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Indoor WIFI Signal Prediction using Modelized Heatmap Generator Tool

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***Abstract*—Wireless design is essential as it provides time and cost saving. Several WIFI planning tools are available on the market but most of them were initially designed to be user-friendly and provided limited configuration options making it hard to model site-specific environment factors. In this paper, we proposed a WIFI heatmap generator tool that allows users to predict wireless signal strength within the building. Our tool allows users to characterize wireless propagation model including pathloss exponent and pathloss attenuation factors which are usually caused by wall partitions, building layouts, etc. Network administrators and wireless users can deploy this tool to visualize heatmaps which represent wireless received signal strength in each location of the floor plan. Limited WIFI coverage area can be easily determined using this tool. This can be helpful during access point deployment and redeployment. A site-specific propagation model was proposed, and the accuracy of this model was discussed at the end of this paper.**

I. Introduction

To design wireless local area network within a building, it is preferable to plan beforehand the installation of the wireless devices by considering several factors that may affect quality of services of wireless networks including density of clients in the area, amount of throughput and tradeoff between installation cost and number of access points to provide optimal WIFI coverage. The information about wireless coverage is usually represented in the form of a heatmap. A heatmap is a graphical representation of data where the received signal strength indicator (RSSI) values at each position are represented as colors.

Several WIFI planners which are currently available on the market allow us to visualize a heatmap in an area of interest to preliminary predict WIFI coverage. However, most of the available tools were designed to be simple, user-friendly and didn't allow much modification to the current settings. Moreover, the details of the propagation model is not available to public. As we wanted to simulate the heatmap in our building and we did not find any tools that allowed us to configure the settings to suit our testing environments, we decided to implement a new WIFI heatmap generator tools that take in to account various factors that may affected indoor propagation of wireless signals.

Our developed WIFI heatmap generator allowed wireless users to simulate wireless signal propagation by considering the layouts of the building, building structures, wall partitions and the materials that they are built of. Therefore, the heatmap generated is more specific to the building environment. The tool allows visualizing with precision the RSSI at each position. This tool will be useful to either wireless users or wireless administrators to serve during wireless survey as it can indicate limited coverage area or simulate the signal propagation for various access point configurations. The survey helps reducing cost and saving time during real access point installation. Our objective is to develop the tool that best assimilate real nature of indoor wireless signal propagation.

This paper was organized as follows: In the first section of the paper, we presented literature reviews of existing wireless propagation models. Next, we described our framework. A propagation model for our site-specific building has been proposed. Later, we represented our simulated results compared to the real RSSI measurements for each position in the floorplan. Finally, a conclusion and future works were proposed in the last section of this paper.

II. Literature Reviews

A. Indoor Propagation Model

Signal is affected by attenuation as its strength decays with the distance. When distance is the only factor that effected the signal such as a transmission in a free-space, without any obstacles between the transmitter and the receiver, the loss of the signal can be represented by a *free-space propagation model* as follow [1], [2]:

$$PL(d) = PL(d_0) + 10n \log \frac{d}{d_0} \tag{1}$$

where d_0 is a reference distance for the antenna far field and is usually assumed to be 1-10 meters indoor, n is a pathloss exponent and d is a distance from the transmitter.

In fact, it is almost impossible to avoid other factors when it comes to consider signal transmission in real world. Wireless signal may be affected by many other factors such as reflection, refraction, diffraction, fading or doppler shift which cause multi-path propagation problem. The characteristics of signals received at the receiver will be altered in terms of amplitudes, frequencies or phases from the original signal. The reconstruction of signal may not be perfect and leads to the loss of information conveyed by the destructive signal. To approximate how a signal has been altered, it is not easy to develop an exact model since each environment affects the signal differently. When it comes to study signal propagation, it is very specific to each location since the layout and the structure of each building are not the same, the material of the

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Model	n	K'	Remark
ITU	1	39.6	
AFC	2.58	53.2	for $d < 9$ meters
AFC	2.91	56.4	for $d > 9$ meters
2.4 GHz model	3.1	47.87	

TABLE I. INDOOR PATHLOSS MODEL PARAMETERS

structure can also be varied between each area too. In [2], the author proposed a well-known empirical propagation model that allows the user to personalize the model. By considering attenuation factors from floors (FAF) and partitions (PAF). The model can be described as:

$$PL(dB) = PL(d_0) + 10n\log\frac{d}{d_0} - K + \sum_{i=1}^{N_f} FAF_i - \sum_{i=1}^{N_p} PAF_i \tag{2}$$

with K a unitless constant that depends of antenna characteristics and the average channel attenuation. Although this model considers characteristics of blockage from walls and floors, in practice, each position is subject to different blockages. Received signal strength indicator (RSSI) at each position in the building will not follow the same rule.

Several statistical or empirical model has been proposed to adapt the model to fit with the indoor environment. By assuming n from equation 2 as an attenuation factor and $PL(d_0) - K + \sum_{i=1}^{N_f} FAF_i - \sum_{i=1}^{N_p} PAF_i$ as a constant K' that allow correcting the slope to fit to empirical data. The (ITU) indoor path loss model was described by this following formula:

$$PL(dB) = 10n\log d + K' \tag{3}$$

where the reference distance d_0 is taken at 1 meter to normalize to that which occurs at the distance d_0 from the transmitter and only the propagation effects are included. d is distance between transmitter and receiver in meters.

Several works have been trying to parameterize the attenuation factor n and the constant K' in equation 3. These included the ITU pathloss model [3], AFC model [4], [5] and the 2.4GHz model from [6]. The results from the experiments in various environments were presented in table I [6].

The movement of people also greatly varies amplitudes of the transmitted signal and make indoor channel non-stationary, this is more noticeable at higher frequency [6]. Accuracy of the experiment can further be enhanced with a more complex model that take into consideration multipath effects.

III. RESEARCH METHODOLOGY

In this work, we have developed a java-based simulator that allow generating WIFI heatmaps. The details of the framework and the testing results are provided in the following section:

A. Framework

The heat map generator developed in this work is a java-based platform. The user interface of this simulator is shown in figure 1. The UI allows the user to upload a floorplan. Next, the user sets the scale of the floor plan by specifying the real distance in meter between two positions on the map. After that, the user can choose to place access points or define walls.

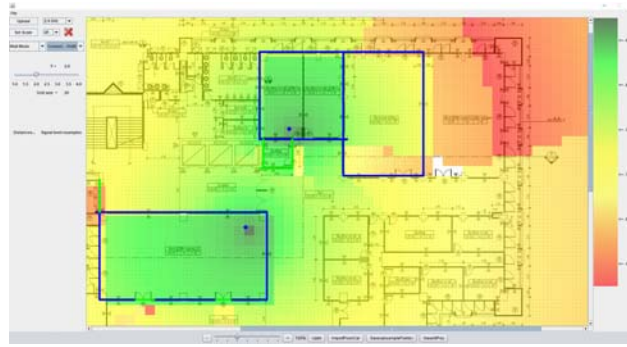

Fig. 1. User interface of heat-map simulator

The user can configure the following characteristics for access points and walls:

- **Access points**: position, transmitting power, transmitting frequency
- **Walls**: layout, wall attenuation (as described in section III.B)

While placing the access points, the wall, the program automatically computes the received RSSI for each position on-the-fly. As a result, each position in the building is subjected to different attenuation factors since signals received at each position travel from different paths. Thus, from equation 3, pathloss exponent n and constant K' of each position vary.

For the rest of the studies, the access points and wall partitions in the area of interest were defined in figure 2. An access points were represented as a big blue circle. We noted 8 access points in total. We have categorized wall partitions into three types: concrete, plaster and steel wall. The attenuation factors of these walls will be later described in subsequent sections.

B. Parameter Setup

The experiments that follow is performed on an HP pavilion 14-e005tx laptop computer. The access points were installed at one-meter height above ground. To calculate the previously described parameters, we have performed the experiments as follow:

- **Pathloss exponent**: we have chosen to evaluate the RSSI of 3 access points as a function of distance away from the access points. The measurement was performed every 2 meters. We took an average from at least 10 samples for each position and we computed pathloss exponent by fitting the curve of graph to equation 3. We obtained the value of pathloss exponents n from access number 1, 2 and 3 to be 2.325, 3.1 and 2.635 respectively so we decided to choose n as an average of 2.687.
- **Wall partition attenuation factor**: after the survey, we can categorize walls in the building into 3 types: concrete, plaster and steel wall. To calculate the attenuation factors for each material, we placed an access point on one side of the wall and measure the RSSI before and after the signal propagation through the

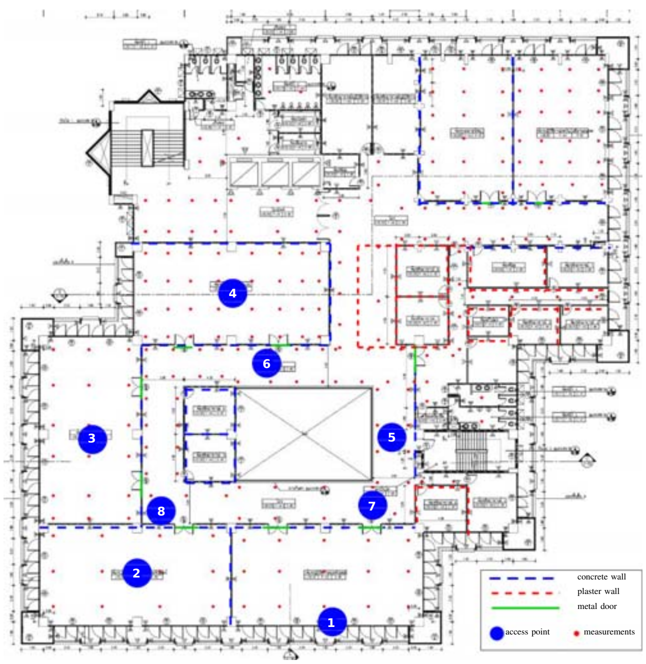

Fig. 2. Access points and wall partitions in a floorplan of interest

wall. By taking an average of 5 measurements for each sample, we obtained the attenuation factors for concrete, plaster and steel wall equals to -10.48 dB, -5.1 dB and -15.4 dB respectively.

C. Heat map generation

Once the pathloss model for each wall partition was computed, the heatmap were be generated. The heatmap represented the maximum received signal strength indicator (RSSI) obtained from available access points in each grid at coordinate x and y. This were retrieved from:

$$RSSI(x, y) = \max_{1 \leq i \leq 8} RSSI(x, y)_i \tag{4}$$

IV. Experimental Results and Evaluation

In this section, we evaluated the accuracy of previously generated heatmap by comparing the simulated results with real measurements collected at 237 positions. The value from each position was taken from an average of 10 measurements spacing between 7 seconds. The positions that we chose to do our experiments were illustrated as small red circles in figure 2.

A. Accuracy testing

a) RSSI testing: Considering RSSI evolving over the distance issued from one access point (e.g. access point number 5) as shown in figure 3, The unit of distance shown in the figure was scaled to 38 units per 1 meter. We noticed that error ratio was improved when the measurement was closed to the access point which is in accordance with the fact that wireless signal is usually fluctuated and unstable due to signal fading and multi-path environment.

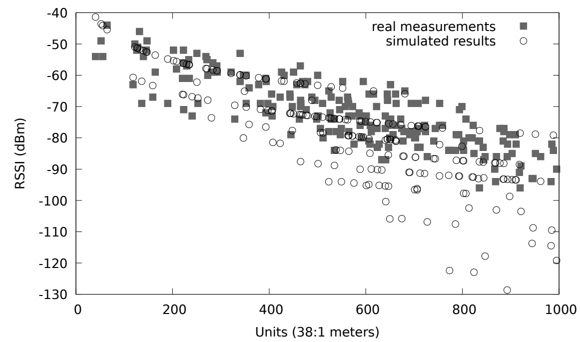

Fig. 3. RSSI level from simulated vs. real measurement

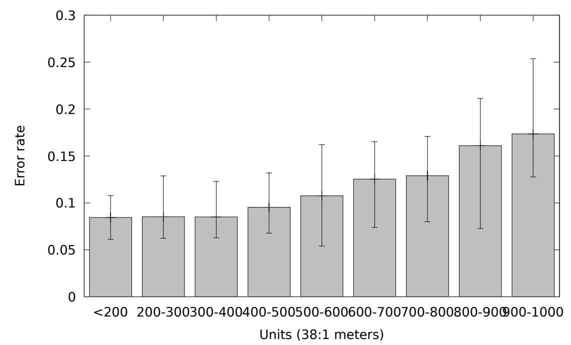

Fig. 4. Average error ratio as a function of distance from all access points

We further studied RSSI as a function of distance of all available access points on the floorplan and presented the results in figure 4. We noticed that within the range of 400 units or approximately 10.5 meters, the error rate was approximately 6%.

To study the effect of access points location on the accuracy of the testing results, we computed the error rate obtained from each available access point as shown in table II, we remarked that most measurements provided error margin less than 10% of accuracy and signals from the access points situated in the corridor were likely to outperform the ones situated inside a room. We could see that most access points that gave error ratio lying within 10% error margin were likely to be situated in an open-air area such as in the corridor whereas others that were shielded by wall partitions provided less accurate results.

b) Overall heatmap testing: The heat map shown in figure 5 was generated by taking maximum samples of RSSI for each location. Almost all RSSI that were shown here were measured within the range of 400 units from the access points. From the previous paragraph, we could assume that error rate should be less than 0.06. Figure 6 represents a gradient of error ratio obtained from comparing real RSSI measurements with

AP number	Error ratio	AP number	Error ratio
1	0.066	5	0.067
2	0.111	6	0.086
3	0.110	7	0.071
4	0.081	8	0.084

TABLE II. Average error ratio of RSSI measurements from each access points

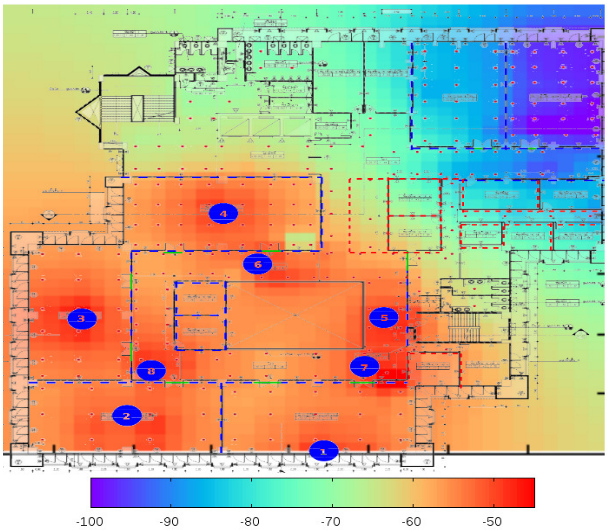

Fig. 5. WIFI heat map

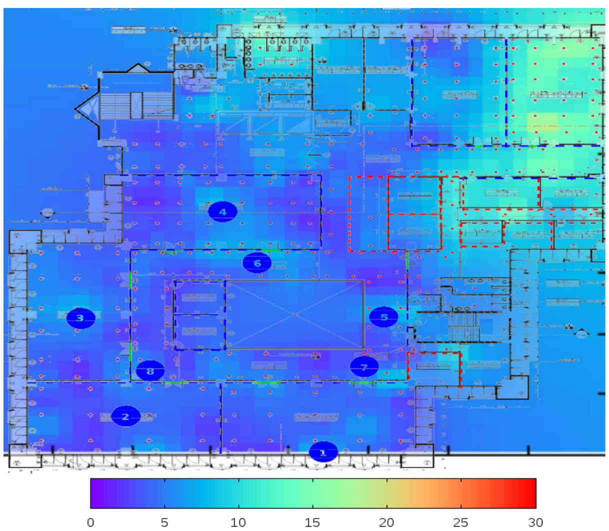

Fig. 6. Error ratio of calculated RSSI compared to real measurements

the simulated results, as expected, most of the testing location had an error ratio less than 6%.

Lastly, we wanted to compare our results with other available WIFI heatmap generator. However, we did not have access to the RSSI data of most of the tools. We were only able to obtain the graphic visualization of the RSSI in term of heatmap. We chose to compare our results with Fotiplanner software since it was more precise than many tools and allow users to modify some of their environment settings. Although Fortiplanner allowed users to place walls and input the pathloss exponent value, the propagation model deployed in the software was unknown to public and could not be changed. The RSSI gradient from Fortiplanner seems to be in accordance to our tool as shown in figure 7. Since we did not have access to its data, we could not determine the error rate of this tool.

After using our tool to survey WIFI coverage in our building, we obtained a satisfactory accuracy of less than 0.06

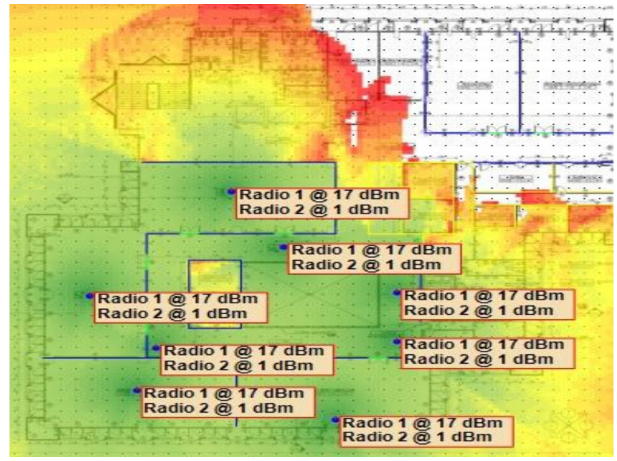

Fig. 7. WIFI heat map generated from Fortiplanner tool

error rate. The developed tool can be used to visualize isolated area. We had suggested adding 2-3 access points to cover the limited signal area in our case study. Wireless users or network administrators can use this information during access point deployment or redeployment. Although this heatmap could give a basic insight of how to cover the interest area with wireless signals. There are other criteria to be considered such as number of users and handover algorithms.

V. Conclusion

In this work, we have developed a WIFI heat map generator tools that allowed users to parameterize various criteria of indoor environment such as placing walls, choosing wall types, computing pathloss factors for these partitions, computing pathloss exponent, dynamically defining indoor propagation model. We proposed a propagation model resulting from our configurations. It has been shown that our tool gives satisfactory error rate of approximately 6%. This tool can be used to predict indoor wireless coverage area which should benefits wireless users and network administrators during wireless design phase. This tool may also interest students or researchers who want to study signal propagation modeling as it can also be served as a testing platform.

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