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Original Article

Installation Criteria for a 5G Technology Cellular Base Station Modernization

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Abstract - *The Non-Standalone (NSA) 5G standard based 5G network deployment has become both a worldwide competition and a need. At the regional level, many countries have adapted their traditional networks to the new 5G technology era. Peru is one of those countries; at the beginning of 2021, the Ministry of transport and communication (MTC) authorized two Peruvian government mobile operators to use the electromagnetic spectrum to provide this service. In this research, employing analysis and study-based methodology, the conditions of the typical cellular base station of the mobile operator were evaluated, finding that the majority of those have 2G/3G/4G technology, so infrastructure, transmission medium, and electrical station system are usually only designed to accommodate this equipment. Due to this, it was proposed to follow an installation criteria series. The results of this study showed that the typical operator networks are not prepared to have the new technology. To overcome the shortcomings, it is needed to make modifications, such as structure evaluation and possible tower reinforcement, migrating from a mixed transmission medium, microwave radio links, and optical fiber links to a transmission medium composed totally of optical fiber, increasing the electrical power that supplies new 5G equipment, since it is at its limit with current equipment. Additionally, the study and analysis in this research will help various mobile operators to incoming the 5G networks implementation and deploy the network without performance inconveniences.*

Keywords - *5G, Standard NSA, Mobile networks, Installation criteria, Station base cellular.*

1. Introduction

The exponential growth of communications and mobile devices is the main engine for continuing the evolution of technologies in telecommunications. The sum of traffic today's users generate in applications like high-definition videos, cloud computing, and portable devices requires a drastic change in mobile telecommunication [1]. The fifth generation 5G technology requires mobile operators to give the final users a solid 5G service. Additionally, it is a priority for the network operator to optimize the current infrastructure and ensure clients quickly and without problems transitioning to 5G [2]. Due to the high investment that 5G implementation represents, just limited and main companies worldwide have been pioneers making tests and implementing it, like the giant Asian Huawei Technologies Co., Ltd. [3].

On the other side, the operators in other South American countries are using Huawei technology to implement their 5G networks, as said in the research developed by [4], [5]. Also, the countries with the highest spectrum release rates are Brazil (609 MHz) and Peru (554,4 MHz), while Ecuador and Bolivia are in the last place with 290 MHz and 284 MHz, respectively. Argentina is an exception since its telecommunication field is decentralized, so many regulators exist [6].

Subsequently, in Peru, to continue the 5G technology deployment in the country, the minister of transport and communication (MTC) authorized, in March 2021, three telecommunication operators to implement 5G technology in mobile services. It will be done in spectrum blocks previously assigned to the 1,7 GHz, 2,1 GHZ, 2,5 GHZ, and 3,5 GHz according to the Non-Standalone (NSA) standard [7]. Also, the starting 5G technology deployment in mobile services will be done in the capital city, then in Huarochirí, Cañete, Arequipa, Trujillo, and finally, Ica. According to authorizations and commercial expansion strategies, operators will diversify along the country [8]. It is important to mention that [9] also says that, in the last years, the number of mobile plans among Peruvians has increased, which means an intensive use of mobile communication since 75% of the house have internet access through the mobile network, especially in The Lima Metropolitan Area.

In the short time it has passed since the MTC authorized the electric radio spectrum for 5G mobile telephony services, the only operators that started the 5G deployment are Claro and Entel. The reasons are, in the first place, the high investment the implementation represents. Second, many existing base stations are not designed to stand this new technology in infrastructure. Third, the high amount of electricity that the 5G equipment requires implies increasing the energy with the electricity public service concessionaires, which, most of the time, become bureaucratic and take up months to be executed. Last, the transport medium is not prepared to stand the high data traffic since, in the antecessor 4G, it is possible to have a mixed network with optical fiber and microwave radio links; otherwise, 5G strictly requires that its transport medium is made with optical fiber, also demand routers and commutators stand a high traffic capacity.

A study from IDC consultancy and Qualcomm showed that 46% of Peruvians have limited knowledge about the opportunities and benefits of 5G [10]. Increasing the data transmission rate in cordless networks increases the electricity used [11]. Therefore, the objective of this research article is focused on proposing installation criteria that an operator must have into consideration when doing a 5G implementation, like the cellular base station infrastructure where the 4G currently works; the use and increase of electricity in the station, the transport medium where millions of user's traffic will go through. To achieve this, it was taken as guide experiences and difficulties during implementations done with the Claro Peru operator, where specific information about the constructive process was collected to propose an improvement in the 5G network deployment at a national level.

In this research work, the information was structured in the following way: Section II shows the reviewed literature, where a comparative analysis with other research similar to the theme of development and contributions for continuous improvement. In Section III, the research methodology was set, where three important aspects of a 5G network implementation were analyzed. In Section IV, the result of each analyzed aspect was presented. Then, in Section V, the discussions on the researched topic were described with the research of other authors. Finally, in Section VI, conclusions and suggestions for future research about what was not deepened in this article were shown.

2. Literature Review

This section will review how telecommunication has an essential role in people's daily life. Over the years, this technology has evolved in mobile communications up to the current fifth-generation technology (5G), which is nothing more than an evolution of the fourth-generation technology (4G).

As mentioned in the research articles by the authors [12] and [25], in Peru, 5G technology has not been implemented massively due to the fear of a large part of the population regarding its antennas. Also, there is an aversion towards this technology because it is said it causes COVID - 19 since the huge amount of false information is shared in digital mediums with no scientific support. Even though to deny this false information, the Peruvian Ministry of transport and communication (MTC) spoke about it and made clear that 5G has nothing to do with the pandemic the world is going through, there is a large part of the population that is against the 5G network deployment. At the end of this work, it is expected to have a continuous and wide implementation of this technology since its deployment will carry many benefits in social and economic sectors.

The definitive race of 5G networks is heavily driven by the amount of traffic generated by current users due to the important increase in mobile devices connected to the network. In [13], it says that the exponential increase in mobile devices is the main driver of the continuous evolution in the telecommunication field. The amount of traffic generated by current users in applications like high-definition videos, cloud computing, and portable devices requires a radical change in mobile communications. Besides that, the research was gotten; as a result, the loss of signal increases as the distance range increases from 10 m to 500 m. Also, the simulation showed that the energy gotten by the User Terminal (UT) approaches zero when the distance between the Base Station (BS) and UT is over 250 m. In other words. the author explains that the communication between the UT and BS will be more efficient when they are near each other, having a transmission rate of Gigabits per second (Gbps). Because of that, in this article, the main considerations about the transport medium before 5G implementation in the BS will be set to decrease la signal loss and network latency.

As [14] shows in their research paper where they propose a resource energy efficiency saving technique based on user concentration model (UC) to heterogeneous network LTE - A (HetNets), in this research, it is also proposed a UC optimization technique like a Mixed Integer Linear Programming (MILP) that minimizes the total energy consumption, respecting the data rate per user, thus achieving efficient energy between the UE and eNodeB. 5G networks must get combined gains in three categories: densification and extreme downloads, higher bandwidth, and higher spectral efficiency to be compatible with thousand times gains in capacity and a hundred billion devices simultaneously connected. The requirement for capacity increase will cause an increase in energy use on a hundred factors. In that sense and in favor of minimizing the energy consumption on the BS, it is needed to follow a series of criteria before the 5G network deployment, with the purpose that implementations are executed and go into production in a short time, which leads to prompt profitability to those who implemented it.

As [15] says, 5G technology presents perspectives on an industry and education revolution, which is no exception. The 5G model generally comprises three main blocks: Enhanced mobile bandwidth, Massive machine-like communication, Ultra-reliable communication, and Low latency. Within these blocks are the services the 5G offers to users. Also, it is mainly focused on modern educational institutions that may benefit from the 5G services deployment enabled in this sector. It also provides an exhaustive discussion about 5G technologies as a facilitator of new teaching technologies and learning in an educational environment. Because of all this, it is needed to guarantee a quick 5G network deployment at every level. To achieve this, in the present research paper, important aspects are released that will be useful for the implementation of 5G mobile networks, such as the BS infrastructure; that is, the physical location where the new equipment will be installed will be essential to know in advance the status of towers and structures, thus avoiding delays on implementation and investment increase.

According to how [16], a 5G network energy consumption survey shows that power control is important in any communication system. Mobile networks worldwide use 0.5% of the total energy, so one of the main aspects to consider when deploying the 5G mobile network is reducing energy consumption. In that sense, it becomes very important to have maximum energy efficiency on this network. To achieves this, in the developed research, a list of criteria and energy considerations that must be taken into consideration when implementing 5G networks, since the current electric power on the BS will be diminished with the installation of new equipment added to it, the high demand for data traffic will cause the BS to have constant maintenance problems which lead to expenses to those companies that chose these services.

Nowadays, various emerging technological theories like Industry 4.0, the Internet of Things (IoT), and autonomous vehicles require reliable communication with low latency and are not connected to cables [17]. Therefore, many researchers have developed tests to optimize information delay from the network core to the final device and vice versa. This is the case of the 5G network under the 5G Non-Standalone (NSA) and Standalone (SA) standards, where 95% of SA download packet delays are in the range of 4 to 10 ms, indicating a wide spread of packets delays [18]. As previously said by the authors, it is essential to propose criteria and considerations for the 5G network implementation, such as the transport medium, which must be composed of 100% fiber optics (FO), high-capacity routers, and those that are on Gigabytes (GB) and Terabytes (TB). Other proposals will be raised in the present research article.

Last generation networks need a high-capacity transport medium so that the traffic of millions of users can travel without being affected by delays and loss of information. As stated by [19], fiber optic implementation projects for high-traffic backbones nowadays have become indispensable for the new generation's networks and avant-garde technology. For this reason, the ongoing research development is based on proposing implementation criteria to consider when deploying recent technologies like 5G. It is proposed that transport networks must use fiber optic from all levels, from the sending device to the network core. Thereby, the current latency on networks will minimize [20].

One of the key mobile challenges facing operators today is how to deploy 5G networks shortly. Networks must support various use cases, each with different characteristics and requirements. 5G use cases are so diverse and challenging that 5G networks must adapt to various scenarios. In his article, the author [21] emphasizes the exact procedures, objectives, and requirements necessary to implement a Smart City Use Case in a 5G mobile network operator. A similar case is raised in the ongoing research; a sequence of characteristics must be considered to execute 5G network implementation correctly and promote its deployment.

In summary, the investigations done by the studied authors are focused on the development of 5G technology at the design and architecture level. In addition, none of them propose the installation criteria that must be followed in the implementation, which is why this research work tries to cover this undeveloped gap by looking for modernization of cellular base stations with 5G technology and contribute to future researchers deepening into this area since the information is deficient.

3. Methodology

The present section analyzed the research core, showing the constructive process that mobile operators follow when implementing a 5G network on their base stations. After making an analysis, improvements that help future network implementations will be proposed.

3.1. Study and Analysis

Then, the constructive process is shown graphically, commonly used by operators when implementing a 5G network. Generally, this process is used when a technological improvement is intended, such as expanding capacity or coverage and adding and changing existing equipment for others with greater benefits. Usually, that improvement does not involve aggressive changes in the transmission part, infrastructure, or energy. On the other side, it happens with 5G NSA. The equipment used for this technology requires necessarily a change in the existing infrastructure, transmission, or energy. In [22], a clear example is that 5G used an Active Antenna Unit (AAU) while 4G used passive antennas.

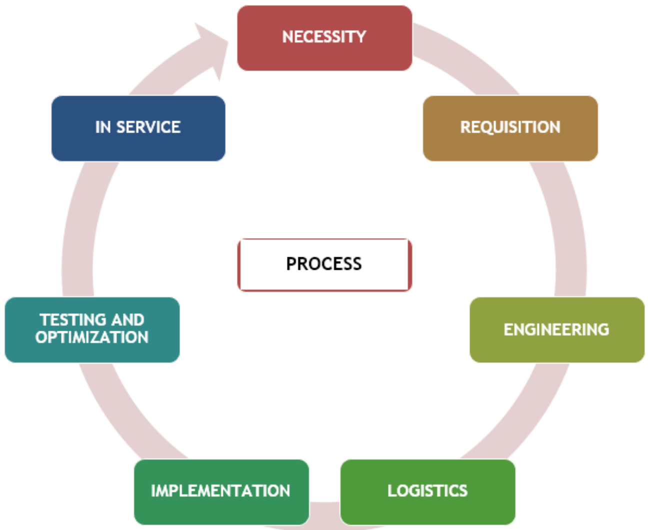

Fig. 1 Typical construction process of a 5G network.

3.1.1. Infrastructure

This section analyzes the condition of the base station's infrastructure, mainly the tower where the radios and antennas of 2G/3G/4G. Structural analysis will determine if it is compatible with the new 5G equipment.

To do this, the objective of the structural evaluation is to verify if the structure of the current tower resists loads of the current antennas 2G/3G/4G and future antennas 5G; and to satisfy the parameters involved in the evaluation like the resistance of the profiles and displacement at the top of the tower. Do not exceed the values recommended in the current standards and codes listed below.

- Structural Standards for Steel Antenna Towers and Antenna Supporting Structures TÍA/EIA-F 1996.
- National Building Regulations 2006: E – 090 Metallic Structures.

For the design of the elements of the tower, the American Telecommunications Code TIA/EIA – 222 – F will be used, in which chapter 3, numeral 3.1.14.1 accepts the use of permissible efforts as regulated by the American Institute of Steel Construction (AISC).

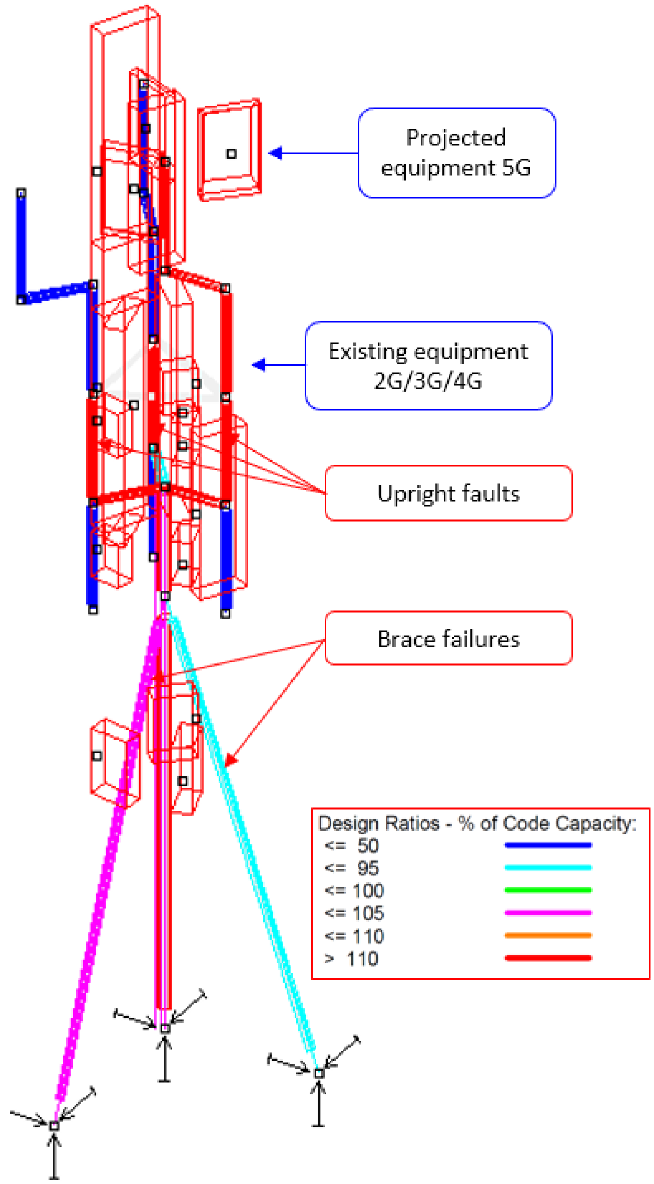

Fig. 2 Fails in ratios Diagram

Fig. 2 shows the relationship between acting stress and permissible stress (ratios), the values considered for this analysis are: height of 8.00 m and wind speed of 100 km/h.

From the obtained result regarding the maximum deflections obtained, for a wind speed of 75 km/h, this is below the established limit (4.50° > 0.75°). FAILS. The structure verified with the current and future antennas DOES NOT SUPPORT the mentioned design loads according to the described standards and design requirements.

3.1.2. Transmission Medium

In the same way, as in the previous sections, the transmission medium of the current 2G/3G/4G network was analyzed, then the improvement was proposed by making changes to the transport network so that it can support the increase in traffic generated by the new 5G network.

It is known that a transport network can be composed of a guided medium (cables), unguided (air), or both at the same time; for this reason, in the present analysis, a typical transport medium will be used, which is microwave radio links and fiber optic links through which all network traffic passes, the same criteria with router equipment.

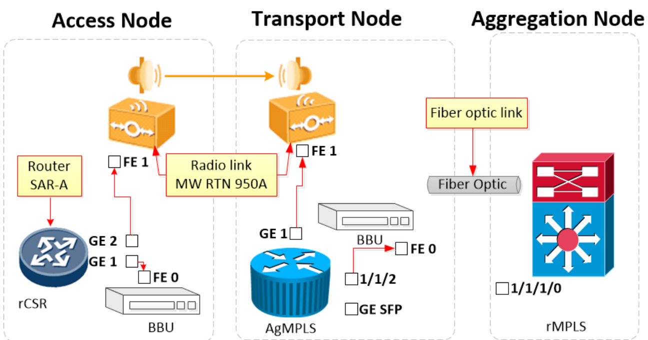

Fig. 3 Typical topology of a transport network for 2G/3G/4G.

In Fig. 3, a typical interconnection of a transport network for mobile services is shown; that network is made up of a microwave radio link and a fiber optic link, which is currently used for 2G/3G/4G traffic; this is due to the low bandwidth that these technologies demand, otherwise it happens with a 5G network, which necessarily has to be entirely fiber optic, thereby guaranteeing the loss of packets in the process due to the high and heavy traffic that it carries.

The key to the optimal implementation of a 5G network consists of migrating from traditional practices to new technological advances in which 5G technology stands out enormously. In addition to fully certifying the fiber optic interconnections from start to finish and maintaining good cleanliness in the implementation, for this to work correctly, a series of recommendations must be followed, as explained in [19].

3.1.3. Energy System

Following the methodology of the previous point, this section shows the analysis and existing conditions in which a 4G cellular base station is. In the same way, the criteria that must be reviewed when modernizing a cellular base station with 5G will also be considered, that is, having a modernization.

Current Condition

Table 1. Station typical consumption

Equipment	Quantity	Technology	Tension (A)	Voltage (V)	Consum (kW)
RRU	3	2G	6	54	0.972
RRU	3	3G	8	54	1.296
RRU	6	4G	15	54	4.86
AAU	3	5G	45	54	7.29
				Total (kW):	**14.418**

Table I shows the characteristic consumption of a base radio with 2G/3G/4G and 5G technology.

From Table I:
- RRU: Remote Radio Unit
- AAU: Active Antenna Unit

The described calculations are based on the equation of Ohm's law, which will help to count the number of battery banks according to the required autonomy, in the same way, to know the power of the rectifier to be used for the new 5G equipment.

A calculation to Comply with the Required Power

In this section, the electrical load of the station is estimated, considering the number of battery banks to be installed according to the calculation of the required autonomy described in the previous section. According to the calculation obtained in this section, the power of the rectifier to be used will be selected. A rectifier is an electrical device that converts the input alternating current (AC) into output direct current (DC) modeled, regulated, and filtered according to to need. The DC output connection powers telecom equipment and can recharge backup batteries [24].

Calculation:
To obtain the maximum consumption in Amps [A]

$$[A_{MAX}] = [BB]^{*} \times [BB]^{**} \times [BB_{TOTAL}]$$

Where:
- $[A_{MAX}]$: Maximum current consumption.
- $[BB]^{*}$: Battery bank %recharge
- $[BB]^{**}$: Battery bank capacity.
- $[BB_{TOTAL}]$: Battery bank quantity (Typical 10%).

To obtain the maximum power in kilowatts [kW]

$$[kW_{MAX}] = [A_{MAX}] \times [V_{DC}]$$

Where:
- $[kW_{MAX}]$: Maximum power consumption.
- $[A_{MAX}]$: Maximum current consumption.
- $[V_{DC}]$: Operating voltage (Typical 48V-53V).

4. Results

This section describes the results of the study and analysis carried out on the existing mobile network, as well as the new projected network, which is described in more detail in the previous section.

Summarizing what was stated in the preceding sections, the graph shown is intended to implement one more process (Installation Criteria) to the typical process used by operators to implement 5G NSA networks. For this process to work correctly, it will be necessary to implement and consider the points discussed in section 3, points a, b, and c of this article.

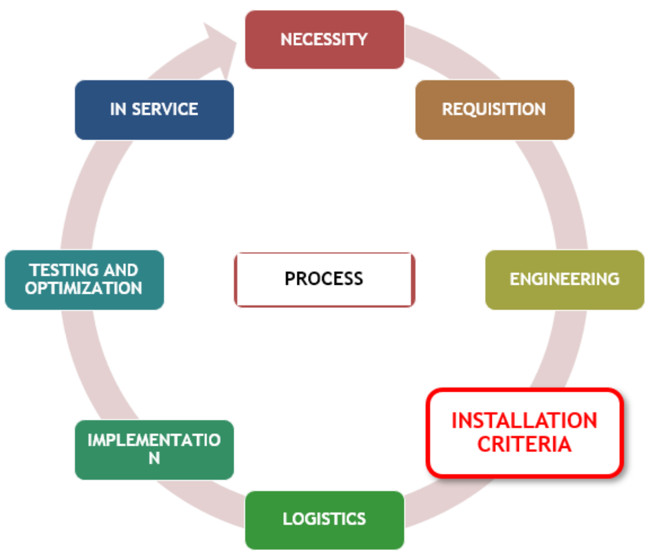

Fig. 4 Construction process proposal for a 5G network.

In Fig. 4, one more step was added to the traditional process used today by operators for the deployment of the 5G network, so it has not been very useful to date since, in the implementation, it was evident serious problems in the base station, whether at the level of infrastructure, transmission medium or the electrical system, greatly impacting the deployment of the network. Thus it is considered necessary to apply the proposed installation criteria for effective deployment and avoid setbacks in the implementation.

The result obtained from each point of the preceding section is listed below.

4.1. Result of the Infrastructure Analysis

The result obtained from each point of the preceding section is listed below.

Therefore, according to the obtained result in the structural evaluation, it becomes mandatory to reinforce the tower to install the 5G equipment. The reinforcement proposal is presented below. Therefore, according to the analysis carried out on the tower, it can be indicated that, for the implementation of a 5G NSA network, it is essential to carry out a previous structural evaluation and thus guarantee the correct functioning of the network.

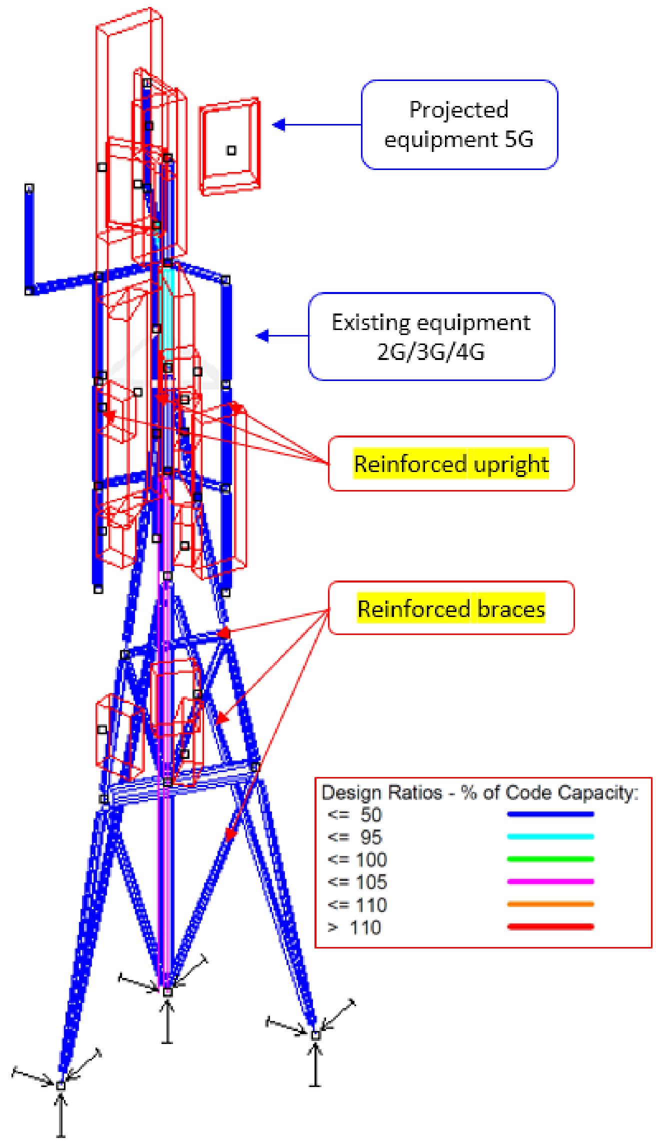

Fig. 5 Fail in ratios Diagram

In Fig. 5, it can be verified that the capacity ratios of the tower are compatible with the existing and projected equipment.

Regarding the maximum deflections obtained, for a wind speed of 75 km/h, this is below the established limit (0. 20° < 0.75°). YES, IT COMPLIES. The structure verified with the current and projected antennas DOES SUPPORT the mentioned design loads according to the described standards and design requirements.

4.2. Result of the Transport Medium Analysis

As an obtained result after having made the changes in the transport network so that network can accommodate the traffic of all technologies, the new topology of the transport medium for the projected 5G network and the existing 2G/3G/4G is shown below.

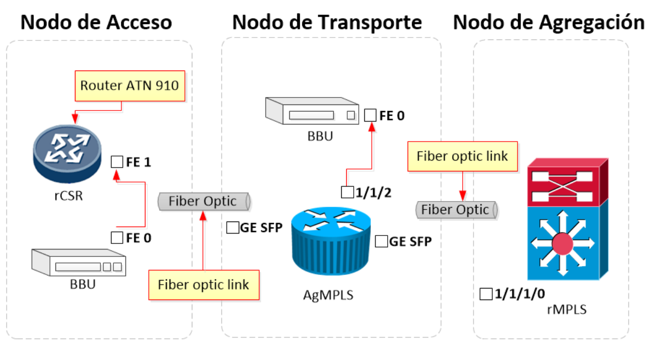

Fig. 6 Required topology for the 2G/3G/4G/5G transport network.

In Fig. 6, the transport network required for a 5G network can be visualized together with existing 2G/3G/4G technologies, a transport network built entirely of fiber optics and high-capacity equipment.

4.3. Result of Power System Analysis

From the results obtained through the calculation of autonomy and electrical power, it can be affirmed that, in a typical mobile phone station, the existing electrical load is around 7.1 kW and what is usually contracted is 9.9 kW; with this value, it will not be possible to turn on the 5G equipment, so it is mandatory to carry out the management of increasing electrical power to a value higher than 14.5 kW, a procedure that must be managed with the electricity public service concessionaire and carry out the adaptations of electrical installations in the station, with these modifications the electrical capacity allows the existing 2G/3G/4G equipment and the new 5G to be put into operation.

5. Discussions

Energy efficiency in 5G networks is very important; for this reason, in the present research work, this topic is emphasized in the same way that the authors [14] and [16] do. In his article, the author [13] mentions that the traffic generated by the users of 5G services will be exponential; however, at no time is the energy consumption that these devices require to be able to work described. As shown in the developed article, in addition to this, it contributes to the massive deployment, raising the considerations that must be taken into account when installing this type of network that consumes large amounts of energy.

Besides that, the author [15] describes the importance of developing 5G technology and the bandwidth it needs. The author [17] also emphasizes that the 5G network requires reliable communication with low latency. However, none mentions the transport medium and the high traffic that goes through it, as does the author [19], who, in addition to recommending that the best transmission medium option for these networks is fiber optics, also details the type and the consideration that should be taken when implementing them. This article considers the transmission part vital to building 5G networks and the infrastructure part, the physical space in the tower where the new equipment will be installed.

Furthermore, at the local level, the deployment has been very slow in the last year due to the population contingency that believes it caused the pandemic, as stated by the author [12]. Despite this, massive and intelligent deployment has been promoted globally to mitigate this, as mentioned [21] in his article. In both cases, it is agreed that the quick and correct implementation of these networks will optimize the deployment at a global level. So, a series of installation criteria companies that opt for this technology must follow were raised.

6. Conclusion and Future Works

It is concluded, after the investigation, that the traditional construction process of 5G networks is currently deficient, so it is essential to carry out a pre-implementation study to identify the conditions in which the cellular base station with existing technology such as 2G/3G/4G are found. Thus, preventing mobile operators from being affected by the delay in deploying this technology would affect the project's capex.

It is resolved that, based on the analysis and result obtained after a structural evaluation of a typical existing telecommunications tower with 2G/3G/4G technology, it does not meet the required parameters according to current regulations and codes that support this study. It was identified that it is mandatory to carry out the structural evaluation of the towers before implementing the 5G NSA since it is generally required even to reinforce the tower. In addition, before the implementation of 5G in an existing base station, it will be a priority to review the electrical system since, currently, the contracted supply only covers the demand for 2G/3G/4G technology; for this reason, it will be necessary to increase the electricity, this must be processed with the local electricity public service concessionaire, which in many cases just collecting the required documentation can take up to 2 or 3 months.

Likewise, according to the study carried out, at the level of transport medium, it will be vital to migrating the microwave radio links to fiber optic links so that this much more robust medium can accommodate the traffic of both the existing 2G/3G/4G technologies and the projected 5G, since, as described in previous sections, the 5G network has much denser traffic.

The limitations found when carrying out the research work was the lack of explicit information on the subject matter since it is a new and poorly developed technology; in addition, there was also the need to resort to professionals and specialists in the area of infrastructure and energy systems to complement the studied information.

As a future research project, I recommend doing a study on the use of lithium batteries in 5G networks. As well as deepening more into energy efficiency and sustainable energy, because today it has become a great challenge for state entities and many private companies in the field point to it, and the main reason is a large number of interconnected equipment to the network, the so-called 5G ecosystem. On another side, it is also encouraged to carry out a study of the fiber optic links to be able to transport high data information, following international recommendations and national codes, since the region where it is located has different geographical zones and climates that reduce the useful life of the optical fiber, thereby avoiding breakdowns and failures in the operation of the network, which in many cases incur high costs for repair.

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