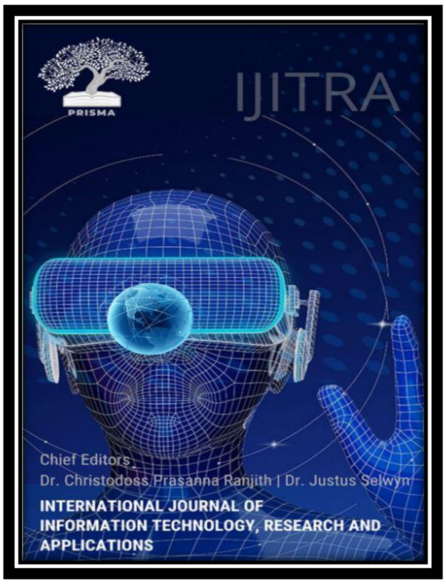

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Measurement and Optimisation of AP Placement and Channel Assignment in Wireless LAN

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ABSTRACT

Wireless local area network (WLAN) planning is a vital phase, and the design of WLAN needs to be planned well to deliver higher data rates, maximum coverage and best service for users. The prediction of how the system components will perform is a significant step when planning to design a digital system. Unlike other systems, quantifying the range of performance of WLAN systems can be difficult due to the impact of the indoor environment on RF signals. Therefore, the most significant deployment decisions are the ones that are related to the placement of access points (APs) and channel assignment. This project mainly focuses on optimising Wi-Fi systems in indoor environments. Therefore, a planning tool 'iBuildNet', along with a modified simulating annealing algorithm, are proposed to find the optimal AP placement and assign non-overlapped channels to them by considering load balancing among APs and channel interference for user traffic demand. The optimisation objectives are to reduce the number of APs and minimise the total pathloss caused by obstructions. It can be seen in the simulation results that the methods used led to obtaining the optimal AP positions and meeting the objectives.

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1. INTRODUCTION

WLAN deployment has been evolving rapidly, and it has been gaining importance in supporting data connectivity and user mobility, such as throughout a campus or building. In an indoor environment, WLAN is usually known as Wi-Fi and it operates in ISM bands, with the unlicensed industrial, scientific and medical at 2.4GHz and 5GHz based on IEEE 802.11 technology [3]. In designing WLAN services, the main issue is associated with determining the APs' locations to deliver the maximum received signal strength and reduce the total pathloss between the user and AP. Many factors can contribute to a decline in signal strength at the receiving end, such as obstructions and type of materials. This means that deriving the optimal placement of APs and channel assignment comprises a problem in deployment for a wireless local area network (WLAN).

For a typical indoor environment, and to show the effect of optimisation, the third floor of the Diamond building, which is located on the University of Sheffield campus, has been examined and simulated using the iBuildNet optimisation tool, and a sample area has been simulated and used as an example of algorithm utilisation as well as to perform compression with a planning tool. The Diamond building is a high-density educational environment. Based on that, the following objectives were formulated to deploy an optimal WLAN service using this realistic scenario:

- Estimate the minimum number of APs to provide the required coverage for the specific service area. The wireless propagation model has complex characteristics which make the task of obtaining the optimal number of APs challenging. In some practices, the number of APs is increased to achieve a large coverage, which leads to introducing the problem of over-deployment, as well as a waste regarding costs. Therefore, the estimation of the AP number for a target area is a critical practice for optimisation.

- Reduce the pathloss of the wireless signals by defining the optimal position of the APs. The wireless signals propagate in space, and so the indoor environment is subject to different effects like pathloss or attenuation. The pathloss can be influenced by the distance between the transmitter and receiver. Therefore, considering the accurate evaluation of pathloss caused by different obstacles is required in the deployment process.
- Find out the optimal channel assignment to minimise channel interference. The WLAN standards define a limited number of channels that can be used in variant user densities. Author [4] shows that 40% of around 80 APs used the same channel and shared the same RF resources. Consequently, the WLAN performance can be degraded significantly if neighbouring APs are assigned to the same channel. Therefore, to avoid problems like co-channel interference or adjacent channel interference, the APs within a specific range should be assigned to different non-overlapping channels for the 2.4GHz band frequency.
- Consideration of load balancing: channel utilisation of the AP can affect the overall performance of the wireless system [3]. Therefore, it is important to consider the load balancing between the connected users and APs during the deployment stage. This can be achieved by deciding on the best locations for APs to meet the user density demand and performance metrics at minimum cost.
- To enhance the performance of the WLAN service, re- configuration of APs and channels with collected feedback information about utilisation statics after deployment is required step. A new AP can be installed, or Aps' locations can be changed according to the traffic demand and user popularity. In addition, re-configuration of channel assignment might be required to avoid interference [3].

In this paper, an optimisation method to decide on the number and locations of APs and channel assignment is proposed by using a modified simulating annealing algorithm, along with iBuildNet, WLAN planning and a design tool, to meet the above objectives. The remainder of this paper is organised as follows: The main performance factors and WLAN optimisation concerns are discussed in section II and III. The methodology is introduced in section IV, while the results and evaluation are presented in section V. Finally, the discussion, conclusion and future work are set out in section VI, VII and VIII respectively.

2. ECONOMIC, LEGAL, SOCIAL, ETHICAL AND ENVIRONMENTAL CONTEXT

Despite wireless devices being everywhere, such as in homes, hospitals, airports, offices, schools, and widely used, some people still feel uncertain about whether wireless radiation and energy is harmful or not. Most studies indicate that the exposure to the Wi-Fi signals is not harmful to the human body. The maximum power the Wi-Fi router can radiate cannot exceed 100mW at the 2.4 GHz frequency band, and since the wireless signal is broadcast over a long distance, the energy is reduced dramatically when the distance is increased [1]. The Wi-Fi is a radio wave which is a part of the electronic spectrum that consists of many other broad range frequencies. However, some radiation from this spectrum can be dangerous, such as gamma rays and x-rays. These types of waves are known as ionizing radiation, and they emit high energy that is able to damage human DNA. On the other hand, Wi-Fi waves are considered to be non-ionizing waves with low energy so they tend to be safe. Therefore, to protect the human body from higher frequency exposure, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) has limited the energy level that the human body can be exposed to in terms of the Specific Absorption Rate (SAR).

3. RELATED PERFORMANCE FACTORS AND OPTIMISATION CONCERNS

In deploying and planning such as for a WLAN, it is good practice to consider the essential factors that affect the system's performance. In the following section, the main factors will be considered.

3.1 Access Points Placement

Access points tend to form the main part of the WLAN system because they provide pervasive connectivity. Therefore, in a high-density indoor environment, controlling where and how the APs should be optimally placed is a tricky task for wireless network designers. Some organisations support the growth of user density by installing more APs, which is not an optimal solution for this issue. For indoor areas, there are various options for deploying APs, but wall and ceiling mounted are the most commonly used plans. The ceiling mounted plan can be used when the height between the AP and the ground is less than 25 feet, because this strategy brings more benefits like clear direct signals path for users. In addition, other factors might influence the placement of APs strategy, such as AP transmission power, antenna gain and type, and the number of connected users [5].

3.2 Channel Assignment

Typically, the total spectrum for wireless networks is divided into channels where each has a specific bandwidth which is utilised by a limited number of users. For instance, the 2.4 GHz carrier frequency, which supports different protocols like 802.11n, is segmented into 11 channels. However, since a substantial bandwidth is used by each channel, there is a significant overlap among these 11 channels, whereas only three of them are non-overlapping 1,6,11. As a result, this leads to problems like co-channel interference needing to be raised when many devices are sending traffic on the same channel. $i=1$

In WLAN design, finding an optimal solution for the channel assignment problem (CAP) seems to be another challenging optimisation issue, since CAP is an NP-problem. Many researchers have proposed different approaches to characterise this issue, and have considered different concerns related to interference and channel utilisation issues. For example, integer linear programming (ILP) and heuristic algorithms are proposed in [2] and graph colouring problem are proposed in [3]. The graph colouring problem in its general form is similar to countries map colouring where two adjacent countries cannot have the same colour. As illustrated in Figure 1, APs are represented as nods, where each needs to be assigned to a channel. The coverage overlaps between these APs are donated by edges, and each edge is associated with weight, which indicates the distance in square meters. In this way, the node will be coloured to minimise the sum of the edge's weight. This corresponds to assigning a channel to the AP in a way that minimises the co-channel coverage overlap. Therefore, to minimise the issue of reducing the available spectrum and interference, which degrades the performance, it is recommended practice to assign each AP within a specific interference range with non-overlapped channels (1,6 and 11) by employing the graph colouring model.

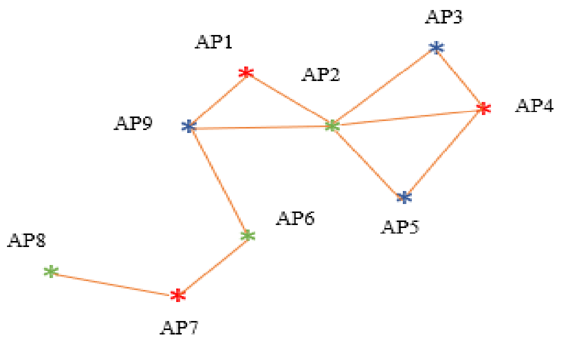

Figure 1: Channel Assignment Colour Graph

3.3 Transmission Power

Each AP has limited transmission power, which refers to the amount of energy or power input into the transmitted signal to a user's device. The range value of transmission power is between 2 dBm as a minimum, and 23dBm as a maximum, but for the indoor environment, the typical range is from 14dBm to 18dBm. The Transmit Power Control approached (TPC) is aimed at reducing the limit of the AP's transmitting power while keeping the throughput and data loss rate within the requirement range. TCP supports improving the wireless network capacity since the interference is minimised. Some studies have shown that a reduction in the AP's transmitted power leads to an improvement of about 46% of the network's overall throughput quality [12]. If we assume that the AP has no limit in its transmit power, this will as a result enhance the level of the signal strength received, but at the same time it will negatively impact on the AP's performance. Also, enhancement of the network's capacity can be achieved by optimising power using the following optimisation equation where P_{ti} indicates the total transmitted power of N network APs and their indexes.

$$power\ optimisation = Min \sum_{i=1}^{N} P_{ti} \quad (1)$$

3.4 Coverage

The process of providing optimal coverage for an intended service area is a complex task. It basically involves processes to improve the quality of the received signal level while reducing the path loss impact in the service area. Coverage optimisation is strongly related to the optimal number of APs and their placement, where total path loss PL between APs and connected users can be reduced, which consequently improves the coverage range. The typical range of good received signal strength is between -30dB and -70dB, and this is measured in terms of RSSI [4].

3.5 Capacity

Capacity is a subset of the network capability and is defined as the maximum reliable data rate with low error probability that can be delivered by the wireless channel. The fundamental theorem for a wireless link is defined by Shannon's formula, which defines the data rate limit as $C = B\ log_2\ (1 + SNR)$. The B bandwidth of a wireless channel is limited, and several factors can affect the aggregate bandwidth available per user in a high density indoor environment. These factors include speed, radio type, frequency band, user density, SNR and so on. The main factor here is SNR, signal level in dBm, and this refers to the power ratio between the signal and noise in a wireless communication system. For example, if the user receives a signal of -80 dBm and the measured noise floor is - 90dBm then the SNR is 10dB. SNR is the best way to judge signal quality since high a SNR indicates good system performance [13].

3.6 Pathloss

The prediction of the pathloss or path attenuation of the signals is based on the MWF indoor wireless signal propagation model. This model refers to Multi-wall-and-Floor and it is used to estimate the attenuation and pathloss inside closed area. To calculate the pathloss, the distance between the transmitter and receiver, as well as the number of obstacles and their thickness that the signal passes through, like doors, wall and windows, need to be considered. In an indoor propagation environment, the signal propagates in the air under the scenarios of Non- Line-of-Sight (NLOS), which arises from the obstruction action. The attenuation of the signal is represented by the difference between P_t the transmitted signal power, and P_r the received signal power. Therefore, the data measurement of the floor and partition loss can be added to an empirical and analytical pathloss model $PL(d)$ [6] as follows:

$$P_r\ dBm = P_t\ dBm - PL(d) - \sum_{i=1}^{N_f} FAF_i - \sum_{i=1}^{N_p} PAF_i \quad (2)$$

Where the attenuation factors for the ith partition and floor signal passes through are represented by PAF_i and FAF_i whereas N_p and N_f represent the partitions and floor number the signal passes through. The floor number is ignored here since one floor is used in this case. Added to this, the signal's attenuation level is affected by other factors like transmission power, antenna gain, and the frequency band the wireless system operates on.

4. METHODOLOGY

To meet the objectives, a planning tool like iBuildnet, along with a modified Simulating Annealing tool in MATLAB, have been deployed, as discussed in the following sections.

4.1 iBuildNet Simulation

iBuildNet is a software tool developed by Ranplan ltd, which can be used for both designing and optimising the indoor and outdoor wireless communication system. Multiple intelligence optimisation modules and system technologies are integrated within it. In this project, iBuildNet has been used to model, predict and optimise the Wi-Fi system by considering the APs' placement and channel assignment optimisation. To model the building structure, the floor plan, which was provided by the CICS department, was imported automatically from AutoCAD. Using this feature helped to model the floor details, including different building elements and obstruction materials like walls, doors and windows, which have been defined based on the material library. However, using the floor plan as a background image was necessary to draw some floor details manually, and the floor plan in 3D modelling is shown in Figure 2.

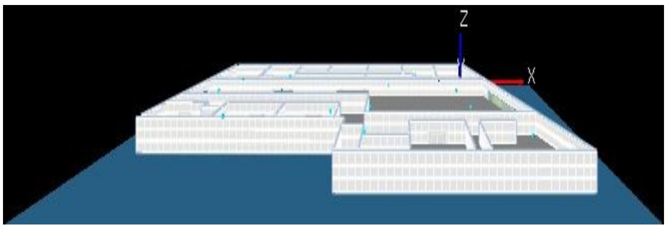

Figure 2: The 3D floor Plan of Diamond's Third Floor

Before moving on to model the network system, a site survey was conducted to fully understand the floor structure and find the number of access points and their locations. Table 1 shows a description of the input parameters used to build the Wi-Fi network system for the third floor. It has been found that the current Wi-Fi implemented a total of fourteen access points in the Diamond building, and the network used is “Eduroam” only, so interference with other wireless systems has not been considered in this case. Although the current system uses 802.11 ac at 5 GHz, in this project the 802.11n protocol at 2.4GHz has been used for various reasons. The 802.11n, along with 802.11g, was fully deployed in iBuildnet, and to perform the optimisation module it was necessary to use only one AP type. Added to this, the lower the frequency of transmission, the better the signal will travel through objects [9], which means 2.4GHz performs better than 5GHz. The iBuildNet provides powerful data analysis and collecting. The model performance was estimated based on the simulation of the performance parameters like RSSI, SINR, path loss, throughput, and so on.

Table 1: iBuildNet Wi-fi system elements

Coverage Target	Coverage percentage 90%
	RSSI Threshold -80 dBm
	Pathloss Threshold 80 dB
Number of non-overlapping channels	3 channels: 20MHz
Protocols	802.11n- @2.4GHz
Transmission power	17 dBm
APs number	13APs

4.2 Simulating Annealing Simulation

The WLAN services design problem for different user densities involved obtaining the optimal APs’ location with non-overlapped channels, as well as enhancing the maximised coverage area. A similar project was studied in [3] to comprehend how to implement an algorithm for WLAN planning. In the following sub-sections, the SA optimisation process and the formulation of the problem, along with a set of assumptions made, will be described:

4.2.1 SA Algorithm Process

SA algorithm is one of the popular local search heuristic algorithms that have been proposed to find an optimal solution for NP-complete and the continued optimisation problem in wireless networks. It has been applied here to find a global minimum numerical solution. The main concept came from the physical process of annealing, where a slow cooling procedure is used to convert liquid metallic objects back to a strong solid state. The problem can then be formulated by defining the proposed solution with slight inner energy. Since the process of SA is a reiterating process toward the optimal point, the probability P of accepting a bad result at the start is high, and it is reduced when the current temperature T factor falls by a certain q cooling rate [30]. The probability of acceptance is calculated as the difference in value $\Delta\boldsymbol{E}$ between the current configuration C and new configuration N, where C will be replaced by N in case N’s value is large than C’s value, as shown in the Metropolis rule [2].

$$P(accept\ N\ as\ next\ solution) = \begin{cases} 1, & \Delta E < 0 \\ \exp(-\frac{\Delta E}{\mathrm{T}}), & \Delta E \geq 0 \end{cases} \quad (3)$$

$$where\ \Delta E = C - N$$

For the optimisation problem, if the difference between the current configuration and the new one $\Delta\boldsymbol{E}$ is positive, this means the change is decent and the new configuration set to the current one, while the old one will be discarded. Otherwise, if the difference is negative, the probability of accepting the new configuration is computed according to the exponential function exp(-x) as shown in Figure 3. This probability depends on the $\Delta\boldsymbol{E}$ and the initial temperature. At the starting of the SA process this probability tend to be very high but reduces when the T is reduced. Thus, T is a decreasing function which is decreased to the minimum temperature according to the cooling rate. This means it is possible for exp(-x) to be a random value between 1 and 0.

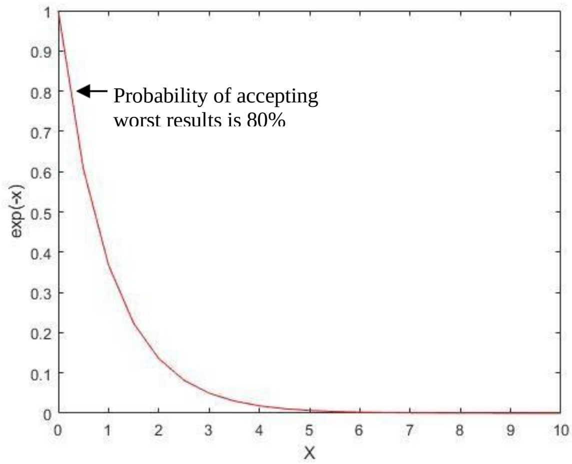

Figure 3: The exponential function

For the target area optimisation, the steps of the SA process are described in Figure 4. The program starts by appropriately defining SA's parameters, which include the starting and stopping temperatures, and the inner iteration time needed at each temperature and cooling rate. The environment parameters, configuration, which includes different obstructions materials like walls and doors, are represented by a two-dimensional figure and studied based on the different functions and structure. In the target environment, similar material obstructions are grouped together and donated by different colours and thicknesses of lines. The entire environment, with its APs, user demand points and obstructions, is represented by a set of matrixes in which each has 2D coordinate indexes that define their positions within the bounded area. The program will arbitrarily select APs from a set of nominee access point matrixes and assign a user demand point for each AP. The selection here depends on the calculation of the total path loss between each selected AP and user. Then, a comparison between the current result and the new result is conducted. The best results with low values of path loss will be stored in another matrix. This process will be repeated by increasing the AP number whenever the current number cannot meet the conditions. The non-overlapped channel will be assigned to each AP when the program finds the global minimum of the total path loss and meets the users' load balance requirements.

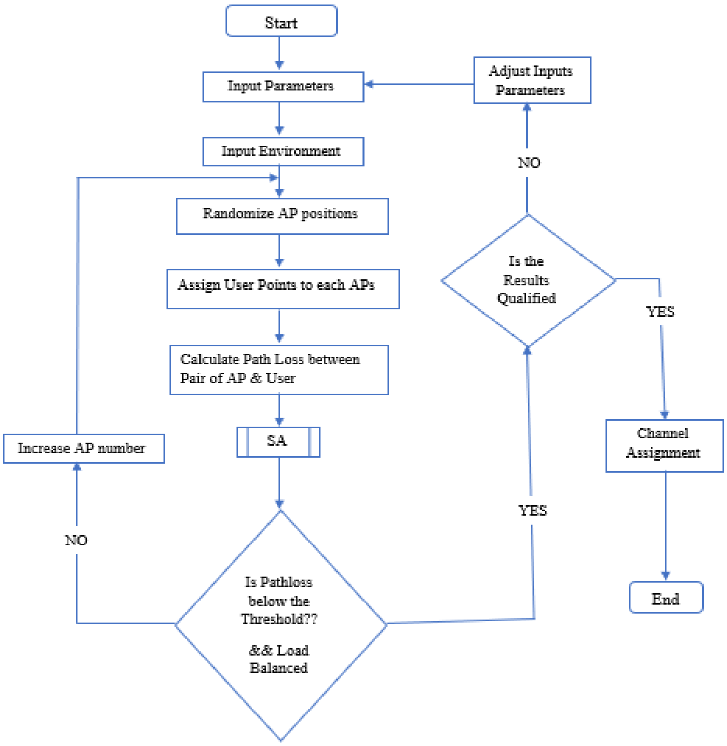

Figure 4: The Program flow

4.2.2 Problem Formulation and Definition

Prior to the problem formulation, a set of constants and variables were defined as follows:

- *AP_num:* refers to the required number of APs
- *nominee_AP:* group of nominee APs where the coordinates of *AP_num* for the target area are stored in this matrix.
- *selec_AP:* A set of APs that are assigned to user points, and the positions of the APs are randomly selected and stored in this matrix
- *user_demand:* A set of user demand points in the WLAN service area where the amount of user popularity is measured. It was assumed that the user demand points are distributed uniformly and located at the centre of blocks, blocks_num, which represent the coverage area.
- *PL_threshold:* This is the resulting value in decibel from the subtraction of each AP, and the lowest received signal strength desired by each user.
- *CN:* Available set of channels
- *D:* The lowest distance in the neighbouring area between two channels where each AP is assigned to a non- overlapping channel.
- B: A binary decision number: 0 is the loads between APs that are not considered, otherwise 1. This should not exceed the number of users each AP point can serve.
- C: A decision variable is used to decide if the channel is assigned to a particular AP. If there are AP_num and CN channels, then let X_{ji} a binary decision for channel assignment where j = 1…. AP_num, i=1…..CN. Then 1, $if\ AP\ j\ is\ assigned\ to\ channel\ i$

$$X_{ji} = \{0, \qquad Otherwise$$

The optimisation problem is defined according to the optimisation target or cost function, which is a combination of functions that represent the system state and inputs. In this case, it represents the AP placement and channel assignment problem to find the optimal coverage area by using a minimal number of APs and optimal positions.

1. Minimize Number of APs

The AP specification and user density, which is represented by the data rate required per user, can define the initial *AP_num* required to provide coverage in the target service area. The AP_num points are randomly picked from *nominee_AP* matrix and the possibility tested.

Minimize AP_num
Subject to
B=1, PLij <PL_threshold
Where i € user_demand and j € selec_AP

2. Minimise the Total Path loss

According to different constrains, the SA algorithm can be modified, and if there are any values of RSS lower than the path loss threshold, they will be discarded. Based on the MWF model, the pathloss between pairs of APs and users can be calculated. The *obst_num* function is used to compute the number of obstructions the propagation signals cross through.

Minimize ∑∑ PLij
Subject to
B=1, PLij <PL_threshold
Where i € user_demand and j € selec_AP

5. RESULTS & EVALUATION

5.1 Environment Initialisation & Prediction data in iBuildNet

The simulated floor area map has to be loaded at the beginning of the modelling process into the iBuildNet tool. A .dwg image file format was used to determine the model floor. The third floor, with a coverage area of around 3141 square meters, consists of three small study rooms- one big closed silent room, one laboratory and two main open study areas, as shown in Figure 5. This model was simplified for accurate prediction and to reduce the calculation load. The implementation of the wireless system was deployed according to the current deployment system on the third floor.

However, a number of re-configurations were carried out to improve the perfection performance. There are a total of 14 access points distributed over the third floor and they were placed on the ceiling and on the wall. The process started with the same specification of the current model in terms of AP numbers and their locations, while the floor height was kept at a default of 3m. The number of predictions and calculations have been considered to analyse the performance factor parameters including RSSI, pathloss, best server and SINR. About eight re-configurations were conducted by changing the locations of three APs in the current model, since their percentage server was low (between 3.9% and 4.2%). Two of them were located on the ceiling close to the lift door in narrow places, while the third one was mounted on the wall close to the open study area as denoted by red stars in Figure 5. It has been found that moving the APs to the corridors and away from the lift doors led to their best server prediction, which increased between 4.9% and 6.2%. These re- configurations were required to keep the loads among all APs identical to some extent. However, the best server for the third AP did not change even after moving it a little. It was attempted to increase its transmission power by 3dBm, but this increased its server by only 1% and at the same time degraded the server of the neighbouring AP by 0.6%. Therefore, it was removed, and the best server estimated, and it was found that the overall coverage was not affected much.

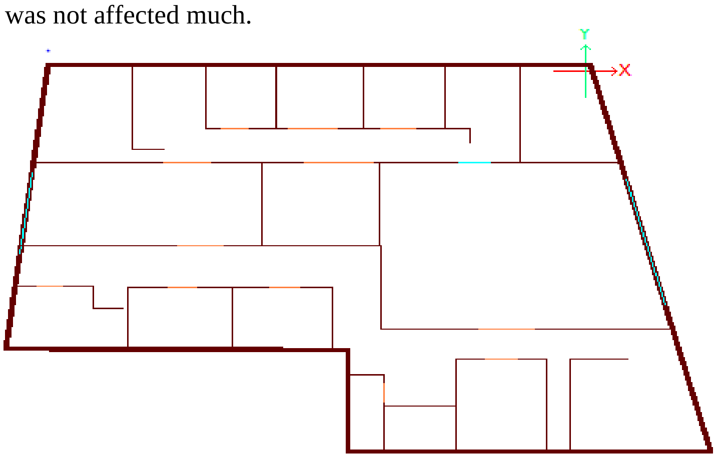

Figure 5: The Modelling Area of Third

Also, a slight movement for two APs was carried out by moving them away from the glass wall, and it was observed that their coverage improved by 0.9%. The final best configuration for 13 APs is presented in Figure 6.

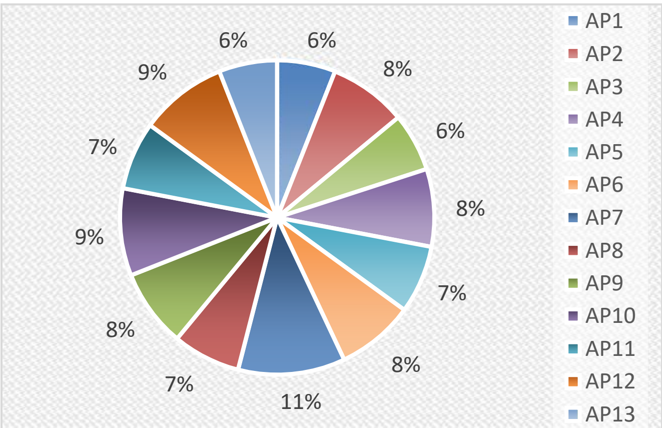

Figure 6:The APs Proportion Distribution

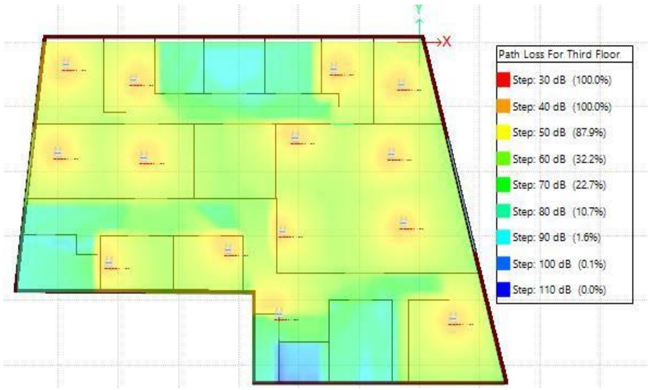

Figure7:Pathloss prediction Before re-configuration

In terms of the path loss calculation for the built module, Figure 7 and Figure 8 illustrate the prediction results. As illustrated in Figure 8, the best prediction after eight re- configurations shows 5.5% of area involvement with 80dB, whereas this percentage reached up to 10.7% for the first configuration, as shown in Figure 7.

Figure 8: Pathloss Prediction after re-configurations

The tool also provided predictions for received signal strength for the simulated model. The RSSI prediction indicates that 90.5% of the area is covered with a good qualified received signal where this coverage was required for web applications for example. However, 9.5% of the area is not covered well by the qualified signal, as illustrated in Figure 9. The overall results of the RSSI distribution area indicates that the RSSI is beyond -80dBm, which is the threshold target level.

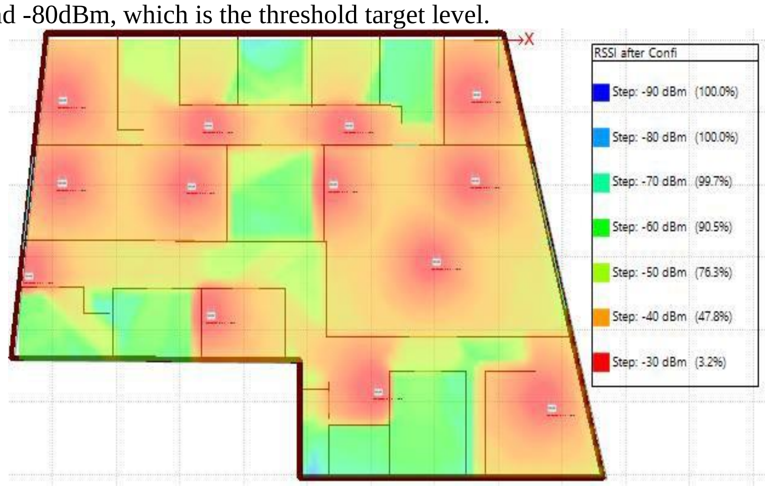

Figure 9:The RSSI Distribution of Third Floor

The signal to- interference plus noise ration degree (SINR) was also calculated by iBuildNet, as shown in Figure 10. The distribution range of the SINR indicates that all results are beyond 0dB, where 30dB covered around 63% of the floor area. However, in some areas this reduced to 20dB and 10dB of the SINR level. Since the 13APs were assigned to only three non-overlapping channels, co-channel interference has been considered in this case. Therefore, the channel assignment arrangement can improve the signal degradation caused by the channel interference. The overall area occupied high SINR which led to more throughput level in the red area, which means the arrangement of the access points is acceptable.

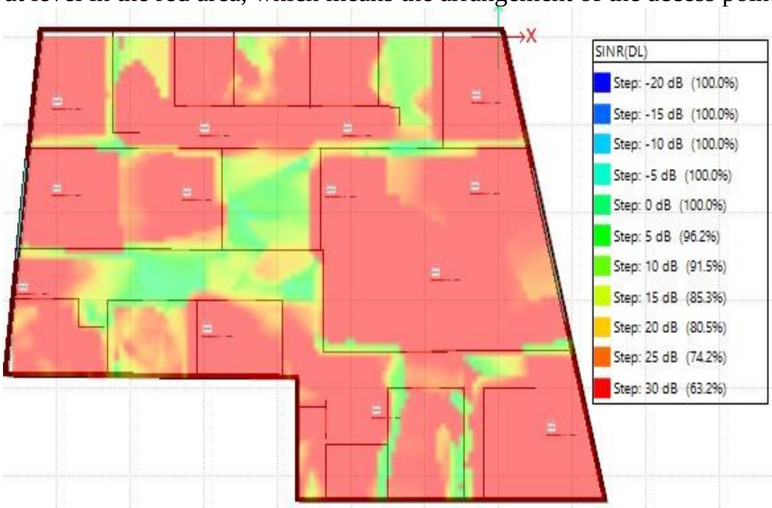

Figure 10: The SINR Distribution of the Third Floor

5.2 The Program Test & Simulation Results Evaluation

After developing a simulating annealing program in MATLAB, this was tested and compared with the results simulated by the prediction tool iBuildNet. Therefore, a sample area, composed of a number of small study rooms from the third floor, was used to test the algorithm. Then the same model for the sample area was built in the iBuildNet tool. Using the sample area causes the prediction to find the optimal locations of APs and makes the program more suitable in terms of testing. The sample area which was developed in MATLAB, as shown in Figure 11, is composed of the same obstructions as the target study rooms on the Diamond floor with an area size of 20m and 15m as the length and width of the area. The pathloss caused by the obstruction materials composed in the sample room is defined as input parameters. For example, 7.0 dB, 4.4 dB and 1.6 dB for heavy walls, light walls and doors respectively, and the impact of the outer wall has been neglected for simplification. The rest of the input data parameters were similar, as shown in Table 1, since this data was used to examine both the Diamond floor and sample area.

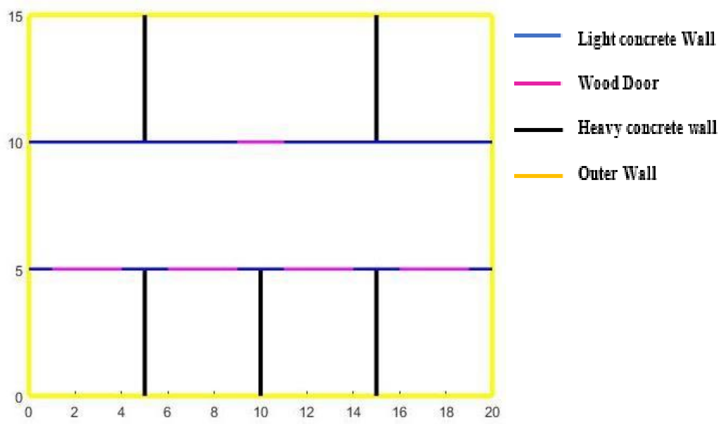

Figure 11: The Sample Area Model

The results show that to achieve the pathloss threshold state and provide full coverage, two APs only were required. Therefore, in this case, the interference caused by co-channel nor adjacent channel has not been considered. Channel 1 and 11 were assigned to two of access points. A total of 300 points form the user demand points, and demand is estimated in a square unit of $1\times1m^2$.The algorithm was used to find the optimal locations of APs eight times, and the results of SA are illustrated in Table 2. The different SA parameters were set, for example the starting temperature was set to 4490, and the probability to accept the worst results was set to 80%; while the end temperatures were set to different values to observe the state of converging points. It has been observed that the pathloss calculations were almost similar at every time of testing. The program found the optimal location of two APs with minimum total pathloss at test number 5. The AP coordinates were at (5.7,8.7) and (15.8,8.7) with almost equal AP load, which is plotted as red crosses in Figure 12. The set of AP coordinates from all tests are shown as black crosses in Figure 12.

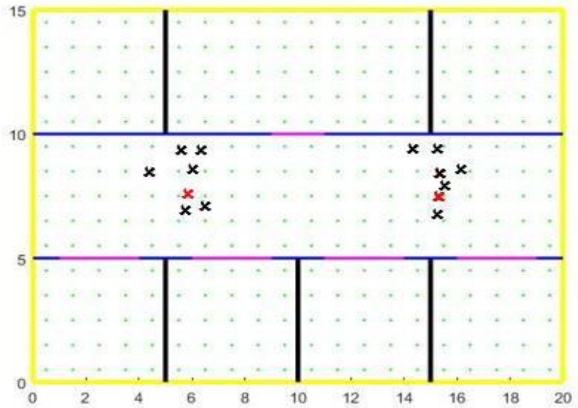

Figure 12: The Result Coordinates of APs

These results indicate that the placement of APs was all round at the optimal position, as defined by the program. Moreover, the results in Table 2 show that the differences in pathloss value became smaller when the time of inner iteration increased. This time depends on two main factors- the stopping temperature and cooling rate. Consequently, it led to maximising the probability of finding the optimal solution. During the time range from zero to 35 there was no noticeable convergence of the optimisation process, but shortly after the 35th iteration it became obvious that there was convergence, as indicated in Figure 13. Therefore, the algorithm can produce the results which meet the requirements and achieve the objectives.

Table 2: The SA Test Results

Sim. #	Sim.Time [sec]	Selected AP's Coordinates	End T	Inner Iteration	Total PL (dB)	AP req #
1	291	6.1,9.2;15,9.1	6	20	16627	2
2	321	6,9.2;16.2,9.2	6	20	16613	2
3	242	5.8,8.8;15,8.8	6	40	16655	2
4	490	5.6,10;15.7,9.8	6	50	16638	2
5	569	5.7,8.7;15.8,8.7	60	50	16605	2
6	586	6,9.8;15,9.8	60	50	16608	2
7	486	6,9.5;14,9.5	600	50	16611	2
8	451	5.7,9;14,9	600	50	16607	2
Avg.	429.5				16620.5	

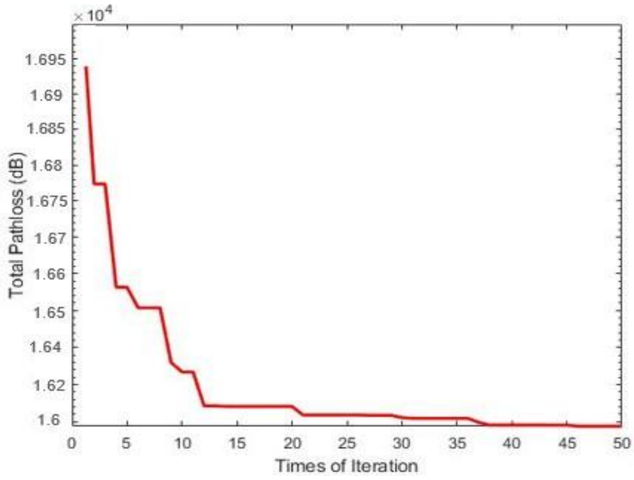

Figure 13:The Optimisation Process of The Optimal Result

On the other hand, the identical sample area was built in iBuildNet tool, and the optimal solution found from the program test (test number 5) was simulated to make a comparison. A number of predictions were carried out, including the pathloss, RSSI distribution, best server and SINR distribution. As illustrated in Figure 14, the pathloss calculations for the simulated model of the sample area indicates that none of the values exceed the threshold of 80dB.

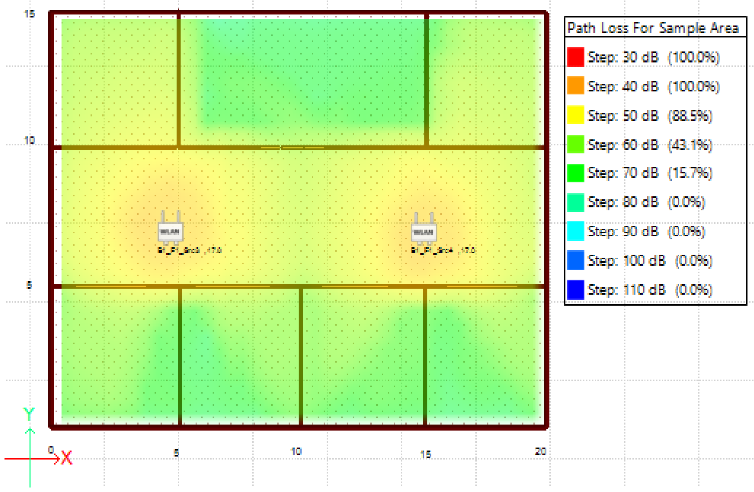

Figure 14: The Pathloss of the Optimal Result

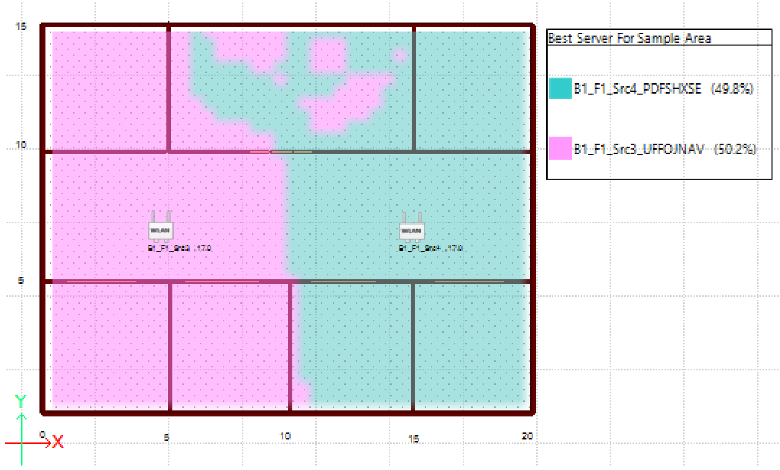

Figure 15:The Best Server for The Optimal Result

The serving areas covered by both APs is shown in Figure 15. It is clear that 50.2% of the area is covered by the AP at coordinates (5.7,8.7) while 49.8% of the area is covered by AP at coordinates (15.8,8.7). Figure 16 shows the RSSI distribution. It is clear that 99.8 percent of the area is predicted to receive a signal strength of over 60dBm. This is related to the absence of interference, since only two APs are used where two different non-overlapped channels are used (11 and 1). Finally, the SINR distribution obtained shows that 100% of the area is covered by qualified signal and high throughput, as shown in Figure 17. These results are similar to the ones delivered by the program, which means that the algorithm can derive the optimal solution.

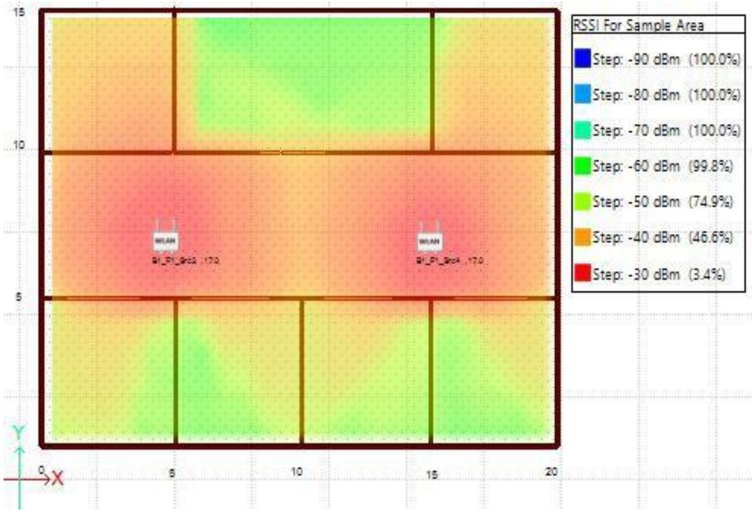

Figure 16: The RSSI Distribution

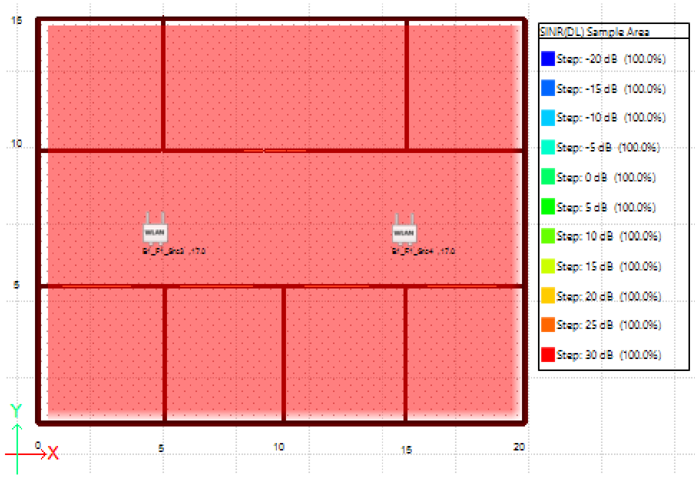

Figure 17:SINR Distribution for the optimal Result

6. DISCUSSION

The main objective of this project was to obtain the optimal WLAN system deployment in the indoor environment by using the iBuildNet planning tool, and simulating annealing to optimise the deployment model. The iBuildNet tool was used to model the target service area and a set of predictions for the number of Wi-Fi optimisation factors were calculated to evaluate the performance of the system. These calculations covered the SINR distribution, pathloss, RSSI distribution, and the best server. The Diamond building was selected to be the realistic scenario to illustrate the impact of wireless system planning. It has been proven that reducing the number of APs to 13 still provides the required coverage service in the given area. The performance target in terms of coverage percentage was 90%, and the result obtained from the iBuildNet indicates that 90.5% of the overall area was covered with a very good qualified received signal. Moreover, the RSSI distribution result shows that the threshold target of -80dBm was achieved because all the results were beyond this level. The SINR calculation covered 63% of the floor area with 30dB, while in some areas this level reduced to 20dB due to interference. The pathloss threshold was stated to be 80dB and the prediction result indicates that only 5.5% of the service area has 80dB as the value of the signal attenuation.

In terms of the SA, the optimisation target has been described based on the cost function. Thus, the SA was developed in MATLAB and a set of functions and parameters were defined to describe the optimisation problem. The sample area was used to examine the capability of the program and meet the objectives statistically. To make a comparison between the capability of both iBuildNet and SA, the sample area model was constructed in iBuildNet and tested in terms of the performance factors stated above. The main probability of simulating annealing is the accepting of bad results at the beginning, and this probability is set to a certain value, for example 0.8, which helps to compute the initial temperature.

After several rounds of testing and analysation, the results obtained from the program indicated that the developed program was able to find the optimal solution for the given optimisation problem. The results obtained from the program and tool are similar to some extent. For the sample area, two APs were enough to provide full coverage where both have almost the same server load. The total pathloss obtained did not exceed the threshold level with an average of 16620.5dB. A hundred percent of the throughput was provided for the sample area. Overall, the Wi-Fi optimisation model was achieved by applying the SA algorithm, and guided by the iBuildNet planning tool.

7. CONCLUSIONS

In this paper, the issue of finding the optimal position of APs for an indoor Wi-Fi system, along with assigning a channel, has been investigated. The number of deployed APs was kept to a minimum and as low as possible, and the total pathloss between pairs of APs and users was reduced to meet the threshold level. For the given problem, a simulating annealing-based method was proposed to find a good solution for the optimal positions of APs and channel assignment. The pathloss was calculated based on the MWF model, and the floor number was ignored here. The load balancing was considered as well. Minimisation of the amount of required APs can lead to reducing the deployment cost and operation expenses. Despite the existence of some limitations, the deployment model indicates a good expectation in terms of system performance.

There are several researchers who have studied the issue of AP placement and channel assignment in WLAN. In [10], a similar problem was studied based on simulating annealing and the Wi-Fi system's performance was investigated in a real environment scenario. Also, in [3], the issue was studied by formulating the problem using optimal integer linear programming. This problem was conducted in [11] as well by using mathematical programming.

8. FUTURE WORK

During this project, some limitations were raised from using iBuildNet, as well as from the proposed algorithm. Firstly, the floor model was simplified to reduce the number of complicated calculations and predications, while in a real scenario the indoor model was packed with a complex environment of obstruction elements. In the future, building similar complicated elements could increase the computation load, and this would provide a more accurate prediction of system performance. The model constructed is based on a 2D model instead of a 3D model; therefore, the APs height has been considered to be the same, while in reality this height may differ depending on the deployment conditions of the celling or the wall. Also, the impact of the outer wall on the propagated signals has not been considered.

Secondly, the current model of the third floor was not modelled and simulated in iBuildNet due to the limitation of the information required from the CICS department. Also, the number of service types including RSSI, SINR and so on, should be considered and simulated in future work using iBuildNet.

Thirdly, the third floor of the Diamond building could be analysed based on the program. This can be achieved by changing the input structures based on the target area. In this case, the time took by the program to perform calculations can be increased to become several hours instead of minutes.

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