



## A Coverage Prediction Technique for Indoor Wireless Campus Network

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**Abstract** — The placement of an Access Point (AP) is an important key to determine the spread of the signal. To get the optimal spread of signals, a network designer is required to understand how much coverage an AP can generate. A prediction is given to describe the coverage area produced based on AP placement for the wireless campus network, using a coordinate map modeling based on the real size for the indoor environment. The theoretical approach is used to determine the coverage area of an AP device by testing the function of the distance between the AP and the user. The results show that the signal generated by an AP will cover the entire area that is still on the LOS propagation path. The coverage area generated through AP placement in this case study reached 77.5%. The maximum distance between the AP and the user so that it is within the coverage area is 13.851m. There are still areas that are not covered by the AP, especially for the NLOS propagation path because of the obstruction around the AP.

**Keywords** – coverage prediction, propagation, LOS, NLOS, access point

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### I. INTRODUCTION

With the rapid development of communications, wireless networks emerged as a flexible communication system, which is implemented as an extension of a local network. Wireless technology uses electromagnetic waves to transmit and receive data through air media, thus minimizing the need for cable connections, but still allows the mobility of users even in closed areas (indoor) without having to lose connectivity to the main network (backbone) [1].

One of the most critical aspects of developing a wireless network is antenna placement. The right placement will produce the optimal signal transmission around the area. Radio wave transmission system in free space (referred to propagation), have different values for indoor and outdoor environment, especially in terms of distance and environmental variability [2].

It will be challenging to figure out where is the best spot to place an access point (AP) in order to achieve the optimal signal strength throughout the area [3]. A network engineer must have complete

information and proper understanding of radio wave behavior at the spot.

The existence of materials around the antenna often causes weakening signal distribution. It can happen because of the numerous walls attenuate the signal when it passes through them [3]. Further, the signal will meet another propagation obstacle, which can affect signal reflection, diffraction, and scattering. These factors make the signal propagation being complicated, especially for indoor environments [4].

Most of the network designers only used a trial and error procedure to place the APs. It required a long time to analyze and understand the signal distribution pattern. They built the network without considering the propagation factors surely. This conventional method ultimately affects some areas became blank spot, or are not reachable by the antennas.

An analytical analysis of the signals generated by the AP can help us to improve network coverage within the building [5]. It can be identified from various parameters, such as type of the device, kind of materials around the APs, the wide range of the observed area, and the height of the AP placement [6].

There has been various research developed to find the coverage area, which can be covered by an AP [7]-[15]. An optimization has done by rearrangement AP placement using Monte Carlo. The research showed that distance function inversely proportional to the power level received by the user [16]. A wireless network coverage prediction using indoor dominant path modeling is carried out to propose algorithms that can be integrated with various wireless network design applications, both in 2D and 3D [3]. An antenna placement planning for indoor environments has been built through simulation using Radio Wave Propagation Simulator. This planning considering user power level parameter as the primary aspect for choosing the AP placement point [17].

An indoor WLAN monitoring and planning using empirical and theoretical propagation model, helped the network designer in visualizing the coverage area of the wireless, overlapping interference channel, data rate, and signal to noise ratio. The calculation using this modeling has been compared with the actual measurement. This research gave a conclusion that wireless network coverage area visualization can be done using propagation modeling [18].

This research aimed to provide a coverage prediction technique based on actual AP placement. This measurement will use distance factor between transmitter and user, also power level values from the AP as the main parameters. This proposed method gives convenience while calculating coverage area prediction for the network designer. A theoretical measurement used to calculate the coverage area generated by each AP for the indoor environment in a campus building. As the case study, we will use actual measurement in STMIK Asia Malang. The results of this study can be used as one of the considerations for campus network designers to take into account the placement of APs for indoor environments.

## II. RESEARCH METHOD

The experimental environment chosen for the site survey measurement was third-floor building at STMIK Asia Malang. This location has three main areas, i.e., the lecturer room, study room and a corridor space area between the study rooms.

To get the prediction model through the proposed modeling system, we took a site survey measurement first to find the power level values (called as Received Signal Strength Indicator – RSSI) using inSIDDER software, which is run on the Line of Sight (LOS) and Non-Line of Sight (NLOS) places.

Line of sight (LOS) is a type of propagation that can transmit and receive data only where transmit and receive stations are given each other without any obstacle between them [19]. Non-line of sight (NLOS) refers to the path of propagation of a radio frequency (RF) that is obscured (partially or completely) by obstacles, thus making it difficult for the radio signal to pass through. Common obstacles between radio transmitters and radio receivers are tall buildings,

trees, physical landscapes, and high-voltage power conductors. While some obstacles absorb and others reflect the radio signal, they all limit the transmission ability of signals [20].

In this study, LOS propagation is carried out in the lecturer room, while NLOS propagation is carried out in both study rooms and corridor areas. There are some obstacles around the transmitter in NLOS propagation, i.e. glass doors, the gypsum walls with a thickness of 170mm, and wooden partitions. Fig.1 showed us the realistic condition of the experimental environment for NLOS propagation.



Fig.1. Experimental Environment for NLOS Propagation

The main parameters used while processing the wireless coverage area prediction in this research included the distance between transmitter and receiver, and RSSI values generated by actual measurement. Table 1 showed the specifications of the measured AP device.

Table 1. Measured Device Specifications [21]

Device	Parameters	Values
Ubiquiti Unifi AP Long-Range	Operating Band	2,4 GHz
	Gain Antenna	3 dBi
	Maximum TX Power	27 dBm
	Line Loss	0,5 dB
	Fading margin WLAN	10 dB

The proposed model used a theoretical method to calculate the coverage area based on the coordinate point. Every single point was calculated to get the distance value and find the RSSI for every coordinate. There was step by step to predict the coverage area for the indoor environment [6]:

- a) Calculate the observed area. The research floor plan has 24 tiles length and 74 tiles width, with a tile size of 50x50 cm.
- b) Determine the initial coordinates of the research plan. The coordinates calculation in this research starts from the upper left part of the lecturer room (0,0). The value of X indicates the movement to the right, while the value of Y indicates the movement to the bottom.

- c) Determine the transmitter coordinate point based on the actual position. There was an AP placed inside the lecture room. From the research plan, this AP at the coordinates (8,23).
- d) Calculate the RSSI values using inSIDDER. The measurement was done at 40 sample points, both on LOS propagation and NLOS propagation.
- e) Calculate distance values using Euclidean, as shown in (1).

$$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \quad (1)$$

Where  $(X_1, Y_1)$  indicates the coordinate of the AP position and  $(X_2, Y_2)$  indicates the receiver position.

- f) Determine the range limitation for the covered area (in pixel) using (2).

$$Range = \frac{S}{Room\ Scale} \quad (2)$$

Where room-scale used 50cm based on the size of the tiles, and S is the threshold value calculated using (3).

$$S = \frac{Th \times S_{max}}{P_{min}} \quad (3)$$

Where  $Th$  is the power level threshold (assumed -30 dBm),  $S_{max}$  is the maximum distance from the measurement (in meters), and  $P_{min}$  is the power level minimum produced.

- g) Determine all of the coordinates who have distance value less than the range limitation as to the covered area.
- h) Calculate the amount of the coverage area using this following (4).

$$\begin{aligned} & Coverage\ Area \\ & = \sum_{x_2=1}^n, \sum_{y_2=1}^n \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \leq Range \end{aligned} \quad (4)$$

- i) Calculate the ratio between the coverage area to the total area of the research. It can be determined using formulation, as shown in Equation 5.

$$Coverage\ Area\ (\%) = \frac{Coverage\ Area}{Total\ Area} \times 100\% \quad (5)$$

Based on the explanation above, Fig.2 represented the flow of the coverage prediction technique of an AP for an indoor environment.

### III. RESULT

Before taking a site survey measurement, we must make a research plan into coordinates maps. As mentioned in the research method (step point b), the initial coordinates start from the upper left of the lecturer room, as shown in Fig.3.

Every square represented the actual tiles on the field. From Fig.1, we know that the research site has 24 tiles in the abscissa axis and 74 tiles on the coordinate axis, with 50x50 cm tile sizes. There is an AP along the area with a coordinate point in (8,23), as shown in Fig.1 in the redpoint.

The research area was divided into two areas, i.e. LOS propagation and NLOS propagation. LOS propagation has a coordinate point from (0,0) until (24,24), which is the area of the lecture room. Moreover, the NLOS propagation has a coordinate point from (0,24) until (24,74) which is the area of the corridor and the study room. Both of this propagation have separated by a wall with 170mm thickness.

Twenty measurements were made on LOS propagation with random coordinate points. This measurement is taken using the walk test in every coordinate. Table 2 presented the results of the site survey measurements in LOS propagation.

Table 2. LOS Propagation Site Survey

No.	Receiver Coordinate	RSSI (dBm)
1.	(2 , 22)	-37,36
2.	(5 , 20)	-40,6
3.	(6 , 22)	-37,3
4.	(5 , 17)	-42,5
5.	(7 , 12)	-43,9
6.	(3 , 5)	-51,3
7.	(10 , 4)	-50,6
8.	(12 , 4)	-57,5
9.	(17 , 6)	-46,4
10.	(3 , 8)	-48,1
11.	(6 , 2)	-53
12.	(3 , 2)	-50,8
13.	(9 , 3)	-55
14.	(13 , 4)	-51,3
15.	(15 , 5)	-46,3
16.	(18 , 8)	-52,2
17.	(15 , 13)	-43,7
18.	(23 , 12)	-49,1
19.	(21 , 20)	-52,3
20.	(18 , 23)	-50,9

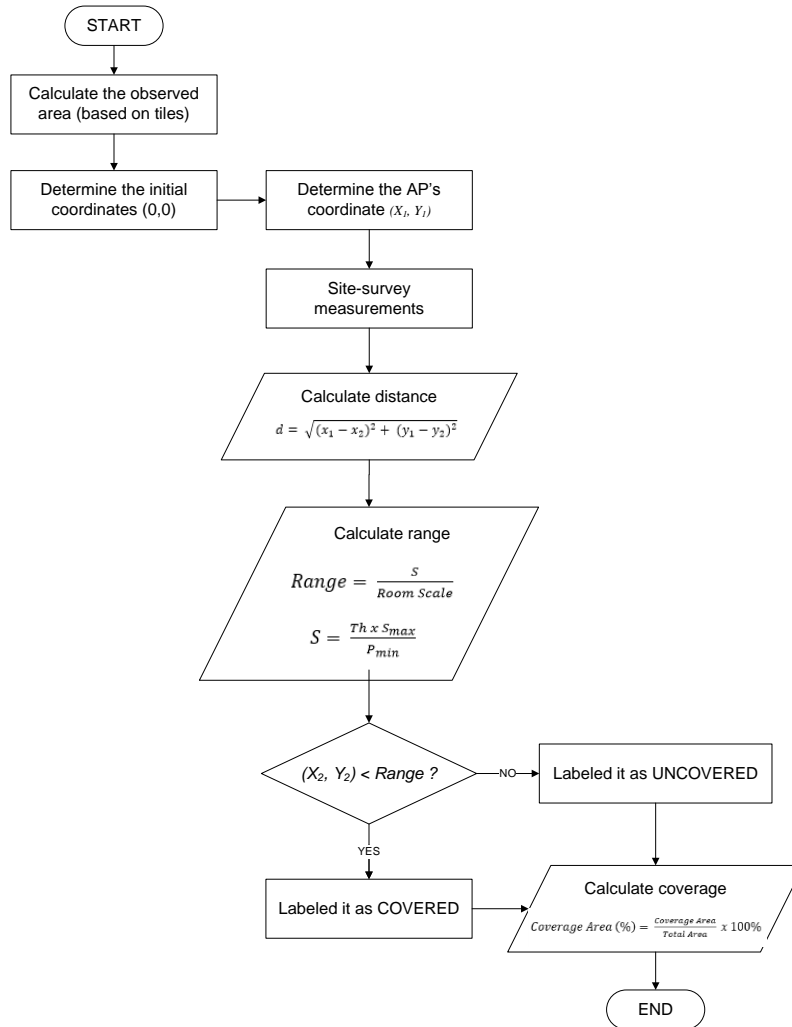


Fig.2. Flowchart of Coverage Prediction Technique

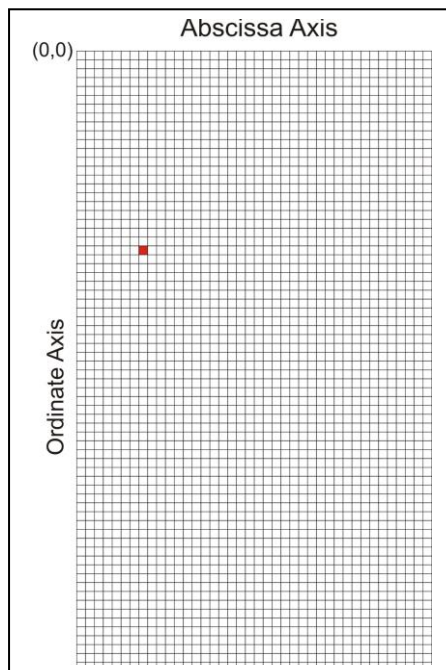


Fig.3. Research Floor Plan

Twenty measurements were made on NLOS propagation with random coordinate points, both on study room and the corridor area. This measurement is taken using the walk test in every coordinate. Table 3 presented the results of the site survey measurements in NLOS propagation.

Table 3. NLOS Propagation Site Survey

No.	Receiver Coordinate	RSSI (dBm)
1.	(5 , 26)	-43,8
2.	(10 , 27)	-64,3
3.	(11 , 31)	-58,7
4.	(9 , 38)	-65,1
5.	(10 , 45)	-64,5
6.	(11 , 50)	-71,6
7.	(4 , 48)	-55,3
8.	(5 , 30)	-46,2
9.	(4 , 36)	-67,7
10.	(7 , 41)	-64,2
11.	(12 , 47)	-54,5
12.	(9 , 55)	-57,3
13.	(6 , 60)	-61,6
14.	(8 , 65)	-63,4
15.	(14 , 63)	-63,9
16.	(18 , 61)	-69,3
17.	(23 , 63)	-75,3
18.	(29 , 59)	-81,3
19.	(28 , 55)	-79,6
20.	(26 , 53)	-81,3

After obtaining the RSSI values based on the receiver coordinates for both LOS and NLOS propagation, the next step is calculating the distance between the transmitter and receiver based on each coordinate samples. Based on the Euclidean method in (1), the result showed us that distance is in coordinate value. A conversion must be done to find the real distance values by multiplying the value with 50 cm (the size of the tiles) and then convert into meters unit.

The main idea in calculating the value of *d* is to be compared with the range value, to determine where are the coverage area and which are not. Every propagation has its own range values, so we compared the *d* values for each propagation.

Based on 20 samples measurements in LOS propagation, we got the maximum distance of measurement in 10.795 m, as the *Smax* value. The minimum power level at -57.5 dBm, as the *Pmin* value. Both of these values will be used as the

parameter to find the threshold value using (3), as seen below.

$$S = \frac{Th \times S_{max}}{P_{min}} = \frac{-30 \times 10.795}{-57.5} = 5.6314 \text{ m}$$

After getting the threshold value, we need to determine the range limitation for the covered area (in pixel) using (2), as seen below.

$$Range = \frac{S}{Room \text{ Scale (in meters)}} = \frac{5.6314}{0.5} = 11.2627999 \text{ pixel}$$

The range value for the LOS propagation is 11.2627999 pixels. Every coordinate which has a distance value less than this range indicates as the covered area, and vice versa. Table 4 showed the results of the calculation of the *d* value which generated for 20 sample data on LOS propagation, along with a description of the coverage.

Table 4. Calculation of Distance Values and Its Coverage Status for LOS Propagation

No.	Receiver Coordinate	d (meter)	Status
1.	(2 , 22)	3,0413	Covered
2.	(5 , 20)	2,1213	Covered
3.	(6 , 22)	1,1180	Covered
4.	(5 , 17)	3,3541	Covered
5.	(7 , 12)	5,5226	Covered
6.	(3 , 5)	9,3407	Covered
7.	(10 , 4)	9,5524	Covered
8.	(12 , 4)	9,7082	Covered
9.	(17 , 6)	9,6176	Covered
10.	(3 , 8)	7,9056	Covered
11.	(6 , 2)	10,5475	Covered
12.	(3 , 2)	10,7935	Covered
13.	(9 , 3)	10,0124	Covered
14.	(13 , 4)	9,8234	Covered
15.	(15 , 5)	9,6566	Covered
16.	(18 , 8)	9,0138	Covered
17.	(15 , 13)	6,1032	Covered
18.	(23 , 12)	9,3005	Covered
19.	(21 , 20)	6,6708	Covered
20.	(18 , 23)	5,0	Covered

The same procedure has been done to find the coverage area for NLOS propagation. Based on 20 samples measurements, we got 21,36 m as the maximum distance (referred to *Smax*) with the

minimum power level at -81,3 dBm (referred to  $P_{min}$ ). We found the range value for NLOS propagation, as seen below.

$$S = \frac{Th \times S_{max}}{P_{min}} = \frac{-30 \times 21,36}{-81,3} = 7,88192 \text{ m}$$

$$\text{Range} = \frac{S}{\text{Room Scale (in meters)}} = \frac{7,88192}{0,5}$$

$$= 15,76384455 \text{ pixel}$$

The range value for the NLOS propagation found in 15,76384455 pixels. Each distance value in coordinate samples has been compared with these range values, as seen in Table 5.

Table 5. Calculation of Distance Values and Its Coverage Status for NLOS Propagation

No.	Receiver Coordinate	d (meter)	Status
1.	(5 , 26)	2,1213	Covered
2.	(10 , 27)	2,2360	Covered
3.	(11 , 31)	4,2720	Covered
4.	(9 , 38)	7,5166	Covered
5.	(10 , 45)	11,0453	Covered
6.	(11 , 50)	13,5830	Covered
7.	(4 , 48)	12,6589	Covered
8.	(5 , 30)	3,8078	Covered
9.	(4 , 36)	6,8007	Covered
10.	(7 , 41)	9,0138	Covered
11.	(12 , 47)	12,1655	Covered
12.	(9 , 55)	16,0078	Uncovered
13.	(6 , 60)	18,5270	Uncovered
14.	(8 , 65)	21,0	Uncovered
15.	(14 , 63)	20,2237	Uncovered
16.	(18 , 61)	19,6468	Uncovered
17.	(23 , 63)	21,3600	Uncovered
18.	(29 , 59)	20,8386	Uncovered
19.	(28 , 55)	18,8679	Uncovered
20.	(26 , 53)	17,4928	Uncovered

#### IV. DISCUSSION

Every coordinate sample has its own coverage status, both on LOS and NLOS propagation. The results showed us that 20 data samples in LOS propagation had been covered. Whereas only 11 coordinate points from the data samples which covered by AP in NLOS propagation.

Based on the type of propagation, it can be seen that all the areas of LOS propagation will be fully covered by the AP. However, not all areas on the

NLOS propagation can be reached by the AP. The research represented the maximum distance between the AP, and the user to get into the covered area was 13,851 m (based on the measurements in (11,50) coordinate point for NLOS propagation). The research sample tested in the range of 16,0078 m – 21,36 m was declared not covered by the AP signal because it has a  $d$  value higher than the specified range value.

For example, the sample coordinate measurement at (9,55) on NLOS propagation has the following procedure in determining the status of the coverage area:

- a) Distance parameter conversion

$$d = \sqrt{(8-9)^2 + (23-55)^2} = 32,0156 \text{ m}$$

- b) The range for NLOS Propagation

$$\text{Range} = \frac{7,88192}{0,5} = 15,76384455$$

- c) Compare the value of distance and range

$$d = 32,0156 \text{ while } \text{range} = 15,76384455 \text{ so } d > \text{range}$$

- d) Assign the coordinate's status

Because  $d > \text{range}$ , the status is UNCOVERED

Based on 40 measurement samples both on LOS and NLOS propagation, the percentage coverage of the AP signal area to the total area of the observed area was calculated. The number of covered areas is 31 coordinate points from 40 observation coordinates, so the percentage of area coverage is obtained as follows.

Coverage Area (%)

$$= \frac{\text{Covered Area}}{\text{Total Observed Area}} \times 100\% = \frac{31}{40} \times 100\%$$

$$= 77,5 \%$$

The presence of 22,5 % of the area that is not covered in the NLOS propagation occurs because of barriers around the AP that cause the signal to experience obstacles such as reflecting, diffracting, and scattering signals. These barriers include walls, glass walls, wood screens, and tile floors.

Further, the research showed that the distance function inversely proportional to the RSSI value. The farther the distance between the AP and the user, the RSSI value generated will also be smaller (indicated by the higher the negative value produced).

#### V. CONCLUSION

This method gives convenience for the network designer in predicting coverage area through a theoretical approach. This method using a coordinate maps modeling based on the real size for indoor environment, especially in the wireless campus network. The method proved that all of the coordinate

points in LOS propagation had been covered by the AP, whereas not all of the NLOS area will be covered by the AP, with 77,5 % coverage area estimation. This method can be combined with propagation modeling to predict the RSSI values for each coordinate point, for both LOS and NLOS propagation.

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