Determining the best location for indoor access point based on received signal strength

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Abstract
Recently, a massive demand for wireless communication for big data transfer has risen. However, the interface and high noise stem from a large number of wireless local area networks require a better improvement of our own wireless devices; one of the best solutions is to locate an optimal location for the access point to achieve good received signal strength. In this research, a case study of a large house is simulated using Wireless Insite software to find the optimum location of the access point to investigate better coverage area. In addition, the performance of wave propagation for frequencies of 2.4 GHz and 5 GHz are carried out to show the differences between them. The results help to find the optimum location that gives optimal coverage area. Also, the results show that using 5 GHz leads to significant attenuation in received power by about 12.744%; this means that the transmitted power of the 5 GHz has to be increased by the same percentage to achieve the same coverage area when using 2.4 GHz.

Keywords
Coverage area, Wireless Insite, access point, received signal strength.

1. Introduction
Wireless communication is commonly deployed in various areas such as homes, workplaces, schools, and other institutions. Wireless Fidelity (Wi-Fi) is well known to be one of the most important and providing technologies, which has been applied in different indoor environments [1]. Furthermore, this technology has been implemented in many devices, such as tablets and smartphones [2]. Wi-Fi’s work is based on the standards of IEEE 802.11, where it has been allocated two unlicensed frequency bands of 2.4 GHz and 5 GHz to be related to any Wi-Fi-based devices [3]. Gaining access to Wi-Fi networks need communication devices such as the communication between the Access Point (AP) and smartphones [4]. Transmitting and receiving data can be used to measure the values of signal strength and analyze it using the appropriate parameters to obtain the coverage area. The latter has been determined based on the number of distributed AP devices in the targeted area [5]. Placing too many AP devices would increase the total cost, noises, and interferences. Meanwhile, placing fewer AP’s would results in insufficient performance, gaps in coverage, downtime, and dead zones [6]. Hence, many of these problems would be solved by placing the access point at the optimal location [7]. However, it is difficult to accurately find the optimum locations without using suitable tools to design and test the received signal strength in various locations to ensure better service and coverage. Wireless Insite is an efficient tool used to module any building and simulates the wave propagation to study and evaluate its performance, for this reason, it has been used by many researchers in recent years [8].
Hence, it was chosen by the authors of this paper to design the simulation module for the case study building.

2. Related works

Many researchers attempted to locate the optimal location for deploying the access point using different methods, techniques, and algorithms. The oldest method was selecting the access point location manually, depending on the experience of the network designer. However, such a method required extra time and achieved inaccurate results [9]. Others introduced mathematical model as in [10], where these models demanded extra computational time and processes. On the other hand, many academics presented algorithms for access point deployment. In [11], the researchers used Multi Objective Genetic Algorithm as a means for maximizing the area of coverage of the access point deployment. Meanwhile, researchers in [12] utilized simulated annealing techniques, where an empirical propagation model has been introduced in an indoor environment to obtain the length of the wireless signal. Then, the area of coverage of the access point would be obtained and used for optimizing the access point deployment. In context, researchers have introduced a mix of greedy algorithms and simulated annealing in [13] to obtain the area of coverage of the access point and its related position coordination. The main drawback of the previous methods that they did not take into account the effects of various building material on signals propagation. In this paper, a big house is selected to apply our experiment to achieve higher received signal strength for the residents. This experiment will use the conventional access point, which works in 2.4 GHz that runs from about 2400 to 2483.5 MHz. The simulation part of the experiment will be carried out using Wireless Insite Software. Also, a real measurement will be applied using WI-FI Metter software to compare with the simulation results to ensure better coverage for our case study building. In addition, for future communications that require a higher capacity, a frequency of 5 GHz will be applied to show the characteristics of such frequency in the same case study. This part of the experiment aims to study the various effects of building materials on 5 GHz propagation and to determine which of the two frequencies is more suitable for indoor environments.

3. Methods and materials

This section provides the theory that this research is based upon as well as the tools used in conducting the research.

3.1. Theory

RSS is the signal power measured at the receiver antenna ($P_r$); it can be calculated according to Friis equation [14]:

$$ P_r = \frac{P_t G_t G_r c^2}{(4\pi)^2 (df)^2} $$

Where $P_t$ transmitter power, $G_t$, $G_r$ are antenna gain of the TX to RX, respectively, $d$ is the distance between TX – RX, $f$ is the carrier frequency and $c$ is the speed of light (3 x 10$^8$ m/s). RSS value represents the power received with noise, and the interference effects according to the equation [14]:

$$ RSS = P_r + I_{total} + N_{total} $$

Where $P_r$ received power, $I_{total}$ total interference and $N_{total}$ total noise within investigated area.
The Free Space Path Loss (FSPL) parameter can be estimated according to the equation [15]:

\[
FSPL = 20 \log_{10}(d) + 20 \log_{10}(f) + 20 \log_{10}\left(\frac{4\pi}{c}\right) - G_t - G_r
\]

The path loss model for indoor is formally expressed as [15]:

\[
L = 20 \log_{10}(f) + N \log_{10}(d) + P_f(n) - 28
\]

Where \( L \) is total path loss in (dB), \( f \) is the frequency of transmission in (MHz), \( d \) is the distance in meter (m), \( N \) is the power loss coefficient of the distance, \( n \) is the number of floors that separates between the transmitter and receiver, \( P_f(n) \) is the loss penetration factor of the floor. However, all results can be obtained in Wireless Insite software.

### 3.2. Simulation module

A simulation module of the case study has been designed in WI software, representing a house in Al-Mansour district, Baghdad, Iraq. This house has an area of 236 \( m^2 \) and consist of two floors with 3.5 \( m \) height of each ceiling, with the transmitter locations (TX) laying on a 2.5 \( m \) height. They are highlighted in black color rectangles illustrated in figure 1, while the receivers (RX) are deployed across the house, and they are highlighted in red color circles. All properties of TX and RX are listed in table 1.

![Image of TX and RX distribution](image_url)

**Figure 1.** The case study with a distribution of TX and RXs.

| Table 1. Transmitter and Receivers Properties. |
|-----------------------------------------------|
| Antenna Properties | Transmitter | Receiver |
| Antenna Type | Omnidirectional | Omnidirectional |
| Gain (dBi) | 7 | 2 |
| Power (dBm) | 9 | - |
| Polarization | V | V |
| Wave | Sinusoid | Sinusoid |

Also, the effects on wave propagation due to the different building materials (Wood, Glass, Brick, and Concrete) were considered for the entirety of the case study. Each material conductivity,
relative permittivity and thickness was based on the recommendation of the International Telecommunication Union for 2.4 GHz [10]. The values of each parameter for the materials used are illustrated in table 2.

| Material  | Connectivity | Permittivity | Thickness (m) |
|-----------|--------------|--------------|---------------|
| Wood      | 0.012        | 1.99         | 0.045         |
| Glass     | 0.0122       | 6.27         | 0.03          |
| Brick     | 0.038        | 3.75         | 0.28          |
| Concrete  | 0.066        | 5.31         | 0.30          |

Several locations for TX are in different rooms throughout the house in order to choose the best one that gives a better coverage area. Eight locations are tested to achieve multiple results that enable us to offer flexibility in choosing the access point location.

4. Results
The estimated RSS and the real RSS readings are compared for both 2.4 GHz and the 5 GHz to evaluate the overall accuracy.

4.1. Results of 2.4 GHz frequency
For simplicity, results of four of the eight locations that were experimented are shown in this section based on 2.4 GHz frequency. Figures 2, 3, 4 and 5 illustrate the estimated RSS with a red line and represent the real RSS with a black line.
Figure 2. Location 2 Received Signal Strength.

Figure 3. Location 3 Received Signal Strength.
Figure 4. Location 4 Received Signal Strength.

Figure 5. Location 6 Received Signal Strength.
From the above figures, it is clear that TX’s best location is location 2 in terms of providing the best signal strength for the receivers. The differences between the estimated readings and the real readings are due to the reflection from obstacles such as furniture, walls and other objects, leading to multipath environments. Also, the attenuation stem from the losses caused by those obstacles that separate between the transmitters and the receivers and the lossy nature of the transmission medium. Finally, the noise level degrade the system’s performance and hence, affects the resolution of the readings.

4.2. Results of 5 GHz frequency
In this section, the 5 GHz frequency simulation and real results for the same four locations previously shown in 3.1 is applied. The results are illustrated in Figures 6,7,8, and 9. The results show that the 5 GHz frequency gives worse performance than the 2.4 GHz in terms of received power and coverage area. This is due to the fact that a signal with a lower frequency is more capable of penetrating solid objects like walls, furniture and other obstacles. In addition, the coverage area for the 2.4 GHz is larger than that of the 5 GHz. The lateral also has noticeably higher propagation losses. Hence, this makes the 2.4 more suitable for indoor coverage than the 5 GHz for the time being until new improvements are applied on the 5 GHz. However, 5 GHz frequency have higher capacity and many researches attempts to improve its performance and reduce the attenuation stem from reflections and obstacles.

Figure 6. Location 2 RSS Using 5 GHz.
Figure 7. Location 3 RSS Using 5 GHz.

Figure 8. Location 4 RSS Using 5 GHz.
5. Discussion
In order to illustrate the differences between 2.4 GHz and 5 GHz in term of RSS values. A list of average RSS for the simulated four locations in 3.1 and 3.2 and the difference between them are shown in Table 4.

| Locations | 2.4GHz Average RSS (dbm) | 5GHz Average RSS (dbm) | Difference (dbm) |
|-----------|---------------------------|------------------------|------------------|
| Location 2 | -49.1169                  | -55.91805              | 6.80115          |
| Location 3 | -62.00485                 | -68.73015              | 6.7253           |
| Location 4 | -54.06845                 | -61.38015              | 7.3117           |
| Location 6 | -53.9605                  | -61.053                | 7.0925           |
| Total     | -219.1507                 | -247.08135             | 27.93065         |

There is a digression of RSS by about 12.744% between 5 GHz and 2.4 GHz; so that 5 GHz needs to improve its power by the same percentage to maintain the same coverage area and received power of the 2.4 GHz.
6. Conclusion
In this work, we have investigated the best location for the access point in a 236-m² area house to achieve optimum coverage for the residents. The results of simulation and real measurements, were applied for investigating better positions. It is found that location 2 provides the best service in terms of RSS. Also, a simulation for using 5 GHz instead of the 2.4 GHz was carried out to compare their performances in terms of received power and coverage area. The results show that 2.4 GHz provides better coverage and higher RSS than the 5 GHz frequency mainly because of the capability of the 2.4 to penetrate solid objects better than the 5 GHz, which also has considerably higher propagation losses than 2.4 GHz. Hence, degrade its performance as compared with that of 2.4 GHz for the given circumstances. We conclude that 5 GHz frequency needs an increase in transmitting power of about 12.744% to achieve the same coverage area and RSS of 2.4 GHz.

7. References

[1] Kondee K, Aomumpai S and Prommak C 2015 novel technique for reference node placement in wireless indoor positioning based on fingerprint technique ECTI Transactions on Computer and Information Technology (ECTI-CIT) vol. 9 pp.131–141,

[2] Puspitasari N, Al Fatta H and Wibowo F 2015 Implementation of greedy and simulated annealing algorithms for Wireless access point placement In 3rd International Conference on Artificial Intelligence, Modeling and Simulation (AIMS). IEEE, pp. 165–170

[3] Abdulwahid M, Al-Ani Sh O, Mosleh M and Abd-Alhameed A 2019 Investigation of Millimeter-Wave Indoor Propagation at Different Frequencies Scientific International Conference Najaf (SICN)

[4] Abdulwahid M, Al-Hakeem M, Mosleh M and Abd-alhameed R A 2020 Investigation and optimization method for wireless AP deployment based indoor network, IOP Conference Series: Materials Science and Engineering

[5] Han D, Andersen D G, Kaminsky M, Papagiannaki K. and Seshan S 2009 Access point localization using local signal strength gradient. in International Conference on Passive and active network measurement. Springer, pp. 99–108

[6] Fang S.H, Fang C.H and Y. Tsao 2015 Compensating for orientation mismatch in robust Wi-Fi localization using histogram equalization. pp. 5210–5220

[7] Anderson H R and McGeehan P 1994 Optimizing microcell base station locations using simulated annealing techniques in Proceeding of the 44th IEEE Conference on Vehicular Technology pp. 858–862

[8] REMCOM Inc. 2009 “ The Wireless InSite User’s Manual." version 2.6.3,remcom Inc. 315 s. allen st., suite 416 state college, p 16801
[9] Cheng Y, Jiang H and Wang F et al 2018 Using high-bandwidth networks efficiently for fast graph computation. IEEE Transactions on Parallel and Distributed Systems

[10] Obeidat H 2013 Indoor localization using received signal strength MSc dissertation, School of Engineering, Design and Technology, University of Bradford, Bradford, UK

[11] Nugroho M A, Wibowo F W 2014 Mapping of Quality of Service Parameter with Monitoring End-to-End Method of ITU-T Y.1541 Standard in The Hotspot Area, Advanced Science Letters, vol. 20, no. 1, pp. 259-263

[12] Lam C and Singer A 2006 Bayesian Beamforming for DOA Uncertainty Theory and Implementation Signal Processing. IEEE Transactions on vol. 54, no. II, pp. 4435-4445

[13] Subramanian A, Deshpande P, Gao P J, and Das S R 2008 Drive-by localization of roadside wifi networks, in INFOCOM. The 27th Conference on Computer Communications. IEEE. IEEE, pp. 718–725,

[14] H. Friis 1946 "A Note on a Simple Transmission Formula," Proceedings of the I.R.E. and Waves and Electrons

[15] J. Seybold, J. Wiley and Sons, 2000 “Introduction to RF propagation”