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Optimization of the Spectral Efficiency in WLAN Networks in the 2.4GHz Band Under the Use of Allocation Models

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Abstract

Background/Objectives: As a result of the proliferation of Access Point (AP) in various environments, it has demonstrated a significant increase in the interference levels betweenadjacent AP Due to sharing of the ISM bands, significantly affecting network performance.The aim of this paper is to propose an optimization model for allocating channels in the 2.4GHz band, supported in the use allocation models. **Methods/Statistical Analysis:** A scenario consisting of 6 storey building and 24 Access Point (AP) distributed inside was proposed. The optimization model for allocating frequencies in the 2.4 GHz band is represented as a linear programming problem based on an allocation model, which is a variant of transport models. The model seeks to minimize interference between AP and thereby increase SINR levels and spectral efficiency. To determine whether the proposed model (MF) makes a better allocation of channels than the current model (MA), which incorporates policies RRM, a hypothesis test is performed under mean difference for two independent samples, by t tests -student. **Topic Relevance:** Although there have been several related channel assignment work, no evidence of any optimization model that has considered using allocation models as a strategy for optimizing spectral efficiency was found. In addition, the model offers levels and reduced computational time complexity. **Findings:** based on the results it was evident that the model proposed optimization (MF) made a better allocation of resources in the frequency domain compared to the current model (MA), reaching an increase of about 15% in SINR average, with 95% confidence. **Application / Improvements:** The MF model can be considered as a tool in future research related to the design and analysis of wireless networks which use the 2.4GHz band, to assess aspects of performance, efficiency and QoS.

Keywords: Channel Assignment, Efficiency, Optimization, Performance, SINR, WLAN

1. Introduction

Currently, wireless networks play an important role in the field of connectivity, due to the benefits associated with mobility, availability, speed and low cost of implementation[1]. Within the range of wireless networks, they are called WLAN (Wireless Local Area Network) supported in the 802.11 standard, which have been used in everyday places such as homes, offices, educational institutions, among others. Such networks are formed mainly by the use of concentrators devices called Access Point (AP), which allow users to connect wirelessly to a distance less than 100m, why the proliferation of AP is each They are increasing due to the need for greater coverage connection.

To the extent that density increases AP in WLAN networks, they have found problems with the performance thereof, which may be the result of lack of policies for user management on traffic load AP, inadequate selection frequency between channels, electromagnetic inter-

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ference, among other aspects; generating the AP are not able attend traffic volumes required to provide adequate levels of QoS (Quality of Service) users connected to the network[2]. In this scenario, WLANs are unable to realize their full potential. However, incorporating smart policies radio resource management RRM (Radio Resource Management), they could be applied to minimize the detrimental effects of interference and non-uniform load distribution[3] TEMS W995 phone interfaced with TEMS investigation tool version 13.1, Gstar GPS location finder and MapInfo professional and analyzed using Root Mean Squared Error (RMSE.

2. Radio Resource Management (RRM)

As a result of the continued proliferation of wireless users and access points, it often happens that in one area can reach coexist different wireless networks that are not part of the same delivery system and whose only relationship is not more than the use of a common means (spectrum unlicensed radio) situation creates difficulties when implementing centralized RRM mechanisms[4].

Mechanisms RRM in the field of networks WLAN IEEE 802.11 are intended primarily to reduce problems related to containment and interference, which results in a better Quality of Experience (QoE) as perceived by users, for it RRM should provide efficient mechanisms using algorithms for channel assignment, the type of modulation, power control and load balancing[5].

3. Allocation of Frequency Channels in WLAN Networks

Channel mapping involves assigning a particular channel for each Access Point in which seeks to minimize the interference levels. However, it is very important to assess the degree of influence of other factors on resource optimization processes as those mentioned above, which play an important role in the performance of WLAN networks.

Currently, two bands of the frequency spectrum available for unlicensed use in the IEEE 802.11 WLAN standard 2.4 GHz bands attached ISM (Industrial Scientific Medical) and 5GHz bands corresponding to the U-NII (Unlicensed National Information Infrastructure). The number of available channels may vary from country to country due to regulations of each relative to the spectrum allocation[6]. In particular, while most European countries and Australia allow the use of channels 1 to 13 in the 802.11b/g band, most countries in North, Central and South America are only allowed to the channel 11 in the same band. In Japan, all 14 channels are allowed. In addition, the IEEE 802.11 specifies a spectral mask defining the allowable power distribution across each cannel[7]. The signal should be attenuated by 30 dB or more from its peak power to ±11 MHz from the center frequency. Thus, channels are effectively 22 MHz wide. The first consequence is that only three or four channels do not overlap, usually 1, 6 and 11 (in the Americas), or 1, 5, 9 and 13 (in Europe). In other words, the ISM 2.4 GHz band provides space for only three or four near simultaneous transmissions without interference[8]. In Figure 1 the distribution channel in the 2.4GHz band is illustrated.

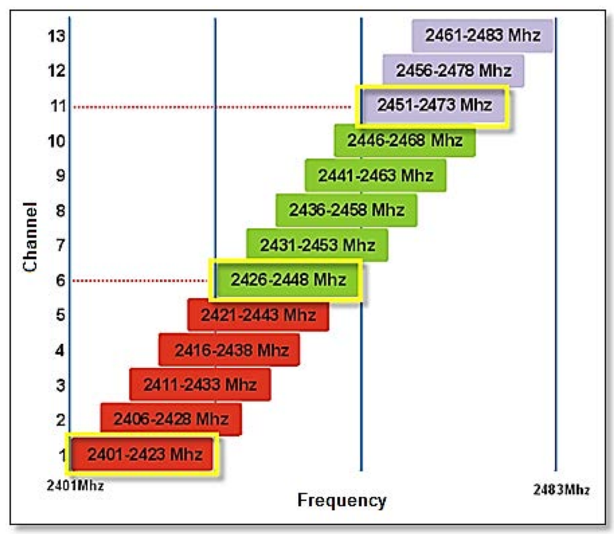

Figure 1. Distribution channels in the 2.4 GHz band[14].

Various strategies have been proposed for channel assignment in WLANs, seeking establish mechanisms selected orthogonal channels with each other or with minimum interference level for each neighboring AP. However, in scenarios with higher density AP, this problem presents greater complexity, because the three channels are often assigned so a priori by network administrators are not enough, causing two or more APs have to compete for the same portion of the spectrum. In this situation, there may be two interference conditions: The first is called "cochannel interference", which occurs when two or more processes performed AP transmission in the same channel. The second is called "adjacent channel interference" which occurs when the channels are partially overlapping each other. Depending on the intensity level and the level of overlap, these types of interference may be regarded as noise, significantly affecting the performance of the network[9].

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)[3]. Product of this situation, have generated problems related to the attenuation of the signal level transmission and reduced network performance. In view of the above, various studies they have been presented using algorithms to establish a dynamic channel allocation, both free bands and licensed bands, which have some sort of temporal or spatial availability[10].

Interest in wireless communications, both indoors and outdoors, has mushroomed because of the ease of installation, flexibility, scalability, mobility, among others. In the specific case of indoor environments, it is important to predict the behavior of radio propagation of signals due to the phenomena of reflection, diffraction, absorption and scattering, which can significantly affect the coverage and network performance[11]. In[12] the models most important propagation are described in the context of WLANs through which it is possible to estimate the losses and scope in conditions coverage channel when performing a transmission process in both environments exterior and interior. Among the propagation models are:

For this research the development of strategies for optimizing the allocation of channels in the 2.4 GHz band, supported in the use allocation models, which are a variant of transport models considered in order to identify the parameters essential for the interaction of various factors that may influence significantly on reducing interference between AP, maximizing throughput levels and improving spectral efficiency levels and SINR which may be present in a particular scenario.

Most Access Point can select the channel automatically, supported in 802.11h standard, which further allows the automatic power control to decrease the effects generated by interference between adjacent Access Point. However, in scenarios with high density AP, this mechanism may not be as efficient in terms of reduced interference when performing frequency assignment processes automatically. Among the major schemes for channel allocation can be mentioned[13]:

- FCA (Fixed Allocation cannel): The channels are assigned manually by the operator
- DCA (Dynamic Channel Allocation): Make a dynamic frequency assignment.
- RRM (Radio Resource Management) Also known as Auto-RF allows dynamic frequency assignment and control of dynamic transmission power to maintain the RF coverage area.

4. Proposed Model for the Allocation of Frequencies in the 2.4 GHz Band (MF_2.4GHz)

IEEE 802.11b/g has 14 frequency channels and provides three channels that do not overlap. As a basic rule of design, the APs within range of each are set up in different "non-overlapping" channels. However, this is severely limited in cases where there is a lot of access points on the local network and/or stations that generate interference within the service área[14]. Consequently, there is an urgent need to extend the channel allocation some overlapping frequency channels. Partially overlapping channels can improve network performance by allowing more channels used in wireless local area as they are always selected in the proper way to seek to minimize the interference levels with neighboring AP[15].

In the proposed, for the allocation of frequencies in the 2.4 GHz band has been considered model seek to minimize the interference levels using the SINR represented as a linear programming problem based on an allocation model. The channel allocation for WLAN using the SINR model can be regarded as a difficult task due to the cumulative nature of the product interference from each adjacent AP, which requires the use of advanced optimization mechanisms to find a solution to the allocation problem.

In view of the above and in order to establish mechanisms to reduce the computational complexity of the optimization process, the design of the matrix channel interference is considered, which calculates interference factors (W_{ij}) in channel i (Ch_i) product of channel j (Ch_i), whose values are estimated according to the following expression:

$$W_{ij} = \max\left(0, 1 - \left|Ch_i - Ch_j\right| f_c\right)$$

With:

$$f_c : = \frac{5MHz}{22MHz}$$

In Table 1 the matrix channel interference for the 2.4 GHz band is illustrated.

To state the problem as an allocation model, the variable X_i is created, which corresponds to the decision variable within the n possible combinations of the N channels available in groups of m AP that are part of the network.

m:Number of AP existing network

N:Number of channels available for allocation (11 for the 2.4 GHz band)

X_i:Decision variable corresponding to the combination number of N channels in groups of m AP with i = {1,2,..n} and whose value is between [0,1].

n:Number of possible combinations of N channels in groups of m AP. Where:

$$n = \frac{N!}{m!(N-m)!}$$

k:Number of potential sources of interference product of m AP that are part of the network on the AP analyzed.

$$k = \frac{m!}{2!(m-2)!}$$

W_{ij}:Interference factor in Channel i (Ch_i) product of Channel j (Ch_j)

WT_i:Total channel interference belonging to the combination i

$$WT_i = \sum_{j=1}^{k} W_{ij} \quad \forall i = \{1,2,\ldots,n\};$$

The approach of the optimization problem as a model allocation is as follows:

Objective Function

$$\min \sum_{i=1}^{n} WT_i.X_i$$

Subject to:

$$\sum_{i=1}^{n} X_i = m$$

$$0 \le X_i \le 1 \quad \forall i = \{1,2,\ldots,n\}$$

The objective function aims to minimize the interference levels between selected channels, taking account that the total of possible combinations only as many as number of APs exist on the network.

Matlab routine developed for the selection of channels with high density in the band AP 2.4GHz, according to the proposed model is:

Routine selection of channels in the 2.4 GHz band

% Matrix construction combinations channels 2.4GHz

1. m = input ('Enter the amount of AP');
2. v = 1: 1: 11;
3. n = nchoosek (11, m); % Number of combinations of channels for AP m

Table 1. Channel interference matrix i and j

W ij	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**eleven**
1	1	.7727	.5454	.3181	.0909	0	0	0	0	0	0
2	.7727	1	.7727	.5454	.3181	.0909	0	0	0	0	0
3	.5454	.7727	1	.7727	.5454	.3181	.0909	0	0	0	0
4	.3181	.5454	.7727	1	.7727	.5454	.3181	.0909	0	0	0
5	.0909	.3181	.5454	.7727	1	.7727	.5454	.3181	.0909	0	0
6	0	.0909	.3181	.5454	.7727	1	.7727	.5454	.3181	.0909	0
7	0	0	.0909	.3181	.5454	.7727	1	.7727	.5454	.3181	.0909
8	0	0	0	.0909	.3181	.5454	.7727	1	.7727	.5454	.3181
9	0	0	0	0	.0909	.3181	.5454	.7727	1	.7727	.5454
10	0	0	0	0	0	.0909	.3181	.5454	.7727	1	.7727
eleven	0	0	0	0	0	0	.0909	.3181	.5454	.7727	1

4. Cn = nchoosek (v, m); % Elaborate matrix combinations for m channels AP
5. lb = zeros ([1 n]);
6. ub = ones ([1 n]);
7. A = [];
8. b = [];
9. Aeq = ub;
10. beq = m;

Build% objective function
% Matrix channel interference

```
11. Wij = [1 0.7727 0.5454 0.3181 0.0909 0 0 0 0 0 0;
    0.7727 1 0.7727 0.5454 0.3181 0.0909 0 0 0 0 0;
    0.5454 0.7727 1 0.7727 0.5454 0.3181 0.0909 0 0 0 0;
    0.3181 0.5454 0.7727 1 0.7727 0.5454 0.3181 0.0909 0 0 0;
    0.0909 0.3181 0.5454 0.7727 1 0.7727 0.5454 0.3181
    0.0909 0 0;
    0 0.0909 0.3181 0.5454 0.7727 1 0.7727 0.5454 0.3181
    0.0909 0;
    0.5454 0 0 0.0909 0.7727 1 0.7727 0.3181 0.5454 0.3181
    0.0909;
    0 0 0 0.0909 0.3181 0.5454 0.7727 1 0.7727 0.5454
    0.3181;
   0 0 0 0.0909 0.3181 0.5454 0.7727 1 0.7727 0.5454;
   0 0 0 0 0 0.0909 0.3181 0.5454 0.7727 1 0.7727;
   0 0 0 0 0 0 0.0909 0.3181 0.5454 0.7727 1];
12. Wij = Wij 1000. *;
13. for i = 1: n
   % Extract row by row and gets combinations in pairs
    Cf = nchoosek (Cn (i, :), 2); k = nchoosek (m, 2);
    s = 0;
    for j = 1 k
    s = s + Wij (Cf (j, 1), Cf (j, 2));
    end
    F (i) = s;
    end
% Solve the system
14. [x, FVAL] = linprog (F, A, b, Aeq, beq, lb, ub);
15. r = find (x> 0.01); % Gets the position of optimum
    result
16. disp ('The suggested channels are:');
17. Cn (r, :) % Prints suggested channels for AP
```

Some examples of the translations of the proposed according to the number of required AP model are presented:

For the case of 3 Access Point

```
Enter the number of AP: 3
Optimization terminated.
Suggested channels are:

Channels =

   1   6   11
```

For the case of 4 Access Point:

```
Enter the number of AP: 4
Optimization terminated.
Suggested channels are:

Channels =

   1   4   7   11
   1   4   8   11
   1   5   8   11
```

In the case of 5 Access Point

```
Enter the number of AP 5
Optimization terminated.
Suggested channels are:

Channels =

 1   3   6   8   11
   1   3   6   9   11
   1   4   6   9   11
```

To calculate the SINR is necessary to determine the levels of total interference based on selected channels. To do this, proceed as follows:

P_{ij}:Power in AP_i product of AP_j. For the estimation of the power of incidence on the AP_i product of AP_j, the use of a supported propagation model in the Log-Normal Shadowing model was considered, which allowed to define in an empirical way the mathematical expressions for the estimation of the power received, both in free space and for environments with obstacles. For the particular case, the expressions for the estimation of the P_{ij} Power values can be calculated according to the following expressions:

Free space:

$$RSSI(d)[dBm] = P_{ij}(d) = -23.95 - 22.16\ Log_{10}(d)$$

Obstacles:

$$RSSI(d)[dBm] = P_{ij}(d) = -22{,}89 - 32{,}98\ Log_{10}(d)$$

Interference in the AP_x product of AP_y

$$I_{xy} = P_{xy}.W_{xy}^{ij}$$

$$W_{xy}^{ij} = \max\left(0{,}1 - \left|Ch_i - Ch_j\right| f_c\right)$$

Where W_{xy}^{ij} is the interference factor between the AP_x due to AP_y, product of the assigned channels i and j respectively.

I_x:Total interference on AP_x

$$I_x = \sum_{j=1}^{k} I_{xy}\ \forall x = \{\ \dots m\}$$

k:Number of potential sources of interference product of m AP that are part of the network on the AP analyzed.

$$k = \frac{m!}{2!(m-2)!}$$

The value $SINR_x$ corresponding to AP_x is given by:

$$SINR_x[dB] = 10log\left[\frac{P_x}{I_x + N_0}\right]$$

P_x:Power on AP_x (for practical purposes this power is calculated at the distance of 1m)

N_0:Background noise level

Let R_x be the data rate for the AP_x, which by Shannon's capacity theorem is given by:

$$R_x = Qlog_2\left(1 + SINR_x[dB]\right)$$

Let ES_x be the Spectral Efficiency for AP_x, which can be estimated by the expression:

$$ES_x = R_x / Q = log_2\left(1 + SINR_x[dB]\right)$$

Spectral efficiency plays an important role in the process of analysis when evaluating the quality of the processes of resource optimization in wireless networks, considering its value the higher, the better the distribution of resources in the frequency domain.

4.1 Current Status of Wireless Network

To perform the monitoring campaigns Acrylic Professional WiFi software tool was used, which allowed us to evaluate the current conditions of the wireless network. The proposed scenario corresponds to a 6-storey building with Access Point distributed inside, which provide students with an educational institution Internet service under RRM policies in the 2.4GHz band. Then the results are presented graphically:

In Figures 2-7 channel assignments for each SSID, the AP configured in that part of the wireless network of the building, in the 2.4 GHz band are presented. they can

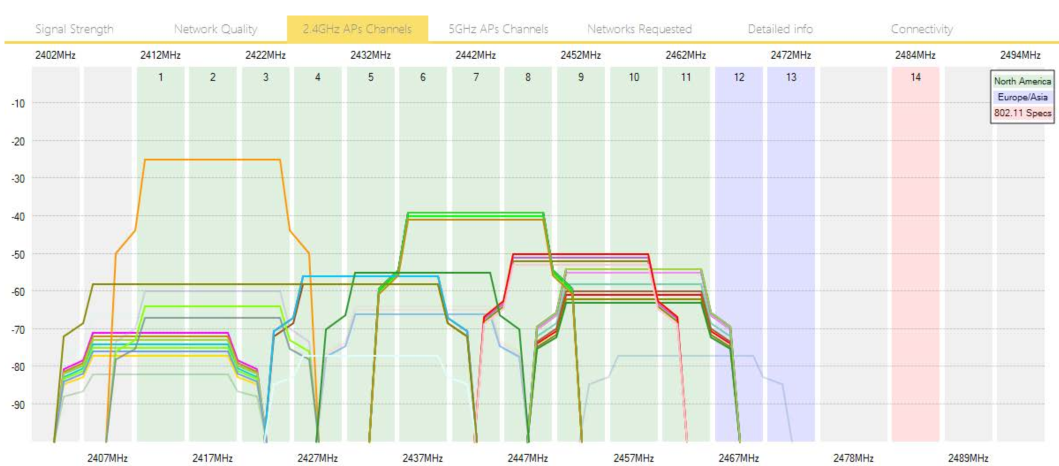

Figure 2. Current status floor 1 - 2.4 GHz band.

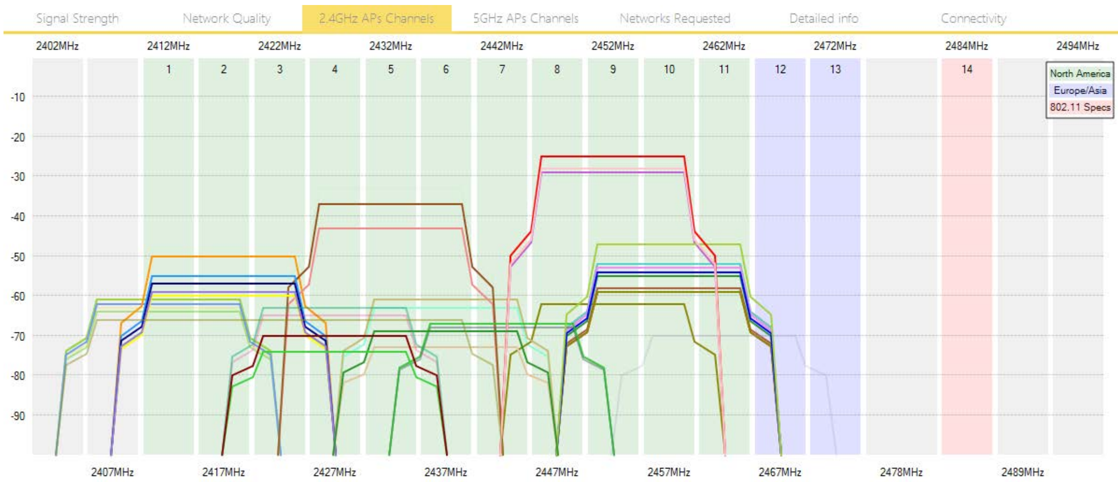

Figure 3. Current status floor 2 - 2.4 GHz band.

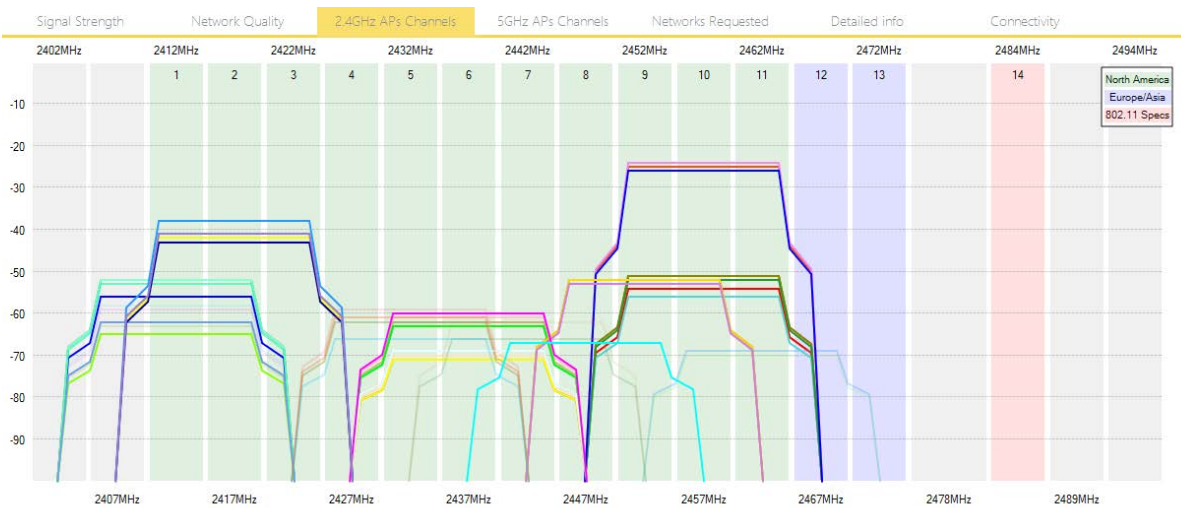

Figure 4. **Current status floor 3 - 2.4 GHz band.**

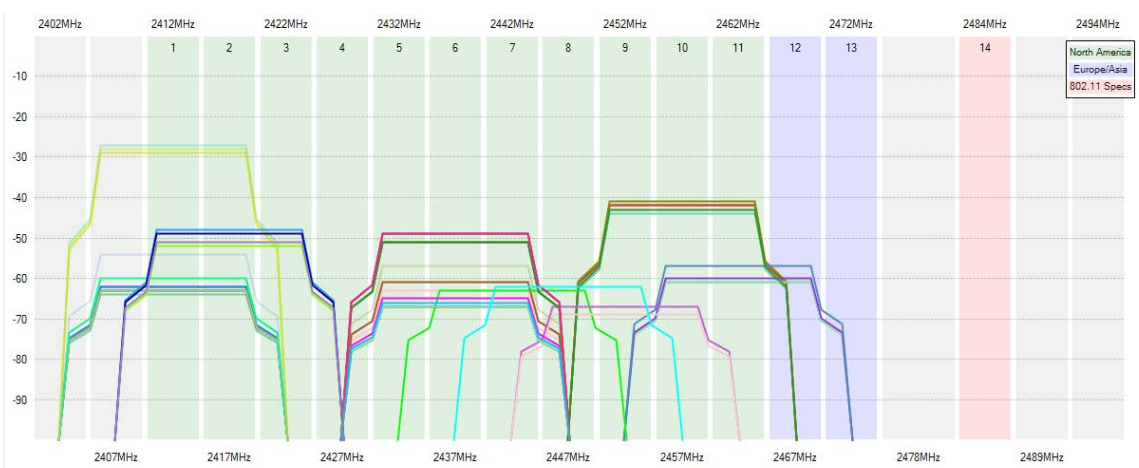

Figure 5. Current status floor 4 - 2.4 GHz band.

Figure 6. Current status floor 5 - 2.4 GHz band.

Figure 7. Current status floor 6 - 2.4 GHz band.

be clearly seen that there are high levels of interference between SSID different AP, because the vast majority are assigned to channels 1, 6 and 11, which are assigned automatically by RRM policies for each AP. On the other hand, areas inside the building where power levels received by the AP located on the same floor and even in flats nearby were less than -70 dBm, an aspect that reflects the critical state of the spectral efficiency is found in some floors of the building, mainly in the intermediate floors.

5. Comparative Analysis of the Current Status Against the Model Proposed Optimization

In view of the above and in order to test the proposed resource optimization in WLAN networks (MF) model, a Tablecomparing the current state of the wireless network in the building, compared to the estimated results was performed by the model proposed (MF). The results obtained are:

5.1 Current Model (MA) Network

Figure 8 shows that for the 2.4 GHz band, the radio coverage is estimated 20m according to the propagation model. On the floor they are located two APs aligned in one direction and on the next floor are aligned in the opposite direction. Radiation patterns for the upper floor are identified by the color “Blue” and the lower floor with color “Red”. In view of the above and analyzing reflected by the figure it can be seen that arise some areas, especially at opposite to the location of the AP, which reach not receive adequate power levels, which were identified with values below places of -70dBm. Faced with this situation is considered prudent to analyze through the proposed model if the number of AP is enough per floor and if the relocation of AP to obtain better conditions of coverage inside the building, according to the patterns of spread is necessary. A similar situation is seen in Figure, which corresponds to the conditions of radio coverage for the 5 GHz band.

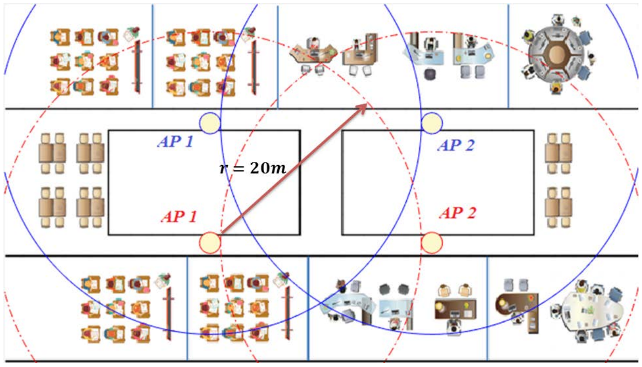

Figure 8. Diagram of coverage in the 2.4 GHz band - Current Model (MA).

In Table 2, corresponding to measurement parameters of the spectral conditions for the wireless network in the current model (MA), which were quantified levels of reception power, interference on each AP function results are presented interference levels generated by neighboring AP, SINR values, maximum transmission rate and spectral efficiency in each AP. In each parameter the average value, standard deviation and the minimum and maximum values, with the aim of testing and comparative statistical analysis with the proposed model (MF) was estimated.

5.2 Estimation of Design Parameters - Proposed Model

Table 3 shows the estimated radio coverage values, outage probability, coverage area and perimeter reception power for the 2.4 GHz band.

Table 4 shows the results of the proposed model optimization, related to the coordinates for location and channel assignment for the AP in the 2.4 GHz band. It shows that the amount of AP suggested by floor has increased 2 to 4. However, for the particular case of the 2.4 GHz band, only 2 of the 4 AP with SSID will be set, considering the location of the AP and the estimated radio coverage. Radiation patterns are considered ample and sufficient to ensure good service, minimizing the areas which could eventually present some shortcomings connectivity. Figure 9 illustrates this situation where it is seen that not only is able to minimize interference levels.

Table 2. Parameters of spectral efficiency in the current model (MA) - 2.4 GHz Band

		2.4GHz band					
i device	***Floor***	***Channel***	***$P_r(d_0)$ [DBm]***	***Interference) [dBm] $I(d_0)$***	***SINR [dB]***	***Max Data Rate () [Mbps] R_i***	***Spectral efficiency [Bps / Hz]***
AP 1	1	7	-27.0	-53.29	26.29z	95.41	4.77
AP 1	2	5	-26.0	-49.30	23.30	92.06	4.60
AP 1	3	2	-34.4	-52.87	18.47	85.66	4.28
AP 1	4	1	-34.0	-51.72	17.72	84.53	4.23
AP 1	5	1	-26.2	-57.26	30.66	99.69	4,98
AP 1	6	eleven	-23.8	-65.82	42.02	108.54	5.43
AP2	1	2	-23.0	-60.98	37.98	105,69	5.28
AP2	2	9	-23.6	-42.32	18.72	86.03	4.30
AP2	3	10	-27.0	-50.54	23.54	92.34	4.62
AP2	4	10	-24.0	-50.17	26.17	95.28	4.76
AP2	5	6	-34.8	-60.78	25.98	95.08	4.75
AP2	6	1	-24.8	-59.13	34.32	102.85	5,14
AP3	5	5	-26.4	-61.96	35.35	103.68	5.18
Half			**-27.3**	**-55.09**	**27.73**	**95.91**	**4.80**
Minimum			**-34.8**	**-65.82**	**17.72**	**84.53**	**4.23**
Maximum			**-23.0**	**-42.32**	**42.02**	**108.54**	**5.43**
Deviation			**4.3**	**6.53**	**7.81**	**7,85**	**0,39**

Table 3. Design parameters estimated for the 2.4 GHz band

Design Parameters	**2.4GHz band**	
Power Transmission ([dBm] P_t)	26	26
Kind	**Free space**	**obstacles**
Sensitivity () [dBm] P_{min}	-70	-70
Prob. Estimated cut ([%] P^*_{corte}	15	15
Prob. Real cutting ([%] P_{corte})	15.05	18.41
Radio Coverage () [m]r	66	20
Reception perimeter power [dBm] $P_r(r)$	-64.27	-65.79
Coverage () [%]C	94.15	95,00

Table 4. Coordinates for location and channel assignments for AP - Proposed Model (MF) - 2.4 GHz Band

Arising coordinates	***X***	***Y***	***couple floors***	***Impares floors***
AP1	**10.6**	**23.4**	**1**	
AP2	**22.4**	**10.6**		**4**
AP3	**33.9**	**23.4**		**11**
AP4	**49.4**	**10.6**	**7**	

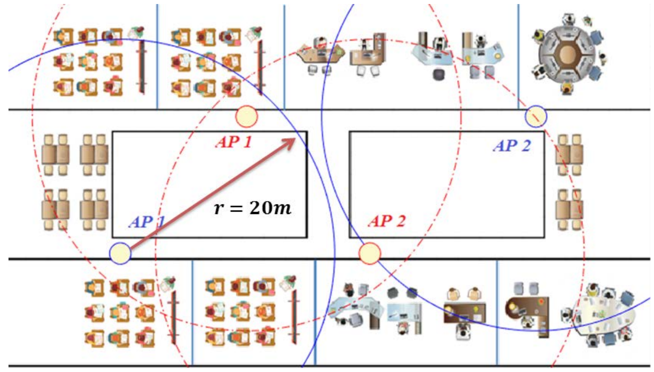

Figure 9. Diagram band coverage of 2.4 GHz - Proposed Model (MF).

Table 5 shows that in terms of SINR, Max Rate and spectral efficiency, improved values compared with those established by the MA model. However, it is necessary to analyze from a statistical point of view if there are indeed significant differences between the two models and if indeed it can be considered that the proposed model is better than the current model.

The result for the location of the AP throughout the building can be seen in Figure 10 and for each floor are located 4 AP, according to the locations set forth in Table 4.

Table 5. Parameters of spectral efficiency in the current model (MF) - 2.4 GHz Band

		2.4GHz band					
i device	***Floor***	***Channel***	***$P_r(d_0)$ [DBm]***	***Interference) [dBm] $I(d_0)$***	***SINR [dB]***	***Max Data Rate () [Mbps] R_i***	***Spectral efficiency [Bps / Hz]***
AP 1	1	1	-23.95	-55.30	31.3529	100.32	5.02
AP 1	2	4	-23.95	-52.25	28.3019	97.46	4.87
AP 1	3	7	-23.95	-55.21	31.2642	100.24	5,01
AP 1	4	eleven	-23.95	-58.87	34.9237	103,34	5,17
AP 1	5	1	-23.95	-54.02	30.0669	99.15	4.96
AP 1	6	4	-23.95	-53.76	29.8147	98.91	4,95
AP2	1	7	-23.95	-56.97	33.0153	101.76	5.09
AP2	2	eleven	-23.95	-57.83	33.8753	102,48	5,12
AP2	3	1	-23.95	-57.54	33.5945	102.25	5,11
AP2	4	4	-23.95	-53.09	29.1372	98.27	4.91
AP2	5	7	-23.95	-54.74	30.7915	99.81	4,99
AP2	6	eleven	-23.95	-58.67	34.716	103.17	5,16
Half			**-23.95**	**-55.69**	**31.74**	**100.60**	**5.03**
Minimum			**-23.95**	**-58.87**	**28.30**	**97.46**	**4.87**
Maximum			**-23.95**	**-52.25**	**34.92**	**103,34**	**5,17**
Deviation			**0.00**	**2,24**	**2,24**	**1,97**	**0.10**

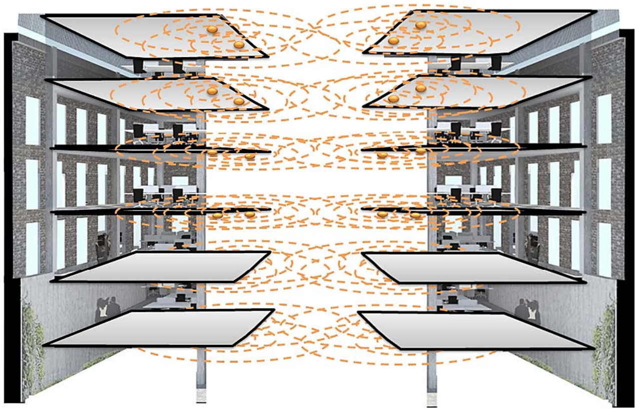

Figure 10. Appearance location of AP resulting building.

5.3 Analysis Model vs MF MA

In order to evaluate if the optimization model for allocation of proposed frequency (MF) performs better process resource allocation method that is currently present in the institution (MA), which incorporates policies RRM arise the following assumptions:

5.4 Evaluation of SINR in the 2.4 GHz Band

$$H_o : \mu_{SINR\_2.4G\_MA} \le \mu_{SINR\_2.4G\_MF}$$

$$H_a : \mu_{SINR\_2.4G\_MA} > \mu_{SINR\_2.4G\_MF}$$

Where $\mu_{SINR\_2.4G\_MA}$ and $\mu_{SINR\_2.4G\_MF}$ are the corresponding means to the actual SINR and SINR estimated by the MF model obtained in the 2.4 GHz band. The hypothesis H_o states that when using the model MF highest levels of SINR are obtained against the methodology current configuration and H_a sets the opposite condition.

Evaluation of Spectral Efficiency () in the 2.4 GHz band

$$H_o : \mu_{\varepsilon\_2.4G\_MA} \le \mu_{\varepsilon\_2.4G\_MF}$$

$$H_a : \mu_{\varepsilon\_2.4G\_MA} > \mu_{\varepsilon\_2.4G\_MF}$$

Where $\mu_{\varepsilon\_2.4G\_MA}$ and $\mu_{\varepsilon\_2.4G\_MF}$ are the respective average value of the current spectral efficiency and estimated by the MF model respectively, obtained in the 2.4 GHz band. The hypothesis H_o states that when using the model MF better spectral efficiency is obtained against the methodology current configuration and H_a sets the opposite condition.

To accept or reject the hypotheses is necessary to make a hypothesis contrast mean difference for two independent samples by t-Student test. To do this, the following steps are established:

Step 1: Calculate the statistical value established for the test by using the following expression[16]:

$$t_{estad} = \frac{\mu_x - \mu_y}{\sqrt{\frac{(n_x - 1)S_x^2 + (n_y - 1)S_y^2}{n_x + n_y - 2}} \cdot \sqrt{\frac{1}{n_x} + \frac{1}{n_y}}}$$

Where :

t_{estad} : Statistical value

n_x ,n_y : Number of samples

S_x^2, S_y^2 : Variances sample in each case

Step 2: Set the acceptance range for each of the H_o for $\{t : t < T_{(\alpha;Gl)}\}$ at 5% significance (α = 0.05), with $Gl = n_x + n_y - 2$ degrees of freedom. To accept it is necessary that the statistic (t_{estad}) be located within the acceptance interval established in each case, otherwise the H_o will be rejected. Making use of the miniTap statistical software, and according to the values recorded in Table 28; The result obtained in each of the tests is consolidated in Table 6.

Table 6 shows that the statistical value for each of the cases set is within the acceptance range, the aspect which H_o is accepted in both cases. In view of the above, it is concluded that the MF model performs better allocation

Table 6. Results Student t test for each of the established hypotheses

Variable	H_o	Degrees of freedom *Gl*	Statistical	Acceptance range $\{t : t < T_{(\alpha;Gl)}\}$	It is accepted H_o
SINR	$\mu_{SINR\_2.4G\_MA} \le \mu_{SINR\_2.4G\_MF}$	2. 3	1713	$(-\infty, 1.7139)$	Yes
Spectral efficiency	$\mu_{\varepsilon\_2.4G\_MA} \le \mu_{\varepsilon\_2.4G\_MF}$	2. 3	1,980	$(-\infty, 1.7139)$	Yes

Source: Author

of space and frequency resources than those currently used, considering that for the proposed scenario, the MF model achieves higher levels of SINR and better spectral efficiency, which will be reflected in higher levels of efficiency in terms of throughput, delay and efficiency versus current conditions, with 95% confidence.

Table 7 shows a comparative table of variables SINR, and Spectral Efficiency Max Data Rate for MF and MA models, based on the average value and the percentage difference. V_{MF} and V_{MA} Correspond to the value obtained with the MF Model and the MA Model respectively. According to the results obtained, the following aspects can be manifested:

- The SINR achieved by MF exceeds by 14.46% in the 2.4 GHz band against the model MA, doubling in the latter levels of SINR with the proposed from the current state model, appearance significantly improves transmission processes and performance network and reflects a considerable decline in the levels of interference between APs.
- In the case of a significant increase spectral efficiency of 4.79% in the 2.4 GHz band against the model MA it is evident, which is quite favorable for the transmission of voice and video in terms of throughput and latency.
- Finally, product of the above two cases, an increase is evidenced by the maximum transmission rate or Max Data Rate offered by the MF model 4.9% in the 2.4 GHz band against the model MA, thereby improving levels Throughput, delay and QoS in the network.

Table 7. Comparison table MF vs MA - Band 2.4GHz

Variable	Model	Half	% Of diference $\%Df = \left(V_{MF} - V_{MA}\right) * 100 / V_{MA}$
WITHOUT R	MF	31.74	14.46
	MA	27.73	
Spectral efficiency	MF	5.03	4.79
	MA	4.80	
Max Data Rate	MF	100.6	4.9
	MA	95.91	

6. Conclusions

During the development of this research it was evident that the MF model, allowed to reach higher levels of SINR, Max Data Rate and spectral efficiency compared to the MA model, which is supported in political RRM and describes the current state of building the wireless network, with 95% confidence. Consistent with the results obtained, the SINR achieved by MF exceeded by 14.46% in the 2.4 GHz band against the model MA, an aspect that would significantly improve the process of transmission and network performance and reflects a considerable decline in the levels of interference between APs. In the case of a significant increase spectral efficiency of 4.79% in the 2.4 GHz band against the model MA it is evident, which is quite favorable for the transmission of voice and video.

Given the need for equitable distribution of resources according to service demand among the AP as part of a wireless network, using allocation models as a strategy for frequency allocation proposedand mechanisms AP location, in order to maximize SINR levels, improving spectral efficiency and reducing the interference levels, providing appropriate QoS levels for each of the nodes. In view of the above c Based on the results obtained was evident that the proposed model (MF) realizaro better allocation of spectrum resources compared to the current model, where an increase of about 15% on the average SINR minimizing interference levels for each node, with 95% confidence was evident. It is very important to mention that according to the consulted biography proposed for the 2.4G GHz band model would be the first model established for resource optimization supported using allocation models, generating an added value to the work done and valuable contribution to the scientific community in terms of evaluation and analysis of wireless networks.

One of biggest problems in implementing any of the algorithms related to resource optimization in wireless networks is related to computational complexity and temporal thereof. In this situation, some researchers have opted for the use of genetic algorithms, heuristic methods among other strategies. However, for the proposed model optimization mechanisms supported on allocation models were used, which they allowed achieve appropriate and feasible solutions for the proposed scenarios, including low levels of computational complexity and time by using tools such as the toolbox of Matlab, which significantly reduced the computational complexity required to provide solution

7. References

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