Enhance Study on Indoor RF Models: based on Two Residential Areas

Er. Neha Sharma and Dr. G.C.Lall
HCTM, Kaithal(affiliated to KUK, Haryana, India)

Abstract

Indoor Propagation modeling is demanded for the design and maintenance of indoor wireless services. Empirical modeling seems to be the most efficient approach. The aim of this paper is, by a precise description of the analytic model for an indoor environment. This paper will investigate the influence of predicted fingerprint on the accuracy of indoor location. These include the non-linear variation of material loss with material thickness or frequency and the average predicted penetration loss versus frequency for a windowed wall. A numerical analysis of measurements in each scenario was conducted and the study determined equations that describe path loss for different scenarios. The results explain the variation in multi-wall model and single wall model, building partitioned model. The planning based on propagation modeling is recognized as a highly preferable approach for design of large WLANs.

Keywords:*WirelessLAN, Metageek Inssider,Partitioned Model, GPS, Google Earth*

1. Introduction

Indoor channels are highly dependent upon the placement of walls and partitions within the building. In such cases, a model of the environment is a useful design tool in constructing a layout that leads to efficient communication strategies [1]. If the APs are placed too far apart, they will generate a coverage gap, but if they are too close to each other, this will lead to excessive co-channel interferences and increases the cost unnecessary. Propagation models provide estimates of signal strength and time dispersion in many indoor environments. These data are valuable in the design and installation of indoor radio systems. Just a few years ago, actual channel measurements were the principal source of information about the characterization of indoor radio propagation.

Site-specific propagation models on the other hand, are based on electro magnetic-wave propagation theory to characterize indoor radio propagation. Unlike statistical models, site-specific propagation models do not rely on extensive measurement, but a greater detail of the layout of the indoor environment is required to obtain an accurate prediction of signal propagation inside a building. Ray-tracing model (RT) is an intuitively appealing site-specific method for calculating radio signal strength. In this paper, one common approach is that the obstruction caused due to walls is indicated using the Wall Attenuation factor [2]. Walls reflect the electromagnetic radiation falling on it producing a shadow region behind it. The attenuation produced depends on the material and thickness of the wall. Another approach is based on a site survey with a lot of measurements and experimental decisions using propagation models.

2. Floor Plan Study

A radio signal behaves like light in free space. As the radio energy expands outward from its source, the energy is dispersed over an increasingly greater area. However, this dispersion causes the radio waves to weaken as they travel away from the end point. This weakening, or attenuation, grows rapidly with distance. The signals weaken with the square of the distance travelled. In this study I take into account the direct Line of Sight (LOS) signal and the signal received after a signal reflection off of each of the walls available.It also serves as a guide for the network design and for installing and verifying the wireless communication infrastructure [2]. The basic requirements for conducting a site survey are: an access point, a laptop with wireless adaptor and a survey utility.

Fig.2.1 Floor Plan of Two Residential Areas

The placementofaccess points in two residential areasprovidesadequatecoverage area. Other important factors' influencing penetration and effectively overall path loss isthe number and size of windows that exist at the illuminated building. These windows can provide a relatively low loss propagation path. Also, insulation used in walls can play an important part in radio wave attenuation since transmission of electromagnetic waves through walls is an important mode of propagation [1]. Another issue is that building materials might absorb moisture (water). The general trend that has been reported under water absorption is that tangent loss and relative permittivity increases [2][3], resulting in increased losses compared with the dry case.

Fig.2.2 Buildings for two residential floor plans.

House1:

- Closed Doors and Windows: The closed doors and windows are used for signal measurements 3m away from the transmitted point. There are two main doors and 4 windows are closed/open.
- Open corridor: An open corridor is used for signal measurements. The corridor is open on one side and closed with a wall on the other side. This corridor is 13’7” high and 15’7” wide. Path loss exponent (n) is 1.688 for AP1 and 1.63 for AP2. Standard deviation (σ) is 3.5773 for AP1 and 3.2642 for AP3.
- Living room: A living room with furniture is considered for signal measurements. This room is 11’-2”X13’-8”. Path loss exponent (n) is 1.258 for AP1 and 1.263 for AP2. Standard deviation (σ) is 3.7607 for AP1 and 4.053 for AP2.

House2:

- Closed Doors and Windows: The closed doors and windows are used for signal measurements, 3.7m away from the transmitted point. There are two main doors and 6 windows are closed/open.
- Open corridor: An open corridor is used for signal measurements. The corridor is open on one side and closed with a wall on the other side. This corridor is 15’5” high and 14’7” wide. Path loss exponent (n) is 1.84 for AP1 and 1.35 for AP2. Standard deviation (σ) is 3.364 for AP1 and 3.58 for AP3.
- Living room: A living room with furniture is considered for signal measurements. This room is 12’-5”X17’-11”. Path loss exponent (n) is 2.008 for AP1 and 2.351 for AP2. Standard deviation (σ) is 4.54 for AP1 and 5.283 for AP2.

3.Free Path Loss Model

Path loss is the reduction in power density of an electromagnetic waves as it propagates through space. Path loss may be due to many effects, such as free space loss, refraction, diffraction, reflection and absorption [3]. Path loss is usually expressed in dB. In its simplest form, the path loss can be calculated using the formula

$$L = 10\ n\ \log_{10}(d) + C \qquad (3.1)$$

where L is the path loss in decibels, n is the path loss exponent, d is the distance between the transmitter and the receiver, usually measured in meters, and C is a constant which accounts for system losses.

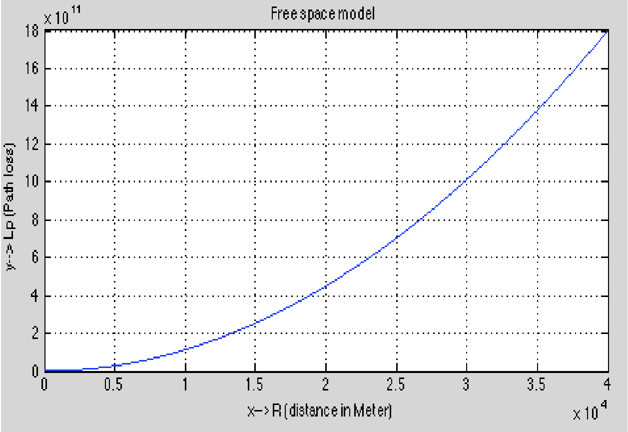

Fig. 3.1 Free Space Path Loss Model in logform

A popular technique to study narrowband path loss is the use of path loss exponents. Fig.3.1 shows Free Space Path loss in Logarithmic form. This method assumes that the average dB path loss w.r.t. 1m free space increases linearly as a function

$$\overline{PL}(d) = 10n \log_{10}\left(\frac{d}{1\mathrm{m}}\right) \qquad (3.2)$$

where d is the distance between Tx-Rx, PL is average path loss a reference distance of 1 m, which is typically for indoor propagation models. Fig.3.2 shows the Free Space Model acc. to the below formulas. If large number of path loss taken into the environment, minimum mean squared technique used to calculate the estimate path loss [4]. For N measured locations with PL_i denoting the ith path loss measurement at a T-R separation of d_i, The value of n is:

$$n = \frac{\sum_{i=1}^{N} \mathrm{PL}_i \log_{10}\left(\frac{d_i}{1\mathrm{m}}\right)}{10 \sum_{i=1}^{N} \left[\log_{10}\left(\frac{d_i}{1\mathrm{m}}\right)\right]^2} \qquad (3.3)$$

It is measured the standard deviation is given by:

$$\sigma^2 = \frac{1}{N}\sum_{i=1}^{N}\left[\mathrm{PL}_i - 10n\log_{10}\left(\frac{d_i}{1\mathrm{m}}\right)\right]^2 \qquad (3.4)$$

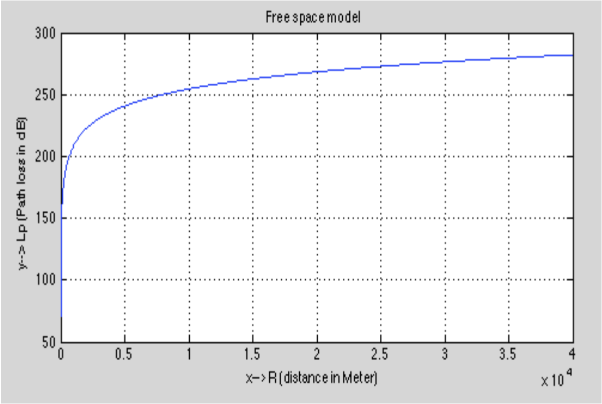

Fig.3.2 Free Space Path Loss Models

Below table3.1 shows the survey calculation based on one house where different obstruction mentioned. On the basis of these obstruction the result or path loss is effected.

Table3.1: Survey calculations

S.No.	Obstructions b/w Tx-Rx	Tx-Rx distance (m)	RSS (dBm)	Path Loss (dBm)
1.	none	1.23	-26.6	33.34
2.	1 wall	2.1	-22	28.31
3.	2 wall, door open	3.98	-37.66	46.3
4.	1 floor	4.50	-46.06	51.98
5.	1 floor, 1 wall	3.49	-44.36	51.46
6	2 walls	5.78	-47.86	55.76

4. Log normal shadowing

The lognormal shadowing model is used to represent the path loss characteristics of natural environments. This model represents the path loss vs. distance relationship through a distance power exponent, *n*, and random shadowing (or large scale fading) effects through a zero mean Gaussian function with standard deviation (in dB). It does not consider the fact that the surrounding environmental clutter may be vastly different at two different locations having the same T-R separation [5].

This model more accurately predicts path loss as a function of distance when the model parameters n are determined as a function of the general surroundings.The PDF of the lognormal variable is:

$$f_X(x) = \frac{1}{\sqrt{2\pi}\sigma_n x} e^{-(\ln x - m_n)^2/2\sigma_n^2} \qquad (4.1)$$

where *m* is the mean value and σ*2* is the variance. The corresponding cumulative distribution is the normal random variable *n*. The corresponding CDF is

$$F_X(x) = \frac{1}{\sqrt{2\pi}\sigma_n}\int_0^x \frac{e^{-(\ln x - m_n)^2/2\sigma_n^2}}{x}dx \qquad (4.2)$$

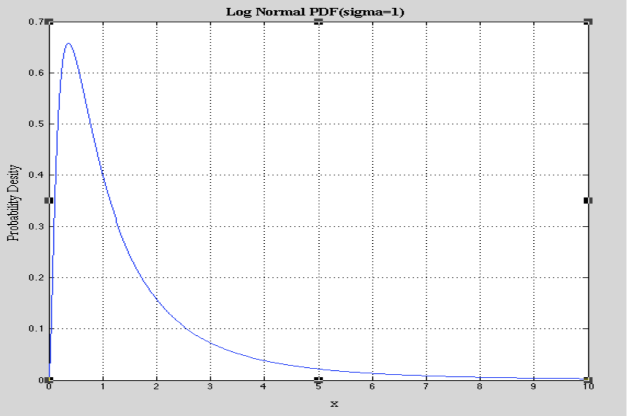

Fig. 4.1 Log Normal PDF

Fig. 4.1 and Fig. 4.2 shows the shapes of the PDF and CDF change with the parameters of the normal variable parameters. It observes how is the probability that the lognormal random variable lies in this interval related to the corresponding PDF and CDF [6][7].

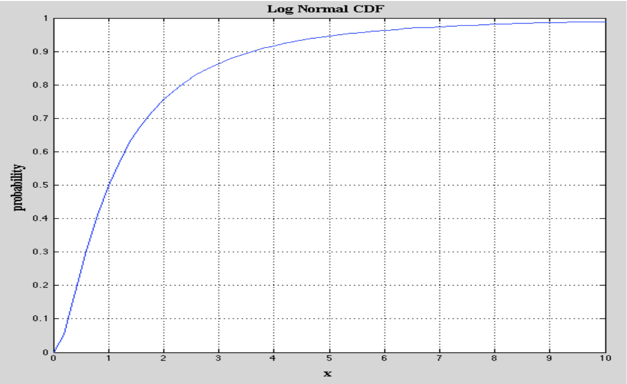

Fig. 4.2 Log Normal CDF

The goal of Log Normal shadowing is to illustrate how the characteristics of the variable changes with the parameters of the corresponding normal random variable. Since the

PDF and CDF are estimated for the generated lognormal sequence.

5. Partition Based Path Loss Prediction Model

The number of walls between the transmitter and receiver can be seen to severely influence the path loss for a given T-R separation. Therefore a more 29 accurate path loss model, named attenuation factor model was described by

$$PL(d)[dB]= PL(d0)[dB]+10nSF \log d +PAF[dB] \quad (5.1)$$

Where*nSF* represents the exponent value for the “same floor” measurement and *PAF*represents the partition attenuation factor for a specific obstruction encountered by a ray drawn between the transmitter and receiver [8][9]. The close in reference distance *d*0, the mean path loss exponent *n*, and *PAF’s* describe the path loss model for any arbitrary location having a specific T-R separation, and this model is used in computer simulation to provide received power levels for random locations in communication system design and analysis.

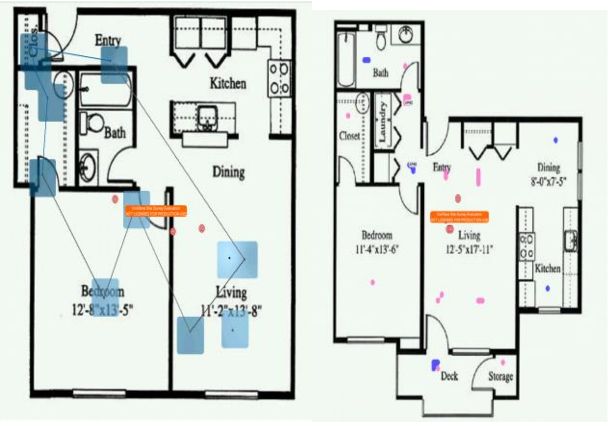

Fig.5.1AP’s measured Points at both location for attenuation

For estimation of wall and door attenuation factors:
We computed the difference between the measured signal strength and the signal power that was obtained due to free space propagation for a transmitter and receiver at the same separation distance.

Table 5.1: Dielectric constant of various material

Glass	4-10	4.1.1.1 Marble	12
Concrete	4-6	Gypsum board	3
Wood	1.5-2	Formica	4
Water	80	Ground	5-30

Table 5.2: Attenuation for Different material

Material	Brick	12mm Ply board	18mm Plywood	Glass
loss at 2.4 GHz	-4Db	-0.5Db	-1.9dB	-0.5dB
loss at 5.2 GHz	-14.6dB	-0.7dB	-1.8dB	-1.7dB

5.1. Multi-Gradient Single-Floor (MGSF) model

The Multi-Gradient Single-Floor (MGSF) model most recently has been used to model the WiFi propagation path-loss in indoor environments. The MGSF model makes use distance partitioning to allow for multiple distance-power gradients to describe the path- loss. The MGSF is the recommend model for the 802.11 standard [9]. The basis for the use of distance partitioning is the assumption that the propagation path-loss from the AP to receiver does not follow a uniform gradient. the distance partitioned MGSF model,

$$L_p = L_0 + \begin{cases} 10\alpha_1 \log(d) & ;d<d_{dp} \\ 10\alpha_1 \log(d_{bp})+10\alpha_2 \log(d/d_{dp}) & ;d>d_{dp} \end{cases} \quad (5.1.1)$$

Where Lp is the path-loss over distance d in dB, L0 is the path-loss over the first meter in dB, α1 and α2 are the distance-power gradients for the path sections one and two respectively, and dbp is the breakpoint distance in meters.
We then add the exterior wall penetration loss to the MGSF+BP to produce a model we denote as MGSF +BPWL. The MGSF +BPWL formula is given by

$$L_p = L_0 + \begin{cases} 10\alpha_1 \log(d_{wbp})+10\alpha_E \log(d/d_{wbp})+L_w & ;d_{bp} > d_{wbp} \\ 10\alpha_1 \log(d_{bp})+10\alpha_2 \log(d_{wbp}/d_{bp}) & \\ \qquad +10\alpha_E \log(d/d_{wbp})+L_w & ;d > d_{bp} \end{cases} \quad (5.1.2)$$

Where Lw is the path-loss for the exterior wall in dB.

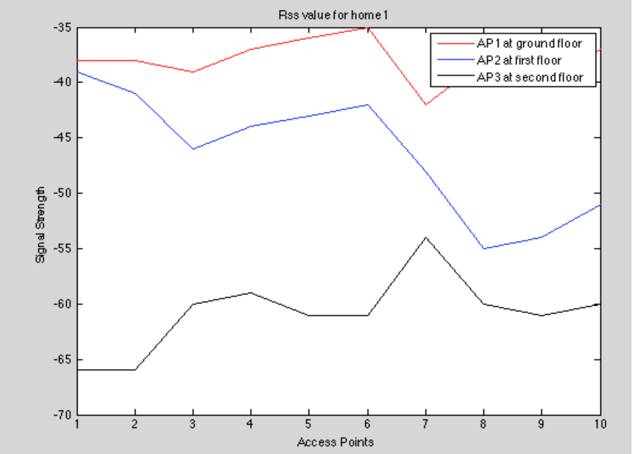

Fig.5.2 RSS value for home1

Fig.5.2 and Fig.5.3 shows the AP's result for each floor in these buildings. Ground floor and Second floor is the main experimental areas for house1, First floor AP's points for open corridor is taken and vice versa for house2. For Fig.3.10 shows the points of the both houses.

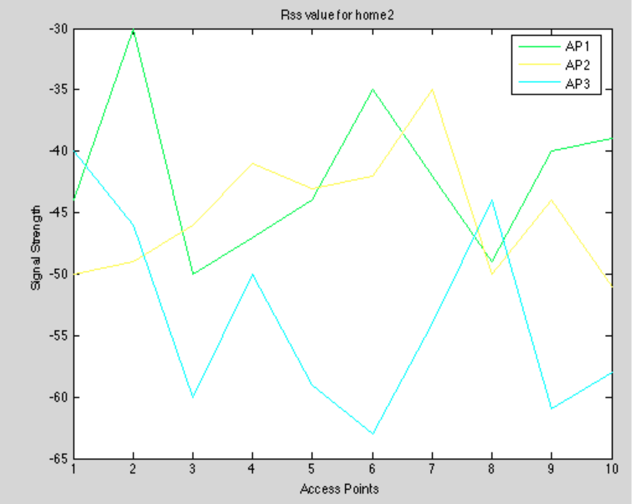

Fig.5.3RSS value for home2

Fig.5.4 RSS values measured in building

5.2 Single-Gradient Multi-Floor (SGMF) Model

The idea behind this model is that the distance dictates if the AP and receiver are located on the same floor the path-loss from the AP to the receiver using a distance power-gradient. If the AP is located on a difference floor than the receiver a floor penetration loss is added to the distance dictated path-loss. The SGMF model assumes that the strongest signal path is through the floors between the AP and the receiver [9].

The path-loss in the SGMF model is given by

$$Lp=L0+Lf(n)+10\alpha\log(d) \qquad (5.2.1)$$

Where L0 is the path-loss over the first meter, Lf (n) is the attenuation attributed to each floor, n is the number of floors between the transmitter and receiver, α is the distance- power gradient, and d is the distance between the transmitter and receiver.

5.3. Partitioned attenuation model

When there are walls in direct path between transmitter and receiver antennas can be expanded to include additional site specific losses:

$$L(d)=L_0+10n\log d+kF_1+\sum_{i=1}A_i \qquad (5.3.1)$$

Where A_i is the attenuation factor for i-th partition [dB]. Free Space Propagation n-2 is often used in COST231 Multi Wall Model. In some situation this approach cannot consider waveguide effects in corridors. The Standard deviation for all the locations was 6.5dB and it caries from 5.0 to 7.2 dB for particular parts of the floor [10].

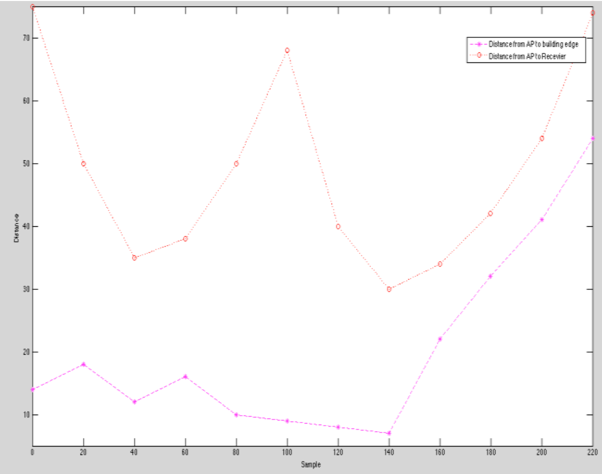

Fig.5.5 The performance of the second floor and ground floor for both houses respectively.

Fig.5.5 represents sample point 24 there was only 16 meters of building for the signal to pass through whereas at sample point 192 there was 37 meters of building to pass through.

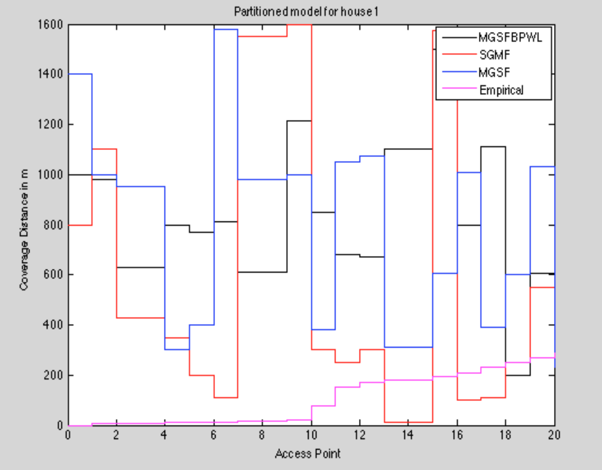

Fig.5.6 Result for Partitioned Model house1

To understand the performance the data should be collected for describing different models. Opposed to the SGMF base model, the MGSF base model showed improved performance when the building partitioning parameters were added. The addition of the wall breakpoint showed a 6% increase, but when the wall path-loss was added the performance increased by 10%. The results follow the expectation that the MGSF+BPWL model with path-loss for the exterior wall of the buildings would outperform the models without the wall path-loss [11][12].

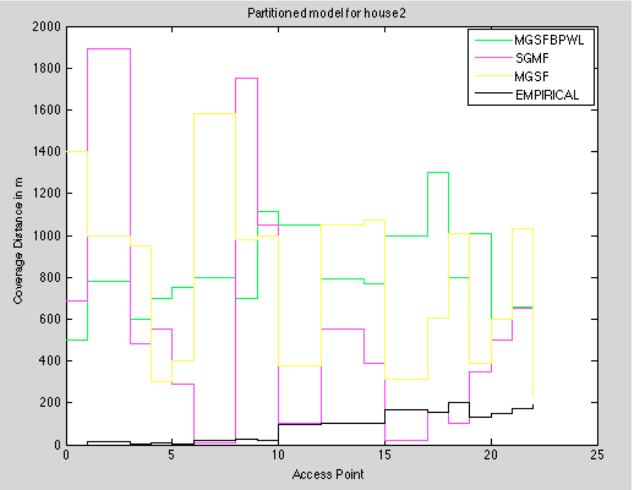

Fig.5.7 Result for Partitioned Model house2

Conclusion

Propagation models provide estimates of signal strength and time dispersion in many indoor environments. These data are valuable in the design and installation of indoor radio systems. This paper also demonstrates the relationship between path loss exponent models and more sophisticated prediction techniques that incorporate site-specific information. The availability of fast interactive-computing environments and high-accuracy graphics databases greatly improves the efficiency. These include the non-linear variation of material loss with material thickness or frequency and the average predicted penetration loss versus frequency for a windowed wall. A numerical analysis of measurements in each scenario was conducted and the study determined equations that describe path loss for different scenarios.Finally it was observed that the RSS signature behavior was affected by the location of the AP within the building in respect to the distance from the exterior wall. The results explain the variation in multi-wall model and single wall model, building partitioned model. Based on these environment characterizations there may be further research needed to design and evaluate models for theses different environments.

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