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Research paper

Estimation of power analysis in WLAN infrastructure

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Abstract

Design of indoor WLAN infrastructure requires prediction of radio waves propagation inside the building, which can be a complex problem. Therefore some sort of planning is required before the wireless networking hardware is set up.The goal of this work is to provide an estimate of the received power within a building. Physical environment is a large office building, of which we consider one part. The building is constructed of various materials. In this paper, we present a model that simulates the considered problem. Received power is calculated and compared to receiver minimum input level sensitivity given by the IEEE 802.11 Standards. Numerical results were obtained using MATLAB.

Keywords: *Propagation model, multi-wall model, indoor WLAN, MATLAB.*

1. Introduction

The propogation of electromagnetic waves will be affected by walls and other obstacles which present inside the closed room. The received signal depends upon both time and position small changes in these parameters both time and position dramatically changes the signal strength.[1].There is no simple way in which various propagation mechanisms can be evaluated. For the practical prediction of propagation in a real environment the phenomena which influence radio wave propagation must be described by approximations. Propagation models are more efficient when only the most dominant phenomena are taken into account [2].The prediction depends on the layout of the building, characteristics of the antennas and wave propagation model. The quality of this approach can be determined in comparison with measurements.

2. Antennas

Antennas are described by a number of parameters. We are interested in antenna gain, radiation pattern and location. In a signal coverage prediction framework we try to simulate antennas in a 3D space.
The standard wireless access point (AP) antenna is an omni-directional dipole antenna. For large areas an omni-directional antenna can be a good solution if it is placed in or near the center of the area. The standard antenna performs well in most office environments.
In this paper we have used the D-Link DWL G700AP AirPlusG High-Speed (802.11g) Wireless Access Point with a detachable antenna. The gain of this antenna is 2 dBi. The manufacturer does not provide the antenna radiation pattern. It is a dipole antenna

and vertical radiation pattern of similar antennas vary between 65 and 75 degrees. We assume that the antenna radiation pattern is 360 degrees in the horizontal plane and 70 degrees in the vertical plane. The three-dimensional radiation pattern is doughnut shaped. The transmitting antenna (AP antenna) was located at 2 m height and the maximum effective isotropic radiated power (EIRP) was 50.7 mW (17 dBm).

The antennas used for laptops can be considered as dipole antennas. The signal at the receiving antenna comes from many different directions in indoor conditions. The details of the antenna pattern are therefore “blurred” by the scattering characteristics of the indoor situation [3]. One approach is to use the “average” gain of the antenna installed on the laptop. The average gain can be obtained from antenna radiation pattern averaged over azimuth and elevation angles and normalized with respect to an ideal isotropic radiator [3]. The laptop antennas radiation patterns and locations were not available, so we assume receiver antenna is half wave dipole antenna and average gain of this antenna is –2.5 dBi.

3. Theoretical approach

The received power depends on the radiated power, antenna characteristics and the path loss. To maintain a connection, the maximum acceptable path loss between the transmitter and receiver must not be exceeded.
The performance characteristics of WLAN systems will depends on the wave path between the receiver and the transmitter. The free space path loss model is used to detect the received signal

strength when the transmitter and receiver have line-of-sight (LOS) path between them. The path loss model is utilized for non-LOS (NLOS) paths. The model estimates total path loss by including the free space path loss and penetration losses caused by different types of obstacles.
The equation (1) can be used to express path loss Lbetween the transmitting and receiving antennas

$$L = L_0(d) + \sum_{n=1}^{N} L_{wn}, \tag{1}$$

where N is a number of walls between transmitter and receiver antennas, L_{wn} [dB] is attenuation factor for n-th wall and $L_0(d)$ [dB] is the free space path loss for the wave-length λ [m] and distance d [m] between transmitter and receiver antennas, given by (2)

$$L_0(d) = 20\log\frac{\lambda}{4\pi d}. \tag{2}$$

The power delivered to the receiver, P_r [dBm], is given by

$$P_r = P_t + G_t + F_t(\theta_t) - L(d) + G_r, \tag{3}$$

where P_t [dBm] is total power radiated by transmitting antenna, G_t [dB] is the transmitting antenna gain, $F_t(\theta_t)$ [dB] is transmitting antenna radiation pattern, $L$is the path loss between transmitting and receiving antennas and G_r [dB] is the receiving antenna average gain. Since the transmitting antenna is omni-directional, the radiation pattern is function only of elevation angle θ_t.
When penetrating an obstacle the signal will experience a loss which depends on the thickness of the object and the material it is made of. The frequency of signal also determines the fraction of the signal power that will pass through the object. There exist a lot of measurements made of loss through different materials for WLAN. Tables 1, 2 and 3 show some values of signal attenuation for the most common types of obstacles [4]-[9].

Table 1: Multi–Wall Model Parameters [4]

f [GHz]	L1 (dB)	L2 (dB)	comment
2.45	5.9	8	office building
2.45	6.0		office building
2.5	5.4		drywalls

Table 2: Typical Path Loss [5]

2.4 GHz Path Loss	
Glass Window	2 dB
Wooden Door	3 dB
Cubicles	3-5 dB
Dry Wall	4 dB
Marble	5 dB
Brick Wall	8 dB
Concrete Wall	10-15 dB

Table 3: Attenuation [6]

Obstacle	Attenuation [dB]
Floor	30
Brick wall with window	2
Office wall	6
Metal door in office wall	6
Cinder block wall	4
Metal door in brick wall	12.4
Brick wall next to metal door	3

4. Results and Measurements

A plan of the office building with the six receiver locations (Rl to R6) is shown in Figure1.

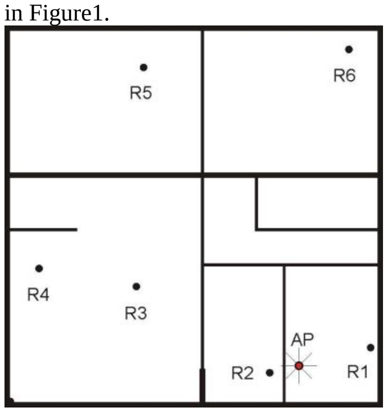

Figure. 1: Office plan

The office building walls are made of brick, width of which was either 0.12 m (thin walls) or 0.40 m (thick walls). Based on measurements and tables 1-3, we have estimated the attenuation introduced by thick walls at 12 dB and the attenuation introduced by thin walls at 6 dB.
Figures 2 and 3 show the values of received power P_r[dBm] in an area of $10.5\ \text{m} \times 10.5\ \text{m}$, at the height of 0.75 m (height of the desktop surface) for different locations of AP antenna at the height of 2 m.

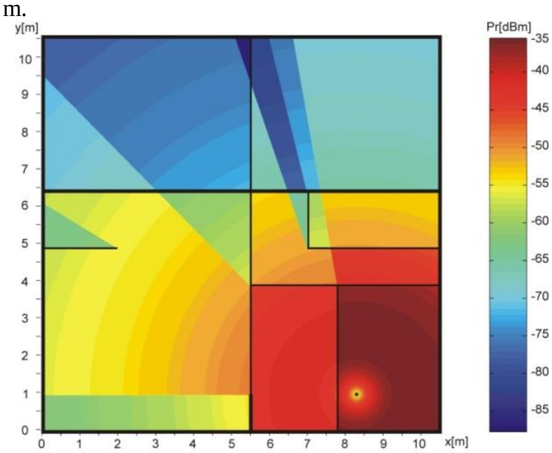

Figure. 2: Multi-wall model: received power from the AP on the first location

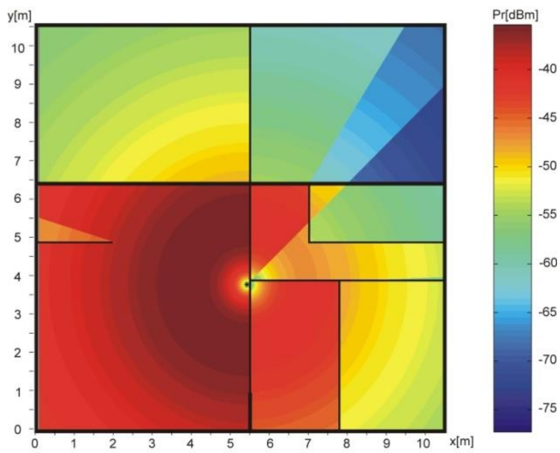

Figure. 3: Multi-wall model: received power from the AP on the second location

The measurements were done in office rooms, after working hours. For measurements, we used an IBM ThinkPad T43 laptop with integrated 802.11abg wireless adapter (Intel Pro/Wireless 2915), two receiver antennas and Wireless Mon software, which provided the signal strength metering. The AP transmitting antenna was placed in a fixed location at a height of 2 m. There were six receiver positions (R1 to R6) in the office. The receiving antenna (laptop) was placed on a table at a height of 0.75 m. Measurements were done with various transmitting powers over the period of two days. Each measurement result represents the average of about 20 measurements. Laptop was rotated in 4 quadrants for each of 6 locations. The measurements were conducted in the office with walls and some furniture. Impact of furniture was not included in the propagation model. People can also act as obstacles, as a single person can attenuate the signal strength by up to −3.5d Bm[10]. During the measurements the authors were present. The wireless transmit power of the AP was adjusted to 15 dBm ± 2 dB and detachable dual transmitting antennas of the AP have 2 dB gain. The connection to the AP was dropped when the received signal strength was less than –87 dBm. The calculated path loss, L_c, was evaluated using(1). The measured path loss, L_m, was evaluated using(3). To indicate the accuracy of the model the prediction error is calculated. The prediction error is the difference between the calculated path loss and measured path loss.

In Table 4below, we present calculated and measured path loss for all positions of the reciver in the office (Figure 1). In Table 4, *d* is the distance between the AP transmitter and the reciver, *N* is the number of walls between the transmitter and the receiver, L_c is calculated path loss, L_m is measured path loss, and $er = L_c - L_m$ is the error.

Table 4: Calculated and Measured Path Loss

receiver position	*d*[m]	*N*	L_c[dB]	L_m[dB]	*er*[dB]
R1	2.5	0	48	48.5	-0.5
R2	1.65	1	50.5	50	+0.5
R3	5.5	2	67	69	-2
R4	8	2	70	74.6	-4.6
R5	10	4	90	93.6	-3.6
R6	9	3	83	87.8	-4.8

The measurements show that the large fluctuations can be observed between signal levels received in the different parts of the office. The rooms close to the access point are illuminated with enough power even when the transmitter and receiver are separated by two walls. The coverage in the office may become critical, if the transmitter and receiver are separated by three or more walls.

5. Conclusion

The proposed propagation model is easy and fast to apply. The office plan description is needed as an input and the results are site-specific. Theoretical results were compared to empirical ones which were obtained by measuring the signal strength with a laptop computer. The signal strength prediction, using a propagation model, is much more convenient way to design indoor wireless LANs than a site survey with lots of measurements.

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