International Journal of Computing and Digital Systems
ISSN (2210-142X)
Int. J. Com. Dig. Sys. 10, No.1 (Aug-2021)

http://dx.doi.org/10.12785/ijcds/100183

Access Point Placement Model for Indoor Environment using Hybrid Empirical Propagation and Simulated Annealing Algorithm

Fransiska Sisilia Mukti[1]

Informatics Department, Institut Teknologi dan Bisnis Asia Malang, Indonesia

Received 31 Jan. 2021, Revised 10 Apr. 2021, Accepted 15 Apr. 2021, Published 5 Aug. 2021

Abstract: Determining of an Access Point (AP) placement is one of the most challenging problems in building a wireless network, especially for indoor environments. A network designer must understand precisely the factor that can affect the transmission of the signals so that they can predict the coverage of an AP based on its location. This research aims to give a novel method in placing the AP (transmitter antenna) for indoor environments using a combination of empirical propagation (ITU-R model) and optimization algorithm (Simulated Annealing). The ITU-R propagation approach is used to predict the signal strength, then calculate the best marking point for the transmitter based on the maximum signal strength in its coverage using the Simulated Annealing algorithm. The research proved that this proposed method could improve the coverage area until 30.964% and the average error value of this method is equal to 12.09%.

Keywords: Access Point, Indoor Propagation, Optimization, Received Signal Strength, Marking Points

1. Introduction

The development of wireless communication technology is increasing rapidly in response to the user growth who needs flexibility in accessing information. This technology has widely implemented in various public areas, both open space or closed area. To be able to connect into this network, users need an intermediary device, namely Access Point (AP). However, AP was not designed for positioning service [1]. In Wireless Local Area Network (WLAN) technology, AP positioning system usually works in two phases: the offline training phase and the online location determination phase. In the offline phase, the test area is decomposed into a grid, while the online phase uses the mobile station to report the measured Received Signal Strength (RSS) from AP to a server. In telecommunications, RSS is a measurement of the power present in a received radio signal [2].

Therefore, determining the AP's placement is one of the most problems in building a wireless network [3]. It usually is done manually based on the knowledge and experience of the network designer. A network designer must understand precisely the factors that can affect the spread of AP signals, either of the strength of the transmit signal of the AP, design, and infrastructure of the room, the pattern of signal distribution from the AP, or radio wave interference caused by various objects around the AP [4]. Usually, the transmitted signal can change due to wave propagation effects such as reflection, refraction, and scattering, which creates a phenomenon called multipath fading [5]. The signal strength and coverage area of an AP are very influenced by its positioning. Therefore, a network designer must understand the propagation characteristics of the wireless network before deployment [6].

There has been much research conducted in developing the propagation models to predict its characteristics for indoor or outdoor environments. It can be classified into three primary models: physical model, theoretical model, and empirical model [4], depending on their environment characteristics. The empirical models give easier method to implement because it is based on the statistical characterization of the received signal, while the physical model (sometimes called ad site-specific model) need more computations because it requires a vast amount of data of the building [7]. The goal of propagation models is to determine the successful probability from a wireless communication system [8].

E-mail: ms.frans@asia.ac.id

In addition to the aspect of propagation, AP placement is also an important issue in building a wireless network. Optimization of AP placement can be done through a mathematical approach [1][9] or using a simulator [10][11]. A mathematical model is proposed to integrate coverage requirements of a wireless network with a reduction of the error of the user position estimate. Near-optimal AP placements computed for various kinds of optimization criteria: localization, signal coverage, and a mixture of two [12]. A new method has been proposed to optimize AP placement for indoor environments using Particle Swarm Optimization (PSO) algorithm and ray propagation method. PSO is used for determining the optimal placement of the AP based on the building layout, while the propagation utilized to specify the fitness of a location [13]. The comparison of two optimization algorithm is presented to find the best algorithm for AP placement in an indoor environment. A data obtained from the measurement has modeled into a simulation of determining a position of the AP using Simulated Annealing and Greedy algorithm. The result showed that the Simulated Annealing algorithm gives a more optimal solution than the greedy algorithm [4].

Radio planning for indoor environments can be challenging because it is difficult to predict the coverage based on the location of the AP. However, it can be sufficient to know the coverage through a threshold description [14]. This research aims to give a novel method in placing the AP in an indoor wireless network using a combination of propagation approach and optimization algorithm. Empirical model propagation will be used to predict the strength of the transmitted signal and to find the coverage area generated by an AP. Then, the Simulated Annealing will be used as an optimization algorithm to find the optimal marking position of the AP placement based on the best RSS value generated in the coverage area. A simulator tool is built to give the visualizations of the coverage area and localization of the AP. The results of this simulation will be compared with the RSSI value in the actual measurement to determine the error rate of the proposed method.

2. MATERIALS AND METHODS

A. Experimental Environments

Three research samples are chosen on the Institut Asia Malang, Indonesia, to allow examination of indoor propagation models in the presence of different cases. The research samples described below:

1) *First floor:* as the central area of the building, which is located in 350 m^2 area. The front office area located at the front with marble tables and wooden cabinets, one customer service room that provided with a glass barrier, four laboratory areas that provided with glass dividers, and two rooms using wooden doors. The corridor in front of the laboratory has an area of 64,5 m^2.
2) *Third floor:* has 7 study rooms and two institutional rooms which have the same dimension 38 m^2 and one large room which used as a lecture room with dimension 140,5 m^2. There is a corridor area in front of the study rooms with 21,86m for length and 3,846m in width. The construction of this building uses gypsum walls with a thickness of 170mm.
3) *Fourth floor:* has an area of 500m^2, which divided into two main areas, namely the lecture hall and the corridor area. Five lecture rooms that are limited to 170mm thick walls, four open lecture rooms (hall rooms) which given 18mm plywood bounding barriers, and one room that is given a glass divider.

There are four measurements cases, divided into two kinds of propagation line: LOS with free space and NLOS with obstacles. Line of Sight (LOS) with free space and Non-Line of Sight (NLOS) with obstacles. LOS propagation is a characteristic of electromagnetic radiation or acoustic wave propagation which means waves travel in a direct path from the source to the receiver. It means that there is no barrier particles between users and AP, so the signal will be transmitted in a straight line. The LOS situation is present in corridors: case 1 with the length of up to 16.8 m and case 4 with the length of over 25 m.

While NLOS propagation refers to the path of propagation of a radio frequency (RF) that is obscured (partially or completely) by obstacles. Common obstacles between radio transmitters and radio receivers for indoor environments are glass door, ceramics, wood interior, etc. These obstacles could make the signal difficult to pass through [3].The obstacles in cases 2 to 3 are wooden partition (50mm), glass doors (80mm), and wooden-glass doors (40mm).

B. Research Data

The primary data which is needed in this study, i.e. room plans and the device specifications. We used the offline training phase, which is the test area decomposed into a grid. Furthermore, devices specification such as maximum transmission power, antenna gain, and antenna frequency will be used as the input parameter. Table I showed us the measured device in this study. The secondary data is obtained from real RSS measurement data on the field. These values are taken randomly at certain distances using WiFi SNR software application.

TABLE I. MEASURED DEVICE SPESIFICATION

Device Type (Location)	Parameters		
	Operating Band (GHz)	*Max. TX Power (dBi)*	*Antenna Gain (dB)*
TP-Link Archer AC1750 (1st floor / laboratory)	2.4	20	5
TP-Link TL-WA701ND (1st floor / lobby)	2.4	20	5
Unifi AP Long-Range (3rd & 4th floor)	2.4	27	3

C. *Empirical Propagation*

An empirical model is one of the propagation approaches to predict the RSS for indoor wireless environments. In general, some models in this approach using formulas of measurements data, thus providing a general description of the channel behavior in the test area. Empirical models usually predict the path loss between the transmitter and receiver depend on the distance and obstacles around the antenna [15].

ITU-R (P.1238) model is one of the empirical models that predict path loss inside a closed area, such as campus building [8]. A comparative study of 4 types of empirical propagation modeling was made to provide the most suitable propagation modeling analysis for campus wireless networks. The ITU-R model (P.1238) provides predictive results that are closest to the actual data in the field [16][17][18].

The mathematical expression to describe the path losses (PL) using this model is given by [8][19]:

$$PL\ (dB) = 20\ .\ \log f + n\ .\ \log d + L_f - 28 \qquad (1)$$

Where f is the frequency of the measured AP (in MHz), n represents the distance power loss coefficient (shown in Table II), d represents the distance between transmitter and receiver (in meters), and L_f represents the floor penetration losses factor (shown in Table III) [19]

TABLE II. ITU-R COEFFICIENT POWER LOSS

Frequency	Building Types		
	Residential	*Office*	*Commercial*
900 MHz	-	33	20
1.8 to 2.4 GHz	28	30	22
5 GHz	-	31	-

TABLE III. ITU-R FLOOR PENETRATION LOSS

Frequency	Building Types		
	Residential	*Office*	*Commercial*
900 MHz	-	9 (1 floor) 19 (2 floor) 24 (3 floor)	-
1.8 to 2.4 GHz	4n	15 + 4(n-1)	6 + 3(n+1)
5 GHz	-	16 (1 floor)	-

D. *Simulated Annealing Algorithm*

The Simulated Annealing (SA) algorithm was introduced by Metropolis in 1953. Furthermore, SA was applied in the first optimization problem by Kirkpatrick et al. (1983). This algorithm is analogous to the process of annealing (cooling) which is used in the manufacture of glassy material (consisting of crystal grains). The annealing process can be defined as a regular or constant decrease in temperature on a solid object that has previously been heated to a state where the object reaches ground state/freezing point. Temperature is reduced continuously and carefully so that at each temperature level, thermal balance is achieved. The search for solutions with SA is a concept of hill climbing where the solution will change over time until the final temperature is reached [20].

```
Procedure simulated_annealing;
(input i_start:iteration;
output c : control, L : length);

{determining optimal solution from the
simulated annealing algorithm
   Input: iteration i_start
   Output: solution of c and L}

Declaration
   k : iteration;
   i, c_0, L_0;

Algorithm
   k←{} {initialization I with zero
   i←i_start
   while (stop criterion) do
   for 1:= 1 to L_k do
        j←SELECTION(Si); {generate j from Si}
        if f)j)<f(i) then i:=j
        else
        if exp((f(i)-g(j))/c_k > random(0,1)
        then i:=j
   end;
   k:=k+1;
   {length(Lk) and control(ck) obtained}
endwhile
```

Figure 1. Pseudocode of Simulated Annealing Algorithm

The modeling SA algorithm in case of getting the optimal placement of an AP for an indoor environment, several objects that must be considered, as described below [4][21]:

1) *Cost Function*: finds the most significant value of coverage area based on the distance between AP and user. This function used for looking a new distance, then calculating new range and new RSS to obtain a new coverage area.
2) *Initialization and new solution mechanisms:* determines the AP placement (coordinate position) and new RSS due to the distance changing.
3) *Cooling scheme:* determine about algorithm's iteration work. The slower the annealing process

lasts, the higher the chances to produce a better solution. It can be reached by increasing an initial temperature, reducing the last temperature, increasing the reduced temperature factor, and increasing iteration for each temperature value.

4) *Iteration process:* find the most optimal value from the covered area randomly. Every solution compared to the previous value to show the accuracy of the solution.

The pseudocode of this algorithm presented in Fig. 1 [4][11][22].

E. Experimental Procedure

To implement this proposed model, at first, we have done the real RSS measurement on the field, namely site-survey measurement. The main idea of this stage is to get more information about AP placement, which is implemented in the test area, and their RSS level based on distance. It has been conducted using Wi-Fi Analyzer that installed in a laptop. We did a walk test survey to measure the transmitted signal strength from the measured AP for each sample and create a database of predetermined RSS values for each MP, both LOS and NLOS cases. This results will be used as reference and input parameters into the software to produce a visualization of signal pattern distribution by an AP. Therefore, the simulation tool will be able to create an analysis for the visualization and optimize it using the SA algorithm to find the optimal AP placement. This optimization will consider the RSS value based on empirical propagation approach, and make an iteration to find the best coordinate for an AP (from the covered area range) using the SA algorithm.

3. Proposed Model

The proposed model used a modeling system in two-dimensional space (2D) with Visual Basic programming language. Before implementing empirical propagation and a SA algorithm, we used a theoretical approach to calculate the coverage area based on the radio map (coordinate plan floor) for each research sample.

The room plan will be converted into coordinate mapping using the tile guidelines used in the research location. The initial coordinate (0,0) started from the upper left of the room. Every grid is an overview of the tiles in the actual plan. The red square showed the AP's placement, while the blue ones is only an aid box because in fact the shape of the room is tilted at the end (shown through the line). Fig. 2 shows an example of coordinate mapping for the third floor (lecture's room).

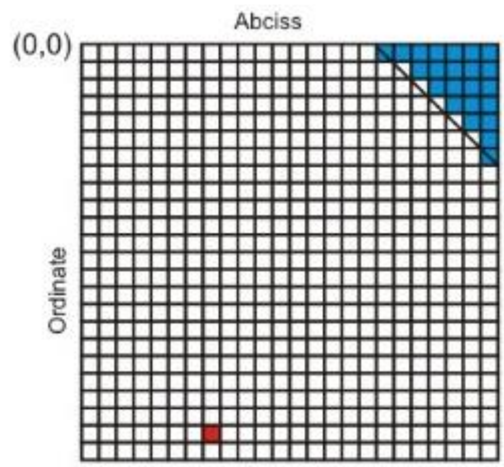


Figure 2. Mapping Coordinate for 3rd Floor (Lecture's Room)

After getting the radio map for each observed area, we must determine the marking position of the measured AP *(α, Ө)* based on the actual location. Table IV shows us the marking position from the AP for every area.

TABLE IV. RADIO MAP AND ACCESS POINT MARKING POSITION

Case	Location	Radio Map		Access Point	
		Length	*Width*	*α*	*Ө*
1	1st floor (Lobby)	18	28	1	10
2	1st floor (Laboratory)	40	40	16	20
3	3rd floor (Lecture's Room)	24	24	8	23
4	4th floor	40	50	20	25

A. Site-Survey Measurement

As mentioned in the previous section, site-survey measurement is used as the input parameter to predict the coverage area of an AP. The measurement was taken randomly in several marking positions. The more data is measured, the higher the level of suitability of the model needed. From this site-survey measurement, we needed the maximum distance (in meters unit) and the minimum signal strength (in dBm). These data are required to calculate the range value of a AP.

In this study, the measurements made at 20 marking points for each case, both LOS and NLOS propagation. To analyze the results, we converted the marking points into the distance in meters unit. The distance (δ) for every marking points is calculated using the Euclidean method, as shown in Equation (2) below [17].

$$\delta = \sqrt{(\alpha_1 - \alpha_2)^2 + (\theta_1 - \theta_2)^2} \qquad (2)$$

where (α_1, θ_1) represents the AP's coordinate and (α_2, θ_2) indicates the marking position of the user. This distance will be used as the primary input parameter to predict the signal strength using the ITU-R propagation approach.

Table V shows the sample of site-survey measurement and its conversion into the distance at the 1st floor-laboratory area (case 2-LOS propagation), with the AP's marking position at (16,20).

TABLE V. SITE-SURVEY MEASUREMENT AND ITS CONVERSION

Radio Map		Access Point		δ (m)	RSS Value (dBm)
Length	*Width*	*α*	*θ*		
16	20	18	3	8.559	-50.4
16	20	22	4	8.544	-57.3
16	20	20	10	5.385	-43.3
16	20	19	15	2.915	-40.8
16	20	16	12	4	-45.4
16	20	17	8	6.021	-49.2
16	20	19	16	2.5	-40.5
16	20	21	19	2.55	-39.3
16	20	17	24	2.062	-41.7
16	20	20	27	4.031	-42.2

We want to provide an analysis of the effect of distance (x-axis) on the RSS value generated by an AP (y-axis), on the propagation of LOS and NLOS. The results of site-survey measurement for LOS propagation in case 1 and case 4 presented in Fig. 3., while NLOS propagation in case 2 and case 3 can be seen in Fig. 4.

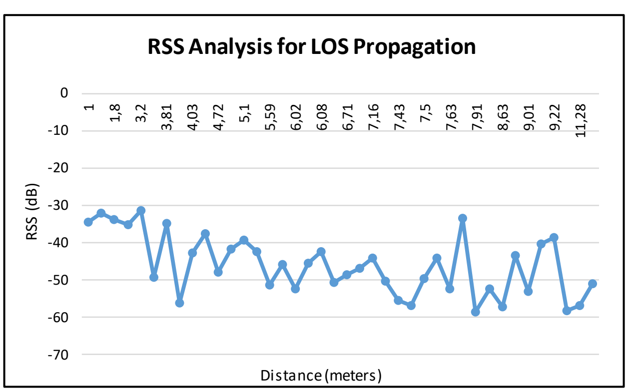


Figure 3. Site-Survey Measurement for LOS Propagation

From the measurement data, as shown in Fig. 3, we can see that the distance affects the RSS. The further distance between AP and user, the smaller RSS will be obtained. It observed from the dotted line, which decreases to large negative numbers as the distance increases.

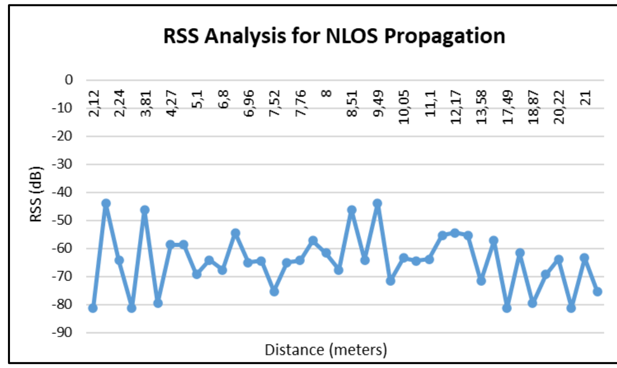


Figure 4. Site-Survey Measurement for NLOS Propagation

Based on the measurement data in Fig. 4, we can see that there is instability in the RSS value received by the user. The data proves that the RSS value does not only depend on the distance between the AP and user but also is affected by the presence of obstructions around the AP. The room's furniture such as partitions, glass-door, wooden-door, and any other property may occur signal attenuation, absorption, and reflection that affected a reduction of signal strength. All of the obstacles will make the signal strength decreases and possible to have the same signal strength value with another user who far away from the AP but without a barrier around it (like in LOS propagation).

B. *Transmitter Coverage Area*

To find the coverage area of an AP as transmitter, the range value must be specified beforehand. Range values are used to determine where is covered and uncovered an area, based on the scale of the transmitted signal of an AP. The range is obtained by entering the maximum distance and the minimum RSS value from the site-survey measurement. The formula for calculating the range is presented in Equation (3) [23].

$$\rho = \frac{\sigma \times \delta_{max}}{\varphi_{min}} \tag{3}$$

where ρ represents the range value in a meters unit, σ is threshold power level in dBm unit (depend on network designer requirement, in this case, we used -57dBm), δ_{max} is the maximum distance from the site-survey measurement (in meters unit), and φ_{min} represents the minimum RSS value for site-survey measurement (in dBm). By using Equation (3), we found the range value for all of the research area, as shown in Table VI.

After defining the range value for each area, the next stage is determining all of the marking points to the covered and uncovered area. The coordinates which have the distance value less than the predetermined range value will be referred to as the covered area. Otherwise, all of the coordinates which have a distance more than the range value will be referred to as the uncovered area. All of these uncovered areas will be optimized so that the entire area can be covered by the AP.

TABLE VI. RANGE VALUE

Location	Site Survey Measurement		Range Value (m)
	δ_{max}	φ_{min}	
1st floor (Lobby)	9.552	-58.5	18.615
1st floor (Laboratory)	11.4	-81.3	8.414
3rd floor (Lecture's Room)	21.36	-81.3	15.76
4th floor	12.04	-56.7	24.21

C. Access Point Placement Optimization

Optimizing the placement of APs is done using the SA algorithm. As explained in the previous section, four main mechanisms which implemented, namely objective function (cost function), initial and new solution mechanisms, cooling scheme, and iteration process. Accurately, the four processes described in the following explanation:

1. Initialization of random generator numbers.
2. Determine the maximum number of loops done by this algorithm. Assumed in this case, the number of iterations used is 1000.
3. Determine the value of the initial temperature used in the calculation process. Assumed in this case, the initial temperature value is 10,000.
4. Determine the temperature-lowering factor when used for the next process. Temperature reducing factors are useful in the process of calculating the possibility of the next solution. When the temperature is high (initial calculation), the solution variable will be easier to accept new solutions, so as not to get caught up in the initial solution that might not be optimal. When the temperature is low (final calculation), the solution variable no longer accepts a new solution, so the answer to the solution does not change. It is assumed in this case, the value of the temperature-lowering factor is 0.995, thus for each subsequent iteration the temperature will decrease by 0.005 * 10,000 = 50 degrees.
5. Determine the random solution as the initial solution
6. Determine the value of energy from the temporary solution. The function value is calculated by summing all RSSI values from the area covered. The procedure for determining energy values is as follows:
   a. The RSSI value is calculated using ITU-R propagation. Calculations are carried out at each coordinate point converted into distance using the Euclidean method. The maximum distance will be stored as a δ_{max} value and the minimum RSS value will be saved as the φ_{min} value.
   b. Calculates range values using equation (2).
   c. If the value of d is within the range, then add the PL value for that coordinate
   d. The energy value is the total PL value of all coordinates whose d values are in the range
7. Perform the calculation process as much as the maximum number of iterations and as long as the temperature is not close to 0 degrees.
8. Determine other possible solutions from each iteration and calculate the energy value for this solution. If the solution found is better than the best solution, then take this solution as the best solution.

4. RESULTS AND DISCUSSION

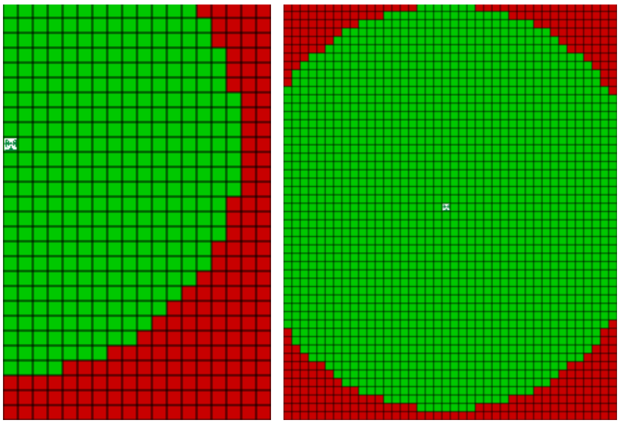
A series of tests were carried out to evaluate the proposed method. There are two primary examination schemes in this study that are wireless network discovery and wireless network optimization. Both of them has been tested using application software, namely WIN-COV.

A. Wireless Network Discovery

Discovery is a process of analysis carried out through a system modeling based on the conditions of the actual AP placement. In this modeling process, an estimation of signal distribution patterns is given based on theoretical calculations. Then the results are converted into a visualization of the spread of signals produced by the AP through a software.

The distance value for each coordinate point will be calculated using the system, and then the value will be compared with the range value. As explained in the previous section, the range value is obtained by inputting the maximum distance value and minimum RSS value on the site-survey measurement using Equation (2).

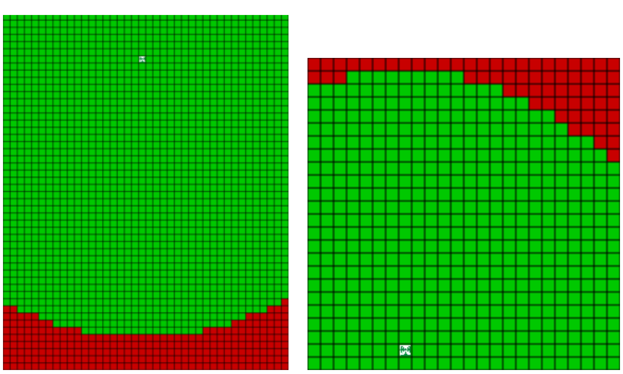
Based on this comparison, there will be two results; namely the area covered and the area not covered. The visualization process is done in 2D, with the green mapping process for the covered area and the red color for mapping the area not covered. This visualization is needed to provide an overview to the network designer, in this case, the the Network Operating Centre of Institut Asia Malang (usually named as Unit Pelaksana Teknis Jaringan dan Komputer / UPT-JAR&KOM) to find out the signal distribution pattern that occurs based on the AP placement point that has been used today. Fig. 5 shows the results of the discovery generated in LOS propagation for case 1 (a) and case 4 (b).



(a) (b)

Figure 5. Wireless Network Discovery for LOS Propagation: (a) Case 1, 1st floor - lobby (b) Case 4, 4th floor

Based on the results of the visualization given, it can be seen that there are still areas that have not been covered by the AP signal in case 1, with details of 337 green boxes and 167 red colored boxes. Based on the results of this mapping, the area coverage for the AP placement point on the 1st floor (lobby) was 66,851%. Whereas for case 4, 1690 green boxes and 310 red boxes were obtained, so the percentage of coverage area produced was 84.5%. The process of analyzing AP signal area coverage also done for case 2 and case 3, NLOS propagation, as seen in Fig. 6.



(a) (b)

Figure 6. Wireless Network Discovery for NLOS Propagation: (a) Case 2, 1st floor - laboratory (b) Case 3, 3rd floor – lecture's room

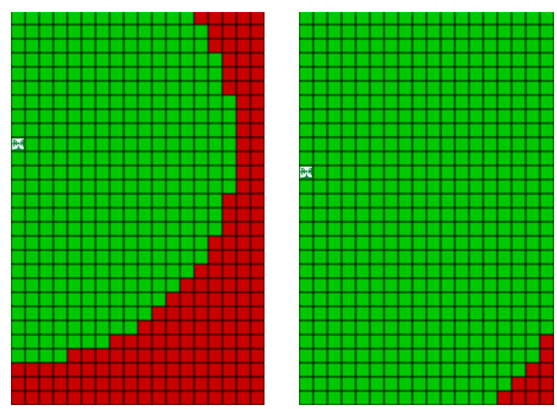
Based on the results of the visualization given, it can be seen that there are still areas that have not been covered by the AP signal in case 2, with details of 443 green boxes and 170 red colored boxes. Based on the results of this mapping, the results of the area coverage for the point of placement of the AP on the 1st floor (laboratory) are 72,315%. Whereas for case 3, 509 green boxes and 67 red boxes were obtained, so the percentage of area coverage produced was 88.368%.

B. *Wireless Network Optimization*

Optimization is done through searching the best AP placement points, based on the calculation of area coverage and the lowest RSSI value (with a negative value close to zero). The process of finding AP placement points is done using the SA algorithm, which is a generic optimization algorithm. Calculation of area coverage applies the same method as the calculation of analysis, namely by using 2D modeling, while the estimate of RSSI value is done using the ITU-R (P.1238) Model propagation approach.

In the optimization process, additional input is needed as a propagation parameter for a closed room, i.e., AP's frequency, maximum AP's power, gain antenna of the AP and antenna gain of the receiver. In this study, we used Qualcomm Atheros AR9485 Wireless Network Adapter with 0dBi of antenna gain.

The optimization results are done through software, and a new AP placement recommendation is generated, which is supported by an explanation of the percentage of coverage area produced. The results of the optimization performed are also shown in the form of visualizing the mapping of area coverage generated by an AP.



(a) (b)

Figure 7. Wireless Network Optimization Visualization for Case 1: (a) Actual Condition (b) Optimization

Fig. 7 shows one sample of visualization results from the optimization carried out in case 1, 1st floor-lobby, LOS propagation. There is a difference in area coverage resulting from AP placement before and after optimization. Based on the actual conditions, the AP is placed at coordinates (1.10) and produces a percentage coverage area of 66.851% (Fig. 7a). After the search optimization of the best AP placement points by using the SA algorithm in the application, the best placement of the AP found at the coordinates (1.12) with the percentage of area coverage produced at 97.8175% (Fig. 7b).

The conclusions of the results of optimization testing using a combination of empirical propagation modeling and SA algorithm in this study shown in Table VII.

TABLE VII. ACCESS POINT PLACEMENT AND COVERAGE OPTIMIZATION

Location	**Placement (α, θ)**		**Coverage (%)**	
	Actual	**Optimize**	**Actual**	**Optimize**
1st floor (Lobby)	(1,10)	(1,12)	66.851	97.815
1st floor (Laboratory)	(16,20)	(1,39)	72.315	89.062
3rd floor (Lecture's Room)	(8,23)	(24,1)	88.368	98.263
4th floor	(20,25)	(1,1)	84.5	91.65

Area coverage increases significantly after the position of the AP placement using the proposed method, which uses the combination of empirical propagation and a SA algorithm. The increase in the largest area of coverage was in the research area, the 1st floor (lobby) reached 30,964%. It can be seen that the entire study area experienced an increase in the coverage area with an average increase of 19.202%.

From the second comparison chart given in Fig. 8, and Fig. 9, we can see that the prediction of RSS values generated through the empirical propagation approach shows a graph that is linear, meaning that the distance function correlates inversely proportional to the RSS value. The farther the distance between the AP and receiver, the smaller (the more negative) the RSS value generated. This applies to the propagation of LOS and NLOS.

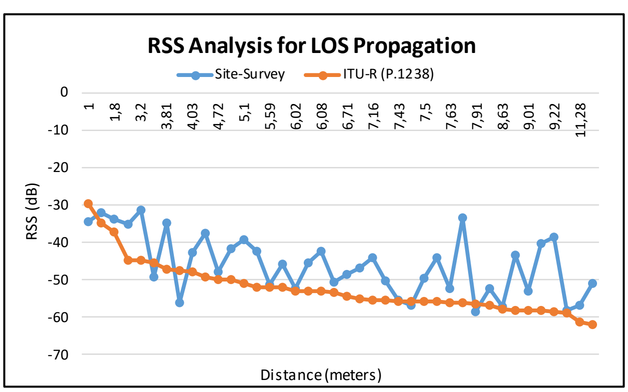


Figure 8. RSS Analysis for LOS Propagation

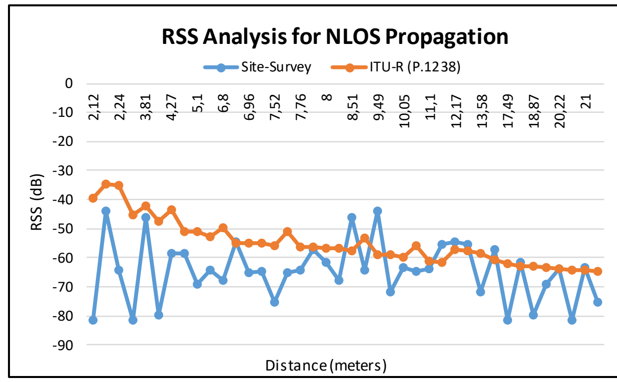


Figure 9. RSS Analysis for NLOS Propagation

Based on the results of testing at 80 points marking points, both for LOS and NLOS propagation, an average error of 12.09% was obtained. This value is calculated based on the RSS values difference between the site-survey measurement and the proposed method. The conclusion of the comparison of these two values explained through Table VIII below.

TABLE VIII. RSS ANALYSIS

Location	**Error (%)**
1st floor (Lobby)	7.29
1st floor (Laboratory)	14.11
3rd floor (Lecture's Room)	8.93
4th floor	18.05
AVERAGE	**12.09%**

5. CONCLUSIONS

The strength of a transmitted signal in a wireless network is strongly influenced by the placement of the AP. The research results that the distance is inversely proportional with the RSS values. The farther the distance between the user and the AP, the smaller the power level received by the user will be. However, the RSS value will also be affected by the presence of obstacles around the AP device. The existence of these obstacles allows a steady decrease in the signal received by the user, even if it is relatively close to the AP.

A novel method is proposed as one form of solution to find the AP placement. The combination of the SA and empirical propagation approximation algorithms is given to analyse and find the AP placement point that is considered the most optimal. We used ITU-R (P.1238) to predict the RSS values, also find the coverage area generated by an AP. Then, the SA Algorithm used to find the optimal marking position of the AP placement based on the best RSS value generated in the coverage area (based on the ITU-R's calculation before).

We found the result that the proposed model can provide an increase in area coverage, reaching 30,964% through the right AP placement. We also demonstrated in-depth research by experimental verification and site surveys. A comparison of RSS values is carried out on the calculation in the field and the proposed model with the average error value up to 12.09%.

A real-time site-survey measurement using augmented reality technology can be carried out as a continuation of this research. Thus, the AP placement recommendation can be immediately identified without having to take measurements manually in the field.

ACKNOWLEDGMENT

We want to thank Institut Asia Malang, especially for the Network Operating Centre team who has given a lot of data to complete our research needs.

REFERENCES

[1] G. Gódor and F. Karoly, "Optimization of Wi-Fi Access Point Placement for Indoor Localization," *Informatics IT Today*, vol. 1, no. 1, pp. 28–33, 2013.

[2] O. Baala, Y. Zheng, and A. Caminada, "The Impact of AP Placement in WLAN-based Indoor Positioning System," *Proc. 8th Int. Conf. Networks, ICN 2009*, no. March, pp. 12–17, 2009, doi: 10.1109/ICN.2009.50.

[3] F. S. Mukti, "Access Point Placement Recommendation Using Cost-231 Multiwall Propagation," *J. Penelit. Pos dan Inform.*, vol. 10, no. 2, p. 103, 2020, doi: 10.17933/jppi.2020.100202.

[4] N. F. Puspitasari, H. Al Fatta, and F. W. Wibowo, "Layout Optimization of Wireless Access Point Placement using Greedy and Simulated Annealing Algorithms," *Int. J. Simul. Syst. Sci. Technol.*, vol. 17, no. 34, pp. 14.1-14.12, 2016, doi: 10.5013/IJSSST.a.17.34.14.

[5] S. Y. Yeong, W. Al-Salihy, and T. C. Wan, "Indoor WLAN Monitoring and Planning using Empirical and Theoretical Propagation Models," in *Proceedings - 2nd International Conference on Network Applications, Protocols and Services, NETAPPS 2010*, 2010, pp. 165–169, doi: 10.1109/NETAPPS.2010.36.

[6] D. Pratap and S. Sharma, "Planning and Modeling of Indoor WLAN through Field Measurement at 2.437 GHz Frequency," *NIET J. Eng. Technol.*, vol. 5, pp. 15–19, 2014.

[7] P. Thu, Z. Tun, and A. S. Hlaing, "Modification of Propagation Prediction Model for 2.4 GHz Indoor Wireless Environment," in *International Conference on Advances in Engineering and Technology (ICAET)*, 2014, pp. 360–364, doi: 10.15242/iie.e0314173.

[8] M. Morocho-yaguana, P. Lude, F. Sandoval, B. Poma-v, and A. Erreyes-dota, "An Optimized Propagation Model based on Measurement Data for Indoor Environments," *J. Telecommun. Inf. Technol.*, vol. 2, pp. 69–75, 2018, doi: https://doi.org/10.26636/jtit.2018.117217.

[9] S. Kouhbor, J. Ugon, A. Kruger, and A. Rubinov, "Optimal Placement of Access Point in WLAN based on A New Algorithm," in *4th Annual International Conference on Mobile Business, ICMB 2005*, 2005, no. May 2014, pp. 592–598, doi: 10.1109/ICMB.2005.75.

[10] A. Mc Gibney, M. Klepal, and D. Pesch, "A Wireless Local Area Network Modeling Tool for Scalable Indoor Access Point Placement Pptimization," in *Proceedings of the 2010 Spring Simulation Multiconference (SpringSim '10)*, 2010, p. 1, doi: 10.1145/1878537.1878707.

[11] A. Huszak, G. Godor, and K. Farkas, "Investigation of WLAN Access Point Placement for Indoor Positioning," in *In: Szabó R., Vidács A. (eds) Information and Communication Technologies. EUNICE 2012*, 2012, no. August, doi: 10.1007/978-3-642-32808-4.

[12] R. Battiti, M. Brunato, and A. Delai, "Optimal Wireless Access Point Placement for Location-Dependent Services," 2003.

[13] M. G. Kelly, "The Automatic Placement of Multiple Indoor Antennas using Particle Swarm Optimisation," Loughborough University, 2016.

[14] F. Agren, "Indoor Radio Propagation Modelling with Antenna Placement Optimization," Lund University, 2017.

[15] M. O. Omae, E. N. Ndungu, P. L. Kibet, and H. Tarus, "Artificial Intelligence Approach to Signal Propagation Modeling For Outdoor to Indoor Wireless Communication Networks ; A Proposed Study," in *Mechanical Engineering Conference on Sustainable Research and Innovation*, 2012, vol. 4, no. May, pp. 289–299.

[16] F. S. Mukti and D. A. Sulistyo, "Analisis Penempatan Access Point Pada Jaringan Wireless Lan STMIK Asia Malang Menggunakan One Slope Model," *J. Ilm. Teknol. Inf. Asia*, vol. 13, no. 1, pp. 13–22, 2019, doi: 10.32815/jitika.v13i1.304.

[17] F. S. Mukti and A. Junikhah, "A Coverage Prediction Technique for Indoor Wireless Campus Network," *J. INFOTEL*, vol. 11, no. 3, pp. 73–79, 2019, doi: 10.20895/infotel.v11i3.434.

[18] F. S. Mukti, "Studi Komparatif Empat Model Propagasi Empiris Dalam Ruangan untuk Jaringan Nirkabel Kampus," *J. Teknol. dan Sist. Komput.*, vol. 7, no. 4, pp. 154–160, 2019, doi: 10.14710/jtsiskom.7.4.2019.154-160.

[19] F. J. Carlos Vesga, H. Martha Fabiola Contreras, and B. Jose Antonio Vesga, "Design of Empirical Propagation Models Supported in the Log-Normal Shadowing Model for the 2.4GHz and 5GHz Bands under Indoor Environments," *Indian J. Sci. Technol.*, vol. 11, no. 22, pp. 1–18, 2018, doi: 10.17485/ijst/2018/v11i20/122149.

[20] A. Hidayatno, A. O. Moeis, Komarudin, and Oscar Sriloka Sukoco, "Konsep dan Manual Pustaka Simulated Annealing untuk Menyelesaikan Permasalahan Tata Letak Mesin," Depok, 2014.

[21] N. F. Puspitasari, H. Al Fatta, and F. W. Wibowo, "Implementation of Greedy and Simulated Annealing Algorithms for Wireless Access Point Placement," *Proc. - AIMS 2015, 3rd Int. Conf. Artif. Intell. Model. Simul.*, pp. 165–170, 2016, doi: 10.1109/AIMS.2015.35.

[22] Z. Varty, "Simulated Annealing Overview," 2017.

[23] F. S. Mukti and A. Junikhah, "Prediksi Cakupan Area untuk Jaringan Wireless Indoor Kampus berdasarkan Penempatan Access Point," *J. Penelit. Ilmu Tek. dan Terap.*, vol. 10, no. 2, pp. 67–72, 2019, doi: https://doi.org/10.48056/jintake.v10i2.55.

Fransiska Sisilia Mukti. Malang, September 28, 1990. Taking her undergraduate at the Institut Teknologi Nasional Malang majoring in Electrical Engineering, for Computer Engineering concentration and graduated in 2013. Then achieved master degree in 2018 from Brawijaya University Malang, majoring in Electrical Engineering, for Communication and Informatics Systems concentration. She has been working as a lecturer for Informatics Department in Institut Teknologi dan Bisnis Asia Malang since 2016 until now and being expert for Computer Networking field. Since undergraduate up to now, various studies has been carried out under the theme of computer networks which include propagation, bandwidth management, traffic management and wireless sensor networks.