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# A binary linear programming to the planning of wireless systems

Programación lineal binaria para la planificación de sistemas inalámbricos

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**ABSRACT**

Locating access points for Wi-Fi networks in a post-pandemic scenario proposes an application in the planning and restructuring of existing wireless systems. Education strategies such as the flipped classroom, among others, demand the overall performance of the system. In this work, we propose a methodology using binary linear programming as a strategy to achieve the planning of a Wi-Fi system that can have the objectives of coverage, user capacity and channel interference. The results show a better coverage, higher speed per user and optimized the amount of equipment per sector in the laboratories of the University of Magdalena.

**Keywords:**

Binary linear programming, Wireless systems, Optimization, Planning.

**RESUMEN**

La localización de puntos de acceso para redes Wi-Fi en un escenario postpandemia propone una aplicación en la planificación y reestructuración de los sistemas inalámbricos existentes. Las estrategias educativas como el aula invertida, entre otras, exigen el desempeño integral del sistema. En este trabajo se propone una metodología utilizando programación lineal binaria como estrategia para lograr la planificación de un sistema Wi-Fi que pueda tener los objetivos de cobertura, capacidad de usuarios e interferencia de canales. Los resultados muestran una mejor cobertura, mayor velocidad por usuario y una cantidad optimizada de equipos por sector en los laboratorios de la Universidad del Magdalena.

**Palabras Clave:**

Programación lineal binaria, Sistemas inalámbricos, Optimización, Planificación.

## Introduction

Wireless communication technologies such as Bluetooth, ZigBee, WiFi, are in constant demand for use, offering convergent information transmission services. In addition, they are being used with a significant boom, in navigation services and indoor positioning; among other [1]. The implementation of Bluetooth low energy access point (APs) is widely used for location inside buildings, taking into account coverage and low consumption [2]. ZigBee has great potential in the field of monitoring environmental variables due to its advantages of low power consumption, low cost and high reliability [3]. On the other hand, unlike Bluetooth, Zigbee allows better device behavior by configuring a mesh topology, operating principle of wireless sensor networks [4]. WiFi technology is widely used by internet operators to access their services, even in public places as a service on demand, generating the deployment of APs following a heuristic approach [5]. Beyond the coverage area and the use of a shared spectrum, what unifies these technologies is the current problem of planning the location of their elements in a certain area [6]. A wireless infrastructure can be oriented to avoid co-channel interference, framed in satisfying a coverage-oriented implementation, allowing connectivity for a maximum number of users, or a combination of the above [7]. Interference is one of the most critical problems and has been addressed with solutions such as cognitive radio [8], which leads to a considerable investment and limitation in the possible brands. Works such as [9]–[11] propose

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solutions to implement Wi-Fi networks aimed at avoiding interference, but it does not allow choosing the optimization objective function with reference to other possibilities such as coverage or guaranteeing quality of service through a limited number of users per wireless access.

Others such as [12] try to generate a planning solely oriented to serve a coverage area or allow the use of a heat map of a coverage area where the theoretical received signal strength (RSS) is appreciated as a possible way of interpret channel capacity [13]. More recent works like [14]–[16] they point to the integration of LTE phentocells and their possible integration with WiFi; 5G services not yet planned in many geographies [17]. Other works like [18] propose a deeper solution by improving the performance of wireless networks that work in half duplex mode by reducing waiting times for queues and switching of uplinks – downlinks [17].

Despite the large number of works, no one has been found that satisfies the planning of a Wi-Fi network, allowing an optimization whose objective function is chosen by the planner, considering the criteria of interference, coverage or capacity or their combination. In this work, an application in m language is developed that allows the heuristic optimization of a WiFi infrastructure that allows choosing the design objective. In addition, a methodology is suggested that allows a high success rate verified with a case study.

## Methodology

The development of the application was presented in three phases. In the first phase of requirements analysis, it contains, in turn, three components. The establishment of the design objectives is carried out according to the information obtained in the drawing components, the interference analysis, and the determination of the electrical and data infrastructure. The second phase involves the computational heuristic solution. Finally, the implementation is carried out in accordance with what was obtained in phase two. Each of the elements of the methodology is described in figure1.

### A.Requirements analysis

Survey of plans: When the planning process begins, the physical location to be submitted is known. It is necessary to know the spatial dimensions of the environment as well as the materials that make up the structure. The higher the level of knowledge, the greater the precision in the implementation. This type of information must be completed on a digital plane at a known scale. The plane with the information will be entered into MATLAB in order to present a graphical interface for the location of the candidate points. A candidate point is a point that has the minimum conditions necessary for its implementation, such as power supply, wired access to the data network and aesthetics, among others. However, they are necessary but not sufficient conditions for it to meet the design objectives.

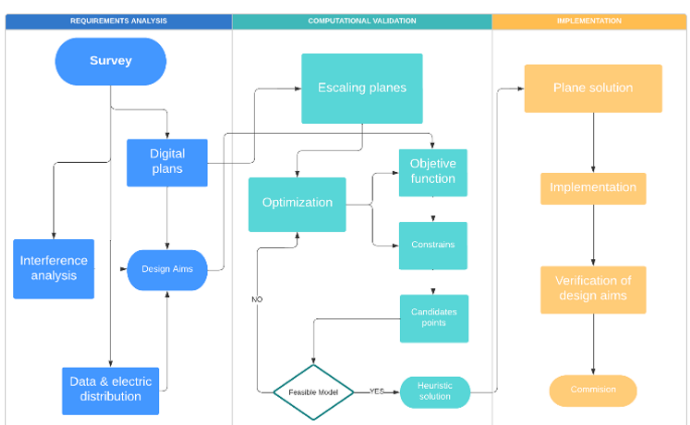


**Figure 1.** Elements of methodology for planning.

Source: Author.

*Interference analysis:* In wireless technologies, one of the great adversities that the designer cannot control is interference. The use of free frequencies for the transmission of information is increasingly recurrent. Thus, the occupation of unwanted frequencies in free radio propagation channels is more frequent. For this reason, an analysis of the possible frequencies or channels with lower occupancy or with total availability for use must be carried out.

For the interference analysis it is possible to use free-use applications on the computer or on a mobile device known as spectral analyzers or follow strategies such as those presented in [12]. However, these applications are limited to the parameters of the device and the frequencies of the wireless network card that it has. A spectrum analyzer is recommended as measurement equipment. Technically, this guarantees greater precision in the measurement campaign of possible radiant sources.

*Infrastructure survey:* You may have wireless devices that you want to reuse or deploy in the area of interest, such as wireless gateways or routers. From these devices, the information provided by the manufacturer should be taken regarding the transmission power, the frequency band in which it can operate, the antenna radiation pattern, the possibility of changing the antenna and the gains of the antennas. commercially available replacement. In case of starting from scratch, it is possible to choose all the same radiating devices, that is, with the same specifications. In this situation, it is recommended to use an Analytic Hierarchy Process (AHP) as a methodology for defining the possible devices to acquire. An application of this is observable in [19].

On the other hand, it is necessary to know the places where there is structured wiring and electrical wiring to feed the wireless accesses [20]. This information is important since it will allow to establish the location of the candidate points within the digital plane. Sometimes, for public places, it is not desirable to see wireless access, impoverishing the design and aesthetics of the physical infrastructure. Therefore, aesthetics is also part of the information to be collected in this item. For simplicity, it is recommended to only mark the points that are not aesthetically viable. In addition, the binary variant allows determining whether a wireless access will be turned on as part of the solution. The convex shape of the solution region presented by the PLB allows choosing a vertex of said region by performing a reasonable number of iterations.

### B. *Computational validation*

*Scaling plans:* All the information collected in the previous phase, must rest on a digital plane, compatible with MATLAB to apply the designed graphical interface. Image files (.png, .jpeg, etc.) containing the information collected are recommended. Although the candidate points are obtained from the survey, the graphical interface allows the selection at a relatively close distance where a known scale should exist.

*Optimization:* In this step, the use of binary linear programming (PLB) is recommended, which has satisfactory results. PLB is the solution to the allocation of resources in the best way when resources are limited and the relationship between the objective function and all its variables involved are linear [21]. In addition, the binary variant allows determining whether or not a wireless access will be turned on as part of the solution. The convex shape of the solution region presented by the PLB allows choosing a vertex of said region by performing a reasonable number of iterations.

*Feasibility of the model:* PBL is limited to solving low-dimensional problems. For multiple variables, a viable solution may not be achieved. However, applying the heuristics to the margins in the constraint equations, such as percentage of users served, increasing the number of candidate points, or limiting the objective function to a couple of design objectives, allows obtaining a feasible solution that satisfies implementation needs.

### C. *Implementation*

*Solution plane: For the case study, the laboratory area of the University of Magdalena was proposed.*

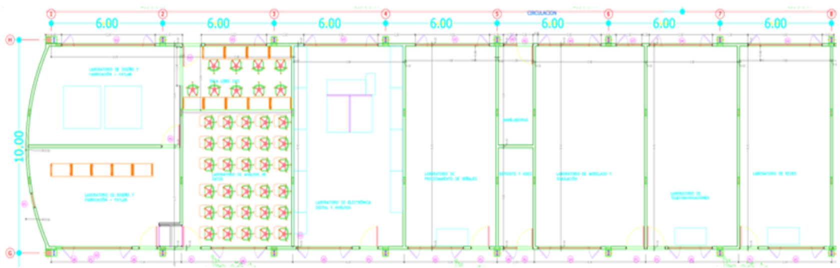


**Figure 2.** Test scenario.

Source: Author.

To apply the methodology, the space of the data science laboratory was chosen, which has an area of approximately 60 square meters. This plane is already to scale and was adjusted in the Matlab graphical interface tool. Previously, a measurement campaign has been carried out with an AGILENT N9344C analyzer that allows establishing the possible interference and usability of the WiFi channels that precede the implementation of the network to be designed. It is established that the possible WiFi channels to implement are channels 2 and 8.

To establish the objective function, 50 potential users were planted, with a coverage of 75% of them and with 15 possible positions for the APs given the location needs for power supply and connection to the high-speed wired network, that is, there are 15 candidate points for installation of APs. Additionally, it is restricted to 25 users per WiFi channel. The image shows the initial plane with the positions of the users and the coverage area of the candidate points.

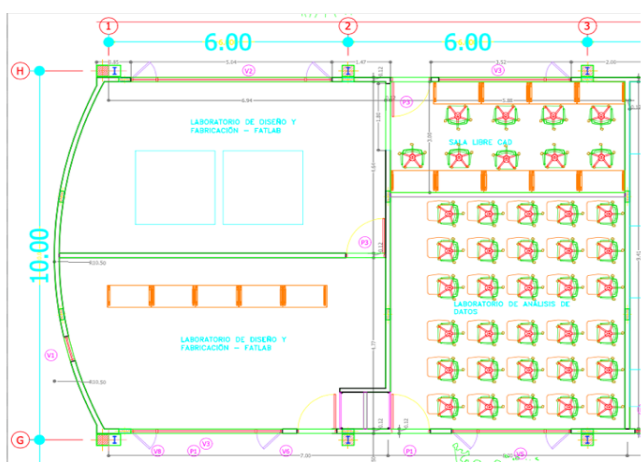


**Figure 3.** Coverage area and location of the users to apply the optimization oriented to coverage, interference and capacity.

Source: Author.

We proceed with the definition of the variables involved and their designation in the Matlab application, where $Z_n$ represents the represents the nth candidate wireless access, $K_n$ the number of available channels and $Y_n$ the nth potential user.

On the other hand, the algorithm returns the constraint equations by adding as a user solution to $X_n\_Z_n\_K_n$; whose meaning is user X who has coverage with wireless access Z and channel K. The objective function with the constraint equations introduced, is given by:

$$min: Z_1 + Z_2 + Z_3 + \cdots + Z_{13} + Z_{14} + Z_{15}; \quad (1)$$

$$Conectivity:$$

$$Y_1 + Y_2 + Y_3 + \cdots + Y_{48} + Y_{49} + Y_{50} >= 75; \quad (2)$$

$$Capacity:$$

$$AP\_1: X_{1\_1} + X_{1\_2} + \cdots + X_{1\_11} + X_{1\_12} \leq 3Z1;$$

$$\vdots$$

$$AP\_15: X_{15\_1} + X_{15\_2} + \cdots + X_{15\_11} + X_{15\_12} \leq 3Z2; \quad (3)$$

$$Constraint:$$

$$R_{1\_1}: X_{1\_1} <= Z_1;$$

$$R_{1\_2}: X_{1\_2} <= 0;$$

$$\vdots$$

$$R_{1\_30}: X_{\_1\_3} <= Z_1;$$

$$R_{1\_40}: X_{\_1\_4} <= Z_{1;}$$

$$R_{1\_50}: X_{1\_5} <= 0; \quad (4)$$

For simplicity, some intermediate constraint equations have been omitted. As can be seen, the software developed in Matlab allows to analyze the plane entered with the candidate points and evaluating the need for a coverage greater than 75% of the users and with only the use of channels 2 and 8 (two channels available), it allows to find the restrictions of the case.

## Results

Once the program was executed, the following optimization parameters are presented:

Runtime: 349 milliseconds.

Optimization time: 46 milliseconds.

Number of iterations: 1,954,738

Number of accesses solution: four (4).

It is important to clarify that the optimization time is low but the graph of the solution is the part that took the most time. The solution plan to be implemented is presented in fig.4.

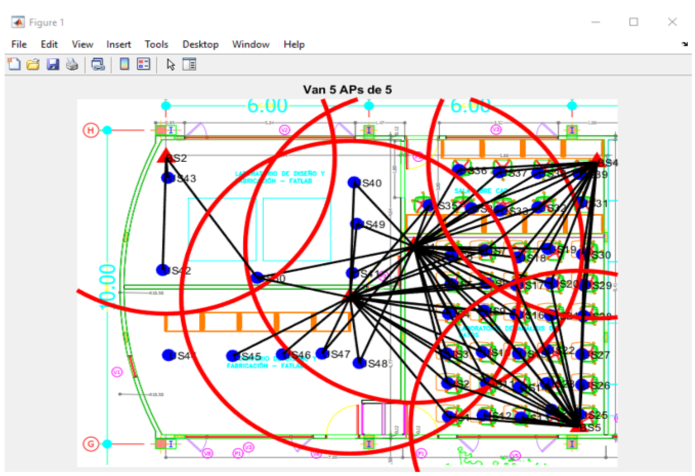


**Figure 4.** Test scenario with the coverage of the APs solution.

Source: Author.

Where it is shown that the number of wireless accesses to be implemented that allows to support the delivered conditions is four. The locations of the wireless accesses are delivered in a previous scale plain text, the same as the initial plane.

As for the propagation model used for the generation of coverage radius, the model of propagation losses in free space was used. This model can be improved by a ray tracer, using optical ray theory and a diffraction model to improve accuracy. The implementation of this algorithm is left for future work.

The limitation of the number of users by wireless access is done by restricting the AP by management software, indicating that it only delivers, X_n IP addresses.

## Conclusion

A methodology is obtained that proposes the use of binary linear optimization as a strategy to achieve the planning of a WiFi system that may have the objectives of covering a specific area, using a certain number of channels avoiding co-channel interference and that allows access to a limited number of users to sustain a quality of service in the speed of channel.

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