IAES International Journal of Artificial Intelligence (IJ-AI)
Vol. 11, No. 4, December 2022, pp. 1384~1394
ISSN: 2252-8938, DOI: 10.11591/ijai.v11.i4.pp1384-1394

Optimal transmitter location using multi-scale algorithm based on real measurement for outdoor communication

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Article Info

Article history:

Received Jul 14, 2021
Revised Jun 22, 2022
Accepted Jul 21, 2022

Keywords:

Average coverage
Average signal quality
Multi-scale algorithm
Optimal tx location
Outdoor localization
Received power
Received signal strength

ABSTRACT

In the era of wireless network communication, the demand for determining the best transmitter (Tx) location is constantly increasing especially in outdoor environments and localization-based services. In this paper, localization optimal location of a Tx has been achieved in electrical engineering technical college by using received signal strength (RSS). We install practical devices in the college to measure the received signal strength in all the college regions. Where each device consists of two pieces which are the AirMAX sector directional antenna and signal broadcast piece (router board). We measured RSS in four directions for each received point in all selected regions using the NetSpot software. An algorithm was created in MATLAB software to determine the average received power (ARP), average signal quality (ASQ) as well as calculate the average coverage (AC) for each Tx device location based on the locations deployed in the real environment. Overall, the results obtained showed that this algorithm effectively demonstrated that it is able to determine the best location of a Tx device compared to other deployed locations in the college. Furthermore, we find large effects when a Tx location changes from one location to another on the RSS because of the surrounding environment effects.

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1. INTRODUCTION

In the past few years, wireless network design has become more complex, secure, and developed in various ways on how to effectively manage the network, and it has become a growing concern for network management system development [1]–[3]. The correct design of the wireless network and the coordination of connection requirements with higher accuracy prevents interference between users and makes the connection between them more quickly in transmitting information through it so that the network will take path correctly [4], [5]. With all these developments that have passed on the wireless communication networks from difficult determine the best location of a best transmitter (Tx) device in various outdoor networks systems. A Tx device is considered the main element in the network and determines the best location of a Tx that makes the network work correctly and makes received power for the user more reliable and faster in data transfer [6]–[8]. Although the possibility exists a large number of algorithms to determine the best location of Tx's, there are not yet clear classifications for multiple types of these algorithms for positioning in outdoor environments [9], [10]. For example, the received signal strength (RSS) algorithm is commonly used to determine a Tx device location in indoor environments, as it depends on the path loss or distance between the Tx device and receiving points. On the other hand, an RSS algorithm does not work effectively and needs a long time to complete the processing [11]. Another easy-to-implement method called angle of arrival (AoA) measures the time it takes for wireless signals to reach multiple receiving points [12]. In contrast, in the AoA method whenever increased distances between the transmitting and the receiving stations will the accuracy of the location estimation decrease, because of changes in the propagation characteristics of the receiving signals. On the other hand, the AoA imposes the use of directional antennas and these antennas have a very narrow beamwidth [13], [14]. There are two methods that are similar to the working principle of the AoA method are time of arrival (ToA) and time difference of arrival (TDoA). However, these methods require very accurate time synchronization between the transmitting stations and the received points and need a long time to the processing and extra cost [15], [16]. Recently, researchers focused on a genetic algorithm to determine the optimal location of receiver devices, which is commonly used in indoor environments. This algorithm has proved to be good in performance but complex in implementation and requires a long time to complete the processing [17].

In this paper, we will determine the best location of a Tx device to obtain the best coverage by using a special algorithm. This algorithm is based mainly on several measurements to determine the best location. This work was done through the installation of practical devices in the college which included the Tx's and the receivers to obtain real values realistically.

The sections rest of this paper are organized as follows: In Section 2, we will discuss related work and compare it with our own. In Section 3, we will provide details of the algorithm adopted and proposed in this paper that has been programmed in Matrix Laboratory (MATLAB) software. In Section 4, we discuss the methodology of measurement and device properties used in the Tx devices and the Rx devices. In Section 5, we discuss results and discussion. The conclusions of our own work in this paper will be presented in Section 6. In addition, suggestions for future research development are also presented in this section.

2. RELATED WORKS AND COMPARE THEM WITH OUR WORK

Recently researchers focused on determining the best indoor Tx location that achieves the best-received power and coverage using a multiple-input and multiple-output (MIMO) antenna by implementing a genetic algorithm (GA). According to the results, they note that this method finds the best location for the fewest number of MIMO antennas. Because whenever an increasing number of Tx's inside the building the algorithm will be more complex and will need a long time and extra cost [18].

Ning *et al.* [19] specified an outdoor optimal location by using the RSS fingerprinting. This proposes a scheme to estimate locations of mobile stations that rely heavily on RSS data and the proposed scheme consists of two parts: offline training phase and online localization phase. The RSS is based on the distance between a base station and received node and that all nodes must be in the form of a cluster to give the best results in determining. The researchers discovered that wherever the distance increased between the base station and received node, will be reduced accurately in determining the optimal of the base station.

Ramakrishnaiah *et al.* [20], implement the Nelder Mead method to obtain the optimal coverage within the buildings. Based on all the results that appeared, the researchers noted this method is accurate in determining the optimal positions of the Tx's when the numbers of the Tx's less inside the buildings and not accurate when the numbers are large. Because of each Tx when sending the beam of paths will collide with the beam sent by the other Tx and the accumulation of these collisions leads to successive losses. This will decrease accuracy in determining the optimal location inside the buildings.

In this paper, we will divide the Electrical Engineering Technical College in Baghdad into two parts, due to the large area of the college and can't be covered by one device. We install the Tx and changing it to different places in the first part and the second part and measure received power in four directions and different regions. We will determine the best Tx location in two parts of the college by implementing and creating a multi-scale (MS) algorithm in MATLAB software to show the results on a graphical user interface (GUI). This algorithm operates on the received power mainly for each received point resulting from the measurement practically by installing the NetSpot software in the laptop. The work basis of this algorithm is to calculate the average coverage (AC) means the probability of the best points that received the highest power and also determine the highest average received power (ARP), and average signal quality (ASQ) for each location to estimate the best location in two parts.

3. MS ALGORITHM USING MATLAB SOFTWARE

This algorithm was based on the received power obtained from a real measurement to determine the best location for the Tx to achieve the best coverage. This algorithm is divided into two stages and each stage contains a set of steps. These two-stages steps are summarized as follows:

Step 1: Measure the RSS value of 43 points in the first part of the college for four Tx locations and 28 points in the second part of the college for two Tx locations.
Step 2: Storage RSS values in the database for all Tx locations deployed in the college.
Step 3: Calculate the ARP for each Tx location as shown in (1).

$$ARP(dBm)_{(i)} = \frac{\sum_{j=1}^{Nrp} P_{R(j)}}{Nrp} \quad (1)$$

Where $P_{R(j)}$ is power for each j^{th} receiving point deployed in each i^{th} location of the Tx. Nrp is the total number of receiving points deployed in an environment. j^{th} is the beginning of reading the measure for receiving points that have been installed throughout the college.
Step 4: Calculate the ASQ for each Tx location as shown in (2) [21], [22].

$$ASQ(\%)_{(i)} = \frac{\sum_{j=1}^{Nrp} 2*[P_{R(j)}+100]}{Nrp} \quad (2)$$

Step 5: The value of the RSS highest received is selected as input to determine best-received power and compare this value with the values resulting from practical measurements using NetSpot software stored in the database to determine the number of received points that receive the highest received power. Selecting the value of the RSS will be based on numbers which are available in Table 1.
Step 6: If the RSS value is existing in the database, it will automatically go to the seventh step and if it is not in the database, it will automatically display a message on the GUI showing that the RSS value does not exist in the database.
Step 7: Calculate the probability (P) of the best points receiving the highest power for each Tx location based on the RSS value by (3).

$$P(\%)_{(i)} = \frac{NHrp}{Nrp} * 100 \quad (3)$$

Where $NHrp$ is the total number of received points deployed in the real environment that received the highest power for the i^{th} location depending on the input RSS value.
Step 8: A comparison of probability values locations to determine the highest value that represents the best Tx location among locations deployed in the college.
Step 9: If the probabilities are equal in all the locations, it will comparison among locations of the ASQ values to determine the highest values which represent the best Tx location among locations deployed in the college.
Step 10: In the end, the comparison results for all Tx locations will be displayed on the GUI.

All these steps of the MS algorithm can be detailed and explained in the form of the flowchart in Figure 1 as shown in Appendix. This flowchart has been summarized in two parts. The first part represents the operations that are performed in the NetSpot software. While the second part represents the programming operations that are performed in the MATLAB software.

Table 1. The values of signal strength (SS) [6]

RSS (dBm)	SS Quality
-30 & -40	SS is very strong
-50	SS is excellent
-60	SS is good
-67	SS is reliable
-70	SS is not strong
-80	SS is unreliable
-90	SS is very low

4. METHODOLOGY OF REAL MEASUREMENT

This section is divided into two sub-sections, in the first sub-section, we will present everything related to the scenario of the first part for the college. In the second sub-section, we will present everything related to the scenario of the second part for the college. The main goal behind this division is to get better coverage, due to the vastness of the total area that cannot be covered by a single device.

4.1. The first part of the college campus

In this part, we have installed a Tx and changed it to four locations located at the beginning of the entrance to the college at 3 m above the ground as shown in Figure 2 and Figure 3. The installed Tx works on the 5 GHz band and consisting of two pieces. The first piece is Ubiquiti AirMAX Sector, which is a phrase a directional antenna as shown in Figure 4. The second piece is Base Box 5 MikroTik Router board 912 UAG-5HPND-OUT as shown in Figure 4. It is phrasing a signal broadcast device. This piece is characterized by power sending up to 30 dBm. It is one of the best devices available in markets for broadcasting in outdoor environments. In addition, the installation of the two pieces is shown in Figure 4. We measured received power in four directions for 43 points and the measurement was achieved by installing the NetSpot software on a laptop and the height of the laptop was 1.20 m as shown in Figure 5.

Figure 2. A Tx's locations will be installed in the two parts

Figure 3. A Tx's locations were installed in the first and front part of the college campus

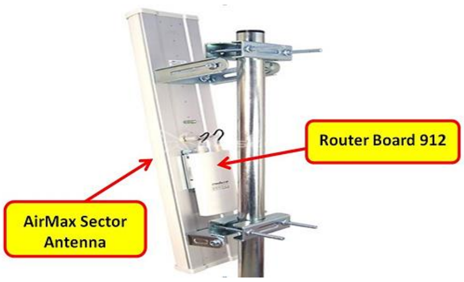


Figure 4. The installation of two pieces are the Air MAX sector antenna and router board 912 for a Tx device

4.2. The second part of the college campus

In this part, we installed the Tx and changed it into two locations in the middle of the college as in Figure 2 and Figure 6. We measured the received power for 28 points by the NetSpot software, where received power for each point is measured in four directions. The main objective behind taking the measurement of the receiving point in four directions in order to take the highest value of the signal strength arriving at each receiving point.

The types of antennas that have been used for both Tx and received points are (Directional and Omni-Directional) respectively. The properties of these antennas are listed in Table 2 [23]–[25]. In addition, the frequency and bandwidth used in the real environment are 5 GHz and 20 MHz, respectively.

Figure 5. Measuring received power in four directions for each received point in the first part of the college

Figure 6. A Tx's locations are installed in the second and back part of the college campus

Table 2. The properties of a Tx device and received points antennas

Properties	Tx Antenna	Rx Antenna
Polarization	Vertical	Vertical
Tx Power (dBm)	30	--
Beam Width Angle	120°	360°
Antenna Type	Directional	Omni-Directional
Antenna Gain (dBi)	19	2

5. DISCUSS AND ANALYSE THE RESULTS

This section is divided into two sub-sections, in the first sub-section, we will present the results of the first part for the college. In the second sub-section, we will present the results of the second part for the college. In addition, we will provide a detailed discussion of all the proposed results in each sub-section with a proposal for appropriate solutions to better cover the college environment.

5.1. Results of the first part for the college campus

The results were obtained from measuring the RSS and coverage area for all locations in the first part of the college using the NetSpot software as shown in Figure 7(a), Figure 7(b), Figure 7(c), Figure 7(d). The point measured by using the NetSpot software takes time about 20 seconds in the NetSpot software to measure the received power. This supports the stabilizing of the signals at the received location in order to measure the received power more accurately. These are good features of this software so that the laptop is able to receive signals better. The maximum received power of these four directions will be taken and stored in a specific database to complete processing and calculations.

In addition, each location of the Tx has a different field of coverage from one location to another, where each location consists of set colors as shown in Figure 7(a), Figure 7(b), Figure 7(c), Figure 7(d). These colors represent the field of coverage for each location of the Tx. These colors are the red color representing the strongest signal that reaches the receiving points. The yellow color represents a good signal, the green color represents a middle signal and the blue color represents a weak signal. While the value of the received power for each color is shown in each figure.

The values of RSS for four locations of the Tx's are shown in Figure 8. Generally, the RSS depends mainly on the Tx location proximity. There are many effects that prevent a Tx device from transmitting signals to receivers properly such as path loss which included reflections, refractors, collisions through the barriers, and as well as environmental conditions, where there are large numbers of users on the same channel and this will lead to interference between signals and increased the noise in the environment. This is considered one of the main reasons for the weakness of received signals in some locations deployed in the college, especially in practical measurement aspects as in 1st, 3rd, 4th locations. The range of RSS on the second location is between -35 to -70 dBm, and the range of this location is better than other locations.

The signal quality of four Tx locations in the first and front part of the college campus is shown in Figure 9. We notice that changing the Tx in more than one place gives different signal quality and coverage and this indicates that each location has its own effects. The signal quality at the second location ranges from 60 to 100 %. Therefore, this range is considered to be better than other locations that are deployed and installed in the college.

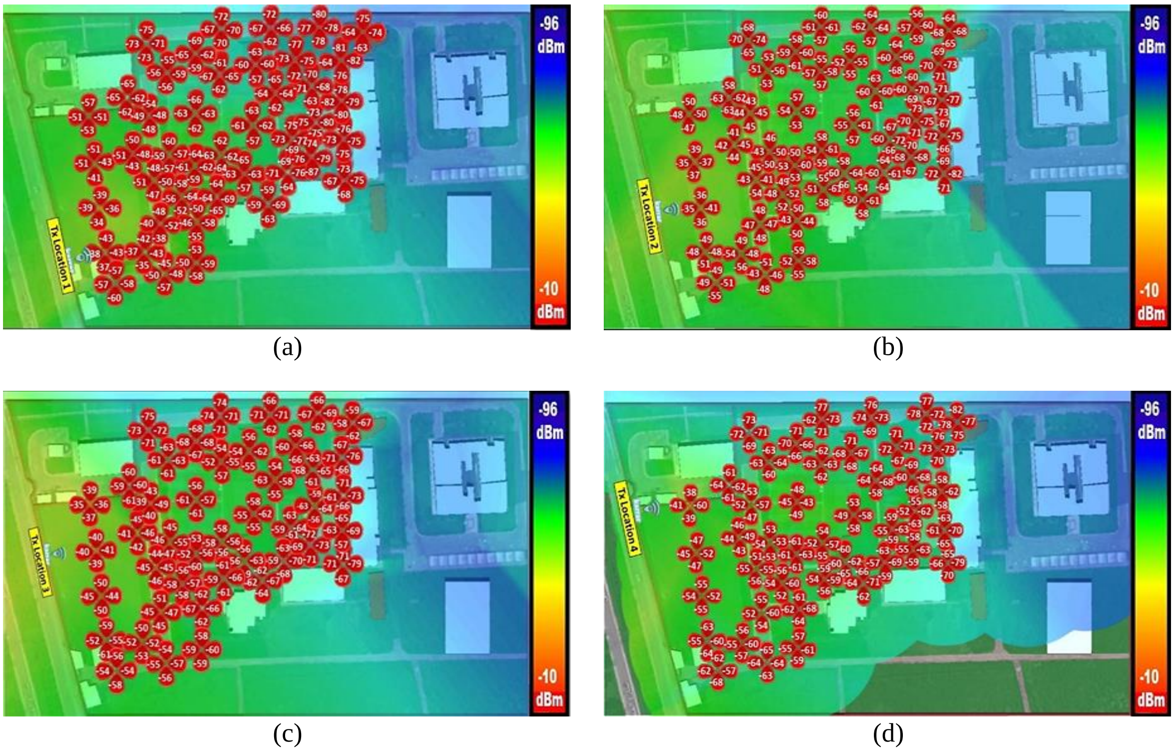


Figure 7. The RSS values and AC were measured for four Tx locations in the first part of the college, (a) 1st location of a Tx device, (b) 2nd location of a Tx device, (c) 3rd location of a Tx device, and (d) 4th location of a Tx device

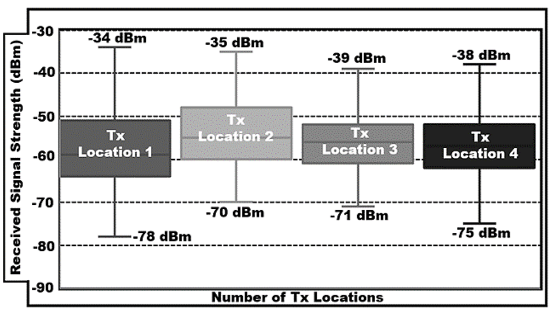


Figure 8. RSS values for four Tx locations in the first and front part of the college campus

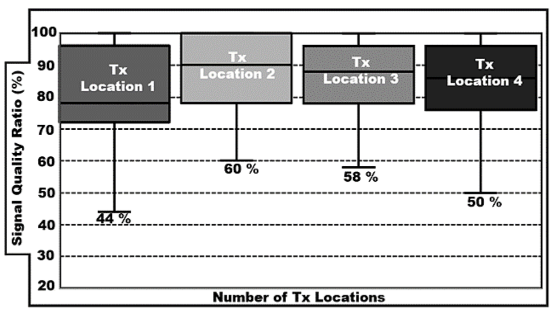


Figure 9. The signal quality for four Tx's locations in the first part of the college

Finally, according to the calculations that have been done through an MS algorithm in MATLAB software for four locations in the first part of the college as shown in Figure 10. We noticed that the second Tx location is better than the others, where this location has received the highest receiving power at all received points, highest ARP, and ASQ. The values of the probability of highest received power which receives from -60 dBm and higher for all locations are (74.4186 %, 88.3721 %, 83.7209 %, 76.7442 %) respectively. The second location is better than the other locations because the second location gets the highest points that receive from -60 dBm and higher.

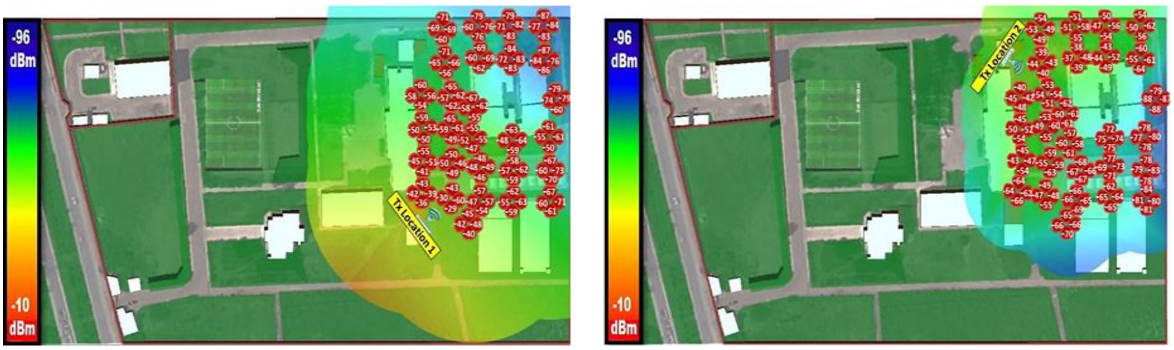
5.2. Results of the second part for the college campus

The results were obtained from the NetSpot software to measure the RSS in the second and back part of the college campus as shown in Figure 11(a) and Figure 11(b). The RSS values for two Tx locations are shown in Figure 12. It can be seen that the first location achieved better results with fewer losses compared to the second location. The RSS range in the first location is between -29 to -77 dBm and this range is considered better than the second location range which ranges from between -37 to -80 dBm.

The signal quality for two Tx locations in the second and back part of the college campus is shown in Figure 13. We note that the first Tx location is better than the second location for signal quality and coverage. The range of the signal quality in the first location is between 56 to 100% and this range is considered better than the second location range which ranges from 40 to 100%.

Moreover, all comparisons and results obtained from the MS algorithm in the second and back part of the college campus are shown in Figure 14. Note that the first location achieved higher values in the probability of the RSS, ARP, and ASQ as compared to the second location. The values of the probability of highest received power which receives from -60 dBm and higher for all locations are (82.1429%, 60.7143%) respectively. The first location is better than the other location because the first location gets the highest points that receive from -60 dBm and higher.

Figure 10. The results were obtained from the MS algorithm and displayed on the GUI for the first part of the college



(a) (b)

Figure 11. RSS values and AC were measured for two Tx locations in the second and back part of the college campus, (a) 1^{st} location of a Tx device, (b) 2^{nd} location of a Tx device

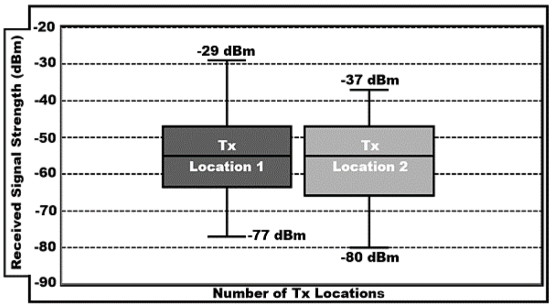


Figure 12. The RSS values for two Tx's locations in the second and back part of the college campus

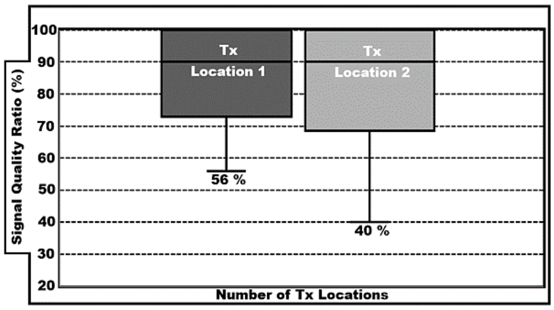


Figure 13. The signal quality for two Tx's locations in the second and back part of the college campus

Figure 14. The results were obtained from the MS algorithm and its display on the GUI of the second part and back of the college campus

6. CONCLUSION

In this paper, the best Tx location to cover the specific college is investigated in a better way. We note that the Tx device, when it is located in a blind spot, cannot properly send signals to the receiving points. In contrast, the RSS will reach the receiving points very weak in some locations, whereas it is strong in other locations. The main reason behind that includes the effects of interference between signals and many obstacles which cause reflection or absorption of the transmitted signal. In addition, we note that the channels in some locations are an effect on the strength of the received signal because a huge number of users on the same channel, will lead to increased noise in the environment. Moreover, good orientation and proper Tx height play a big role in improving wireless network efficiency performance. For this, an MS algorithm has been implemented to determine the best Tx location in the college. As a result, this algorithm has proved its ability effectively to determine the best Tx location as compared to other deployed locations in the college in both LOS and NLOS regions. As mentioned in this paper, it is found that the second location in the first part gives the higher received power as compared with other selected positions. In contrast, in the second part, the higher received power is recorded in the first location of the Tx. In future work, we will study the effect of student's density on outdoor network performance.

ACKNOWLEDGEMENTS

We would like to thank the Islamic University (https://iunajaf.edu.iq/) located in the Najaf city and the Middle Technical University for their continuous support in accomplishing this scientific work that simulates the development of wireless communications.

APPENDIX

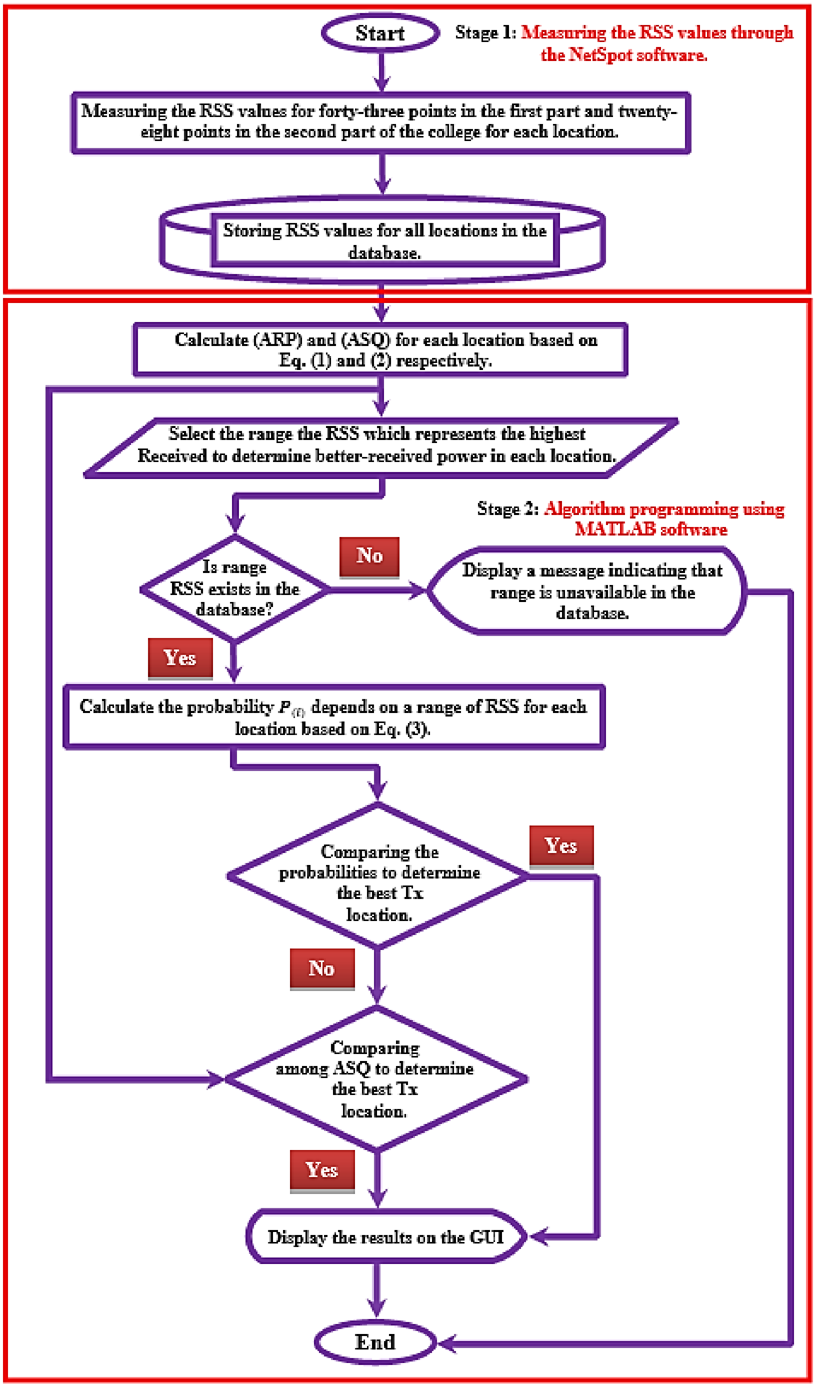


Figure 1. A flowchart showing the sequence of steps and procedures for an MS algorithm to determine the best Tx location

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