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Utilization of Three-dimensional Spatial Maps in Access Point Placement Optimization

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***Abstract*—The placement of access point locations is now a necessity in planning computer networks in particular wireless networks. In the study of wireless networks, at present, the design and adjustment approach has replaced the experience-based approach. In some wireless network planning tools the location map is only used for visualization only, so it needs to be developed for the calculation of location optimization as well. The use of spatial data has already been applied in location optimization. Application of optimization techniques in network planning will reduce costs and time compared to trial and error techniques. Spatial location data still uses two-dimensional data, namely latitude and longitude data. However, spatial location data in three dimensions have not been widely used in this optimization method. This research implements three-dimensional spatial data in the location optimization method. In this case, the spatial analysis of GIS (Geographic Information Systems) will be useful for predicting coverage and signal strength. Integrating spatial data analysis and programming techniques can lead to improvements in wireless network design. The use of evolutionary algorithms will provide solutions for optimal access point locations. This approach provides the right solution in design and evaluation. The results of the optimization of 3-dimensional maps provide better design values compared to 2-dimensional optimization. This can be seen from the reduction in the number of access points and the average distance, although this also results in a reduction in the area of coverage.**

***Index Terms*—location optimization, three-dimensional spatial data, wireless networks**

I. Introduction

Based on Gartner Wireless and Mobile Summit recommendations, the evolution of mobile network design tools from intuitive placement methods to design scenarios that can be adjusted [1]. However, wireless network design has not used geographical mapping. So the exact location cannot be determined right away. Although some tools to help network plans utilize the map geographically, it is still limited to the visualization process without taking into account the calculations for optimization.

Therefore, the capabilities of GIS can be explored not only for visualization but also for the calculation and optimization process. Furthermore, the problem of making decisions with the data spatially can be explained as a solution of the best location that is based on either a single criterion or even a double with the highest value. The best location depends on criteria such as optimal distance, maximum cost, population density and so on. This can be optimized by a single criterion such as determining the proximity of the location of the optimal or add some other criteria such as optimal costs and the proximity of the location together. The method of determining the location in general relativity relates to data sets in bulk. Commercial GIS software has implemented the problem of locating as an additional function in network analysis. This software only handles one objective function for location problems by minimizing the total distance. If there are combinatorial optimization problems such as some objective functions, the additional functions cannot handle them. The deterministic method is not feasible because it takes time to calculate while calculating the solution in the study area. This problem can be difficult to store data in each location, especially when using raster data with multiple cells [2]. The radio frequency location survey method is usually used by network planners to implement location placement of access points. They are going around the area of coverage and measuring the RF signal strength at various locations of measurement points. This measurement identifies suitable locations based on signal strength, noise level, and signal quality received. It must be repeated several times to get reliable results. This method will require a lot of time and money to identify whether the results are reliable enough or not. This is because the characteristics of the location or area of the user can change at different times [3]. The results of location optimization have an error rate of 35 m for locations outside the building [4] and 12 m for locations inside the building [5]. Meanwhile the results of research in dimension two show quite good results [6], so it is necessary to develop the use of three dimensional spatial data. According to [7] the design of a WLAN (Wireless Local Area Network) service was prepared through the following activities: Firstly estimating the demand area, choosing the location of the AP (Access Point) candidate. Then measuring the signal strength level of the request location in the service area and disconnect AP without channel interference. Finally, it re-configures the AP and its channel with feedback information.

This study aims to produce an optimization model for locating access points based on three- dimensional spatial data. Which is the optimization method for locating access point locations by utilizing spatial data has not used location altitude information. Therefore, how to implement the optimization technique of access point location in three dimensions by considering the vector of latitude, longitude and altitude can improve the final result, in this case reducing the misplacement of locations for outside space / buildings.

II. Literature Review

Farsi et.al introduce a heuristic approach in the planning of AP positions and frequencies [8]. The problem of positioning the AP is optimized by the principle of circle and MCL-IP (Markov Clustering and Integer Linear Programming). The planning problem could be solved with PFVA (Predefined Frequency Vector Approach) and LICS (Least Interfering Channel Search). Meanwhile reference [9] presents a comparative evaluation of four state-of-arts genetic algorithms namely SPEA2 (Strength Pareto Evolutionary Algorithm version II), NSGA-II (Non-Dominated II Sorting Genetic Algorithms II), PESA (Selection Based on Pareto Envelope Algorithms) and SEAMO (Simple Evolutionary for Multi-objective Optimization) performs an optimal solution to the problem of multi-purpose antenna placement. El-deen [10] introduces two types of evolutionary algorithms namely traditional genetic algorithms with penalty functions and randomly weighted genetic algorithms in cell radio planning. The author proposes a model for the problem of sitting at the base station and using a multi-criteria analysis of its implementation. The results of the optimization problem come from traditional genetic algorithms compared to randomized weighted genetic algorithms. Both of these algorithms provide optimal solutions for radio placement which are random weighting algorithms that provide better solutions than traditional solutions. Discussion on optimizing node placement and configuration of wireless local area networks using genetic algorithms by [11]. Which is the author proposes a new algorithm for creating high-quality network plans for WLAN. Genetic algorithms are used to explore design space. The results of the network plan program will reduce the time in designing and planning the network compared to the manual. The use of several objective criteria for the placement of wireless access points has been proposed by [12] which is the average SNR (Signal to Noise Ratio) and coverage area.

WLAN installation tools have been developed by many vendors. Airaspace and Aruba are two examples of this product. Their products use a computerized development plan approach to simulate the layout (mostly using AutoCAD) and generate RF wave patterns. However, the tool has no special demands on regional information. Field adjustments are a way to get a reliable design. Some vendors such as Wireless Valley provide WLAN design tools by taking a lot of information into their Access Point placement design. It also adds a mapping feature to simulate network design. Nevertheless, the use of mapping technology for wireless network planning still poses several challenges.

A. Problem Formulation

The placement of access point locations in wireless computer network planning can be done by considering several aspects including the position of an access point not adjacent to each other so that the accumulation of coverage areas [13] . Therefore it is necessary to optimize the location placement process based on these criteria.

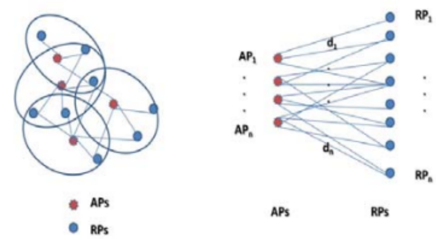

Fig. 1. Location Optimization Model

2 This optimization has two objective functions: minimizes the number of access points and maximize the coverage area based on predictions of strong signal receiver RSSI (Received Signal Strength Indication). The boundary conditions used in this optimization are the distance of the radius of the coverage area. The optimization of the location of the proposed access point location is the development of an "Island-based Algorithm" algorithm model from [14], that shows the concept of the optimization method in Fig. 1.

This method uses the assumption that the coverage area of an access point transmitter is a set of receiving locations that can receive signals from an access point transmitter. A location is said to be included in the coverage area if it can receive signals from transmitters with certain limit values. The optimization of the transmitter location is to find the optimum distance from each receiver location to each transmitter location. The formulation of the optimization model is as follows;

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

subject to

$$x, y, z \epsilon R, d_{ij} \leq radius, \forall_{ij} = 1, ..., N \quad (1)$$

2

The parameters used in the optimization model above can be explained as follows: x, y, z is the geographical position of the receiver and transmitter according to the alignment, latitude and altitude in the geographic coordinate system. While i, j is the connectivity matrix between the transmitter and receiver, while d is the Euclidean distance between the transmitter and receiver. The minimum total distance from the transmitter and receiver connectivity illustrates the optimum location of the transmitter.

B. Research Method

This research is a qualitative experimental study. Research activities can be described as follows: Determination of the three-dimensional optimization model through literature study, in this case looking at the development of the latest optimization model through journal search. The optimization model used as listed in (1) and (2). In the equation the three-dimensional vector used is X as longitude coordinates, Y as latitude coordinates and Z as height of the research object. The algorithm of solving location optimization with genetic algorithm techniques can be seen in Fig. 2.

Developing and collection of spatial map of the coverage area of a wireless network (wireless local area network), in this case the planning database and modeling spaced a l and manufacture optimization program utilizing GIS software (Geographic Information System). Meanwhile the measurement of field data is done by measuring the strength of the reception signal from several test points. This study uses secondary data in the form of measurement results in the area of a campus. Testing simulation data on optimization models and evaluation of optimization results , in this case the program outputs are analyzed using spatial analysis techniques to get an idea of the extent to which three-dimensional spatial methods can improve the results of two-dimensional methods. Spatial regression is used to determine the level of accuracy of the results of location optimization compared to the initial state . Wireless network planning often uses wave propagation models as a way to estimate the signal strength. Optimization for strength value signal receivers can use the following equation models; P is the strength of the receiver signal from each range of access points, the value is affected by the strength of the receiving signal at the shortest distance from the access point plus the propagation loss. While the parameter values i and j are the starting point to the last measurement.

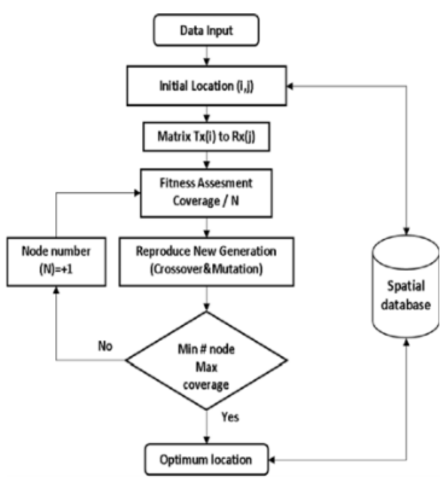

Fig. 2. Optimization Algorithm

Signal propagation models between transmitters and receivers in wireless computer networks can be calculated based on the strength of the receiving signal and the trajectory power losses [15]. The signal strength equation must be able to be used for the frequency range between 500 MHz to 2000 MHz. Therefore an equation known as the COST-231 Hatta model is used and is formulated as follows;

$$maximize \sum_{j}^{n} \sum_{j}^{n-1} P_{ij} \tag{2}$$

subject to
i, j ϵ *R*
where

$$P_{dBm} = P_{0,dBm} - L_p \tag{3}$$

The parameter f is the working frequency in MHz, d is the distance between AP and RP in km, and hb is the height of the AP antenna above ground level in meter. Meanwhile cm is defined as area correction factor that is worth 0 dB to environmental suburban or open area and 3 dB for the area urban, and a (hm) is the height of the transmitter antenna correction factor on the environment; hr is height of antenna receiver above the ground in meter.

III. Result and Discussion

The research begins with measuring and determining AP location and RP location in the area to be evaluated. This study uses secondary data from the results of measurements that have been carried out in previous studies. The results of measurements of AP and RP positions are listed in Table I. Not only the location of the AP but also the RSSI of each AP at the remaining location of the studied location.

The 3-dimensional spatial location field is shown by the following parameters: X_Point is the latitude of the location (latitude), Y_Point is the location of longitude (longitude) and High is the height (elevation).

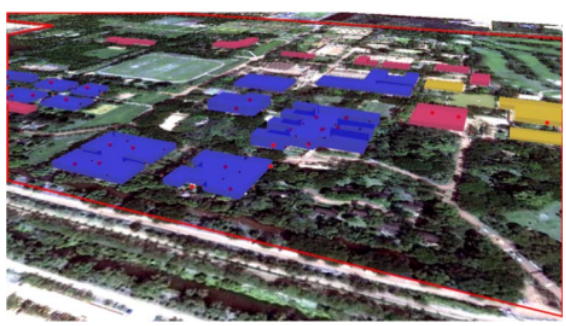

Fig. 3. Base map of the access point location in 3D

The basic map used in this study is presented in Fig. 3. The map illustrates the condition of the field where the test is in a box and three dimensions. The Distance parameter is the

TABLE I
AP POSITION COORDINATES (ACCESS POINT)

No	X Point	Y Point	AP_ID	Lo	Cha.	High
1	674332	1557042	AP-1	-48	1	3
2	674027	1557024	AP-2	-53	1	4
3	674237	1557021	AP-3	-53	1	4
4	674117	1556965	AP-4	-53	1	4
5	674117	1556931	AP-5	-48	1	4
6	674084	1556954	AP-6	-48	1	4
7	674102	1556920	AP-7	-48	1	4
8	674070	1556907	AP-8	-48	1	4
9	674070	1556861	AP-9	-53	1	5
10	674102	1556877	AP-10	-53	1	5
11	674086	1556818	AP-11	-53	1	5
12	674048	1556801	AP-12	-53	1	5
13	674072	1556766	AP-13	-48	1	5
14	674040	1556757	AP-14	-48	1	5
15	673941	1556804	AP-15	-48	1	4
16	673915	1556801	AP-16	-48	1	4
17	673935	1556763	AP-17	-48	1	4
18	673915	1556753	AP-18	-48	1	4
19	673750	1556946	AP-19	-53	1	4
20	673763	1556895	AP-20	-53	1	4
21	673684	1556946	AP-21	-53	1	4
22	673708	1556892	AP-22	-53	1	4
23	673685	1556879	AP-23	-48	1	4
24	673712	1556791	AP-24	-48	1	4
25	673638	1556780	AP-25	-48	1	4
26	673615	1556779	AP-26	-48	1	5
27	674070	1556940	AP-27	-53	1	5
28	673984	1556945	AP-28	-53	1	5
29	673985	1556981	AP-29	-53	1	5

three dimensional Euclidean distance calculated using (1).

Fig. 4. Optimum Location on a 3 Dimensional Map

The next stage consists of two stages. This stage is to do location optimization by using data that has been generated and evaluation of results by comparing the results of optimization between two-dimensional and three-dimensional spatial data. The results of spatial statistical analysis are presented in Fig. 5 and Fig. 6. Spatial statistical data results are used to determine the average distance between the location of the optimization results and the initial location.

TABLE II
RP (RECEIVED POINT) COORDINATE POSITIONS

No	X Point	Y Point	RP_ID
1	674358	1556961	RP_1
2	674304	1556973	RP_2
3	674255	1556984	RP_3
4	674248	1557052	RP_4
5	674195	1557071	RP_5
6	674176	1556989	RP_6
7	674142	1556974	RP_7
8	674138	1556947	RP_8
9	674109	1556949	RP_9
10	674101	1556933	RP_10
11	674109	1556908	RP_11
12	674074	1556938	RP_12
13	674079	1556901	RP_13
14	674080	1556870	RP_14
15	674102	1556856	RP_15
16	674087	1556838	RP_16
17	674054	1556830	RP_17
18	674062	1556802	RP_18
19	674086	1556781	RP_19
20	674055	1556784	RP_20
21	674002	1556802	RP_21
22	674000	1556769	RP_22
23	673968	1556818	RP_23
24	673970	1556785	RP_24
25	673954	1556751	RP_25
26	673920	1556769	RP_26
27	673921	1556820	RP_27
28	673881	1556850	RP_28
29	673795	1556797	RP_29
30	673688	1556775	RP_30
31	673662	1556774	RP_31
32	673641	1556818	RP_33
33	673658	1556889	RP_34
34	673728	1556889	RP_35
35	673786	1556895	RP_36
36	673781	1556939	RP_37
37	673729	1556945	RP_38
38	673723	1556911	RP_39
39	673660	1556924	RP_40

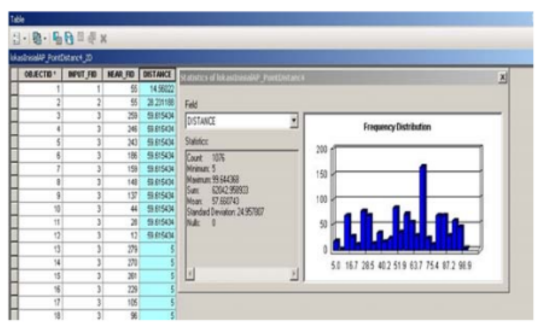

Fig. 5. Results of Spatial Statistical Analysis on 2 Dimensional Maps

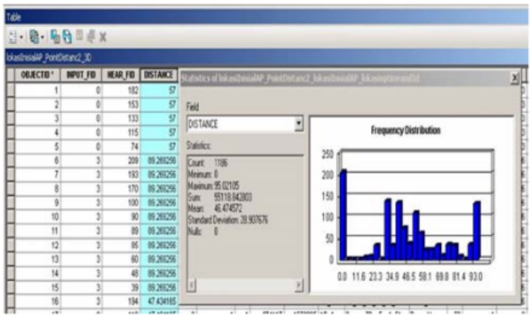

Fig. 6. Results of Spatial Statistical Analysis on 3 Dimensional Maps

Comparison of the results of location optimization using three dimensional and two dimensional optimization spatial data can be seen in Table III. These results when compared to the initial location of 29 access point points with an area of 270 thousand square meters, 3-dimensional optimization is better than 2-dimensional optimization. This is because the number of access points has decreased, whereas in 2-dimensional optimization has increased.

TABLE III
COMPARISON OF OPTIMIZATION RESULT

No	Optimization	Number of Access Point	Coverage Area (square meters)	Distance (m)	
				Mean	Std. Dev
1	2 Dimensional	40	270.840	57.6	24.9
2	3 Dimensional	17	198.791	46.4	28.9

Meanwhile, the coverage area in 2-dimensional optimization tends to be fixed, while in 3-dimensional optimization the area has decreased by around 40% from the initial coverage. However, this is not a problem when the average distance of 3-dimensional optimization results is smaller than the results of 2-dimensional optimization.

IV. Conclusion

A Utilization of spatial maps in planning the optimum location of access point placement on wireless networks has been implemented well. The results obtained show that there is an improvement in the plan between 3-dimensional optimization compared to 2-dimensional optimization. This is proven by the reduction in the number of access points and the average distance, even though the coverage area is smaller. However, reducing the number of access points will reduce implementation costs, in this case the cost of procuring access point devices. Further research is still needed on the optimization model that is used for example to consider the effect of the number of access points on the speed of access in the network being built.

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