Outdoor Transmitter Localization using Multiscale Algorithm

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Abstract - Current demand for wireless communications is increasing continuously, especially on localization services in determining optimal transmitter location through intelligent wireless communications. Using Received Signal Strength (RSS), the determination of the optimal transmitter location is realized. In this paper, we simulate a model for a case study, where the Wireless InSite program has been used to investigate the wave propagation with the reasonable RSS. Different locations of directional antenna transmitters have been selected to get a better coverage area in the selected case study using multi-omnidirectional antenna receivers. An algorithm was formulated using the MATLAB program to determine Average Signal Quality (ASQ), Average Received Power (ARP) and the probability of the best receiver points. We find significant effects of the changing of the location of the transmitter which affected by environment including the presence of barriers and its related material properties.

Keywords - outdoor optimal location; RSS; received power; ASQ; ARP.

I. INTRODUCTION

In the last few years, the design of the network is become more developed, more complexity and more safety where arguments about the method of managing communication network being increasingly attracted attention to developing the operation of the systems of the network [1]. Transmitting of the wave with high speed, resolution within right path can be obtained by reducing the interface between signals in particular when the selected design of the communication network is correct regarding locations of the transmitters and the receivers [2]. However, it is difficult to determine the optimal location of the transmitter, which is the main element in the network, that contribute to make the network work efficiently to produce reliable received power with fast data transfer [3]. Although there are several possible algorithms have been used to determine the optimal location of the transmitter and the receiver, it is still unclear to propose an algorithm that gives high accuracy to select the optimal position particularly in outdoor environments [4]. For example, there is an algorithm that based on set of measurements self-assumed reference locations as a probability distribution to determine the location of the transmitter in the region. In contrast, this assumption is not always realistic in determining the optimum location for the region, especially in external environments [5]. The RSS algorithm is another method which commonly used to determine the location of the transmitter in indoor environments, where it is depend on path loss and distance than target nodes. On the other hand, in the RSS method, there is at least three reference nodes are necessary to locate the target node. Furthermore, the RSS algorithm does not work effectively in case of NLOS (Non-line of sight) because of effects residue to the effect of signal interferences in multiple paths. Another related method which is called Angle of Arrival (AOA), which is easy to implement as limited parameters are used. Furthermore, this method is more quickly to obtain the results of receiving wireless signals measurements that rely on a directional antenna [6]. However, in this method, it is required at least two reference stations to operate effectively. In addition, the accuracy of the transmitter location is affected whenever the increased distance between transmitting and receiving stations in particular it is based on directional antennas with a very narrow beamwidth [7, 8].

In this paper, optimal locations of the transmitter are examined at the Electrical Engineering Technical College in Baghdad by implementing an algorithm in MATLAB program to get the optimal location of the transmitter quickly and high reliability with show the obtained results using the GUI interface. This algorithm works that basically worked on the received power of each selected point that has been designed using the Wireless InSite program. Furthermore, this the algorithm in this work is used to calculate the probability of the best receiver points which high received power, ASQ and ARP for each transmitter location. This paper is organized as follows: in Section II, we discuss the related works. In Section III, we discuss the effect of the materials on the received signal. In Section IV, we discuss substantial algorithm by MATLAB. In Section V, we discuss the simulation model setup. In Section VI, we discuss the results of the simulation model. Finally, we summaries and concludes the paper with highlighting some suggestions for future works in Section VII.

II. Related works

Recently, the researchers focused on RSS algorithm which is based on measuring path loss for each sample in the outdoor network. In this method, a few numbers of samples are required to work well but it may not able to determinate the selected sample correctly in particular in NLOS regions due to effects of multiple paths reflections on the wave propagation [9].

The study in [10] was conducted to determine the optimal location of the receivers implemented in the outdoor environments using the RSS algorithm based on path loss with 2.4 GHz. In this algorithm, obtained data are almost accurate particularly in LOS (line of sight) regions. However, inaccurate results are found in NLOS regions due to barriers resulting from reflections.

The study in [11], was proposed the optimal location of the transmitter inside buildings which produce the best received power and coverage in Multi-Input Multi-Output (MIMO) channel during indoor network using Genetic Algorithm (GA). According to results, they noticed that this method find the best location for the minimum number of MIMO transmitter.

The researchers in [12] have built RSS algorithm based on path loss to determine the optimum transmitter location in external environments, where the path loss values were stored in the database and worked on through the algorithm. The researchers have discovered that the optimum location of the transmitter cannot be accurately determined when it is located in many barriers. It gives an approximate value for the location because the beam emitted from the transmitter to the receivers will collide with the barriers and these barriers will reflect or dispersion of beam strength according to the type of material.

In all of these researches [9, 10, 11, 12], the researchers used the RSS algorithm or genetic algorithm to determine the optimal location of the transmitter. The principle of these algorithms depends on the distance between the transmitter and the receivers or path loss to determine the optimal transmitter location to get on the best coverage in external or internal environments. They noted that the optimal location of the transmitter in the LOS regions could be accurately determined, whereas the optimal transmitter location in the NLOS regions could not be determined, which give the approximate value of the location due to the barriers between the transmitter and the receivers. In this paper, we built multiscale algorithm depend on multiple scales which including (RSS, ASQ, ARP and probability of highest received power from receivers for each location of the transmitter) in order to get the optimal location of the transmitter accurately in both LOS and NLOS regions for the best coverage in the outdoor environments.

III. EFFECT OF MATERIALS

The most commonly used materials in the construction industry to create buildings and structures are the concrete and bricks [13]. These materials have a significant impact on received signal strength. In particular, for signals that cannot penetrate concrete where fully reflected. In contrast, signals that can penetrate some other types of materials as brick and wood may suffer from a total or partial dispersion. In general, the thickness of the material has a considerable impact on the possibility of penetration [14]. Generally, building materials are mainly dependent on representative electrical properties. It is therefore, necessary to know their conductivity (σ) and permittivity (ε) for each material which changes with frequency change (f). The equations that represent both σ and ε are shown below [15].

$$\varepsilon = a * f^{(b)} \tag{1}$$

$$\sigma = c * f^{(d)} \tag{2}$$

where a, b, c and d are constants which characterizing for each material.

It is reported by the International Telecommunication Union (ITU) that relative permittivity is fairly stable with frequency, whereas conductivity is varying based on frequency variation [16]. In this work, a special software by MATLAB program has been designed to calculate the value of the permittivity and the conductivity for each material at different frequencies and flowchart of this work is illustrated as in Fig. 1. The obtained results of σ and ε for 5 GHz frequency are listed in Table I [13].

TABLE I. VALUES OF CONDUCTIVITY (σ) AND PERMITTIVITY (ε) FOR DIFFERENT MATERIALS.

Types of materials	**5 GHz**	
	σ	ε
Concrete	0.11996	5.310
Brick	0.0380	3.750
Metal	1.0e8	1.0
Wood	0.0264	1.990
Dense foliage	0.1	1.0

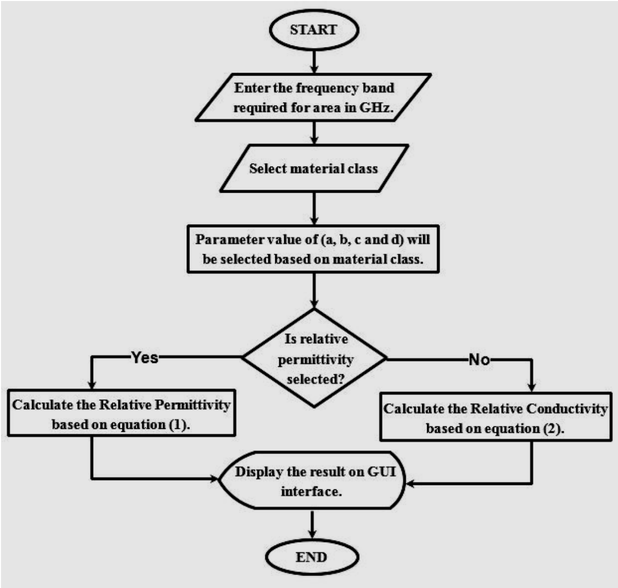

Figure 1. The flowchart describing the steps and procedure of our software to calculate conductivity and permittivity for each material.

IV. THE ALGORITHM

This algorithm used received power resulting from the simulation model of the Wireless InSite program to estimate the optimal location of the transmitter for better coverage in the outdoor networks. The steps to build this algorithm are illustrated below:

Step 1: calculate to ASQ and ARP for each location of the transmitter as had been studied previously in [17].

$$ASQ_{(i)} = 2 * \left(RP_{(i)} + 100\right) \quad (3)$$

Here $RP_{(i)}$ is the received power for each i^{th} location in dBm.

$$ARP_{(i)} = \left(\frac{SRP_{(i)}}{NRP_{(i)}}\right) \quad (4)$$

where $SRP_{(i)}$ is the total received power for each i^{th} location of the transmitter and $NRP_{(i)}$ is the number of receiver point for each i^{th} location of the transmitter.

Step 2: the received power is used as an input for each location. Then, the values of obtained received power and stored in the database are compared together to find the strongest signal basing on the input received power. If the input received power equal to -50 dBm and more, then ASQ equal to 100 %. In contrast, if the input received power equal to -60 dBm, then ASQ equal to 80 %. The input received power will based on numbers are available in Table II [18].

TABLE II. VALUES OF SIGNAL STRENGTH QUALITY FOR EACH INPUT RECEIVED POWER.

Input received power	Signal strength quality
-30 dBm -40 dBm	Signal strength is very strong, you are most likely standing in front of AP.
-50 dBm	Signal strength is excellent
-60 dBm	Signal strength is good and reliable.
-67 dBm	Signal strength is reliable.
-70 dBm	Signal strength is not strong.
-80 dBm	Signal strength is unreliable as it will not suffice for most services.
-90 dBm	The chance connection at this level is very low.

Step 3: if the input received power is exist in the database goes to the fourth step and if it does not exist in the database, it will display a message on GUI interface shows that the input received power that entered is not present in the database.

Step 4: calculating the probability of the best receiver points which high received power for each location of the transmitter depending on the input received power by [19]:

$$PL_{(i)} = \left(\frac{HRP_{(i)}}{NRp_{(i)}}\right) \quad (5)$$

where $HRP_{(i)}$ is the highest received power for each i^{th} location in dBm.

Step 5: comparing among probabilities of the RSS, ASQ and ARP resulting from any location to find highest rate between locations which represented the optimal location of the transmitter.

Step 6: display the results and image of the optimal location on the GUI interface.

Step 7: if the probabilities are equal among them will display a message indicating that range probabilities are equal to each other and the optimal location of the transmitter cannot be determined.

V. SIMULATION MODEL SETUP

A simulation model of the Electrical Engineering Technical College in Baghdad, where it was carried out by Wireless InSite program. The height of the buildings are 3, 7 and 12 meters as in real dimensional. We divide the college into two parts: in the first part, we deployed 43 receiver points and the transmitter for four locations, i.e. we changed the location of the transmitter to different places at the entrance of the college as shown in Fig. 2 to determine the best coverage in this the part of the college. In the second part, we deployed 28 receiver points and the transmitter, i.e. we changed the location of the transmitter into two different places which both are lie at the middle of the college as shown in Fig. 3 to determine the best coverage in this the part of the college.

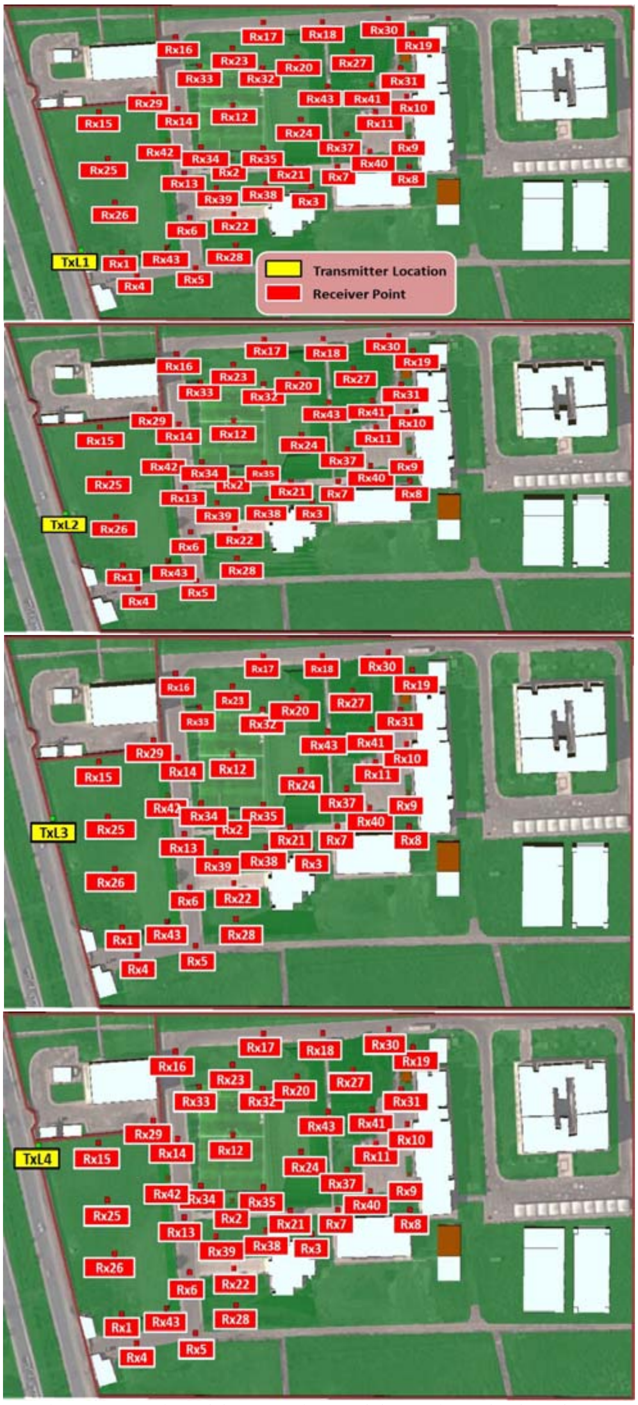

Figure 2. Location of the transmitter and the receivers that have been installed in the first part of the college.

The characteristics of the constructed building are fixed. For example, the thickness for each material that present in this building is listed in the following Table III.

Figure 3. Location of the transmitter and the receivers that have been installed in the second part of the college.

TABLE III. THICKNESS FOR EACH MATERIAL THAT PRESENT IN THE SELECTED BUILDING.

Types of materials	Thickness (m)
Ceiling from concrete	0.30
wall from bricks	0.28
Metal	0.0625
dense foliage	0.00035
Wood	0.045

The types of the antennas that have been used for both the transmitter and the receivers are directional and omnidirections respectively, while properties of directional and omnidirectional antennas that appear in Table IV. The frequency used in this study is 5 GHz and bandwidth is 20 MHz.

TABLE IV. PROPERTIES OF THE ANTENNAS.

Properties (Antenna)	Transmitter	Receiver
	Directional	**Omnidirectional**
Waveform	Sinusoid	Sinusoid
Polarization	Vertical	Horizontal
VSWR	1	1
Input Transmitter Power (dBm)	30	--
Temperatures (K)	293	293
Receiver Threshold (dBm)	96-	96-
Electric Field Plane Beam width	°120	°360
Antenna gain (dBi)	19	2

VI. RESULTS

In Fig. 4, shows the number of the receiver points versus received power in the first part of the college. The signal strength received for each receiver point depends on proximity of the transmitter. There are many effects that prevent the transmitter from sending the signal correctly to each receiver point. The most important of these effects are materials used in the construction that have an effect large on the signal dispersion or prevention of the signal penetration and some other influences are weather conditions as well as path loss and other from barriers. According to the algorithm work make sure that the probability of the RSS in the second location of the transmitter is better compared to other locations. Because the signals emitted from this the place do not encounter large amounts of the collisions and reflections. While other places where we observe that the signals emitted of the transmitter are experiencing reflections and collisions severe which will dispersion of the signal strength and from this will arrived the signals to receiver points very weak.

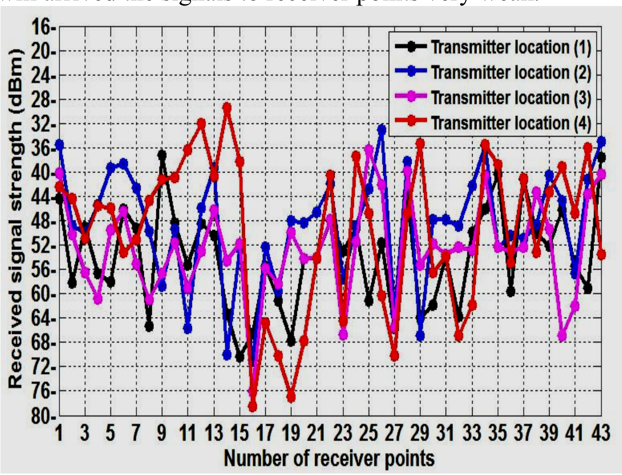

Figure 4. The number of receiver points versus received power in the first part of the college.

In Fig. 5 shows the number of receiver points versus signal quality for each transmitter location in different places at the first part of the college. This indicates that changing the location of the transmitter from place to another gives different coverage and signal quality. This because each place has different specifications such as reflections and collisions. This algorithm determine that the second location of the transmitter is better in the coverage and signal quality compared to other locations.

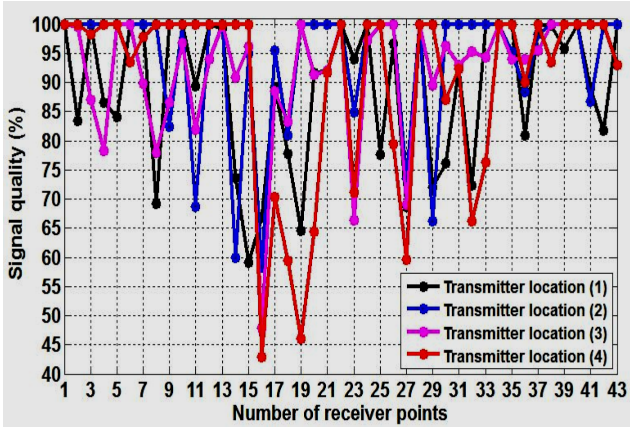

Figure 5. The number of receiver points versus signal quality in the first part of the college.

In Fig. 6 shows the number of receiver points versus received power in the second part of the college. It is also noted that the emitted signal from the second location of the transmitter is affected by collisions and reflections more than the first location. Consequently, this evidenced of poor received power in some the campus regions during the second location. According to the algorithm that has been simulated in this the work, the probability of the RSS in the first location of the transmitter is found to be better than other the location.

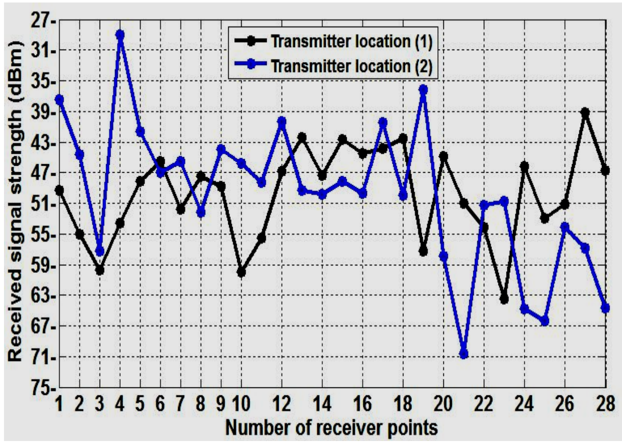

Figure 6. The number of receiver points versus received power in the second part of the college.

In the second part of the college, we find that the first location of the transmitter represents the best location regarding the coverage and signal quality as compared with the second location as shown in Fig. 7. This is due to the fact that signals emitted from this the location of the transmitter is fewer losses compared to the second location.

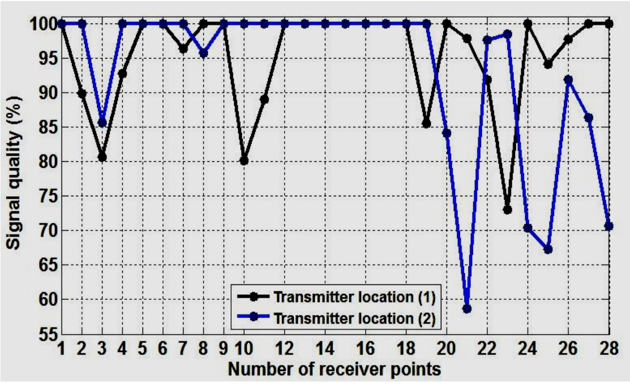

Figure 7. The number of receiver points versus signal quality in the second part of the college.

Finally, according to comparisons conducted during algorithm for four locations of the transmitter at the first part of the college in the MATLAB program and show results on GUI interface as shown in Fig. 8. The results show that the second location of the transmitter is relatively better than other the locations. In other the words, the signal quality of this the location is high and the coverage is better than the rest of the locations. Fig. 8 shows the probability of each location for highest received power when input RSS is -60 dBm and larger enter in the algorithm which is best-received power. Fig. 8 also shows ASQ and ARP of each location. According to the results obtained, the transmitter location can be determined accurately in LOS and NLOS regions. While in the previous works noted that cannot determine the transmitter location accurately in NLOS regions and this is one of the defects that cannot be resolved in the previous works. In this paper we used a multiscale algorithm to solve this problem which included a set of the scales as shown in section IV.

Figure 8. The results obtained from MATLAB by using GUI interface in the first part of the college.

Moreover, the results obtained from the MATLAB program in the second part of the college illustrated in Fig. 9. It shows that the first location of the transmitter is better than the second location. Because the probability of the RSS, ASQ, and ARP are higher than the rest of the locations and in addition to better coverage.

Figure 9. The results obtained from MATLAB by using GUI interface in the second part of the college.

VII. CONCLUSIONS

In this paper, the optimal location of a transmitter was highlighted in order to provide better coverage of the emitted signals in the college. The most important outcome is our finding where the transmitter in some areas is located in a blind spot and cannot send signals to the receivers correctly. This is the main reason behind the absence of the signal in some regions in the college as in the first, third and fourth locations from the first part and the second location from the second part. There are other reasons including interference between signals, barriers, reflections and others. From this, an algorithm was implemented to determine optimal location of the transmitter in the college. We concluded during this study that this algorithm has a good potential in determining the optimal position among locations deployed in the college and in both LOS and NLOS regions as in the second location from the first part and first location from the second part. In future work, we will implement this work in a practical way and compare the simulation results obtained in this research with the results obtained in practice.

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