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Wi-Fi Coverage Area Analysis And Pathloss Parameter Modeling Using The Linear Regression Method

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Abstract*—Pathloss effects in Wi-Fi telecommunication standard looks at the effect of distance as it effects mobility of mobile terminals in and around these wireless environments. Since network parameters should be well implemented initially during the link design, to achieve good and quality signal distribution , the Linear Regression Method is invoked here and MATLAB software is used to simulate and show the signal degradation (pathloss) as the coverage distance increase. From the result, it was shown that effective management of coverage distance could result to effective mobility in and around this wireless domain; since the pathloss (rate of signal degradation) could be handled by proper management of these link parameters: thus a better quality of service with a reduction in call drop rate.

***Keywords*— Pathloss; signal; wireless; coverage; standard; regression**

I. INTRODUCTION

Wireless Fidelity (Wi-Fi) is a wireless technology which provides internet connectivity among users [3] . It is a company that certifies WLAN (Wireless Local Area network) products [1]. This wireless standard takes care of wireless connectivity among user within a localized distance, like in an office or department. In 1997, IEEE provides a set of specifications and standards for Wi-Fi which is under the 802.11 WLAN working group, and thus explains the structure of the comparatively short range radio signal for WI-Fi services [1]. After that, several other specifications came out and the most commonly used today are 802.11, 802.11g and 802.11a [2]. However, the 802.11a can provide higher speeds within the various radio frequencies. IEEE is presently working on a new standard 802.11n, which is more reliable, secure and faster than the other standards [4].

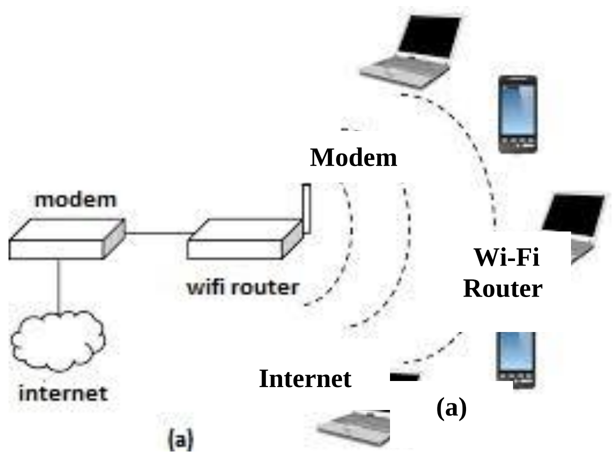

Fig. 1: Wi-Fi network and architecture. (Frank et al.2003).

Originally, WIFI was created for wireless extension for the wired LAN. That is why the distance between the WIFI access point and user equipment is limited to around 100 feet indoor and up to 300 feet outdoor [2]. So if a user moves its computer to a new location, he/she should find a new access point for continuing the communication. Due to the cheap availability of the equipment and its maintenance and servicing cost, WIFI is widely accepted throughout the world and it is widely used in restaurants, hotels, airports and school campuses. Internet service providers also use it for individual home connectivity and connectivity to commercial complexes [2].

II. LINEAR REGRESSION METHOD

Linear regression analysis is used to model the relationship or to establish the connection between two variables. This is achieved by putting the observed field data in a linear equation. These field data can either be the dependent variable or the explanatory variable [5].

The relationship between the distances of coverage (d) of a Wi-Fi network to the signal degradation or pathloss (PL) is established. The coefficient / exponential term indicate the strength of the association between the observed field data for the

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two variables of the distance of coverage (d) and the pathloss (PL).

A linear regression line equation is of the form

$y = \alpha + \gamma x$.(1)

Where,

x is the explanatory variable (distance (dBi)

y is the dependent variable (pathloss)

The slope of the line is γ and the x is the point of interception (value of y (pathloss) when the distance (x) =0).

Thus, the linear regression techniques could be invoked to do a model of the area under study, where Hata model pathloss equations signal degradation (pathloss).

III. Field Data Collection

The experimental data was taken in Izombe (Addax-Sinopec Petroleum) Fig. 2 rural area in Imo state.

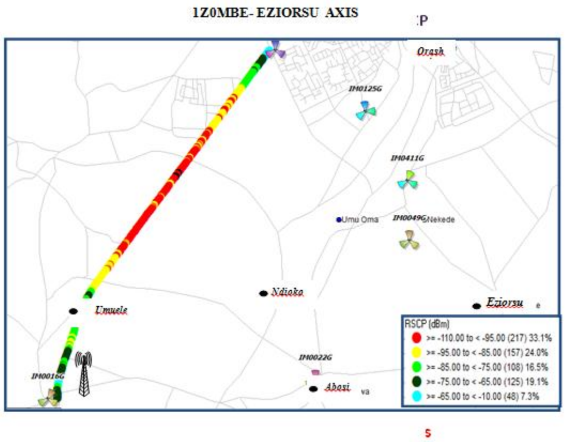

Fig. 2: Field drive test diagram.

In this location, the terrain had much leaves present on the trees. The Wimax base station antenna was in the range from 12m to 80m. The base station antenna transmitted continuous wave (cw) signals with an Omni directional azimuth pattern and gain 8.24dBi (as observed from the back of the antenna). The mobile antenna (mounted on top of the moving vehicle; 2m of height, has also an Omni directional azimuth pattern and gain of 2.45bBi.

The mobile antenna was connected to the back of the receiver, set for 1 sec interval as the vehicle moved around the wireless environment. Data is collected here.

Firstly, as the vehicle moves around the vicinity, there is a lot of fading due to multipath reflections from the vegetation around. However, these fadings were noted at specified distance and the values were calculated to get the average, yielding the estimate for the local mean power (Lmp).

For each of these, values computed, Wimax transceiver transmitted close to 1.9GHz, and the vehicle drove around the cellular coverage area measuring and recording the local mean power at these intervals. Also in addition, global positioning system (GPS) data were recorded at these intervals, which made it easy to calculate the radial distance (dr) from the Wimax base station, as associated with each power measurement. The experimental data were taken at distances ranging from tens of meters to 8km. it is to note that the tree density around the cellular environment where the recording took place is much. The terrain is flat.

Table 1 below shows the pathloss and distance from 0-100m

PATHLOSS	GPS RADIAL		DISTANCE	POWER RECEIVED bB(m)
	LONGTITUDE	LATITUDE		
109	7.03141	5.49367	0.4145	-76
112.4	7.03134	5.49364	10.3268	-79.43
112.5	7.0313	5.49361	20.44015	-78.53
110.2	7.03122	5.49362	30.05157	-77.2
104.9	7.03118	5.49354	41.8925	-71.93
104.7	7.03112	5.49352	49.7968	-71.71
107	7.03103	5.49352	60.7904	-74.0
111	7.0309	5.49362	71.6610	-78
114.3	7.0309	5.4937	81.176	-81.33
116.9	7.03086	5.49376	93.3480	-83.93
145.2	7.03082	5.49384	100.7705	-83.67

IV. Result

It is common knowledge that the pathloss in a macro cellular environment increases with the coverage distance from the base. This is shown in simulation (1), which shows a plot of measured pathloss (pl) and distance (d). However, we can use the above data of table 2 to compute a linear regression mathematical model and obtain a linear graph for the pathloss.

Table 2: below shows the pathloss and the corresponding average mean value.

S/N	DISTANCE (m) X	PATHLOSS (dBi) Y	XY	X^2
1	0.4145	109	45.1805	0.17181025
2	10.3268	112.4	1160.73232	106.6427982
3	20.44015	112.5	2299.517875	417.799732
4	30.05157	110.2	3311.683014	903.0968595
5	41.8925	104.9	4394.52325	1754.981556
6	49.7968	104.7	5213.72496	2479.72129
7	60.7904	107	6504.5728	3695.472732
8	71.6610	111	7954.371	5135.298921
9	81.176	114.3	9278.4168	6589.542976
10	93.3480	116.9	10912.3812	8713.849104
11	100.7705	145.2	14631.8766	10154.69367
	$\in x$= 560.66822	$\in y$ =1248.1	$\in x\, y$ = 65706.97932	$\in x^2$ =39951.27145

. From the above table, n=11

Thus, from the linear regression equation $y = \alpha + \gamma x$.(1)

Where x is the explanatory variable (distance)

y is the dependent variable (pathloss)

γ is the regression coefficient / exponential term, and

α is the intercept.

From the formula, $\gamma = \frac{n\in xy-(\in x)(\in y)}{n\in x^2 -(\in x)^2}$.(2)

By substitutions from the above table,

$\gamma = \frac{11(65706.97932)-(560.66822)(1248.1)}{11(39951.27145)-(560.66822)^2}$.(3)

$\gamma = \frac{722776.7725-699770.0054}{439463.986-314348.8529}$.(4)

$$\gamma = \frac{23006.7671}{125115.1331} = 0.1838847673$$

$\therefore \gamma \cong 0.1839 \cong \underline{0.18}$

From equation (1) $\alpha = \bar{y} - \gamma\bar{x}$.(5)

Where $\bar{y} = \frac{\in y}{n} = \frac{1248.1}{11} = 113.4636364$

And $\bar{x} = \frac{\in x}{n} = \frac{560.66822}{11} = \underline{50.96983818}$

$\therefore \alpha = 113.4636364 - 0.1838847673(50.96983818$

$$\alpha = 113.4636364 - 9.372576833$$

$$\alpha = 104.0910595$$

$\alpha \cong 104.0911 \cong 104.09$

Hence the linear regression line from equ. (1) becomes: y = 104.0911 + 0.1839 x .(6)

Using equ. (3) and by keeping the values of x constant, thus the new table becomes:

Table 3: Table of values for Linear regression

S/N	DISTANCE (m) X	PATHLOSS (dBi) Y
1	0.4145	104.1673
2	10.3268	105.9902
3	20.44015	107.8500
4	30.05157	109.6176
5	41.8925	111.7951
6	49.7968	113.2487
7	60.7904	115.2705
8	71.6610	117.2696
9	81.176	119.0194
10	93.3480	121.2578
11	100.7705	132.6228

A new linear equation and table is generated and a graphical plot are shown in Fig 1, where the intercept on the y axis was obtained and it is seen to correspond with that calculated.

Table 4: Table of Values For The Graph

S/N	DISTANCE (X)	PATHLOSS (Y)
1.	0.4145	104.1673
2.	10.3268	105.9902
3.	20.44015	107.8500
4.	30.05157	109.6176
5.	41.8925	111.7951
6.	49.7968	113.2487
7.	60.7904	115.2705
8.	71.6610	117.2696
9.	81.176	119.0194
10.	93.3480	121.2578
11.	100.7705	122.6228

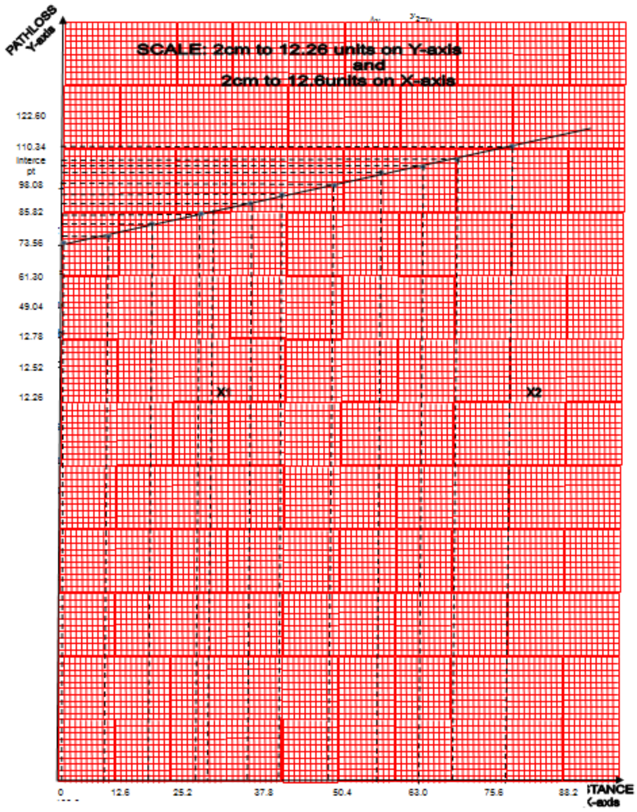

Fig 1: Pathloss versus distance plot

V. COMPUTATION

From equation 1 above,

Given that: $\Delta h_b = 20m$.(7)

R = 0.4145X10^{-3}km

F = 2000MHz

By substitutions,

PL = 40(1-4X10^{-3}X20) $\log_{10}(0.4145X10^{-3})$ - $18\log_{10}(20) + 21\log_{10}(2000) + 180$

PL = 1.427992871

Then, substituting the above value of PL into equ(3) in order to find np,

Given that: do = 100.7705 and

D = 0.4145

Hence,

$1.427992871 = 1.427992871(100.7705) + 10np\log_{10}(\frac{0.4145}{100.7705})$

$np = [1.427992871-(1.427992871 \times 100.7705)] \div 10\log_{10}(\frac{0.4145}{100.7705})$

:. np = 5.971625138 ≅ 6.0 to nearest 1d.p

Thus, the pathloss exponent, np = 6.0

VI. Comparison of Result

It is seen that the obtained pathloss value from the linear regression graph for a distance of 0-100m is 132.6228. Whereas the pathloss calculated from the pathloss equation is 1.42799281 (from the initial value). Therefore for a 100m value, we have it to be 142.7. This shows a form of similarity between the field value and the computed value

Conclusion

An analysis of Wi-Fi (IEEE 802.11) coverage area and effect of pathloss was carried out using Linear regression model. Technical data was collected and the exponential coefficient was calaculated. The results shows that the Wi-Fi technology has a limited range data coverage area.

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