Real measurement of optimal access point localizations

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Abstract. The widely applied location-based services require a high standard for positioning technology. With the development of the wireless communication technology, the positioning services based on Wi-Fi are increasingly demanded. To understand the positioning accuracy limits under a certain given Access Point topology and to be able to make design recommendations. This paper proposed a method for proper deployment of AP devices on the building of the electrical department in the university of technology and computing the measurements of the Received Signal Strength (RSS). Received Signal Strength measurement was obtained from different received points located within the targeted building. Many software can be used for the measuring of RSS values. In our work, it has been used NetSpot pro software. Net Spot is a software tool for wireless network assessment, scanning, and surveys, analyzing Wi-Fi coverage and performance. RSS reading were measured for four directions (North-South-East-West). It should mention that each RSS measurement obtained per each direction, is actually the average of 4 RSS measurement samples. This trend is to provide more accurate results than a single measurement. Floor layout has been designed and imported to the software and used to allocate the measurements in the exact received point locations. The objective of this paper is to achieve full coverage area with less number of AP devices and reduce the total implementation costs.

1. Introduction
The designing of wireless networks has developed in a consistent manner in the last past years. The needs to deploy the proper design for wireless network get a higher significant by the researchers recently to achieve different aspects [1]. One of these important aspects was the services-based localization approaches [2, 3], the wireless signals have been used for various purposes. Even though, the system widely used for localization is the Global Positioning System (GPS) and different location estimation issues [4]. However, its effectiveness was only for outdoor environments. Indoor environments suffer from many challenges of its complexities, the presence of moving objects, obstacles and barriers. In addition, the effects of interferences were another significant challenge [5]. As a result, the proper deployment of wireless network for indoor environments has a primary significant to provide the total coverage for the desired users. Such coverage has been determined by the number of Access Point (AP) devices distributed within the targeted area, where placing too many AP’s would increase the total implementation costs and interferences. On the other hand, placing less than need would results in a dead zones and coverage gaps [6].

The selection of optimum locations and proper deployment for AP devices has an important issue for operating, managing the network and obtaining the characteristics of the Radio Frequency (RF) [7]. For these reasons, many algorithms and methods have been proposed and presented by many researchers and industries, which will be discussed briefly in the next section.
Several methods have been utilized by researchers. For example, the researchers in [8] uses the Angle-of-Arrival (AoA) to improve the accuracy of AP location. However, this method requires additional time and cost.

On the other hand, time-based approach including Time-of-Arrival (ToA) was another method proposed by other researcher as in [9] and shows an impressive result. However, methods based ToA requires additional medium, time synchronization and requires at least two reference point to be operated.

In the recent time, many researchers concentrated on the Received Signal Strength (RSS) parameter and proposed many methods and algorithm to obtain the best deployment of AP devices. The oldest and first method back to 1994 when the researchers in [10] select the AP location manually and based on the guess of the network designer. However, such traditional method requires extra time and cost and its effectiveness would be only for small area.

Meanwhile, other researchers proposed mathematical models as in [11]. These models require extra computational time.

In addition, researcher in [12] developed AP localization algorithm to estimate the best placement based on the use of Differential Equation (DE) method. Such method shows effectiveness in AP localization approach. However, it has been considered to be an old method, requires extra time, requires knowing the coordination of each AP device within the indoor environment.

Additionally, researchers in [13] developed an algorithm for optimal AP placement in an office building, which consist of Drywall and Concrete walls. The aim of this algorithm was to minimize the number of used AP. However, this algorithm didn’t consider the effects of other materials containing in the indoor environments.

In addition to that, a group of researchers in [14] presents a method for AP placement based on the use of Particle Swarm Optimization (PSO). However, the presented method shows ineffectiveness in the issue of handling the attenuation caused by different type of walls. The aim of this work was to provide higher throughput for 2.4 GHz band.

In line with all these contributions, in this paper a method has been proposed to deployment of AP devices on the building of the electrical department in the university of technology. The procedure of the practical part divided into two part, the first was based on simulation scenario, which has been presented and discussed in previous work. While, the second part would be based on the real RSS measurement for the confirmation and comparing the results of the two parts. In addition, improve the reliability and efficiency of the proposed deployment for AP devices. RSS measurement obtained from different received points located within the targeted building. The objective of this proposed method is to achieve full coverage area with less number of AP devices and reduce the total implementation costs. Also, considering the effects of different interferences sources, noises and objects within the real scenario. In order to highlight the reliability of the current experiment, a comparison between the results of simulation and real measurements is applied to achieve an exact location of Aps. The paper is divided as follows. The measurement and its methodology of RSS was discussed in section 3 and 4 respectively. The results described in section 5. Finally, the conclusion is drawn in the last section.

2. Received Signal Strength (RSS)

Signal strength refers to as received signal level or field strength. Typically, it is expressed in voltage per length or signal power received by a reference antenna. The value of power was transmitted from an Access Point device at a known time and received by another device placed in other location [15].

In the recent system and deployment methods, RSS was the most interesting method to estimate the optimum APs locations. This significant increase rapidly since these wireless devices provide direct access to RSS values [16]. Furthermore, it should be noted that RSS value is actually represents the value of power received by the receiver device with the noise and interference effects based on below equation. [17]

\[
RSS = P_R + I_{total} + N_{total}
\]  

(1)
Where $P_R$ is the received power, $I_{total}$ is the total interferences and $N_{total}$ is the total noise within the investigated area.

3. Measurement Methodology

3.1 Case Study

The site selected as a case study for our work was the building of electrical department in the university of technology, which it lies in Baghdad. A set of received points with total number of (52) points have been selected in different rooms and labs within the fifth floors of the targeted building. On the other hand, it has been selected (8) locations for the deployment of AP devices within the building. The distribution of each AP device and each received points per each floor can be seen in Figure 1. the total number of AP and received points per each floor are listed in Table 1.

![Figure 1](image1.png)

**Figure 1.** The distribution of AP device and received point locations per each floor in the targeted building where: (a) ground floor, (b) 1st floor, (c) 2nd floor, (d) 3rd floor and (e) 4th floor

| Floor | No. of AP devices | No. of Received Points |
|-------|------------------|------------------------|
| G-Floor | 1                | 12                     |
| F1     | 1                | 12                     |
| F2     | 2                | 12                     |
| F3     | 2                | 10                     |
| F4     | 2                | 6                      |
| total  | 8                | 52                     |

**Table 1.** The total number of AP devices and received point locations per each floor
3.2 Measurement Setup

The laptop Wi-Fi was selected with preinstalled software for Received Strength Signal measurement, to configure the receiver device in each received point. The TP-Link AP device of model of TL-WR941HP was selected as the transmitter shown in Figure 2 and configure it to work as an Access Point device. It has been utilized 8 AP devices and allocated within the targeted building. These devices have been selected due to its facilities of including three detachable Omni-Directional antennas. The using of multiple antenna was to reduce the loss of connection, multipath effects, and improve the quality and reliability of link by utilizing different places. In addition, another feature of these selected devices has an amplifier with high power and high gain for antenna [17]. The properties of both AP and receivers are listed in Table 2. The Access Points works at the band of 2.4 GHz and placed in a selected location shown in Figure 3. The procedure of measurement contains a set of AP in each selected location with a height of 2.5 m. The laptop height was 1.10 m and it has been used to perform the measurement of the RSS value in each location of received point and in the four known directions per each location as seen in Figure 4. An example of RSS measurement obtained from each AP device to the received point in the ground floor can be seen in Figure 5.

![Figure 2. Front and back view for the utilized AP devices](image)

| Antenna properties | Tx Antenna | Rx Antenna |
|--------------------|------------|------------|
| Antenna type       | Omni-Directional | Omni-Directional |
| Input Power (dBm)  | 30         | -          |
| Gain (dBi)         | 9          | 2          |
| E-Plane HPBW       | 90°        | 90°        |
| Waveform           | Sinusoid   | Sinusoid   |
| Polarization       | V          | V          |
Figure 3. Access Point Distributed in all floor

Figure 4. Person who take the Reading for the building
Figure 5. The RSS measurement obtained from NetSpot software on the ground floor received points and from: (a) F1-AP (b) F2-AP1 (c) F2-AP2 (d) F3-AP1 (e) F3-AP2 (f) F4-AP1 (g) F4-AP2 (h) GF-AP
4. Result and Discussion
The case study that has been clarified in previous section has been investigated. The results obtained from the real measurement scenario will be discussed based on the total performance of all (8) AP devices and based on each received point location in the entire building. For accurate analytics, communication based multi-floor scenario will be involved with our investigation. Hence, the performance and efficiency of each AP device will be investigated to cover the entire building and based in measurement of RSS parameter.

To illustrate the performance of RSS versus the distance and for all the received points in each floor. Figure 6 shows the values of RSS that has been measured from each AP device. It can be seen generally that there is a reversal correlation between the RSS and distance due to many reasons related multipath effects and effects of different barriers and obstacles within the indoor environment. Furthermore, it can be seen that there is a serious effect of the concrete layer separated between the floors of the targeted building. As a result, the multi-floor communication scenario could be performed for our building and could achieve reinforcement and support the network coverage in the entire building.

Figure 6. The effect of each AP device located in the targeted building on the received points of: (a) ground floor, (b) 1st floor, (c) 2nd floor, (d) 3rd floor and (e) 4th floor.
In order to achieve proper understanding in the manner of network coverage optimization, it has been selected a valuable RSS value of \((\geq -60\text{dBm})\) to be the threshold of the RSS values obtained from the measurement scenario. It is worth to mention that it has been measure the RSS value in four directions. However, the optimum direction has been selected to form the optimum value per each received point location. The selection of threshold RSS value was based on the previous recommendation for achieving the requirements of higher throughput application such as VoIP (Voice over IP) and video streaming. For that reason, it has been utilized the below equation to obtain the percentage of coverage area for each AP device and per each floor and listed in Table 3.

\[
CP = \frac{P_{\text{selected}}}{P_{\text{Total}}} \times 100
\]  

(3)

Where \(CP\) represent the coverage percentage, \(P_{\text{selected}}\) represent the selected received power values within the range of \((\geq -60\text{dBm})\) and \(P_{\text{Total}}\) is the total number of received points in each floor which has been listed previously in Table 1.

### Table 3. The overall value of received power about all building

| Received Points | TxG | TxF1 | TxF2-AP1 | TxF2-AP2 | TxF3-AP1 | TxF3-AP2 | TxF4-AP1 | TxF4-AP2 |
|-----------------|-----|------|----------|----------|----------|----------|----------|----------|
| RX1             | -55 | -60 | -70      | -64      | -80      | -71      | -87      | -78      |
| RX2             | -39 | -73 | -66      | -69      | -74      | -72      | -83      | -86      |
| RX3             | -72 | -76 | -70      | -69      | -74      | -76      | -81      | -84      |
| RX4             | -41 | -73 | -67      | -73      | -64      | -82      | -79      | -88      |
| RX5             | -59 | -69 | -80      | -77      | -74      | -73      | -82      | -90      |
| RX6             | -47 | -64 | -75      | -72      | -83      | -76      | -85      | -78      |
| RX7             | -59 | -80 | -64      | -80      | -75      | -87      | -88      | -88      |
| RX8             | -36 | -67 | -74      | -80      | -85      | -87      | -82      | -86      |
| RX9             | -81 | -66 | -77      | -81      | -75      | -87      | -86      | -86      |
| RX10            | -54 | -74 | -65      | -86      | -74      | -86      | -80      | -88      |
| RX11            | -61 | -81 | -81      | -86      | -80      | -86      | -87      | -86      |
| RX12            | -46 | -80 | -60      | -79      | -74      | -86      | -88      | -85      |
| RX13            | -59 | -62 | -57      | -70      | -70      | -75      | -76      | -84      |
| RX14            | -64 | -60 | -51      | -60      | -63      | -66      | -77      | -76      |
| RX15            | -65 | -62 | -45      | -60      | -70      | -68      | -76      |
| RX16            | -59 | -72 | -56      | -70      | -70      | -75      | -76      | -84      |
| RX17            | -63 | -60 | -52      | -63      | -67      | -77      | -76      |
| RX18            | -65 | -45 | -60      | -55      | -73      | -65      | -82      | -71      |
| RX19            | -55 | -65 | -44      | -64      | -59      | -66      | -68      | -80      |
| RX20            | -65 | -56 | -71      | -56      | -79      | -77      | -88      | -85      |
| RX21            | -67 | -63 | -56      | -70      | -62      | -70      | -83      | -89      |
| RX22            | -71 | -41 | -80      | -80      | -85      | -79      | -90      | -80      |
| RX23            | -78 | -52 | -86      | -86      | -89      | -79      | -90      | -88      |
| RX24            | -67 | -30 | -66      | -64      | -81      | -70      | -87      | -82      |
| RX25            | -77 | -50 | -52      | -34      | -70      | -67      | -85      | -80      |
| RX26            | -74 | -39 | -51      | -33      | -66      | -54      | -78      | -69      |
| RX27            | -70 | -64 | -46      | -40      | -56      | -45      | -69      | -58      |
| RX28            | -67 | -66 | -42      | -49      | -58      | -55      | -66      | -68      |
| RX29            | -55 | -74 | -38      | -55      | -47      | -46      | -63      | -75      |
| RX30            | -55 | -74 | -38      | -55      | -47      | -56      | -70      | -71      |
| RX31            | -72 | -69 | -45      | -41      | -57      | -47      | -69      | -60      |
| RX32            | -67 | -54 | -68      | -43      | -74      | -67      | -80      | -66      |
| RX33            | -80 | -60 | -60      | -48      | -74      | -65      | -84      | -72      |
| RX34            | -76 | -60 | -68      | -53      | -78      | -70      | -85      | -74      |
| RX35            | -65 | -66 | -70      | -55      | -78      | -75      | -89      | -85      |
| RX36            | -75 | -79 | -43      | -56      | -48      | -66      | -67      | -82      |
| RX37            | -74 | -50 | -57      | -50      | -57      | -65      | -65      | -82      |
| RX38            | -67 | -73 | -70      | -40      | -55      | -41      | -68      | -51      |
| RX39            | -81 | -78 | -60      | -60      | -42      | -31      | -58      | -54      |
| RX40            | -86 | -86 | -39      | -74      | -30      | -56      | -51      | -64      |
| RX41            | -71 | -82 | -52      | -64      | -41      | -43      | -52      | -55      |
| RX42            | -62 | -67 | -70      | -55      | -50      | -39      | -67      | -74      |
| RX43            | -80 | -71 | -72      | -63      | -63      | -58      | -82      | -67      |
| RX44            | -81 | -77 | -75      | -67      | -70      | -60      | -86      | -69      |
| RX45            | -67 | -67 | -56      | -74      | -49      | -56      | -59      | -65      |
| RX46            | -86 | -87 | -56      | -56      | -56      | -56      | -56      | -64      |
| RX47            | -84 | -82 | -69      | -78      | -58      | -56      | -45      | -44      |
| RX48            | -81 | -87 | -58      | -80      | -59      | -54      | -66      | -59      |
| RX49            | -80 | -85 | -65      | -74      | -58      | -60      | -51      | -40      |
| RX50            | -88 | -78 | -75      | -64      | -65      | -58      | -66      | -44      |
| RX51            | -88 | -88 | -87      | -79      | -60      | -68      | -52      | -63      |

In order to get a deeper view on the coverage area and select the minimum number of devices that could use to get to total coverage area for the targeted building. The amount of RSS measured from each received location has been illustrated and listed in Table 4, where the points with colors represent the points within the preselected threshold. Furthermore, the effect of interferences and overlapping could be reduced based on the previous table by checking the value of each point individually. As a result, it has been found that using TxG, TxF2-AP1, TxF3-AP1 and TxF4-AP2 could achieve a
valuable coverage area where only 7 from 52 points within the targeted building would form the dead zone and as seen in Table 5. The previous selection of AP devices based on the data analysis could achieve a total coverage of 86.5% within the targeted building.

Table 4. The coverage percentage of each AP device and per each floor

| Received points | TxG   | TxF1 | TxF2-AP1 | TxF2-AP2 | TxF3-AP1 | TxF3-AP2 | TxF4-AP1 | TxF4-AP2 |
|----------------|-------|------|----------|----------|----------|----------|----------|----------|
| RxG            | 100%  | 16.6%| 25%      | 0        | 0        | 0        | 0        | 0        |
| RxF1           | 33.3% | 58.3%| 66.6%    | 50%      | 16.6%    | 8.3%     | 0        | 0        |
| RxF2           | 8.3%  | 50%  | 83.3%    | 100%     | 50%      | 50%      | 8.3%     | 16.6%    |
| RxF3           | 0     | 10%  | 50%      | 40%      | 80%      | 100%     | 50%      | 50%      |
| RxF4           | 0     | 0    | 16.6%    | 0        | 66.6%    | 50%      | 83.3%    | 83.3%    |

Table 5. Best coverage access point that have high-received power

| Received Points | TxG | TxF2-AP1 | TxF3-AP1 | TxF4-AP2 |
|----------------|-----|----------|----------|----------|
| Ground Floor   |     |          |          |          |
| RX1            | -55 | -70      | -80      | -78      |
| RX2            | -39 | -66      | -74      | -86      |
| RX3            | -39 | -60      | -70      | -84      |
| RX4            | -41 | -57      | -64      | -88      |
| RX5            | -42 | -65      | -74      | -90      |
| RX6            | -47 | -75      | -83      | -78      |
| RX7            | -59 | -64      | -75      | -88      |
| RX8            | -56 | -74      | -80      | -86      |
| RX9            | -41 | -75      | -81      | -78      |
| RX10           | -44 | -65      | -74      | -88      |
| RX11           | -46 | -81      | -87      | -87      |
| RX12           | -46 | -80      | -74      | -85      |
| RX13           | -60 | -57      | -66      | -75      |
| RX14           | -64 | -51      | -63      | -76      |
| RX15           | -65 | -45      | -60      | -76      |
| RX16           | -59 | -55      | -70      | -84      |
| RX17           | -63 | -52      | -67      | -76      |
| RX18           | -65 | -60      | -73      | -71      |
| RX19           | -55 | -44      | -59      | -80      |
| RX20           | -65 | -71      | -79      | -85      |
| RX21           | -57 | -56      | -62      | -89      |
| RX22           | -71 | -80      | -85      | -80      |
| RX23           | -78 | -86      | -89      | -88      |
| RX24           | -67 | -66      | -81      | -82      |
| RX25           | -77 | -52      | -70      | -80      |
| RX26           | -74 | -51      | -66      | -69      |
| RX27           | -71 | -46      | -56      | -56      |
| RX28           | -68 | -42      | -56      | -68      |
| RX29           | -69 | -38      | -47      | -75      |
| RX30           | -55 | -38      | -47      | -71      |
| RX31           | -72 | -45      | -57      | -68      |
| RX32           | -74 | -58      | -74      | -66      |
| RX33           | -80 | -60      | -74      | -72      |
| RX34           | -76 | -68      | -78      | -74      |
| RX35           | -71 | -66      | -78      | -87      |
| RX36           | -75 | -43      | -48      | -82      |
| Third Floor    |     |          |          |          |
| RX37           | -79 | -72      | -57      | -60      |
| RX38           | -87 | -70      | -55      | -51      |
| RX39           | -81 | -60      | -42      | -64      |
| RX40           | -86 | -39      | -30      | -64      |
| RX41           | -71 | -52      | -41      | -56      |
| RX42           | -82 | -70      | -50      | -58      |
| RX43           | -80 | -72      | -63      | -67      |
| RX44           | -81 | -75      | -70      | -69      |
| RX45           | -82 | -50      | -40      | -64      |
| RX46           | -86 | -56      | -49      | -65      |
| Fourth Floor   |     |          |          |          |
| RX47           | -84 | -69      | -58      | -44      |
| RX48           | -81 | -58      | -58      | -59      |
| RX49           | -80 | -65      | -58      | -40      |
| RX50           | -88 | -75      | -65      | -44      |
| RX51           | -88 | -87      | -65      | -58      |
| RX52           | -88 | -67      | -60      | -63      |
5. Conclusion
In this paper, we discussed indoor Wi-Fi positioning technology; we compute the real measurements of Access point locations that distributed on the building of the electrical department in the University of Technology and computing the Received Signal Strength (RSS). RSS measurement obtained from different received points located within the targeted building at different location using NetSpot pro software to analyzed Wi-Fi coverage and comparing the result with simulation results.

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