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5G technology deployment in Latin America: An analysis of public policy and regulation environment

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Abstract

5G has become a reality in Latin America and it is expected to boost the digital revolution with key capabilities, including higher speeds and ultra-low latency, thus enabling innovative solutions and socioeconomic development. But its deployment faces many challenges related to, among other factors, spectrum allocation and infrastructure deployment. In this work we assess the current public policy and regulatory environment in Latin America regarding the adoption and deployment of 5G technology, considering mainly the above-mentioned challenges. From the analysis, it is possible to note that Latin American countries exhibit different levels of commitment and progress in 5G deployment since, for example, the spectrum allocation and assignment for 5G is still underway, and many regulations hamper instead to facilitate the implementation of 5G networks. On the other hand, the analysis confirms the necessity of having public policies and regulations which define flexible, efficient and transparent processes for all aspects related to 5G deployment.

Keywords: 5G; Latin America; Public Policy; Regulation; Spectrum allocation; Wireless communications

1. Introduction

The growing demand for immediate access to information due to the continuous development of human society around communications technology results in increasingly strict regulations regarding speed and reliability of telecommunications systems. Particularly, worldwide societies demand consistent and uninterrupted mobile connectivity, and providers of this service are compelled to follow more demanding quality standards regarding network access, low latency, high transfer speed, and coverage.

To meet these demands, 5G networks have been developed as a disruptive technology when compared to previous iterations of mobile network access technologies. This is based on the novel commercial opportunities created by various features of the 5G standard, such as how network virtualization capacity enables the development of services tailored to particular industrial and/or economic sectors by network operators.

5G technology is aimed to meet the communication demands, push the development of directional consumer markets, and foster the fourth industrial revolution [1] by introducing several societal paradigm shifts. And one important element to make this possible and take advantage of all its capabilities is an adequate technological and political framework. This could boost 5G as a true societal agent of change.

5G networks, dictated by the IMT-2020 standard, are not limited by design to enhance conventional human-human or human-machine communications, but 5G is intended to expand the current machine-machine communication that is

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ubiquitous on the Internet of Things (IoT) applications. Following 5G deployment, a wide range of devices such as those related to home electronics, industrial and manufacturing machinery, transportation, power generation, and wearable technologies will be further enabled to operate in a sustainable and cost-effective manner without the significant introduction of additional operating costs or excessive loads on information and power distribution infrastructure [2].

According to the International Telecommunications Union (ITU), 5G technology is expected to offer users a connectivity experience unlike the one provided by fixed networks. 5G technology introduces revolutionary advantages when compared to current technologies by offering higher data transfer speeds, higher data traffic densities, increased reliability, increased support for mobile user physical movement speeds without connectivity failures [3], reduced network latency, increased device count capacity, increased energy efficiency in IoT applications [4] and spectral efficiency. These improvements are highlighted in Figure 1.

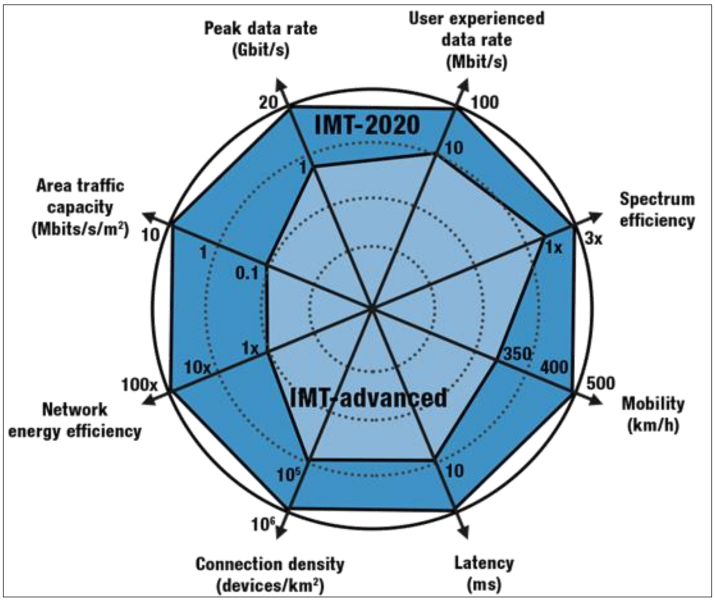

Figure 1 Fundamental improvements to IMT-Advanced technology introduced by the IMT-2020 standard

Currently, large-scale deployments of 5G technology are beginning to take place around the world. For this reason, network operators, regulating agencies and other related agents are beginning to visualize the necessity to establish clear deployment parameters and regulations in order to reduce potential deployment complications [4][5][7], by considering the needs and vulnerabilities of every agent involved, and guaranteeing optimal conditions for local deployments. In this way, local public policy must balance any safety and regulatory concerns with technology deployment to speed up 5G and let it become the disruptive societal factor it promises to be.

Currently, various international and regional telecommunications-related organizations, including local and international regulatory agencies, are debating several aspects of 5G technology deployments. One central issue is the creation of 5G deployment plans that meet current regulations and consider any necessary modifications in order to maximize the benefits of such deployments [8]. These plans have three key aspects: spectrum allocation, regulations for physical infrastructure deployments, and public policies with a special focus on reducing the digital gap, which is a serious concern in Latin America and other world south territories. [9]–[12].

In the context of the Latin American political, economic, and regulatory environments, there exist three main areas that represent challenges towards the deployment and utilization rates observed in developed countries: Industrial development, existing telecommunication infrastructure and regulatory activity. Unlike previous deployments of upgraded communication standards, a significant portion of the benefits introduced by 5G technology are centered on providing solutions to existing limitations faced by the industrial sector, in addition to providing new possibilities through IoT applications.

Broadly speaking, the Latin American industrial sector has been noted to be going through a process of premature deindustrialization due to its inability to fully integrate into the manufacturing Global Value Chains [13]. For this reason, most of the productive activities in the region are structured upon low and medium-low technology industrial activity, with some of these low-tech activities being performed as a service for further high-technology operations outside of the region, such as logging, agricultural, and mining activities [14], [15]. For these reasons, it is important to consider the level of technological development of local industrial activities, in order to make sure they are able to take advantage of the new possibilities introduced by a massive 5G rollover, either in the present or the near future.

5G technology is, in very broad terms, a network access technology, and as such operates as a link between wireless devices and an established, high-capacity backbone network. It is important for the interested parties in each particular region to evaluate the current state, reach and data transfer capacity of this backbone network to ensure that it is capable of handling the significantly elevated traffic levels it will be expected to handle following a massive 5G deployment. For these reasons, it is important to establish a regulatory framework that incorporates all interested parties. Particularly, the interests of potential large-scale users and concerned citizens must be consolidated order to ensure the viability of the investments of wireless operators and communications backbone operators, who are responsible in most regions for their respective 5G deployment operations.

This work is focused on providing an assessment on the current public policy and regulatory environment in Latin America regarding the adoption and deployment of 5G technology. Besides, we discuss the main challenges that must be addressed in order to reach deployment levels and modalities that meet the necessities and interests of the general public, the regulatory agencies, and all other entities related to the various deployment operations. This is illustrated with some examples of the Panamanian experience.

We expect this work to be useful by given indications of required changes in current regulations and market rules to ensure the sustainability and growth of the regional telecommunications market in Latin America and other similar regions.

In the following sections we first identify the minimal requirements and several challenges for a successful 5G technology deployment, from the perspective of public policy development, spectrum management and regulation. Then, we briefly summarize and analyze regulatory policies in Latin America to establish the effective deployment strategies, presenting particular strategies of individual countries related to spectrum allocation of the frequency bands for 5G. Further, some insights are given on the relationship between 5G deployments and various complementary technologies, and finally, we present the conclusions.

2. Minimum Technical Requirements and Challenges for 5G Deployment

At the regulatory and public policy level, the implementation of 5G technology have to satisfy some minimum technical requirements. In the following, we consider those related to spectrum allocation and regulations for physical infrastructure deployment. One of the main requirements for 5G deployment is an expanded spectral bandwidth, which is necessary to attain high data throughput capabilities. To this end, 5G requires the availability of spectral bands within three frequency ranges: sub-1 GHz range (low spectrum), 1-6 GHz range (middle spectrum), and over 6 GHz ranges (high spectrum) (according to the GSM Association) [16].

Each of these frequency ranges will enable attaining the required network access/coverage and data transfer capacity needs necessary to meet certain 5G implementation scenarios. Figure 2 give information on the data transfer and coverage capacities for different frequency bands. The low spectrum range is ideal for providing large coverage areas, particularly in rural scenarios, due to its long-range propagation and small free-space path loss (FSPL) properties [17], [18]. The medium spectrum (1-6 GHz) combines the benefits of data transfer capacity and coverage and will be the initial basis for 5G services. This is in part because, in many countries, segments of this spectrum have already been assigned or are planned to be assigned in the near future for mobile communication purposes [19]. The high spectrum (> 6 GHz), despite having more limited coverage, will be allocated for providing high localized capacity (such as indoor applications) due to the reduced competition for spectral allocation in these frequencies[20].

In this regard, it is important to highlight the key role of spectrum allocation policies for the so-called *millimeter waves* in fostering the expected potential of 5G technology.

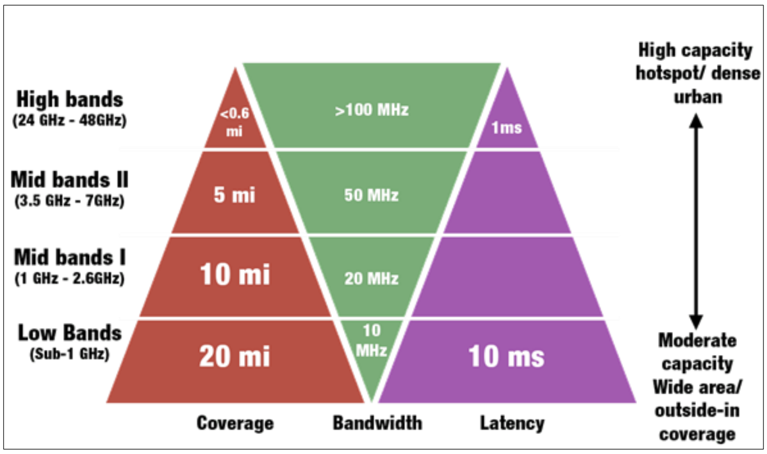

Figure 2 Low, medium and high spectrum data transfer and coverage capacities

These frequencies, also known as Extremely High Frequency (EHF) waves, consist of the highest frequency bands in the radio frequency spectrum - between 30 and 300 GHz and wavelengths between 1 to 10 mm [16]. It is important to note that, when referring to millimeter waves in the context of 5G, they correspond to frequencies below 30 GHz, such as the 26 and 28 GHz bands. The use of millimeter waves presents challenges not only in terms of spectrum allocation, but also in terms of massive deployment of physical infrastructure to achieve the coverage and speeds offered by 5G. This is due to the significant amount of FSPL produced by atmospheric and rain attenuation losses. To overcome these propagation losses, a larger number of base stations need be installed, albeit with smaller antennas than those used by previous generations of mobile technology [21], [22].

Moreover, the higher required density of antenna equipment introduces the nontrivial issues of visual and radioelectric pollution in high-density areas [23]–[25], and for service providers, it brings a series of challenges related to the implementation of additional equipment. These challenges include the necessity of acquiring local permits for infrastructure construction, high rental fees for installations in public urban settings, control of ongoing human exposure to electromagnetic radiation, and codified access and rights [26], [27].

These challenges, in addition to preventing rapid and cost-effective deployment of 5G networks, introduce excessive administrative and financial obligations on operators that could hinder the attractiveness of the required investment [28], [29]. All this motivates an adequate implementation of regulations that balance the requirements for physical infrastructure deployment, necessary to provide the intended services, and the risk of potential harm to the general population due to excessive deployment. In addition, it is also necessary to implement appropriate public policies focused on two key aspects: to reduce any risks of widening the digital divide, and to encourage the private sector interest in expanding its networks to reach a large proportion of the population, particularly those located in rural and suburban areas. This last is important because, for commercial reasons, this segment of population is less likely to be considered a priority for service availability due to higher costs of infrastructure deployment in proportion to population densities [30], [31]. To this end, it is essential to develop clear strategic guidelines for the public and private sectors in order to build a robust 5G ecosystem. These guidelines must include fundamental short, medium and long-term steps and milestones in order to establish clear objectives and ensure the commitment of service providers towards prioritizing resources for critical areas of development [28].

Currently, in Latin America most mobile operators are in the phase of enabling their systems to support 5G technology. Twenty one test rollouts have already been announced in different countries in the region (see Table 1), as well as 4 commercial launches by operators in Uruguay, Brazil and Puerto Rico [32]. In these deployments, dynamic spectrum sharing (DDS) technology is used because there has not been yet auctions for a more suitable spectrum for 5G [33]. In this regard, Chile has been the first country in the region to announce the first spectrum auction exclusively for 5G deployment in the 700 MHz, AWS (1.7 GHz - 2.1 GHz), 3.5 GHz and 26 GHz bands [34].

3. Current Regulatory and Public Policy Environment in Latin America

The regulatory framework in most of the countries in the region is focused on emission intensity management, with the majority of them adopting the non-ionizing emission limits recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the World Health Organization (WHO) [35], as shown in Table 2.

Notice that only Mexico and Bolivia did not base their non-ionizing radiation regulations on ICNIRP recommendations. In the case of Mexico, it did not include reference to the most common recommendations, but carried out independent evaluations in order to establish the parameters reflected in its regulations. On the other hand, Bolivia chose to use the recommendations issued by the Federal Communications Commission (FCC) of the United States. Meanwhile, Nicaragua has not yet established limits for non-ionizing emissions in its technical regulations [36].

In general, the regulatory authority of each country, as an administrative unit of the central government, regulates the maximum power of antennas and limits the exposure of their population to electromagnetic radiation. It is also responsible for ensuring compliance with the technical conditions and that network operators fulfill the indicated limits. In addition, the regulatory authority is responsible for the spectrum management, as well as the spectrum assignment, and to issue good practice manuals, including aspects of visual impact of infrastructure deployment.

Other important elements related to regulation are the urban planning, installation and operating procedures, and the particular entities involved in the infrastructure deployment process.

At the regulatory level, the requirements to obtain the necessary local permits for infrastructure deployment vary widely among Latin American countries. But a common feature is the heavy bureaucratization of the process to obtain these permits, which leads to elevated upfront costs and extended periods of time to comply with all requirements.

Table 1 Commercial 5G deployment tests and rollouts in Latin America and the Caribbean

Country	Spectrum	Service Provider	Use
Argentina	28 GHz	Ericsson	Test and Demonstration
	28 GHz	Huawei/ Nokia	Test and Demonstration
Brazil	N/A	Ericsson	Commercial Launch
	3.5 GHz	Huawei	Deployment Test
	3.5 GHz	Huawei	Demonstration
Bolivia	N/A	Huawei	Deployment Test
Chile	27 GHz	Nokia	Deployment Test
	28 GHz	Ericsson	Test and Demonstration
	28 GHz	Nokia	Laboratory Test
	3.5 GHz	Huawei	Deployment Test
Colombia	N/A	Huawei	Deployment Test
	3.5 GHz	Nokia	Deployment Test
	28/3.5 GHz	Ericsson/ Huawei	Deployment Test
Ecuador	N/A	Huawei	Deployment Test
	N/A	Nokia/ ZTE	Deployment Test
	N/A	Huawei	Deployment Test
Perú	AWS/5 GHz	Ericsson	Deployment Test
	3.5 GHZ	Huawei	Deployment Test
Puerto Rico	28 GHz	Ericsson	Deployment Test
	28 GHz	N/A	Commercial Launch
Uruguay	28 GHz	Nokia	Commercial Launch

In general, the local municipalities define the requirements for the installation of mobile communications infrastructure and grant the installation permits. And in some countries, the regulatory authority must grant a prior authorization

[37]. In most cases, other institutions such as environmental and aeronautical authorities, fire departments and citizen consultation boards are also involved and must generally give their approval.

In Panama, for example, the National Authority of Public Services (ASEP) is the entity in charge of overseeing the installation and operation of telecommunications infrastructures. In this regard, in 2009 ASEP issued Resolution AN N°2848-Telco, which regulates the installation, operation and shared use of towers and/or telecommunications-related structures. According to this resolution, operators and installers must request the construction permits to the municipal authorities and comply with all the required provisions such as: use of land or zoning, presentation of blueprints and designs, authorization/approval from the Civil Aeronautics Authority and the Fire Department Safety Office, and several other institutions related to various aspects of these deployments. These permit requirements may vary depending on each municipality. This regulation is based on three general principles, namely:

- Prioritization of the use of existing structures in order to avoid the unnecessary proliferation and redundancy of towers.
- Establishment of clear regulatory frameworks for technical parameters of installation, operation and shared use of towers.
- Hosting open consultations that include local citizens in order to inform the residents closest to the tower of the intended deployment.

Table 2 Regulation parameters for the emission of non-ionizing radiation in various Latin American countries

Country	Main aspects of non-ionizing radiation regulations.
Argentina	Set (previously) similar levels to those established in the ICNIRP 1998 recommendations.
Bolivia	FCC
Brazil	ICNIRP
Chile	Based on ICNIRP, but with lower limits (ICNIRP /10, ICNIRP/100 for sensitive areas)
Colombia	ICNIRP
Costa Rica	ICNIRP
Ecuador	ICNIRP
El Salvador	ICNIRP
Honduras	ICNIRP
México	IFT-007-2019
Nicaragua	Undefined
Guatemala	ICNIRP
Panamá	ICNIRP
Paraguay	ICNIRP
Perú	ICNIRP
Uruguay	ICNIRP
Venezuela	ICNIRP
Dominican Republic	ICNIRP

It is necessary when deploying infrastructure to take into account, in addition to the regulatory framework, the so-called provisioning cycle of operators. The cycle explains, in broad terms, the internal procedures applied by operators and consists of the following phases: network deployment planning and operating license applications, civil works and infrastructure deployment, equipment operation and maintenance, and decommissioning strategies [38].

From an observation of the provisioning cycle steps, it becomes apparent that regulatory requirements have an impact on the first and second phases of it. In the first phase, operators must be very clear about the legislation in force in the country in which they operate, especially those related to license applications, at the municipalities and a central government institution. In the second phase, it is essential to know the limitations related to deployment, as well as the regulations for reducing visual impact and restrictions on electromagnetic radiation levels.

Regarding the spectrum allocation, it is worth notice that public policies are motivated by the harmonization of the spectrum carried out by ITU, which is responsible for the allocation of different portions of the radio electric spectrum and the services provided in particular frequencies. For this purpose, the ITU divides the world into three regions, where Latin America is within Region 2 [39]. It is worth to indicate that Latin America is noticeably delayed in the allocation of spectra for delivering mobile services with respect to the recommendations made by the ITU. According to the document ITU-R M.2290 of 2013, estimations consider necessary between 1340 and 1960 MHz of spectrum assigned to mobile services by 2020 [40].

For Latin America, it is the Inter-American Telecommunications Commission (CITEL) (part of the Organization of American States, OAS) the responsible for consolidating proposals from public and private sectors on the use of the radio spectrum [41]. The identification of spectrum for mobile services, its allocation and assignment is the result of a regional concession that generates economies of scale for the industry in general. It is in the World Radiocommunication Conference, held every four years, that the international frequency band allocation table is agreed, and it serves as the basis for the tables of each individual country. Governments must define their frequency allocation plans, radiation emission requirements, the specific modalities for the use of the radioelectric resource (licensed or free) and how to make it available to interested parties. They must also define the intended signal transmission and reception scheme to be utilized (TDD or FDD) [42].

3.1. Spectrum Allocation

One fundamental element for implementing 5G is the spectrum allocation for mobile telecommunication services and the related spectrum policies. In this regard, Latin America and the Caribbean face several challenges. At the international level, the region must submit its spectrum needs to international standardization organizations in order to be considered in their decisions. At the regional level, countries should develop long-term spectrum regulations that encourage private investment under a transparent and predictable approach. Similarly, countries should focus on issuing licenses at appropriate prices to enable the deployment of 5G. In addition, this should ensure effective use of the assigned spectrum to close the digital divide in their populations by providing coverage in both rural and urban areas at affordable prices. This last is essential in the development of public policies concerning spectrum needs for 5G technology.

One key characteristic of frequency bands below 1 GHz is their high capacity for signal propagation. This is essential for expanding the coverage of mobile broadband services in rural areas with low population density, and a more economical and faster deployment. This makes the 700 and 600 MHz bands attractive for the so-called low band block for 5G deployment. However, the reality of both bands in Latin America is quite different. The 600 MHz band incorporates the 614-698 MHz range and is allocated primarily for broadcasting with a secondary use for Mobile and Fixed services, as is the case of Chile, Cuba, Jamaica and Panama (only for Fixed services), among others. However, in other countries, e.g., Bahamas, Belize, Canada, Colombia, United States and Mexico, it is currently allocated primarily for mobile services. The 700 MHz band in Region 2 (America), is between 698-806 MHz and is allocated primarily for mobile and broadcasting services, and as a secondary use for fixed services [43, p. 2020]. Table 3 summarizes the current situation of both bands in countries of the region.

On the other hand, access to mid-bands, particularly the 2.5 GHz and 3.5 GHz bands, will be essential for 5G deployments in the region, due to the attractive combination of capacity and coverage benefits they offer. About the 2.5 GHz Band (frequencies from 2,500 to 2,690 MHz), the Resolution No. 223, issued at the 2015 World Radiocommunication Conference (WRC-15), states that it has been identified by many administrations to introduce IMTs (International Mobile Telecommunications systems). Furthermore, it adds that in many countries IMTs have already been implemented or are being considered for implementation in this band, indicating that equipment is readily available for deployments.

This resolution also emphasizes that administrations should have the flexibility to determine the amount of spectrum for IMTs and when should it be made available, taking into account the benefits of harmonized spectrum utilization for IMTs. All this within their own transition plans and taking into account specific user demands and other public and private considerations. It should be noted that the 2.5 GHz band is allocated to the mobile service on a primary basis in all three ITU Regions, which has favored its potential as a global band for use in mobile services.

Initially, in the Latin America, the 2.5 GHz band was intended for Pay TV, data transmission and Internet access services. However, due to business opportunities, technology evolution and lack of large-scale availability of certain technologies, it is an underutilized portion of the spectrum. Table 3 shows the current state of this band in the region.

Table 3 Current allocation of the 600 MHz, 700 MHz and 2.5 GHz bands in Latin America

	600 MHz		700 MHz		2.5 GHz	
Country	**Mobile Attribution**	**Assigned**	**Mobile Attribution**	**Assigned**	**Mobile Attribution**	**Assigned**
Argentina	No		Yes	Yes	Yes	Yes
Bolivia	No		Yes	Yes	No	
Brazil	No		Yes	Yes	Yes	Yes
Chile	Yes	No	Yes	Yes	Yes	Yes
Colombia	Yes	No	Yes	Yes	Yes	Yes
Costa Rica	No		Yes	No	Yes	Yes
Ecuador	No		Yes	Yes	Yes	Plan/allocation stage
El Salvador	No		No		No	
Guatemala	Yes	No	Yes	No	No	
Honduras	Yes	No	Yes	No	No	
Nicaragua	Yes	No	Yes	Yes	No	
Mexico	Yes	No	Yes	Yes	Yes	Yes
Panama	No		Yes	Yes	No	
Paraguay	Yes	No	Yes	Yes	No	
Peru	No		Yes	Yes	Yes	Yes
Uruguay	No		Yes	Yes	Yes	Yes
Venezuela	No		Yes	No	Yes	Yes
Dominican Rep.	Yes	No	Yes	No	Yes	Yes

The other mid-band, the 3.5 GHz (frequencies from 3300 to 3800 MHz), has also been identified for implementation of IMTs by many administrations in Region 2. At regional level, the 3.5 GHz band aims to be one of the pioneer bands for 5G, supported by its use in a significant part of the 5G technology deployments worldwide. For this reason, several countries in the region have proceeded, in principle, to allocate frequency ranges in these bands for future assignment in their respective frequency allocation plans [44]. In the Americas, this band is divided into several segments, 3.3-3.4 GHz is allocated on a secondary basis for mobile service, while 3.4-3.8 GHz has a primary allocation for mobile services.

Although the occupation of the 3.3-3.8 GHz range is heterogeneous, in Latin America there is a noticeable trend towards the release of the 3.3-3.4 GHz and 3.4-3.6 GHz ranges for IMT services. In this regard, it is important to note that several countries in the region such as Chile, Colombia, Costa Rica, Ecuador, Mexico, Peru, Dominican Republic and Uruguay have already allocated at least 100 MHz in that range [45]. Table 4 indicates the current allocation of this mid-band.

The other band identified for 5G applications requiring very high speed communications is the millimeter wave band. The Latin America region is in the early stages of identifying potential millimeter bands, which is why most countries have only contemplated their use in their spectrum planning, while others have proceeded to reserve spectrum capacity for future needs without having allocation plans yet. But there are exceptions like Uruguay and Puerto Rico that have made allocations in the 28 GHz band. The Uruguayan case corresponds to an allocation made by the regulator in 2006 of an 850 MHz block (27.5-28.35 GHz) for an LMDS (Local Multipoint Distribution Service) system, and the Puerto Rico case corresponds to a spectrum auction held in 2020 [46]. Table 4 shows an overview related to the identification of millimeter bands by some of the countries in the region.

Table 4 Current allocation of the 3.5 GHz and millimeter-wave bands in Latin America

	3.5 GHz		**Millimeter-wave**	
Country	**Mobile Attribution**	**Assigned**	**Mobile Attribution**	**Assigned**
Argentina	No	3,3 – 3,4 GHz allocated for second mobile use	24,25-29,50, 37-43,5 GHz	Reserved (new assignments suspended)
Bolivia	Yes	No		
Brazil	Yes	No	26 y 39 GHz	26 GHz to be auctioned in 2021, currently in discussions for 39 GHz.
Chile	No		26 y 28 GHz	26 GHz to be auctioned in 2020. 28 GHz included for discussion.
Colombia	Yes	Yes	26, 28, 37-43,5, 47, 2-48, 2, 45, 5-47 y 70 GHz	Mentioned in the spectrum allocation plans for 5G.
Ecuador	Yes	No		
El Salvador	Yes	No		
Guatemala	Yes	No		
Honduras	Yes	3,4 – 3,7 GHz allocated for primary mobile use		
Nicaragua	No			
México	Yes	No	26, 28, 42, 48 y 51 GHz	Mentioned in spectrum allocation report for 5G
Panamá	No		26, 28, 40 y 66-71 GHz	Reserved (new assignments suspended)
Paraguay	Yes	No		
Perú	Yes	Yes	26 y 28 GHz	Evaluation stage 26 GHz will be subject to public consultation by 2020.
Dominican Rep.	Yes	No		
Uruguay	Yes	No	28 GHz	In use
Venezuela	N/A	N/A		

For instance, regarding spectrum policy, the Panamanian government has issued guidelines, based on international organizations recommendations, seeking to meet the spectrum needs for the deployment of 5G. One of these guidelines is Resolution AN No. 15710-Telco of 2019, which modifies the National Frequency Allocation Plan (PNAF) to allocate the Cellular Mobile Telephony and Personal Communications Services in the segment from 1427 MHz to 1518 MHz. Additionally, Resolution AN No. 16403- RTV of October 19, 2020 resolved to suspend the granting of automatic extensions of concessions for the Type A Paid TV service with main frequency allocation in the 2500 to 2690 MHz band until the respective evaluations regarding the identification of this band for IMTs by the ITU are completed. Similarly, in relation to the use of millimeter bands, Resolution AN No. 13530-Telco of 2019 suspended the allocation of frequencies in the segments between 24.25 to 27.5 GHz (known as 26 GHz Band), from 26.5 to 29.5 GHz (known as 28 GHz Band), from 37.5 to 43.5 GHz (known as 40 GHz Band) and from 66 to 71 GHz, at national level.

In general, spectrum allocation is used by authorities to impose new rules on operators participating in new spectrum allocation processes. These new rules can impact both new frequencies and those currently in use. Spectrum assignments are made through auctions or open bidding events. In the latter alternative, which has been employed by Chile and Colombia, the government determines the awardees for spectrum concessions according to their respective investment and coverage deployment plans. In addition, usually the concession awarded in an open bidding event is accompanied by a strict coverage schedule that may be determined in percentages of the national geography, serviced population, or both. The open bidding process cannot be considered free of charge, since there are different costs for operators in the form of coverage and other requirements that the operator must meet.

On the other hand, in the auction process the government benefits obtained through radio spectrum concessions for mobile service providers are not limited to the amounts paid during the auction process. Revenue continues to be collected during the life of the concession directly and indirectly through tax payments, technology investments and the creation of direct and indirect jobs.

An important fact is that in Latin America, most spectrum assignments are made through auctions instead of open bidding events. This is an indication that the region's governments put free market processes and the revenue element before technical or social priorities.

Nevertheless, in recent years a shift has been observed regarding the governments' approaches towards awarding spectrum concessions. The division line between auctions and open bidding events is becoming blurred, as more and more markets include as a requirement for new licenses (or renewal of existing ones) the acceptance of coverage obligations and specification of downstream/upstream data rates that the technology to be deployed should theoretically offer, among other aspects [44].

Although great progress has been made in all countries, 5G requires large amounts of spectrum and not only in the so-called 5G frequencies which has not been allocated as of the time of this writing. In addition, it is necessary to develop a clear spectrum policy, aiming to participate in a globally and regionally harmonized spectrum.

3.2. Deployment of 5G Infrastructure

In Latin America, there exists currently a constant demand, from regulators to telecommunications operators, to increase the service coverage and quality of services. However, from a regulatory perspective, there exist a number of barriers for infrastructure deployment which limit the previous demand. One of them is the regulation of non-ionizing radiation emissions. Most regulations in the region incorporate the limits recommended by ICNIRP and WHO, and the responsibility of operators to carry out measurements and raise awareness among the population about the importance of connectivity and any risks (or lack thereof) to the health of citizens.

Another barrier is related to urban planning and the visual pollution generated by telecommunication antennas. In general, regulations on this topic are linked to local governments. However, sometimes there are national laws that allow a certain degree of predictability to operators, although in practice they are not respected by municipalities. Thus, when considering the deployment, mainly in historical and tourist areas, operators must take into consideration the different requirements on urban environment, environmental protection and safety of existing structures, as well as urban and natural preservation. All this with the purpose of improving infrastructure deployment times.

Undoubtedly, one of the most common barriers in the region to infrastructure deployment are the bureaucratic and complex processes resulting from the lack of standardized procedures at national and municipal levels. In order to avoid so many inconsistencies between national and municipal regulations, it is necessary that regulators promote public policies and national regulations that encourage the deployment of infrastructure and facilitate the private sector to invest in 5G networks. These regulations must favored streamlined approval processes, harmonizing and simplifying local permitting; defining reasonable requirements and efficient and transparent procedures; and establishing a maximum response time and automatic approval in case of non-responsive municipalities. In this way, any operational delays related to differences with particular municipalities regulations, and even those of the central government, can be avoided.

Another issue of the infrastructure deployment is the economic aspect linked to its high costs. These costs are related to a variety of factors, such as payments to government entities, which include those related to civil works and telecommunications equipment, inflation, and elevated fees collected by individual government authorities, like municipal permits for installation, construction, land use for antennas, air space allocation for antennas and towers, burying of cables or overhead wiring, and charges from other institutions such as the fire department for specific safety-related inspections.

Some of these costs can be lowered if regulations encourage infrastructure sharing of all types of networks on commercially and technically agreed terms that are beneficial to all the involved public and private agents. This could result in substantial cost savings, and the increased attractiveness of future investments - 5G deployment will require significant densification (including pico and nanocells), and infrastructure sharing may be the only way to overcome community resistance to dense deployments in urban areas.

Finally, we have the limitations related to radioelectric spectrum allocation. In this regard, we must point out that it is necessary for both the state and operators to develop a clear roadmap regarding the deployment of a fast and secure implementation of 5G. This includes granting of radioelectric spectrum in the medium and long term, which is an essential measure for adequate planning and deployment of future networks [30].

Regulatory barriers are often caused by regulatory rigidity, which cause regulations to lag behind technological changes, and greatly affects innovation. In order to mitigate these factors, several strategies have been proposed, one of them being the so-called regulatory sandbox. This is defined as a limited set of regulatory exemptions granted to a project or company to allow them to test new business models with reduced regulatory requirements. Generally, these include mechanisms aimed at guaranteeing general regulatory objectives being developed and administered on a case-by-case basis by regulators. These regulatory sandboxes seek to enable technological evolution and innovation by responding in a more agile manner based on a more flexible regulation.

4. Conclusion

As 5G deployment in Latin America is underway, progress between countries is uneven and depends not only on the plans of the operators but on political processes, availability of spectrum and other internal factors. One of them are public policies and regulations, which may hinder or foster successful deployments. In this sense, Latin American countries exhibit different levels of commitment in their policies and plans to promote the development of mobile connectivity and 5G systems, but according to the Digital Agendas of the countries in the region, it is expected that connectivity will continue growing in years to come.

The previous review and analysis on the public policy and regulation environment of 5G technology in Latin America led us to the following conclusions and recommendations: All countries must have clear strategic guidelines and a roadmap to build a robust 5G ecosystem, considering both public and private sectors. It is necessary to develop a clear spectrum policy since 5G requires large amounts of spectrum and, in many countries, it has not been allocated yet. The spectrum policy should aim at a global and regional harmonized spectrum, and granting this radioelectric spectrum in the medium and long term, which is necessary for an adequate planning and deployment of future networks.

Public policies and regulations should promote the deployment of 5G technology by considering adapting existing regulatory frameworks to provide operators with the flexibility for providing their services through traditional terrestrial infrastructure or new technologies, depending on the circumstances, and by reducing excessive administrative and financial obligations on operators.

Governments and their agencies must overcome bureaucratization by developing public policies and national regulations that encourage the deployment of infrastructure and facilitate the private sector investment. Regulations must favor efficient and transparent procedures - harmonizing and simplifying local permitting, defining reasonable requirements and, limiting response times.

Appropriate public policies are necessary to reduce the digital divide, and to promote the private sector interest in expanding its networks to reach larger portions of the population. High costs must be reduced, and public policies and regulation must help to this purpose by regulating payments, local government fees, costs of permits, and encouraging infrastructure sharing of all types of networks. One important feature of regulations must be flexibility, since actual rigidity becomes a barrier to deployment of advanced technology, innovation, and an adequate deployment of 5G networks.

Compliance with ethical standards

Disclosure of conflict of interest

All authors declare that there exists no conflict of interest in this work.

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