze the cost of these changes without spending much time, money and effort.

1. Introduction

In telecommunication, a path profile refers to the physical features of a propagation path in the vertical plane containing both endpoints of the path, showing the surface of the Earth and including trees, buildings, and other features that may obstruct the radio signal, for cellular network or mobile network [1].

A cellular network or mobile network is a communication network where the last link is wireless. The network is distributed over land areas called cells, each served by at least one fixed-location transceiver, but more normally three cell sites or base transceiver stations [2].These base stations provide the cell with the network coverage which can be used for transmission of voice, data, and other types of content. A cell typically uses a different set of frequencies from neighboring cells, to avoid interference and provide guaranteed service quality within each cell [3]. These cells provide radio coverage over a wide geographic area. This enables a large number of portable transceivers (e.g., mobile phones, tablets and laptops equipped with mobile broadband modems, pagers, etc.) to communicate with each other and with fixed transceivers and telephones anywhere in the network, via base stations, even if some of the transceivers are moving through more than one cell during transmission. The most common example of a cellular network is a mobile phone (cell phone) network. A mobile phone is a portable telephone which receives or makes calls through a cell site (base station) or transmitting tower. Radio waves are used to transfer signals to and from the cell phone [4].

As the wireless communications systems became more and more sophisticated, so did the cost of planning and implementation of this systems. This leads to the development of Radio Propagation Models also known as Channel models. They are used for the design, simulation and planning of wireless systems. These models represent important properties of propagation channels that affect the transmission of electromagnetic signals. They also help the design engineer to make changes to blueprints and analyze the cost of these changes without spending much time, money and effort. An important aspect of these models is the path-loss of the propagation channel. This can be defined as the loss of energy in free space due to the conservation of energy and geometric reasons. These reasons are due to the effects of reflection, refraction, diffraction, scattering etc.

1.1. Related Work

There are several models that can be used for the calculation of path losses in line with received signal strength while taking into consideration both small- and large-scale effects.

i. Free-space propagation model

This model is used for predicting received signal strength when the transmitter and the receiver both have a clear, unobstructed line-of-sight. This model predicts the received signal by making it a function of the distance between both the transmitter and the receiver raised to some power i.e., it is a power function.

$$\text{Path-loss} = 20\log10\,(d) + 20\log10\,(f) - 27.55 \qquad (1)$$

Where d is the distance from the transmitting station and f is the frequency of the transmission.

ii. Okumura- Hata propagation model

In mobile communications, the terrain between the transmitter and the receiver plays a very important role in determining the signal strength at the receiver. Okumura-Hata model is one of the popular models, especially used for urban or suburban areas. It is generally applied for frequencies in the range of 150 MHz - 1920 MHz, for a distance separation ranging from 1 km to 100 km, and for antenna heights from 30 m to 1000 m.

In the first form, the path-loss (in dB) is written as:

$$PL = PL_{freespace} + A_{exc} + H_{cb} + H_{cm} \qquad (2)$$

Where PLfreespace is the Free-space path-loss, A_{exc} is the excess path-loss (as a function of distance and frequency) for a BS height is h_b, and a MS height is h_m. H_{cb} and H_{cm} are the correction factors that are provided in graphs. The more common form is a curve fitting of Okumura's original results. In that implementation, the path-loss is written as:

$$P_L = A + B\log(d) + C \qquad (3)$$

A, B, and C are factors that depend on frequency and antenna height.

$$A = 46.3 + 33.9\log(f_c) - 13.82\log(h_b) - a(h_m) \qquad (4)$$

$$B = 44.9 - 6.55\log(h_b) \qquad (5)$$

$$C = -2\left[log\left(\frac{f_c}{28}\right)\right]^2 - 5.4 \qquad (6)$$

Here f_c is given in MHz and d in km.
The function a (h_m) and the factor C depend on the environment, which is suburban as related to the scope of study.
For suburban environment;
The function a (h_m) in suburban and rural areas is the same as for urban (small and medium-sized Cities) areas.

For rural areas:

$$C = -4.78[\log(fc)]^2 + 18.33\log(fc) - 40.98 \quad (7)$$

iii. Others

[5] investigated the effect of buildings on GSM signals of four (4) telecom providers using an RF (radio frequency) signal to obtain path loss measurements on five (5) category of buildings (mud-house with thatched roof, mud house/rusted corrugated iron sheet roof, sandcrete building/rusted corrugated iron sheet roof, sandcrete building/unrusted corrugated iron sheet roof and building with alucoboard wall cladding) in Rivers State, Nigeria. Their results showed that path loss exponent varied from 3.06 – 459.

2. Methodology

2.1 Description of study area

The Faculty of Engineering, University of Benin is located in the city of Benin, specifically Ovia North East local government area, Edo State Nigeria.
University of Benin is a research university located in Benin City, Edo State, Nigeria. It is among the universities owned by the Federal Government of Nigeria and was founded in 1970. In terms of demographics and building structures, it can be classed as a suburban area. It is located at 6.3931° N, 5.6195° E.

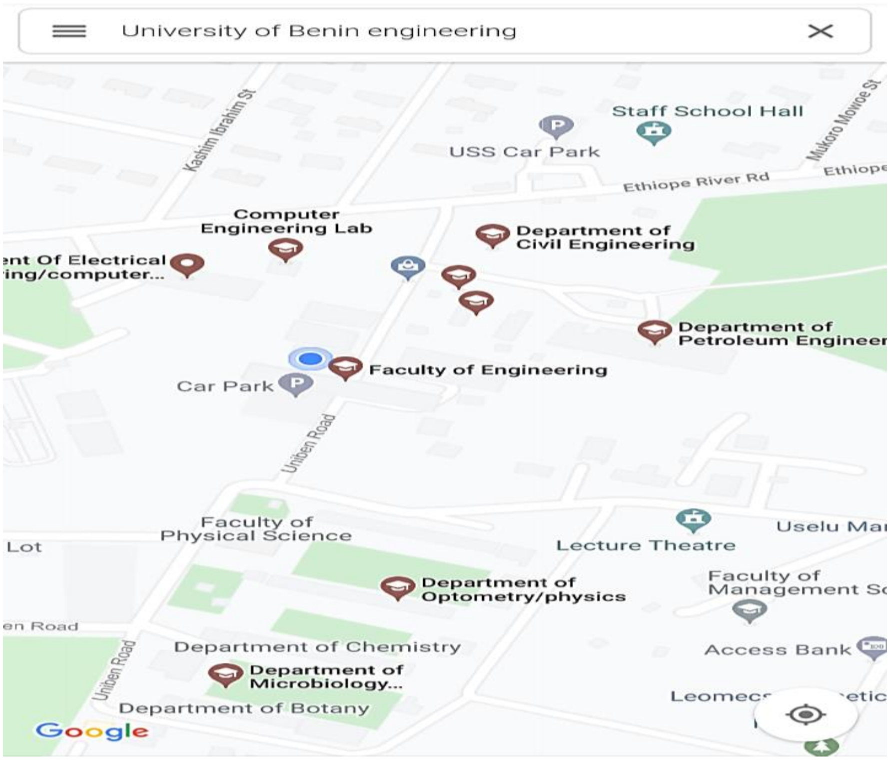

Figure 1 Map of engineering and its environs

Figure 2. Physical view of the Base Transceiver Station (BTS) at engineering.

2.2 Description of Method

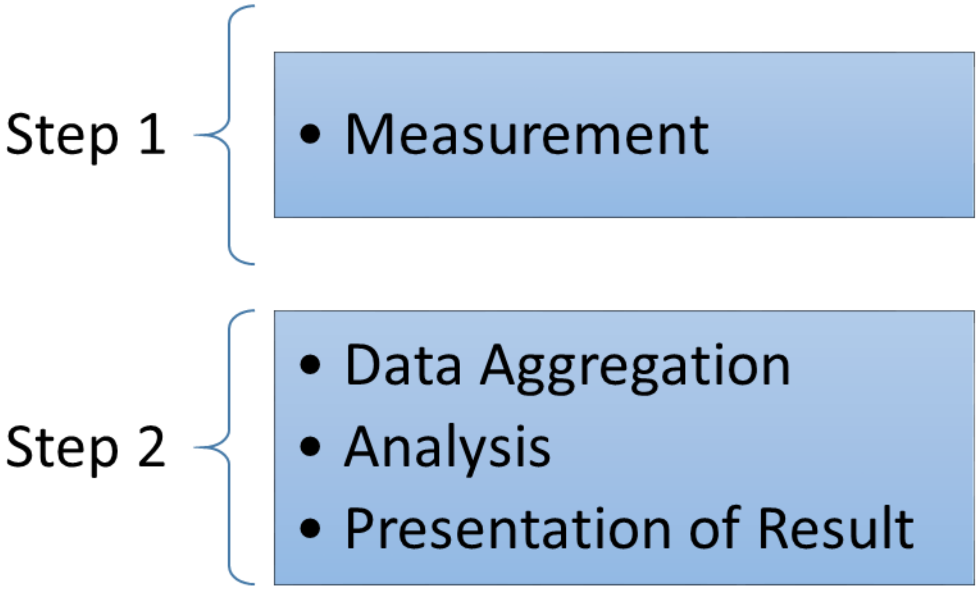

Figure 3 Methodology

i. Measurement Tools

Measurement was taken using a mobile device running Network Analyzer© Software; an android based app used to obtain RSSI readings from the base station under study. Also, measuring tapes were used in order to obtain some required distances.

ii. Measurement

Measurements were taken at 2m interval from the base station in order to obtain readings at those intervals for data collection purposes. This stage also involved the extraction of the received signal strength values from the field at the said intervals using signal strength and net monitor application software.

iii. Data Aggregation

After measurements the data obtained was collated, sorted and cleaned to filter outliers and finally stored for further processing

iv. Analysis

This stage involved the analysis of data obtained in order to develop the propagation model.

3. Results and Discussion

Data obtained from field measurement after cleaning and sorting is presented in summary in Tables 1 & 2.

Table 1: Provider 1 (3G)

S/N	DISTANCE (METERS)	Summarized RSSI for (dbm) signal strength app	Summarized RSSI (dbm) (net monitor app)	MEAN(dbm)
1	50	-59	-53	-56
2	200	-60	-62	-61
3	400	-64	-63	-63.5
4	600	-64	-69	-66.5
5	800	-70	-69	-69.5
6	1000	-70	-76	-73
7	1200	-78	-78	-78
8	1400	-86	-83	-84.5
9	1600	-83	-89	-86
10	1800	-93	-89	-91
11	2000	-105	-102	-103.5

Table 2: Provider 1 (2G)

S/N	DISTANCE (METERS)	Summarized RSSI FOR (dbm) signal strength app	Summarized RSSI (dbm) (net monitor app)	MEAN(dbm)
1	50	**-49**	**-49**	**-49**
2	200	**-52**	**-54**	**-53**
3	400	**-57**	**-55**	**-56**
4	600	**-68**	**-65**	**-66.5**
5	800	**-72**	**-71**	**-71.5**
6	1000	**-76**	**-72**	**-74**
7	1200	**-72**	**-74**	**-73**
8	1400	**-78**	**-73**	**-75.5**
9	1600	**-72**	**-74**	**-73.5**
10	1800	**-78**	**-76**	**-77**
11	2000	**-87**	**-82**	**-84.5**

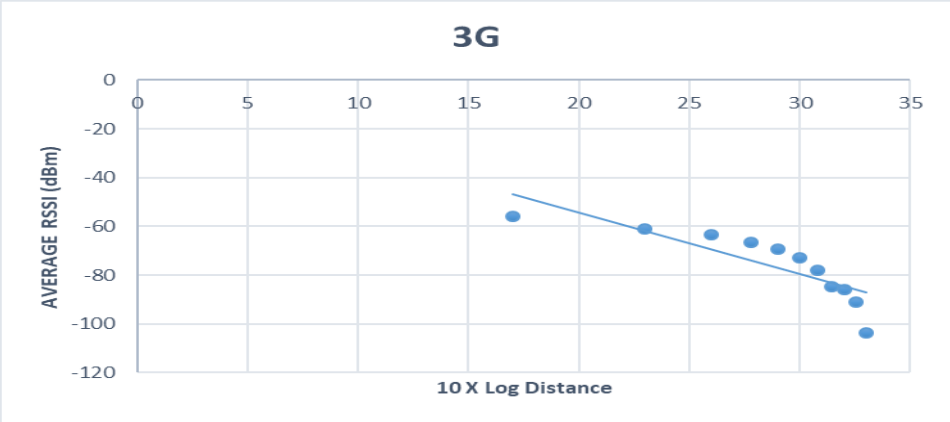

Figure 4 Plot of RSSI versus Log Distance for Provider1 (3G)

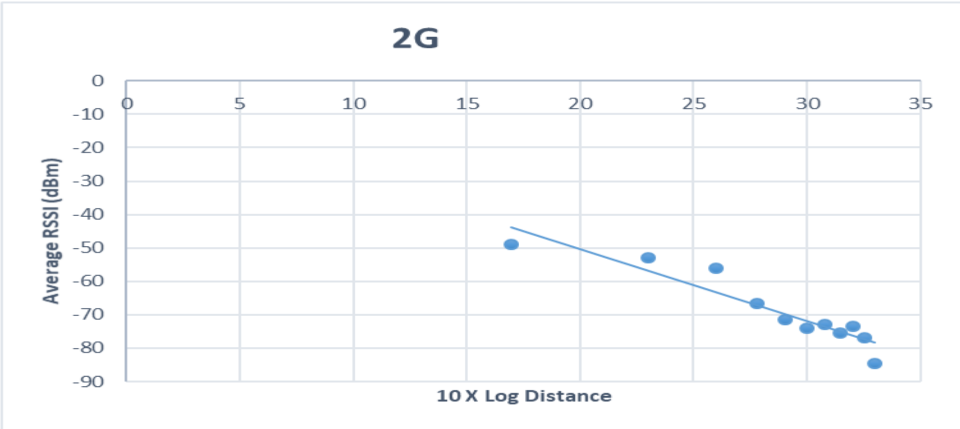

Figure 5 Plot of RSSI versus Log Distance for Provider1 (2G)

3.1 Path Loss Models

The path Loss Models are represented in Figures 6, 7 and 8 for 2G, 3G and both technologies respectively.

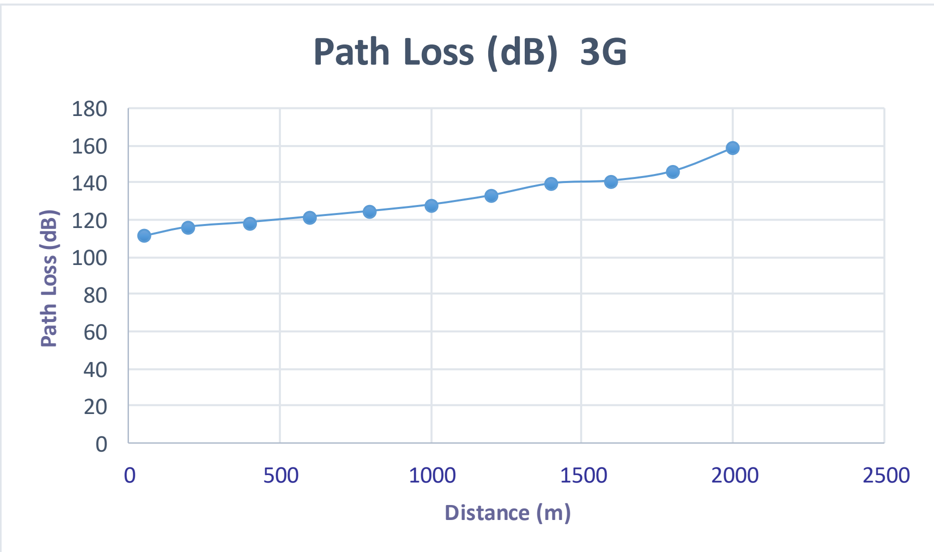

Figure 6 Plot of Path Loss versus Distance for Provider1 (3G)

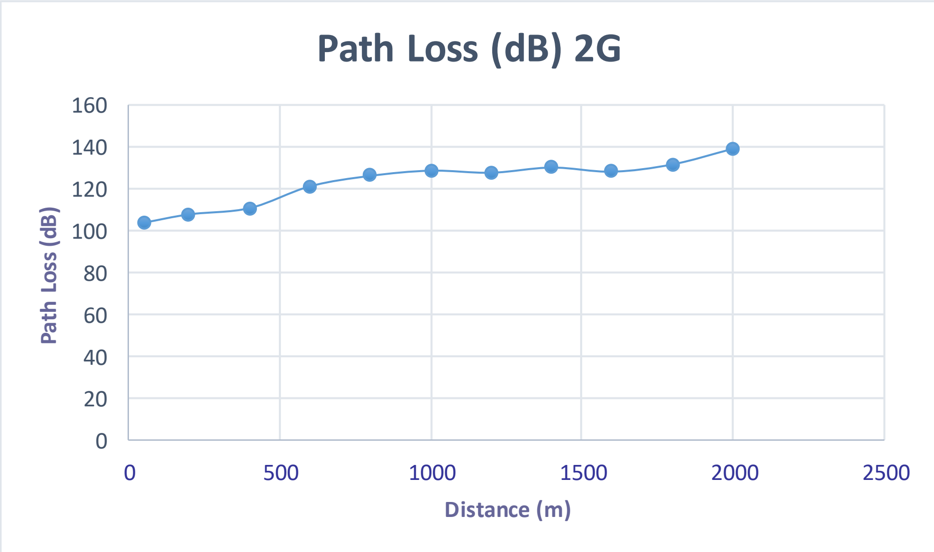

Figure 7 Plot of Path Loss versus Distance for Provider1 (2G)

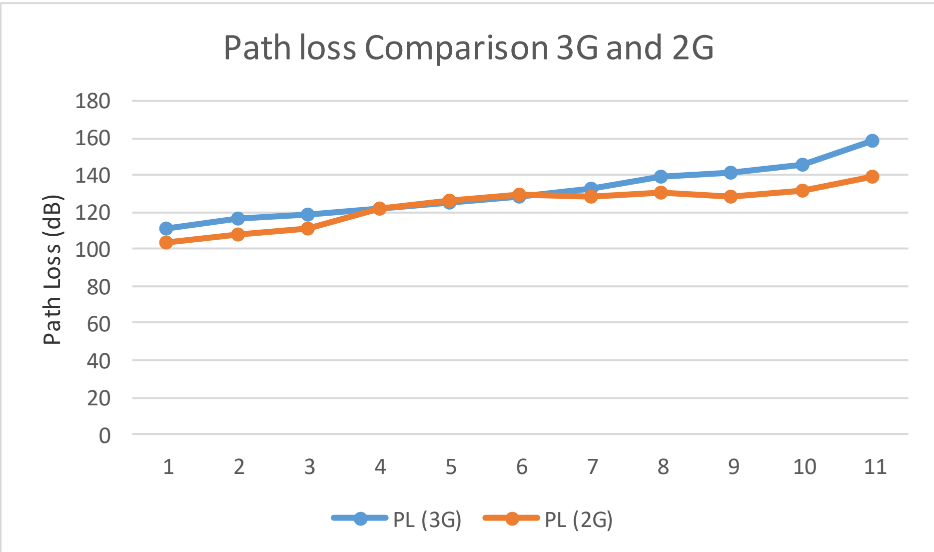

Figure 8 Path Loss Comparison of 2G and 3G signals from Provider 1

3.2 Discussion

From the RSSI models presented in Figures 4 and 5, the following path profile mathematical models were obtained for 3G and 2G technologies respectively:

$$RSSI = -2.5188(10XLogDistance) - 4.0802 \quad (8)$$

$$RSSI = -2.1574(10XLogDistance) - 7.1736 \quad (9)$$

From these it can be inferred that the path loss exponent ranges from 2.52 and 2.154 for 3G and 2G signals propagating around the Faculty of Engineering and environs.

The combo plot of the Path Loss Models in Figure 8 show that 3G signals suffer more path loss as distance increases compared to its 2G counterpart.

4. Conclusion

This paper has presented a path profile for the Faculty of Engineering, University of Benin and analyzed the received signal strength obtained from the base station of an internet service provider specifically “AIRTEL”. The predicted path loss was calculated for two telecom technologies and it was found that 2G fared slightly better in terms of coverage. This paper also determined the path loss exponents for both 2G and 3G technologies for the area under review.

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