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Design of sites for radio networks on Colombian cartography through the technological tool Xirio Online, Case study: Caparrapí – Cundinamarca

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Abstract

At present, with the development of emerging technologies, society is facing the need for network infrastructure to guarantee full broadcasting and coverage; thus requiring the development of tools, strategies and / or techniques such as the sites of base stations of telecommunications operators, also taking into account that with the appearance of 5G the number of antennas will increase because the use of high frequencies has less coverage. The implementation of the necessary infrastructure to achieve the desired deployment of the telecommunications network represents cultural, organizational, ecological and financial challenges, which is why in Colombia the Ministry of Information and Communications Technologies (MinTIC) established public policy guidelines for the massification of 5G technology seeking to reduce the existing digital divide between urban and rural territories. For this reason, the project supports its methodology in the Xirio Online Software, which using high resolution cartography allows planning, controlling and simulating radio frequencies in rural and urban environments; At the same time, it analyzes the configuration parameters implemented in the simulation of the site and its coverage. The results obtained will serve as a tool for the installation or adaptation of the Telecommunications infrastructure in the municipality of Caparrapí – Cundinamarca, seeking in it a quality interconnection.

Keywords: Antennas, sites, broadcasting, 5G technology, Caparrapí.

Introduction

The absence of technological tools and Internet connection, are constituted as the main factors in the inequality of access to Information and Communication Technologies (ICT), this inequality is called "digital divide". Affecting the educational, labor, personal and social development of different groups or individuals pigeonholed in this problem; especially during and after the COVID-19 pandemic, where teleworking and virtual classes were chosen as preventive measures.(Lloyd, 2020)(Net, 2020)

These social needs and technological trends drive countries to take on the challenge of interconnecting their entire territory if possible, with the purpose of improving the quality of life of their inhabitants. Colombia, not being the exception, demands immediate attention to the deficit of reach of the Internet network in specific sectors, having insufficient infrastructure as the main cause of this problem. This is due to the fact that the Colombian geography hinders the proper implementation of telecommunications towers for full coverage of the connectivity service.(Manrique & Torres, 2019)

As a result, since 2019 the Ministry of Information and Communications Technologies (MinTIC) of Colombia launched the 5G plan, prioritizing in it the deployment, massification and demand for technology adjusted to the country's geography.(Constaín, Mantilla, Rueda, Trujillo, & Barrera, 2019)

Reason why it is necessary to carry out studies on technological tools that allow simulating environments of location of radio networks, creating particular maps that allow a diagnosis of interferences in the main points of transmission for the optimization of the sending of information and expansion of coverage on Colombian cartography, such as Xirio Online, specifically in the case study of the Caparrapí municipality in Colombia.

Figure 1 identifies the tree of problems with the central idea "Insufficient infrastructure for the transmission of information with equity", from which the causes and effects derived from the lack of technological infrastructure in communications, mainly in mobile telephony, as a result of public policies and investment by service providers in the national market. As a result, there is a lack of coverage and performance of networks, limiting the access of some populations to emerging technologies such as 5G.

As a result of the analysis of the problems presented, it is obtained that the direct causes such as the difficult access of the infrastructure to specific geographical areas, impossibility of supplying the demand in telecommunications due to high costs and the current distribution of infrastructure that is not projected to growth, indirectly causes that both the implementation projects and the coverage and performance of the networks is not sufficient to that information and technology are accessible to specific groups of people.

On the other hand, the tree determines the related effects, finding that the limitation for the growth of networks and the inequality caused by the digital divide generate indirect effects such as the conditioning of technological development to the available equipment and educational development in specific areas without technological tools.

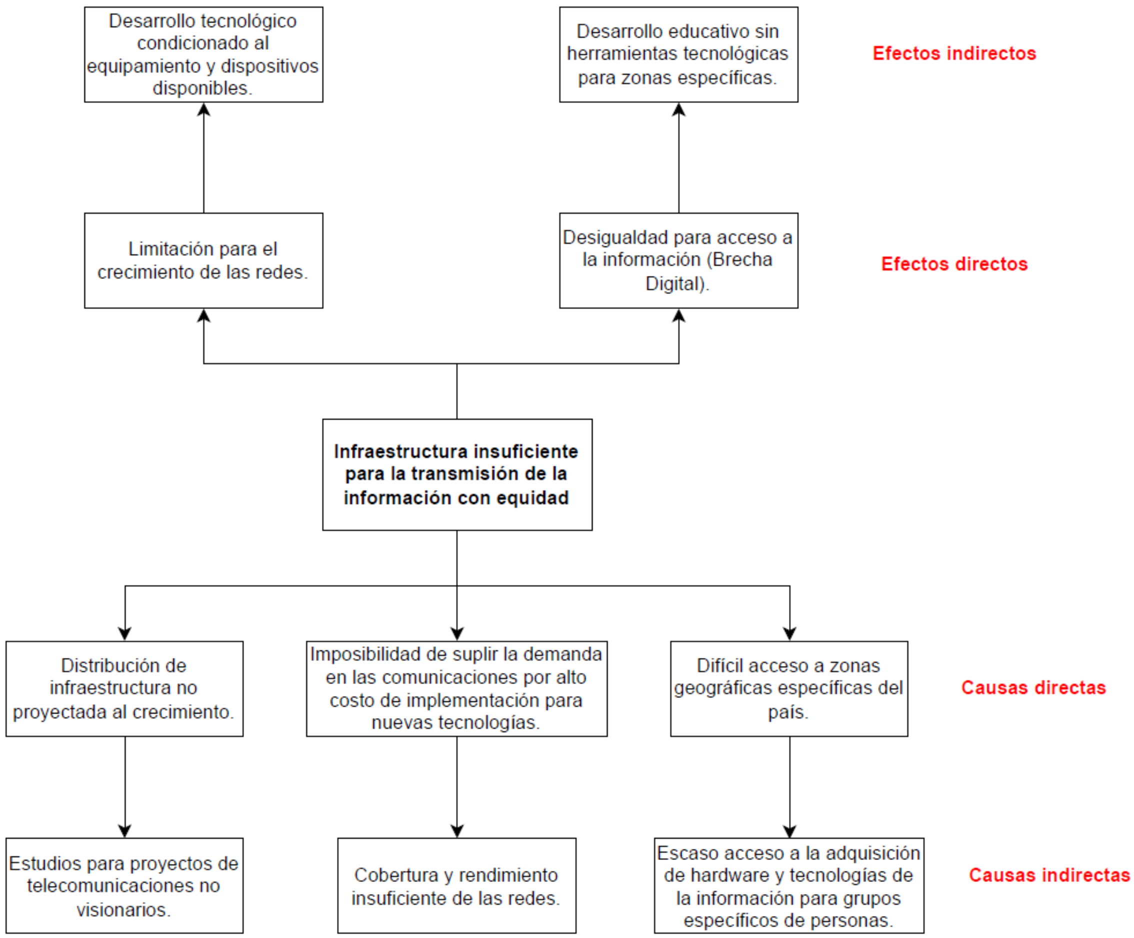

Figure 1. Problem tree.

Related works

Based on the search carried out to identify research carried out from the different areas around the sites of radio networks, whose application will allow the implementation of 5G networks in Colombia optimally, they are detailed below:

Forge and Vu identified that, for the adoption of new technologies, it is necessary to establish policies that allow formulating and planning which are the strategies that enable the correct application of these, as is the case of 5G technologies, since, you can find a series of problems related to financial viability, technical decisions of impact, as well as public health problems. On the other hand, the critical issues of industry and government entities in planning for the implementation of 5G were addressed, mainly in lower-income countries. As a consequence, it is necessary to obtain the strategies for the adoption of 5G, these must be consolidated from the identification of criticality problems for its implementation. So, taking into account that not all countries that want to implement 5G technology are high-income, a plan for the deployment of the required infrastructure must be determined, so it is necessary to consider the modification of the frequency band in the radio spectrum, as well as sharing a single network between operators to generate a greater deployment of this technology. Moreover, it is important to recognize that the implementation of 5G may be too expensive, therefore, it can be connected to existing LTE infrastructure for rural or less densely populated populations, thus reducing expenses (Forge & Vu, 2020).

Hernández and Ovando delved into the identification of the cultural factors that influence the creation and permanence of the digital divide, based on academic literature in order to generate a frame of reference in this regard; as a result of the digital divide between different population groups and the need to reduce or disappear this phenomenon. For the analysis, they carried out a systematized review of the research published in Scopus and Google Scholar between 1970 and 2020 in any geographical region, finding cultural dimensions that influence the digital divide, called: "evasion of uncertainty", "power distance", "individualism" and "masculinity", allowing that in the interest of reducing this phenomenon, policies can be directed, standards and others to these identified factors (Hernández & Ovando, 2022).

Radicelli et al. in response to the need to define an appropriate technology to provide Internet in rural areas of Latin America explored the benefits, characteristics and architecture of DVB-RCT2 wireless return channel DTT technology against 4G LTE cellular telephony technology; so it is important to define the most appropriate technology to provide Internet connectivity in rural areas of Latin America. For this, they established a comparison between DTT technology with DVB-RCT2 wireless return channel and 4G LTE cellular telephony technology, additionally, the characteristics to be taken into account for this parallelism are bandwidth (BW), modulation, download and upload speed, necessary access method, implemented carrier waves, IP transmission and methods used for error correction; The results of the comparison were obtained: a) DVB-RCT2 technology uses DVB-T2 features and combines them with DVBRCT to increase transmission capacity with lower carrier-to-noise ratio (CNR); and b) it was determined that the DTT solution is the most appropriate to bring internet to rural areas of Latin America. For this they mainly took into account the factors of speed and equipment necessary by the user for the implementation of the technology (Radicelli, Pomboza, & Cepeda, 2018).

Cortés et al. proposed the optimization of a return network and the indirect estimation of demographic behaviors based on spectral analysis, based on the digital divide existing in the Colombian territory. Therefore, they studied the scanning of the electromagnetic spectrum in the 5Ghz frequency band and graphics generated by the AirView Analyzer Software embedded in Ubiquiti devices. The aforementioned devices were installed in the municipalities of Ovejas and Chalán as part of a rural return network in the department of Sucre, Colombia. Additionally, the optimization of the working frequency of the telecommunications system between the nodes of Almagra and La Ceiba was configured at 5790 MHz. Obtaining the following aspects: a) unlicensed frequency bands in Colombia are an option for rural connectivity; and b) WiBACK technology is presented as a useful tool for connectivity in rural areas, since it has benefits such as the ability to self-adjust the frequency of work and low energy consumption (Cortés, Montaño, & Guerrero, 2022).

Arévalo and Gonzales, in order to find studies in which the online tool Xirio Online has been used, found that it was used for the elaboration of maps of received power according to the geography of a specific terrain in which a broadcast transmission was made, facilitating together with other variables to form the coverage map of the reception scenarios for the 5G Broadcast standard. This allowed them to gather information on the benefits, scope and limitations of the aforementioned standard. However, there is no record of studies that allow verifying the power levels of telecommunications services and knowing the behavior of frequencies in the range of 3KHz to 6.2GHz in the historic center of the city of Bogotá. Additionally, to obtain the results they made measurements with the TEKTRONIX RSA600A spectrum analyzer properly calibrated and the analysis of the Radio Frequency signals was carried out with the SignalVU-PC software, likewise, the measurements were made in the facilities of the Telematics and Antennas laboratories of the Electronic Engineering program of the Autonomous University of Colombia. From where they obtained that in the geographical range studied there is no evidence of assignment to mobile operators of the frequencies of the ranges 1.9 GHz to 1.99GHz, 2.5 GHz, 2.5 GHz to 2.66 GHz. Similarly, it was possible to validate that the 700MHz and 900MHz frequencies were assigned to mobile operators, but little use of these is evident and, in addition, the frequency range between 3 GHz and 6.2 GHz shows low or no use (Arévalo & González, 2020).

Bellary et al. evaluated signal power, intensity, quality, and signal-to-noise ratio parameters to analyze QPSK and QAM propagation models of a multiple-input-multiple-output (MIMO) antenna in 2x2, 4x4, and 8x8 configurations at a specific geographic location. Taking into account the possible configurations for MIMO antennas, it is necessary to identify which is the optimal one regarding the transfer and data rate when applied in a specific area. Therefore, they sought to establish the configuration of the radio network in a specific geographical situation through the FEKO-WinProp tool. As a research methodology, we sought to establish the configuration of the radio network in a specific geographical situation through the FEKO-WinProp tool. The above, so that once the simulation is carried out in all the mentioned configurations, they could determine that the dominant model for the MIMO antenna is the 8x8, which effectively covers the geographical area with a speed and performance of 3,827,995 MBit / s and 3,577,930.1 MBit / s respectively, on the other hand, this model allows a maximum data transmission rate of 1.37 GBit / s in antenna base stations (Bellary, Kandasamy, & Rao, 2022).

Dahri et al. establish that in view of the evolution of technology and telecommunications, it is necessary to analyze the adaptability of reflective antennas, therefore, the technical characteristics and design of these are reviewed, to identify the topologies and configurations that are compatible with the high frequency systems that 5G brings. The above taking into account that 5G technology works on frequencies much higher than those worked by the current 4G, so it is necessary to minimize all the inconveniences that may be associated with the loss of the signal when propagated in the reflective antennas, this to allow the operation of IoT applications correctly. For the review carried out, the authors analyzed the behavior of the reflector antenna using different techniques, with the aim of identifying the loss of reflection, reflection phase and beam width, factors that are of high importance for the design to be implemented in 5G technology; Concluding that reflector antennas can continue to be implemented for future technologies, as long as an adequate design of the entire structure is made, additionally, it is important to mention that the most profitable option still needs great efforts, because in order to support the sensitivity of these designs to high frequencies, it is required to add computer numerical control technology (Dahri, Jamaluddin, Abbasi, & Kamarudin, 2017).

Khan et al. conducted a review of the research developed in the last 7 years on mobile terminal antennas focused on 5G, as well as the challenges they must face related to the influence of users; considering that the incorporation of the 5G network represents a challenge for the design of antennas of mobile terminals, since they must meet the needs of size, design and operation, highlighting among them the multiband capabilities. As a methodology, they first highlighted the antenna frequencies used by mobile terminals for different applications, and then identified which of them have been used in the application of the 5G network. Subsequently, they validated the perceived effects on the antennas as a result of user manipulation and finally, the results obtained and the upcoming challenges were analyzed; thus concluding the following aspects: a) the influence of the migration of mobile technologies towards 5G has influenced the operating requirements of the antennas, as well as the line of development of this and the operation in single-band and multiband scenarios, followed by MIMO and Massive MIMO antennas; and b) the incidence of the hand influences the operation of the antennas, since it was perceived that the detunement of the BW impedance for the antennas studied indicated consistency, because they usually move down the device due to the dielectric load of the housing and the hand (Khan, Al-Hadi, Soh, Kamarudin, & Owais, 2018).

Farasat et al. conducted an evaluation of design techniques to overcome degradation of frequency band performance, because MIMO-compatible antennas need to be implemented, as they must support a wide frequency range. This is due to the existing limitations in the design of antenna base stations for the implementation of 5G. In order to carry out the above, the authors evaluated multiple methods to eliminate interference caused by antennas implemented in 5G technology. As a result they identified that LTE and 5G antennas implement several sets of antennas, therefore, they must be able to accept multiple bands and implement MIMO antennas, since these elements cause interference, techniques such as hidden dipoles, parasitic elements, FSS and filters must be applied (Farasat, Thalakotuna, Hu, & Yang, 2021).

Ikram et al. describe the design techniques for antennas in 5G and 6G applications, presenting the challenges of the current infrastructure to support all the bandwidth requirements of IoT applications, thanks to the latter and portable devices in which various services such as telephony will be operational. Telemedicine, intelligent traffic, etc., communications present challenges in the quest to meet the demand for bandwidth. For this purpose, the authors determined the design techniques for the existing antennas since the bandwidth provided by the current technology is limited, additionally the implementation of MIMO antennas was contemplated. Thus concluding that the new communications and mobile telephony systems are intended to increase speed and security to support IoT applications, so they will be implemented over a high range of frequencies, so it is established that the current technology of last generation will open the way to the development of future technologies (Ikran, Sultan, Lateef, & Alqadami, 2022).

Liu et al. analyzed the functionality of detection and integrated communications (ISAC) regarding waveform design, signal processing and integration with communications, this originated by the high demand for quality bandwidth in data transmission through wireless connectivity. For the analysis, the evolution of radar systems was historically reviewed to justify detection and communications (S&C) functionality and establish use cases. Following ISAC's research, the authors show the benefits aimed at the networks of the future and the challenges presented by using the base infrastructure of 5G; Additionally, they examined the behavior of this functionality with other technologies, since it will not only be the foundation of 6G, but will allow the physical and cybernetic world to be intelligently interconnected (Liu, et al., 2022).

Guillermo et al. conducted a review of issues related to shared spectrum and base station deployment. They also analyzed the regulation of citizen broadband radio service (CBRS) in the United States. The foregoing, considering the effects related to the deployment of transmitters or base stations. For this study, the authors collected the main reasons why there are problems in the implementation of transmitters, identifying that, with the deployment of small cells to offer greater bandwidth capacity to users, the limitations for the location of these according to CBRS regulations arise, as well as the interferences that affect the coverage and metrics of the network. These metrics establish the number of transmitters that can be deployed (Guillermo, Bustamante, & Caicedo, 2022).

Elfergani et al. conducted a review of the advances developed in the design of antennas focused on 5G technology, since this technology and its applications are limited by the non-compliance with the requirements of the antennas to implement these advances. As a result, the potential of 5G has not been fully exploited, in addition to the fact that transmission rates are still limited by bandwidth and millimeter wave has not been possible to implement it in the current 5G system. In this sense, the authors carried out the analysis of the literature regarding the recent advances in the designs of antennas projected to be implemented in 5G networks, finding that advances were presented in the designs of this type of antennas, which need to be categorized according to the applications in which each of these can be implemented and is as close as possible to compliance with the requirements so as not to limit the performance and benefits of such applications (Elfergani, Hussaini, Rofríguez, & Abd-Alhameed, 2022).

Simkó and Mattsson made an analysis of the available literature in order to present advances regarding the uncertainty of the possible impacts that telecommunications infrastructure may have on health, considering that the inclusion of 5G wireless communication technology will increase the number of base stations powered by high frequency and other devices, So it is necessary to know if this infrastructure and its operability can have an impact on health. Its methodology was based on the analysis of relevant publications that conducted in vivo or in vitro research; including other variables that represent different scenarios to be studied. They also established the following conclusions: a) almost all studies using exposures to MMW (6–100 GHz, millimeter waves) show biological responses. However, no conclusions can be drawn from this validation regarding biological and health effects; and (b) about the health effects of emissions at frequencies 6 to 100 GHz, the results of the studies do not provide clear evidence, given the contradiction between in vivo and in vitro research (Simkó & Mattson, 2019).

Hussain and Khan studied 5G network architecture and related technologies. In addition, they emphasized improvements and limitations identified to achieve stability in the network architecture. This arises from the need to provide stability in the architecture of the 5G network. Therefore, a specific review of the different techniques of emerging 5G technologies was carried out, seeking to identify the benefits and limitations of each of them. Obtaining as a result that the 5G core network and its technologies, such as mmWaves, Small Cells, Massive MIMO, among others, have research gaps in the architecture of each system; Additionally, the problems, advances and limitations of the techniques object of this study were identified.(Hussain & Khan, 2020)

Cama et al. conducted a study in which it was established that Colombia is among the countries that are in the pilot phase in the implementation of 5G, the MinTIC as a regulatory government agency delivered the results of which the main problems of the deployment of this technology can be determined, additionally, this will allow planning the coverage of 5G based on the 4G infrastructure. The central problem is that the implementation of 5G technology in Colombia is not yet aligned with other countries, so a plan is needed to achieve full coverage in the national territory. The authors developed as a strategy the identification of the drawbacks that the implementation of 5G technology has presented and establish the mechanisms that allow to carry out the migration plan, therefore, it has that the use of shared dynamic spectrum allows to improve the coverage of the networks to rural areas and remote population, therefore, a combination of this with MIMO antennas and beamforming can be implemented when there is no line of sight, in order to improve the connectivity of the different sectors (Cama, et al., 2021).

Lehr et al. established differences between the telephony technologies of previous generations with 5G technology, which modifies and expands the panorama against the competitiveness of the wireless services market, also analyzes what are the infrastructure requirements required by 5G for its implementation, additionally, the advantages and potential of the next generation of mobile telephony technology are highlighted, With the advent of 5G, industries and mobile service providers must consider the implications on their current networks to transition to this revolutionary new technology. For the identification of the differences already mentioned, the authors made a comparison between the different technologies to identify the advantages of 5G, under which it was determined that for the implementation of 5G standards it is necessary a greater deployment of base stations, an intelligent central network and to make increasing use of the electromagnetic spectrum to expand coverage, which means advancing an important management by telephony providers to provision the required infrastructure and go hand in hand with market opportunities and government policies (Lehr, Queder, & Haucap, 2021).

Aranda et al. indicated that, with the adoption of 5G technology, other factors aimed at the protection of network devices and applications will have to be considered, taking into account the multiple vulnerabilities of the software, therefore, a standard and normativity must be presented that allows regulating everything related to its implementation and considering that 5G is based on software, The vulnerabilities to which it is exposed must be taken into account. Consequently, the authors defined the use cases of 5G technology and the business models it will bring, additionally evaluated the risks involved in the implementation to be taken into account from the beginning. In addition, they established that in the face of business models it has to be possible to develop models based on network segmentation, however, with the deployment of 5G new ones may arise; With respect to the tests carried out by different laboratories for the implementation of 5G, the incursion into applications such as Industry 4.0, smart cities and satellites was evaluated, so it is necessary to understand the risks to which the network is exposed and manage resources in such a way that it safeguards all the information and commercial data that will be circulating there (Aranda, Sacoto, Haro, & Astudillo, 2021).

Barrios et al. point out that considering that the growing demand for mobile data is associated with the requirement of these services by users and applications, it is important to talk about 5G as the technology that stands out mainly in the increase in transmission speed and greater reliability, so Colombia is no exception and is conducting pilot tests before massifying the service nationwide. For this reason, from government entities such as MinTIC, a resolution was issued in 2020 to use the radio spectrum and move forward with the respective tests. Therefore, to determine the step by step to follow, it was necessary to identify the factors that prevent the large-scale growth of 5G in Colombia; As a result, the authors obtained that 5G technology will not be available before September 2022, this because the 4G infrastructure has not been completed, which is required as a basis for the evolution of networks in Colombia. In this sense, to increase coverage in the national territory, it is important to establish agreements between operators and the government to reach territories that are difficult to access. This will enrich the different economic activities of the regions in Colombia through IoT applications, which offer an improvement in the quality of life of its inhabitants (Barrios, Cama, Mardini, Díaz, & Cama, 2021).

Dike and Akujuobi conducted a review of the various generations of networks to date, emphasizing their efficient scheduling and resource sharing schemes taking into account the need to manage mobile networks due to the growth in mobile service consumption. As a research methodology, the authors identified the effective programming and resource distribution schemes with respect to the bandwidth available for mobile networks, obtaining as a consequence the following conclusions: a) 5G has higher data speeds than its predecessors, as well as higher connection density and lower latency; and b) 5G has the tools to address identified cellular network management issues using network segment provisioning on the Radio Access Network ((Dike & Akujuobi, 2022)RAN).

Al Shinwan et. Through their research they propose a distributed network in 5G, to overcome the latency and routing problems suffered between the Service Gateway, Packet Gateway and other entities involved in the 4G technology network. The proposed network features data connection and delivery processes based on the evolved packet kernel known as EPC, a protocol that provides convergence between voice and data. For the development of the architecture, numerical developments and simulations based on NS-3 software were carried out, results that yielded a positive perspective by evidencing an improvement in performance and a decrease in latency.(Al Shinwan, et al., 2021)

Khwandah et.al seek to present the challenges and advantages behind the implementation of Massive MIMO antennas in 5G, which provide better performance and efficiency at the level of the electromagnetic spectrum than other solutions, additionally allows its adaptability to a large number of users who require to make use of high performance, that is, with low interference. The above is proposed by directing the antennas and their radiation simultaneously to the large volume of users. Following the research, it is determined that the adoption of MIMO models present an improved capacity, allowing improvements in flexible azimuth and elevation radiation. (Khwandah, Cosmas, Lazaridis, Zaharis, & Chochliouros, 2021)

Alieldin et.al propose the design of an antenna base station for 2G, 3G, 4G and 5G communications, with two antennas that offer 3 frequency bands operable independently, also offering stability against the desired frequency bands. This type of antenna proves to be a good option to be implemented in base antennas that operate in 5G applications in addition to the bands already in operation, taking into account its performance.(Alieldin, et al., 2018)

Agiwal et. al proposes in his research that a solution to the problems faced by the implementation of 5G technology is the joint operation between 4G and 5G technology, highlighting that this solution allows a network operator to optimize the existing infrastructure and in turn, guarantee the conditions for the transition to 5G technology. For this, they evaluated the performance and management of radio resources for different 4G-5G dual connectivity options proposed by the standardization of the 3rd Generation Partnership Project (3GPP), as well as the possibilities of sharing spectrum between 4G and 5G wireless networks.(Agiwal, Kwon, Park, & Jin, 2021)

Mendes et. They present an alternative and scalable business model for the options of access to connectivity services that have the less favored areas in telecommunications technological development in Brazil, seeking to reduce the existing digital divide between urban and rural populations. In this model they included the analysis of obstacles, the dimensioning of opportunities, business cases, costs and revenues, among others; in addition to having as a central element the partnership between a Mobile Network Operator (MNO) and a Rural Mobile Infrastructure Operator (RMIO). .(Calvalcante, Marquezini, Mendes, & Moreno, 2021)

In conclusion, in the current state of the art, research focused on the various areas competent to the work object of this document were found, such as: 5G technology, antennas for 5G technology, the digital divide, connectivity services in rural areas, the use of the Xirio Online tool, the social impact of the installation of antennas, among others. For further information, please refer to Annex 1. Analysis matrix.

Methodology

Type of research:

For the fulfillment of the objectives proposed in this research, a qualitative approach will be used, considering that the current conditions of the networks in geographical areas must be analyzed in a particular way, since the results may change according to the study population.

Variables or categories:

In the development of the modeling of radio maps in the technological tool Xirio Online, the following variables were considered:

Coverage of telecommunications networks: corresponds to the power or electric field that the signals of the antennas throw in a delimited area, to determine these values the technical specifications of the transmitters and receivers are taken into account.**Invalid specified font.**

Link study: these are created with the purpose of making the links between stations viable, to obtain results it is required to configure the parameters of the equipment such as: type of span, objectives, method of protection, diversity, speed, time between failures, etc. .**Invalid specified font.**

Calculation method in the modeling of the signals: the software allows to adjust the calculations to the selected method or international standard, within these are: Rec. ITU-R O.526, Deygout, Line of sight, Rec. ITU-R P.1546, Okumura-Hata, etc. .**Invalid specified font.**

Planning process: for the process of simulating in cartography, the tool provides different types of radio services that go according to the selected methodology, so it must be determined what are the options to apply for the design of an optimal network.**Invalid specified font.**

Information collection techniques and instruments:

Taking into account each of the established objectives, the following activities were planned:

Characterize the current implementation of telecommunications networks in the municipality of Caparrapí – Cundinamarca to determine the level of coverage.

I. Georeferenced identification of the current base stations in the municipality of Caparrapí - Cundinamarca.
II. Calibration of data in simulation with real field measurements in the Xirio Online platform
III. Interpretation of the simulation resulting from propagated signals

Analyze what are the interferences presented in the transmission of information from sites or base stations that may harm the implementation of 5G technology.

I. Results manager query in Xirio Online
II. Transmission interference diagnostics for radio network sites

Propose the strategic location of the sites or base stations to minimize interference and improve the propagation of signals in the municipality of Caparrapí – Cundinamarca using Xirio Online software.

I. Spectral occupancy analysis for the radio network environment
II. Frequency assignment in the absence of interference in the municipality of Caparrapí - Cundinamarca.
III. Optimization of sites on the cartography of the municipality of Caparrapí - Cundinamarca using the Xirio Online software
IV. Radio coverage simulation

Results

In the first instance, the 3G / 4G / 5G coverage map of Colombia available on the *nperf* page was verified, which has the information on the scope of the different mobile operators, from there it was possible to determine that for the municipality of Caparrapí - Cundinamarca currently has the service of 4G technology with the operator Claro Móvil (COMUNICACIÓN CELULAR S.A. - COMCEL S.A.), while the operator Movistar offers 3G coverage for that municipality, as can be seen in the following images:

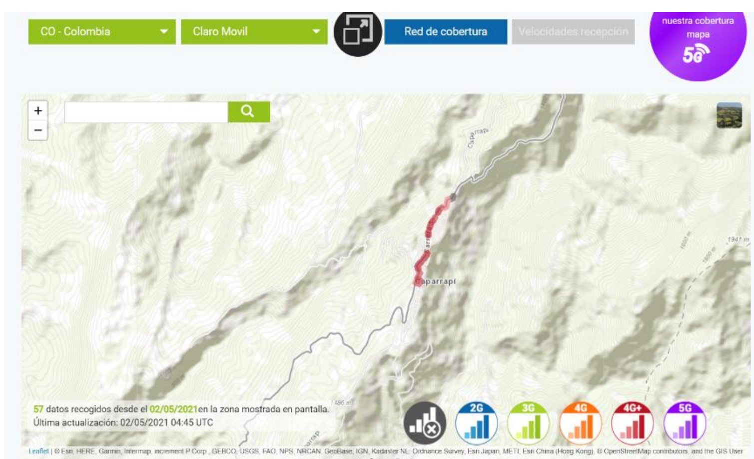

Figure 2 Claro's 4G coverage (Nperf, Nperf, 2021)

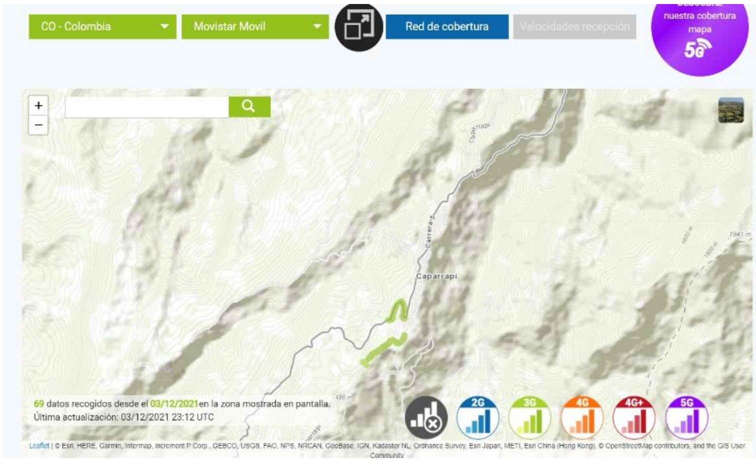

Figure 3 Movistar 3G coverage (Nperf, Nperf, 2021)

The company COMCEL S.A. has permission for a term of 20 years for access, use and exploitation of 20 MHz in the 700 MHz band, which are located in the frequency range of 733 MHz to 743 MHz and 788 MHz to 798 MHz, as established in Resolution 331 of February 20, 2020 by the Ministry of Information and Communications Technologies. Therefore, for the purposes of the current study on the location of existing antennas of 4G LTE technology, the frequency of 738 MHz was assigned to them. (MinTIC, 2022)

For the identification of the Telecommunications infrastructure that allows the provision of the services previously mentioned in the municipality of Caparrapí - Cundinamarca, the information was extracted from the spectrum viewer that the National Spectrum Agency has, from which the coordinates and other specifications such as power and height of the existing antennas with influence in the municipality of interest were taken as a reference.

Below, you can view the detailed information of the two bases and the repeater that are registered in the ANE and currently operate in the area:

ANE
Agencia Nacional del Espectro

Generado por	Visor de espectro
Fecha	22/Sep/2022 08:35
Servicio	Cubrimiento

Distintivo	Tipo	Banda	Frecuencia Tx (MHz)	Frecuencia Rx (MHz)	Ancho de banda (kHz)	Potencia (W)	Altura de antena msns (m)	Departamento	Municipio	Código Dane	Longitud DMS	Latitud DMS
5MG310	Base	VHF	170,975	172,95	12,5	25	30	Cundinamarca	Caparrapi	25148	74° 28' 60,00" W	5° 19' 60,00" N
HJC5529	Base	UHF	445,875	440,875	12,5	25	10	Cundinamarca	Caparrapi	25148	74° 28' 60,00" W	5° 19' 60,00" N
5JA2625	Repetidor	UHF	447,7875	442,7875	12,5	25	27	Cundinamarca	Caparrapi	25148	74° 32' 31,00" W	5° 12' 40,40" N

Figure 4 Existing network infrastructure in the municipality of Caparrapí - Cundinamarca and registered in the ANE

In the Planning Tool of the Xirio Online platform, 3 studies were established in the LTE-A band, one for each antenna and in turn one sector per study, configuring all the properties such as the operating band, coordinates, antenna parameters, transmission frequency, power, LTE parameters, DownLink and Uplink.

Once the parameters have been configured by independent sector, it is necessary to configure a multi-coverage study that allows integrating the created readers and generating additional calculations, for this it is necessary to configure the operation service and relate the studies created.

In the Software, the calculation method used for 4G technology is Met526_15.

To enable interference study, the required environments must be configured to apply according to the services operating in the zone and the user density per service. This calculation took into account the population density of the municipality established by DANE according to the National Population and Housing Census carried out in 2018, which is 10301 inhabitants.(DATA, 2018)

Among the results of the study on the existing antennas, the RSRP (*Reference Signal Received Power*) signal coverage analysis was extracted, where it can be visualized that the municipality of Caparrapí and its surrounding rural areas have adequate coverage for the frequencies required by 4G technology.

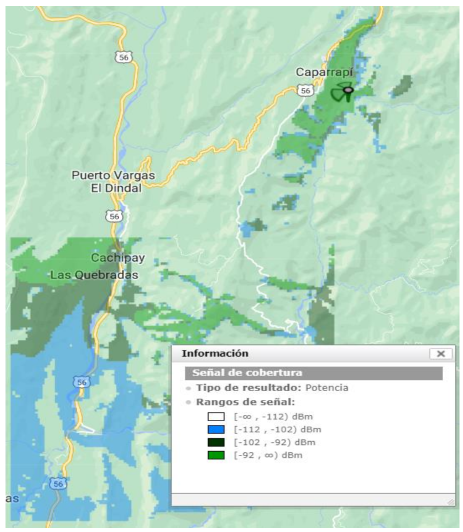

Figure 5 RSRP (Reference Signal Received Power) signal coverage analysis - 4G - Caparrapí - Cundinamarca

Similarly, it was possible to find which of the antennas gives better coverage to a specific area, as can be seen in the following image.

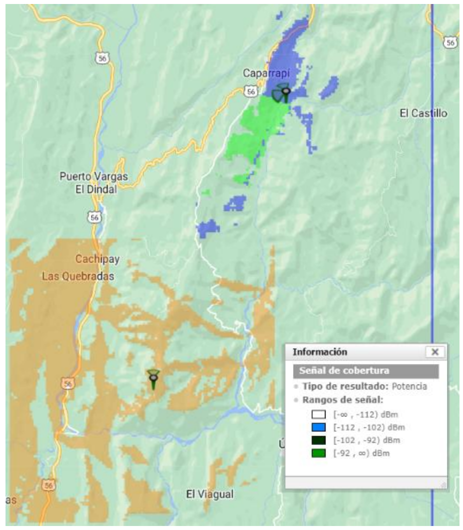

Figure 6 Antenna coverage - 4G - Caparrapí - Colombia

As a result of the multi-coverage study, it is also possible to visualize if the signals have overlap, showing that since there is no competition between the coverages provided by the existing antennas, they are less likely to present interference.

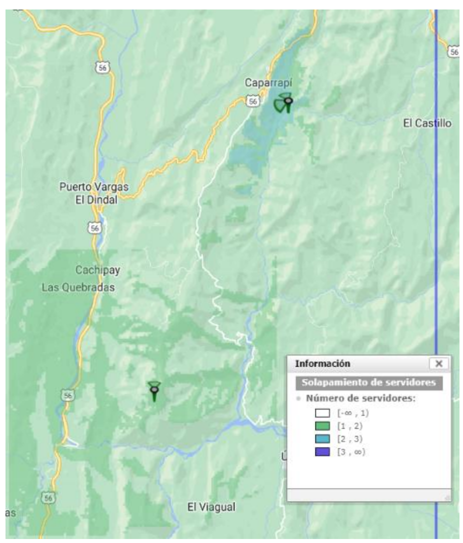

Figure 7 Antenna overlap analysis - 4G - Caparrapí Cundinamarca

On the other hand, to deepen the analysis of the current network infrastructure, the RSSI signal analysis was advanced, which indicates the strength of the received signal (RSSI for the acronym of the English *Received Signal Strength Indicator*) and for this particular case allows to visualize that the signal strength that currently has the urban perimeter of the municipality of Caparrapí is adequate for the use of 4G technology.

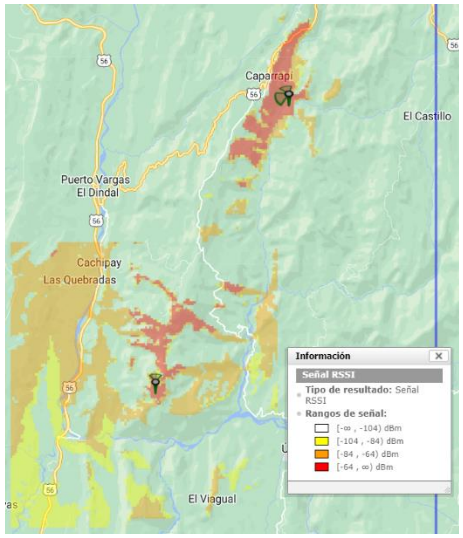

Figura 8 Análisis RSSI (Received Signal Strength Indicator) - 4G - Caparrapí Cundinamarca

Other results that can be analyzed within this study correspond to: the RSRQ signal (*Reference Signal Received Quality*), PDSCH SINR and PUSCH SINR from which the power relationship with respect to noise can be determined, both for downlinks and uplinks. As well as you can analyze the theoretical Throughput DL, theoretical Throughput UL, Theoretical Throughput per user DL, Theoretical *Throughput* per user UL, whose values can be evidenced in the bandwidth graph obtained from the capacity calculation, where it is indicated that there are no impossible users to attend and that the maximum bandwidth for download is 3527.23Mbps and download of 2404.29Mbps.

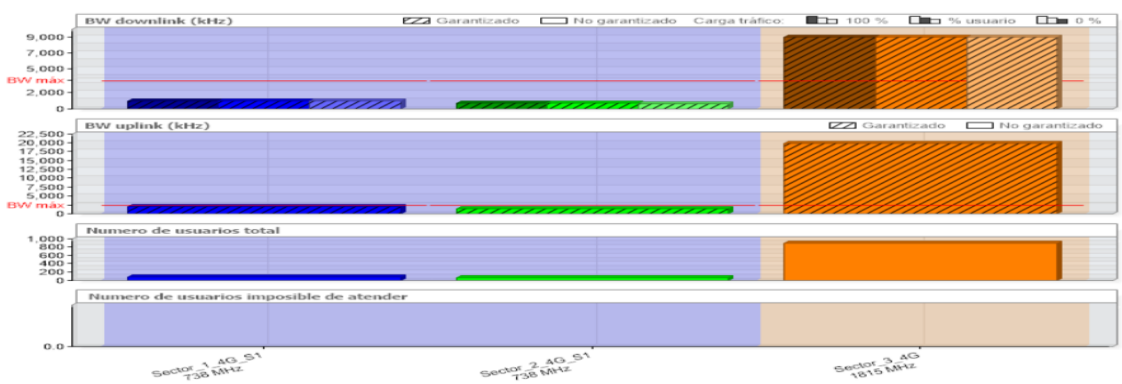

Figure 9 Bandwidth Capacity Calculation - 4G - Caparrapí Cundinamarca

Once the interference and capacity studies have been verified, it is possible to determine that the 4G LTE band implemented in the municipality offers acceptable coverage, allowing that there are no impossible users to meet the need for data and voice. However, it should be noted that the bandwidths it offers are not optimal for navigation if you need a large amount of resources and speed. Therefore, and with the aim of meeting the demand for bandwidth caused by the evolution of technology and communications in recent years, the most common frequency bands in which 5G services operate were evaluated, these being the millimeter bands.

For the case of the proposed study, it was proposed to calculate the studies in 5G derived from the 3.5GHz band, considering that this frequency is approximately 5 times the current operating frequency and represents a considerable improvement for the main parameters of data transmission, such as speed.

For the purposes of the simulation developed in the Xirio Online Software, the following sites were proposed to analyze the behavior of 5G technology in the municipality of Caparrapí – Cundinamarca.

Table 1 Sites for 5G technology - Caparrapí Colombia

Emplacement	**Latitude**	**Longitude**	**Antenna height [m]**	**Orientation**	**Power [W]**
1	05° 21' 09.28" N	074°29'07.77"W	30	120°	25
2	05° 21' 09.28" N	074°29'07.77"W	30	240°	25
3	05° 21' 09.28" N	074°29'07.77"W	30	0°	25
4	05° 20' 46.10" N	074°29'52.29"W	30	120°	25
5	05° 20' 46.10" N	074°29'52.29"W	30	240°	25
6	05° 20' 46.10" N	074°29'52.29"W	30	0°	25
7	05° 20' 17.76" N	074°29'35.26"W	30	120°	25
8	05° 20' 17.76" N	074°29'35.26"W	30	240°	25
9	05° 20' 17.76" N	074°29'35.26"W	30	0°	25
10	05° 21' 01.23" N	074°29'30.41"W	30	120°	25
11	05° 21' 01.23" N	074°29'30.41"W	30	240°	25
12	05° 21' 01.23" N	074°29'30.41"W	30	0°	25
13	05° 21' 25.38" N	074°29'14.24"W	30	120°	25

Emplacement	Latitude	Longitude	Antenna height [m]	Orientation	Power [W]
14	05° 21' 25.38" N	074°29'14.24"W	30	240°	25
15	05° 21' 25.38" N	074°29'14.24"W	30	0°	25

In the results obtained from the simulation of the sites previously exposed, the SS-RSRP signal (*Synchronization Signal-Reference Signal Received Power*) shows the linear average of the power of all the contributions of the resources that transport the secondary synchronization signals (SS), where the 15 antennas located in 5 different infrastructures and configured at a frequency of 3330 MHz managed to cover the urban area of the municipality of Caparrapí, thus guaranteeing the possibility of operating at higher frequencies than the current one.

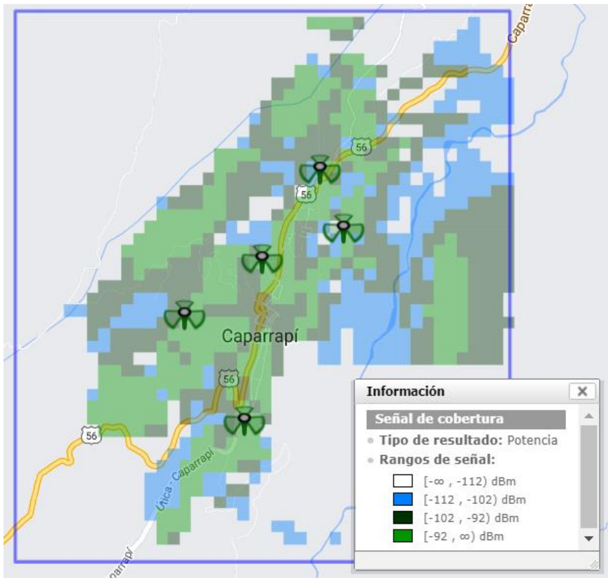

Figura 10 SS-RSRP (Synchronization Signal-Reference Signal Received Power) - 5G - Caparrapí Cundinamarca

Similarly, it was possible to find which of the antennas gives better coverage to a specific area, as can be evidenced in the "best server" analysis presented in the following image.

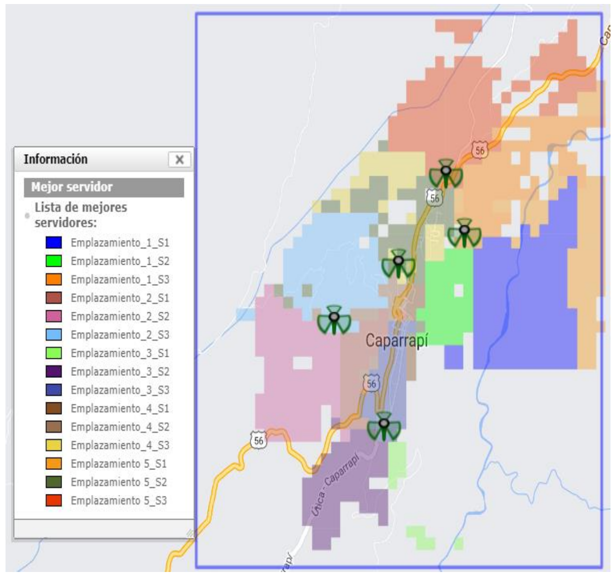

Figure 11 Best Server - 5G - Caparrapí Cundinamarca

As a result of the multi-coverage study applied to the sites already described, it is also possible to visualize if the signals have overlap, showing that the areas with greater competition of the antennas as "best server" represent a potential risk of generating interference. However, the user's request will be directed to the server that represents the best technical conditions at the time of using the service.

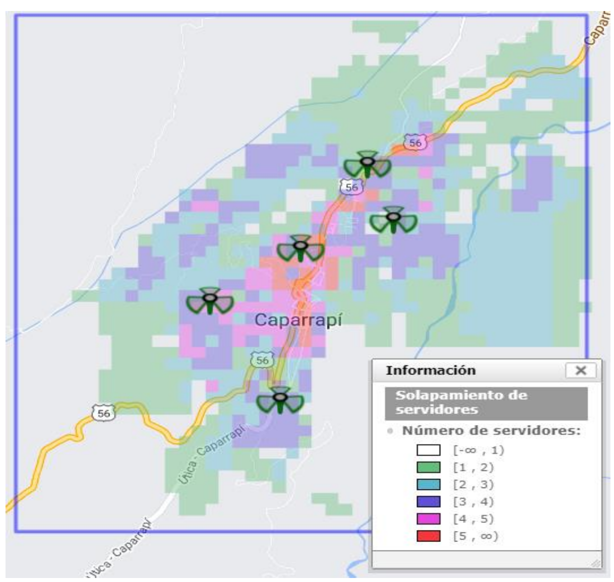

Figure 12 5G coverage overlap - Caparrapí Cundinamarca

On the other hand, once the interference calculation has been generated, it is possible to show that the RSSI (*Received Signal Strength Indicator*) signal of the servers is within the ideal power parameters, thus allowing a good level of coverage for the 5G network.

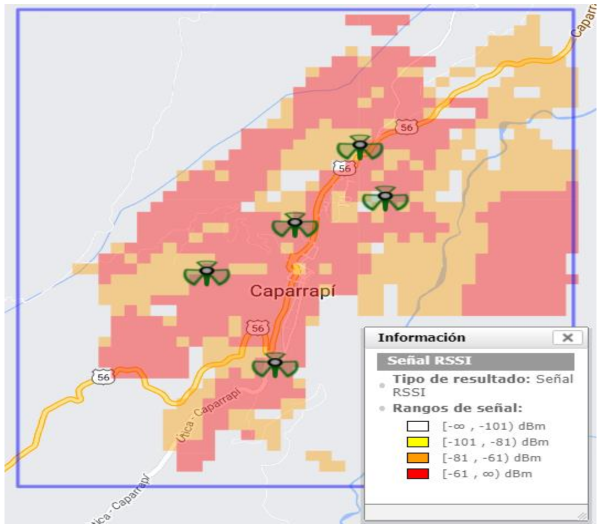

Figura 13 RSSI (Received Signal Strength Indicator) - 5G - Caparrapí Cundinamarca

As can be seen in the following graph and according to what was obtained from the simulation of the current network conditions in the municipality of Caparrapí – Cundinamarca, it is possible to compare the difference with the maximum available bandwidth, since having 3Mbps could have up to 59Mbps.

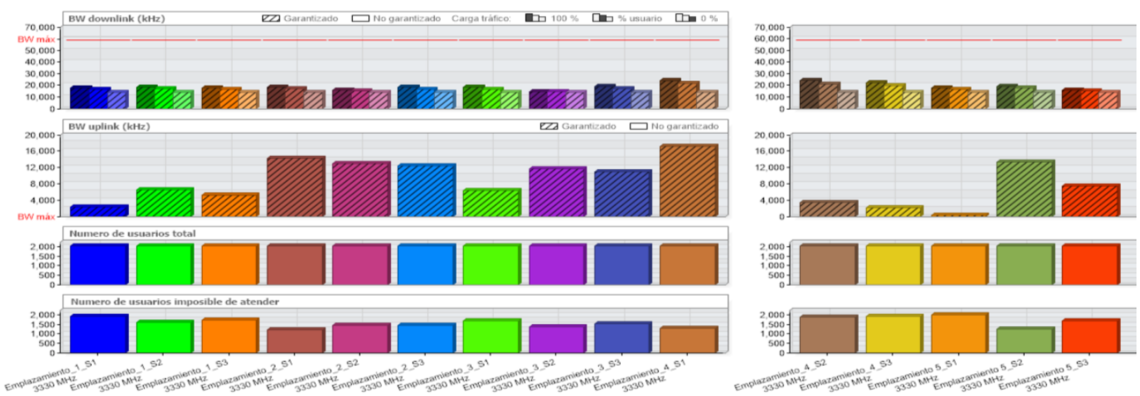

Figure 14 Bandwidth Capacity Calculation - 5G - Caparrapí Cundinamarca

Additionally, it should be mentioned that, with the configuration established according to the population density of the municipality, none of the sectors is exceeding 37% of its maximum traffic load capacity, so, if a higher load is required at the data level, the infrastructure would be in line with the needs of growth, according to the technological demand.

Conclusions

The network infrastructure that Caparrapí currently has for 4G technology offers coverage over the entire urban perimeter of the municipality, however, to implement 5G technology it is necessary to install new telecommunications towers and expand the number of antennas, this because 5G technology uses higher frequencies for its operation and as a consequence the propagation distance reached by each antenna is less in relation to 4G technology.

By increasing the number of antennas and placing them at short distances, the probability of having interference is also increased, this is mitigable to the extent that the requests for the services are directed towards the antenna that offers the best response due to its location and the power with which it reaches the point from which the request is being made.

Considering the economic impact of the implementation of telephony services in 5G, it is important to mention that it is possible to implement the existing infrastructure for the operation of 4G technology, taking advantage of the fact that both LTE and 5G require the implementation of MIMO antennas for data transmission.

The implementation of 5G technology offers benefits commensurate with the speed and bandwidth demands generated by users today by making increasing use of virtualization of academic and work environments.

Bibliography

[1] Agiwal, M., Kwon, H., Park, S., & Jin, H. (2021). A Survey on 4G-5G Dual Connectivity: Road to 5G Implementation. *IEEE Access*, 1;16.

[2] Al Shinwan, M., Abualigah, L., Huy, T.-D., Shdefat, A. Y., Altalhi, M., Kim, C., . . . Kwak, K. S. (2021). An Efficient 5G Data Plan Approach Based on Partially Distributed Mobility Architecture. *Sensors*, 1;17.

[3] Alieldin, A., Huang, Y., Boyes, S. J., Stanley, M., Joseph, S., Hua, Q., & Lei, D. (2018). A Triple-Band Dual-Polarized Indoor Base Station Antenna for 2G, 3G, 4G and Sub-6 GHz 5G Applications. *IEEE Access*, 1; 6.

[4] Aranda, J., Sacoto, E., Haro, D., & Astudillo, F. (2021). 5G networks: a review from the perspectives of architecture, business models, cybersecurity and research developments. *Novasinergia*, 1.

[5] Arévalo, J., & González, R. (2020). MEASUREMENT OF RADIO SPECTRUM IN THE RANGE OF 3 KHz TO 6.2 GHz IN AN URBAN AREA OF BOGOTÁ D.C. *Poligran*, 1;7.

[6] Barrios, A., Cama, D., Mardini, J., Díaz, J., & Cama, A. (2021). Projections of IoT Applications in Colombia Using 5G Wireless Networks. *Sensors*, 1;18.

[7] Bellary, A., Kandasamy, K., & Rao, P. (2022). Analysis of Wave Propagation Models With Radio Network Planning Using Dual Polarized MIMO Antenna for 5G Base Station Applications. *IEEE Access*, 1;10.

[8] Calvalcante, A., Marquezini, M., Mendes, L., & Moreno, C. (2021). 5G for Remote Areas: Challenges, Opportunities and Business Modeling for Brazil. *IEEE Access*, 1;13.

[9] Cama, D., Damas, M., Holgado, J., Gómez, F., Calderin, A., Martínez, J., & Cama, A. (2021). 5G mobile phone network introduction in colombia. *Electronics*, 1;12.

[10] Constaín, S., Mantilla, I., Rueda, G., Trujillo, L., & Barrera, J. (2019). *Plan 5g Colombia The digital future belongs to everyone.* Bogotá D.C.: Ministry of Information and Communications Technologies.

[11] Cortés, C., Montaño, M., & Guerrero, N. (2022). Spectral Map-Based Tool for Backhaul Rural Network Optimization and Indirect Estimation of Demographic Behaviors. *Applied Sciences*, 1;11.

[12] Dahri, M., Jamaluddin, M., Abbasi, M., & Kamarudin, M. (2017). A Review of Wideband Reflectarray Antennas for 5G Communication Systems. *IEEE Access*, 1;10.

[13] DANE. (2018). *National Administrative Department of Statistics.* Obtained from https://www.dane.gov.co/files/censo2018/informacion-tecnica/CNPV-2018-VIHOPE-v2.xls

[14] Dike, B., & Akujuobi, C. (2022). 5G Emancipation: A Review of the Panacea for an Efficient Communication Growth in the Evolution of Cellular Networks. *American Society for Engineerieng Education ASEE*, 1;8.

[15] Elfergani, I., Hussaini, A., Rofríguez, J., & Abd-Alhameed, R. (2022). Recent Advances in Antenna Design for 5G Heterogeneous Networks. *Electronics*, 1-4.

[16] Farasat, M., Thalakotuna, D. N., Hu, Z., & Yang, Y. (2021). A Review on 5G Sub-6 GHz Base Station Antenna Design Challenges. *Electronics*, 1;17.

[17] Forge, S., & Vu, K. (2020). Forming a 5G strategy for developing countries: A note for policy makers. *Telecommunications Policy*, 1;19.

[18] Guillermo, J., Bustamante, R., & Caicedo, C. (2022). Literature review of deploying small transmitters on a spectrum sharing scheme. *Facultad de Ingeniería Universidad de Antioquia*, 1.

[19] Hernandez, M., & Ovando, M. (2022). Cultural factors influencing ICT and internet adoption: a literature review. *Journal of Technology and Society - University of Guadalajara*, 1;26.

[20] Hussain, I., & Khan, F. H. (2020). Limitations Constraints in 5G Architecture and Emerging Technologies. *Mobile Applications & Technologies*, 1;7.

[21] Ikran, M., Sultan, K., Lateef, M., & Alqadami, A. (2022). A Road towards 6G Communication—A Review of 5G Antennas, Arrays, and Wearable Devices. *Electronics*, 1;23.

[22] Khan, R., Al-Hadi, A., Soh, P., Kamarudin, M. A., & Owais. (2018). User Influence on Mobile Terminal Antennas: A Review of Challenges and Potential Solution for 5G Antennas. *IEEE Access*, 1;17.

[23] Khwandah, S. A., Cosmas, J. P., Lazaridis, P. .., Zaharis, Z. D., & Chochliouros, I. P. (2021). Massive MIMO Systems for 5G Communications. *Wireless Personal Communications*, 1;12.

[24] Lehr, W., Queder, F., & Haucap, J. (2021). 5G: A new future for Mobile Network Operators, or not? *Telecommunications Policy*, 1.

[25] Liu, F., Cui, Y., Masouros, C., Xu, J., Xiao, T., Eldar, Y., & Buzzi, S. (2022). Integrated Sensing and Communications: Towards Dual-functional Wireless Networks for 6G and Beyond. *IEEE Journal on Selecter Areas in Communications*, 1;35.

[26] Lloyd, M. (2020). *Educational inequalities and the digital divide in times of COVID-19.* Mexico City: National Autonomous University of Mexico, Institute of Research on University and Education.

[27] Manrique, F., & Torres, A. (2019). Use of LoRaWAN Networks in unmanned, self-sustaining aerial vehicles as a solution to the problem of connectivity of IoT devices in rural areas of little coverage in Colombia. 1;5.

[28] MinTIC. (May 12, 2022). *MINISTRY OF INFORMATION AND COMMUNICATION TECHNOLOGIES.* Obtained from https://www.mintic.gov.co/micrositios/asignacion_espectro-imt/742/articles-172502_recurso_36.pdf

[29] Net, G. (March 25, 2020). *Teleworking as a COVID-19 preventive measure*. Obtained from gotelgest.net Dynamic Management : https://www.gotelgest.net/teletrabajo-como-medida-preventiva-covid-19/

[30] Nperf. (May 02, 2021). *Nperf*. Obtained from https://www.nperf.com/es/map/CO/-/198197.Claro-Movil/signal/?ll=4.811839202362843&lg=-74.3862304184586&zoom=9

[31] Nperf. (December 03, 2021). *Nperf*. Obtained from https://www.nperf.com/es/map/CO/-/7239.Movistar-Movil/signal/?ll=5.337557902206416&lg=-74.49125289916994&zoom=13

[32] Radicelli, C., Pomboza, M., & Cepeda, L. (2018). Connectivity to the Internet in rural areas using DTT (DVB-RCT2) technologies, or mobile telephony (4G-LTE). *Facultad de Minas Universidad Nacional de Colombia*, 1;5.

[33] Simkó, M., & Mattson, M.-O. (2019). 5G Wireless Communication and Health Effects—A Pragmatic Review Based on Available Studies Regarding 6 to 100 GHz. *International Journal of Environmetnal Research amd Public Health*, 1;16.