Empirical Approach to Determine Path-Loss Exponent for Indoor LOS Environment

Yogeshwari K J¹ & G Poornima²

¹ Post Graduate Student, Department of Electronics and Communication Engineering, B M S College of Engineering, Bengaluru
² Professor and HOD, Department of Electronics and Communication Engineering, B M S College of Engineering, Bengaluru

Abstract: Path-Loss is the depletion of Power of Electro Magnetic (EM) Waves when they propagate through an Environment is. It is important to understand the various parameters affecting the Radio Signal Path-Loss because Estimation of the Loss in any Path becomes easy and Coverage achievable for a particular Access Point also becomes easy. Therefore estimation of Path-Loss Exponent is crucial. So an Empirical Approach is developed to Determine Path-Loss Exponent for Indoor Line-of-Sight (LOS) Environment. The determined Path-Loss exponent is used to estimate the Distance between the Wireless Client Device and the Access Point (AP).

1. Introduction

Depletion of power of an EM waves when they propagate through an Environment is known as Path-Loss of the Radio Wave. Various causes for the Path-Loss of Radio Waves are: Free space Path-Loss, Diffraction around the objects in the Environment, Multipath propagation, Reflections and Absorptions by buildings and structures, Atmospheric effects. Path-Loss is also because of the medium of propagation, separation of transmitting and receiving antennae, and height of antennae [1]-[3]. Assessment of Path-Loss will be unambiguous for free space case but the assessment is very difficult for practical Environments where there will be obstruction to wave propagation offered by different objects and structures. A variety of methods are utilized in Path-Loss estimation. For Free space the Received Signal decreases with the square of the Distance between the communicating Antennas, i.e. 20 dB decrease in the received power for a decade increment in Range. Implementation of this computation is easy, though practically the existence of free space is very rare, so practical Path-Loss prediction involve complex computations. Statistical Approach considers the average Signal loss of general radio Communication paths for estimating the Path-Loss for the Signal [4]. The metrics are utilized in building projection Model for calculating the Path-Loss depending on the statistical data collection. In planning. The coverage for any cellular Network, Range estimation for Wi-Fi Network for home, organization and office Environment this Approach is generally made use [5].

WLAN Network design uses the idea of an AP and Clients. The AP or router is the equivalent of a base station in a cellular Network. AP serves as a link between the wired Network and the Wireless end-user traffic. Few Clients devices are smart phones, desktops, laptops and printers. An emerging WLAN Standard given by IEEE is 802. 11ac; it is exclusively a 5GHz technology. Its speed and scalability is more compared to 802. 11n. Huge number of Personal computing devices like detachable laptops, laptops, smart phones and desktops are incorporated with Wireless-ac Adapters. IEEE 802. 11ac has higher bandwidth and MU-MIMO capabilities. The Standard is more suitable for business applications such as video conferencing, Wireless display, Real-time update of applications, business analysis. Therefore the recent Wireless Adapters are moving towards incorporating IEEE 802. 11ac Standard [6]-[7].

2. Requirements

- Client Device with 802.11 ac Wireless Adapter
- Router that supports 802.11 ac Wireless Standard
- Netstumbler to scan the Received Wireless Signal

3. Methodology

Among the various indoor Models, a particular form of a Power-Law Model for characterizing the Path-Loss is considered here. The descriptive parameter is the power raised to the Distance; Statistical properties for indoor Environment are to be studied experimentally. For indoor Environment major mode of Communication between AP and Client Device is LOS. In LOS Communication there will be no
obstruction between the Antennas of transmitter and receiver [8].

To Compute the Path-Loss Exponent in LOS region following Power – Law Model is used.

\[ P_r = \frac{P_t}{d^n} \alpha_p \left( \frac{\lambda}{4\pi} \right)^2 (g_{rx} \times g_{tx}) \]  

\( d \) is the predicted Distance between the transmitter and the receiver. \( P_t \) is the power of antenna in the transmitter in dBm and \( P_r \) is the power received at the receiving antenna in dBm . \( g_{tx} \) is the antennae gain of the transmitter in dBi, \( g_{rx} \) is the antennae gain of the receiver in dBi, \( \lambda \) - is the wavelength for the Signal, ‘n’ is the Exponent to Path-Loss, which measures of influence of obstacles in the Communication path [9]-[10]

Benefits of Log-Distance path loss Model:
- They have their roots from free-space propagation loss.
- Log-Distance Model is obtained by modifying the free-space Path-Loss with the Path-Loss Exponent ‘n’ that varies with the Environments.
- Most suitable for Empirical Modeling due to their applicability in LOS Communication.

In order to ease the recording of the RSSI values captured at various Distances and availing these RSSI values in the calculation of the Distance, a Python code is developed. This code will take all the recordings of the RSSI values obtained from the Netstumbler according to the Distance where they were captured. Based on these input RSSI values the Distance calculation is done. In general the Range of ‘n’ that are proposed by the ITU for indoor LOS Communication are given as input to the code.

For each of the ‘n’ value in the specified Range the Distance are calculated and plotted for the measured RSSI values. Actual Distance is also plotted. The value of ‘n’ which closely approximates this Actual Distance would be the Path-Loss Exponent for the Environment.

The initial study conducted involved setting up AP which involved configuring it to the 5GHz frequency band and adjusting the transmitter power to radiate 100% power. RSSI samples are captured by Netstumbler tool by slowly moving the DUT away from the AP. The experiment was conducted in LOS Environment. Antennas of AP and DUT should be maintained at the same height of 0.25m. The Distance between the Antennas was increased step by step from 0.0 m to 3 m. The Distance from only 0 to 3m. The step size is taken as 0.25 m. The samples showed a trend of RSSI decreasing with Distance as is expected. At every 0.25 m Distance the RSSI values are captured 20 times and the average of them is considered as the received RSSI at that position.

When the RSSI values are captured 20 times, they deviated less from each other. This can be indicated by using Standard Deviation (SD); it is a number used to describe how measurements for a group are spread out from the average value. Lesser the value of SD, most of the values in a given set are more close to the average value. Higher value of SD highlights that the values in a given set are spread out. For a set of data the Mean and the SD are written together; then it is easy to understand the average number and how widely other numbers in the group are spread out. From our survey the Mean and the SD are plotted in the figure 1 and figure 2 respectively.

Figure 1 shows the RSSI values captured on the DUT from Distance 1m to 3m. The Mean and the SD are decreasing as the Distance between the DUT and AP is increased. The Mean values are considered only from 1 m to 3m, because in the close proximity of transmitter and receiver there is fluctuation in the RSSI due to the near filed effects. Because of the fluctuations in the RSSI values, they deviate to the extent of ± 10 dBm and the average value calculated will not be suitable to use for Path-Loss Exponent prediction and thus the Distance estimation. This behavior can be confirmed from the SD computed for each set of RSSI values. Higher the SD higher will be the fluctuation.

![Variation of Mean of RSSI with Distance](image)

Figure 2 which shows that the SD computed for the set of RSSI values captured from Distances 0.25m to 3m. At the Distance 0.25m the SD is 2.5, implies the 20 readings of RSSI values at 0.25 m deviated from each other leading to the high SD. At Distance 0.5m the SD is around 1.8 less than that at .25m, so lesser deviation between the RSSI readings. At 0.75m also the SD is around 1.8 indicating variations of RSSI readings. Therefore for less than 1m SD is between 1.5 to 2.5 marking the Distance less than 1m as a highly fluctuating region of RSSI. At Distance 1m to 1.5m the SD is 0, indicating all the RSSI values are equal and hence the average RSSI is same as the individual RSSI.

From figure 1 at Distance 1m the Mean RSSI value is -11dBm, the SD of 0 indicates that all the 20
readings of RSSI are equal to -11 dBm, hence the Mean RSSI is also -11 dBm. Similarly at Distances 1.25m and 1.5 m the Mean RSSI are -13dBm and -14 dBm respectively and SDs are 0 at both the Distances. Hence all the 20 RSSI readings were -13dBm and -14 dBm at 1.25m and 1.5m respectively.

The RSSI values collected are used to tune the parameters in the Signal propagation Model. The key unknown in the Path-Loss Model in (1) for our application is the quantity ‘n’. Here, we seek empirical study to find ‘n’ that gives accurate Path-Loss estimation. For n={1.5,1.6,1.7,1.8,1.9,2.0,2.1,2.2,2.3,2.4,2.5} the Distance are calculated using the formula in equation (1). Though it is stated that inside a close Environment and for LOS Communication the Range of ‘n’ is 1.5 to 1.8, the set of ‘n’ has values more than 1.8. This is to show that the value for the said scenario will not exceed the value greater than n=2. There are 11 values of ‘n’ which are taken as references and one among them will be the Path-loss Exponent. Thus we obtain a set of Distances for every ‘n’ value in the above set of ‘n’. For example for n=1.5, Mean RSSI values captured from 1m to 3m. As per figure 1, the Mean RSSI values from -11dBm to -19dBm are considered and set of Distances are obtained. The calculated Distances are the Distances which we get if we consider ‘n’ to be 1.5. In the similar fashion, for all the ‘n’ values and RSSI values the Distances are calculated. Now we have 11 sets of Distances and a set of Actual Distance.

Figure 2. Variations of Standard deviation of RSSI with Distance

The RSSI values at every position were collected for a range of Distances from the AP. These values were used to tune the parameters in the propagation Model. The key unknown in the path-loss Model in our application is the quantity n. Here, we seek empirical study to find n that gives accurate path-loss estimation. The empirical results are arrived with Distance versus RSSI according to (1) with various n values. We further plot the actual Distance at each time of RSSI recording. Inferring from the plot n=1.6 seems to be the appropriate choice for the path-loss Model for most of the RSSI readings.

Figure 3. Variations of Standard deviation of RSSI with Distance

Figure 3 shows the Distances plotted for all the ‘n’ values and the Actual Distances at which the RSSI values are captured. The curve of Distance which very closely approximates the Actual Distance curve is considered to be best suitable curve for Distance estimation. The ‘n’ value corresponding to that curve will be the Path-Loss Exponent for the indoor Environment. From figure 3 the Distance curve for n=1.6 closely matches to the Actual Distance curve. So n=1.6 can be considered as the Path-Loss Exponent for indoor LOS Environment.

Conclusion

Power Law based estimation of Path-Loss exponent in an Indoor closed Environment is considered to be more suitable for Line-of-Sight Communication. Log-Distance Path-Loss Model is developed by the survey of RSS to estimate the Path-Loss Exponent for indoor Environment. n=1.6 is found to be the Path-Loss Exponent. The estimated Path-Loss Exponent, n=1.6 offers accurate estimation of the Distances of the Client Device from the AP than the Distances estimated if n=2 was considered.

4. References

1] Dinesh Tummala, B.S.,“Indoor Propagation Modeling At 2.4 GHz for IEEE 802.11 Networks”,Thesis - University Of North Texas, 2005


