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Model for Optimizing the Location of the Access Point in 802.11ac Networks Supported in the Model Log-Normal Shadowing

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Abstract

Background/Objectives: Designing a Wireless Local Area Network (WLAN) assumes great importance in determining the optimal placement of Access Points (APs) and assigning channels in order to achieve maximum levels of coverage and performance. The aim of this paper is to develop an optimization model for the location of the AP in indoor environments, the 2.4GHz and 5GHz, supported on the propagation model Log-Normal Shadowing. **Methods/Statistical Analysis:** To estimate the optimal location of the AP model, nonlinear optimization was proposed based on the probability cutting frequency bands, the dimensions of the environment, the transmission power, sensitivity receptor and the coverage radius, which two routines in Matlab for systematization model, supported in the propagation model Log-Normal Shadowing path loss, which allows developed decompose the received power at an average power and attenuation term shadow. **Topic Relevance:** Although there have been several related resource optimization work WLANs are very few studies have considered engaging in their research strategies for optimizing the geographic location of the AP. Aspect by which developed in Matlab routines may be used in future research related to the design of WLANs. **Results:** Based on the results it was evident that it is possible to predict the optimum location of the AP for the 2.4GHz and 5GHz, depending on the transmission power, the detection threshold of the receiver, the probability estimated cut and characterization of the environment between the AP, either free space or obstacles, supported the use of a shadow attenuation model. In addition, routines allowed establishing the Cartesian coordinates in which the location of the AP function of the radius of coverage, frequency band and environmental conditions, with 95% confidence is suggested. **Application/Improvements:** The developed routines can be used as support tools in future research work, related to the design and analysis of wireless networks that use the 2.4GHz and 5GHz bands, in order to evaluate aspects of interference, coverage, performance, efficiency and QoS.

Keywords: Coverage Area, Interference, Location, Optimization, Outage Probability, WLAN Networks

1. Introduction

The growing demand for wireless connectivity supported in the IEEE 802.11 standard in areas with high density of users, it has generated a lot of AP operate independently without any coordination in the same geographical space, generating high levels of interference devices, due to sharing of the bands ISM (Industrial, Scientific and Medical)[1]. Product of this situation have generated operating problems such as attenuation of the signal level transmission and consequently low network performance[2].

Planning is one of the most important tools in reducing interference problems during the process of implementing a wireless network, seeking to ensure minimum quality level of coverage and QoS[3]. It is important during this stage to consider that the parameters describing

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the environment such as the propagation dynamics and user mobility can be susceptible to change over time. In order to meet the needs of the service, it is vital to establish mechanisms to provide adequate levels of coverage for the user, which will depend on the radii of coverage and optimization of the location of the AP[4].

In view of the above, the design of a Wireless Local Area Network (WLAN) assumes great importance in determining the optimal placement of Access Points (APs) and assigning channels in order to achieve maximum levels coverage and performance[5]. To provide maximum coverage for WLAN service areas, APs should be installed so that the sum of measured signal at each point traffic demand is maximized[6]. However, when users connected to an AP share the bandwidth of the wireless channel with others in the same AP, the AP location should be carefully defined to maximize performance, considering the load balancing among APs and interference channel for user traffic demand[7]. In view of the above, this article seeks to establish a model to optimize the location of AP in Indoor environments supported on the propagation model Shadowing Log-Normal.

2. Proposed to Optimize the Location of the Access Point Model

The problem of design and optimization of wireless networks has been addressed a long time, promoting a large number of investigations. Although there have been several related resource optimization work WLANs are very few studies have considered engaging in their research strategies for optimizing the geographic location of the AP[8]. Among the most important works in which techniques that seek to establish the optimal location of the AP inside a building used may be mentioned.

In[9] presents a work developed at the Czech Technical University in Prague on modeling and optimization of heterogeneous WLANs based optimization method is implemented evolutionary strategies. The application is developed with languages for Web tool allows modeling the coverage area at specific sites and the capacity of the wireless network by using propagation models semi-empirical and restricted to the 2.4GHz band. Unfortunately, the article only mention of the tool and the results shown without the possibility of knowing your code or access thereto under web environment to comparative processes with the proposed model is made[10]. Clustering in a combination based on neural networks and genetic algorithms multi-purpose applications on 802.11n. Development requires measurements for optimization. Data is analyzed through a cluster of neural networks by establishing the location of APs through measurements and from this the genetic algorithm finds the best settings for the mesh APs.

This article describes a model that optimizes the number of APs required and geographic inside a building location, taking into account power levels, propagation models, patterns of interference and radio coverage both in the band of 2.4 is proposed GHz and the 5 GHz band, the model is posed as a problem of nonlinear programming, offering a low computational complexity and time for use and implementation.

2.1 Methodology for using the Optimization Model the Location of the AP

As part of the work done a methodology for optimizing the geographic location of the AP inside a building it was designed. To do this you must perform the following steps:

Step 1. Estimation of the average coverage radius for each of the frequency bands, which can be calculated according to the Cut Probability, the frequency band, the type of coverage (free space or obstacles) and the sensitivity of reception by the use of the functions Prob_Corte24G (Pt, Type, Pmin, Pc) and Prob_Corte5G (Pt, Type, Pmin, Pc)[11]. Table 1 shows the results obtained according to the input parameters required by each of the functions.

Step 2. Estimation of the number of AP required in each frequency band per level of the building as a function of the average radius of coverage obtained in step 1. Figure 1 presents the geometric estimation of design parameters such as Side and Semi-Arc of Interference, which have been considered by criteria for the design of the optimization model and play an important role within the constraints that are part of the proposed model for the geographical location of the AP.

Figure 1 shows that we want to estimate the value corresponding to the largest square that can be inscribed inside the circle of radius r, where r corresponds to the coverage radius calculated in the previous step for each of the frequency bands and propagation environments. Bearing in mind that for design criteria the worst condition should always be considered, it will be adopted as a design criterion under this principle that the coverage radius that will be considered in both the 2.4 GHz band and the 5 GHz band will be that obtained product of calculating the coverage radius for environments with obstacles. In view of the above and according to the geometric diagram, the value corresponding to the Side of the inscribed square can be calculated as follows[12]:

$$r = \sqrt{(L/2)^2 + (L/2)^2}$$

$$r = \sqrt{2L/4} = L/\sqrt{2}$$

$$L = r.\sqrt{2}$$

On the other hand, it is observed that the union of two inscribed squares through a common side, allows to analyze the way in which two cells with different frequency could interact with each other, defining not only the coverage area established by the union of the It also allows us to know the area of interference that will exist between them, taking into account a minimum separation between AP of *L* meters[13]. Aspect by which the *L* factor will play a very important role within the optimization model, taking into account that the separation between AP must be greater than and equal to *L*.

Step 3. To estimate the area of the half-arc of interference, the geometric diagram of Figure 1 will be used as a basis. To calculate it, it is observed that an angle θ is formed between the radius of coverage and the upper corner of the square. It is very important to keep in mind that the area of the semi-arc will depend on the distance between AP and the angle θ.

To calculate the distance between $AP_i \, and AP_j$ located in the Cartesian coordinates $(X_i, Y_i) and \ (X_j, Y_j)$ respectively, the following expression is used[14]:

$$d_{ij} = \sqrt{(X_i - X_j)^2 + (Y_i - Y_j)^2}$$

The angle $\theta$is given by:

$$\theta_{ij} = \theta(d_{ij}) = Acos\left[d_{ij}/2r\right]$$

To estimate the area of interference between cells we proceed as follows:

Let A_{sa} be the upper semi arc area

$$A_{sa} = \frac{\theta_{ij} r^2}{2}$$

Let A_T be the area of the upper triangle[15]:

$$A_T = \frac{rcos(\theta_{ij}).rsin(\theta_{ij})}{2} = \frac{r^2 cos(\theta_{ij}).sin(\theta_{ij})}{2}$$

Let $A_I(\theta_{ij})$ be the area of interference between cells produced by $AP_i \ and \ AP_j$, which can be calculated as follows:

$$A_I(\theta_{ij}) = 2(2A_{sa} - 2A_T) = 2\left[2\left(\frac{\theta_{ij} r^2}{2}\right) - 2\left(\frac{r^2 cos(\theta_{ij}).sin(\theta_{ij})}{2}\right)\right]$$

$$A_I(\theta_{ij}) = 2\left[\theta_{ij} r^2 - r^2 cos(\theta_{ij}).sin(\theta_{ij})\right]$$

$$A_I(\theta_{ij}) = 2r^2\left[\theta_{ij} - cos(\theta_{ij}).sin(\theta_{ij})\right]u(\Delta d)$$

Where,

$$\Delta d = 2r - d$$

$$u(\Delta d) = \begin{cases} 1 & si \ \Delta d \geq 0 \\ 0 & si \ \Delta d < 0 \end{cases}$$

Step 4. Calculate the required AP number. For this process, the total area of the environment must be calculated in the first instance[14].

$$Area_E = Largo * Ancho$$

Subsequently, the area of one of the squares enrolled in the coverage area of a cell is calculated.

$$Area_C = L * L$$

The number of AP required (m) equals the ratio of the area of the environment and the area of the inscribed square.

$$m = \left\lceil \frac{Area_E}{Area_C} \right\rceil$$

Step 5. Introduce coverage parameters and solve the problem of non-linear optimization to establish the location of the AP within the construction, in order to maximize the total coverage area of the associated cell system on the environment, through the following optimization model.

Objective Function

$$max \left[m\pi r^2 - \sum_{j=1}^{m} A_I(\theta_{ij}) \ \forall i,j = \{1,2,\dots,m\}; i \neq j \right]$$

Subject to:

$$d_{ij} \geq L$$

$$d_{ij} = \sqrt{(X_i - X_j)^2 + (Y_i - Y_j)^2}$$

$$L/2 \leq X_i, X_j \leq Largo - L/2$$

$$L/2 \leq Y_i, Y_j \leq Ancho - L/2$$

Step 6. The system prints the coordinates (X, Y) of each of the APs that are part of the level or floor, which can be replicated at later levels.

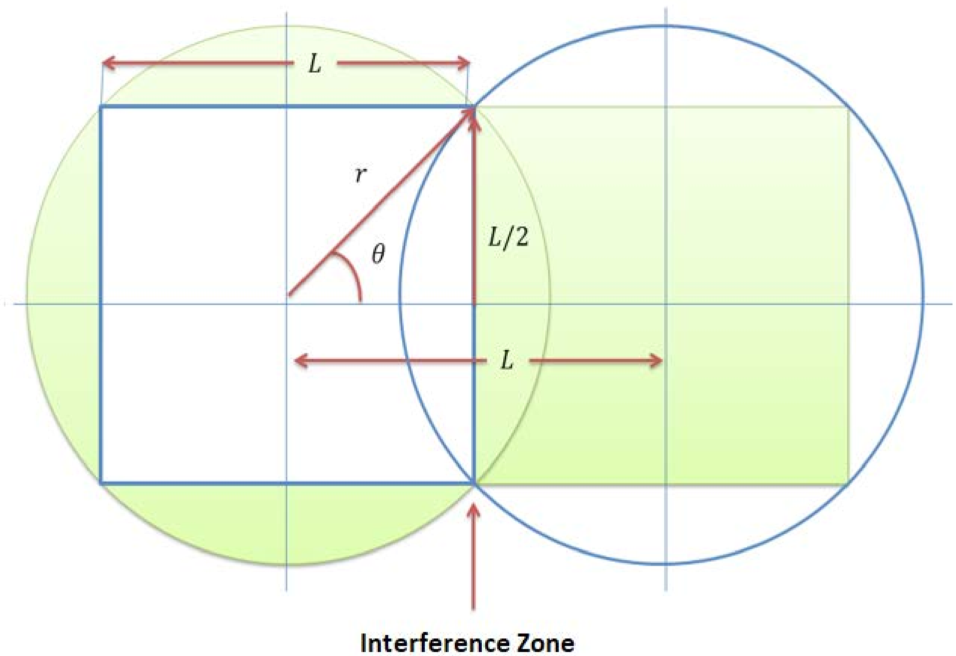

Figure 1. Geometric estimation of design parameters (Side and Semi Arc of Interference).

Table 1. Estimate the coverage radius, outage probability and probability of coverage for specific design values in the bands 2.4 GHz and 5GHz

Design Parameters	**2.4GHz band**		**5GHz band**	
Power Transmission (P_t) [dBm]	26	26	25	25
Kind	**Free space**	**obstacles**	**Free space**	**obstacles**
Sensitivity (P_{min}) [dBm]	-70	-70	-80	-80
Prob. Estimated cut (P_c^*)[%]	fifteen	fifteen	fifteen	fifteen
Prob. Real cutting (P_{cut})[%]	15.05	18.41	15.12	15,65
Radio Coverage (r) [m]	66	twenty	53	fifteen
Signal strength (P_r)[dBm]	-64.27	-65.79	-72.74	-74.66
Coverage (C) [%]	94.15	95,00	93.56	94.18

3. Results

Next, we present the routine developed in Matlab that allows optimizing the location of the AP according to the methodology described above, minimizing the levels of interference and maximizing the coverage area[16].

Routine to optimize the location of the AP

```
1.  r = input ('Enter the average coverage radius');  Radio coverage%
2.  RAP = 10;  % Radio chart for AP
3.  Length = input ('Enter the value corresponding to the length of the building');
4.  Width = input ('Enter the value corresponding to the width of the building');
5.  L = sqrt (2) * r;
6.  Area_C = L * L;
7.  Area_E = Length * Width;
8.  Nap = round (Area_E / Area_C); % Estimated number of AP required
9.  Area_E = Length * Width;
10. switch NAB

    a.  case 1      % If the required number of AP is 1
        f = imread ('Edificiok.png');
        f1 = imresize (f, [Width * Length * 10 10]);
        imshow (f1);
        Holdon;
        R1 = R * 10; % Radio

        Angle = (0: 0.01: 2.01 * pi); Draw% coverage radius
                  Xc = (length * 10/2) + R1 * cos (Angle);
        Yc = (width * 10/2) + R1 * sin (Angle);
        Plot (Xc, Yc,'-b')

        Xc = (length * 10/2) + RAP * cos (Angle);  % Draw AP
        Yc = (width * 10/2) + RAP * sin (Angle);
        Color = [0.99 0.78 0968];
        Fill (Xc, Yc, color);
        Plot (Xc, Yc,'-b')

    b.  case 2      % If the number of AP required is 2

        X0 = zeros (1.2 * NAP); % Vector of initial conditions


        % Upper and lower limits of the vector x
        Xi = Length / 4;
        Xf = Long-Xi;
        Yi = Width / 4;
        Yf = Width-Yi;
        For i = 1: NaP
        Lb (i) = Xi;
```

```
Lb (i + Nap) = Yi;
    ub (i) = Xf;
ub (i + Nap) = Yf;
End

% System solution
[X, FVAL] = fmincon (@ (x) funobj (x, R, NaP), x0, A, b, Aeq, beq, lb, ub, @ (x)
            restricnl (x, L, NaP));

XAxis = x (1: NAP);
YAxis = x (Nap + 1: 2 * NAP);
Result = [xAxis 'yAxis'];

% Graphics coverage areas for each AP according to the points suggested
% for maximum coverage

x1 = 10 * x;
f = imread ('Edificiok.png');
f1 = imresize (f, [Width * Length * 10 10]);
   imshow (f1);
Holdon;
R1 = R * 10;  % Radio

for i = 1: NaP
        Angle = (0: 0.01: 2.01 * pi); % Coverage Draw radios
        Xc = x1 (i) + R1 * cos (angle);
        C = x1 (i + NAB) + R1 * sin (angle);
Plot (Xc, Yc,'-b')

        Xc = x1 (i) + RAP * cos (angle); % Draw AP
        C = x1 (i + NAB) + RAP * sin (angle);
        Color = [0.99 0.78 0968];
        Fill (Xc, Yc, color);
        Plot (Xc, Yc,'-b')
End
        FVAL
        Result
```

c. Otherwise% If the required number of AP is greater than 2

```
        X0 = zeros (1.2 * NAP); % Vector of initial conditions

        % Upper and lower limits of the vector x
        Xi = L / 2;
        Xf = Long-Xi;
```

```
            Yi = L / 2;
            Yf = Width-Yi;
            For i = 1: NaP
            Lb (i) = Xi;
            Lb (i + Nap) = Yi;
            ub (i) = Xf;
            ub (i + Nap) = Yf;
            End

            % System solution
            [X, FVAL] = fmincon (@ (x) funobj (x, R, NaP), x0, A, b, Aeq, beq, lb, ub, @ (x)
                    restricnl (x, L, NaP));

            XAxis = x (1: NAP);
            YAxis = x (Nap + 1: 2 * NAP);
            Result = [xAxis 'yAxis'];

            % Graphics coverage areas for each AP according to the points suggested
            % for maximum coverage

            X1 = 10 * x;
            f = imread ('Edificiok.png');
            f1 = imresize (f, [Width * Length * 10 10]);
        imshow (f1);
            Holdon;
            R1 = R * 10; % Radio

            For i = 1: NaP
            Angle = (0: 0.01: 2.01 * pi); % Coverage Draw radios
            Xc = x1 (i) + R1 * cos (angle);
            C = x1 (i + NAB) + R1 * sin (angle);
            Plot (Xc, Yc,'-b')

            Xc = x1 (i) + RAP * cos (angle); % Draw AP
            C = x1 (i + NAB) + RAP * sin (angle);
            Color = [0.99 0.78 0968];
            Fill (Xc, Yc, color);
            Plot (Xc, Yc,'-b')
            End
            FVAL
            Result
    end
```

Routine that contains the algorithm for constructing the objective function for the optimization model of the location of the AP

```
Function f = funobj (x, R, NaP) Function maximize target%

% Routine to minimize the coverage area
1. v = 1: 1: NaP;              % Vector number AP
2. n = nchoosek (NaP, 2); % Number of links between AP
3. Nchoosek Cn1 = (v 2); % Matrix combinations possible links
4. f1 = 0;
5. for i = 1: n
   Distance between APs%
   d = ((x (Cn1 (i, 1)) - x (Cn1 (i, 2))) ^ 2 + (x (Cn1 (i, 1) NAP) -x (Cn1 (i, 2) + NaP )) ^ 2) ^ 0.5;

   % Angulo to estimate the area of semi-arch Interference
       Angle = acos ((d / 2) / R);
       % Area calculation Interference
       Interf = (2 * R ^ 2) * (Angulo (sin (angle) * cos (Angle))) * heaviside (2 * Rd);
       f1 = f1 + d;            % Sumatoria interference
End
   if NaP <6
       Function maximize target%
            f = f1;
Else
       Function maximize target%
       f = - ((NAP * pi * R ^ 2) -f1);
   End
   End
```

Routine containing the nonlinear constraints optimization model for the location of the AP

```
Function [C, ceq] = restricnl (x, L, NaP)

1. ceq = 0;
2. R = L / sqrt (2);
3. v = 1: 1: NaP; % Vector number AP
4. n = nchoosek (NaP, 2); % Number of links between AP
5. Cn = nchoosek (v, 2); % Elaborate matrix combinations possible links
6. for i = 1: n
   c (i) = - ((x (Cn (i, 1)) - x (Cn (i, 2))) ^ 2 + (x (Cn (i, 1) NAP) -x (Cn (i, 2) + Nap)) ^ 2) ^ 0.5 + L;
End
End
```

In order to verify the validity of the proposed model will be introduced in the system parameters of two cases and the results will be assessed:

Case 1: Radio Coverage 15, 60m long, 34m wide (dimensions of the proposed building).

Result =10.6066 23.3934
22.3955 10.6066
33.8867 23.3934
49.3934 10.6066

In this first case, it is observed that for a radius of coverage of 15m and according to the dimensions of the building, the system suggests that at least 4 Access Points are required, as shown in Figure 2. In the result matrix, the

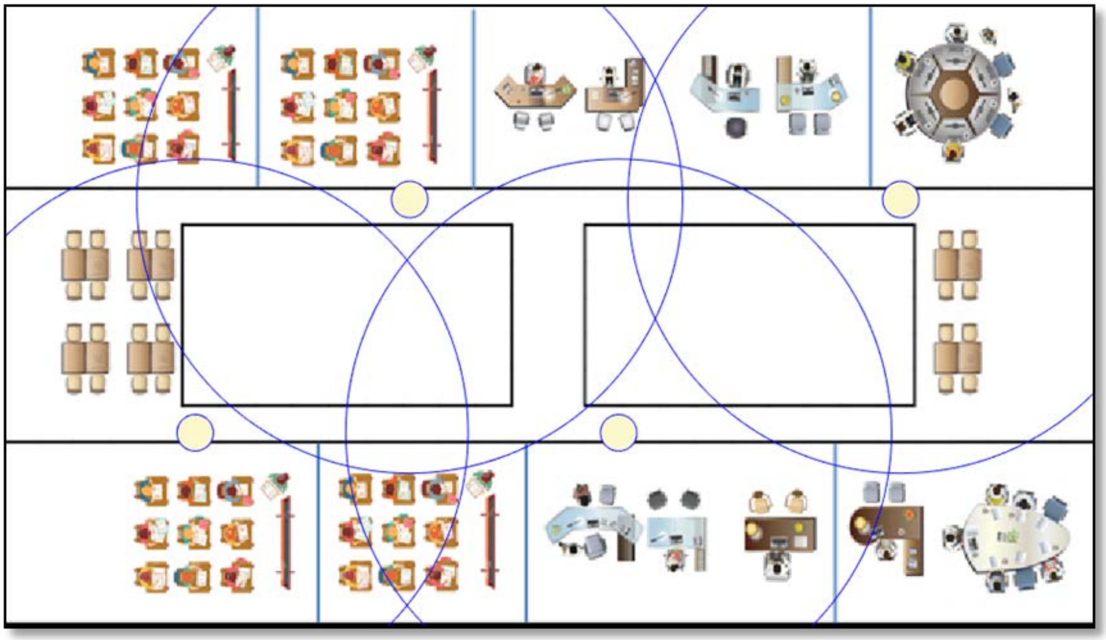

Figure 2. Diagram of coverage and location of AP - Case No. 1.

coordinates (X, Y) for each AP, where the first column is the values of X and the second the values of Y.

Case 2: Radio Coverage 20, 60m long, 34m wide (dimensions of the proposed building)

Result =45.0000 25.5000
15.0000 8.5000

In the second case it is observed that for a radius of coverage of 20m and according to the dimensions of the

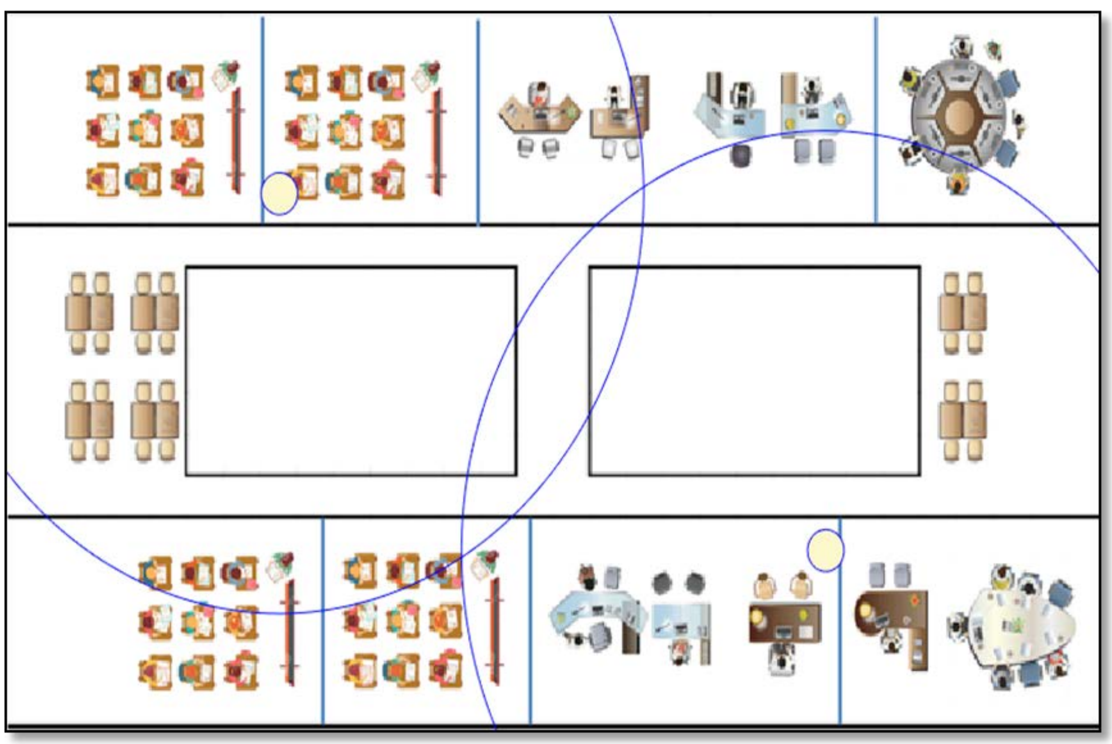

Figure 3. Diagram AP coverage and location - Case No. 2.

building, the system suggests that at least 2 Access Points are required, distributed according to Figure 3. In the result matrix, the coordinates (X, Y) for each AP, where the first column is the values of X and the second the values of Y.

4. Conclusions

Given the need to establish levels of coverage in indoor environments from the design stage, an optimization model was proposed for the location of the APs that are part of a wireless network. In view of the above and based with the results it was verified that the proposed optimization of the location of the AP model provides a fairly high performance with low computational complexity and time due to the use of allocation models in its structure. This model yielded excellent results when setting the Cartesian coordinates for the location of the AP, in order to maximize the coverage area and decrease levels of interference between cells. Additionally, the model is hinged to use Log-Normal model Shadowing, which is one of the most used to estimate RSSI levels and attenuation in wireless networks, due to its ease of implementation models, accuracy parameter estimation because of the implicit account of factors due to its empirical essence and low computational complexity and temporal. Aspects that are vitally important when developing new propotipos, especially focused on low-cost embedded systems. In view of the above, these elements can be considered as tools vital in future research related to the field of wireless networks, which is required to perform optimization processes spectral efficiency and thus maximize SINR levels.

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