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Developmentof a Propagation Model for IEEE 802.11 Wireless Networks: Case of GidanKwano Campus, FUT MINNA

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ABSTRACT—Wireless propagation modeling is an essential task in planning wireless networks. In the last few decades, the use of Wireless Local Area Network (WLAN) popularly referred to as Wi-Fi(Wireless Fidelity) in communication system has been on the increase with the exponential usage of handheld cell phones, laptops, and palm-tops to mention but a few. Notwithstanding, WLAN faces a peculiar propagation issue which lies in its changing propagation environment and this affects the quality of service. Poor quality of service is experienced on WLAN of GidanKwano campus of Federal university of technology, Minna. This arises due to signal propagation impairment caused by the terrain and the structures within the campus. Received Signal Strength (RSS) measurements were conducted at different locations away from the selected Access Points (APs) both in Line of Sight (LOS) and Non- Line of Sight (NLOS) situations. The path loss exponent (n) and standard deviation (σ) were estimated for the environment. The obtained results were contrasted with the already published work to show the level of agreement. The empirical models were developed for LOS and NLOS situations and compared with the existing standard models.

KEYWORDS—Wireless Local Area Network, Path loss model, Path loss exponent, Propagation impairment, Access Points (APs)

INTRODUCTION

Wireless Local Area Networks (WLANs) popularly referred to as Wi-Fi (Wireless Fidelity) have recently gained prominence in various walks of life, including medical centre, retail, assembling, warehousing, and academic environment [2] [4][9]. These sectors have benefitted immensely by utilizing hand-held gadgets and notebook computers for real time data transmission [13]. Wireless communication offers clients and associations numerous advantages, for example, compactness and adaptability, increment profitability, and lower cost of installation when compared to the wire line communication systems [18] [23]. WLAN gadgets enable clients to move their cell phones from place to place without the requirement for wires [5]. Less wiring implies more noteworthy adaptability and increment proficiency. Handheld gadgets, such as, Personal Digital Assistants (PDA) and mobile phones permit remote clients to synchronize individual databases and give access to network services, for example, remote email, web browsing, and other web administrations [6]. However, as wireless signals move from a transmitter to a receiver, they get diffracted, scattered, and absorbed by the territory, trees, building, vehicles and individuals which constitute the environment of propagation [1] [3] [11] [20] [21] [23]. The nearness of obstacles along the path of wireless signal may cause great signal attenuation more noteworthy than it would under free space conditions [8] [12] [14]. Radio signal attenuation and path losses are greatly due to the terrain of propagation [10] [15] [16] [17]. Poor network planning is a factor responsible for WLAN poor quality of service [18] [19] [20] [24]. For accurate network planning, a good knowledge of propagation characteristics is of great importance [22] [25]. In the literature, empirical propagation models are most prevalently used for handling network planning issues. However, due to changes in the environment of propagation, the empirical models are not globally applicable [1] [21]. Accordingly, it is important to determine the particular radio propagation characteristics that will be ideal for the environment under study while carrying out network planning [23].The Gidan Kwano campus of FUT, Minna often times encounter poor quality of service arising from the signal propagation impairment. The accurate prediction of well-known propagation models is not suitable to evaluate the propagation characteristic of this campus due to the peculiarity of its terrain. This paper is geared toward developing a propagation model for this campus using received signal strength measurements from a selected access points within the campus.

METHODOLOGY

Many techniques and materials have been utilised in taking information from an access point (or a base station) [17] [22]. These techniques include radio frequency (RF) overview and drive test among others [18] [7] [2]. For this work, the technique for RF overview was utilised and this section describes the materials and strategies used to achieve this investigation. Figure 1 shows the summary of the methodology deployed.

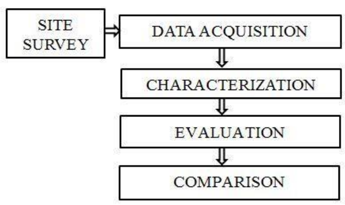

Fig.1. Summary of the methodology

A. Study area description

The GidanKwano campus of Federal University of Technology (F.U.T) Minna is situated in Minna, the Niger state capital, Nigeria. It lies on Longitude 6.50*E* and Latitude 9.70*N*. The campus is moderately sized with complex terrain because of the presence of tall structures, classrooms and trees within it. The attenuation of the Wi-Fi signal within the campus is attributed to numerous reflections, absorption and diffractions off rooftops, trees, cars and so on [**?**]. The access points (APs) utilised for this work are referenced with respect to the campus building they were mounted on, in particular, ITS Wi-Fi, LIB. Wi-Fi, SEM Wi-Fi, SEET2 Wi-Fi, PTDF Wi-Fi, AGRIC-AP, CON-Wi-Fi, SICT Wi-Fi, ABE Wi-Fi, and SET Wi-Fi. These APs were picked as a result of accessibility of their hardware specifications and configuration.

B. Radio Frequency Site Survey

An RF site review is the initial phase in the deployment of a Wireless network and the most significant advance to guarantee wanted operation [22]. A site study is a step-by step process by which the surveyor thinks about the facility to understand the RF behaviour, finds RF coverage areas and decides the appropriate placement of Wireless devices [18]. There is no viable alternative for measuring real-world obstruction, blockage and Received Signal Strength Indicator (RSSI) at a site, just on-location measurements and overviews can give the total picture. RF site over view were led utilising studying apparatus that enable data to be gathered from an access point, example of such data is the RSSI.

C. Surveying Tools

In carrying out the site survey, Air Check Wi-Fi Tester 2.4GHz and 5.0GHz was utilised to capture wireless packets from an ad-hoc or infrastructure network setup utilising an access point. The specifications of the software and hardware equipment utilised for this study are given below.

1) Software specifications:

i. Insider software
ii. Matlab version R2014a
iii. Microsoft window 8 Pro.

2) Hardware specifications:

a: Air Check Wi-Fi Tester 2.4GHz and 5.0GHz
*b:*Laptop

i. Vendor Hp
ii. Model: Note book 15
iii. CPU Speed: 2.7GHz
iv. Memory: 2GHz
v. Wireless Card: Intel PRO/Wireless 2200BG

c: IEEE 802.11b/g Access Point

i. Vendor: Mikrotik RB Metal G52SHPacn
ii. Range: $\approx 183m = 600ft$
iii. Transmitter reference Power: *1W*
iv. Bands: *2.4GHz* to *2.4835GHz*
v. Transmission speed-Wi-Fi 2.4GHz: 150Mb/s

d: Global Positioning System (GPS)

i. Vendor: Magellan
ii. Model: Explorist 500

e: 25-foot measuring tape.

D. Data Collection Methods

An Hp laptop with a Network Interface Card (NIC) installed and running on Microsoft Windows 8 Pro with Inssider software was utilised to obtain RSSI information at varying radial distance from the chosen APs on the campus. The following privacy guidelines were observed during data collection:

1) The Inssider software did not attempt gaining access to the network.
2) The Inssider software sees all the access points publiclycommunicating their Service Set Identifier (SSID).

Ten (10) APs were chosen on the Campus at distinctive areas. The chosen APs were from a similar vendor and with similar specifications utilising IEEE 802.11 b/g standard. At each AP, straight ways were stamped out at various bearings from the AP to the laptop. On every one of these ways, test points were physically estimated at a 10m interval utilizing a measuring tape estimating to a 100m stamp from the AP.

1) Line of Sight (LOS) data collection procedure scenario:

In a LOS environment, the receiving antenna is detectable to the transmitting antenna with an exceptionally minimal obstacle. The origins of attenuations are essentially from the movement of individuals and vehicles over the path of signal transmission. This is so since the human body is made of around 70 percent water, hence, it ingests some amount of signal accordingly causing loss of strength of the signal being transmitted. Signal information with relating separations fromthe APs were measured, and at each measured separation, a few estimation of RSSI were gathered. The APs in a LOS environment situation are FUT Wi-Fi (ITS), FUTLIB. WiFi, SEM MBB Wi-Fi, SEET2-Wi-Fi and GOOGLE Wi-Fi (PTDF).

2) Non-Line of Sight (NLOS) data collection procedure scenario: For NLOS condition, there were no visual observable pathway between the receiving and the transmitting antennas. The radio transmission way is mostly or completely impeded by the nearness of physical obstructions, for example,tall structures, trees, slopes, individuals, vehicles and so on[16]. These interference bodies weaken the signal strength by method of absorption, reflection, scattering and diffraction.

RSSI values were gathered from five (5) APs on the campusat estimated separations from the APs in a NLOS domainsituation. The APs in a NLOS situation are FUTAGRIC-AP,CON-FUT Wi-Fi, GOOGLE Wi-Fi (SICT), ABE-Wi-FiandGOOGLE WIFI (SET). Data were gathered between the hours of 10 am and 12 pm and between 2 pm and 4 pm from Monday through Friday. Themovement of individuals and vehicles is reduced at these hoursof the day being the lecture hours. This is aimed at reducingthe attenuation caused by individuals and car movement. There is an interior antenna situated behind the laptop screen, so the laptop screen was directed toward the apex sky keeping in mind the end goal to improve the probability that the direct beams signal path falls on the beam width of the antenna.

II. RESULTS, DISCUSSION AND ANALYSIS

In the study of wireless data communication networks, the path loss exponent is the principal parameter of interest [2]. The path loss exponent relies greatly upon the environment of propagation. High path loss exponent symbolizes how quick the signal strength drops with respect to the distance between the transmitter and the receiver [19] [21]. Therefore, in carrying out signal propagation modeling for a given study area, the path loss exponent for such study area has to be determined. This section shows results, discussion and analysis of information gathered on RSSI from the environment of propagation.

A. Presentation of results

The ranges of the signal strength measurements and the corresponding signal quality from Inssider software is presented in Table I based on the standard [18]. The measurement surveyed signal strength obtained for some of the APs in LOS and NLOS are presented in Tables II and III respectively.

TABLE ISURVEY OF THE RSSI

Received Signal Strength in dBm	Signal quality
-60<RSSI≤-20	Excellent signal
-75<RSSI≤-60	Good signals
-85<RSSI≤-75	Low signal
-90<RSSI≤-85	Very Low signal
-108<RSSI≤-90	No signal

TABLE II MEAN RSSI FOR LOS ENVIRONMENT SCENARIO

d(m)	Mean RSSI FUT Wi-Fi (ITS)	Mean RSSI FUT_LIB. Wi-Fi	Mean RSSI SEMMBB Wi-Fi	Mean RSSI SEET2-Wi-Fi (ITS)	Mean RSSI GOOGLE Wi-Fi(PTDF)
1	-14.03	-14.03	-14.03	-14.03	-14.03
10	-41.65	-42.70	-43.45	-42.35	-42.75
20	-42.35	-44.45	-45.85	-46.40	-43.90
30	-43.25	-42.65	-46.75	-44.35	-45.80
40	-42.85	-44.35	-47.50	-47.10	-48.65
50	-48.05	-47.40	-45.90	-54.90	-47.55
60	-53.75	-51.30	-53.05	-57.85	-53.65
70	-52.90	-52.85	-56.95	-56.75	-62.25
80	-56.55	-54.70	-54.85	-62.50	-52.60
90	-61.80	-52.40	-65.75	-65.00	-65.40
100	-67.85	-60.25	-63.55	-66.75	-69.40

TABLE III. MEAN RSSI FOR NLOS ENVIRONMENT SCENARIO

d(m)	Mean RSSI FUTAGRIC-AP	Mean RSSI CON-FUT Wi-Fi	Mean RSSI GOOGLE Wi-Fi (SICT)	Mean RSSI ABE-WIFI	Mean RSSI GOOGLE WIFI (SET)
1	-14.03	-14.03	-14.03	-14.03	-14.03
10	-54.10	-52.60	-48.85	-50.80	-48.35
20	-57.15	-57.85	-52.50	-55.40	-54.50
30	-62.25	-56.80	-55.75	-59.65	-57.20
40	-68.60	-58.50	-62.90	-61.50	-56.95
50	-65.65	-66.20	-70.25	-59.05	-59.95
60	-67.75	-62.35	-67.30	-63.20	-66.45
70	-74.20	-83.85	-66.60	-71.10	-70.45
80	-73.30	-81.40	-74.85	-69.00	-75.85
90	-86.25	-85.70	-81.90	-79.15	-79.85
100	-84.90	-87.80	-79.85	-84.05	-78.95

B. Computation of path loss exponent using Log distance path loss propagation model

Where $P_t$is the reference transmitter power of *1W*, W_m *equals* 10^{-3} *W*, P_T is the transmitter power in dBm, $P_L(d)$ is the Path Loss at distance *d* and $P_L(do)$ is the Path Loss at reference distance 1m.

RSSI are the measured data against distance at the various locations.With reference to RSSI expression of (1), (4) is obtained.Utilizing (4) obtained the path losses. With reference to (4) at reference distance of 1m away from the access point, RSSI is -14.03dBm. From which P_L (do) is solved to be 44.03dB. Hence (3) becomes,the path lose exponent for both LOS and NLOS were obtained using (5). The standard deviation (σ) and Sum of Square Error (SSE) of the developed models from the established standard model were computed by applying (6) and (7) utilizing MATLAB tool.

Where $y_i$is the measured path loss at a particular interval, $\bar{y}$ is the developed model path loss and *M* is the data length. Table IV and V show the mean path loss exponents for LOS and NLOS scenarios respectively.

TABLE IVTHE MEAN PATH LOSS EXPONENTS FOR LOS

Location	Mean Path Loss Exponent(n)
FUT Wi-Fi(ITS)	2.24
FUT_LIB Wi-Fi	2.16
SEM MBB Wi-Fi	2.34
SEET2 Wi-Fi	2.44
GOOGLE Wi-Fi(PTDF)	2.36

TABLE VTHE MEAN PATH LOSS EXPONENTS FOR NLOS

Location	Mean Path Loss Exponent(n)
FUTAGRIC-AP	3.36
CON-FUT Wi-Fi	3.34
GOOGLE Wi-Fi(SICT)	3.14
ABE Wi-Fi	3.11
GOOGLE Wi-Fi (SET)	3.07

DISCUSSION OF RESULTS

The standard deviation σ and SSE of the developed models from the field measurements were the parameters used to evaluate the models quality. In this analysis, the standard deviation of the measured LOS path loss and the developed model LOS path loss was 2.81dB as opposed to 5.60dB of the measured LOS path loss and Free Space Lose. Also, the standard deviation of the measured NLOS path loss and the developed NLOS model was 3.23dB while that of Hata model and the measured NLOS path loss was 7.04dB. The SSE of the measured LOS path loss and the developed model LOS path loss was 8.87dB while that of the free space model and themeasured LOS path loss was 17.71dB. The measured NLOS path loss and the developed model NLOS SSE was 10.20dB while that of Hata model and the measured NLOS path loss was 22.26dB. Path loss exponent is the most imperative model parameter obtained from the analysis. This parameter gives noteworthy knowledge into how wireless signals attenuate with respect to the distance between the access point and the mobile receiver. In the analysis, it was gathered that, the path loss exponent for NLOS scenario was higher when compared to that of the LOS environment. This shows that, the signal strength for NLOS scenario decreases faster due to the presence of obstructions along the path of propagation than for LOS scenario. The obtained path loss exponent in this analysis falls within the range of the most researchers published results [7][12][22]. Table VI gives the summary of the path loss exponents for both LOS and NLOS scenarios.

TABLE VISUMMARY OF THE PATH LOSS EXPONENTS FOR BOTH LOS AND NLOS SCENARIOS.

Environment	Mean Path Loss exponent (n)
LOS	2.31
NLOS	3.20

(8) and (9) are the derived mean path loss models for LOS and NLOS scenarios.

Comparison with standard models

Propagation path loss exponents obtained from the empirical measurements were contrasted with that of the free space loss and Hata model (Refer table VII and VIII) and depicted in Figures 2 and 3. Obviously, the path loss exponents from the empirical measurements as contrasted with the free space loss appeared to be higher, and this was seen to be caused by extra losses from the environment of propagation, which attenuates the signal quickly than in free space.

TABLE VII COMPARISON BETWEEN MEASURED DATA, DEVELOPED MODEL AND FREE SPACE LOSS

d (m)	Measured data [PL_{LOS}]	PL (d) [LOS] For n=2.31	PL (d) [FSL] For n=2.0
10	71.95	67.13	64.03
20	75.90	74.08	70.05
30	73.80	78.15	73.57
40	75.95	81.03	76.07
50	83.30	83.27	78.01
60	86.25	85.11	79.60
70	84.40	86.65	80.93
80	88.50	87.99	82.09
90	89.80	89.17	83.11
100	90.85	90.23	84.03

TABLEVIIICOMPARISON BETWEEN MEASURED DATA, DEVELOPED MODEL ANDHATA MODEL

d (m)	**Measured data [PL_{NLOS}]**	**P L (dB) [NLOS] For n**=3.20	**PL(dB) Hata Model**
10	83.60	76.03	72.46
20	89.10	85.66	81.44
30	92.25	91.30	86.69
40	98.45	95.29	90.42
50	97.70	98.39	93.31
60	98.25	100.93	95.67
70	105.30	103.07	97.67
80	103.15	104.93	99.40
90	108.75	106.57	100.92
100	109.90	108.03	102.29

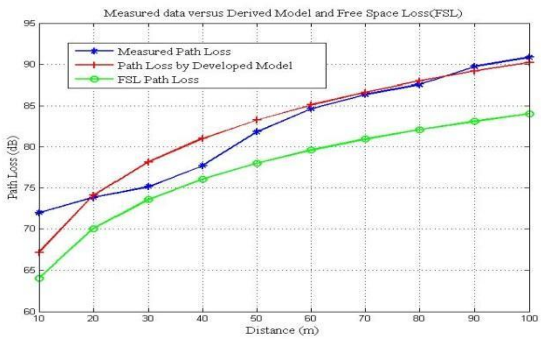

Fig. 2. Comparison of the measured data with the derived model and Free Space Loss (FSL).

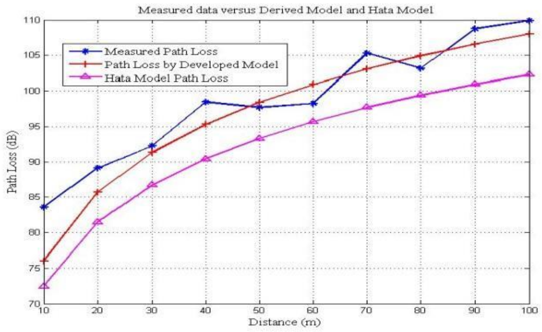

Fig. 3. Comparison of the measured data with the derived model and Hata Model.

CONCLUSION

This work has developed a propagation model that can be utilised in describing the signal attenuation within the GidanKwano campus of FUT, Minna. This was actualised by investigating the effect of the environment on radio frequency signal quality. It was discovered that the nearness of obstructions attenuates the signal strength which degrades the performance of the wireless network. RSSI data were gathered in a LOS and NLOS situations. The path loss exponents and standard deviations acquired for the obstructed environment (NLOS) were seen to be higher than those obtained for unhampered (LOS) condition. This perception demonstrated that the nearness of hindrances truly have effects on radio frequency signal quality. Based on the empirical data gathered, propagation models were determined for both NLOS and LOS conditions. The obtained results were then contrasted with the existing standard models and the outcome demonstrated high level of agreement. The results were satisfactory, showing the developed models can effectively be utilised for APs deployment at FUT Minna to accomplish high quality signal coverage for optimal performance.

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