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Investigation and optimization method for wireless AP deployment based indoor network

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Abstract. In indoor communication, when handling the design issue for the wireless network, it is very important to select the appropriate wireless Access Point (AP) devices and specify the optimum locations for these devices deployment. In addition, reducing the total number of disseminated devices. In this paper, it has been investigating the network performance on the presidency building of middle technical university and based on AP deployment in the targeted building. Such investigation has been achieved using Wireless InSite software, based on the calculation of the parameters of path loss, and received power. Results obtained show significant variation in network performance and coverage at a different part of the building. As a result, a significant contribution has been proposed in enhancing the network performance, reducing the number of utilized AP devices from 13 to 8 devices. Furthermore, reducing both the total implementation costs and the interference effects inside the building.

1. Introduction

Wireless Fidelity (Wi-Fi) has been known to be the one of the most significant and utilized technology, which has been used for wireless internet connection in a different type of building [1]. One advantage of this technology has being implemented in a large range of devices such as smart phones and tablets, which has been widely used recently [2]. Wi-Fi was based on the standards of IEEE 802.11, where it has been using two unlicensed frequency bands of 2.4 GHz and 5 GHz [3]. In context, it might be significant to obtain large number of AP devices within indoor environment due to reasons related with its higher attenuation. Particularly, when signals pass through walls, obstacle and objects. As a result, the proper deployment of Wireless Local Area Network (WLAN) has a significant impact on providing the total coverage for the end users [4]. Coverage area has been determined by the number of AP devices, which has been distributed in the targeted area, where the placement of too many AP's increases the total costs and interferences. On the other hand, placing fewer AP's will produce a dead zone and leads to coverage gap [5].

The estimation of best deployment approaches for AP devices was and still on of the most important aspect, which has been investigated by many researchers. The first presented approach have been selected the AP locations manually and based on the guess of the network operator [6]. However, such approaches has confirmed to be time consumption and achieved inaccurate results. Other approaches as expressed in [7] proposed mathematical model to cover many user within the network. While, in [8] the researchers uses the Multi-Objective Genetic Algorithm (MOGA) as a method to maximize the signal coverage area. Meanwhile, Simulated Annealing techniques have been widely implemented by many

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researchers for different AP location estimation. For example in [9], the researchers propose a novel technique using heuristic approach that can specify locations to install the reference nodes and improve the location determination performance for a single-floor area and the multi-floor building. However, such method suffered from drawback of analysing results. In context, a combination of Greedy algorithm with Simulated Annealing has been proposed in [2] to implement the coverage area of AP devices and its position coordination of AP devices. However, it has been reported that the utilizing of such methods would regard the cost function. Recently, many methods have been presented for the optimization of AP placement, where in [10] the researchers presented model based on the use of Particle Swarm Optimization (PSO) with taking the attenuation consideration of wall. However, this study didn't consider the attenuation and effects of different walls. In [11] the researchers presented a mathematical representation and solution for AP placement problem by proposing algorithm to recommend the AP locations and increase the system accuracy. Such algorithm has not been tested by any simulation or real measurement testing. Meanwhile, the researchers in [12] developed a Genetic algorithm (GA) to solve the placement problem and find the global optimal solution. Such method has a drawback of ignoring the effects of obstacles and this mean that any two building with the same size would have the same AP deployment regardless to building materials and wall types.

In line with these contributions, in this paper an investigation for the deployment of AP devices in real building has been simulated and presented. Investigation has been achieved by using Ray-Tracing approach based Wireless InSite software [13]. The effect of building material on the utilized 2.4 GHz band has been corporate with investigation. Results obtained based on the parameters of path loss and received power obtained previous software. In addition, an optimization for AP deployment has been investigated and presented, where it has been proposed using another AP model. This method has the capability to increase the received power and reduces the losses. Moreover, reducing the total number of utilized AP devices and the total implementation costs. The rest of the paper is organized as follow. The propagation characteristics are described in section 2, section 3 presented the case study, and section 4 discussed the obtained result. Finally, section 5 presents the conclusion.

2. Propagation Characteristics

The characteristics of wireless signal would be changed in a significant manner, when these signals transfer from the transmitter to the receiver's antenna. As a result, many parameters are used to define the characteristics of signal propagation. The parameters utilized in this study are the path loss and received power. On the other hand, the different type of materials has a significant impact on the wave propagation and as a function to the frequency [13]. Hence, in this paper the dependency of frequency on different material properties has been considered and based on the electrical constants of each material. These constants represented by the relative permittivity (η ') and conductivity (σ), which has been obtained based on the utilization of 2.4 GHz frequency band.

2.1. Path Loss Characteristics

Which represent the amount of power transmitted by the transmitter device to the power amount that has been received. In addition, it can be denoted as the measurement of the attenuation value for signal propagated at the receiver [14]. Path loss has a significant in the calculation of coverage area and identifying the sensitivity of the receivers [15]. Path loss can be calculated based on equation (1) as seen below [16,17].

$$PL(d) \text{ in } dB = \overline{PL}(d_0) + 10\alpha \log\left(\frac{d}{d_0}\right) \tag{1}$$

Where $\overline{PL}(d_0)$ is the path loss value at a reference distance d_0 and d_0 is equal to 1, d is the separated distance between the transmitter and receiver and α is the path loss exponent.

2.2. Received Power Characteristics

Received power is the most important parameter for describing the multipath propagation characteristics, which represent the power level received by the receiver device after being exposed to many influences. Received power can be calculated based on equation (2) [13].

$$P_{R}(dBm) = 10 \log\left(\frac{P_{T} \lambda^{2} \beta}{16\pi^{2} d^{2}}\right) + 30(dB) - L_{s}(dB)$$
(2)

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Where P_T is the time averaged of the power, λ is the wavelength of the carrier frequency, L_s is any additional losses that pass through the network system and β is an overlap of the frequency spectrum in the transmitted waves.

3. Case Study

The site investigated in this work including the presidency building of middle technical university, the network deployment and performance within targeted building has been incorporated with investigation. The case study has been designed, modelled and simulated using Wireless InSite software as seen in Figure 1. The network deployment has been simulated, where it has been distributed the same number of AP devices with the same real scenario locations. The total numbers of AP were 13 devices distrusted within the three floors of the targeted building and as seen in Figure 2. For the receivers, it has been distributed 20 received points within each floor and in each room with a height of 1 meter and as seen in Figure 3. The properties of both AP and receiver antennas have been listed in table 1. The serious effects of different building materials and building structure on propagation characteristics was taken into consideration for the entire investigation, where each material thickness, conductivity (σ) and permittivity (η) was calculated based on software designed in a previous work and based on the recommendation of International Telecommunication Union (ITU) [18]. In addition, these values have been listed in table 2. It is worth to mention that the selected bandwidth was 20 MHZ with 2.4 GHz frequency band.



Figure 1. The simulation model of the targeted building.



Figure 2. The distribution of AP devices in each floor of the targeted building.



Figure 3. The distribution of received points in each floor of the targeted building.

Antenna properties	TxAntenna	Rx Antenna		
Antenna type	Omni-Directional	Omni-Directional		
Input Power (dBm)	28	-		
Gain (dBi)	5	1.8		
E-Plane HPBW	90°	90°		
Waveform	Sinusoid	Sinusoid		
Temperature (k)	293	293		
VSWR	1	1		
Polarization	V	V		

Table 1. AP and Receiver Antenna Proprieties

Materials	Thickness (m)	η`	σ		
Concrete	30	5.31	0.066		
Wood	4.5	1.99	0.012		
Glass	0.3	6.27	0.012		
Brick	28	3.75	0.038		
Ceiling Board	0.9	3.66	0.001		
Floor Board	2.2	1.5	0.014		
Drywall	0.9	2.94	0.021		

Table 2. Material thickness, conductivity and permittivity values

4. Results and Discussion

The aforementioned case study in the previous section has been simulated using Wireless InSite program. The obtained results will be discussed based on the two investigated parameters of received power and path loss. To study the performance of received power versus the separation distance and for all the 20 received point located in each of the three floor of the targeted building. Figure 4 shows the amount of received power obtained from each AP's devices in each floor respectively. In addition, the amount of received power for the optimized deployment method has been clarified in the same figure. In general, it can be seen that the new AP deployment (labelled in red) has achieved relatively higher values as compared to the values obtained from the current deployment (labelled in blue).



Figure 4. The amount of received power versus separation distance obtained from each AP located in each floor.

Furthermore, this optimization method was based on the requirement of less AP devices to be deployed as compared to the traditional one, where it has been reduced the number of devices by 1, 2 and 2 AP devices in ground, first and second floor respectively. The average received power amount has been calculated for each AP connection in each floor and as listed in table 3. It can be seen the optimization of AP deployment has raised the values of received power. Moreover, reducing the number of deployed AP. On the other hand, the hardware specification and characteristics has a significant impact in limiting the capacity and the availability of the communication. Particularly, as can be seen in our targeted building where it has been deployed Pico Station AP devices with 5 dBi antenna gain. Based on our investigation it has been deduced that using these devices with such indoor environment would not achieve valuable performance and cover the entire area. As a result, it has been investigated the ability to replace these devices with AP model TL-WR941HP which includes three antennas of 9 dBi gain and as seen in Figure 5 [19]. The proposed locations for the new deployment of our targeted building can be seen in Figure 6.

Floor	AP1	AP2	AP3	AP4	AP5	New1	New2	New3
Ground Floor	-34	-31	-33	N/A	N/A	-28	-26	N/A
First Floor	-39	-34	-31	-31	-41	-26	-32	-27
Second Floor	-41	-36	-33	-30	-32	-29	-27	-26

Table 3. Average received power values obtained from each AP devices in each floor



Figure 5. The proposed AP device to be replaced with in our targeted building as an optimized method for network and coverage.



Figure 6. The proposed AP deployment within the targeted building.

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Path loss parameter has been studied by clarifying its relation with the separation distance. In general, it can be seen that raising the separation distance would increase the losses. The amount of average path loss values obtained from each AP device located in each floor and based the original and optimize deployment can be seen in table 4. It can be seen that the optimization deployment proposed for the targeted building reduced the losses in general manner as compared to the original deployment. Hence, it could be a brief consideration to verify the optimization proposed based on the use of powerful wireless InSite software.

Floor	AP1	AP2	AP3	AP4	AP5	New1	New2	New3
Ground Floor	69	66	68	N/A	N/A	69	68	N/A
First Floor	74	69	66	66	76	73	69	67
Second Floor	76	71	68	65	67	76	70	66

Table 4. Average path loss values obtained from each AP devices in each floor.

5. Conclusion

Network performance for the targeted building has been investigated in this paper. In addition, optimization deployment for AP devices have been presented and carried out based on the parameters of received power and path loss that obtained from Wireless InSite software. The targeted building has been designed and modelled using the previous software. The effect of building material and frequency sensitivity material has been considered in this investigation. The presented Network coverage and performance has been analysed and showed discouraging results in covering the entire building. As a result, it has been proposed an optimization for the deployment of AP devices in order to enhance the coverage area and overall network performance and by using another model of AP devices. The proposed AP device has the capability to provide higher power and higher antenna gain. Hence, a new deployment has been presented to reduce the total number of AP devices from 13 to 8. Additionally, increasing the received power and reducing the path losses. Furthermore, reducing the total interference effects and achieving higher coverage area at lower Implementation costs. For future work, the presented deployment would be implemented in real scenario to verify it and the related accurate results obtained from Wireless InSite software.

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