

# Prediction of LOS based Path-Loss in Urban Wireless Sensor Network Environments

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**Abstract.** In this paper, to model the path-loss characteristics in urban line-of-sight(LOS) propagation, we performed measurements in Goyang, Republic of Korea, at a frequency of 2.4GHz using the IEEE 802.15.4 standard. Although path-loss variance for any street existed, measurements yielded a typical path-loss of  $PL(\text{dB}) = \alpha L + L_0$ , where  $\alpha$  is the path-loss coefficient,  $r$  is the street length, and  $L$  is the additional loss incurred at the streets. The path-loss coefficient was measured with a variation of  $\alpha$  in experiments. This measurement will be useful for the estimation of the shadowing area that appears in urban environments, and is motivated by its potential in determining efficient placement strategies for urban coverage.

**Keywords:** Urban Sensor Network, Wireless Sensor Node, Path loss

## 1 Introduction

Wireless sensor networks are important for the analysis and utilization of the 2.4GHz wireless channel, because they decrease redundancy and power-loss with the design of effective network configurations. Particularly in urban environments, there are many obstacles that disturb radio propagation paths like buildings and trees, because radio waves are influenced by reflection and diffraction. Therefore, we need a technique that exactly predicts the loss of wireless signals.

Many methods have been suggested for predicting path-loss. [1],[2] report methods that compute the radio signal strength by using urban environment information like buildings and roads and can predict the path-loss with high accuracy. But these methods are not easy to apply in the many different dynamic situations of an urban environment, because it requires significant processing resources and digital information to ensure a high degree of accuracy in these environments [3].

With different points of view, [4],[5] can predict path-loss through the relative relationship between elements representing an urban environment: the surface area and height of a building in between the transmitter and receiver. This method can reduce the cost and a process time, but it has limits in that the Non LOS (Non line of sight) problem solves only a few parameters that do not reflect sufficiently the path-loss characteristics in the city.

In a sensor network, wireless environments have the property that an antenna is close and is installed on the surface of the earth, and is independent of the movement of the sensor node as well as the LOS-based displacement among sensor nodes. As a result, by considering this property, we can decrease the NLOS complexity and decrease the error range from the mobility. Thus, it is possible to predict path-loss more accurately.

## 2 Wireless Channel Characteristics in an Urban Environment

The path-loss is the reduction in power density of an electromagnetic wave as it propagates through space. In free space, the received power  $P_r$  does not consider direct paths and reflected paths on the earth, nor does it consider the loss factor of urban obstacles like buildings. In a real urban environment, the path-loss model must be use a coefficient that reflects the loss factors and the distance of transmission. In log-normal expression of this model,  $L$  is the path-loss coefficient and is a measure of how fast it increases according to increasing distance  $r$  (in meters) between a transmitter and receiver.

(1)

Here,  $L$  is the additional path-loss constant and is a normal distribution defined with an average  $m$  and a standard deviation  $\sigma$ . We measured and analyzed the loss effect from around an obstacle that is a common source of path-loss so that we could specify path-loss much more accurately in the urban environment.

Urban GIS (Geographic information system) provides information about the streets and buildings that affect the wireless channel conditions. We utilize the Urban GIS in the selection of a measurement section that ensures LOS in the city and the prediction of loss that reduces the error range.

On a street, wireless nodes for collection of channel data were used additionally to cover a wide communication range with high output power. In wireless nodes, the use of the range extender(CC2590) can minimize all energy consumption of a network by maximized transmitter power and minimized hop counter by this. The maximum transmission power ( $P_t$ ) is 10dBm. The acceptable maximum loss is -99dB, including the 6dB gain in HGM (High gain mode).

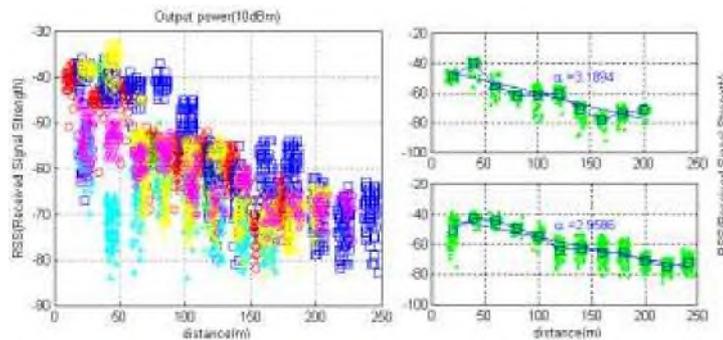
Received power ( $P_r$ ) uses the RSSI (Received Signal Strength Indicator) values received from the RF modules of wireless nodes. The transmitter and receiver antennas are 1.8m high.

## 3 Analysis and Evaluation of Wireless Channel

During propagation, radio signals are affected by reflection, dispersion and diffraction, depending on the static or dynamic obstacles in urban environments. In this chapter, we describe the path-loss prediction and compare it to real measurements.

### 3.1 Collection of RSSI data

The following example is the collected and measured RSSI data around the city of Goyang.



**Fig. 1.** (a) RSSI data that received in the major streets of the city. (b) Real signal strength measured and the approximative loss pattern in a special street. The path-loss coefficient about a particular street approximates to 3.1894. is 4.9568dB. The transmitter and receiver are close to and fixed to the surface of the earth.

In order to simulate the measured pattern in a real environment, we use the break point that is known as having the most influence in the rear distance and the control of the coefficient reflecting the intervals of buildings

### 3.2 Path-loss Prediction based on LOS

The existing two-path method considers only a direct path and reflected path between the transmitter and receiver. This method can be largely distorted in near distances without consideration for the many different urban obstacles and the mutual interference between wave paths due to the close surface of the earth.

We consider a break point as the first element for revising this. A break point is a minimum distance at which an earth reflected wave influence to a direct wave. The following figure shows the trend that the two path-loss coefficients have been divided according to a break point ( ) instead of a single path-loss coefficient by an approximate rule. The real break point is short compared to the theoretical break point ( ).

This is why we say that this trend appears to be much more the effect of a reflected wave through the low position of antenna. According to a measured result, is observed at around 85m. As a result, it is possible to have an analysis that is similar to a real measurement by applying each of the two path-loss coefficients before and after .

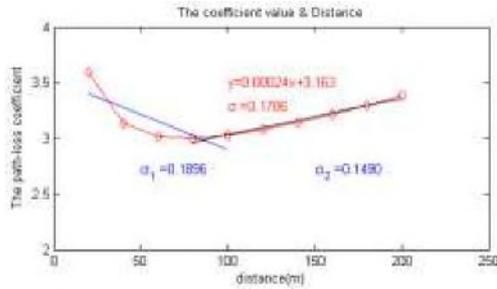


Fig. 2. in the case of a singular path-loss coefficient, but we can have much less error rate and in the case of two path-loss coefficient divided by a break point.

Second, we consider the interference by buildings to improve the prediction of path-loss. But, this paper uses only minimum elements unlike existing methods, such as the building interval, crossroad, etc. Through this, it is possible to minimize the process time and to more closely approximate real urban environments.

In detail, revised path-loss coefficient draws a correlation between the measured results collected and the interval rates around buildings that are representative of the interference. Then the total building interval is the sum of both sides of the building having a tunnel effect between suggested transmitter and receiver. The length of a building interval divides this sum into the distance between transmitter and receiver.

The figure shows the relation of the path-loss coefficient observed while considering the building length. Generally, the building interval is between 0 and 2.

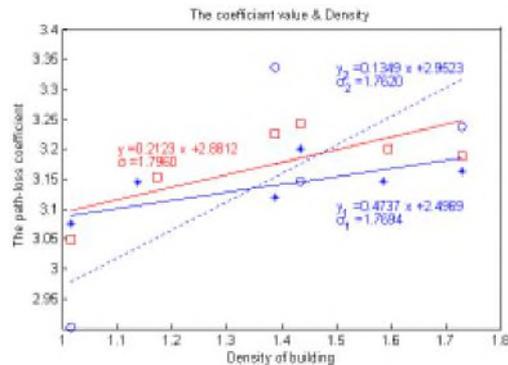


Fig. 3. We can obtain new path-loss coefficients as and as a result of linear regression analysis of 16 two path-loss coefficients ( , ) through applying the building length.

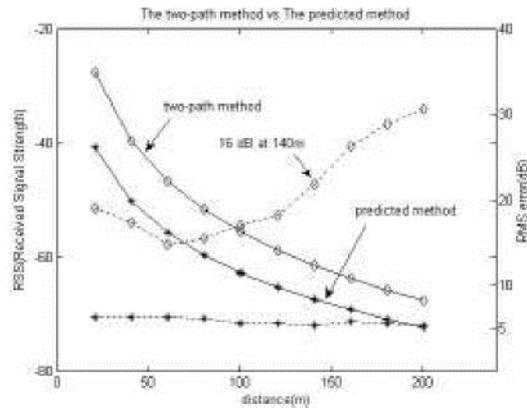
In an LOS environment, the path-loss coefficient is observed  
as the relation between a distance and path-loss coefficient to prepare a fixed

transmission power because of the effect of multiplexed diffraction by surrounding buildings. We know that the path-loss coefficient at the front and rear of is more than path-loss coefficient without but can be significantly improved. Also, we can observe a current that before the loss of is much changed much more.

In an urban environment, there are additionally many dynamic urban obstacles in addition to the static obstacles described in the previous section. Additional loss is observed from vehicle movement in proportion to antenna height. There are also different types of loss according to street crossing and they are measured within 2~5dB according to neighboring geographic features. It is necessary to consider the loss due to the structure and the material that forms a building near a street. It is known that the complement in the range of 3~5dB is much more believable [6].

### 3.3 Comparison of Path-loss Predictions

This section describes an existing two-path method and our path-loss prediction method revised by both the break point( ) and the building interval rate suggested in this paper. Data is repeatedly collected for the distances and building interval rates, and is applied to the linear regression analysis.



**Fig. 4.** Two-path method has indicated each different change in the front and the rear of . Specifically, after , RMS error keeps increasing. By comparison with this, our revised prediction is different from existing methods; it appears equally in RMS error of level about the change of distance compared to measurements in real urban streets (at 140m, the two-path method has an RMS error of 21.7359dB, and the revised method is improved to 16dB ).

Consequently, our prediction method does not satisfy the accuracy(<4.0dB) of existing research [1,2] that utilizes enough computational support and high-precision

GIS resources. But it satisfies the error level (4.1~6.4 dB) of existing research that utilizes only limited computational resources like in our method.

## 4 Conclusion

This paper describes the path-loss prediction of a wireless sensor network that uses the 2.4GHz band in an urban environment. We utilized  $\alpha$  as a typical path-loss expression. The suggested path-loss prediction separates two leveled path-loss coefficients using a break point, and utilizes the interval rate of surrounding buildings for each coefficient. In detail, the two path-loss coefficients ( $\alpha_1$ ,  $\alpha_2$ ) by

are revised to  $\alpha_1'$  and  $\alpha_2'$ , respectively, by utilizing the linear regression analysis of the interruption of surrounding buildings. Also, we made sure that the two path-loss coefficients ( $\alpha_1'$ ,  $\alpha_2'$ ) can predict with the accuracy of about 5.1dB RMS error level compared with the received signal strength.

Our method can predict the propagation coverage that is possible to reach from a transmitter to a receiver, and can be utilized as a major factor in deployment strategies by using structural information from GIS for an entire city. Also, it can be applied to the power management of wireless sensor networks through transmission power control that is compared to a received power.

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## References

1. Rustako A. J., Amitay N., Owens G. J., Roman R. S.: Radio Propagation at Microwave Frequencies for Line-Of-Sight Microcellular and Personnel Communications. *IEEE Trans. Vehicular Technology*, vol. 40, pp. 203--210, Feb. (1991)
2. Sarkar T. K., Zhong Ji, Kim K. J., Medouri A., Salazar-Palma M.: A Survey of Various Propagation Model for Mobile Communications. *IEEE Trans. Antennas Propagation*, vol. 45, no. 3, pp. 51--82, June (2003)
3. Oda Y., Tsunekawa K, Hata M.: Advanced LOS Path-Loss Model in Microcellular Mobile Communications. *IEEE Trans. Vehicular Technology*, vol. 49, no. 6, pp. 2121--2125, Nov. (2000)
4. Degli-Esposti V., Fuschini, Vitucci E. M., Falciaesca G.: Speed-Up Techniques for Ray Tracing Field Prediction Models. *IEEE Trans. Antennas and Propagation*, vol. 57, no. 5, pp. 1469--1480, May (2009)
5. Carisio L. and Soares A. J. M.: Simplified Characterization of the Urban Propagation Environment for Path Loss Calculation. *IEEE Trans. Antennas and Propagation*, vol. 58, no. 1, pp. 24--27, Jan. (2010)
6. Herring K. T., Holloway J. W., Staelin D. H., Bliss D. W.: Path-Loss Characteristics of Urban Wireless Channels. *IEEE Trans. Antennas and Propagation*, vol. 58, no. 1, pp. 171-177, Jan. (2010)