Spectrum Challenges for Beyond 5G: The case of Mexico

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***Abstract*— In recent years, there has been an increasing interest in satisfying the spectrum demand for communications beyond 5G (B5G) at a global level. However, in such a large and diverse country as Mexico, the implementation of B5G wireless networks towards 6G will require new spectrum regulation policies that also take into account the particular aspects of the country, such as population density, geographic diversity, as well as social and economic issues. This paper discusses the asymmetries of the urban and rural scenarios of mobile communications and examines their relationship to the current status of the spectrum for 5G mobile communications in Mexico. Then, it explores the spectrum-related challenges that must be overcome to attain ambitious goals beyond 5G technologies. Thus showing the necessity of novel spectrum allocation mechanisms that consider the myriad of scenarios and their different demands in similar countries, in order to satisfy the requirements of B5G wireless communications and networks.**

Keywords—spectrum regulation, spectrum measurements, spectrum challenges, beyond 5G

I. INTRODUCTION

The deployment of the fifth generation of mobile communications (5G) is just around the corner. It promises more network capacity to support a greater number of devices and users with higher data rates and lower delays [1]. However, since every day more and new kinds of devices and users are wirelessly connected, and new applications are emerging, wireless communications requirements are constantly increasing.

More importantly, derived from the challenges in terms of sustainable development that the world is facing today, it is expected that new requirements will emerge that should be addressed by future mobile communications (i.e., beyond 5G). Indeed, considering the impact that wireless communications have in the social and economic development of people, the Sustainable Development Goals (SDGs) recently introduced by the United Nations to deal with the inequality, poverty, climate change, amongst other humanitarian challenges, should be seriously considered when establishing the goals of future wireless communications [2]. Hence, beyond 5G (B5G) and future generations of mobile communications (6G) should promote access to information and communication technologies for all people, especially those living under vulnerable conditions, such as urban poor or rural inhabitants [2]. All this certainly challenges the availability and exploitation of spectrum resources. On the one hand, since B5G networks will demand wider radio bandwidths, the use of higher frequencies beyond the microwave range will be required; e.g., the use of terahertz frequency bands for ultra-fast networks (i.e., terabit-per-second-links), which implies new challenges, such as its standardization [3]. On the other hand, more sophisticated mechanisms (e.g., dynamic approaches [4]) to ensure the efficient utilization of the spectrum, including lower frequency bands (existing and new) utilized for large-area coverage networks, are needed to provide the required amount of this resource.

In this regard, analyzing the case of Mexico from the perspective of the spectrum for the B5G is interesting. At the beginning of the 2020 decade, it is a fact that, in a country as large and diverse as Mexico, not all people enjoy the benefits of wireless communications. This is, on the one hand, because they do not have sufficient financial resources to acquire either the service or smart devices; but, on the other hand, it is also due to the fact that numerous population centers still do not have wireless broadband connectivity. Reducing the problem of lack of connectivity in Mexico and the continuous search to increase the traffic capacity of mobile networks in order to meet the demand for future connectivity, has worried the telecommunications industry, the academy (universities and research centers) and the Federal Telecommunications Institute (IFT, for its name in Spanish), which is the regulatory body in Mexico. They have joined forces to seek alternatives, both regulatory and technological, that allow quick implementation and provide high transmission speeds with an acceptable quality of service, and especially identifying and releasing new bands for wireless services [5,6], besides looking to implement new disruptive technological paradigms such as dynamic access and spectrum sharing that allow a more efficient use of the radio spectrum.

In this paper, the general status of the spectrum in Mexico for rural and urban scenarios is presented to provide a current view on the availability of resources. Moreover, regulatory aspects of mobile communications in Mexico are addressed. Then, the challenges to meet the spectrum requirements for B5G communications are mentioned to visualize the general landscape that such diverse countries face towards the implementation of B5G.

II. The Urban and Rural Mobile Communications Scenarios in Mexico

Providing communication services to all people is a challenge, especially in a country of many societal and economical contrasts such as Mexico. With a total area of 1,964,375 Km^2, Mexico is the number thirteen in the largest countries in the world. Its population exceeds 120 million (distributed as shown in Fig. 1), where almost half of the inhabitants live in geographical locations of more than 100,000 people, while almost a quarter of inhabitants in the country (27,486,214 by 2015) live in geographical locations of less than 2,500 people. This means that there are millions of people living in big cities, such as Mexico City (one of the most populated cities in the world). At the same time, there are millions of people living in small communities, some of them are located far away from cities in zones that are hard to reach. For example, there are zones in the state of Oaxaca (one of the poorest states in the country, which is located in the south of Mexico and with 52.6% of its population living in small localities of less than 2,500 people), known for being isolated and unattended because of the difficult geographic environment and the lack of communication infrastructure [7]. All these facts represent barriers to satisfy the requirements of mobile communication services for everyone, given that the necessities for urban and rural areas are different. On the one hand, urban areas can be extremely populated, concentrating in small spaces a huge quantity of devices and users that requires high data rates wireless communications services. Indeed, as also seen in the map shown in Fig. 1, the highest number of mobile communications subscribers (137 for every 100 inhabitants) is in Mexico City, a small region compared with the size of the entire country [7]. In contrast, many rural areas are remotely distributed in a large geographical zone where the density of users is very small to ensure the investment in connecting those localities. In recent years, the government, academia, and private companies are making efforts to improve the quality of future mobile communications and extend the coverage in the country. Some of these remarkable efforts are mentioned in what follows.

1) Red Compartida Mayorista (wholesale shared network): This project emerged with the objective to create a wholesale shared network to offer voice and data broadband wireless services to other operators such as mobile network operators (MNOs), fixed network operators, and mobile virtual operators, which in turn will offer retail services to end-users, e.g., individuals, companies, public institutions, etc. The main goal of the shared network is to increase the coverage and the quality of mobile services in Mexico, offering the opportunity to provide telecommunication services in unattended zones in the country where there is no coverage of wireless services. For the project to offer services, 90 MHz in the 700 MHz frequency band was assigned through a public-private partnership in which the state, represented by the public entity PROMTEL, owns the rights of the assigned spectrum (i.e., the spectrum license) and leases it to a private company (Altán Redes), which is responsible for the design, deployment, operation, and service commercialization. By the end of 2019, the wholesale shared network was expected to provide coverage to 50% of the aggregate population [8].

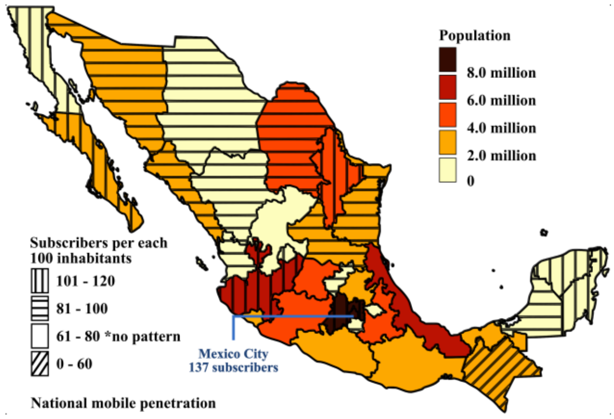

Fig. 1. Map of the population in Mexico (colors) and national mobile penetration in terms of the number of subscribers (patterns) [7].

2) Indigenous Communities Telecommunications: It arises to provide non-profit mobile communication services in indigenous communities that do not have coverage of commercial mobile communication networks. The essence of this project is that people in the community, accompained and trained by an operative team, implement, manage, and operate the network. To date, some communities in the state of Oaxaca own a mobile network of this kind.

Despite these efforts, there are still many challenges that need to be faced, especially in terms of spectrum including the following:

- the allocation of new frequency bands to cover the requirements of B5G networks.
- the efficient utilization of the allocated frequency bands to reduce the underutilized spectrum and increment the spectrum availability.
- the promotion of access to spectral resources for zones without mobile communications coverage.

In the next sections, the status of the spectrum for mobile communications in Mexico is reviewed and more details about the above challenges are presented.

III. Current Status of Spectrum Regulation for Mobile Communications in Mexico

A. Regulatory Framework

In Mexico, the IFT is the entity that supervises that the use and exploitation of the radioelectric spectrum are according to the regulation defined in the Federal Law of Telecommunications. Conforming to this law, the radioelectric spectrum that has been classified as determined spectrum contemplates all the frequency bands that can be used for the services specified in the Nacional Table of Frequency Allocations through concessions (or licenses), which can be for commercial (for-profit services), social (non-profit cultural, scientific, educational, or community services), private (private communication services and experimentation), or public (non-profit services for public entities) use. Concessions for commercial and private use (for private communication purposes) are granted through public tenders. Whilst the concessions for public, social or private (for experimental, diplomatic, or amateur radio purposes) use are granted through direct assignment, once satisfied the availability of frequencies and demonstrated the scope of the proposal. Moreover, licenses can be granted for nationwide coverage or determined by a specific geographic zone.

In principle, MNOs offer communication services in the frequency bands for which they own a concession that is obtained through a public tender. However, MNOs can acquire the rights for the use and exploitation of the spectrum by means of the secondary market. The secondary market arises from the necessity to improve the efficient utilization and exploitation of the radioelectric spectrum by allowing third parties to use the underutilized allocated spectrum. In Mexico, the regulatory framework allows the concessionaires that hold a license for the commercial or private use of the radioelectric spectrum to lease or to transfer its rights to other concessionaires, thus enabling a secondary market. Thus, in the primary market, the IFT bestows the rights for the usage and exploitation of the radioelectric spectrum through licenses. The rules in the primary market are established a priori by the regulator and contemplate the number of concessionaires, the amount of spectral resources assigned to each concessionaire and the usage that they must have; as well as their obligations and the services authorized to provide. On the other hand, the secondary market in Mexico is composed of the radioelectric spectrum leasing, frequency bands exchange, and rights cession; allowing other users to access the radioelectric spectrum without the necessity of a bidding process organized by the government [9]. These three concepts are defined as follows:

1) Spectrum leasing: A third party, authorized by the IFT, can be allowed to temporally use and exploit one or more previously allocated frequency bands, at a certain price. Only the frequency bands that have been allocated for commercial or private use can be leased. It is important to mention that this spectrum leasing does not imply the transfer of the frequency bands' license.

2) Exchange of frequencies: Allows the concessionaires to exchange between them an number of frequencies, prior authorization of the IFT. This frequency exchange can also be between a concessionaire and the IFT, for example, for bands reordering purposes.

3) Cession of the rights: Allows the concessionaires to transfer its rights and obligations, whether partial or total, to a third party, as long as the concessionaire meets the obligations that remain pending. This cession is only allowed for commercial or private use concessions, for which the IFT must authorize such transference.

B. The IMT spectrum in Mexico

Currently, a total of 584 MHz has been assigned for International Mobile Telecommunications (IMT) in Mexico, distributed in the frequency bands listed in Table I. The concessions for the commercial usage and exploitation of these frequency bands are owned by four main MNOs: AT&T, Altán Redes, Movistar and Telcel [5].

Furthermore, the actual spectrum occupancy of these bands of interest in the Mexican city of San Luis Potosi can be seen in Figures 2 to 4. They were obtained through a spectrum occupancy measurement campaign conducted by the authors in 2018 [10]. The measurements were taken in three different geographic locations (with a total duration of one week each) in the city of San Luis Potosi. Generally speaking, the figures show the underutilization of the IMT bands in an urban

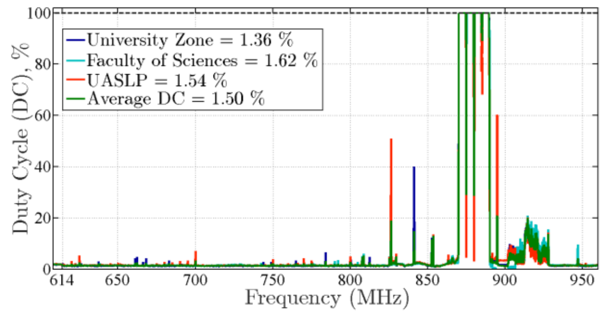

Fig. 2. Duty cycle from 608 MHz to 960 MHz of three different locations in the city of San Luis Potosi, Mexico.

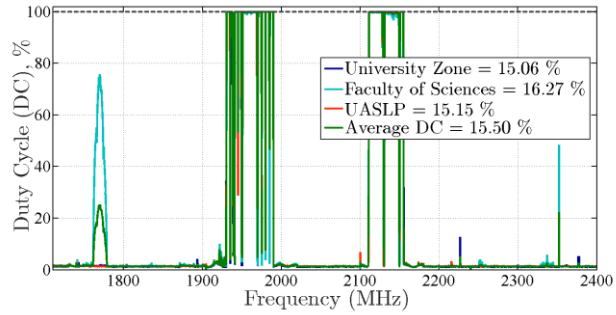

Fig. 3. Duty cycle from 1700 MHz to 2400 MHz of three different locations in the city of San Luis Potosi, Mexico.

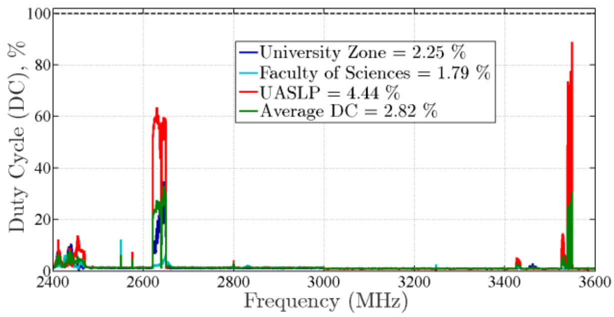

Fig. 4. Duty cycle from 2400 MHz to 3600 MHz of three different locations in the city of San Luis Potosi, Mexico.

scenario in Mexico, thus exhibiting the need to take action to comply with the requirements of B5G wireless communications. Indeed, the plan in the IFT is to allocate more frequency bands in the next few years to cope with the required spectrum for 5G. The radioelectric spectrum unit of the IFT has identified the following frequency bands as viable for 5G communications in Mexico [6]:

1) 600 MHz band (614 MHz – 698 MHz): Originally assigned for TV services, this band is now available for IMT, Mexico being the first country in Latin America in releasing it. By 2020, two blocks of 35 MHz will be available to public tender [6]. It can be seen in Fig. 2 that the average percentage of time that the frequency band was used (i.e., duty cycle), before its new allocation, was practically zero even though TV services were allowed in the band.

700 MHz Band (698 MHz – 806 MHz): To date, 4G services are offered in this frequency band, however, it is planned that 5G services will be offered by the wholesale shared network in the future. It can also be seen in Fig. 2 that the duty cycle

TABLE I. IMT SPECTRUM IN MEXICO [5]

Frequency Band	Number of MHz Assigned	Operator	Percentage or Bandwidth Awarded
700 MHz (698 MHz – 806 MHz)	90 MHz	Altán Redes[a]	90 MHz
800 MHz (806 MHz – 824 MHz / 851 MHz – 869 MHz)	22 MHz	AT&T	100%
850 MHz (824 MHz – 849 MHz / 869 MHz – 894 MHz)	42 MHz	AT&T	28.81%
		Telcel	49.73%
		Telefónica Movistar	21.46%
1900 MHz (1850 MHz – 1910 MHz / 1930 MHz –1990 MHz)	120 MHz	AT&T	30.04%
		Telcel	23.67%
		Telefónica Movistar	46.30%
Advanced Wireless Services (1710 MHz – 1780 MHz / 2110 MHZ – 2180 MHz)	130 MHZ	AT&T	38.46%
		Telcel	61.54%
2.5 GHz (2500 MHz – 2690 MHz)	180 MHz	AT&T	80 MHz
		Telcel	60 MHz[b]
		Telefónica Movistar	40 MHz

a. The operator is Altán Redes, although the license of this band belongs to PROMTEL.

b. Acquired through the secondary market to operate in some regions of the country.

of this band was zero at the time the spectrum measurements were taken indicating that the wholesale shared network was not yet in operation in the measurement area.

2) 2.5 GHz Band (2500 MHz – 2690 MHz): This band was previously assigned to microwave-restricted television services. However, this band was rescued by the IFT to tender it to mobile communication services. During the spectrum occupancy measurements campaign in 2018, this band was still in use by the previous dealers, which had tendered the segments 2500-2530 MHz (uplink) and 2620-2650 MHz (downlink). The average duty cycle measured in the downlink band was 23.11% for the three locations, as can be seen in Fig. 4. To date, 120 MHz of this band have been awarded, as seen in Table I, and some available portions in the segments 2500-2530/2620-2650 MHz will be available for a public tender in different regions of the country.

3) 3.5 GHz Band (3.3 GHz – 3.6 GHz): To date, 150 MHz in this frequency band has been awarded to three mobile network operators (each of them with a block of contiguous 50 MHz). In 2020, portions of the spectrum from 3300 MHz – 3400 MHz will be offered through a public tender [5]. The actual spectrum occupancy of this band can also be seen in Fig. 4.

4) 26 GHz (24.25 GHz – 27.5 GHz), 38 GHz (37 GHz – 40 GHz), 42 GHz (42 GHz – 43.5 GHz), 48 GHz (47.7 GHz – 48.2 GHz), and 51 GHz (50.4 GHz – 52.6 GHz): These bands were considered to be identified for IMT spectrum in the World Radiocommunication Conference 2019 (WRC-19) and the use of these bands for IMT is considered afterwards.

IV. SPECTRUM CHALLENGES TOWARD B5G IN MEXICO

The targets of B5G networks should not only satisfy the requirements of urban scenarios but also consider those of rural areas to promote access to wireless communication services for all. This represents a huge challenge, especially in terms of spectrum allocation, for a country with densely populated zones and millions of people living in rural areas distributed across a very large territory, as is the case in Mexico. Spectrum for B5G communications should include a variety of frequency bands for the different scenarios in the country and the currently allocated spectrum will not be enough to satisfy the demand. Thus, the allocation of new spectrum is necessary. Hence, higher frequency bands, e.g., those in the sub-THz and THz bands, will be needed to provide a wider radio bandwidth for ultra-high data rate transmissions. Additionally, access to lower frequency bands will be required for large area coverage. At the moment, only portions of the spectrum below 4 GHz have been assigned to MNOs for IMT, as seen in Table I, mostly through long-term national level concessions although there is no mobile communication coverage on the whole territory. In this sense, the challenge is the allocation of higher frequency bands with less coverage range, which indeed could be a matter of new spectrum strategies for B5G in Mexico, e.g., allowing spectrum sharing models or assigning them by states or smaller regions, e.g., to supply spectrum for specific sectors, such as industrial.

Besides the allocation of more frequency bands, since the demand for spectral resources grows every day as the number of wirelessly connected users and devices is increasing as well as advanced broadband services become increasingly popular, the efficient utilization of the spectrum is mandatory to improve its exploitation. In this sense, the new legislation has introduced new concepts to improve the use of the spectrum, such as i) secondary market, in which concessioners can be authorized by the IFT to lease their unused frequencies, ii) band sharing for public use dealers, and iii) secondary use of spectrum under concession (for determined spectrum) or non-concessions (free spectrum, protected spectrum, and reserved spectrum) schemes, were secondary services can operate without interfering primary services. However, spectrum measurement campaigns have shown, as those exhibited in Figs. 2 - 4, that there are still spectrum opportunities in the already assigned spectrum. Thus, more actions to avoid the misuse of this resource are needed, e.g., the implementation of dynamic approaches to share the spectrum and improve its efficient use. This imposes a challenge in terms of legislation since, at the moment, it does not contemplate more flexible scenarios for spectrum sharing. Moreover, an important challenge to overcome in the implementation of dynamic spectrum sharing approaches is that all the entities involved (mainly, the Regulator, the Concessionaires and those spectrum users benefiting from the sharing) must be considered and they must have sufficient incentives to be able to share the spectrum. For instance, economic, depending on the geographical area, amount of spectrum, and the time of use, or there may also be non-economic incentives such as reducing regulatory burden and expediting procedures for spectrum sharing.

In addition to the challenges described above, it is important to mention the one related to the allocation of frequencies to improve the coverage of mobile communications, especially in rural zones. Although the government has been working on the assignment of spectrum to improve the coverage of mobile communications, e.g., through the wholesale shared network, it is a fact that there are still numerous small communities that have not benefited from this project. On the other hand, Indigenous Communities Telecommunications have provided mobile services to some isolated localities, especially in the state of Oaxaca. The challenge to face here is the allocation and assignment of frequency bands to this purpose since spectrum concessions for commercial use are expensive. Also, these mobile communications networks are deployed for non-profit reasons and it is evident that indigenous communities cannot pay for these kinds of concessions. Although the IFT has assigned the first indigenous social-use concessions for mobile communication services based on the right of indigenous people to have its own media, more frequency bands for indigenous social-use and the implementation of more networks of this kind are needed to extend the mobile communications coverage in rural zones and to cope with the societal challenges imposed by the SDGs for beyond 5G.

V. Conclusions

The spectrum challenges towards the implementation of B5G mobile networks in Mexico have been addressed. The social and economic differences that exist in a large number of communities with a small number of inhabitants have postponed vast rural areas to benefit from wireless connectivity and mobile services up to this date. The current regulatory framework of mobile communications in the country has been reviewed from the perspective of primary and secondary markets. Moreover, the current IMT allocation has been inspected; identifying those frequency bands suitable for B5G. Furthermore, the actual spectrum occupancy of the IMT bands has been shown to highlight the need for new spectrum policies towards 6G in Mexico. Future investigations regarding the allocation of frequency bands for B5G in Mexico need to consider the myriad of wireless communications scenarios, thus opening the possibility to propose novel spectrum frameworks to overcome the current issues.

Acknowledgment

This work was partially supported by the Finish National Agency for Education under the Finish Government Scholarship Pool / KM-19-11064 and by the Mexican National Council for Science and Technology (CONACYT) under the grant number 633737/331743. The authors would also like to acknowledge funding from Academy of Finland in 6G Flagship (grant no. 318927)

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