Multi-objective Genetic Algorithm for Access Point Optimum Location: A Case Study of Wireless Digital Campus

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ABSTRACT

WLAN access point placement problem solution was needed to explore while designing and implementing. This paper proposed a solution for access point placement in campus area. The main objective of the research was to minimize the number of access point and maximize its coverage area for certain area. There were three studied received power level model i.e. log-distance, empirical and cost231Hatta. Which is the empirical received power level model gave optimum solution in compare with others. Based on sensitivity analysis, there was no significant result while changing the crossover and mutation rate for the genetic algorithm. This study has a limitation on error distance while placing new location in compare with the existing one. Future study will be done to minimize the error distance and expanded for different received power level model

Keywords - received power level; optimum solution; genetic algorithm; location placement problem.

I. INTRODUCTION

The Based on a recommendation of Gartner Wireless and Mobile Summit, the evolution of network design tools moves from intuitive layout to an adjustable design scenario[1] which are the most network design tools for the wireless outdoor network did not use geographical mapping, see Fig1. So the exact location could not be determined as well. Even if the network designer shows the design in the geographical map, the visualization process was separated from the calculation. Therefore, GIS capabilities can be explored not only for visualization but also for the calculation and optimization process. Furthermore, spatial decision problem can be explained as a finding solution for the best site which is fitted by single or multiple criteria with the highest values. The best location depends on the criteria like the optimal distance, optimal cost, population density, etc. It can be optimized by single criterion like defining the optimal closeness or adding several criteria orders like optimal cost and optimal closeness together and so on. A traditional location allocation method relatively deals with a small data set.

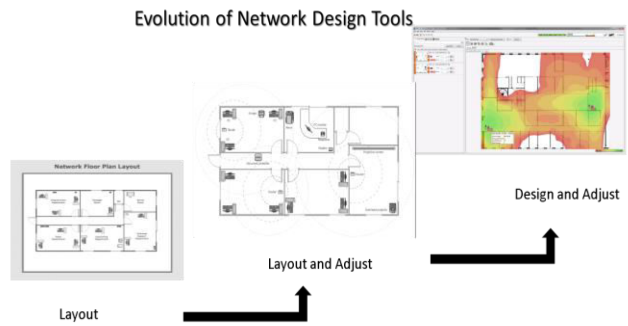

Figure 1 Evolution of Wireless Design

Commercial GIS software has applied a location-allocation problem a network analysis extension tools. This software only deals with one objective function for location problem by doing minimizing its total distance. If there is a combinatorial optimization problem such as the multiple objectives problem, it cannot handle many demand location or sites in datasets of GIS. A deterministic method is not feasible because of its time consuming for computation while calculating solution in the study area. This problem can be difficult to store the items at each location, especially when it used raster data with many cells [2]. The radio frequency site survey method usually used by network engineers to implement the access point location placement. Which is the network designer goes around the area and measure the RF signal strength at various locations. These measurements identify the appropriate location based on received signal strength, noise level, and signal quality. It should be repeated for several times to find the reliable results. This method will need much time and cost to identify whether its results are reliable enough or not because the location or area's characteristic of the users can change in time [3]. According [4] the WLAN service design is composed through the following activities:

- Estimating the demand area
- Selecting the AP candidate locations
- Measuring the signal strength level of the demand location in the service area

- Deciding the APs without channel interference
- Re-configuring the APs and its channel with feedback information

II. OPTIMIZATION MODELING

Finding an optimal location for AP in the grid of digitalized terrain in the interest area can be developed through an algorithm as a function of the AP efficiency score. If two or more AP transmitters are near enough to one another, their influence areas are overlapped, and then the locations inside these areas can have different degrees of coverage [5]. For this reason, the information stored in every position of the grid must take into account the following data: The degree of coverage, availability of location for a transmitter, possibility of AP transmitter is located or not and the kind of transmitter

Fig 2 show coverage optimization method that uses an "Island-based Algorithm", that was modified from [6]. This method assumes to cover the area of a transmitter that is defined as the surface covered by a set of transmitters. A geographical location is said to be covered when it can receive the signal from the transmitter with a minimum threshold.

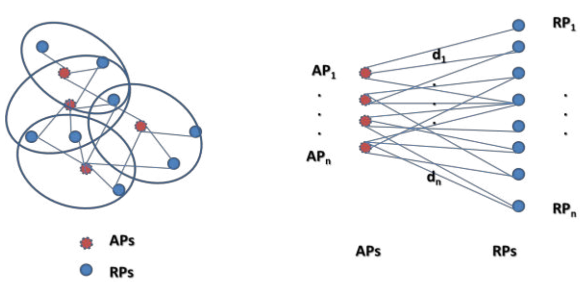

Figure 2 Algorithm Model

The optimum solution is the minimum total distance of each location to another location. It can be derived as;

$$Minimize\ d_{(i,j)} = \sum_{i=1}^{N}\sum_{j=i+1}^{N}\sqrt{(x_j - x_i)^2 + (y_j - y_i)^2}$$

subject to (1)

$x, y \in R$

$d_{ij} \le radius, \forall_{i,j} = 1, \dots, N$

Some parameters used in this optimization modeling can be described as follows: x is the node coordinate of longitude in the X-Y plane, y is the node coordinate of latitude in the X-Y plane, i is the starting node, j is the end node, d is the Euclidean distance between node i and node j. Minimizing operation is finding the minimum distance by comparing the total distance from node i to node j.

In WLAN deployment, the free space propagation model is usually used to predict the signal strength at a receiver where there is no obstruction or attenuation between the AP and RP. In terms of receiving signal power, the optimization of the RSSI calculation is given by

$$Maximize \sum_{i}^{n}\sum_{j}^{n-1} P_{ij} \qquad (2)$$

subject to $i, j \in R$

In which P is the received signal level between node i and node j, i is the starting node, j is the end node. The signal level comes from a predicted model equation.

In WLAN deployment, it usually uses the model of free space propagation for signal strength prediction at a receiver where there is no obstruction or attenuation between the access point and received point. In terms of received signal power, the propagation model of the RSSI calculation that uses one slope model in path loss is given by

$$P_{dBm} = P_{0,dBm} - 10\, n\, log_{10} d \qquad (3)$$

where $P_{0,dBm}$ is the received power obtained at 1 meter distance from the access point, d is the distance from a received point to the access point and n is the experimental result by using interpolation [7]. This model is a classical propagation model and widely used in a large number of environments, including industrial and wide area network. Empirical Coverage Model can be performed as:

$$P_{dBm} = P_{0,dBm} - 10\, n\, log_{10} d - EF \qquad (4)$$

EF is an environment factor that is calculated from the received signal strength difference between propagation with and without environment attenuation. This model is used to accommodate the environment attenuation that impacts the signal quality of the receiver. Some other models have also been proposed with different conditions [8]. Another empirical model that has been formulated to simplify calculation of path loss is Hatta Model. This formula can be used for 500 MHz to 2000 MHz of the frequency band. It is also known as COST-231 Hatta model which is formulated as

$$P_{dBm} = P_{0,dBm} - L_p \qquad (5)$$

$$L_p = 46.3 + 33.9 log_{10}(f) - 13.82 log_{10}(h_b) - a(h_m) + (44.9 - 6.55 log_{10}(h_b)) log_{10} d + c_m \qquad (6)$$

Where f is defined as the working frequency in MHz, d is defined as the distance between AP and RP in *km*, and h_b is defined the height of AP antenna above the ground level in *m*. Whether c_m is defined as environment correction factor of 0 dB for suburban or open environment and 3 dB for urban environment, and $a(h_m)$

is a correction factor of antenna height that is defined for urban environment as

$$a(h_{m)} = 3.20(\log_{10}(11.75h_r))^2 - 4.97 \quad (7)$$
$urban\ and\ f > 400\ Mhz$

or

$$a(h_m) = (1.1\log_{10}f - 0.7)h_r \;\; - (1.56\log_{10}f - 0.8), \quad (8)$$
$suburban\ or\ rural$

When, h_r is the RP antenna height above the ground level in *m.*

III. METHODOLOGY

This research was conducted by following procedures, such as device requirements, field data collection, network optimization, that resulted in data map development (see Figure 3.). In the beginning, network device specifications were defined, i.e. the maximum power output of the Access Point of 100mW, which means a maximum coverage radius of 100m and coverage signal direction of omnidirectional.
Access point placement problem was considered with location and number of APs within desired coverage area. Sukamoto at.al concerned with programming technique on node placement [9]. Which were three programming techniques has been developed and compared i.e. hill climbing, simulated annealing, and genetic algorithm. They concluded that genetic algorithm did not faster for convergence result. Whether [10] provided a realistic solution for multi-objective node placement with genetic algorithm technique. The algorithm starts with initial location and followed by distance calculation between RPs and APs respectively. This distance matrix will be used as data optimization input. By running the algorithm with defined its parameter found the best generation that represents the optimum location of the access point.

3.1 Initial Location of Access Points and Received Points

Field data collection was performed to get the RSSI (Received Signal Strength Indication) field strength from several RP (Received Point) locations to a certain AP that was being assessed. This measured field strength was used to develop coverage prediction of the network strength. The receiving point test-bed is a received point location to measure the Access Point signal strength. GIS model for interconnection of RPs and APs was developed to calculate the Euclidean distance, followed by analyzing priority locations based on an analytical hierarchy process. The connection AP and RP was built as a byte stream to represent the generation for the algorithm. For example, byte stream of 1111 0000 1110 0000 represented an AP location for 1111 0000 (the first byte) and it is connected to RP location of 1110 0000 (the second byte).

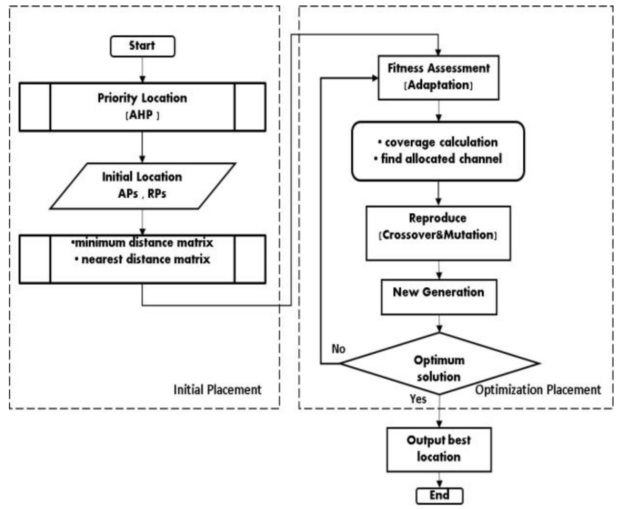

Figure 3 Main Algorithm

3.2. Fitness Assessment

Optimum AP locations were determined based on distance and signal strength. Database of APs and RPs provides information about the location and measured RSSI for each RP location from each connected AP. This database includes Location of Access Point (Longitude and Latitude in UTM), Location of Received Point (Longitude and Latitude in UTM), calculated distance between APs and RPs covered, measured field strength of the RP to the assessed APs in a certain location of each covered area, MAC Address of the accessed APs, and the Location name of each assessed AP. Data sets are needed such as location, elevation, and antenna height, transmit power and coverage area radius, received signal level measurement in the interest area, and the used channel numbers.

3.3. Crossover and Mutation

The crossover and mutation type used single point crossover and swap type mutation. This single point crossover randomly selects the point within the chromosome. Due to interconnection placement location gives only one direction between the access point and received point, a single point crossover will give a combination of the minimum connection between APs and RPs. Which is the optimum location was derived from the minimum distance from all possible location of the APs. This algorithm used crossover rate as 0.1 to 1.0 consecutively. Furthermore, the mutation type of the algorithm was swap mutation, this mutation will swap the bit stream of the interconnection data in between APs and RPs. This swap mutation gives a combination of APs and RPs to get maximum signal coverage of the placement location. Whether, the mutation rate was selected as 0.01 to 0.1 consecutively.

IV. EXPERIMENTAL SETUP

4.1. Device Specification

Specifications of the Access Point device in this research are type of the access point is outdoor with power output (EIRP) of 35 dBm and antenna gain of 12 dBi. Coverage distance of access Point is 100 meters. Furthermore, measuring of signal level and map location used android application i.e. Network Signal Info and AndroidTS GPS Test. This application was freely to download from Google Play Store. The Network Signal Info measured RSSI level of the received point to the desired access point base on SSID. Whether, AndroidTS GPS Test found the longitude and latitude of the APs and RPs location. Software used for simulating and programming is ArcGIS with Python language.

4.2. Data Collecting and Preprocessing

This study firstly collecting data about wireless network installed in the entire study area. These data was collected from Office of Facility and Asset Management of the Asian Institute of Technology administration. Information about location criteria was discussed with the engineer by doing fulfilling questionnaire form of the factor in access point placement priority.

Table 1 Data of Initial Access Point Location

No	Location	AP ID	MAC Address	Eastern	Northern
1	Arcade	AP_1	0c_85_25_ab_02_d6	674332	1556985
2	Reg_West	AP_2	20_bb_c0_83_17_71	674207	1557024
3	Reg_East	AP_3	f0_29_29_78_ae_d1	674237	1557021
4	Dorm_H	AP_4	3c_ce_73_c5_e1_51	674117	1556965
5	Dorm_G	AP_5	68_bc_0c_0a_6b_31	674117	1556931
6	Dorm_F	AP_6	3c_ce_73_09_80_61	674084	1556954
7	Dorm_E	AP_7	3c_ce_73_c5_ea_21	674102	1556920
8	Dorm_B	AP_8	3c_ce_73_9b_06_21	674070	1556907
9	Dorm_A	AP_9	3c_ce_73_09_7f_41	674070	1556861
10	Dorm_D	AP_10	3c_ce_73_c5_cd_91	674102	1556877
11	SV_2	AP_11	3c_ce_73_c5_f2_f1	674086	1556818
12	SV_9	AP_12	3c_ce_73_09_93_21	674048	1556801
13	SV_12	AP_13	3c_ce_73_e9_93_21	674072	1556766
14	SV_19	AP_14	3c_ce_73_c5_c6_a1	674040	1556757
15	SV_22	AP_15	a4_56_30_cc_a9_c1	673941	1556804
16	SV_29	AP_16	5c_50_15_d1_72_36	673915	1556801
17	SV_32	AP_17	3c_ce_73_9b_2f_71	673935	1556763
18	SV_39	AP_18	5c_50_15_d1_9a_b6	673915	1556753
19	SV_58	AP_19	68_86_a7_52_2f_b6	673750	1556946
20	SV_50	AP_20	d4_a0_2a_10_8c_e6	673763	1556895
21	SV_68	AP_21	68_86_a7_46_41_26	673684	1556946
22	SV_53	AP_22	3c_ce_73_c5_cd_66	673708	1556892
23	SV_47	AP_23	3c_ce_73_09_5e_b6	673685	1556879
24	FH_1	AP_24	dc_9f_db_0a_98_20	673712	1556791
25	FH_2	AP_25	dc_9f_db_08_4b_22	673638	1556780
26	FH_4	AP_26	dc_9f_db_08_4b_98	673615	1556779
27	Dorm_C	AP_27	3c_ce_73_c5_cd_01	674070	1556940
28	Dorm_J	AP_28	3c_ce_73_c5_e3_91	673984	1556945
29	Dorm_K	AP_29	0c_85_25_aa_22_51	673985	1556981

Source: compiled by author

V. RESULT AND DISCUSSION

Multi-objectives optimization that was proposed used distance and signal strength to find the minimum number of the access point with a maximum of the coverage area. The objective functions of this optimization are finding minimum distance from the total distance from each access point to the received points. Which is received a point that already associates to one access point will not calculate with another one. Furthermore, the maximum signal strength of the received point that was associated with the desired access point will calculate the maximum strength of each access point. This multi-objectives optimization was developed with a genetic algorithm that was appropriate in 1000 generation to get the optimum solution. This software was developed with Python programming language in Python evolutionary module.

5.1. Generation Number

The optimization model was developed with the island-based genetic algorithm. This algorithm has been calculated in a different number of generations. An appropriate number of generation was 1000 generation based on raw score and fitness score (see Fig.4 and Fig.5) based on data calculation in [11]. So that, obtaining optimization will define a number of generation for 1000 generations and crossover rate of 0.1, whether mutation rate as 0.03

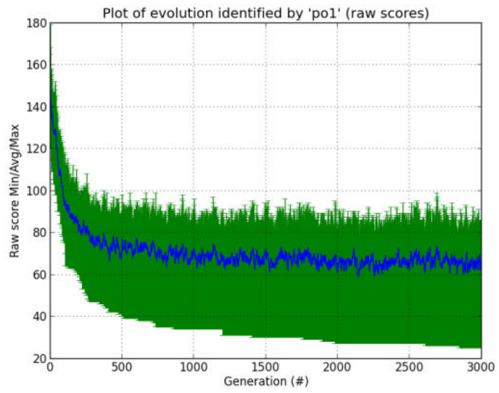

Figure 4 Algorithm performance computation based on the Raw Score

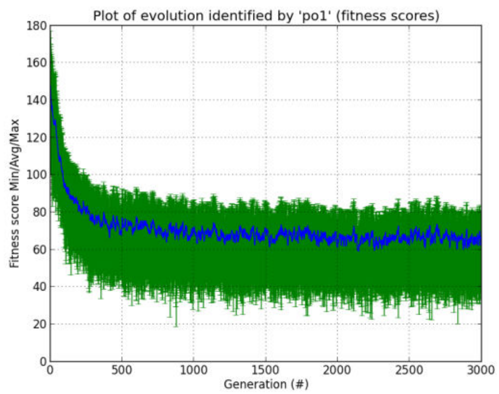

Figure 5 Algorithm performance computation based on the Fitness Score

5.2. Sensitivity Analysis on Genetic Algorithm Variables

The parameters of Genetic Algorithm were analyzed for the changes of values will impact to the output. This analysis was changed input parameter of crossover rate and mutation rate to find out the output of the optimization, in term of distance error of the proposed location to the existing location. The default model was the optimum output for the appropriate solution. This default model will compare with another combination of the mutation and crossover rate as model number one to model number six. The complete combination displayed in Table 2. These models will be implemented with three consecutive signal strength model i.e. Classical, Empirical and Cost231Hatta model.
The combination of mutation rate and crossover rate were displayed in Fig. 6 and Fig. 7, which was the combination of crossover rate gives no significant difference of the distance error among the three model. Which is the distance error of the proposed location from each model relatively closed to the default model.

Table 2 Values Combination on Crossover and Mutation Parameter

Model	Crossover rate	Mutation rate
Default	**1.0**	**0.03**
1	1.0	**0.01**
2	1.0	**0.05**
3	1.0	**0.1**
4	**0.5**	0.03
5	**0.1**	0.03
6	**0.8**	0.03

Source: compiled by author

This condition can be concluded that the changes of crossover rate for among three signal strength model were not sensitive to find proposed location. On another hand, the combination of mutation rate gave a different condition. The mutation rate parameter was sensitive when changed its value for two consecutive signal strength model of empirical and cost231Hatta. Whether the classical signal strength model was not sensitive to the combination of mutation rate

Figure 6 Sensitivity Analysis of the Crossover Parameter

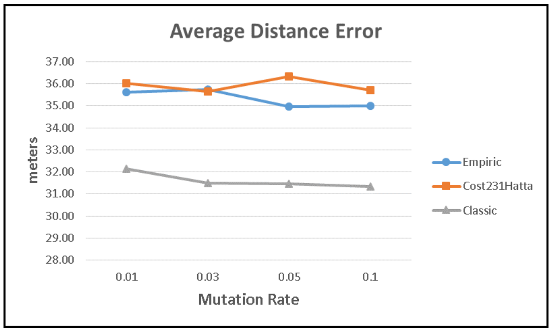

Figure 7 Sensitivity Analysis of the Mutation Parameter

Optimization with the random location of the access point has been performed to exercise the model and framework. This process, firstly defines the priority location of the access point placement based on analytical hierarchy process. By using random point placement defines a random location which is area with high priority was placed by three access point then followed by two access point in medium priority and on the access point for low priority. The coverage and number of APs for each prediction model in comparison with the initial placement show that empirical predicted model gives coverage result closer to the initial with a minimum number of APs. By using empirical prediction model gives 27 APs to cover the area of the study, although it needs more time process than cost231COST231Hatta model.

Table 3 Performance of the Optimization Process with Random Placement

Model	Optimum AP (unit)	Percent AP	Percent Coverage	Average Distance (m)	Coverage Index
Initial	29	100%	100%		9,369.52
Log-distance	42	145%	132%	31.5	8,516.53
Empirical	27	93%	112%	35.7	11,314.50
Cost231Hatta	27	93%	132%	35.6	13,247.93

Based on simulation results as in Table III, it shows the empirical models provide optimal results are better than the other models. It can be seen from the percentage of coverage and the percentage of the number of access points to the initial conditions. Optimization results with empirical models provide a percentage of the initial condition of 112% while the classical model and COST231Hatta generate a percentage of 132% and 132%. While the value of the percentage number of access points to the initial conditions of the optimization results got 93% for COST231Hatta and empirical model while classic models provide 145% of the results.

VI. CONCLUSION

This proposed technique on access point placement problem has been implemented. Objective goal of the problem found to reduce the number of access point and enlarge its coverage area for desired area. The empirical received power level model gave optimum solution in compare with other model. Otherwise, there was no significant output while changing the crossover and mutation rate in programming result. This model has a limitation on error distance while placing new location in compare with the existing one. More study should be done to reduce the error distance and expanded for different received power level model.

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