Layout Optimization of Wireless Access Point Placement using Greedy and Simulated Annealing Algorithms

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Abstract **- The development of Wi-Fi network is not only about the installment of access point infrastructure, but also related to various factors such as signal strength of the access point, design and infrastructure of the room, distribution of groups of access point users, radio wave interferences, and signal obstacles. Therefore in a Wi-Fi network, the placement of access point has a significant impact on receiver's coverage area. In this paper, a signal strength of the receiver's access point was measured using InSSIDer application and RSSI (Receive Signal Strength Indicator) values on Line of Sight (LoS) propagation and Non Line of Sight (NLoS) were obtained. A data obtained from the measurement has been modeled into a simulation of determining a position of the access point using Simulated Annealing and Greedy Algorithms. Testing result determined optimal coordinates for access point positions for both algorithms and performance of both algorithms has been compared to previous design before optimization conducted.**

Keywords – access point; greedy; optimization; simulated annealing; wifi

I. INTRODUCTION

An information and communication technology is growing very rapidly in response to the growing needs of the service for mobile users. The Internet is a communication service that provides convenience way of sending data on-line and real-time. Accessing the Internet can be done in various ways including using the Network LAN (Local Area Network) by using cables and other means such as Bluetooth, Wireless Modem etc.

A technology that is widely used by internet users is Wireless Fidelity (WiFi), it is because a technology is very easy to implement in the workplace and other public areas such as offices, campuses, restaurants, airports, cafes, playgrounds, libraries and many more. An advantage of using WiFi is that it can give a freedom to the user to be able in accessing it anytime and anywhere. To connect to a WiFi, users need communication devices, namely Wireless Access Point (WAP), Hub, and Switch that serve to connect local networks with wireless networks or wireless, Bluetooth or other communication networks. By using the Access Point, an internet connection may be transmitted or sent via radio waves. Signal strength also affects the coverage area to be covered, the greater the signal strength it will be more far-reaching.

Determining locations of the access point is one of the problems in the network infrastructure. A WiFi network designer requires theoretical analysis to adjust the layout of the access point at the right spot and optimal before implemented. A designer of WiFi networks are not just installing infrastructure access point device, but also must consider a variety of factors including the strength of the transmit signal of the access point, design and infrastructure of the room/space, distribution of groups of access point users, radio wave interference, signal block such as radio frequency and other objects that disturb signal reception from access point (transmitter) to receiving devices.

Therefore, determining the layout of the access point manually would require more resources because this method requires survey measurements at the actual location. This will be time-consuming and costly. A good strategy is needed by a designer of WiFi networks in arranging the layout of the access point in the optimal place. Thus resulting better coverage and an ideal number of access points with various sizes can be determined through calculation without performing actual field survey.

A good quality of services (QoSs) in accessing the internet can make a good recommendation to the stakeholders, in order not to get server performance downs. In addition, some parameters of QoSs implemented on the standardization of internet access usage needs to be analyzed more often [1]. The Standardization of the network infrastructure must also be concerned, especially in organizing the placement of the access point to get optimization solution in the field of network infrastructures. The WiFi network designers require theoretical analysis to make a proper placement of the access points. In this case, the planning of WiFi network is not only installing access point device infrastructure, but it must also consider a various factors such as the transmitted signal strength of the access point, network configuration and infrastructure, the distribution of the access point groups, the occurrence of radio wave interference, and obstacles of the transmitted and received signals. Therefore, in the placement layout of the access point, if it is done manually, it would require more consuming power, cost and time. So, a good mechanism to decide performance on organizing of access point placement in such way will make an efficiently wireless neighborhood network [2,3].

The optimization of access point placement in coverage area issue needs to be observed. Obtaining ideal placements are not so simple, this problem caused by some factors those are affected by the performances of access point [4]. However, a wireless local area network access points (WLAN APs) placement must be considered due to mobility and activity, and the WiFi areas also could be categorized into walking and resting areas whether crowded or not. Some aspects could be considered as an important factor in the observation and it is coverage area and throughput data [5,6]. Meanwhile, optimization of AP's placement to cover many users and the mathematical model could be used as approaching [7] or simulation testbed [8]. The usage of a multi-objective genetic algorithm (MOGA) has been used to maximize signal coverage area than standard placement technique [9] and method of Simulated Annealing has been implemented in an indoor [10]. Indoor empirical propagation model (IEPM) can be implemented to predict the length of the radio wave signal in indoor area of WiFi networks, thus the coverage area of the access point could be determined through calculation. This method helps in optimizing of the WiFi network and reducing costs. The aim is to perform access point layout optimization mechanisms on the WiFi network using Simulated Annealing and Greedy algorithms. In some cases, the short-anneal method has performed worse than the Greedy method, but for several trial runs, the Simulated Annealing method is a better method than Greedy method, even both method could be combined and parallelized [11,12]. Some parameters could be employed in making application of Greedy-Simulated Annealing for wireless access point placements to determine coverage area and its coordinate position automatically [13]. A Greedy Simulated Annealing algorithm had been researched for a problem of controller location in wireless networks to be optimized [14].

This research aims to optimize the layout of the WiFi access point on the network using a greedy and simulated annealing algorithms and to compare the results of the optimization of the two algorithms.

II. RESEARCH METHODS

A. Tools and materials

1) *Tools*

Tools used in this paper are:

a) *Access Point*

TP-Link TL-WA701ND for Access Point *(transmitter)*.

b) *Netbook*

Serves as receiver

c) *Handphone*

Used as an alternative receiver.

2) *Materials*

Materials used in this paper are:

a) *InSSIDer*

InSSIDer is a software to measure signal strength, can be installed on notebook or android based cellular phone.

b) *UTP (Unshielded Twisted Pair) Cable*

UTP cable is used to make a connection between repeater and transmitter.

c) *Measuring Tape*

To measure the height of transmitter and receiver positions.

B. Procedures and Data Collection

1) *Research procedures conducted by researcher are:*

- Preparing tools and materials
- Conducting Access Point verification by setting up receiver IP Address and make sure that receiver's IP address is in the same network with the access point.
- Test connection between both access point and receiver
- Install insider application for Windows 7 and for android Gingerbread v2.3 to measure the WiFi strength signal.
- Activate inSSIDer application for automatic WiFi scanning to obtain RSSI *(Receive Signal Strength Indicator)* value.

2) *Data collection during this research is conducted in the following steps:*

- Conducting research plan focused on data to be retrieved during research including floor plan, elevation of the access point, coordinates, distance, RSSI, and propagation.
- Determine the coordinates of the position of the Access Point and the receiver position on the propagation LoS (Line of Sight) and NLoS (Non Line of Sight). There are 43 points for the receiver position coordinates on the propagation LOS, and 65 points on the NLoS propagation.
- Enable inSSIDer application to obtain RSSI value data received by the receiver.

C. Results of RSIS Measurement

The signal strength (RSSI) transmitted by the access point is influenced by various factors such as the brand of the access point, the access point position coordinates, altitude and distance between the access point to the receiver. This will generate data to support the modeling system to be implemented in an application modeling software using Java programming language. The main parameters of this are height, distance, and RSSI.

The results of data collected on the access point using LoS propagation at the coordinates (22, 28) can be presented as follows.

- Data measurement at coordinate position (22, 28) with LoS propagation at a height of 50 cm is presented in Fig. 1.

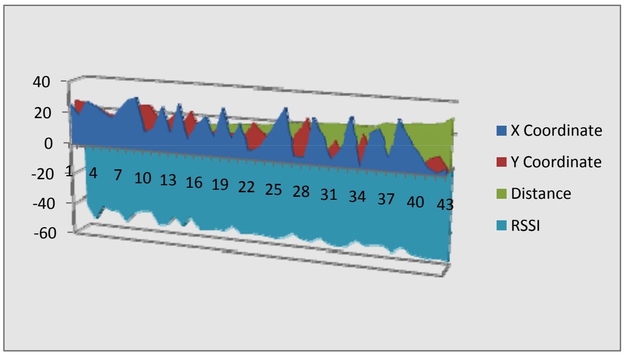

Fig. 1. The measurement of the LoS propagation at a height of 50 cm

From the measurement data as shown in Fig. 1, the maximum distance measurement on a scale coordinates of 31.6228, equivalent to 9.48 meters and minimum RSSI value at the access point at a height of 50 cm is -61.33 dBm.

- Data measurement at coordinate position (22.28) with LoS propagation at a height of 120 cm is presented in Fig. 2.

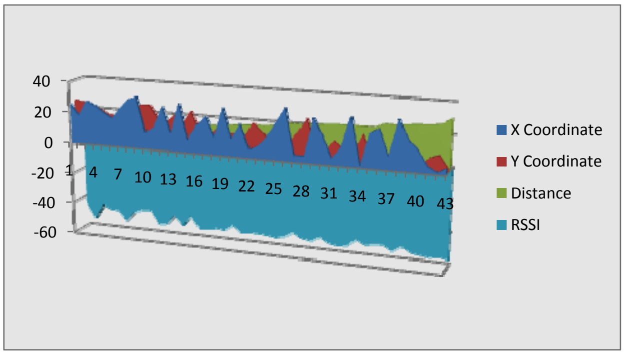

Fig. 2. The measurement of the LoS propagation at a height of 120 cm

From the measurement data as shown in Fig. 2, the maximum distance measurement on a coordinate scale of 31.6228, equivalent to 9.48 meters and minimum RSSI value at the access point at a height of 120 cm is 57.47 dBm.

- Data measurement at coordinate position (22, 28) with LoS propagation at a height of 230 cm is presented in Figure 3.

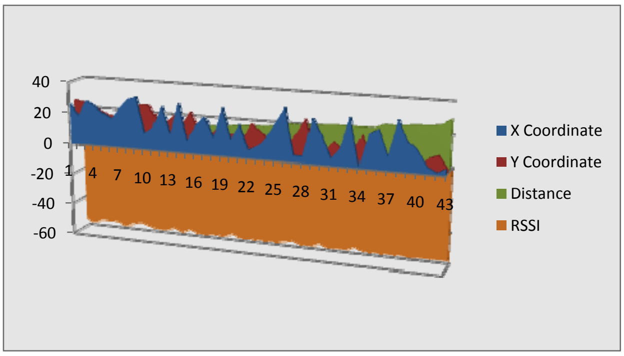

Fig. 3. The measurement of the LoS propagation at a height of 230 cm

From the measurement data as shown in Fig. 3, the maximum distance measurement on a coordinate scale of 31.6228, equivalent to 9.48 meters and minimum RSSI value at the access point at a height of 230 cm is -57.95 dBm.

The results of the data collected on the access point using NLoS propagation at the coordinates (22.28) can be presented as follows.

- Data measurement at coordinate position (22.28) with NLoS propagation at a height of 50 cm is presented in Fig. 4.

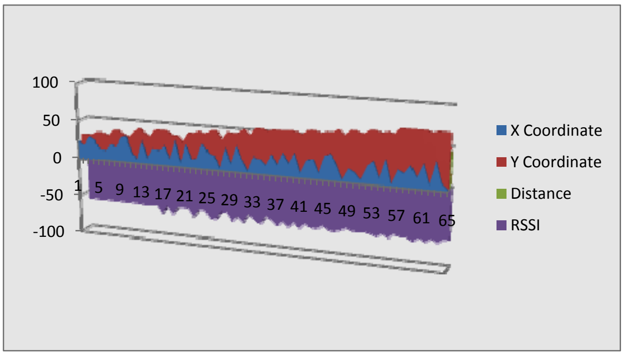

Fig. 4. The measurement of the NLoS propagation at a height of 50 cm

From the measured data as shown in Fig. 4, maximum distance is equal to 46.5188 coordinate scale (13.95 meters) and the minimum value of the measurement results at the access point with a height of 50 cm is -68.93 dBm.

- Data measurement at coordinate position (22.28) with NLOS propagation at a height of 120 cm is presented in Fig. 5.

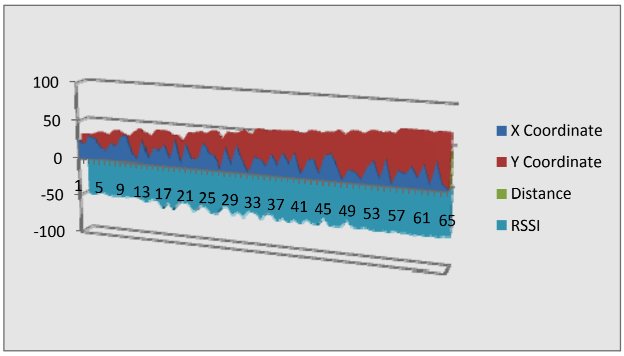

Fig. 5. The measurement of the NLoS propagation at a height of 120 cm

From the measured data as shown in Fig. 5 maximum distance is equal to 46.5188 coordinate scale (13.95 meters) and the minimum value of the measurement results at the access point with a height of 120 cm is -62.34 dBm.

- Data measurement at coordinate position (22, 28) with NLoS propagation at a height of 230 cm is presented in Fig. 6.

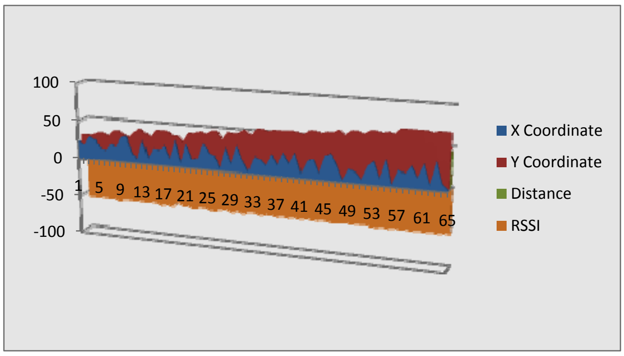

Fig. 6. The measurement of the NLoS propagation at a height of 230 cm

From the measured data as shown in Fig. 6, maximum distance is equal to 46.5188 coordinate scale (13.95 meters) and the minimum value of the measurement results at the access point with a height of 120 cm is -52.12 dBm.

D. *Analysis of Measurement Results of RSSI*

From the measurement conducted by the researcher, there are some analysis results presented as follows :

- Altitude of the location of the access point affects the reception signal (RSSI) received by the receiver. In the access point coordinates of (22, 28) with LoS propagation, changing of the AP height has affected to the RSSI value which is received by the receiver. The equation of average of RSSI (ω) as in (1).

$$\omega = \frac{\vartheta}{\lambda} \quad (1)$$

The average of RSSI (ω) is a ratio between the total value of RSSI (ϑ) and the number of receiver coordinates (λ). The three used types of AP height are 50 cm, 120 cm, and 230 cm. Each average value of the received signal at position coordinates of (22, 28) shown in TABLE I.

TABLE I. THE AVERAGE RECEIVED SIGNAL AT AP COORDINATES (22, 28) ON LOS PROPAGATION

Altitude of AP	LoS	
	Receiver Number	Average Received Signal
50 cm	43	-58.13 dBm
120 cm	43	-53.61 dBm
230 cm	43	-54.02 dBm

TABLE I shows that the average received signal with a height of 120 cm access point at -53.61 dBm. This result is better than the average received signal with a height of 50 cm access point at -58.13 dBm and 230 cm at -54.02 dBm.

In the coordinates of the access point (22, 28) with NLOS propagation, changing the height of the access point (transmitter) affects the RSSI value received by the receiver as seen in Fig. 1, Fig. 2, and Fig. 3. With the same distance and different heights, RSSI value produced is also different. Of the three types of a height of the access point that are 50 cm, 120 cm, and 230 cm, the average received signal receiver shown in Table II. The formula for the average RSSI signal reception shown in equation (5).

TABLE II. THE AVERAGE RECEIVED SIGNAL AT AP COORDINATES (22, 28) ON NLOS PROPAGATION

Altitude of AP	NLoS	
	Receiver Number	Average Received Signal
50 cm	65	-61,56 dBm
120 cm	65	-56,26 dBm
230 cm	65	-53,94 dBm

Table II shows that the average received signal with a height of 230 cm access point at -53.94 dBm. This result is better than the average received signal with a height of 50 cm access point at -61.56 dBm and 120 cm at -56.26 dBm.

E. *The Effects of Signal Strength (RSSI)*

RSSI signal strength received by the receiver does not only depend on the distance between transmitter and receiver but showed a large variation against fading and shadowing at a location. Of the research that has been done, the environmental conditions at many properties like in the room with partitions, cabinets, desks and other property may occur signal attenuation, signal deflection and signal reflection resulting the reduction of signal strength emitted by the transmitter to the receiver. Although the distance between the transmitter and the receiver close enough, the obstacles in the surrounding property will make the signal strength decreases and the possibility of signal strength will be equal to the strength of the signal at the transmitter away from the receiver position, but does not have a barrier around it.

III. System Analysis and Modeling

A. System Modeling

The system created using the Java programming language to model optimization placement of the access point on the 2 (two) dimensional space, while the algorithm used is a Greedy algorithm. Parameters to be calculated include: determining the evaluation function or objective function of greed generated from a function of distance, obstacles, altitude transmitter, user, type and brand of the access point on site.

Modeling based on the actual position of the access point grouped by its propagation consist of Line of Sight (LoS) and Non Line of Sight (NLoS). Modeling of the position of the access point is described as follows:

- Dividing the area of the room according to the number of tiles, because at the time of measurement, the sample point placement based on the tile in the room. The sample has an area of 226.80 m2. While the tiled area is 2520 units of tiles gained from the acquisition of long of tiled room 36 units and 70 units wide tiles, where one tile length of 30 cm.
- Determining the calculation of the coordinates that begins from the top left of the faculty room (0,0). Furthermore, the addition of X-axis coordinate value is to the right and the addition of the Y-axis coordinate is down.
- Determining the height of the transmitter that is divided into three types of height of 50 cm, 120 cm, and 230 cm.
- Determining the coordinates of the transmitter -1 with the actual position which is at the coordinates (22.28) and the coordinates of the transmitter to-2 in which the position of the access point is at coordinates (22.3).
- Measuring the magnitude of RSSI (Receive Signal Strength Indicator) of a corresponding increase in the distance between the transmitter coordinates and the coordinates of the receiver with the help of applications inSSIDer with propagation LOS (Line Of Sight) and NLOS (Non Line Of Sight).
- Find the distance (δ) between coordinates of transmitter and receiver using the Euclidean method as in (2).

$$\delta = \sqrt{(\sigma_1 - \sigma_2)^2 + (\psi_1 - \psi_2)^2} \qquad (2)$$

- Determine thresholds range. A range is the range of the signal that is expressed on a scale that otherwise covered or not covered by the signal emitted by the access point (transmitter). To calculate the value range obtained by the formula in equation (3).

$$\rho = \frac{\alpha}{\eta} \qquad (3)$$

The symbol of ρ is a limited range in a pixel unit, α is threshold distance that has scale space (η) of 30 cm. The α is obtained from (4).

$$\alpha = \frac{\tau.\delta_{\max}}{\varsigma_{\min}} \qquad (4)$$

Where τ is threshold power level that of -30 dBm, δ_{max} is the maximum distance in meter unit and ς_{min} is minimum power. Data obtained based on the research that has been done is as follows:

- In the coordinates of the access point (22.28) with LoS propagation, obtained variable data shown in Table III.

TABLE III. Variable data for LoS and NLoS propagations

Description		LoS	NLoS
α	:	-30 dBm	-30 dBm
δ_{max}	:	9.48 m	13,95 m
ς_{min}			
50 cm height	:	-61,33 dBM	-68,93 dBM
120 cm height	:	-57,47 dBM	-62,34 dBM
230 cm height	:	-57,95 dBM	-56,12 dBM
Space scale	:	30 cm	30 cm

TABLE III shows the average received signal that has the height of 120 cm is better than the average received signals that have heights of 50 cm and 230 cm. Either in the position coordinates of (22,28) with NLoS propagation, changing of the AP transmitter has effected to the RSSI values. The average value of the received signal at position coordinates of (22,28) with NLoS shows that the average received signal that has the height of 230 cm is better than the average received signals that have the height of 50 cm and 120 cm.

- Furthermore, the coordinates of which are less than a predetermined range is an area that is covered by the access point coordinates (22.28), while the coordinates of which has a distance of more than a predetermined range are colored red. The area in red will be optimized so that the entire area can be covered by the access point.
- Calculate and compare the area covered by the area observed. Figure 7 shows the sample area is covered by the access point on the coordinate access point (22.28) with LoS propagation and a height of 120 cm access point.

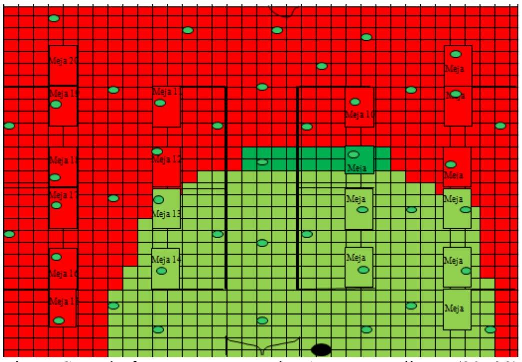

Fig. 7. Sample for coverage area by AP on coordinate (22, 28)

The coverage area percentage (ζ) can be obtained from (5).

$$\kappa = \sum_{\sigma_2=1}^{n}\sum_{\psi_2=1}^{n}\sqrt{(\sigma_1-\sigma_2)^2+(\psi_1-\psi_2)^2} \le \rho \qquad (5)$$

Coordinates of σ_1 and ψ_1 are the AP coordinates and $\sigma 2$ and $\psi 2$ are the receiver coordinates. So the AP coordinates have a coverage area (κ) of 195.3395 and area total (χ) of 2520. The coverage area percentage (ζ) can be obtained from (6).

$$\zeta = \frac{\kappa}{\chi}.100\% \qquad (6)$$

The percentage of coverage area (ζ) is 7.75%. The error percentage (ξ) can be obtained from (7). Calculate the percentage of error based on the formula (12)

$$\xi = \frac{\zeta-\gamma}{\zeta}.100\% \qquad (7)$$

From the result of simulated calculation (γ) is 11.51%, so the error percentage is -0.48%.

B. Modeling System using Greedy Algorithm

In modeling using the Greedy algorithm, this algorithm will be used to model the layout of the access point. Here is the pseudocode of the algorithm:.

```
Procedure greedy(input C: candidate_set;
                 output S : solution_set)
{determining    optimal    solution    from    the
  optimization problem using Greedy algorithm
  Input: candidate set C
  Output: solution set S
}
Declaration
     x : candidate;

Algorithm:
     S←{} {initialization S with zero
     while (not SOLUTION (S)) and (C ≠ {} ) do
        x←SELECTION(C);{choose a candidate from C}
        C← C - {x}
{candidate set elements decreased}
        if PROPER(S ∪ {x}) then
            S←S ∪ {x}
        endif
     endwhile
{SOLUTION(S) have been obtained or C = {} }
```

There are several things that must be designed in applying greedy algorithm: determining the candidate set, the solution set, the selection function, feasible function and the objective function. Each case will be described in the following sections:

- Candidate Set.

A set contains the elements forming the solution. At each step, one piece is taken from the set of his candidate. On this issue, the candidate representing the coordinate of the receiver and coordinate of the access point.

- Solution Set

Contains candidates elected as a solution to the problem. In other words, the solution set is a subset of the set of candidates. On this issue, the set of coordinates represent the distance from the receiver to the transmitter within range.

- Selection Function

Functions that are used for each step, is to choose the candidate most likely reach the optimal solution. Candidates elected in a move never be considered again at the next step. Functions used in this research is to calculate the value of RSSI of each receiver, the value is generated using inSSIDer application.

- Feasibility Function

Function to check whether a candidate has been selected can provide a viable solution. The candidates together with a set of solutions that have been formed not violate constraints (constraints) which exist. Viable candidates, incorporated into the solution set, while the unacceptable candidates discarded and never considered again. On this issue, the checking will be done to find out if all receivers already generate RSSI values and then calculated the value of the area covered by the transmitter.

- Objectives Function

Functions that maximize or minimize the value of the solution. In this problem, the objective function is calculated for the highest value of its covered area, selected through the feasibility function. In calculating the value of the objective, having obtained a temporary solution, a new calculation of the distance between the transmitter and receiver is done, then obtained a new range, the next new RSSI value of the receiver is calculated, and the results of the final calculation of the value of the area covered. To calculate the new distance using the formula in equation (6) derived from the formula in equation (1). A new RSSI value obtained from (8).

$$\varphi' = \frac{\alpha'}{\rho'}.\delta' \quad (8)$$

Where α' is threshold power that of -30 dBm, while ρ' is a first range obtained from (9) and δ' is a new distance obtained from (10). A new coverage area obtained by (11).

$$\alpha' = \frac{-30dBm.\delta'_{\max}}{\varsigma'_{\min}} \quad (9)$$

$$\delta' = \sqrt{\left(\sigma'_1 - \sigma'_2\right)^2 + \left(\psi'_1 - \psi'_2\right)^2} \quad (10)$$

$$\kappa' = \sum_{\sigma'_2=1}^{n} \sum_{\psi'_2=1}^{n} \sqrt{\left(\sigma'_1 - \sigma'_2\right)^2 + \left(\psi'_1 - \psi'_2\right)^2} \leq \rho' \quad (11)$$

- Early initialization and New Solutions Development Mechanism.

In this paper, the initial solution selected as a variable solution, so, in this case using a variable solution if there is no better solution than the initial solution. The mechanism used to generate a new solution is to select the location of the access point on the coordinate as the new position of the access point, which is not a previously occupied coordinate. Then each access point will allocate new RSSI value in accordance with changes in the distance to the receiver.

- Iteration process

The iteration process is performed to find the most optimal value of the covered area, where the iteration process is carried out without the target value then the current solution is always compared with the previous value to indicate the accuracy of the value of the solution.

C. Modeling System using Simulated Annealing Algorithm.

In modeling using simulated annealing algorithm, this algorithm will be used to model the layout of the access point. Here is the pseudocode of the algorithm:

```
Proceduresimulated_annealing;(inputistart:iteration;
          output c : control, L : length);

{determining optimal solution from the simulated
  annealing algorithm
  Input: iteration istart
  Output: solution set of C and L
}
```

```
Declaration
     k : iteration;
     i, C0, L0;

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

There are several things that must be designed in applying simulated annealing algorithm: objective function (cost function), initialization mechanisms of initial solution and granting new solutions, cooling scheme (cooling schedule) and the establishment of limits to the desired output. Each case will be described in the following sections:

a. Objective Function

The objective function finds the value of the largest covered area based on the value of the distance between the transmitter and the receiver position among a number of access points that have been initialized at random. n calculating the value of the objective, having obtained a temporary solution, followed by a new calculation of the distance between the transmitter and the receiver, and then obtained a new range, then calculated the new RSSI value of the receiver and the final calculation of the value of the covered area. To calculate the new distance using the formula in equation (8) derived from the formula in equation (1), and subsequently, a new RSSI value will be calculated using equation (8). Where α' is threshold power that of -30 dBm, while ρ' is a first range obtained from (9) and δ' is a new distance obtained from (10). A new coverage area obtained by (11).

b. Initialization and new solution establishment mechanisms

In this paper, the initial solution for the formation of the placement of the access point initialized randomly by dividing the access point at random into the coordinates on site. These coordinates are obtained based on the number of tiles in this site in which the coordinates of the length (x-coordinate) and the coordinates of the width (y-coordinates) and each access point will allocate new RSSI value of the receivers on the position of specific coordinates that have been set in order to obtain changes in the distance between access point and receiver. Then the value of the new range will be calculated to produce the optimal value of the covered areas. The mechanism used to generate new solutions are randomly select the access point to the coordinates of the position of a new access point, which is not a previously occupied coordinates, then each access point will be allocated to the receiver with a new RSSI values correspond to the distance change.

c. Cooling Scheme
   Before the annealing process is done, the cooling scheme to be used must be determined beforehand. In principle, the slower the annealing process lasts, the greater the chances to produce a better solution, because it will produce number of solutions that can be evaluated or the wider search space to be explored. There are three ways to slow the process of annealing, namely: to increase the value of the initial temperature, or to reduce the final temperature, raise the reduced temperature factor and increase the number of iterations in each temperature value. After conducting a series of experiments on various combinations of annealing parameter value, taking into account the quality of the solution and computing time required, it is determined where the cooling schedule Initial temperature = 1000; Final temperature = 1; Reduced temperature factor= 0.995; and the maximum number of iterations = 1000;
d. Iteration Process
   The iteration process is performed to find the most optimal value for the covered area where the iteration process is carried out without the target value then the current solution is always compared with the previous value to indicate the accuracy of the value of the solution.

IV. RESULT AND DISCUSSION

This section will explain about a series of tests and evaluation of the methods used. Tests have been conducted to determine the performance of the methods used in the implementation process. Evaluation has been done by analyzing the test results, then drawing a conclusion and suggestions. The data used in this paper there are 324 data is grouped by the coordinates of the access point, 3 sizes height of the access point and two types of propagation are presented in Table III.

TABLE IV. AP COORDINATES, HEIGHTS AND PROPAGATION TYPE

Access Point Coordinates	Height of Access Point	Propagation type	
		LoS	NLoS
(22, 28)	50 cm	43 data	65 data
	120 cm	43 data	65 data
	230 cm	43 data	65 data

There are several tests performed in this paper:

1. Tests on the transmitter based on the parameters for the brand, the height and the propagation of the receiver based on the parameters of the coordinates, distance, and RSSI.
2. Comparing- the test results based on parameters of the actual position of the access point- to access point position resulting from the optimization process uses the Greedy algorithm.
3. Perform data analysis of optimization results against the initial measurement.

A. Simulation Result and Analysis

1) Optimization Result using Greedy Algorithm

The data analysis based on optimization testing using a greedy algorithm to generate random coordinates access point (random) as many as 10 times each by three (3) test samples based on altitude/height of access point and type of propagation can be presented as follows:

a. At the access point with a height of 50 cm with LOS propagation, data showed the best area percentage of 49.25% at coordinates (24.28.). Chart for coverage area iteration on the modeling results can be displayed in Fig. 8.

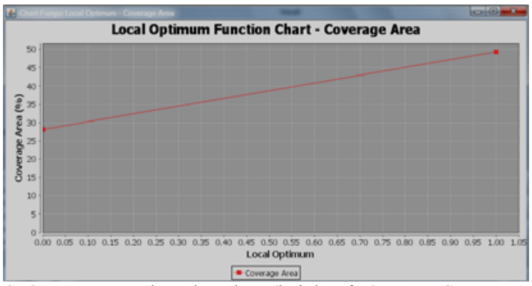

Fig. 8. Coverage area iteration chart (height of 50 cm, LoS propagation)

b. At the access point with a height of 50 cm with NLOS propagation, data showed the best area percentage of 43.05% at coordinates (16,51). Chart for coverage area iteration on the modeling results can be displayed in Fig. 9.

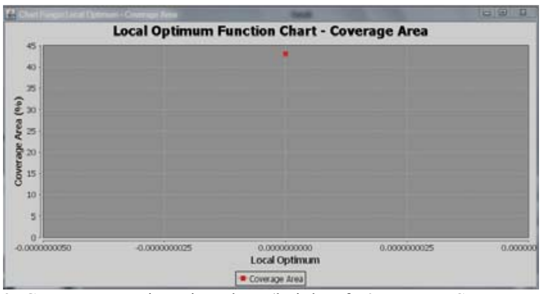

Fig. 9. Coverage area iteration chart (height of 50 cm, NLoS propagation)

c. At the access point with a height of 120 cm with LOS propagation, data showed the best area percentage of 58.98% at coordinates (11,16). Chart for coverage area iteration on the modeling results can be displayed in Fig. 10.

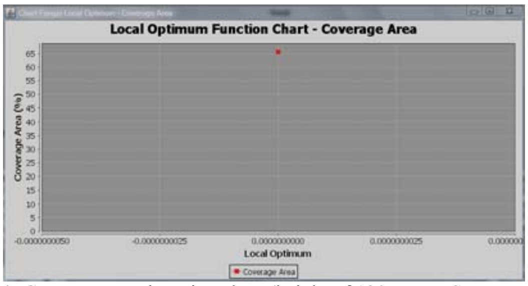

Fig. 10. Coverage area iteration chart (height of 120 cm, LoS propagation)

d. At the access point with a height of 120 cm with NLOS propagation, data showed the best area percentage of 48.14% at coordinates (18,40). Chart for coverage area iteration on the modeling results can be displayed in Fig. 11.

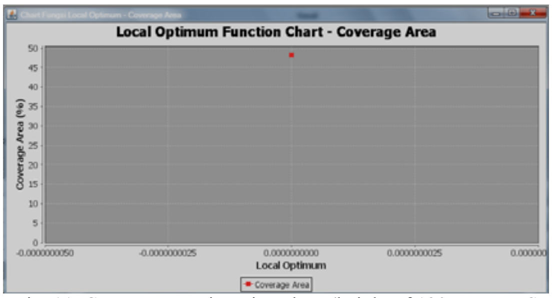

Fig. 11. Coverage area iteration chart (height of 120 cm, NLoS propagation)

e. At the access point with a height of 230 cm with LoS propagation, data showed the best area percentage of 37.69% at coordinates (14,16). Chart for coverage area iteration on the modeling results can be displayed in Fig. 12.

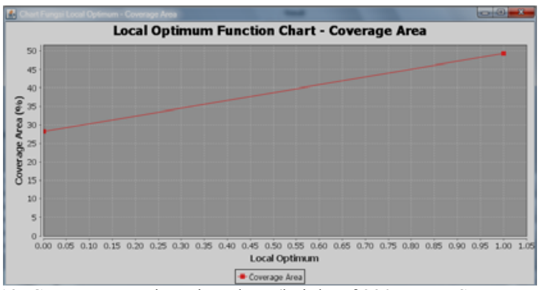

Fig. 12. Coverage area iteration chart (height of 230 cm, LoS propagation)

f. At the access point with a height of 230 cm with NLOS propagation, data showed the best area percentage of 54.77% at coordinates (17,32). Chart for coverage area iteration on the modeling results can be displayed in Fig. 13.

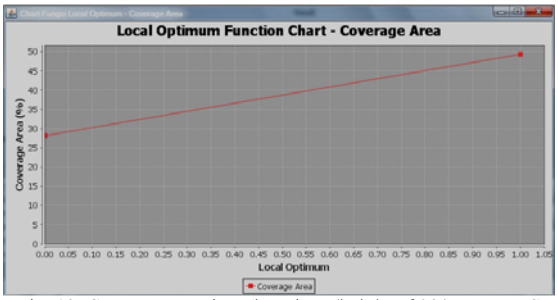

Fig. 13. Coverage area iteration chart (height of 230 cm, NLoS propagation)

2) Results of Optimization Using Simulated Annealing Algorithm

The data analysis based on optimization testing using Simulated Annealing algorithm to generate random coordinates access point (random) as many as 10 times each by three (3) test sample based on altitude/height of access point and type of propagation can be presented as follows:

a. At the access point with a height of 50 cm with LOS propagation, data showed the best area percentage of 70.90% at coordinates (21,24). Chart for coverage area iteration on the modeling results can be displayed in Fig. 14.

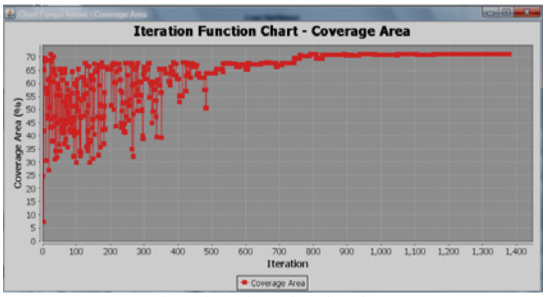

Fig. 14. Coverage area iteration chart (height of 50 cm, LoS propagation)

b. At the access point with a height of 50 cm with NLOS propagation, data showed the best area percentage of 44.24% at coordinates (24,46). Chart for coverage area iteration on the modeling results can be displayed in Fig. 15.

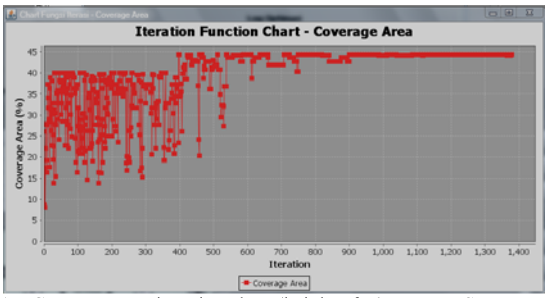

Fig. 15. Coverage area iteration chart (height of 50 cm, NLoS propagation)

c. At the access point with a height of 120 cm with LOS propagation, data showed the best area percentage of 76.97% at coordinates (33,11). Chart for coverage area iteration on the modeling results can be displayed in Fig. 16.

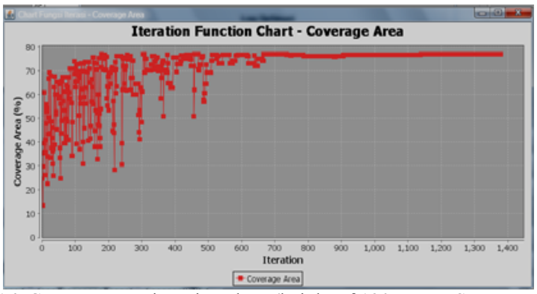

Fig. 16. Coverage area iteration chart (height of 120 cm, LoS propagation)

d. At the access point with a height of 120 cm with NLOS propagation, data showed the best area percentage of 51.23% at coordinates (25,63). Chart for coverage area iteration on the modeling results can be displayed in Fig. 17.

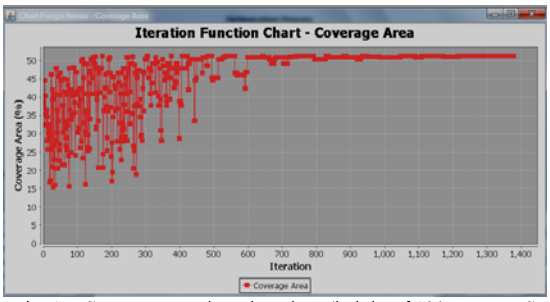

Fig. 17. Coverage area iteration chart (height of 120 cm, NLoS propagation)

e. At the access point with a height of 230 cm with LOS propagation, data showed the best area percentage of 73.95% at coordinates (5,28). Chart for coverage area iteration on the modeling results can be displayed in Fig. 18.

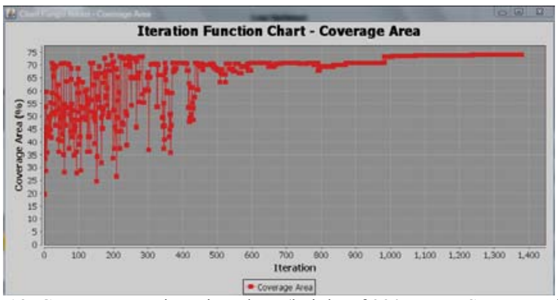

Fig. 18. Coverage area iteration chart (height of 230 cm, LoS propagation)

f. At the access point with a height of 230 cm with NLOS propagation, data showed the best area percentage of 54.81% at coordinates (7,35). Chart for coverage area iteration on the modeling results can be displayed in Fig. 19.

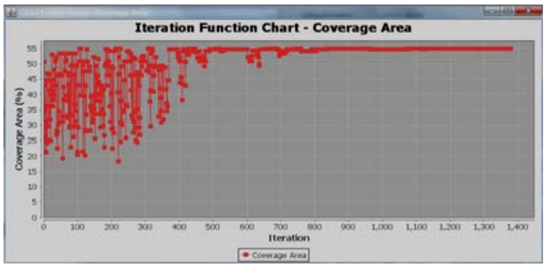

Fig. 19. Coverage area iteration chart (height of 230 cm, NLoS propagation)

B. Optimization Result Analysis

1) Analysis of the influence of variations in the height of access points to the value of RSSI.

Changing the height of the access point greatly affect RSSI value received by the receiver. As evidence, after optimization using a greedy algorithm to three (3) types of the height position of the access point (50 cm, 120 cm, and 230 cm), at a height of 120 cm LOS propagation provides the best presentation coverage area of 58.98% of the receiver. While on the NLOS propagation, a height of 230 cm provides the best value for the coverage area of 54.77% of the receiver. On the results of optimization using simulated annealing algorithm on the LoS propagation with a height of 120 cm gives the best results on the receiver coverage area of 76.97%. While on the NLOS propagation, a height of 230 cm gives the best results on the receiver coverage area of 54.81%.

2) Analysis of the signal strength after optimization compared to the initial conditions.

Signal strength increased significantly after it is created using a greedy algorithm modeling and simulated annealing algorithm compared with the placement of the access point with the initial conditions. For example, in the initial conditions of 120 cm height of the access point with LOS propagation, the percentage of coverage area is 11.51%. After optimization using a greedy algorithm percentage of coverage area is increased to 58.98%. In this paper succeeded in raising the percentage of the coverage area of 47.47%. While on simulated annealing algorithm percentage increase of 65.46% coverage area can be achieved.

3) Analysis of optimization result signal strength comparison using Greedy and Simulated Annealing algorithms

After testing the results of optimization using a Greedy and Simulated Annealing algorithms, then the comparison of the results of the percentage coverage area on LOS propagation is presented in Fig. 20.

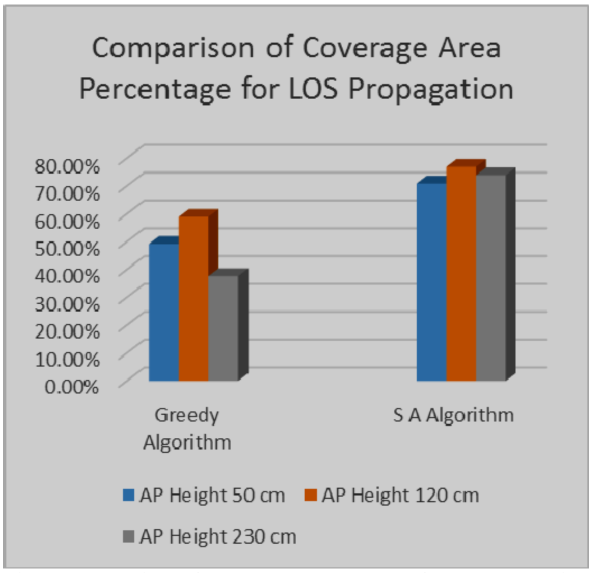

Fig. 20. Comparison of coverage area percentage for LoS propagation

Meanwhile, the comparison of the percentage of coverage area in NLOS propagation is presented in Figure 21.

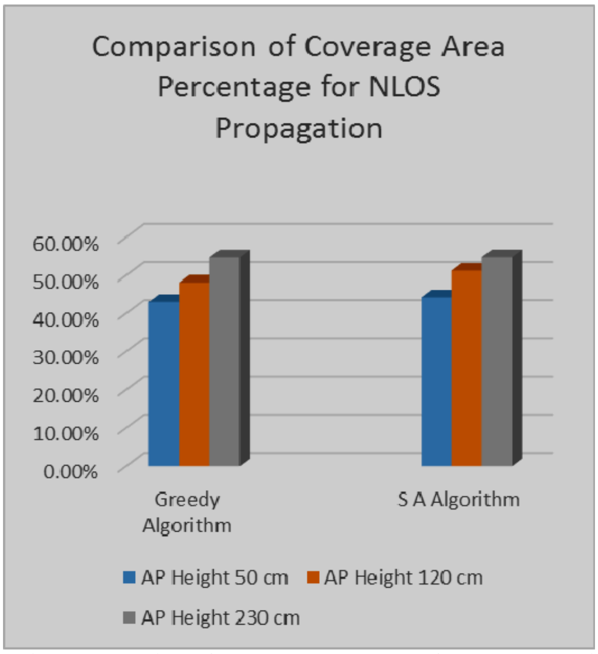

Fig. 21. Comparison of coverage area percentage for NLoS propagation

V. CONCLUSIONS

The setting of the access point layout greatly affects the strength of the signal received by the receiver. From the test results and analysis that has been done, it could be concluded that:

1. Both algorithms used in this paper provide better optimization results compared to the initial layout.
2. Based on the results of tests that have been conducted to determine the performance of the algorithm resulting from the implementation process, the simulated annealing algorithm gives more optimal solution than the greedy algorithm on the setting of the layout of the access point.

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