

Enhanced indoor propagation model for WLAN System

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Abstract: Radio propagation in the local networks (IEEE 802.11g) is the object of intensive researches. This paper provides an indoor channel propagation model for wireless local access network (WLAN). The considered model is built based on various power measurements of the channel signal level at different positions in the covered area. The collected data is associated to the moment and the tridimensional position. The computation enables the establishment of a new WLAN propagation model which is more accurate compared to the existing one found in the literature. The simulations results highlight the efficiency of the considered model.

I- INTRODUCTION

Wireless communications based on the local area networks denoted by IEEE 802.11 are largely deployed in homes and premises. The success of this technology could be explained through three essential assets which are the lower and lower cost of equipment acquisition, the time gain in the deployment and facility of the installation process compared to wired local area network. One of the most important advantages of WLAN technology is the mobility enabling the user to get network access facility anywhere in the covered network. Despite this wide deployment, the radio coverage and quality of service analysis related to these networks has pointed out the presence of weak signal at some places and at some moment of the day. It is the reason why a number of studies [1-3] focused on proposing a propagation model which could help more accurately in the prediction of the signal.

The radio engineering process might be done by choosing a propagation model that best reflects the physical phenomena encountered in the local area. Various models [1-5] are actually proposed in the literature, namely, the empirical models, the determinist models and the semi-empirical models. However, we have found that these models [4-5] are not well adapted to our case of study which is indoor environment. Then we have investigated the Design of a Wi-Fi propagation model for indoor coverage.

The remainder of this work is organized as follows. Section II is dedicated to describe the main existing WLAN propagation models. Section III deals with the description of data acquisition process. Section IV describes the enhanced indoor propagation model. In section V, the introduced model has been

implemented and compared to existing one. A Conclusion finally ends our study.

II- Main existing WLAN propagation models

II.1 Free space propagation

The power level of the received signal emitted from an identified position depends on the propagation environment. The well-known propagation model in free space provides a first approach. This free space model could be only applied to an ideal environment characterized by homogeneous properties and without any obstacle. Then transmission between the transmitter and the receiver might be Line Of Sight (LOS). At a given transmission frequency, lower power of the signal depends only on the distance between the two points of transmission and it follows the Friis transmission formula expressed as:

$$Pr = \frac{Pe \cdot Ge \cdot Gr}{\left(\frac{4\pi}{c} \times d \times f\right)^2} = \frac{Pe \cdot Ge \cdot Gr}{L_0} \quad (1)$$

Where

$$L_0(d, f) = \left(\frac{4\pi}{c} \times d \times f\right)^2$$

is called Path Loss and could be rewritten as

$$L_0(\text{dB}) = 32.45 + 20 \log(d * f) \quad (2)$$

With d , the distance in Km and f corresponds to the propagating signal frequency in MHz.

II.2 Indoor propagation model

Radio signal propagation path loss has been approximated in different ways.

➤ One slope model

One slope model is based on the equation of propagation in free space. It gives attenuation at distance " d " as :

$$PL(d)[\text{dB}] = 10 \log \left(\frac{d}{d_0} \right)^n + A_0 \quad (3)$$

Where d_0 means the reference distance used to normalize the attenuation of the distance from the transmitter; n is the exponent of loss and A_0 denotes a constant.

➤ Honcharenko Model

In this model the dependence between the exponent of the attenuation and the distance to the transmitter is taken into account. Indeed, when the distance

between the transmitter and the receiver is low (less than 10 meters), attenuation is comparable to the one in free space because it is the direct signal which is dominant compared to the reflections and the diffractions phenomena. But for long distance, the indirect paths are dominant. With Honcharenko model [5], it is possible to calculate the break distance d_c regarding this approximation. The propagation equation is detailed as :

$$PL = 10 \log \left(\frac{d}{d_0} \right)^{n_1} U(d_c - d) + 10 \left[\log \left(\frac{d_c}{d_0} \right)^{n_1} + \log \left(\frac{d}{d_c} \right)^{n_2} \right] U(d - d_c) + \sum_{p=1}^P W AF(p) + \sum_{q=1}^Q F AF(q) + A_0 \quad (4)$$

$$U(d) = 0 \text{ if } d < 0$$

$$U(d) = 1 \text{ if } d \geq 0$$

III- Description of data Acquisition process

Field measurements were made possible first through the use of an access point, namely Linksys WAP54G which is based on the IEEE 802.11g standard. It operates in the frequency band of 2.4 GHz and offers a throughput of 11 Mbps. Its transmission power is 20 dBm. A laptop with a wireless network adapter, Atheros brand, was used to measure the signal strength.

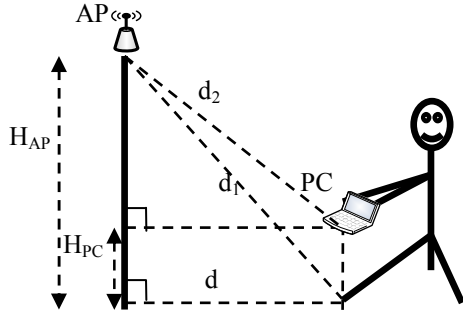


Figure 1: Taking of measurements parameters

The terms of the distances are given by the following formulas:

$$\begin{aligned} d_1^2 &= H_{AP}^2 + d^2 \\ d_2^2 &= (H_{AP} - H_{PC})^2 + d^2 \end{aligned} \quad (5)$$

H_{AP} : height of the access point

H_{PC} : height of the personal computer

d : orthogonal distance between the AP and the PC

d_1 : direct distance from AP to footprint

d_2 : direct distance from AP to PC

Measurements of signal level were performed using the software named “Wifi coverage”. It is a tool designed for windows operating systems for the measurement of the signal level in a wireless local

area network using the standard IEEE 802.11a, IEEE 802.11b and IEEE 802.11g.

Diversified measurements campaigns were performed at regular distance intervals. Thus, at each interval signal measurements were taken by rotating the laptop twice along its axis, to take into account directions of arrival of the wave. For each measurement, we have granted about 1 min and the best power was considered.

For indoor measurements data collection of three places has been considered case by case. Firstly, a lecture room with furniture. This room is 10.5 m X 7.5 m X 2.75 m. The access point was at height of 2.2 m and the laptop at height of 1.5m. For each series of measurements, signal measurements are taken twice in round trip at every 1m interval diagonally across the room. Secondly, a computer room named Cybercafe is considered. This room is 9 m X 6.8 m X 2.75 m. The access point was at height of 2.6 m and the laptop at height of 1.5m. For each series of measurements, signal measurements are taken twice in round trip at every 1m interval diagonally across the room. Thirdly, a closed corridor is chosen. This corridor is closed mainly by three doors in windows. This corridor is 21.5 m X 1.8 m X 2.4m. The access point was at height of 2 m and the laptop at height of 1.5m. For each series of measurements, signal measurements are taken twice in round trip at every 1m interval in the middle of the corridor.

To avoid considering values of received powers deviating too much from the others at the same point, we perform a first processing step as follows: for each series of measurements, if at a given distance, a level of received power taken in absolute value, exceeds furthermore of 7dBm the average of the other levels of power received at the same distance and also taken in absolute value then, this power level is replaced by the average of these last ones. Linear regression is performed thanks to the use of Matlab toolbox which achieved different types of linear regression. Considering our work that is mainly the study of the radio propagation according to the distance, we have opted for a linear polynomial regression. The regression will be good when the correlation coefficient $r^2 = 1$. As in [4],

$$\begin{aligned} \sum e_i^2 &= 0. \\ y &= P_1 X + P_2 \end{aligned} \quad (6)$$

y : explanatory variable

X : descriptive variable

P_1, P_2 : constants

In this work, y represents the vector of the observed loss and X the vector of the logarithmic distances.

For indoor collected data processing, the following algorithm allows us to describe all the activities that will be made to conduct to the proposition of an indoor model:

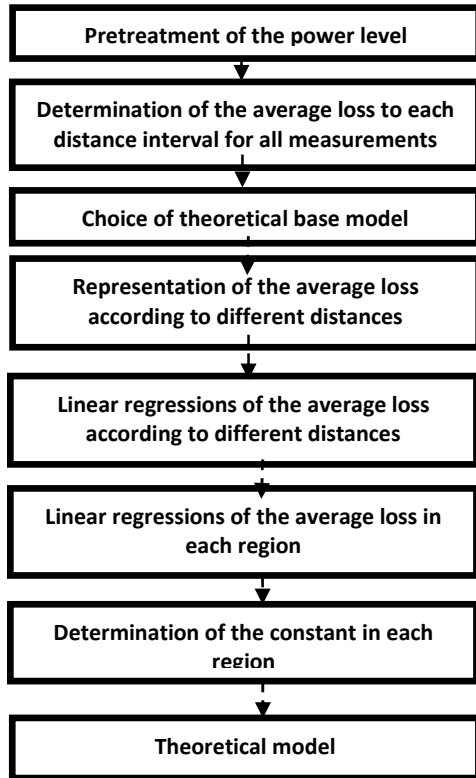


Figure 2: Elaboration algorithm of the theoretical indoor model

IV- Enhanced propagation model

IV.1 Dependence with height

Figure 1 below roughly illustrates that attenuation of propagating wave depends on the height or the altitude between the transmitter and receiver, then the greater the height will be, same will be the attenuation.

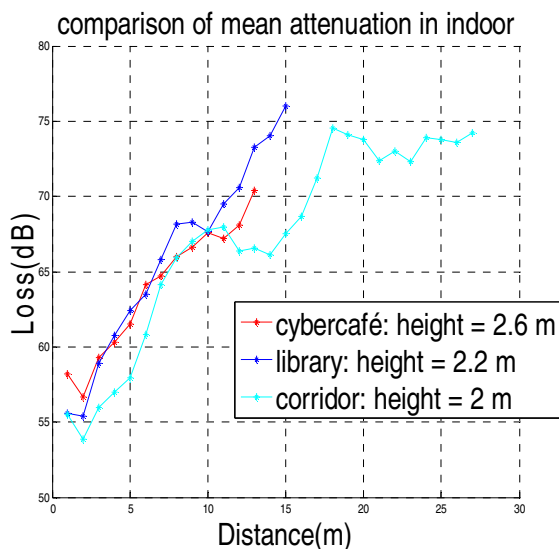


Figure 3: Comparison of mean attenuation in indoor

Therefore, it comes from the observation in Fig.3 that the propagation of radio waves emanating from local IEEE 802.11 networks depends on the height. On the other hand, for indoor environment attenuation also depends strongly on the configuration of the room. It could be also pointed out that attenuation introduced by the papers in the library is higher than that of computers in Cybercafé.

If the path loss were not a function of height, then these curves might be combined. If there is a point of junction of all the curves, this point corresponds to the one from which the height becomes negligible compared to the distance. We propose to call it point of convergence.

The determination of this point of convergence has been possible thanks to the plan of the rights of linear regression of the average loss according to these three various distances.

IV.2 Theoretical indoor model

In this section, a new theoretical propagation model has been elaborated based on one slope model described in section II.

This theoretical model is obtained after running the algorithm for the indoor environment at 2.4 GHz based on the IEEE 802.11g standard. It is expressed as:

$$PL(dB) = \left[10 \log \left(\frac{d}{d_0} \right)^{n_1} + 10 \log (H_{PA})^{n_1} + c_1 \right] U(d_c - d) + \left[10 \log \left(\frac{d_c}{d_0} \right)^{n_1} + 10 \log \left(\frac{d}{d_c} \right)^{n_2} + c_2 \right] U(d - d_c) \quad (7)$$

d_0 : reference distance used to normalize the attenuation at the distance from the transmitter.

d_c : convergence distance.

H_{PA} : height of the access point.

n_1 : exponent of loss in the first region.

n_2 : exponent of loss in the second region.

c_1 : constant in the first region.

c_2 : constant in the second region.

$U(d) = 0$ si $d < 0$

$U(d) = 1$ si $d \geq 0$

VI.3 Implementation of the indoor model

The distance of convergence (logarithmic distance) has been estimated from the intersection of the regression of the average loss according to different distances. In addition, the values of n_1 and n_2 in each region have been also estimated through the regression slope $10 n$, which allow us to deduce c_1 and c_2 . These constants correspond to the average of the difference between the average loss and the uncalibrated theoretical loss in each region.

Library: average loss according to different distance

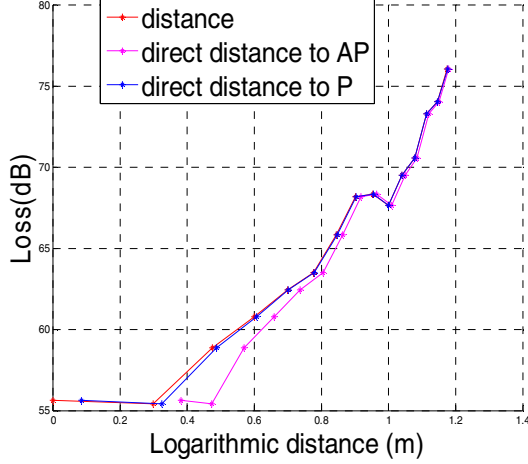


Figure 4 : Average loss according to different distance for library

Library: linear regression in the 2nd region

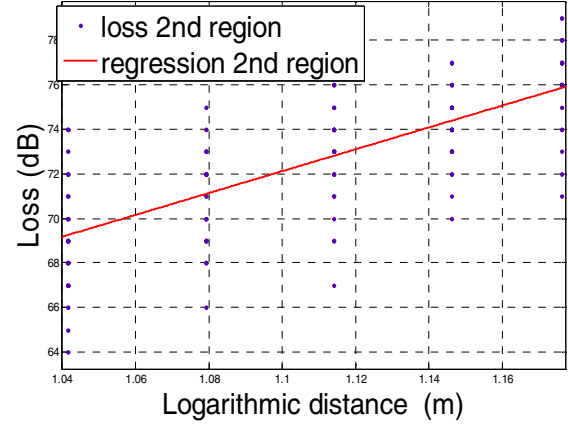


Figure 7: Linear regression in the second region for library

Library: : linear regressions to determine the convergence distance

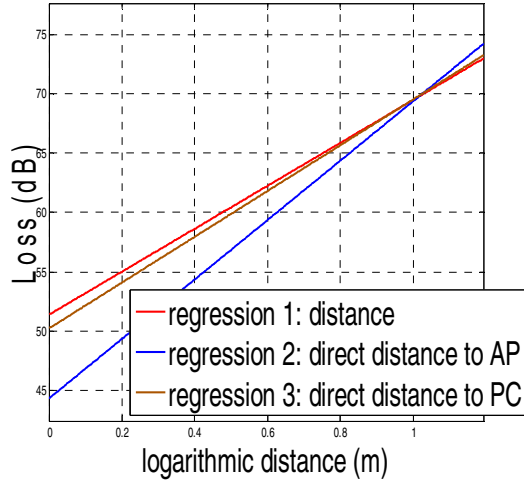


Figure 5: Linear regressions to determine the convergence distance for library

Library: linear regression in the 1st region

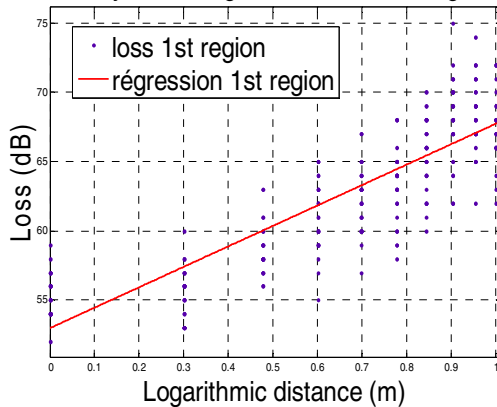


Figure 6: Linear regression in the first region for library

Regression Parameters	Regression 1		Regression 2		Regression		Regression 1 st region		Regression 2 nd region	
	R= .9023		R=.9675		R=.9216		R=.7345		R=.4986	
	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂	P ₁	P ₂
Library	18.09	51.38	25.05	44.32	19.29	50.22	14.74	52.98	49.05	18.17

Table 1: regression parameters with 95% confidence interval

parameters of model	d_c	n_1	n_2	c_1	c_2
Library	1.0144	1.474	4.905	47.9367	52.9664

Table 2: Parameters of the theoretical model

➤ Analysis

It can be observed that: n_1 is lower than n_2 , as well as c_1 is lower than c_2 . It means that n_1 and n_2 evolve in the same sense as c_1 and c_2 . We notice that the exponent of loss n_1 is close to that in buildings with LOS (1.6 to 2.5), while n_2 , meanwhile is close to that in buildings with NLOS. Moreover, the convergence point separating both regions of loss is about 10.3371 m from the access point.

➤ discussion

Considering the configuration of the environment, the values obtained from the exponents of loss are not surprising. The loss in the first region, that is until approximately 10.3371 m is close to that in free space. But because of the strong wave attenuation of the paper, the second region appears as a multi-room propagation.

Thus loss in the first region is lower than in the second region.

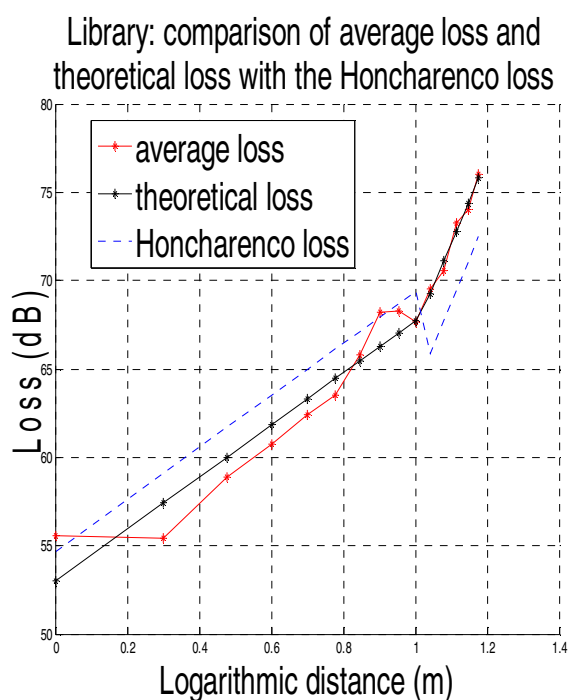


Figure 8: Comparison of average loss and theoretical loss with the Honcharenko loss for library.

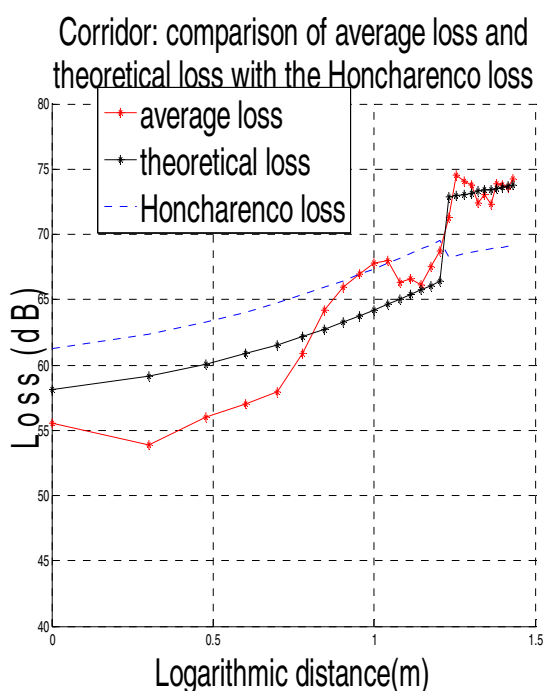


Figure 9: Comparison of average loss and theoretical loss with the Honcharenko loss for corridor.

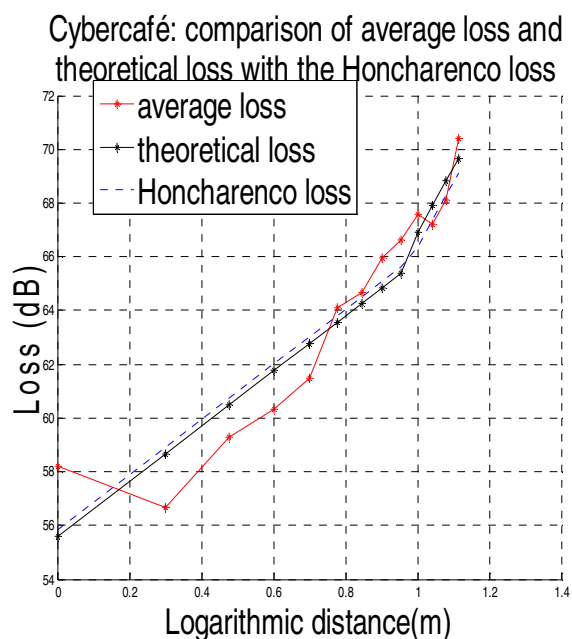


Figure 10 : Comparison of average loss and theoretical loss with the Honcharenko loss for cybercafé.

V- CONCLUSION

Prediction of radio signal propagation power distribution in an indoor area is a hard task because of the multiple paths emanating from potential indoor reflections. This paper has proposed an enhanced propagation model. As depicted by the comparison results, this new model outperforms the existing one as shown by the simulation results.

VI- REFERENCES

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