Investigating the Access Point height for an indoor IOT services

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Abstract. The prospects of location estimation and localization approaches in Wireless Local Area Network (WLAN) by using Received Signal Strength (RSS) have gained significant resonance recently. Selecting the appropriate highest for Access Point (AP) and Transmitter devices can achieve higher accuracy for different localization approaches and IoT (Internet of Things) based services. In addition, reducing the shadow fading effects and increasing the coverage area. In this paper, the effect of different AP height on the variation of signal strength was investigated with a height ranging between (1-2.5) m. The obtained RSS measurement indicates that AP height at 2.5 m can achieve best RSS measurement with respect to receiver height of (1.10) m, especially for NLoS received points. Furthermore, RSS measurement system has been designed and utilized for this investigation. The measurement system is connected with an open based cloud platform for aggregation, visualization and analysing the measurement data. The proposed system can achieve high-speed RSS measurements, low-cost implementation and provide more facilities in collecting and monitoring a huge amount of data.

1. Introduction
During the past last years, wireless communication has become more significant on our daily life [1]. The huge development of such communications and techniques has opened new prospects to exploit the availability of the wireless radio signal [2]. The most important uses for the later was services based localization approaches [3, 4], where the wireless signals have been utilized for several purposes of localization. Even though Global Positioning System (GPS) has been fairly used for outdoor scenarios [5], it performs poorly in indoor environments [5]. Localization-based indoor scenario suffers from bunch of challenges as compared to outdoor localization due to the complexity of indoor environment [6], the observed effect of different materials inside the building on the dissemination of signal and the need for higher accuracy at a lower cost and no extra hardware support [7]. In contrast, Indoor localization market had been suffered from rapidly increasing lately and the growth is in a persistent basis [8, 9]. The locating of the Radio wave (RW) transmitter in a wireless network (WN) has a significance over an extensive range of purposes [1], such as the locating of the non-functional Access point (AP), operating and managing the WN and estimating the propagation characteristics of the RW [10].

The efforts of the researchers and industrials have resulted in developing several approaches and techniques for accurate and low-cost localization methods, especially for indoor environments. These techniques based on the measurement of Received Signal Strength (RSS), Time-of-Arrival (ToA), Angle-of-Arrival (AoA), Artificial Neural Networks (ANN) and other methods. ToA-based techniques presented by researchers in [11, 12] which require synchronization and accurate timing for...
components and thus the complexity of the system has been increased. In contrast, researchers in [13] use AOA for localization, such as system will require antenna array (directional antenna) and extra cost and time. Researchers in [14, 15] uses neural networks and probabilistic methods. However, these methods require a higher capacity for computational processes. On the other hand, RSS based method has gained researcher interest, due to the main reason of not needing additional infrastructure cost since most of the building is equipped with Wi-Fi AP [16].

Several RSS based localization approach has been utilized; one approach was fingerprint-based approach, where the location fingerprint approach uses the RSS for location estimation [17, 18]. Such an approach would consider 2 phases, the off-line phase, and the on-line phase. In the first phase, a database is created by collecting and storing the RSS measurement. The second phase starts by comparing measurements value with actual values for different location estimation issues. The most important drawback of this approach related with the size of the database when handling a large number of observations. The model for indoor propagation channel has a significant impact on RSS value which shows variability with changing locations [19]. This variability based on many effects of the separation distances, the geometrical, different materials used and the movement of the objects. Additionally, multipath and shadow fading have a great effect on RSS values [20]. In contrast, RSS based location estimation is significantly affected by the position of the AP and position of received points. AP location estimation was highlighted by many researchers. For example in [21], the researches proposed neural networks method for AP locating. The drawback of this method was considering all receiver locations are in LoS scenario with AP. Other researchers in [22] proposed Kernalised distance algorithm (KDA) for AP positioning. However, such technique is very complex to be implemented in real scenarios. In contrast, researchers in [23] study the effect of transmitter placement in the wireless sensor network. It's worth to mention that, all these proposed methods have not been addressed the effect of different AP height on RSS variation.

From this standpoint, in this paper, the effect of AP height on RSS measurements was investigated with height ranging between (1-2.5) m. RSS measurement of 250 samples per each received point location were taken. In addition, measurement system was designed to calculate the RSS value from each received points. The system has a capability to remotely connect to open based cloud platform for the live visualization and analysing of RSS data stream obtained from each received points. In addition, the serious effect of different obstacles and furniture within the targeted area are considered within the selection of AP height. The paper construction is as follow, RSS measurement and case study are explained in section 2 and 3 respectively, section 4 clarified the measurement system, and section 5 demonstrates the result and discussion of our work. Finally, section 6 highlights the conclusion.

2. Received Signal Strength (RSS) Measurement

The characteristics of wireless signal would be changed in a significant manner, when these signals transfer from the transmitter to the receiver antenna. As a result, many parameters are used to define the characteristics of signal propagation. The parameters utilized in this study is received signal strength. 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].

RSS was one of the most utilized measurements in recent localization systems and wireless coverage estimation methods [10], because its works together with the powered noise to define the value of the Signal to Noise Ratio (SNR) for the signals. Based on Shannon low [24], SNR represents the valuable capacity of the communication system. Furthermore, RSS measurement play major role in monitoring the performance of different wireless devices [25] since most of such devices offer direct access to RSS values. In addition, being available in the most popular operating system such as Microsoft Windows and Android [26, 27]. RSS represent the power received by the receivers in each location with the total effects of interferences and noises as seen in eq. 1.

\[ RSS = P_R + I_{total} + N_{total} \] (1)
Where \( P_R \) is the received power in the selected location, \( I_{total} \) is the total noise and \( N_{total} \) is the total interference. For accurate results, we measure 250 RSS measurement samples per each location, and then the mean value would be obtained from these samples. In order to measure, handle and analyse the huge amount of measurements, a dedicated measurement system was designed to measure RSS values at high-speed measurement and low cost implementation. This system will be discussed in next section.

3. Measurement System

The performance of different AP heights with respect to different received points will be investigated in this work. Realistic RSS data are collected in both LoS and NLoS scenarios. LoS represented the case of direct path between the AP and received points, while in NLoS the path is partially or fully obstructed. In our case, the wireless signal is obstructed by different furniture and object within the targeted area. A wireless router (TL-WR941HP) is configured and used as an AP device. The most important AP and properties are listed in Table 1.

| Properties       | Access Point device |
|------------------|---------------------|
| Type of antenna  | Omni- Directional   |
| Transmit power (dBm) | 30                  |
| Gain of the antenna (dBi) | 9                   |
| Frequency (GHz)  | 2.4                 |
| Type of polarization | Vertical           |
| No. of antenna   | 3                   |
| Data rate        | 450 Mbps            |

Table 1. The selected AP properties
For the receiver, it has been selected EPS8266 Wi-Fi module chip [28] as seen in Figure (2-a) to form the receiver device. In addition, the chip is configured to measure the RSS value obtained in each location for each AP height scenario. Furthermore, it is configured to be remotely connected with open cloud platform provided by Thing Speak web service to aggregate, visualize and analyse data measurements directly as obtained from each location. The later web service is compatible with much hardware such as Arduino, Nod MCU, Raspberry Pi and other hardware. The configuration includes setting the parameters of channel ID and API keys for writing and reading data stream which in our case the RSS measurement values. Note that, these parameters provided from our web services. The reason behind designing our measurement device with previous configuration is to make the system more reliable and can handle huge amount of data measurements, which in our case 250 RSS sample per each location. The measurement procedure can be clarified in Figure 3, where the laptop with Nod MCU (EPS8266) chip is connected to wireless AP device and configured with appropriate API keys and channel ID provided from the cloud platform. Next step was setting the laptop in each selected received point locations for measuring the RSS values. Another laptop can be used for online visualization and monitoring the real time measurements. Finally, obtained measurement data would be organized and stored for further analysis. It is worth to mention that the main reason for using this device rather than using free RSS measurement software is the ineffectiveness in performing and handling huge data measurement. The above steps of our proposed system could be summarized in the flowchart described in Figure 4.
Figure 2. EPS8266 Wi-Fi module chip connected to laptop

Figure 3. Measurement procedure with open based cloud platform

Figure 4. Flowchart describing the steps of our proposed measurement system

4. Case Study
The floor plan of the targeted area that has been investigated in this work is illustrated in Figure (5-a), where it can notice the distribution of different furniture of metal and wood. For the transmitter or AP device, it has been selected a fixed location for AP within the investigated area. In contrast, the height of the AP was ranging from (1-2.5) m within fixed location. For the received points, it has been selected (10) locations to be incorporated with investigation. The height of received points was 1.10 m
above the floor ground. The selected locations can perform both scenarios of Line-of-Sight (LoS) and Non-Line-of-Sight (NLoS). The deployment of AP with selected previous range and received points can be clarified in Figure (5-b). Furthermore, the effect of different building materials, wall thickness and the distribution of different obstacles and furniture were considered with selecting the optimum height for achieving the best coverage and reducing the shadow fading effect.

![Figure 5. Floor plan for targeted area where: (a) the distribution of different furniture and objects, (b) the deployment of AP and received point locations.](image)

5. Results and Discussion
The penetration of wireless signals is in all directions. Hence, it affected by the reflection of walls, furniture, and other objects. As a result of reflection, multiple copies of the originally transmitted signal arrived to the received points with different delays and attenuation. Such a phenomenon is known as multipath propagation. RSS measurement is susceptible to characteristics of the indoor channel including multipath, shadow fading and objects movement. To display the performance of RSS versus separation distance between AP and each received points, Figure 6 illustrates that relation. RSS measurements were obtained by deploying the AP at the particular locations. An average of 250 RSS measurement observations is taken as a result for each received point location as listed in Table 2. It can be deduced that for near distances (< 10 m) the AP height of 1.75 was the optimum for deployment. While, for long distanced (>=10 m) 2.5 m was the best choice to perform better RSS measurement. Hence, it can be concluded that effect of different distributed objects, obstacles and barriers within the indoor environment can be reduced with AP height of (2.5m).

![Figure 6. Received Signal Strength (RSS) vs. separation distance](image)
Finally, the relation between RSS versus the location number is illustrated in Figure 7, where a direct relation can be seen between AP height and RSS values. Generally, increasing in AP height can lead to increase the RSS measurements and raise the coverage area. In addition, the effect of shadow fading would be reduced. For that reason, it can be concluded that setting the AP with height of 1.75 m is suitable for better coverage within points in the same room of AP device (which in our case were the point from 1 to 6). However, for the case of points located within other rooms (which in our case points from 7-10), the height ranging between 2.25-2.5 m has recorded the better results. Furthermore, selecting the appropriate AP height can contribute to improve many localization aspects and enhance performance for both services based IoT scenarios and location estimation.

| Rx Location Number | Average Value for RSS in each Access point Height |
|--------------------|--------------------------------------------------|
|                    | 1 m  | 1.50 m | 1.75 m | 2 m  | 2.25 m | 2.5 m |
| 1                  | -41  | -45    | -33    | -42  | -37    | -36   |
| 2                  | -42  | -38    | -44    | -41  | -42    | -33   |
| 3                  | -43  | -33    | -32    | -38  | -34    | -37   |
| 4                  | -37  | -42    | -40    | -41  | -37    | -40   |
| 5                  | -39  | -45    | -39    | -43  | -41    | -42   |
| 6                  | -56  | -61    | -55    | -49  | -61    | -47   |
| 7                  | -48  | -44    | -48    | -43  | -40    | -44   |
| 8                  | -67  | -68    | -66    | -65  | -67    | -63   |
| 9                  | -63  | -66    | -69    | -65  | -60    | -59   |
| 10                 | -73  | -71    | -66    | -66  | -72    | -64   |

**Figure 7.** Received signal strength measurement vs. location number

6. Conclusions
In this paper, an investigation of different AP height based on RSS measurement has been presented. The investigation involves AP height ranging between (1-2.5) m. Furthermore, in this paper it has been designed and presented RSS measurement system. The system uses EPS8266 Wi-Fi module chip with appropriate configuration to measure and collect 250 RSS value per each location. Such system has configured to remotely connect with open based cloud platform to aggregate, visualize and analyse measurement data directly as obtained from each location. Obtained results indicate that there is a reverse relation between RSS and separation distance. On the other hand, a direct relation was found between RSS and AP height. It has found that for distance less than 8 m the optimum height was 1.75. However, for long distances the optimum height for AP would be ranging between 2.25-2.50 m.
additionally, the effect of shadow fading, multipath propagation, different objects and obstacles could be decreased with selecting optimum AP location. For that reason, selecting the optimum height may contribute to enhance the accuracy for localization approaches and location estimation issues. As well as, enhances the network coverage and overall performance. In the future, the presented connectivity method could be performed as a client-to-cloud communication model for different IoT scenarios to achieve both reliability and robustness.

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