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Challenges and Opportunities of 5G Deployment in Ecuador (extended version)

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Abstract

The potential of fifth generation (5G) networks will contribute to the development of countries. The capabilities of 5G, such as a huge increase in transmission speed, decreased latency, improvement of the service delivery in places with a high user density and facilitates ubiquitous communication between devices. This allows 5G cellular networks to be the required support to establish reliable communications in real time with a view to the massification of the services established in Internet of Everything (IoE). In particular, the challenges and opportunities involved in the deployment of 5G in Ecuador are analyzed and discussed. This paper presents a review of recent literature on the deployment of 5G networks and the status of the implementation of this technology in Ecuador, considering its advantages, health implications and policy strategies on the use of frequencies and deployment. In addition, potential applications are mentioned that could be used to take advantage of many problems that have arisen during the COVID-19 pandemic, such as the lack of Internet access networks. In particular, it analyzes and discuss the challenges and opportunities involved in the 5G deployment in Ecuador.

Keywords: 5G, 5G architecture, 5G services, 5G health issues

1 Introduction

5G is the latest technology currently being deployed in cellular networks; according to Ovum, there will be around 1.9 billion subscribers by 2024 and the Internet of Things (IoT) connections up to four billion [2]. 5G specifications have been included in the Third Generation Partnership Project (3GPP) Release 15 and Release 16, but it is still in the early stages of its life cycle. Therefore, the 3GPP is still developing enhancements for 5G, those will be included in the 3GPP Release 17. Currently, operators are migrating their Non-standalone (NSA) 5G networks to the Standalone (SA) architecture to decrease their network latency and improve their coverage, by including the usage of frequencies above 6GHz using Massive Multiple Input Multiple Output (MIMO) and beamforming. Those achievements have been reached using Multi-access Edge Computing (MEC) and Artificial Intelligence (AI) [3].

Several studies [20,27,21] have analyzed the policy and regulation of 5G networks for several countries. In this context, Ecuador still does not have a regulation or deployment policy for 5G networks, where frequency allocation is established. It has caused that cellular operators in the country do not have a basis to be governed that allows them to plan the 5G launching according with national and international standards [18]. It is also important to point out that infrastructure is a determining factor, since 5G technology requires the implementation of small antennas, installed every two blocks, connected by fiber optics and updating the 4G radio bases [10]. The Director of the Association of Telecommunications Companies (ASETEL) points out that another limitation is the cost of the radio spectrum, because it is the second most expensive in the region, only surpassed by Mexico cost [18].

In Ecuador, only trial sites of 5G networks have been deployed, but it has not been put into commercial operation yet. It is in Ecuador's best interest to reuse the installed 4G networkinfrastructure, since installing new network infrastructure takes too much time and re-quires significant investment. It is important to point out that now is the time to carryout work in rural areas, since in Ecuador there is a total of 366 rural parishes that do nothave SMA coverage, i.e. they do not have radio bases installed [11].

The methodology used within this work is a review of recent literature on the deployment of 5G networks, and the status of the implementation of this technology in Ecuador. This paper is structured as follows. After the introduction, Section 2 presents the architectures proposed for the deployment of 5G networks, considering their advantages and health implications. Section 3 presents the current status and challenges of 5G deployment in Ecuador. It also analyzes the mobile networks deployed in Ecuador, the 5G network equipment of manufacturers, and the frequencies used by mobile operators in Ecuador. Section 4 analyzes the opportunities involved in the 5G deployment in Ecuador. Finally, we discuss and conclude this work.

2 5G Architecture and Deployment

Two architectures have been proposed for the deployment of 5G networks. The first, NSA requires changes at the base station level, both at the hardware and software levels, but reuses the 4G core (Evolved Packet Core - EPC). NSA seeks to take advantage of the deployment of 4G networks at the EPC core level and connect it to the new 5G base stations, this is called Dual Connectivity and allows maximizing the evolution of 5G with a slow and smooth transition, taking advantage of 4G coverage and 5G reliability [1]. The second, SA is a completely new infrastructure, both at the radio base level and at the network core level. The main disadvantage is that the development of the core is more complex and takes time since it requires the use of new technologies. The main advantage of this architecture is that it will allow the deployment of a network with better characteristics compared to a network deployed based on NSA [1]. Due to the changes that need to be made at the base radio level in both architectures, users need a new device to connect to 5G networks.

5G deploys a new radio interface; as a result, it establishes two working Frequency Ranges (FR). First, FR1 band from 410 MHz to 7.125 GHz; each of the sub bands are numbered from 1 to 255, previously it was known as the 6 GHz band because that was the upper limit, but in Rel 16 it was changed to 7.125 GHz. This band is characterized because the signals can be transmitted by diffraction, reflection and bounce allowing the coverage area to be larger, but the main problem is that they do not have large bandwidths which makes it difficult to provide high speeds [2], [7]. Second, FR2 band from 24.25 GHz to 52.6 GHz is called the millimeter band due to the size of the wavelengths of the signals operating in this band. This band is numbered from 257 to 511; it is characterized because the signals do not bend or reflect, but they can bounce; as a result of the increased frequency brings with, it increased free space losses and causes the signal to become more directive so it is no longer possible to pass through objects. On the other hand, the advantage of this band is that it has large bandwidths (up to 400 MHz) that allow delivering high transmission speeds. To compensate for losses due to the operating frequency, smart antennas are used to deploy beamforming and also MIMO. [2], [7].

2.1 Deployment

The deployment of 5G requires the use of three key technologies. First, EPC-5GC Tight Interworking allows users who cannot connect to the 5G network due to lack of coverage to connect to the existing 4G network, which facilitates the mobility of users between these networks. Second, dynamic spectrum Sharing allows spectrum sharing with existing 4G networks; Third, NR carrier aggregation facilitates the deployment of 5G networks in low frequencies, resulting in higher coverage and increased transmission speeds compared to the current deployed networks.

The new 5G network has been completely redesigned from previous generations to offer new services thanks to the support of technologies such as Software-Defined Networking (SDN) and Network Function Virtualization (NFV) and also improves its scalability using a cloud-native architecture. The implementation of these technologies requires enhanced network security in order to add an additional layer of defense in edge networks, including new protocols to fulfill the requirements for network slicing, MEC and Radio Access Network (RAN) disaggregation [5].

The deployment of 5G networks requires consideration of the overall device ecosystem including the network architecture, the existing infrastructure and the regulations in place where the network will be deployed [8]. It should be noted that to transmit the large amount of information sent by base stations, transport networks with demanding specifications such as high speed, low latency and reliability are needed to meet the success of 5G deployment. New wireless networks like Integrated Access and Backhaul (IAB) and significant improvements in wireline networks such as WDM, HFC, PON and Ethernet, can be used to transport data between the 5G core network and its radio access network [4].

2.1.1 Advantages of 5G networks deployment.

5G enables transmission speeds of up to 1 Gbps with latency times of 1 ms, for which it introduces improvements compared to 4G networks, among which the following stand out:

- The complementary carriers are wider (up to 400 MHz) and it also allows the use of multiple frequency carriers, the final device selects the carriers with which it will work.
- It enables carrier aggregation (frequency bands), even though they are separated in order to obtain wider bandwidths and achieve higher transmission speeds.
- Use of up to 256QAM modulation in the Downlink (DL) and Uplink (UL), increasing the number of subcarriers up to 3276. In addition, in the upstream channel it uses both Cyclic Prefix - Orthogonal Frequency Division Multiplexing (CP-OFDM) and Discrete Fourier Transform (DFT-OFDM), the latter enabling energy savings in the user's end device since it uses a simpler method by means of the Fast Fourier Transform to recover the information.
- It uses beamforming to concentrate the radiation beam on the end device to obtain higher power and improve the Signal to Noise S/N ratio, in order to compensate for losses due to high operating frequencies compared to the frequencies used in predecessor technologies. Finally, it adds the use of dynamic Time Division Duplexing (TDD) as a duplexing mechanism.
- 5G networks provides Voice-Over-New-Radio (VoNR), which adds improvements in the call quality, operational costs reduction, and allows a faster network technology migration, even more it includes the benefits already offered by Voice Over LTE (VoLTE) such as Enhanced Voice Services (EVS) codec-based HD voice, Video calling, and Rich Communication Services (RCS) [8].

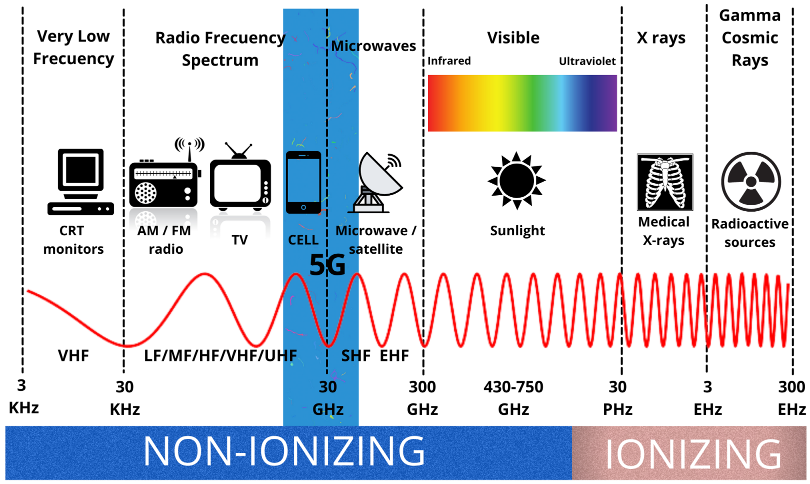

Figure 1: Graph showing where the higher range 5G frequencies land on the electromagnetic spectrum.

2.2 Health implications

Since the beginning of 2020, the world has been affected by COVID-19, a disease caused by a new coronavirus known as SARS-CoV-2. Uncertainty about the virus origin has prompted a myriad of reactions, including vandalism against wireless towers and other telecom facilities, as well as protests and attacks on employees. In fact, according to the New York Times, there is an Internet conspiracy theory that links the coronavirus spread to 5G [34]. In contrast, the World Health Organization (WHO) ensures that viruses cannot travel on mobile networks or radio waves; as evidence thereof, COVID-19 quickly spread throughout the world, including countries where 5G has not been implemented yet. Also, the fear of radiation has no fundamentals based on the fact that even light is a kind of radiation [25]. Figure 1, shows that the frequency range used for 5G communications is even below visible light; consequently, solar radiation should be considered a greater concern than 5G.

Moreover, with the purpose of avoiding any harmful effect on human health, the Institute of Electrical and Electronics Engineers (IEEE) has published some standards such as the IEEE C95.1-2019 Standard for safety levels with respect to human exposure to electric, magnetic, and electromagnetic fields (0 to 300 GHz), and the IEEE C95.3-2021 recommended practice for measurements and computations of electric, magnetic, and electromagnetic fields with respect to human exposure to such fields [24].

Cellular phones radiate radio frequency energy, which is on the non-ionizing radiation spectrum; this energy is not high enough to be considered a risk to human health. In fact, the main effect for frequencies above 6 GHz is surface heating. On the other side, ionizing radiation, such as sunlight, medical x-rays, gamma rays and cosmic radiation, acts by to tearing electrons from atoms, causing real chromosomal DNA damage [40]. Although, there are three main reasons why some people remain fearful about 5G. The first reason is the use of millimeter wavelengths, the second reason is the use of higher frequencies compared to 3G and 4G; finally, the deployment of more base stations and antennas [26]. In this regard, considerable research has been developed. Preliminary studies showed effects above 6 GHz; however, many of the reported effects occurred at levels greater than the guidelines stated by The International Commission on Non-Ionizing Radiation Protection. Despite the complexity of dosimetry and temperature control, recent studies have demonstrated that millimeter wavelengths do not cause damage in epithelial and skin cells, and there is no evidence of DNA damage.

Moreover, it has been proved that low-level millimeter wavelengths do not change the rates of cell survival or malignant cells proliferation linked to cancer. Also, the study carried out with human sperm, found no harmful effects of low-level millimeter wavelengths [26]. Besides, due to the fact that coverage areas are smaller in 5G, cell towers would not have to transmit as much power as current facilities [47].

3 Status and Challenges of 5G in Ecuador

Mobile operators in Ecuador are testing 5G technology. The National Telecommunications Corporation (CNT) conducted the first trial site with Huawei Technologies in July 2019, but they also performed tests using Nokia's Mobile Network Technology. In April 2021 while this test was carried out, the Administration Square in downtown Guayaquil, became a space with permanent 5G connectivity. It included a connection established between Guayaquil and Lima and also a movie was downloaded, both activities were carried out without interruptions, thanks to the approximate speed of 500Mb that this 5G site provided [31].

CNT has a NSA core with Huawei at national level and it also has a small core with Nokia in Guayaquil. CNT has proposed to install the NSA 5G network, i.e. upgrade its LTE infrastructure to NSA, maintaining the transport network and their 4G core network and increase antennas and 5G access nodes. It allows them to gradually switch to SA, which is the pure 5G. This is the procedure or roadmap established by CNT [42].

On the other hand, CONECEL, whose trademark is Claro, performed a trial test reusing the 3.5 GHz band with Huawei equipments in September 2019 at the "Ecuador Digital" event held at the Palacio de Cristal in Guayaquil. This demo reached speeds between 1.7 and 5.3 Gbps per user. Claro is waiting for the frequency allocation to be granted by ARCOTEL to start planning the deployment of their 5G network.

To implement the 5G network, the mobile operators intend to reuse the 3.5 GHz band assigned for the CDMA, which is for fixed wireless telephony; this band has been assigned to CNT and Claro. The most desired bands are the 3.5 GHz and 6 GHz bands, in the 6 GHz band no operator has spectrum assigned by ARCOTEL; another band to consider is the 28 GHz band, which is a millimeter band, but since it is a very high frequency, there are not non-ionizing radiation studies yet.

3.1 Mobile networks deployed in Ecuador

In Ecuador, the mobile operators: CNT, CONECEL and OTECEL have had a marked technological evolution in the mobile network, because each generation has led to the emergence of new devices and new services such as: mobile internet, video calls, video conferencing, among others. Figure 2, shows the increase in installed base stations per operator in Ecuador. CONECEL S.A. has the largest installed infrastructure, its growth has been progressive, surpassing OTECEL S.A., which is in second place, and CNT E.P., which is in third place.

Figure 3, shows the number of radio bases installed by each of the mobile operators and by technology. It can be seen that the three operators have deployed infrastructure for the Advanced Mobile Service at a national level. In addition, it is evident that the operator CONECEL S.A. would have an advantage to deploy the 5G NSA network since it requires the deployment of new hardware in existing sites, it should be noted that it is also essential to increase 5G nodes. [10]

Regarding the provinces, it is important to point out that the provinces of Pichincha and Guayas are the ones with the largest infrastructure deployment, Pichincha with 1932 and Guayas with 1677 4G radio bases installed. Therefore, a larger deployment of 5G could be carried out in these provinces. It is worth mentioning that Galapagos only has 9 4G radiobases installed.

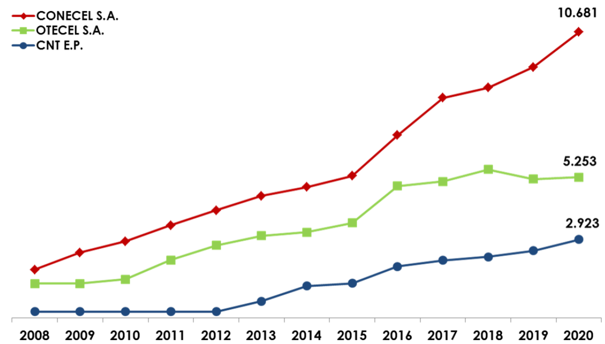

Figure 2: Evolution of the number of base stations per operator [10].

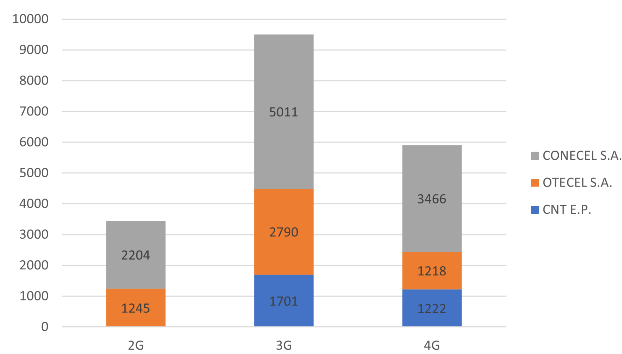

Figure 3: Number of base stations by provider and by technology

3.2 5G network equipment manufacturers

In Latin America, the following companies stand out: Huawei, Nokia and Ericsson, which have advanced, through negotiations with cellular operators, in Latin American countries. Huawei, being a Chinese company, has competed intensely to lead the world market in terms of the fifth generation, however the United States wants to withdraw it from the market in its country and in other allied countries for political reasons [32]. On the other hand, the Finnish provider Nokia is making agreements with the operators Antel of Uruguay, CNT of Ecuador and Telecom of Argentina. In addition, it has agreements with AT&T and T-Mobile, in order to expand its services in the countries where these companies have presence [13]. The Ericsson company also has presence in Latin America, and intends to offer 5G solutions in order to be an industry leader in conjunction with massive MIMO, Cloud RAN and software to strengthen 5G networks [17].

Although there are many manufacturers that may offer their support for the deployment of 5G, cellular operators should deploy the solution with the same manufacturer, so that full compatibility between elements is ensured and guarantees can be accessed. An analysis of the current infrastructure and the supplier proposal must be analyzed in advance.

3.3 Frequencies used by mobile operators in Ecuador

In Latin America, regulatory entities are analyzing and introducing new bands for mobile services. Some of those bands are currently occupied by other services. For instance, according to the National

Frequencies Plan in Ecuador, the FR1 band is assigned to fixed and mobile services, space research, radiolocation systems, Earth exploration, radio-broadcasting, aeronautical radionavigation, mobile satellite systems, meteorological aid service, among other services. On the other hand, the FR2 band is assigned to services including radionavigation, radiolocation, fixed and mobile satellite services, space research, radioastronomy, inter-satellite links, among other services [12]. Though future mobile services demands will require low, medium and high spectrum, Latin America has made progress in analyzing frequencies below 3 GHz and at 3.5 GHz. To illustrate, some control agencies in the region have introduced 1.4 GHz, 2.3 GHz and frequencies between 3.3 GHz and 3.7 GHz into the mobile services spectrum [11]. It is a fact that 5G deployment requires to operate under a licensing agreement; thus, operation harmony will not only be guaranteed, but will also heighten security and efficiency levels.

Figure 4 summarizes the spectrum assignment for land mobile communications in Ecuador. In the 700 MHz band, frequencies between 698 MHz and 748 MHz are reserved for the UL and from 758 to 806 MHz for the DL; it is important to emphasize that only CNT is qualified to provide service through this band with a total of 15 MHz for the UL and also for the DL, respectively. Besides, the 850 MHz band is used by CONECEL and OTECEL, both for the UL and DL reach a total bandwidth of 12.5 MHz, respectively. Moreover, none of the frequencies of the 900 MHz band has been assigned yet. Furthermore, the 1700/2100 MHz band is assigned to CONECEL and CNT, including 20 MHz for the UL and DL, respectively; it is important to highlight that 30 MHz are available in this band for both the UL and DL. Finally, despite the availability of 190 MHz in the 2.5 GHz band, it has not been assigned yet.

The use of frequency bands currently assigned to mobile communications in the country, would be by far the simplest and fastest alternative for 5G deployment, in terms of spectrum occupancy management; thus, it is necessary to consider the available bands, information depicted in Table 1. As can be seen, the 2.5 GHz band provides the greatest available bandwidth, followed by the 700 MHz and 1700/2100 MHz. In contrast, the 900 MHz band has the lowest availability of bandwidth and, as if it were not enough, the 850 MHz band does not have available frequencies. In short, considering the current assignment, the available bandwidth is 350 MHz.

Frecuency Band (MHz)	Assigned to	Bandwidth (MHz)	Uplink and Downlink (MHz)
700	CNT E.P.	30	15
	Available	60	30
850	CONECEL S.A.	25	12.5
	OTECEL S.A.	25	12.5
	Available	0	-
900	Available	40	20
1700 / 2100	CONECEL S.A.	40	20
	CNT E.P.	40	20
	Available	60	30
2500	Available	FDD: 140	70
		TDD: 50	-

Table 1: Summary of mobile spectrum band allocations [9].

Since FR1 and FR2 include more bands than the ones shown in Figure 4, and Table 1, ARCOTEL should undertake a detailed analysis of frequencies considered to land mobile communications that have not been awarded to any provider yet. Nevertheless, this study would require substantial efforts due to the fact that each band has particularities to be considered, including sharing with other services, radiated power limits, among others. Table 2 shows the bands for land mobile communications within FR1 and FR2 that should be analyzed; they have not been awarded to any provider yet.

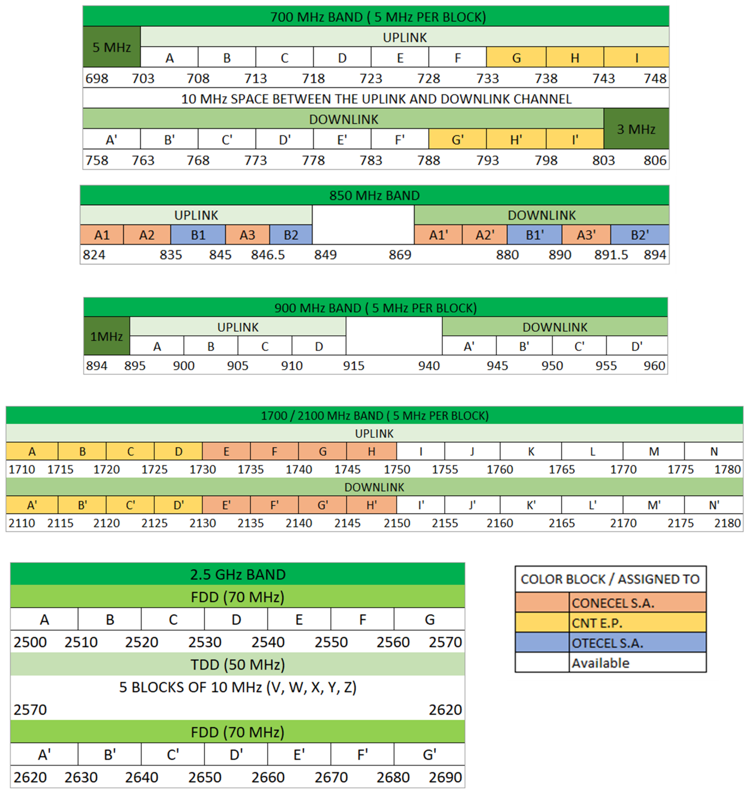

Figure 4: Spectrum band allocation for mobile networks [9]

The allocation of frequencies to be used for mobile services should be a priority issue in Ecuador, especially since the assigned frequency resource is far below the suggested by the ITU. It is a matter of concern that the bandwidth of 290 MHz assigned for mobile services in 2015, represented only 22,3 % of the suggestion issued by the ITU. Besides, an even more worrying aspect is the reduction in this percentage to 14,8 % by 2020 [16]. Therefore, frequency selection will be one of the most critical aspects of 5G deployment. Indeed, the "Digital Ecuador" strategy, included the invitation to tender for new frequencies in the 700 MHz and 2.5 GHz bands during 2019; nonetheless, it was deferred. Also, the 3.5 GHz band auction was scheduled for 2020; however, this was not fulfilled due to the pandemic and the subsequent critical situation in the country.

4 OPPORTUNITIES OF 5G IN ECUADOR

Nowadays mobile voice service has decreased due to the introduction of Over-the-top (OTT). mobile operators, with the support of 5G and the introduction of VoNR, can offer new services to their customers, such as video calling and RCS; in this way, mobile operators can compete with OTTs to win back their customers [8]. Until the 5G SA network deployment is completed, to provide a solution for full VoNR service, an Evolved Packet System Fallback (EPSFB) has to be used for the 5G NSA networks to connect to the 4G core network to deploy the service. Once the 5G SA network is completed, then both networks will have to work to ensure proper VoNR service delivery [8].

Frecuency Range	Lower Limit	Upper Limit	Bandwidth	Total	Units
FR1	410	430	20	3571.5	(MHz)
	440	512	72		
	614	698	84		
	1427	1518	91		
	1660,5	1690	29.5		
	2180	2500	320		
	3300	4200	900		
	4800	5000	200		
	5150	5350	200		
	5470	5725	255		
	5850	5925	75		
	6700	8025	1325		
FR2	25.5	29.5	4	20.5	(GHz)
	31	31.3	0.3		
	36	47	11		
	47.2	50.2	3		
	50.4	52.6	2.2		

Table 2: Frequencies to be considered, not yet assigned to mobile operators.

The application of the nomenclature established by CONATEL's resolution TEL-068-04-CONATEL-2013 for the provision of services through devices that use Subscriber Identity Module (SIM), will allow the assignment of an identifier by sector to services such as the provision of basic services in such a way that they can be identified by the operator and in the event that it is necessary to prioritize them.

Most deployed 5G networks have faced spectrum scarcity issues and limitations due to the low frequencies used within the FR1 band. To solve this problem, millimeter wave spectrum can be used, as it has massive bandwidth to deploy high-speed data networks for congestion scenarios such as stadiums, campuses, shopping malls, among others, in addition to ultra-low latency and backhaul base station applications. The cost to pay is the decrease in coverage or even the requirement of line of sight to establish communication [6].

4.1 Industry 4.0

Currently, the industry is taking on a new facet, in this case it has evolved over time to the fourth version. With this new version of the industry, a new point of view is needed in which all the elements are interconnected to be able to collect data and information [41]. In this way, this integration through Internet of Things (IoT) can be used because these small systems can acquire a very large amount of information and send it to a central server, which has as main objective the storage of information as well as its processing [22]. With the information collected, a variety of technologies can be used such as data meaning, machine learning big data among some with this type of technology can be given a meaning to the information collected [46]. However, when sending this substantial amount of information, there is a limitation which is the access to the information, since 802.11 cannot cover the entire industry; therefore, the starting point is the management of information sending through 5G technology and all the benefits that this technology offers.

The communication aspects of industrial automation can be represented according to the RAMI 4.0 reference model [39]. In the RAMI 4.0 communication layer, where several types of data networks coexist, the difference between these technologies will depend on the latency of the information. Currently, there are several open and proprietary standards for industrial automation. There is a new standard which is used for the industry, it is called Time Sensitive Networking (TSN). It has protocols compatible with 802.3 that determines low latency to perform real-time communications [33]. But there is a problem with wireless technologies since it is a medium which has a lot of interference, but at the same time, it has a very fast growth and covers a very wide coverage. Also, it has been focused on designing new automation and connectivity products to create an intelligent industry that can process information. In technologies prior to 5G, automation had not been considered, but 5G addresses and creates a new market for new industries called verticals through their own characteristics as well as the coverage they will provide.

The 3GPP standard has also identified some examples where it can be applied in 5G networks and adds minimum levels at which such communication can be provided for automation in vertical domains. An outstanding example corresponds to the Factories of the future, where the standard aims to add a link with superior features in cellular technologies in the industrial environment; thus, increasing the efficiency and flexibility of the mobile [23]. From the point of view of the 3GPP standard, the most difficult implementations to set up are those with low latency, high reliability and high performance involving closed-loop control, safety-critical Human Machine Interface (HMI) and augmented reality.

4.2 5G in healthcare

From another point of view, Ultra-Reliable, Low-Latency Communications (URLLC) can be used to manage patients in hospitals. Based on the experience of recent years, with the emergence of a pandemic, the management of remote equipment in the healthcare area, the medical team would have lower probability of being infected and of safeguarding their health. Through the use of IoT and 5G networks, patients with highly contagious diseases such as COVID-19 can be monitored without the medical team becoming contaminated and contracting the disease [45]. IoT equipment can be used to obtain information that is called primary, such as vital signs, weight and size, which in this case all the information can be stored on a server and not as it is currently done in Ecuador on a sheet of paper that the doctor reviews when the patient is going to be treated.

In some Latin American countries, such as Chile, this type of technology is already being deployed with robots that directly attend to patients with COVID-19 [38, 37]. In addition to these actions in the IoT world [36], it is also possible to collect valuable information on the behavior of a virus and thus provide scientists with an additional tool to solve the problem it generates. There is a turning point that goes beyond 5G technology, which is the storage of confidential information, since in many countries there are regulations that must be complied with in order to store and enter patient information [43]. In order for 5G cellular systems to comply with these regulations, several requirements must be met, which are specified in 3GPP TR 22.826.

4.3 Stationary wireless accesses

In the current pandemic that the whole world has gone through, it became evident that in the country there is a very big problem with the access to the Internet at national level. In large cities such as Quito, Guayaquil and Cuenca, the digital gap is small, but for remote cities the problem is aggravated. At present, studies have been carried out where it can be observed that during the pandemic there was a large number of students who could not study in an educational institution [14, 15]. There are several reasons for this, but the most important is the lack of Internet access that students had as well as the lack of access to computer equipment. Currently, 5G networks can be deployed because the performance and capacity of the wireless medium is increased and therefore a larger number of users can be reached.

Fixed Wireless Access (FWA) [44] can be used to provide broadband Internet access to places that are difficult to access or where conventional Internet access services such as fiber optics, coaxial cable or subscriber lines do not cover, thus providing an efficient option to supply such service without making structural changes to the site [29].

4.4 Automated drone management for crop areas

5G cellular networks use URLLC; this technology can be applied in different areas such as the following: robotics, drones, Unmanned Aerial Vehicle (UAV), among others. In the case of agriculture, UAV equipment can be used, it is a combination of drones and unmanned aerial systems, in order to monitor all the crops that are on a farm or also to perform spraying and sample extraction from very distant points [28, 19, 30, 48]. The requirements for this type of drones to send information to the operator which is located at a long distance is necessary to use a highly reliable network; therefore, it is seen as an opportunity to manage a 5G network.

With these advances and with the 5G network technology, agriculture can be automated at a national level; with this, it is possible to increase production and make the leap to industry 3.0, which is currently already in many developed countries such as the United States or China. Not to go too far away in Latin America, in Chile there are many seed projects that are trying to carry out this type of large-scale production. Ecuador can take this development as an example to be implemented in its territory [35].

5 Conclusions

The new frequency bands, together with other technologies, allow 5G to offer high transmission speeds with low latency and high efficiency, but it requires more bandwidth, so higher frequencies are needed. This causes a decrease in the coverage of each radio base, forcing a greater number of them to be deployed to cover the same area that would be covered by previous technologies using lower frequencies. As a result, network design becomes more complex, but with the help of artificial intelligence and machine learning, network deployment costs can be reduced and network coverage optimized.

The government must guarantee the allocation required for the deployment of mobile telephony networks because it is a key factor for the development of the industry, as well as helping to reduce the digital divide by providing better connectivity to users. Even more so when the mobile telecommunications industry is one of the industries that moves large amounts of money and provides jobs to countless workers. In the event that the spectrum to be assigned to mobile networks is occupied, it is necessary to clear the spectrum to free up the frequencies, but this is not possible immediately since the spectrum is usually occupied and there is usually no exact information on who occupies it. If the spectrum to be auctioned to mobile operators is not free, the clearing costs must be covered by them.

The use of the available bandwidth, 350 MHz, within the mobile spectrum bands, would be the simplest alternative for 5G deployment in Ecuador; meanwhile, in case higher frequencies or wider bandwidth are required, a thorough review must be carried out. In addition, the government should establish some kind of regulation that does not allow the dominant operator to deploy its 5G network first even if it obtains the frequency concession, because having a large installed infrastructure will allow it to easily upgrade its equipment to deploy 5G NSA and this would give it a competitive advantage that could break the market.

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