Wireless Optimization Algorithm for Multi-floor AP deployment using binary particle swarm optimization (BPSO)

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Abstract: Optimizing the Access Point (AP) deployment is of great importance in wireless applications owing the requirement to provide efficient and cost-effective communication. Highly targeted by many researchers and academic industries, Quality of Service (QOS) is an important primary parameter and objective in mind along with AP placement and overall publishing cost. This study proposes and investigates a multi-level optimization algorithm based on Binary Particle Swarm Optimization (BPSO). It aims to an optimal multi-floor AP placement with effective coverage that makes it more capable of supporting QOS and cost effectiveness. Five pairs (coverage, AP placement) of weights, signal thresholds, and Received Signal Strength (RSS) measurements simulated with Wireless Insite (WI) software were considered to work in conjunction with the proposed optimization algorithm. Additionally, the AP deployment results obtained from WI and optimization will be compared with the simulation results of the current AP diffusion within the target building. These comparisons will be based on the most important RSS parameters, path loss (PL) and interference. The comparison results showed a significant improvement in RSS and path loss values of (-11.55) dBm and (11.55) dBm. While the interferences are decreased by (7.87%). Furthermore, the result of performance analysis showed that the proposed algorithm outperforms the current AP deployment by 39.23% in coverage ratio.

1. Introduction

Communication based wireless technology has generally been developed and gained consideration, for studying the proliferation properties of wireless signals within the indoor and outdoor environment. After that, the development of wireless technology gained some preferences, for example, cost-effectiveness, adaptability, speed, and accessibility [1, 2]. Henceforward, many wireless innovations have been used in internal scenarios, to accomplish correspondence purposes, that can provide a wide range of applications for customer versatility, ease of setup, and peripheral device reconfiguration [3].

Network planning is not an easy process. It requires scheduling and studying the factors that affect RSS, then calculating the network cost [4]. Sometimes the network planner relies on a traditional manual method to predict the best access point number, and followed by a site survey to modify and configure network parameters [5, 6]. They may run a site survey multiple times after the initial deployment until they find the model sites. For the indoor environment, paths and their number are difficult to define due to radio signal propagation mechanisms such as reflection, diffraction and scattering [7]. This makes the
behavior of the scattered signal unpredictable and the receiving power (Rx) receives paths with different power strengths [8, 9]. The main factors that affect the signal propagation are frequency, building structure, present furniture material and size Line-of-Sight (LOS) and Non Line-of-Sight (NLOS) propagations, the distance between AP, or transmitter power (Tx) and the Rx and the number of APs and their position in term of interference between signals transmitted by the neighbors APs [10, 11]. Implementing adequate network arrangement planning has an alternative method of optimizing various network characteristics [12]. These features may include improvements in the coverage area, higher security, lower latency, higher transfer speed, and lower energy use [13, 14]. The main factor for adequate planning was AP mode enhancement devices, as it had a major impact on improving coverage, operation and management of networks more than developing the behavior of wireless network characteristics [15]. It should be noted that the location of the AP device in a wireless local area network (WLAN) has improved a wide range of purposes, for example, finding unwieldy AP devices and evaluating the propagation characteristics of the wireless signal [16]. Based internal communication faces many difficulties due to the complex nature of these environments.

These difficulties can be summed up in the true effects of various building materials such as wall thickness for signal infiltration into the building. Also, the impacts of different interference sources which are gained by the misconfiguration of AP placement and the utilized channel [16]. Moreover, multipath propagation (MP) depicts the method of receiving duplicate copies of the first signal, that is traded during different time delay times caused by the reflection, diffraction and diffusion of these signals [17]. These MP signals can be easily interrupted by moving objects, obstacles, furniture, and the body of the device holder [18]. Thus, there are requirements for productive progress measures to optimize the AP placement, and to cover the entire subject area with a base number of AP devices to control both expenditures and interference and reduce the presence of dead zones.

2. Related Work

Several academic researchers have proposed several works for the purpose of improving AP placement in indoor cases, and by using various optimization techniques. For example: In [19] a new global optimization algorithm (AGOP) was used, to produce a complete indoor environment coverage and compute the PL at Rx’s with different receiver sensitivity thresholds, and different transmission capabilities. The results obtained indicate that the above-described model can be used to find the optimal number and position of APs while covering all parts of the design area. It is noted that the dimensions of the building, the number of users and their locations, the value of the transmitted power and the threshold of the receiver have an effect on the number and position of the access points needed to cover an area.

In [20] the authors optimized the AP position by simulating and proposing a method using a genetic algorithm (GA) and measuring RSS at different Rx nodes. The proposed method aims to provide an infrastructure, to improve the quality of the internal navigation system and increase the accuracy of internal localization. However, this approach has the disadvantage of ignoring the effects of obstructions and walls, which means that any two buildings of the same size will be in the same AP position regardless of different building materials and structure.

Also, in [21], a range of frequencies was approved to verify the effect on the performance of the Wi-Fi system in an indoor environment. The author used the 3D SBR method to simulate the characteristic LOS and NLOS at 26 GHz, 28 GHz and 60 GHz and study the effects of these frequency-dependent electrical properties of building materials. The performance was evaluated in terms of receiving power, PL and Delay-Spread. The author concluded that the nature of building materials, especially concrete walls at each LOS and NLOS frequency is much affected the radio signal. Additionally, with high frequency, PL will increase, while the received power and the Delay-Spread will inevitably deteriorate.
In [22], the authors used particle swarm optimization (PSO) based Adaptive Neural Fuzzy Inference System (ANFIS) to determine the strength of the Wi-Fi signal in the corridor. Several factors affecting received signal and PL were investigated, including the properties of the distance and the radio signal. By results, it is clear that the signal strength decreases with the increase in the distance between Tx and Rx. The authors found that the PSO trained ANFIS has a high accuracy to the model prediction of signal propagation.

Also, in [23] the authors proposed a framework based on a GA, Geno Placement that deals with different types of building materials to improve the position of AP on the floor of a building. The obtained results showed that this algorithm can deal with many types of obstacles, such as glass, brick and concrete walls. Moreover, the accuracy of the proposed algorithm is not related to the AP number.

Recently, a lot of work has been proposed in the line, where the researcher [24] performed an algorithm for the optimized AP location between four locations previously identified in the corners. Simulation results that represent the optimal target AP were compared and confirmed according to real measurement results. However, the researcher's study was limited to obtaining only one access point between four distributed access points, using a single objective measure function based on RSS.

The same authors [25] presented an optimization method by using the BPSO algorithm based on the use of a multi-objective function. In their study, a small portion of the target area was used to identify and suggest AP deployment locations based on two different objectives. However, this study does not consider the effects of different sources of interference and co-channel interference.

3. 3D view to the proposed AP deployment optimization scenario
This section will introduce 3 prospects related to our work and as clarified in figure 1. where these three sections would be demonstrated in details.

**Figure 1. Flow Work of the proposed algorithm**

**3.1 Case Study Wireless Topology**

Wireless InSite (WI) is a three-dimensional (3D) package tracking program that contains the following set of beam models and highly stable electromagnetic developments (EM), for investigating the explicit radio wave propagation of the site and remote correspondence organizations [26]. WI software provides productive and accurate predictions of EM spread and the attributes of the correspondence channel for complex metropolitan, indoor, country and mixed conditions. The structure of the Department of Computer Science and Mathematics, Figure 2. was presented in the Fundamentals of the University of Baghdad as a contextual investigative climate using InSite software. It covers an area of (95.5 * 52.5) square meters, and the absolute number of rooms is 115. The room sizes are (3*6), (6*6), or (9*6) m². It is a two-story fabricating that serves two divisions of Science College, CS, and Math. The total number of LOS and NLOS TP's were 24 and 223 within our entire case study respectively.
Figure 2. Dept. of Computer Science and Mathematical building - College of science - University of Baghdad (the case study)

WI software has been used to design, model and simulate the targeted building with real measurements for internal rooms and laboratories Figure 3. In the case of AP devices, a total of 125 APs was initially distributed over two floors, where 9 APs were placed at a height of 4m other than 62 APs with 2.5m distributed in the 1st floor. Furthermore, 54 APs distributed in the 2nd floor. The specifications of the proposed model are listed in Table 2. Meanwhile, for the Test Points (TPs) they distributed as points of TPs with a total number of 135 and 112 in the 1st and 2nd floors respectively, each TP fixed at 1m height.

Figure 3. The modeling of our targeted building using WI Software

Table 1. The specifications of our targeted building and case study

| Specification                | Value |
|------------------------------|-------|
| Total number of distributed APs | 125   |
| AP height                    | 2.5, 4 m |
| Number of APs in the 1st floor | 71     |
| Number of APs in the 2nd floor | 54    |
| Total number of distributed TPs | 247   |
| Number of TPs in the 1st floor | 135   |
| Number of TPs in the 2nd floor | 112   |

Figure 4 and 5 demonstrates the distribution of APs and TPs within two floors respectively. It is worth to mentioning that the (247) TP has distributed within the two investigated floors. The selected antenna properties of APs and TPs are listed in Table 3. In this work, the effect of different building materials has been considered, besides the sensitivity of frequency-per material depending on the parameters of the relative permittivity ($\epsilon$) and conductivity ($\sigma$). Additionally, five threshold cases of RSS are
considered to evaluate the optimization deployment of AP devices. These RSS cases are (-40, -45, -50, -55 and -60) that maintain the overall coverage and the QoS factor. Furthermore, in each of mentioned cases, there are five different weights as sub cases will be discussed.

Figure 4. The distribution of AP's within the (a) the first floor, (b) the second floor
In this work, the procedure followed would be classified into two stages, where in the first the previously mentioned case study would be executed using InSite software based on the utilized parameters which will be discussed later. Then these results would be gathered from InSite software to be handled by using

**Figure 5.** the distribution of TP's within the (a) first floor, (b) second floor

**Table 2.** The antenna properties of AP and TP inside

| Antenna properties | AP (TP-link n450) | TP |
|--------------------|-------------------|----|
| Type of Antenna    | Omni              | Omni |
| Power (dBm)        | 20                | -   |
| Antenna Gain (dBi) | 5                 | 1.8  |
| E-Plane HPBW       | 90˚               | 90˚  |
| Waveform           | Sinusoid          | Sinusoid |
| VSWR               | 1                 | 1    |

In this work, the procedure followed would be classified into two stages, where in the first the previously mentioned case study would be executed using InSite software based on the utilized parameters which will be discussed later. Then these results would be gathered from InSite software to be handled by using
the proposed algorithm for obtaining the optimum AP coverage and its minimum distribution for our case study.

3.2 The utilized wireless parameters

We explained the parameters that will be used in our investigation and analysis of performance in this section, as shown below.

3.2.1 Received Signal Strength (RSS)

Signal strength is a measure of power estimation, which is sent from the access point at a specific time and obtained by a remote device and placed in a different area. RSS has been considered as the main viewpoints, as it works with the loud ability to process signal-to-noise ratio (SNR). As Shannon low has been announced, the SNR shows the maximum limit for the correspondence frame. The meaning of the RSS rating is rapidly increasing since the large part of the remote organization gives direct acceptance to the RSS rate as expressed in [27], was determined RSS and obtained from WI programming based on equation (1) [28].

\[ P_R = \frac{\lambda \beta P_T}{(4\pi R)^2} |g_{T,\theta}(\theta_D, \Phi_D) g_{R,\theta}(\theta_A, \Phi_A) + g_{T,\phi}(\theta_D, \Phi_D) g_{R,\phi}(\theta_A, \Phi_A)|^2 \] (1)

Where \( P_R \) and \( P_T \) are the received and transmitted powers respectively, \( R \) is the distance between the transmitter and receiver, \( \lambda \) is the wavelength, \( \beta \) denotes the overlap of the frequency spectrum, \( (\theta_D, \Phi_D) \) symbolize the direction in which ray leaves the transmitter and \( (\theta_A, \Phi_A) \) denote the direction in which the ray arrives at the receiver. Finally, \( g_T \) and \( g_R \) represent the direction of arrival for both transmitter and receiver respectively.

3.2.2 Path Loss (PL)

It represents the ratio of the amount of power sent by the transmitter to the amount of power given by the receiver [29]. It also may be referred to as a measurement of attenuation of the propagated signal at the receiver.

Path loss or Free Space Path Loss (FSPL) can be calculated in a free space and based on the Friis transmission equation that described in the equation (2)

\[ FSPL(dB) = 10 \log_{10} \left( \frac{P_T}{P_R} \right) = 10 \log_{10} \left( \frac{(4\pi R)^2}{G_T G_R \lambda^2} \right) \] (2)

Where \( G_T \) and \( G_R \) are the transmitter and receiver antenna gain. It is important to note that the Friis equation assumes the unit antenna gain to both the transmitter and the receiver. Hence, the previous equation can be rewritten as shown below in the equation (3).

\[ FSPL \; (dB) = -10 \log_{10} \left( \frac{\lambda^2}{(4\pi R)^2} \right) \] (3)

Moreover, the most commonly used path loss equation can be calculated with respect to the Omni-directional antenna pattern as expressed in the equation (4).

\[ PL \; (dB) = P_T(dBm) - P_R(dBm) + G_{T,Max}(dB) + G_{R,Max}(dB) - L_s \] (4)
9

Where $G_{T,\text{Max}}$ and $G_{R,\text{Max}}$ are the transmitter and receiver maximum gains, respectively and $L_s$ is the sum of all other losses in the system (in dB).

### 3.2.3 Carrier to Interference Ratio (CIR)

It is the ratio of the received power from one transmitter (the carrier) to the sum of power received from all other transmitters (the interferers), the equation represents the CIR can be seen in (5)

$$CIR \ (dB) = 10 \log_{10}(P_R(i)) - 10 \left( \log_{10}(\sum_{j \neq i}^{N_T} P_R(j)) \right)$$

Where $P_R(i)$ is the received power due to $i^{th}$ transmitter, $j$ is the total number of transmitters, and $N_T$ is the number of active transmitters.

### 3.2.4 Permittivity ($\varepsilon$) and Conductivity ($\sigma$)

In order to improve the accuracy of internal diffusion, valuable efforts have been made to study the effect of different building materials in the utilized frequency band. As a result, two general representations followed by WI software are required for this mission and known as the relative permittivity ($\varepsilon$) and conductivity ($\sigma$). Relative permittivity represents the reflection of material influences on the electrical field, which is highly dependent on the selected frequency [30]. In most ray-tracing simulations, the $\varepsilon$ values for various materials are an approximation that fails to represent the true measurement in a real environment, and leads to an inaccurate prediction of the simulation results [31]. Each material permittivity can be represented as expressed in the equation (6)

$$\varepsilon = \eta' - j\eta''$$

Where $\eta'$ and $\eta''$ represent the real part and imaginary parts of relative permittivity respectively. For the conductivity, it describes the imaginary part of relative permittivity [30]. The conversion between them can be clarified in equation (7)

$$\sigma = \eta'' \omega$$

Where $\omega$ is the angular frequency of the transmission carrier frequency in radian/sec.

### 3.3 Binary Particle Swarm Optimization (BPSO) Based Optimization Algorithm

The coverage ratio differs inside the building according to a difference in the location of the AP that is influenced by the structure, objects, and obstacles of the building. Hence, several optimization algorithms have been exploited by researchers to solve the AP coverage problem. Among these algorithms, there is the one that inspired by swarm intelligence like BPSO that characterized by accuracy and less time consuming, making it more flexible for various problem domains [32].

BPSO changes the particle velocity and position to guide all particles towards the best position, by comparing the best position of each particle to the best place of the entire swarm [22]. The BPSO algorithm has been widely and successfully used in many applications, such as the optimization of effective parameters during the wireless network planning process, besides the effective parameters during its operation. Moreover, it has been used in other applications such as determining the optimal...
feature set for speech and hearing recognition, optimizing the power system, and training neural networks [33].

The steps below demonstrate the flow work of our proposed algorithm:

- **Initialization the parameters for BPSO algorithm**

In this step the AP-TP Matrix of RSS monitored at each TP as seen in figure 6 which produced by WI software as a result of simulation for the distribution of APs and TPs within target building. The Matrix imported to the MATLAB, where the size of AP-TP Matrix corresponds to (125*247) APs times TPs of RSS values.

![Figure 6. the AP-TP Matrix](image)

After that, the parameters of our proposed BPSO algorithm would be Initialized and as seen in the below table 4. Another initialization step is required in this stage represented by initializing the AP-Matrix with random binary value which are generated for each iteration. The AP-Matrix can be seen in Figure 7. Thereby, If AP(i) equal to (0), then the corresponding index in the AP-TP Matrix set to -100 (as initial RSS) in order to guarantee that such AP would be OFF, otherwise would be considered as ON. Meanwhile, this condition \( \sum_{1 \leq i \leq n} AP_i \geq AP_{min} \) specify the solution validation for each iteration based on the number of APs which should be at least equal to \( AP_{min} \). For the invalid solution, the current fitness would be set to 100 (neglected situation).

![Figure 7. The AP- Matrix](image)
Table 3. The parameters utilized within the initialization of BPSO algorithm

| Parameter               | Description                          | Value               |
|-------------------------|--------------------------------------|---------------------|
| C1, C2                  | acceleration coefficients            | 1, 1                |
| α1, α2                  | random number                        | (0-1)               |
| Bird steps              | total number of iterations           | 100000              |
| W1, W2                  | weights of Coverage and AP placement| (0.3, 0.7), (0.7, 0.3), (0.5, 0.5), (0.6, 0.4), (0.4, 0.6) |
| W                       | BPSO momentum or inertia             | 0.9                 |
| APmin                   | minimum number of required APs for the building | 3                   |
| APposition              | random integer                       | (0, 1)              |
| APvelocity              | random number range                  | (0-1)               |
| RPth                    | received power threshold             | (-40, -45, -50, -55, 60) |
| TPtotal                 | total test point                     | 247                 |
| RSSmax                  | Maximum RSS at each TP               | Max RSS at each TP from all APs |
| RSSmaxCount             | counter for the Maximum RSSs for all TPs that passed the threshold | 0                   |
| APPbest                 | best position per particle           | Current fitness     |
| APGbest                 | Global best position for all particles | Current fitness     |

As a result, the algorithm will check and count the maximum RSS for each TP and the number of APs for all TPs, where TP counted as active if RSSmax received and passes the RPth at that TP. Thus, RSSmaxCount = RSSmaxCount + 1 if RSSmax ≥ RPth. For example, if RPth equal to -50 then RSSmaxCount incremented by 1 if current TP receives >= -50 as RSS. Another condition used to count the number of active APs that passes the RPth at each TP based on the condition: if no. of active APs per TPi ≥ RPth, at current iteration, the total AP deployment would be calculated using equation (8)

\[
\text{Total AP deployment} = \sum \text{no. of active APs per TP}_i \geq \text{RP}_{th} \quad (8)
\]

Finally, our algorithm will take into account two functions called coverage fitness and AP placement fitness and obtained as seen in equation (9) and (10). In addition, the proposed algorithm may run five times or cases, one time for each W1 and W2 pair values, as mentioned in table 5. Finally, we obtain the optimal deployment from our proposed algorithm denoted by AP deployment fitness as explained in the equation (11).

\[
\text{Coverage fitness(Max)} = w_1 \times \frac{-\text{RSSmaxCount}}{\text{TPtotal}} \quad (9)
\]

\[
\text{AP placement fitness(Min)} = w_2 \times \frac{\text{Total AP deployment}}{\sum AP_i \times \text{TPtotal}} \quad (10)
\]

\[
\text{AP Deployment fitness(Min)} = \text{Coverage fitness} + \text{AP placement fitness} \quad (11)
\]

- **Evaluation the proposed algorithm**

First, the BPSO based algorithm will evaluate the initial solution of AP deployment fitness function, where our utilization of BPSO to the AP deployment determines both APpbest and APgbest. If AP deployment fitness is less than APpbest, then APpbest equal to AP deployment fitness. Otherwise, APpbest
is equal to current AP\textsubscript{best}. The updated parameters of AP velocity and position will be calculated according to equation (12) and (13) respectively.

\[
AP\text{velocity}(i)(t + 1) = w \ast AP\text{velocity}(i) + c1 \ast \alpha1 \ast (AP\text{pbest}(t) - AP\text{position}(i)(t)) + c2 \ast \\
\alpha2 \ast (AP\text{gbest}(t) - AP\text{position}(i)(t))
\] (12)

\[
AP\text{position}(i)(t + 1) = AP\text{position}(i)(t) + AP\text{velocity}(i)(t + 1)
\] (13)

Where AP\text{velocity}(i) is the velocity of ith particle, \(i\) is the initial position of the ith particle, AP\text{pbest} acts as best position for the ith particle, AP\text{gbest} denotes the global best position for all particle, \(w\) parameter applied as weight to initialize the AP\text{velocity} and \(t\) indicates the round number for which this AP\text{velocity} applied.

Then, the population has a set of particles where each particle represents a binary decision that is evaluated to either (True=1) or (False=0) that corresponds to AP and based on the equation (14). The AP\text{velocity} and AP\text{position} of all particles are accumulatively updated until it achieves the best solution depending on the total number of iterations based on the equation (15).

\[
\text{Sigmoid}(AP\text{velocity}(i)^n(t + 1)) = \frac{1}{1 + e^{AP\text{velocity}(i)^n(t)}}
\] (14)

\[
AP\text{position}(i)^n(t + 1) = \begin{cases} 1, & r < \text{Sigmoid}(AP\text{velocity}(i)^n(t + 1)) \\ 0, & \text{otherwise} \end{cases}
\] (15)

Where \(r\) denotes a random number selected from a uniform distribution (0-1). Applying the sigmoid function to get binary results suitable for the On/Off property of AP. AP\text{position}(i)(t) set to 1 if the random number is less than AP\text{velocity} sigmoid function value at the current iteration else it will be set to 0. The AP\text{velocity} and AP\text{position} of all particles are accumulatively updated until it achieves the best fitness solution depending on the total number of iterations.

**Principle of Result analysis of our proposed algorithm**

The results of the proposed algorithm will be shaped by analyzing the overall performance of the wireless network, based on five different RSS thresholds and three parameters investigated. It's worth to mention that our optimized algorithm will consider the AP location by using the AP deployment function of 100,000 iterations per case, in terms of minimum APs and achieve best wireless coverage.

4. Results and Discussion

4.1. Overall achieved Results

The results of the BPSO based algorithm are discussed in this section by analyzing the overall performance of the wireless network. To obtain accurate results, \(w1\) and \(w2\) are used to represent priority (weight) values for coverage and AP placement respectively. The number of APs, the number of TPs covered, coverage ratio, coverage fitness, AP placement fitness and AP deployment fitness have been withdrawn in Table 5 for each case. It can be notice that there is a direct correlation between the RSS signal threshold and the number of required AP devices. For example, when the case of (0.5, 0.5) activated with RSS threshold of (-40, -45, -50, -55 and -60) dBm, it results (25, 23, 20, 18 and 15) required APs respectively.
Table 4. Overall results obtained from our proposed algorithm

| Signal     | Weight | Coverage (W1) | AP Placement (W2) | AP | TP | Coverage % | Coverage Fitness | AP Placement fitness | AP deployment fitness |
|------------|--------|---------------|-------------------|----|----|------------|-------------------|----------------------|----------------------|
| -40 Excellent case | 0.3    | 0.7           | 20                | 139| 56.28 %   | -0.1200            | 0.0185               | -0.1198              |
|            | 0.4    | 0.6           | 23                | 151| 61.13 %   | -0.2240            | 0.0150               | -0.1995              |
|            | 0.5    | 0.5           | 25                | 175| 70.85 %   | -0.3600            | 0.0139               | -0.3381              |
|            | 0.6    | 0.4           | 28                | 183| 74.09 %   | -0.4000            | 0.0096               | -0.4268              |
|            | 0.7    | 0.3           | 32                | 193| 78.14 %   | -0.5280            | 0.0074               | -0.5279              |
| -45 Very good case | 0.3    | 0.7           | 18                | 177| 71.66 %   | -0.1680            | 0.0356               | -0.1758              |
|            | 0.4    | 0.6           | 20                | 202| 81.78 %   | -0.2240            | 0.0278               | -0.2650              |
|            | 0.5    | 0.5           | 23                | 215| 87.04 %   | -0.2960            | 0.0242               | -0.4203              |
|            | 0.6    | 0.4           | 24                | 223| 90.28 %   | -0.3600            | 0.0184               | -0.5391              |
|            | 0.7    | 0.3           | 27                | 236| 95.55 %   | -0.3680            | 0.0149               | -0.6500              |
| -50 Good case | 0.3    | 0.7           | 17                | 212| 85.83 %   | -0.1680            | 0.0529               | -0.1803              |
|            | 0.4    | 0.6           | 18                | 221| 89.47 %   | -0.1440            | 0.0567               | -0.3120              |
|            | 0.5    | 0.5           | 20                | 230| 93.12 %   | -0.2400            | 0.0360               | -0.4372              |
|            | 0.6    | 0.4           | 21                | 238| 96.36 %   | -0.2560            | 0.0270               | -0.5471              |
|            | 0.7    | 0.3           | 25                | 243| 98.38 %   | -0.2480            | 0.0209               | -0.6558              |
| -55 Normal case | 0.3    | 0.7           | 15                | 215| 87.04 %   | -0.1120            | 0.0911               | -0.1749              |
|            | 0.4    | 0.6           | 16                | 228| 92.31 %   | -0.1600            | 0.0736               | -0.3140              |
|            | 0.5    | 0.5           | 18                | 236| 95.55 %   | -0.1760            | 0.0579               | -0.4308              |
|            | 0.6    | 0.4           | 18                | 240| 97.17 %   | -0.1920            | 0.0505               | -0.5482              |
|            | 0.7    | 0.3           | 22                | 246| 99.60 %   | -0.2160            | 0.0371               | -0.6641              |
| -60 Poor case | 0.3    | 0.7           | 12                | 222| 89.88 %   | -0.1200            | 0.0968               | -0.1723              |
|            | 0.4    | 0.6           | 13                | 231| 93.52 %   | -0.1360            | 0.0955               | -0.2923              |
|            | 0.5    | 0.5           | 15                | 241| 97.57 %   | -0.1520            | 0.0976               | -0.4238              |
|            | 0.6    | 0.4           | 16                | 243| 98.38 %   | -0.1600            | 0.0572               | -0.5427              |
|            | 0.7    | 0.3           | 17                | 247| 100 %     | -0.1680            | 0.0373               | -0.6593              |

Furthermore, Figure 8. shows the results of the five cases (weights) as a relationship between the number of iterations and the values of the fitness function for each RSS threshold value. The effect of selecting a number (100,000) iterations on the results in all curves, making them appear linear to achieve the best solution.

In addition, Figure 9. shows the Cumulative Distribution Function (CDF) or F(x) for the maximum power received by each TP for five pair weights cases. It depicts the behavior of the fitness function till reaching the stable state as a solution by using 100000 iterations. Moreover, the figure shows the behavior relationship between the probability (or CDF) that the obtained received power (or RSS) takes a value less than or equal to the power threshold. The selection of suitable cases will depend on the customer's requirements in both the coverage area and the number of APs, as well as the type of frequently required applications such as video / HD / audio streaming.
Figure 8. The AP Deployment Fitness function for the signal thresholds of (a) -40, (b) -45, (c) -50, (d) -55 and (e) -60 in dBm
Figure 9. The F(x) (or CDF) for the maximum received power obtained from each TP of (a) -40, (b) -45, (c) -50, (d) -55 and (e) -60 in dBm
4.2. Comparison results between the optimization and the real present network

In this section, the results obtained from the proposed BPSO-based algorithm to optimize the minimum number of AP location and enhance the coverage area, will be compared with the results obtained from the current AP deployment simulation of the target building, the -55 state will be chosen from the RSS threshold with weights (0.5, 0.5) for comparison. The comparison is based on three main parameters, RSS, path loss, and interference, with 50 TP (out of 247) randomly selected for comparison. The top view of the deployment for both compared cases can be seen in figure10.

![Figure 10](image)

**Figure 10.** AP deployment from both the optimization case of -55 dBm (0.5, 0.5) in off white dots and the present AP deployment in black dots within the (a) first floor and (b) second floor

According to the results of RSS-based comparison, as shown in the figure11. It can be clearly seen that the optimized AP deployment (blue curve) has achieved the best coverage of the selected TP’s, compared to the current AP position (red curve) inside the building. As a result, the average RSS for the optimization and real network were (-45.7) and (-57.25) dBm respectively.
For the path loss comparison, it has been illustrated in Figure 12, where it can be seen that the far distance TP has achieved higher path loss values indicating the direct correlation between them. Additionally, the optimization deployment showed a significant in reducing the overall path losses with our investigated TP's, where the average values were 72.7 and 84.25 dB for both the optimized and real AP deployment respectively.

In addition, the effect of interference was considered as the most important factor to QOS. As a result, it was considered in this study as shown in Figure 13, in which the same previous comparison was carried out. The overall trends showed a decrease in the interference to the propagation based on the optimization algorithm compared to the real diffusion, where the average interference was reduced to its double value.

5- Conclusion
This paper proposed an algorithm to optimize the AP deployment inside the target building based on the

Figure 11. The RSS vs. different selected TP in both optimized and real deployed scenarios

Figure 12. The path loss vs. different selected TP in both optimized and real deployed scenarios

Figure 13. The interference vs. different selected TP in both optimized and real deployed scenarios.
published BPSO for the AP mode. Five RSS signal thresholds and weightings were chosen for the study in order to achieve adequate AP deployment. Additionally, two fitness functions denoted as the coverage and AP placement have utilized based on the change of weights. It has been proposed the algorithm for two-floor deployment by using 3D WI software. The results obtained from the case of (0.5, 0.5) in -55 dBm threshold showed that our proposed algorithm outperforms the current AP deployment by 39.23% in coverage ratio. As a result, the selection of suitable cases will depend on the customer’s requirements in both coverage area and number of APs. Hence, the wireless coverage gaps are expected to be reduced. Finally, for the future, the other studied parameters can be implemented in real environment scenario by using real AP devices and perform the required measurement using dedicated software.

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