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Spectrum Management

The Key Lever for Achieving Universality

Authors:
Antonio García Zaballos and Nathalia Foditsch

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Inter-American Development Bank

Cataloging-in-Publication data provided by the
Inter-American Development Bank
Felipe Herrera Library

García Zaballos, Antonio.
Spectrum management: the key lever for achieving universality / Antonio García Zaballos, Nathalia Foditsch.

p. cm. — (IDB Monograph ; 322)
Includes bibliographic references.

1. Wireless communication systems—Government policy—Latin America. 2. Broadband communication systems—Government policy—Latin America. 3. Spectrum analysis—Government policy—Latin America. I. Foditsch, Nathalia. II. Inter-American Development Bank. Capital Markets and Financial Institutions Division. III. Title. IV. Series.
IDB-MG-322

Publication Code: IDB-MG-323
JEL Codes: D47, L1, L5, L88, L96, R5
Keywords: spectrum, telecommunications, public policy, regulatory policy, competition

Inter-American Development Bank
1300 New York Avenue, N.W.
Washington, D.C. 20577
www.iadb.org

The Institutions for Development Sector was responsible for the production of this publication.

Production Editor: Sarah Schineller (A&S Information Specialists, LLC)
Editor: Margie Peters-Fawcett
Design: Word Express, Inc.
Proofreaders: Audrey Esquivel and Steven Nelson (TriLexica Editorial)

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Preface and Acknowledgments

Wireless broadband has been a key lever for digital inclusion in developed and developing countries. Penetration of wireless Internet and the economic and social benefits deriving from it have been increasing. Ensuring that citizens in Latin American and Caribbean (LAC) countries have access to universal and affordable broadband will lead to accelerated development throughout the region.

Examples of the benefits of wireless broadband include access to educational content, health services, and e-governance solutions. Broadband also affects how people connect to each other, how they engage to democratic processes, and how they read their daily news. These factors have generated an increase in data traffic and demand at an unprecedented rate. Efficient spectrum management is mandatory to meet these challenges and bridge the digital divide.

This study examines the experiences of spectrum management in four countries with a high percentage of wireless broadband penetration (Australia, Germany, the United Kingdom, and the United States). What actions have they undertaken to achieve an efficient management of spectrum? How have they have shifted toward more modern management approaches? These answers can be used as a benchmark for good regulatory governance.

Governance is a key issue in decisions related to spectrum management in the LAC region. Sound policy and regulatory frameworks should be able to address issues such as the allocation of the digital dividend bands, the refarming of frequencies, the availability of unlicensed spectrum, and the adoption of new technologies. These decisions will ultimately have an impact on the quality and cost of future broadband services. The occasion for this publication is opportune, and the knowledge gained from it will ultimately contribute to a proactive agenda by the decision makers in the region.

In closing, we would like to extend our gratitude to Darrin Mylet, Sidney Nakao Nakahodo, Konstantinos Stylianou, and Anne-Lise Thieblemont for their invaluable contributions to this publication.

Antonio Zaballos
Nathalia Foditsch

Executive Summary

The Inter-American Development Bank (IDB) is committed to the development of countries in the Latin America and the Caribbean (LAC) region. The IDB currently supports the efforts of countries to close the digital divide and achieve universal access to broadband by promoting more affordable services. For a country's development, it is crucial that the electromagnetic spectrum be the finite resource behind the revolutionary increase in Internet access. This study aims to inform policymakers, practitioners, and civil society about the current status and future trends of spectrum management.

While spectrum is a scarce resource, the rate of increase in data traffic and demand is exponential. "Will we have sufficient spectrum to meet future demand?" This is a question posed by the industry. "Will we be able to pay a lower price for more data?" This is a concern to the consumer. While the answers are yet unknown, it is clear that network capacity and the efficient management of spectrum are major challenges that are the responsibility of governments. Opportunities are now available to ensure efficient management of spectrum. These opportunities will enable countries to provide more affordable Internet access and allow them to progress towards the goal of universal access. These two objectives are the key pillars of national public policy relating to the development of broadband.

The timing of this study is pivotal to the many policy and regulatory decisions that are currently under way in various regions. Countries are considering the following: (i) to auction their digital dividend bands, (ii) which band plans to use, (iii) whether or not to refarm their frequencies, and (iv) how much unlicensed spectrum should be made available and under what circumstances. Their decisions, ultimately, will have an impact on the quality and price of future broadband services.

The first part of this study provides the rationale for the constant increase in demand for spectrum. How the wireless market has been evolving is then discussed, including the new technologies responsible for its evolution, namely Long-Term Evolution (LTE) and LTE-Advanced; small cells; Dynamic Spectrum Access (DSA); and Wi-Fi.

The second part of the analysis addresses the main issues involved in managing spectrum, from frameworks to how these have been evolving throughout the years. In terms of the spectrum debate, the harmonization of band plans, spectrum caps, and the neutrality of service and technology are discussed.

The third section explains the new spectrum trends relating to (i) infrastructure sharing, which may take different forms, ranging from the sharing of site, tower, and radio access networks to network roaming and core network sharing; and (ii) spectrum sharing, which can be licensed or unlicensed. The latter reflects licensed spectrum that can be shared, given that the rights can be traded on the market. In the case of unlicensed spectrum, there are new technologies to enable sharing. The main advantages of each is discussed, as well as their potential to democratize access to broadband services.

An analysis of analogue switchoff and digital switchover is included in the fourth section of this study. This relates to the transition from analogue to digital broadcasting, resulting in the freeing up a large amount of frequencies. Many countries are now selecting what frequencies should be assigned and which of those should be used.

A comparative analysis of current issues in spectrum management in four reference countries is made in the fifth section of the study. These include Australia, Germany, the UK, and the United States, which have undertaken different policy and regulatory spectrum measures, and whose experience can be useful to other countries. The following criteria relate to each of these four countries: (i) regulatory and institutional framework; (ii) institutional, policy, and regulatory frameworks; (iii) availability of spectrum; (iv) innovative policies that have been implemented or are being considered; and (v) main aspects of the analogue switchoff process. From this analysis, the key findings and lessons learned will be determined.

The sixth segment of the document will include a systematic analysis of the LAC region by applying these five criteria. The comparison between the experience of the reference countries and that of the LAC region will determine the main gaps that exist relating to spectrum management. In addition, issues such as spectrum band plan alternatives for switchover, the approach to spectrum caps, and the unlicensed use of spectrum are addressed.

Finally, the Spectrum Management Index (SMI) is discussed. This is an innovative index that demonstrates the ability of selected LAC countries to create opportunities to improve the management of spectrum, thus expanding Internet access through four pillars: (i) Government Institutions, (ii) Policy and Regulation, (iii) Infrastructure, and (iv) Competitiveness and Innovation. Each of these pillars comprises a different set of indicators.

1

Introduction

The Digital Divide, which is the disparate access to and the use and/or knowledge of information and communication technologies (ICT) between groups, is one of the main factors underlying social inequality in the twenty-first century. As the development of technology exponentially grows, the same may occur in terms of access to ICT knowledge, especially in those regions that suffer from poor infrastructure.

The benefits from accessing ICTs can help transform people's lives in numerous ways, such as improving access to health and education. Fostering access to broadband, therefore, is a key to achieving the Millennium Development Goals (MDGs) of the United Nations (UN). The UN has stated "by end of 2013, an estimated 2.7 billion people will be using the Internet, which corresponds to 39 percent of the world's population. Growing infrastructure in information and communications technology, including mobile wireless broadband networks, along with social media, innovative applications and falling prices for services continue to drive Internet uptake in all regions of the world" (UN, 2013a). MDG 8 commits, among its objectives and in cooperation with the private sector, to make available the benefits of new technologies to all (UN, 2013b).

Fast and reliable Internet access promotes business opportunities, empowers citizens, and creates space for social interaction. Its benefits are nonlinear and are growing exponentially as the level of penetration increases (Galperin, 2012). The Internet of Things, a concept that is still evolving, whereby "the virtual world of information technology integrates seamlessly with the real world of things" (Uckelmann, Harrison, and Michahelles, 2011) is an example of the potential to maximize the Internet's positive impact on society. For this to occur, a critical mass of broadband penetration and its adoption in households and businesses is essential.

Broadband Internet penetration can be measured as the sum of fixed and mobile broadband subscriptions within a country. Mobile broadband penetration, however, is still low in most developing countries—at an average of 8 percent versus 51.3 percent in developed countries (ITU, 2011).

Fixed line broadband has been the Internet enabler in developed markets, but is quite costly, especially in the context of developing markets. Mobile infrastructure is less expensive as it requires lower capital expenditure. Mobile access is not only the fastest growing modality of high speed Internet; it may also produce a higher impact on development. While mobile broadband was once viewed as a complement to an existing broadband service, some studies indicate that the number of households that use mobile broadband as their only connection is on the increase (Ofcom, 2010). Additionally, the rate for mobile phone penetration is above 100 percent in most LAC countries and it is the fastest growing modality of high speed Internet. These factors are thus driving the need to accelerate the rate of penetration and usage of mobile broadband services in the region.

The electromagnetic spectrum is the finite resource for revolutionary Internet access increase and it will stimulate the Internet of Things. As previously mentioned, data traffic and demand are increasing at an unprecedented rate and Internet usage has become so popular that the industry fears a spectrum crunch in the upcoming years. In order to meet the growing need for network capacity, countries should ensure that electromagnetic spectrum meets the high demand and that it is used in the most efficient way. Because of its importance, effective management of the spectrum is critical to the efforts of government to expand Internet access to its population. The development of new technologies and the transition from analogue to digital broadcasting—which affect the spectrum—will change the way countries will view their roles expanding Internet access through efficient management.

Two objectives of national public policy in terms of broadband development are the opportunities for more affordable Internet access and the progress towards universal access. Universal access and spectrum management are closely related, since mobile broadband services cost considerably less than fixed broadband services in developing countries: 8.8 percent of gross national income (GNI) a month per capita for 1 gigabyte (G) of data relating to a postpaid, computer-based mobile broadband plan compared to 30.1 percent of GNI a month per capita for a postpaid fixed broadband plan with 1G of data (ITU, 2013). Since the mobile broadband resource is finite, good spectrum management is essential for prices to be affordable to all people.

Latin American and Caribbean countries have varying views of broadband access, usage, and adoption. Despite the disparities between and within countries, the region faces a significant increase in wireless penetration. National broadband plans are now being developed and many of them include guidelines on how the electromagnetic spectrum should be managed in the future, as well as goals in terms of access, speed, and coverage.

The debate on spectrum management is timely, since relative policy and regulatory decisions are currently under way in the region. The goals of each country may differ in terms of the efficient usage of spectrum, rapid introduction of new wireless technologies, protection of public services and social welfare, minimization of interference, solutions for technical coexistence issues, revenue generation and, as previously mentioned, universal access.

The analysis in this publication has sought similarities between the four referenced countries on some of the key questions of spectrum management. They include how these countries have managed to achieve more efficient management of spectrum and how they have shifted towards more modern and market-based approaches in contrast to that of a command-and-control basis. The knowledge gained from this study can contribute to a proactive agenda by LAC governments, as well as to the decision makers in the region.

2

Market Evolution and Demands

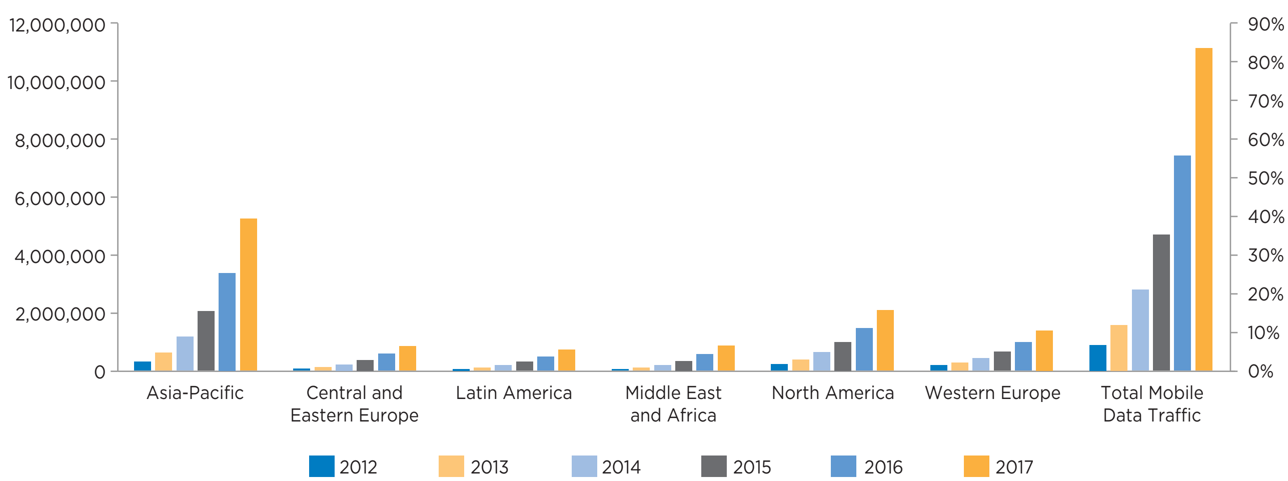
2.1. Traffic and Speed Demands

The need for spectrum has grown at a fast pace around the world.[1] In 2012, mobile data traffic was nearly 12 times the volume of the entire global Internet in 2000 (Cisco, 2013). Last year, it reached 885 petabytes a month, equivalent to more than 29 times the content found in all academic research libraries per diem in the United States—an increase of 70 percent compared to 2011 (Caltech, 2013). Figure 1 illustrates this fast increase in traffic, as well as an estimate for the next few years.

Mobile connection speeds were twice as high in 2012 compared to 2011, with an average rate of 526 Kilobits (Kbps) a second (Cisco, 2013) (see Figure 2). While fixed Internet is anticipated to grow at a compound annual growth rate of 21 percent by 2017, mobile data is estimated to increase by 62 percent by the same year (Cisco, 2013).

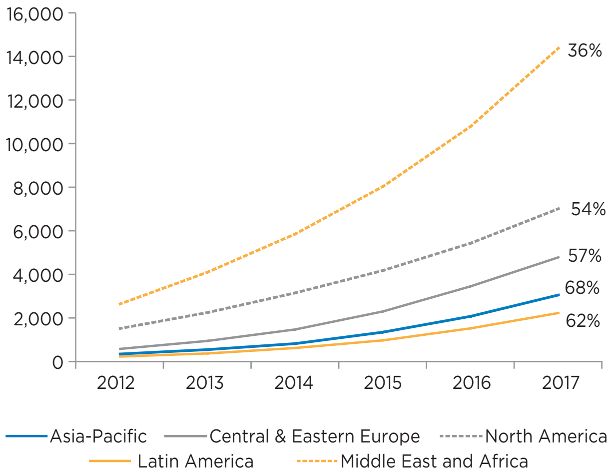
[1] The concepts of wireless and mobile technology are linked; wireless is the enabler for mobile connectivity, but does not only encompass mobile connectivity, as described further on this document.

FIGURE 1. Global Mobile Data Traffic, 2012–17



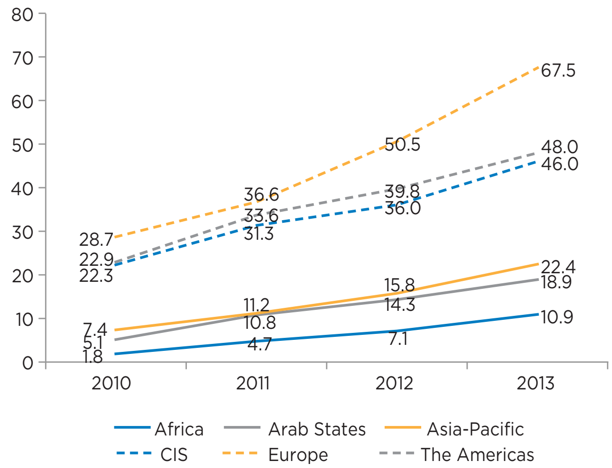
Source: Authors; data from Cisco (2013).

FIGURE 2. Projected Average Mobile Network Connection Speeds by Region (in Kbps)



Source: Authors; data from Cisco (2013).

FIGURE 3. Active Mobile Broadband Subscriptions per 100 Inhabitants



Source: Authors; data from the ITU's ICT Indicators database.

The escalating rise in the use of smartphone and other wireless technologies has influenced the demand for wireless broadband Internet. As previously mentioned, the Internet of Things will drive the critical mass of broadband penetration and adoption (Uckelmann, Harrison, and Michahelles, 2011). It is estimated that by 2017, there will be 2.5 networked devices per capita, globally, and 54 percent of these will be mobile-connected (Cisco, 2012). Table 1 shows the global actual and anticipated increase in mobile broadband subscriptions in the period 2012–17.

Figure 3 illustrates the rise in active mobile broadband subscriptions per 100 inhabitants in different regions of the world. Despite differences between regions, a consistent positive trend can be determined for each.

In developing countries, where fixed-line broadband infrastructure is scarce or nonexistent, wireless broadband may be a more cost-effective substitute, since the need for fiber-optic lines for fixed-line broadband infrastructure requires higher levels of capital expenditure (CAPEX) (McDonough, 2012) compared to wireless infrastructure. This is especially so when low frequencies are used, as they have a higher spectral efficiency, thus allowing for more capacity to deploy fewer base stations. This would incentivize businesses to place infrastructure in underserved areas. Wireless access would then become not only the fastest

TABLE 1. Worldwide Smartphone Usage and Penetration, 2012–17

	2012	2013	2014	2015	2016	2017
Smartphone users (billions)	1.13	1.43	1.75	2.03	2.28	2.50
% change	68.4%	27.1%	22.5%	15.9%	12.3%	9.7%
Mobile phone users (%)	27.6%	33.0%	38.5%	42.6%	46.1%	48.8%
% of population	16.0%	20.2%	24.4%	28.0%	31.2%	33.8%

Source: eMarketer (2014).

Box 1. Difference in Spectral Efficiency among Bands

Different bands have varying propagation characteristics that make the spectrum more or less appropriate for mobile broadband use. Low frequency spectrum allows a high level of coverage with a small fraction of the number of sites deployed and, therefore, requiring much less CAPEX. These technical differences among the bands create substantial variations in terms of deployment needs and costs. With 800 MHz, for example, only 2,000 sites are necessary to provide certain coverage, whereas with 1,800 MHz, this number will increase to 10,000 sites. With 2.6 GHz, the number rises to as high as 20,000 sites (Cramton, 2012).

There is debate on whether fixed broadband and mobile services are complementary or substitute each other. Studies already indicate, however, that the number of households that use mobile broadband as their only connection is increasing (Ofcom, 2010).

growing method for high speed Internet; it may also have a higher impact on development.

2.2. Wireless Market Evolution in the Future

Wireless access systems are defined as broadband radio systems. According to the International Telecommunications Union (ITU) (ITU, 2001), wireless access refers to "end-user radio connections to core public and private networks." The types of wireless access can be classified as:

- **Fixed wireless access:** Wireless access application in which the location of the end-user termination and the network access point to be connected to the end-user are fixed.
- **Mobile wireless access:** Wireless access application in which the location of the end-user termination is mobile.
- **Nomadic wireless access:** Wireless access application in which the location of the end-user termination may be in different places, but it must be stationary while in use.

The Radio Access Network (RAN) is an important piece of the network infrastructure as it provides wireless connectivity to mobile devices in a wide area. It also resolves the issue of calculating how best to use and manage limited spectrum to achieve connectivity. Traditionally, RAN architecture has a base station that connects to a fixed set of antennae that cover a given area and can only handle uplink and downlink signals on the surface it covers.

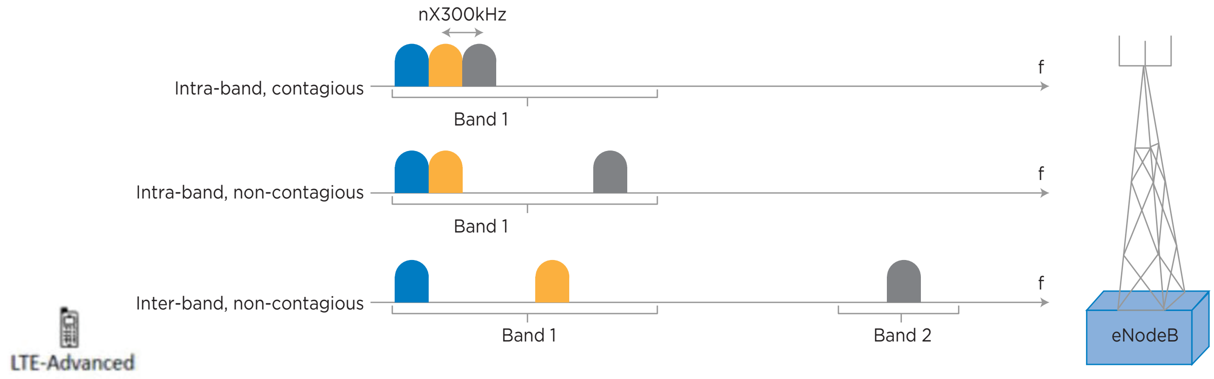
To expand RAN capacity, it is necessary to build more base stations, while upgrading the system can require changing the stations, both of which are costly, thus increasing CAPEX and operational expenditures (OPEX). To optimize the performance of existing infrastructure, various technical solutions are now available. These are described below.

2.2.1. *Long-Term Evolution/LTE-Advanced*

LTE is one of the technologies that enable the optimization of network performance. It is a standard 4G wireless broadband that is part of the Global System for Mobile Communications, originally the *Groupe Spécial Mobile* upgrade. The technology offers higher data rates and shorter latency times when compared to previous methods. It also provides operators with the capacity and speed to handle a rapid increase in data traffic. The first commercial LTE networks were launched in December 2009 and more than 60 percent of operators in the LAC region were expected to launch LTE by 2014 (Rojas, 2012).

Frequency Division Duplexing (FDD) and Time Division Duplexing (TDD) are two versions of LTE

FIGURE 4. Carrier Aggregation: Intra-Band and Inter-Band Aggregation Alternatives



Source: 3GPP (2013).

technology. FDD uses symmetric paired blocks for uplink and downlink frequencies and it is the most common band plan in the United States. TDD uplink and downlink frequencies occur in blocks that are segmented by time, and TDD is more suitable for asymmetrical broadband (Musey, 2013).

LTE-A is the next step in the LTE evolution, which allow for downlink and uplink rates of 3G and 1.5 gigabits, respectively—up to 10 to 20 times faster than the original LTE. The main new functionalities are (i) carrier aggregation, through which bandwidth is increased by aggregating spectrum; (ii) spatial multiplexing, where multiple antennae are used; and (iii) Relay Nodes which are low-power base stations that can improve the efficiency of macro and small cells (3GPP, 2013). In short, carrier aggregation is used in LTE-A in order to increase the bandwidth and efficiency.

The best way to arrange aggregation would be to use contiguous component carriers within the same operating frequency band, known as intra-band contiguous. Allocations are not always contiguous, however. For noncontiguous allocation, it can be either intra-band or inter-band. Intra-band takes place when component carriers belong to the same operating frequency band, but have a gap, or gaps, in between. Inter-band takes place when the component carriers belong to different

Box 2. Supplemental Downlink

Carrier aggregation has made new uses of spectrum possible, such as the Supplemental Downlink (SDL), currently under study by the 3rd Generation Partnership Project (3GPP). It will allow operators to make the most of fragmented spectrum holdings and unused parts of the spectrum, as described in the box below.

The European Union's standards entity, the European Conference for Postal and Telecommunications Administrations (CEPT), has approved the use of this mobile satellite band for two-way mobile use, reserving the L-band and maintaining it specifically for SDL. It is also under analysis before the Federal Communication Commission (FCC) in the United States, which describes it as a "voluntary industry solution that would resolve the lack of interoperability in this band while allowing flexibility in responding to evolving consumer needs and dynamic and fast-paced technological developments" (FCC, 2013a). The technology is expected to enable consumers to enjoy the benefits of greater competition and promote widespread deployment of mobile broadband services, especially in rural areas. The standards for this technology are now under study by 3GPP.

operating frequency bands (3GPP, 2013). Figure 4 illustrates the intra-band and inter-band aggregation alternatives.

2.2.2. *Small Cells*

Between 50 and 60 percent of mobile data traffic is concentrated in 10–15 percent of the global geographic area. In addition, between 2 percent and 3 percent of users generate almost half of the total volume (Dhawan, Mukhopadhyay, and Urrutia-Valdés, 2013). This is the basis for recent developments regarding small cells, which relate to traffic within smaller geographic areas, reducing the CAPEX of operators.

According to the Small Cells Forum, it is "an umbrella term for operator-controlled, low-powered radio access nodes, including those that operate in licensed spectrum and unlicensed carrier-grade Wi-Fi. Small cells typically have a range from 10 metres to several hundred metres".[2] They are classified as femtocells, picocells, metrocells, and microcells (Small Cells Forum, 2013). Small cell units tend to be less powerful, but have the size and weight advantage compared to macro cell equipment. They can be used as a standalone application or with macro-coverage, used indoors and outdoors, and support ideal and nonideal backhauls, ensuring greater flexibility (Nakamura et al., 2013).

2.2.3. *Dynamic Spectrum Access*

DSA is a basic concept underlying the current spectrum sharing trends—possibly due to the development of new technologies, such as Software Defined Radios (SDR) and Cognitive Radio Technologies,[3] which allow for "opportunistic spectrum access" when frequencies are used without causing harm to the incumbent operating services in the occupied television (TV) channels. One example of DSA technology is the TV White Spaces (TVWS)—parts of the spectrum purposely left unused in order to avoid interference.

These technologies have the potential to support various uses and are currently being researched in depth. They are viewed as disruptive, however, since they enable the prompt launch of new wireless technologies and services without setting aside any new spectrum to assist the industry to meet traffic demand.

By unitizing the spectrum in time and/or geography, Cognitive Radio Technologies allows for a more dynamic use of spectrum, detecting frequencies that are not being used, as well as adjusting to those frequency bands that are available. The main concern with regard to DSA, however, is the potential for interference, which could hamper the quality of service (QoS). Moreover, there are concerns about the reliability of service due to competition for the same frequencies (Altamimi, Weiss, and McHenry, 2013). Nonetheless, such challenges may be tackled as the technology evolves.

The advances described above will allow for more efficient use of spectrum and, the faster these are adopted, the sooner operators and wireless broadband users will benefit. At the same time, it is crucial to channel efforts for good spectrum management and, for this, it is important to establish a regulatory framework in anticipation of the launching of such technologies by the industry.

[2] See Small Cell Forum: http://www.smallcellforum.org/aboutsmallcells-small-cells-what-is-a-small-cell.

[3] CRs and SDRs are terms that are often used interchangeably. In this study, we will follow that practice, but the main differences are that "CRs distribute decision making functionality into the radio access network, and ultimately to the handsets allowing them to make operational decisions, including such functionality as sensing the RF environment for spectrum white spaces, controlling frequency selection, power, or other operating parameters/modes. In contrast, SDRs are an implementation technology, implementing in software what previously would have been implemented in radio hardware. As such, SDRs are a key enabling technology for CRs" (Weiss et al., 2012).

3

Spectrum Management

3.1. The Role of Government

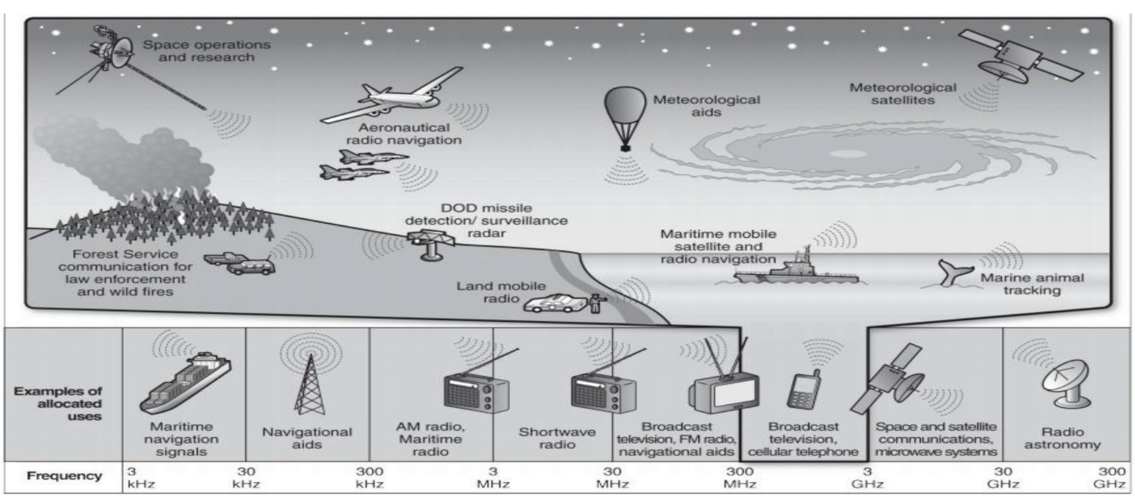
As explained previously, spectrum management is crucial for the development of wireless broadband. The following relates to the role of government and how the approach to management has been changing over time.

Spectrum is a finite resource and must be administered accordingly. As Stine and Portigal (2004) describe, the ultimate goal of spectrum management is "to prevent users from harmful interference while allowing the optimum use of the spectrum." Economic factors are also important to maximize the net social benefit of spectrum use.

Spectrum is a resource used for several of the technologies surrounding us, such as broadcast TV, radio, cellular telephone, satellite communications and, most recently, wireless Internet. Figure 5 illustrates an example of how spectrum has been utilized to date.

These various uses are possible due to spectrum management, which involves frequency allocation, allotment, and assignment, as well as planning, authorizing, engineering, and monitoring their use as established in the National Tables

FIGURE 5. Examples of Spectrum Allocation



Source: GAO (2011).

Box 3. Allocations, Allotments, and Assignments

Spectrum management is viewed as a system of frequency allocations, allotments, and assignments. The entire spectrum is divided into frequency bands, known as allocations. These allocations specify the permitted use of frequencies within the band. The uses are referred to as radio services (e.g., fixed, mobile, broadcasting, radiolocation, amateur, satellite, radio astronomy, etc.).

The allocations may then be further subdivided into allotments. Frequency channels are allotted within the band, according to an agreed plan, for use by one or more administrations in one or more identified countries or geographic areas and under specific conditions. Allotments attempt to prevent interference among users that are managed by different administrations. One example is the allotment of channels in plans to avoid interference along borders of countries that are members of the plan.

Finally, an assignment is a grant of authority or license to a specific user for a band of frequencies or a radio frequency channel under specific conditions. Assignments are the final subdivision of spectrum.

Source: Stine and Portigal (2014).

of Frequency Allocations for each country. Box 3 explains the system of frequency allocations, allotments, and assignments.

The ITU is the specialized agency of the United Nations that is responsible for issues relating to information and communication technology. Its framework voluntarily guides national regulators on the enforcement of norms relating to spectrum management. The Inter-American Telecommunication Commission (CITEL), Caribbean Telecommunications Union (CTU), and Association of National Telecommunication Organizations also play an important coordinating role in the LAC region. Despite the role these organizations have in terms of general management, each country maintains authority over its own spectrum and is responsible for establishing the legal, policy, and regulatory frameworks that relate to it.

Governments play a pivotal role in reconciling short-term priorities with long-term goals. National goals for spectrum management include the following:

- Efficient use of spectrum (e.g., avoidance of spectrum hoarding).
- Rapid introduction of new technologies (e.g., introduction of more efficient wireless technologies that utilize a smaller amount of spectrum and provide improved service).
- Protection of public service and social welfare (e.g., use of spectrum for public purposes, such as communications for forest service communication).
- Minimization of interference and the solution for coexistence issues (e.g., authorization of devices that employ digital signal processing that coexist without interference).
- Generation of revenue (e.g., revenue from auctions used to balance national accounts).
- Promotion of universal access (e.g., ensuring that the underserved areas have access to broadband).

3.2. Management Frameworks

Spectrum management frameworks have been traditionally classified according to three models: command-and-control, licensed, and unlicensed. The command-and-control model establishes a top-down approach, where the government has power to designate the use, technology, and users of the spectrum in the interest of the public. The licensed model is a market-based approach, whereby licensees follow the rules established by regulators. Under the unlicensed model, spectrum is available to all with no limitation.

A range of products and technologies has changed in ways that could not possibly have been foreseen. For this reason, there is no one-size-fits-all solution and governments should avoid the powerful vested interest of substituting rules that will make necessary changes in the future difficult to implement. A brief description of each of the command-and-control, licensed, and unlicensed models is outlined in Box 4.

Box 4. Main Spectrum Management Frameworks

Command-and-control (authoritative): With this model, government is able to designate the use of spectrum, the technology, and its users. The government becomes the central authority for spectrum allocation, assignment, and usage decisions, and determines the use of specific portions of the spectrum, which players will have access to them, for how long, and which physical layer technologies can be used. It neither ensures whether the spectrum is efficient nor—as is often the case—whether the allotments are used at all. Underutilization of spectrum is, therefore, one of the main challenges under this model.

Licensed (property rights): This approach provides users the exclusive right to use spectrum, in addition to the right via administrative (comparative selection), market mechanisms (auction), or the right to trade spectrum in secondary markets. It may be suitable when scarcity is high and transaction costs, associated with access rights, are low (OECD, 2007), but it can also lead to spectrum underutilization.

Unlicensed (commons approach/open spectrum): Unlicensed spectrum is a regime under which the use of spectrum is open to anyone and interference is avoided through the use of technologies that allow for this sharing model. This model is particularly useful for applications in which the transaction costs of licensing users would far exceed the value of the small quantity of spectrum that they consume (Matheson and Morris, 2012). This regime encourages innovation without permission—reducing barriers to entry and enabling experimentation.

3.2.1. *Command-and-Control Model*

The command-and-control model is justified on the grounds that spectrum is a public resource that requires government to act in the public interest. Despite being more transparent, however, command-and-control is associated with higher costs and more delays because of the regulatory processes and rules to protect public authorities from regulatory capture and which are designed to enhance the quality of shared information (Lehr and Crowcroft, 2005).

This model is arguably considered to be inadequate, as governments may lack the expertise to make informed decisions (Lehr and Crowcroft, 2005). The inefficiency could slow down innovation due to the maintenance of old technologies (OECD, 2007). This approach also leads to the underutilization of spectrum by the spectrum holder, since the dominant market players may be inclined not to make use of it.

Example:

- This is the default method of government to utilize spectrum to accomplish its tasks, such as using radar systems, voice communication systems, and aeronautical radio navigation.

3.2.2. *Licensed Model*

As already described, the key purpose for managing spectrum is to increase the social gains from its use while avoiding interference between different users. The way in which this optimal management has been viewed, however, has changed in the past years as countries transition from more constrained to more market-based models. Since the time that Coase (1959) advocated that spectrum rights should be sold to ensure efficient use through market allocation, licenses have been used in order to prevent radio interference.

Under a Coasian bargaining process, users may have exclusive rights to use spectrum, plus rights through administrative (comparative selection) or market mechanisms (auctions). The key to this model is that it can result in spectrum scarcity and low transaction costs associated with access rights (OECD, 2007). Spectrum holes are also a potential problem in this model. These relate to a band of frequencies assigned to a primary (licensed) user, although the band may not be utilized by that user at a particular time and specific geographic location (Haykin, 2012). This underutilization of spectrum is an issue in various countries, as explained in Box 5.

Flexible-use spectrum rights could accommodate competitive new services and allow for more efficient market allocations of rights across exclusive rights holders. The property rights model makes possible the creation of secondary spectrum markets, in which license holders can trade their property rights, thus helping to advance economic welfare. Nevertheless, such secondary markets are not yet a reality in many countries.

Licensing schemes vary depending on the country. Most times, however, the right to a license comes with obligations such as coverage requirements. This reflects an important step towards achieving universal service.

Example:

- The Authorized Shared Access/Licensed Shared Access (ASA/LSA) is an example of a framework that is currently being actively discussed in international forums. It proposes a sharing scheme in which dedicated spectrum should be assigned by either the incumbent user or by the licensee in any given place at

Box 5. Spectrum Underutilization

Spectrum is, by definition, a scarce resource. Such scarcity is frequently aggravated by the abuse of the market power of spectrum holders, such as the intentional underutilization of the spectrum. Spectrum hoarding makes the markets significantly less accessible to new entrants; spectrum holders thwart competition among providers. The traditional command-and-control model, whereby the government decides the purpose, the technologies, and which frequencies can be used, generally does not ensure that the spectrum is efficiently employed, if at all. Under the license model, spectrum holders may not be motivated to make use of spectrum, especially when they are in a dominant market position.

Spectrum measurement studies, undertaken some years ago in Manhattan, New York, and Washington D.C., showed that less than 20 percent of the frequency bands below 3 gigahertz (GHz) were employed over the course of a business day, and the highest occupancy rate below 3 GHz was only 13 percent in New York City and an average 6 percent across various locations included in the studies. The underutilization of spectrum has not always been easily measured, but new technologies have made it possible to create an inventory of underused frequencies (Calabrese, 2006). Inventories provide "an opportunity for identifying spectrum supply, assessing its demand and consulting with all stakeholders on the different proposals. This could assist, together with technical studies, in identifying candidate bands for sharing and assessing the feasibility of deployment scenarios for new entrants" (OECD, 2014).

Another mechanism that has been discussed in various countries is the use-it-or-lose-it provision, whereby those license holders who do not make use of the spectrum licenses lose their rights. In Jamaica, the ICT Policy expressly includes such provision within its strategies.

any given time. More information on ASA/LSA is provided below.

3.2.3. *Unlicensed Model*

Advocates of the open spectrum approach argue that such a model would create a more innovative and cost-effective ecosystem due to the lower costs associated with executing asset management solutions. It would entitle users, who comply with established technical limits and equipment certification, to access the spectrum and become more competitive as the barriers to access are removed.

Proponents of unlicensed spectrum will argue that innovation can be harnessed—as the experience of the past two decades suggests, in that "however scrappy and uncertain Internet innovations may seem at first by comparison to the highly-engineered models of the telcos, these innovations quickly catch up and surpass their competitors" (Benkler, 2012). This model, however, is subject to what is referred to as tragedy of commons, whereby individuals in a group will act in their self-interest while sharing a common resource. This results in the over-exploitation and degradation of finite resources—contrary to the long-term best interests of the group. Interference is part of this commons problem, although technologies are evolving towards devices that will employ digital signal processing and coexist without interference. Moreover, despite the advantages, the coverage obligations that focus on universality do not apply to this model.

Examples:

- TV White Spaces: Due to new Cognitive Radio Technologies, it is possible to access parts of the spectrum purposively left unused to provide Internet. The United States has already created a regulatory framework for the use of TVWS, and other countries are considering doing the same.
- Wi-Fi is one of the most prominent examples of innovation and actual market practice. "Carriers and consumers, however, have relied on the flexibility and rapidly growing capacity of Wi-Fi, rather than on secondary spectrum markets, to add capacity and sustain service in the teeth of sharply growing demand."

3.2.4. *Hybrid Model*

Instead of a one-size-fits all solution, countries are currently implementing a mix of policies that will ensure a more efficient use of spectrum. Modernizing spectrum assignment arrangements is necessary, since spectrum sharing has moved from being a radical notion to a principle policy focus in the past decade (Altamimi, Weiss, and McHenry, 2013). This traditional characterization of the regulatory models presented above does not encompass the complexity of the different regimes in place (Lehr and Crowcroft, 2005). Nowadays, the use of mixed or hybrid assignment frameworks convey a new trend in which different frameworks are merged.

An example of how models have been changing and adapting to the new technological realities is the license-light scheme, implemented by the FCC. Under this light type of licensing scheme, users must comply with specific service rules, but they do not have to obtain individual station licenses.

Balancing the trade-offs in policy design is also a crucial role governments must take on. Whenever a decision is taken, there are advantages and challenges as a result. Table 2 summarizes the main management approaches with the key characteristics and trade-offs.

TABLE 2. Management Frameworks

Regulatory approach	Concept	Main characteristics	Positive features	Trade-offs
Command-and-control	Authoritative	• Governments designate use, technology, and users • Dedicated spectrum	• More effective when (international) harmonization of technical standards is needed	• Inefficient allocation • Presence of old technologies might slow down innovation • Potential underutilization
Licensed	Market-based property rights	• Market-based mechanism • Exclusive rights	• Suitable when scarcity is high and transaction costs associated with access rights are low • Enables the creation of secondary markets, which are not possible in the command-and-control model • Coverage obligations help achieve the goal of universality	• Unsuitable when there are high transaction costs and competing claims to scarce resources • Potential spectrum underutilization
Unlicensed	Commons approach	• Market-based mechanism • Spectrum sharing	• Lowers barriers to access to spectrum and stimulates technological innovation • Flexible and available to users who comply with established technical limits and equipment certification • Most adequate in situations of low scarcity and high transaction costs	• Potential overuse • Potential tragedy of commons • Not possible to establish coverage obligations
	Mixed approach	• Combines characteristics from the other approaches	• Flexibility combining different market mechanisms	• Uncertainty about regulatory framework

Source: Authors, with inputs from OECD (2007) and Lehr and Crowcroft (2005).

4

Crucial Issues Affecting Spectrum Management

As already described, the task of managing the spectrum is a complex one, since it involves a wide range of policy and regulatory decisions made by government. One concept that permeates all others is that of legal and regulatory guarantee. Unless this is present, market players will be unable to invest due to the uncertainty of returns. This uncertainty could delay not only the development of new technologies, but also the entire development of the ecosystem.

Ultimately, the lack of guarantee can imply higher prices and a setback of services to consumers. The disparities relating to access among countries will potentially be increased, based on the varying levels of guarantee offered. In addition, there are several issues in the debate of spectrum management, given the complexity of the topic and its increasing importance. Some of the crosscutting issues that make it so important and urgent a topic are mentioned below.

4.1. Spectrum Harmonization and Band Plans

Since radio waves do not stop at geographic borders, countries should harmonize their band plans to avoid interference along frontiers. Compatibility—the uniform allocation of radio frequency bands, channels, out-of band emissions, among others—between countries or across entire regions can create enormous benefits in terms of social impact and increased productivity. Specifically, an efficient and compatible spectrum management is essential to a digital economy to reduce service charges and roaming fees.

Increasing mobile services, thus lowering the cost of equipment, can create economies of scale. Moreover, a more attractive market would encourage competition to motivate companies to produce less expensive products in more quantity and to enable the mobile wireless market to grow at a faster pace. Compatibility provides additional and broader benefits, such as the adoption of common frequencies and international protocols for disaster management and emergency communications.

It is important to highlight, moreover, that spectrum harmonization does not include technology. Coordination of the latter relates to the use of compatible services within different countries or across regions.

Efficient spectrum management will depend, to a large extent, on following international standards due to the nature of cross border conformity. Initiatives have been taken globally and regionally to reduce the digital divide and ensure compatibility, which is resulting in social and economic benefits. The Office of Communications (Ofcom) in the UK recently demonstrated the importance of harmonizing bands and the benefits it brings to consumers:

> Only bands that are internationally harmonized are likely to be economically viable for the delivery of mobile data services. International harmonization is essential to operators and handset and device component manufacturers as it delivers the economies of scale required for the development and production of network and consumer equipment. Harmonization also offers consumers a widening of choice of mobile devices developed and sold in global markets that are compatible with the use of frequency bands used internationally (Ofcom, 2013g).

The international framework for the utilization of the radio frequency spectrum is set out in the ITU's Radio Regulations. It coordinates the information of individual and nationally based frequency assignments with other countries, which is then registered in a Master International Frequency Register. Each of the three ITU regions has engaged in meetings to agree on common regional band plans. With regard to the LAC region, the options available are those of the United States and Asia Pacific (Asia-Pacific Telecommunity (APT)) band plans.

An analogue switchoff will provide countries the opportunity to harmonize the frequencies of the dividend and, by doing so, delivering broadband service to the segment of the population that has no Internet accessibility. As previously mentioned, the spectral efficiency of 700/800 MHz bands is higher and, for this reason, networks can be deployed at lower cost. The impact of technical harmonization and the allocation of a 700 MHz band for mobile broadband in the Asia Pacific region, by 2020, is estimated to produce a cost reduction of 50 percent in infrastructure, a 6–10 percent decrease in subscription fees, and an increase in rural penetration of between 10 percent and 20 percent (GSMA, 2012a).

4.2. Creation of Secondary Markets

Secondary spectrum markets are those in which spectrum rights licensees are permitted to make all or parts of their assigned frequencies and/or service areas available to other entities and for other uses (FCC, 2000). This would allow for various types of trading arrangements, such as lease agreements, franchises, and joint operating agreements. Australia, Guatemala, the UK, and the United States have already created such a secondary market in order to provide greater flexibility in services and in the use of technology.

The concept of a secondary market is that licensees would improve the efficiency of spectrum. As stated by the FCC (FCC, 2000):

> While secondary markets are not a substitute for finding additional spectrum when needed and should not supplant our spectrum allocation process, a robust and effective secondary market for spectrum usage rights could help alleviate spectrum shortages by making unused or underutilized spectrum held by existing licensees more readily available to other users and uses and help to promote the development of new, spectrum efficient technologies.

The objective is to promote a more efficient allocation, assignment, and use of technologies. Spectrum trading may remove the inflexibility of a primary assignment; facilitate entry into the market; reduce the transaction costs of acquiring spectrum; reduce administrative workload; permit faster deployment; and meet short-term increases in demand. It would promote more market innovation—as new entrants would be able to access the spectrum—and would allow for the introduction of new technologies and services (Xavier and Ypsilanti, 2006).

Making the use of spectrum flexible, relaxing the constraints on usage and technologies, and allowing for license-exempt frequencies are not simple in terms of policy and regulation. It is necessary to provide some level of technical restriction to adequately protect against interference, although advances in technology have somewhat lessened interference issues. As new regulatory models and the sharing of these possibilities become more popular, the more the optimal usage of spectrum will become, as the constraints will be minimized to increase user flexibility and freedom to respond to changing conditions.

4.3. Spectrum Caps

Spectrum caps are a mechanism that was introduced in the 1990s to ensure effective competition in the mobile market. The electromagnetic spectrum is a scarce resource, and, as a result, many countries apply ex ante measures to prevent a single or small number of operators from constraining most of the spectrum available for commercial use. This avoids anti-competitive behavior, which would cause market failures to the detriment of customers and overall social and economic welfare.

The theory behind spectrum caps is that these market failures should be avoided. Each license has an economic value—based on the return on investment in spectrum licenses and network infrastructure—as well as a foreclosure value, which is the value of a wireless company that already has substantial market share and intends to maintain its dominant position by preventing competition (Moore, 2013). Companies that hold a large amount of spectrum have the ability to prevent smaller national and regional carriers from obtaining the necessary licenses to provide services.

Spectrum caps have the ability to prevent the abuse of market power; they may, however, cause adverse consequences, depending on how they are applied. Operators under tight spectrum caps may find it more expensive to offer a full-service portfolio. By capping the amount of spectrum, congestion may occur, which would require operators to apply methods, such as cell splitting (Roetter, 2009) in an attempt to improve the efficiency of spectrum usage. This would require, however, the addition of more equipment to existing sites to increase the number of connections in a network, resulting in an increase in CAPEX and OPEX costs.

The application of heterogeneous spectrum caps across countries could prevent operators from offering comparable service portfolios to clients travelling internationally. This lack of harmonization of policies and spectrum frequencies would thus counteract the social and economic benefits that can be derived from a homogenous approach across countries.

Spectrum caps have changed considerably over the years to the extent that they have been removed in some countries as a result of progress in wireless technology, a growing demand for mobile services, and the application of new spectrum bands for commercial mobile communications (Roetter, 2009). In the United States, for example, spectrum caps have not been applied for more than ten years, although the United States (U.S.) Department of Justice (DoJ) and some groups within civil society have recently advocated the reintroduction of caps as the FCC prepares to auction 600 MHz spectrum. As already mentioned, LAC countries have differing approaches with regard to spectrum caps.

The FCC ceased the application of spectrum caps as of 2001, but with the ongoing debate on whether to adopt it or not, the FCC has reviewed its mobile spectrum holding policies (FCC, 2012b). The DoJ is advocating for "rules that ensure the smaller nationwide networks, which currently lack substantial low-frequency spectrum, have an opportunity to acquire such spectrum," as the FCC prepares to auction 600 MHz spectrum (FCC, 2013a).

Civil society groups recently published a letter in which they state that they support the position of the DoJ and affirm that limits to spectrum caps contribute to "increasing auction revenue by attracting a wider base of potential bidders—bidders that might otherwise be deterred from participating. Just as important, pro-competitive spectrum holdings limits will increase downstream competition, investment, and innovation in the wireless marketplace"(FCC, 2014a).

4.4. Neutrality

The neutrality debate is one of the most prominent when deciding the future of networks, since it affects a large number of stakeholders and since there are different associated dimensions, both of which are fully supported by the ITU. The first is the concept of service neutrality. This refers to the right to change the type of use to a spectrum (e.g., transitioning from broadcasting to mobile services). The second is the concept of technology neutrality (e.g., transitioning from a Global System for Mobile Communications to a Universal Mobile Telecommunications System)—having the right to select which technology will access the spectrum. As technologies converge, the issue of service neutrality becomes even more obvious (see Box 6).

Technology and service neutrality are fundamental to licensees, enabling them to adopt the least expensive options. Furthermore, they contribute towards the realization of economies of scale and scope, thus decreasing costs. While technology convergence and innovation continue at a significant pace, regulators are less aware that it will take time to adapt to change and regulation, which will prevent markets from becoming competitive.

Box 6. Convergence and Service Neutrality

For decades, electronic communications have been divided into varying wired types of communication, such as those provided by telephone companies and the broadcasting that is transmitted through the electromagnetic spectrum. This has led policymakers, worldwide, to develop "elaborate regulatory regimes based both on the technological and economic characteristics of the transmission medium on the one hand, and the nature of communications being transmitted on the other" (Yoo, 2006).

Broadband platforms now allow the convergence of voice, video, and data services onto a single network, and regimes need to adapt to this convergence. Voice over Internet Protocol (VoIP), as an example, is a technology that uses Internet Protocol (IP) instead of traditional analogue systems. It converts the voice signal from telephones into a signal over the Internet, which is becoming increasingly popular. The over-the-top VoIP market is expected to represent 20 percent of total mobile voice revenues by 2016 (Thunström et al, 2011).

A consequence of this convergence is the introduction of a greater degree of service neutrality. Nonetheless, network operators often resist these technologies, since they compete with existing traditional services. Policymakers need to be aware of this and recognize the benefits that convergence can provide. By imposing fewer restrictions on licensees, regulators/administrators can encourage companies to innovate and expand the number of services, leading to lower prices and further competition. Katz and Avila (2010) have demonstrated that broadband prices were drastically reduced when cable TV operators were able to enter the market.

A related concept is transferability, which addresses the different means by which idle spectrum can be used without exchanging legal usage rights. This means that the licensee undertakes the rights, obligations, and protection associated with the license. Traditionally, spectrum has been assigned to particular users for specific purposes. Secondary trading, on the other hand, enables new technologies to flourish. Neutrality in a secondary market results in licenses being more fungible and spectrum more flexible.

Despite its clear benefits, neutrality is not a solution in all cases. There are risks, such as spectrum fragmentation and interference across long-ranging frontiers. Furthermore, technical issues can be resolved before service neutrality is implemented, such as those relating to network architectures and duplexing approaches (Frullone, 2007).

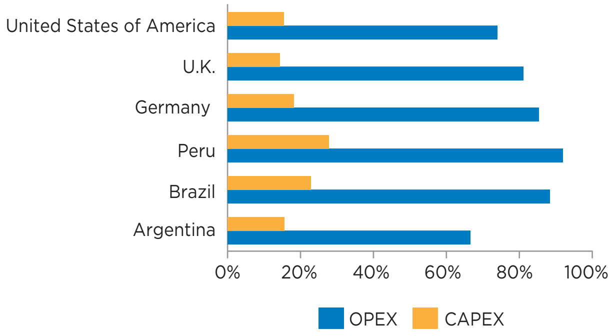
As stated below, most countries in the LAC region still rely on service-specific licensing regimes for telecommunication services. They are, however, gradually adopting technology and service-neutral licensing frameworks, and are starting to reap the benefits.

4.5. Infrastructure and Spectrum Sharing

The mobile industry is one of the most capital intensive ones. Applying new technologies is especially expensive, the high costs of which relate to equipment and spectrum. Nevertheless, there are ways in which to share resources to not only minimize cost but also to improve efficiency. Thus, the possibility of sharing spectrum and infrastructure is further described.

The global mobile market CAPEX investment is estimated to grow by 3.7 percent from 2012 to 2017. This growth will come mainly from mobile operators, representing US$164 billion (80 percent) of the nearly US$200 billion invested in 2012. Three types of mobile operator CAPEX justify this increase: maintenance, capacity extension, and new services (Page, Molina, and Jones, 2013). Maintenance relates to expansion in coverage and data, as explained above; capacity extension relates to growing network infrastructure increases; and new services correspond to the

FIGURE 6. Total CAPEX and OPEX Ratios for MNOs



Source: Authors, with data from GSMA (2013a).

4G technologies being rolled out. Figure 6 illustrates how high these costs are, while illustrating the OPEX and CAPEX ratios[4] for mobile network operator (MNOs) in different countries.

The capacity of networks is directly proportional to the amount of spectrum available and to the number of sites employed. As the demand for data connectivity continues to grow, many operators predict a scarcity in spectrum, referred to as the spectrum crunch, which relates to the amount of spectrum available. In addition, an infrastructure crunch in connection to the number of sites is also occurring as operators “attempt to serve a growing volume of traffic using networks originally designed to provide outdoor voice services and not ubiquitous, largely indoor, data” (Thanki, 2012). To survive in the market, operators should take the following steps: (i) share infrastructure in order to mitigate the costs of sites and (ii) share spectrum so as to mitigate the lack of availability of spectrum.

Network access costs usually represent between one sixth and one third of an operator’s total costs. A study from Analysys Mason (Analysys Mason, 2010) reviewed the costs and benefits over five years in relation to various types of radio network access sharing. It was found that operators

[4] CAPEX and OPEX ratios are a measure of the total CAPEX and OPEX, compared to the total revenue of the operators.

in a development economy gained 30 percent CAPEX in savings, accumulated over five years, as well as a 15 percent reduction in OPEX each year over a five-year period, when the building of 2,500 sites was shared. Other studies refer to 40 percent in total savings through sharing arrangements in mobile markets (Friedrich et al., 2012).

Network sharing is taking place in a number of forms in developing and mature markets. These range from site-, tower-, and radio-network access sharing to roaming and core network sharing. The rationale for sharing in developed markets is to reduce operating costs and provide additional capacity in areas that are congested and where space for sites and towers is limited; and sharing in developing markets may expand coverage into previously unserved areas (GSMA, 2012b).

Infrastructure sharing can stimulate benefits that go beyond the operators. Consumers can also benefit from lower prices for services. Furthermore, the digital divide will be bridged as coverage expands through agreement sharing, and energy consumption will decrease by sharing power supplies, contributing to environmental objectives.

The following chapter further explains the benefits of spectrum sharing. Ways in which licensed and unlicensed spectrum can be shared will be described.

5

Spectrum Sharing

Spectrum sharing is a concept that has existed for a long time, the development of which is being stimulated by new regulatory approaches and technologies. Licensed spectrum can be allocated through liberalization methods that allow spectrum rights to be traded. Unlicensed spectrum can now also be shared with new DSA technologies. Below are the most debated examples of licensed and unlicensed shared use of spectrum.

5.1. Unlicensed Spectrum Sharing

The ability of the industry to meet the traffic demand and move data at affordable prices by using only licensed spectrum is of concern. On the other hand, unlicensed spectrum technology contributes to market expansion, increases competition among providers, and is a benefit to the population.

5.1.1. *Wi-Fi, WiMAX, and Data Offloading*

Wi-Fi is a key networking technology that uses unlicensed spectrum to offload data by providing wireless high speed Internet and network connections. According to the Organisation for Economic Co-operation Development (OECD) (OECD, 2013), most of the traffic that is generated from handsets and tablets is linked to Wi-Fi-associated fixed networks, which are the default backhauls for mobile devices.

These interoperable networks offload data from cellular networks in order to cope with growing demand. As consumers offload mobile device traffic over Wi-Fi, it reduces CAPEX and licensed spectrum capacity, the latter of which can be diverted to other connections. In addition, as Wi-Fi is integrated into LTE, the required number of small cells is considerably reduced.

Box 7. Nomadic Wireless and Data Offloading

Offloading data is important because most mobile devices are Wi-Fi-enabled and the use of mobile communication is mostly nomadic, as devices can usually connect to a Wi-Fi network. As described below, Wi-Fi is becoming increasingly popular. On average, mobile devices are used 2.5 hours a day in the home and 1.0 hour a day at work compared to less than 0.5 hour while on the go (Cisco, 2012). When consumers offload mobile device traffic over nomadic wireless networks, it reduces the CAPEX of networks; enables licensed spectrum capacity to be directed to other connections; and contributes to a lower number of small cells being required when Wi-Fi is integrated into LTE.

Recent studies also suggest that social welfare is improved after an optimal level of unlicensed spectrum is made available. Beyond this, however, the price would continue to rise at the risk of losing clients, who could possibly migrate to the services provided through unlicensed bands, as these can reach a quality threshold (Nguyen et al., 2011). Opening a substantial amount of spectrum for unlicensed use, therefore, is critical to its success.

Despite the many benefits, Wi-Fi has its limitations, such as adjacent channel interference, device standards, range of connection, and number of concurrent users. Nevertheless, with the exponential increase in demand for data services, the integration between fixed and mobile networks will be further developed.

Wi-Fi technology allows connectivity from peer to peer or operates in an ad hoc network mode, enabling devices to connect directly with each other. Mesh wireless networks are an example of peer-to-peer communication technology, offering "the ability of users to connect directly to each other and facilitate a distributed network infrastructure that provides multiple paths for communication to the network and does not require centrally-located towers. They can bypass obstacles like buildings, hills, and trees by using different signal paths, have no single point of failure, and are easily expandable. With existing open source tools, a mesh network can be built with a diverse set of hardware from high end carrier class equipment, familiar off the shelf in home routers, existing computers and laptops, to common mobile devices" (New America Foundation, 2011).

This model is a pragmatic high bandwidth network that avoids path dependencies and vendor lock-in from the large network providers. It is typically less expensive, given that the CAPEX is much less due to lower infrastructure costs. The OPEX is also lower as a result of the distribution across lightweight nodes. Furthermore, a key feature of mesh networks is their potential to achieve high levels of coverage by routing around problem areas. The quality of service, however, could be an issue because of the existing dependence on node numbers and movements. Mesh application examples include (i) disaster scene or military

Box 8. HetNets and Vertical Handovers

In order to reduce traffic, a combination of licensed and unlicensed technologies is now in place. The industry is shifting towards heterogeneous networks (HetNets), which are those that connect computers and other devices to different operating systems and/or protocols, which comprise traditional large macrocells and small cells. Most devices are neither solely mobile nor solely nomadic; they are a combination of both, and most networks already allow for this interoperability.

Wi-Fi is largely used to offload data and when it is integrated into mobile networks, a reduced amount of infrastructure is required. Another example of a hybrid network is the Worldwide Interoperability for Microwave Access (WiMAX) which is a wireless communication standard that has been created for last-mile broadband access.

WiMAX and Wi-Fi are the principle technologies that transmit high-speed communication over the network, "but when a mobile node moves outside the coverage area of its base station, it is required to switch to some other base station. This process is called handover. When working with dissimilar networks, it is called Vertical Handover" (Saini et al., 2013). Vertical Handover is a process that contributes to democratizing last-mile wireless broadband services, and its integration includes a cost-effective backhaul, freedom from interference, and a combination of licensed and unlicensed spectrum use, which are of benefit.

team communications; (ii) hotspot extension of urban public wireless access; and (iii) rural community networks, among others. These have been implemented in various countries (Plextek, 2006). They represent an affordable solution for Internet access and can contribute to the achievement of universality.

5.1.2. *TV White Spaces*

TV White Space is one of the most promising innovations to resolve the issue of spectrum scarcity. TVWS represents parts of electromagnetic spectrum used by analogue broadcasting TV channels, although they are not assigned as protection bands. The main purpose of these spaces is to eliminate interference between channels in very high frequency (VHF) bands and in ultra-high frequency (UHF) bands. TVWS cannot be considered as part of the digital dividend, as they do not result from digital conversion and already exist in the bands occupied by analogue TV broadcasting.

The geographic nature of these bands helps to explain why they are left unassigned. As Freyens and Loney (2011) point out, TVWS has emerged as a means to protect the spaces between analogue TV services in the same licensed area and to ensure geographic separation between TV services in different license areas that transmit in the same channel.

The unlicensed TV band devices that operate in these white spaces apply two types of cognitive radio technologies: (i) a combination of geolocation positioning and a database of incumbent services and (ii) spectrum sensing. Spectrum sensing is a bottom-up approach to make use of cognitive radiotechnology. It is embedded in TVWS devices to identify unoccupied radiofrequencies of TV channels (Saeed and Shellhammer, 2012). Geolocation databases, which comprise the list of available TV channels at a given location, can be classified as top down, utilizing cognitive networks. The downside of these is that a receiver, such as digital TV, cannot be detected, resulting in false positives (or false negatives) and may, by themselves, only benefit the sensing device or homogeneous network (Stanforth, 2013).

One of the main differences between the geolocation and spectrum sensing technologies is that "cognitive radio technology is split between the TVWS device (geo-location) and an external entity (TVWS database). In the second case, the cognitive radio technology (spectrum sensing) is embedded entirely within the white space device" (Saeed and Shellhammer, 2012). The TVWS database is that which stores information on all the licensed services in the TV, and which can calculate a geographic region where TV receivers can receive the broadcast signal without harmful interference.

The technologies using TVWS can penetrate walls and provide faster speeds than Wi-Fi can provide, which is why it has been coined, Super Wi-Fi.[5] In most countries, however, TVWS cannot be used due to a lack of, or nonexistent, regulation. Some countries, such as Canada, European Union, the UK, and the United States, are beginning to develop regulations for TVWS usage.

In June 2014, the Infocomm Development Authority of Singapore announced its Regulatory Framework for TVWS Operations in the VHF/UHF Band.[6] The framework will take effect as of November 2014 and is part of the Intelligent Nation Masterplan, a strategy to place the country as the world's foremost in the harnessing of infocommunications, adding value to its economy and society.[7] The framework was subject to public consultation in 2013 for feedback from industry stakeholders.

[5] As TVWS cognitive radio technologies are not equal to Wi-Fi technologies, the term, Super Wi-Fi, has been criticized. Moreover, Wi-Fi is a trademark, which cannot be used by TVWS providers.

[6] See http://www.ida.gov.sg/~/media/Files/PCDG/Consultations/20130617_whitespace/ExplanatoryMemo.pdf.

[7] See http://www.ida.gov.sg/Infocomm-Landscape/iN2015-Masterplan.

TVWS can be beneficial in a number of ways. It is a prime spectrum, given its significant propagation, coverage, and availability,[8] as well as its potential to synergize with commercial wireless services because of its spectrum closeness. The first standard for TVWS operation, identified as IEEE 802.22, has been approved. This allows broadband wireless access up to 100 kilometers and up to 29 megabytes per second (Mbps) for each TV channel, thus increasing the data rate through the use of multiple channels (IEEE, 2011).

The potential to control TVWS for wireless broadband use in the United States is progressing rapidly. As of July 2013, the FCC has processed applications for equipment certification, approved database administrators, established a process for wireless microphone registration, and granted waivers to register certain TV database receiver sites. In October 2009, Microsoft implemented the world's first operational White Space network at its Redmond Campus (Chandra, 2013). The first TVWS device developed was approved in 2011 and, in January 2012, it was commercially employed in Wilmington, North Carolina (Knapp, 2012).

The Wilmington experience[9] has shown that TVWS can help address spectrum congestion and enable the expansion of applications relating to video surveillance, facilities control (lighting), and public Wi-Fi access, among other urban services. Recent developments go beyond last-mile access to broadband; they include automated agricultural applications (autonomous equipment management and remote sensors), Supervisory Control and Data Acquisition (advanced broadband), and telemetry systems (Stanforth, 2013). Since 2013, Google and Microsoft have been testing TVWS technologies to provide broadband access to connect schools in South Africa,[10] and in rural areas in Kenya. Microsoft is also considering countries in the LAC region.

5.1.2.1. Regulatory Implications of TVWS

There is a growing recognition that assigning fixed frequencies to one purpose in large areas is inefficient, leading to spectrum underutilization As technology evolves at such a fast pace, new opportunities and challenges for regulators continue to surface.

The use of cognitive radio with geolocation positioning and databases has been a key approach to constrain the potential of TVWS. The idea is to protect the operations of incumbents that are listed in the databases and to identify spectrum channels that are available for use in a particular area. In the United States, broadcasters initially were concerned about the reliability of the database, the accuracy of responses, and their ability to deal with multiple database operators.

As expected, implementation of TVWS can be questionable. As Stanforth (2013) states, "white space is not really 'white', as spectrum availability varies according to time, location, and device type." Nevertheless, most regulators have endorsed its use because it is an easier solution to implement when compared to the sensing alternative (Stanforth, 2013). Databases are flexible and easily upgradable without impacting installed technology. Furthermore, rules can be adapted to suit location, frequency, and time specificities.

TVWS facilitates the innovation of applications that are not fully supported by existing technologies. They also can expand the resources of existing applications for improved performance (Sum et al., 2012). Table 3 shows a list with potential applications relating to TVWS.

5.1.2.2. European Union and TV White Spaces

Since 2010, the European Commission has demonstrated its commitment to reviving Europe's

8 Availability depends on the country.

9 Wireless Innovation Alliance includes Dell, Microsoft, Google, Carlson, Spectrum Bridge, Viacomm, New America Foundation, and Public Knowledge. See http://www.wirelessinnovationalliance.org.

10 See The Cape Town TVWS trial, concluded on September 25, 2013. More information available at http://www.tenet.ac.za/tvws/.

TABLE 3. Potential Applications, Descriptions, and Examples of TVWS

Application	Description	Examples
Large Area Connectivity	• High-data-rate backbone for fixed stations • Hubs are connected to nodes forming a sub-network	• Municipal and rural areas • Buildings in a campus area network • Business enterprise • Industrial site • Military premises
Utility Grid Networks	• Connectivity for complexity-constraint fixed stations • Utility consumers with smart metering devices connected to the utility transceiver station	• Smart electricity, gas, and water meters
Transportation and Logistics	• Logistics control for mobile stations • Connectivity from nodes to hubs, and from hubs to the main concentrator	• Public transportation information systems • Transportation virtual payment systems • Baggage management • Freight distribution logistics • Shipping container management
Mobile Connectivity	• Seamless connectivity for mobile stations • Network consists of a main concentrator (base station) and surrounding mobile nodes (laptops, smartphones, transceivers in ships, etc.)	• Land and maritime mobile connectivity
High-speed Vehicle Broadband Access	• High-data-rate backbone for high-speed mobile stations • Base station is connected to hubs along a railway track or roadside	• High-speed trains • Long-distance buses • Subways and underground transportation
Office and Home Networks	• High-data-rate short-range indoor connectivity	• Personal workspace connectivity • Office area connectivity • Home area networks
Emergency and Public Safety	• Mission-critical and highly reliable connectivity	• Safety surveillance systems • Emergency surveillance

Source: Elaborated by authors with inputs from Sum et al. (2012).

economy through the development of a Digital Agenda and corresponding initiatives. Neelie Kroes, the previous Vice-President of the European Commission responsible for Digital Agenda and Society, revealed the large-scale ambitions of the program, describing them as pragmatic. According to Ms. Kroes, while networks and regulations tend to be on a national basis, Europe as a whole needs to focus on a practical approach to relieve bottlenecks and remove barriers, in order to boost the market, improve services, increase networks speed, and offer better prices. The review of the Agenda, published in December 2012, established that the first priority is to create a new and stable broadband regulatory environment. Having effective spectrum policies in place will help to achieve this.

In their objectives to contribute to the internal market's wireless technologies and services, the European Parliament and the Council of the European Union approved the first Radio Spectrum Policy Programme (RSPP) in March 2012 (EC, 2012a). Through the RSPP, the Commission will ensure that the spectrum that is currently allocated be exploited to the fullest extent possible. This will depend on a broad political endorsement of the proposed steps in order to foster the development of wireless innovation in the European Union. The three key goals of the RSPP are to (i) harmonize spectrum access conditions to enable the interoperability of economies of scale with regard to wireless equipment; (ii) work towards a more efficient use of spectrum; and (iii) increase the availability of information regarding current use, future plans, and the availability of spectrum.

The RSPP will identify at least 1,200 MHz by 2015 and will facilitate access to spectrum through general authorizations. Radio Local Area Networks, small cell-based stations, and mesh networks are explicitly referred to in the document in terms of spectrum-sharing approaches. The document also addresses the issue of TVWS, requesting the Commission—in cooperation with Member States—to assess the possibility of extending the allocation of unlicensed spectrum to wireless access systems.

Research has shown that TVWS are, indeed, less abundant in Europe than in the United States (van de Beek et al., 2011). On average, approximately 56 percent of spectrum is unused by the TV networks in Europe, compared to the 79 percent in the United States. Furthermore, Europe is administratively very diverse, which could delay the adoption of TVWS over a longer period (Saeed and Shellhammer, 2012).

A study on the value of shared spectrum access was conducted by the European Commission in early September 2012 (Forge, Horvitz, and Blackman, 2012). It included an assessment of the socioeconomic value of shared spectrum access and its impact on competition, innovation, and investment. The main recommendation of the study is to develop light licensing and delicensing schemes of spectrum management, so as to offer a novel mix of old and new ideas (e.g., nonexclusive frequency rights, opening of government allocations to new sharing arrangements with commercial secondaries). Much of the research undertaken for this study reveals the need to change shared access allocations for technologies to enter the marketplace.

The study also contains a quantitative assessment of the impact that increased shared spectrum access for wireless broadband has in terms of net economic benefit to the European Union. The net increase in GDP is estimated at between EUR 200 billion to over EUR 700 billion until 2020, with an allocation increase of 200 MHz and 400 MHz, respectively.

An analysis of 23 OECD countries was recently undertaken to forecast TVWS in the context of a diffusion of innovation (Saeed and Shellhammer, 2012). It is estimated that the four top-ranking countries with the highest market potential in Europe are France, Germany, Italy, and the UK. The study concluded, moreover, that there was little impact during the early years of adoption, given that larger economies rapidly shadow the first innovation adopter within the diffusion curve.

In September 2012, the European Commission issued a communication on "promoting the shared use of radio spectrum resources in the internal market" (EC, 2012b), in which the use of TVWS devices—based on harmonized standards for geolocation databases—was advocated. Among the conclusions in the document is that the lower part of the UHF band (in particular, 470–698 MHz) should provide a pioneer-sharing opportunity to pave the way for this approach in terms of other bands. Harmonization at the level of the European Union is also highlighted as one of the main steps to foster wireless innovation.

The European Commission is undertaking a study relating to cognitive radio systems for efficient sharing of TVWS in Europe (COGEU, 2013). It is coordinated by the Telecommunications Institute of Portugal with a budget of more than EUR 5 million. Under this project, several technical, business, and regulatory/policy studies are being conducted. Begun in 2010, the project will take advantage of the digital switchover by developing cognitive radio systems. These systems will leverage the favorable propagation characteristics of TVWS through the introduction and promotion of real-time secondary spectrum trading and the creation of a new spectrum management regime.

5.2. Licensed Spectrum Sharing

Licensed spectrum methods are being proposed in addition to unlicensed spectrum sharing. A description of the ASA/LSA is included below, including a proposal to increase capacity to complement dedicated licensed spectrum.

5.2.1. *Shared Access/Licensed Shared Access*

As the demand for spectrum significantly increases, there are new ideas to resolve potential crunches. ASA/LSA is one method being proposed. According to the Electronic Communications Committee (ECC), it "allows fine management of network deployment and effective control of the sharing arrangement, as opposed to licence-exempt regulatory approach" (ECC, 2013). It is a different approach to secondary use or opportunistic spectrum access, where the applicant has no protection from the primary user and where one of its key features is that it "allows offering a predictable quality of service for the incumbent as well as for the LSA licensee when each has exclusive access to that spectrum at a given location at a given time" (ECC, 2013).

To repurpose and vacate spectrum are simultaneous processes that take time. Differing from LSA, ASA is a solution that limits the number of MNO licensees that have exclusive access to underutilized higher spectrum bands. These bands are licensed for international mobile telecommunications (IMT) wherever and whenever incumbents are not using them (GSMA, 2013a; FCC, 2013e).[11] The European Union's Radio Spectrum Policy Group, on the other hand, refers to the concept of LSA as the following:

> A regulatory approach aiming to facilitate the introduction of radiocommunication systems operated by a limited number of licensees under an individual licensing regime in a frequency band already assigned or expected to be assigned to one or more incumbent users. Under the LSA framework, the additional users are allowed to use the spectrum (or part of the spectrum) in accordance with sharing rules included in their rights of use of spectrum, thereby allowing all the authorized users, including incumbents, to provide a certain QoS.

ASA/LSA has been proposed for different bands, depending on the region. The 2.3 GHz band is being considered for Europe, while in the United States the 3.5 GHz band is viewed as a possible option. In the latter, the band is operated for naval radar as opposed to Europe and the LAC region, where it exists primarily for satellite use. These are bands that are generally assigned for government and military purposes.

The concept behind ASA/LSA complements the capacity of the dedicated licensed spectrum. It varies from the licensed and unlicensed approaches, given that it assigns dedicated spectrum in a binary way; that is, the spectrum is used either by the incumbent or by the licensee in any given place at any given time. This characteristic provides predictability and security for licensees and protection to the incumbent, since geolocation databases can technically enable such a sharing scheme.

Unlicensed spectrum lowers the barriers for market entry; however, it can be subject to a tragedy of commons, challenging the number of operators and level of interference. Proponents of the ASA/LSA framework argue that ensuring QoS and the predictability of access and service remain issues in terms of unlicensed frameworks.

Current proposals for ASA/LSA include the concept that the national regulatory authority should "set the authorization process with a view to delivering, in a fair, transparent and non-discriminatory manner, individual rights of use of

[11] The definitions of LSA and ASA have been discussed in various forums. No definitions have been made official to date.

TABLE 4. Summary of Main Characteristics of ASA/LSA

Scope	Framework and allocation	Authorization process
Individual licensing regime to facilitate the introduction in a frequency band of new users. Requires access, while maintaining incumbent services in the band of a certain level of guarantee in terms of spectrum.	The sharing framework includes the set of sharing rules and/or conditions that materialize the change, if any, in the spectrum rights of the incumbent(s) and define the spectrum, with corresponding technical and operational conditions.	The Administration/NRA would set the authorization process with a view to delivering, in a fair, transparent, and non-discriminatory manner, individual rights of use of spectrum to LSA licensees, in accordance with the sharing framework defined beforehand.
Licensees and incumbents operate different applications and are subject to different regulatory constraints.	Sharing framework should be determined by each regulator/administration in national governments.	LSA does not prejudge the modalities of the authorization process to be set by administration/national regulators that take into account national circumstances and market demand.
Each licensee has exclusive individual access to a portion of spectrum at a given location and time.	The decision on the services to be protected within the sharing framework is to be made by national administrations in the light of national policy objectives.	LSA is not a tool to regulate the electronic communications service market; it is based on different principles from spectrum trading.

Source: Authors, based on ECC Report 205 (ECC, 2013).

spectrum to LSA users, in accordance with the sharing framework defined beforehand. The LSA does not prejudge the modalities of the authorization process to be set by national regulatory authorities taking into account national circumstances and market demand" (update proposals to the draft ECC, 2013). The framework provides for a vertical sharing scheme, reflecting the possibility and the hierarchy of the access to spectrum.

The use of ASA/LSA would be advantageous to licensees, offering predictability, quality of service, and prompt market availability. Timely availability is impossible in traditional methods (e.g., refarming) due to the amount of time it takes for the undertaking. Additional advantages to this innovative sharing approach are the potential opportunities for economies of scale and assurance of effective spectrum harmonization. LSA addresses bands with the significant probability of global harmonization, as "uncoordinated sharing activities could be counterproductive to global harmonization and could potentially reduce the economies of scale necessary for the development of a sustainable technology sector" (GSMA, 2013a).

This approach is considered to be optimal for small cells, since the additional capacity available to the macrocell and small cell can be committed to improving service quality or to accommodating additional users in order to share capacity. Furthermore, it would decrease the transaction costs between commercial and government users—key to ASA/LSA. All these advantages can potentially reduce costs for the operator and, ultimately, the consumer.

The FCC is considering this model in its efforts to advance small cells and spectrum sharing. It has been proposed in a Notice of Proposed Rulemaking (NPRM) with regard to the 3.5 GHz band.

6

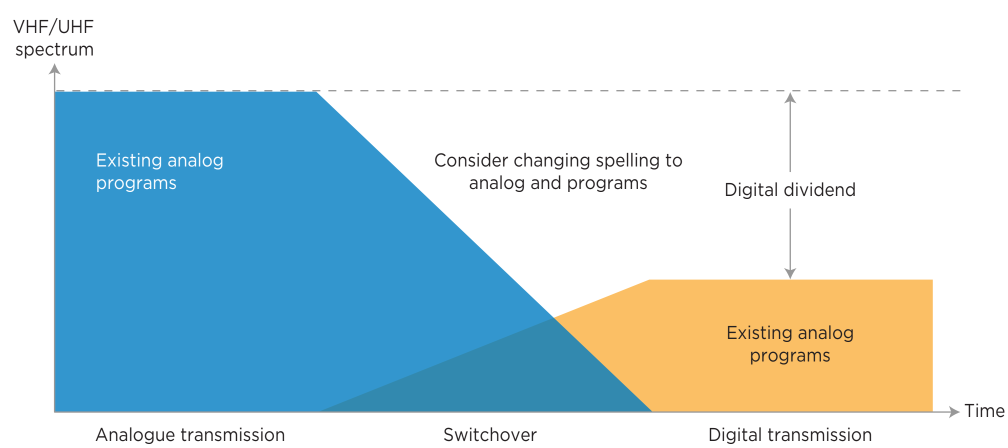
Analogue Switchoff/Digital Switchover

Broadcast TV has occupied, for many years, significant parts of the spectrum in the Ultra High Frequency (UHF) and Very High Frequency (VHF) bands to deliver analogue TV signals. This framework dates back to the 1960s and, since then, new technologies have emerged and the use of spectrum has significantly increased.

By transitioning from analogue to digital TV, a portion of the UHF band will be freed up and used for mobile broadband services—defined as the digital dividend. This is derived from the improvement in spectrum efficiency and it corresponds to the amount of spectrum made available as a result of the transition of TV broadcasting from analogue to digital.

The increase in data demand and the imminent spectrum crunch has motivated many countries to agree to the switchoff of analogue TV signals and to shift to digital transmission, a process referred to as analogue switchoff. Subsequently, a number of the channels may be allocated to new services, such as mobile broadband.

FIGURE 7. Digital Dividend Spectrum



Source: ITU (2013).

Box 9. Why the 700 MHz Band is an Ideal Band for Broadband Use

Bands have differing propagation characteristics that make spectrum more or less appropriate for mobile broadband use. The 700 MHz band is a significant band for broadband deployment, as it is more spectrally efficient and has broad coverage with a lower CAPEX relative to fixed broadband.

The use of the 700 MHz band is less costly for companies and it offers more broadband services that would otherwise be available from higher spectrum bands that would require a larger number of radio base stations. Its impact on rural connectivity is higher, since it will encourage operators to enter these traditionally under-served areas.

As a result of the lower CAPEX, a company that establishes its cellular infrastructure in the 700 MHz band will spend three times less than it would in the 1.9 GHz band for the same area of coverage (García-Zaballos and López-Rivas, 2012). Accordingly, in areas where the capacity and peak data loads are not an issue—as occurs in most rural areas—operators will be able to provide broadband at a much lower cost by using the 700 MHz band than by using higher frequencies (García-Zaballos and López-Rivas, 2012).

Lastly, these frequencies will provide improved indoor coverage, passing through walls more easily than with higher frequency signals. Ofcom has shown that the 900 MHz network will deliver a minimum of 8 Mbps to 70 percent of locations, whereas the 2,100 MHz will deliver the same data rate to only 45 percent of locations.

The allocation of digital dividend bands for mobile broadband would result in the following:[12]

- Asia/Pacific region: 6–10 percent less in subscription fees for consumers as a result of reduced service costs; a 10–20 percent increase of subscription for rural households; and 2.7 million new jobs by 2020.
- Brazil: The availability of mobile broadband to increase to 95 percent—a reduction in CAPEX of US$1.6 billion when compared to infrastructure in higher frequency bands; an additional US$1.3 billion in taxes; and the creation of 4,300 new jobs.
- Europe: EUR 55 billion of tax revenue, 80,000 new businesses, and 156,000 new jobs.

Some countries have selected various technologies to implement the digital switchover. At the ITU Regional Radiocommunications Conference, held in Geneva in 2006 (Geneva-06 Plan), countries in Africa, Europe, and the Middle East agreed to apply the Digital Video Broadcasting-Terrestrial and Digital Terrestrial Audio Broadcasting technologies in VHF frequency Band III (174–230 MHz) and the DVB-T technology in the UHF frequency Band IV/V (470–862 MHz) (OECD, 2006). In many cases, however, the actual use of freed channels will be flexible, in which instance some channels may be allocated to new services (e.g., mobile TV, high-definition TV, datacasting, or other as yet unspecified services).

In the case of the Americas,[13] band 698–806 MHz (700 MHz) was identified at the ITU's World Radiocommunications Conference 2007 as being underutilized in most of the region. It is to be freed up for IMT as requirements issued by the Radiocommunications Sector of the ITU (ITU-R). Box 9 explains why the 700 MHz band is ideal for broadband use.

Despite the role played by the ITU, its ITU-R framework leaves considerable flexibility for

[12] See Annex 1 for a complete table of estimated benefits and the studies that have been undertaken.

[13] For a list of ITU BDT Regions and Region 2, see ITU (2013).

national policy. Europe's CEPT, for example, has already allocated the 800 MHz band for mobile broadband services. Discussions in Europe began in 2006 and a nonbinding decision was approved in May 2010 with the "harmonized technical conditions of use in the 790–862 MHz frequency bands for terrestrial systems capable of providing electronic communications services in the European Union" (EC, 2010).

Nearly all OECD countries have begun tendering processes for the 800 MHz (from 790–862 MHz) band for digital dividend frequencies for mobile broadband. European countries have auctioned digital dividend spectrum since Germany commenced the process in May 2010, followed by France, Italy, and Spain, continuing throughout 2011. Nevertheless, in many instances, bands will not be available until their current licensees have migrated to other bands or refarmed the frequencies currently assigned to them (OECD, 2013). This may take some time. Box 10 describes spectrum refarming.

Box 10. Spectrum Refarming

As technology evolves, spectrum change will yield greater economic or social benefits. The process, referred to as refarming, occurs when a government reassigns spectrum frequencies for different purposes than those currently in place. Existing users of spectrum on a certain band are obliged to transition to other frequencies. Cave (2010) describes this as a process "achieved by giving substantial notice that a spectrum license will be terminated, and sometimes—where demand for the end user service will continue—by providing a new frequency and funding the licensee's move to that frequency". Countries differ with regard to the way in which licenses are revoked and the ability of regulators to do so; however, in many cases, this process takes time.

Europe is in the initial stages of considering a second digital dividend that would create another large band of low frequency spectrum. This came about subsequent to the ITU World Radio Conference 2012, during which it was decided to allocate additional UHF spectrum to mobile services in ITU Region 1[14] in 2015—from 694 MHz to 790 MHz. This new digital dividend is contiguous to the first one that took place at 800MHz. Furthermore, the 700 MHz band will provide further bandwidth to accommodate mobile broadband services in Europe to meet future demand. The 700 MHz allocation in Europe raises the prospect of harmonization with other ITU world regions, such as Region 2, in which LAC is included.

Box 11 includes the case of Spain with regard to its switchover. It illustrates the importance of the legal and regulatory limitations, as well as the applicable international rules and standards.

[14] ITU Region 1 consists of Europe, Africa, and parts of the Middle East.

Box 11. The Digital Switchover in Spain

The case of Spain with regard to its digital switchover is unusual. To enable it to execute the switchover, a new entity was created in 2005 under the presidency of the Spanish State Secretary of Telecommunications: the Commission for Monitoring the Process of Transition to Digital Television (Comisión para el Seguimiento del Proceso de Transición a la Televisión Digital). The transition was planned to be completed in 2010.

In May 2010, however, CEPT proposed to harmonize the technical conditions of use in the 790–862 MHz frequency bands for terrestrial systems, capable of providing electronic communications services in the European Union. This action happened subsequent to Spain having completed the digital switchover process one month prior to most digital TV services being offered on the digital dividend band.

The 800 MHz band was not used in Spain and, as a result, this part of the spectrum was available to DTT stations. This move proved to be incompatible with the decision by CEPT in 2010 to implement its proposal by January 2013. Consideration was given to the unusual case of Spain and the deadline was extended to January 2015. Spain now has to create an action plan (Government of Spain, 2012) to harmonize its frequency plan with that established by CEPT so as to free this portion of spectrum and reallocate these services to other frequencies.

Broadcasters were then required to broadcast simultaneously, using two channels, over a transitional period of 6 to 24 months. The ensuing costs were borne by the consumer because of the need to adapt to multifamily buildings for adequate reception. To meet the costs, Spain offered compensation to the (i) broadcasters for the additional costs incurred as a result of their obligation to broadcast simultaneously during the transition; and (ii) dwellers of collective residential buildings by offering subsidies as a means for them to continue to have reception of free-to-air channels. The total budget was estimated at EUR 600–800 million.

The European Commission has examined whether this compensation plan was proportionate and necessary, in accordance to Article 107 (3) (c) of the Treaty of the Functioning of the European Union (EC, 2012c). The ruling relates to the "aid to facilitate the development of certain economic activities of certain economic areas". For compatibility with the internal market, such aid shall not "adversely affect trading conditions to an extent contrary to the common interest". The European Commission also inquired whether the measure favored terrestrial broadcasting over other available technologies.

The European Commission asserted that it was irrelevant that the Spanish compensation scheme was a way in which to assist companies to meet their legal obligations; it was deemed as a grant. The conclusion of the European Commission was that the burden of regulatory obligations should be borne by broadcasters and operators to avoid potential distortions to competition (Government of Spain, 2012). According to the ruling, the country should have carried out the digital switchover in a technology-neutral manner.

The experience of Spain exemplifies that when implementing policies that relate to the digital switchover, countries should be familiar with legal ramifications and regulatory limitations, as well as applicable international rules and standards.

7

Competition and the Future of Spectrum

To preserve and to encourage competition are essential to spectrum management. Exercising market power leads to higher prices for the consumer and diminishes the quality of service and innovation. The new opportunities that arise from spectrum access (e.g., digital dividend bands), the ability to create innovative business models, and the use of unlicensed parts of the spectrum will promote change and shift the power dynamics of the wireless industry. These, among other changes, should be reflected in regulatory frameworks to prevent the convergence of products and services (García-Zaballos, 2013).

The continuous transformation in the access to networks and spectral resources encourages the entry of operators into the market place. This will result in more competition within the telecom sector. As previously mentioned, infrastructure and spectrum licensing is costly. Competition, therefore, would encourage licensed spectrum sharing, either by the unlicensed application of frequencies or by sharing licensed spectrum.

Lowering the barriers to market entry could be advantageous to spectrum and infrastructure sharing. Thanki (2012) argues, however, that it will be the large operators that will win the bids and which will take advantage of the secondary market transactions. For this reason, sharing licensed spectrum may not be necessarily to the benefit of new entrants. In addition, it will lead to spectrum accumulation and consolidation, since the amount of spectrum held by each operator determines the capacity. A competitive environment thus can be created when new market players are able to deploy networks in terms of unlicensed spectrum use.

As markets become increasingly integrated on a vertical basis, operators will be able to apply their market power against anticompetitive behavior (e.g., margin squeeze, predatory pricing, and collusive behavior). The latter example has taken place in cases where license fees are too high (Gruber, 2001). The potential for collusion is considered as anticompetitive behavior and it can arise in relation to the agreement of infrastructure sharing, where the stakeholders do not maintain independent control over certain key network elements (Cave, Avgousti, and Foster, 2012).

The convergence of the wireless broadband environment can give rise to several competitive issues. One is the extent to which regulators should interfere, ex ante, and what should be assessed, ex-post, in terms of competition. Competition policy should take the middle ground in situations where the architectural approach becomes ambiguous (Yoo, 2006); it should allow for various alternatives to take place, unless it can be demonstrated that the competition can be detrimental.

A strong private sector market presence can accelerate innovation and the deployment of new technologies if it is adequately supported. In countries where companies have to compete, mobile access rates tend to be lower compared to those in countries where the case is monopolistic or quasi-monopolistic.

As the OECD (2013) reports, competition has led "operators to open and share their access to customers with far more success than could have been achieved under the imposition of regulatory arrangements." Governments are thus responsible for leveling the playing field by stimulating competition, which is a key to ensuring mobile broadband access. The wide variety of players to have "ever increasing weight within the sector of wireless technologies" (Cave, Avgousti, and Foster, 2012) confirms that further attention should be paid to the legal interventions related to competition. A careful review of ex ante and ex post-regulatory approaches is required.

8

Analysis of Reference Countries

Australia, Germany, the UK, and the United States were selected as reference countries, since they are at the institutional forefront in terms of policy and regulation of spectrum. The Telecommunications Regulatory Governance Index (TRGI), created by Waverman and Koutroumpis (2011), is an attempt to establish a benchmark for the quality of telecommunications regulatory governance. Australia, Germany, and the United States are ranked at the top in their respective regions: Asia-Pacific, Europe, and the Americas. The UK ranks fifth in Europe and seventh globally.

These four countries can be used as a reference point in terms of spectrum management. Table 5 illustrates various indicators relating to the mobile sector in these nations.

The four countries count on a high percentage of wireless broadband penetration, as well as advanced mobile technologies in comparison to most. Figure 8 shows this progress relating to the penetration between 2009 and 2013.

These countries are ahead in terms of innovative approaches in the use of spectrum. Germany and the UK now allow pilots of TVWS, and both are expected to have the highest market potential for TVWS in Europe. In terms of spectrum allocation to mobile broadband, Germany and the United States are the leaders.

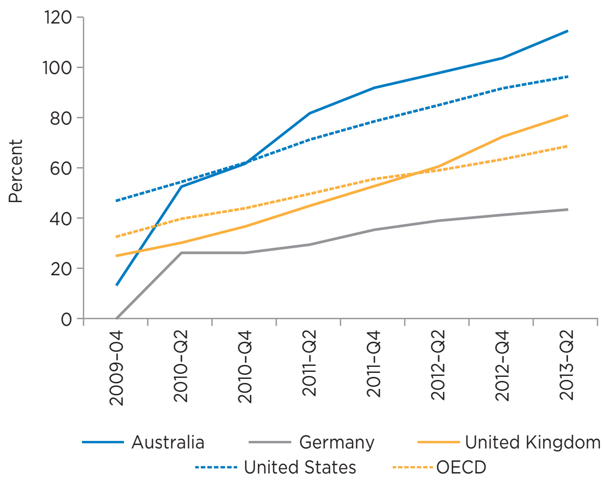
The aspects described above will be assessed, among others, in this section. The analysis for each country includes a description of the (i) institutional, policy, and regulatory framework; (ii) availability of spectrum; (iii) innovative policies that

TABLE 5. Different Indicators of the Mobile Sector in the Selected Countries

Indicator	Australia	Germany	U.K.	U.S.
Market penetration – Mobile Broadband	108.92%	63.06%	74.79%	83.88%
Market penetration – 3G	92.24%	66.44%	80.22%	62.30%
Market penetration – 4G	16.69%	3.49%	1.09%	21.59%
Market penetration – LTE	16.69%	3.49%	1.09%	18.93%
OPEX/revenue, annual	75.43%	85.12%	80.95%	73.93%
CAPEX/revenue, annual	11.69%	18.16%	14.30%	15.45%
Herfindahl-Hirschman Index	3,795	2,649	2,757	2,487

Source: Authors with data from GSMA (2013a).

FIGURE 8. Historical Wireless Broadband Penetration Rates in Selected Countries, 2009–13



Source: OECD (2014).

TABLE 6. Mobile Broadband Indicators: United States, 2013

Indicator	
Population	318.8M
GNI/capita	$48,450
Connections	347.2M
Market penetration – Mobile Broadband	83.88%
Market penetration – 3G	62.30%
Market penetration – 4G	21.59%
Market penetration – LTE	18.93%
OPEX/revenue, annual	73.93%
CAPEX/revenue, annual	15.45%
Herfindahl-Hirschman Index	2,487

Source: Authors with data from GSMA (2013a).

have been implemented or are being considered; and (iv) main aspects of the analogue switchoff process.

8.1. United States

8.1.1. *Overview*

The United States is a very large country in terms of population and land. Nonetheless, despite its challenges, more than 80 percent of the population uses the Internet. Since early 2009, nearly US$250 billion in private capital has been invested in U.S. wired and wireless broadband networks. Between 2012 and 2013, more high-speed fiber cables have been laid than in any other period since 2000 (President's Council of Advisors on Science and Technology, 2012).

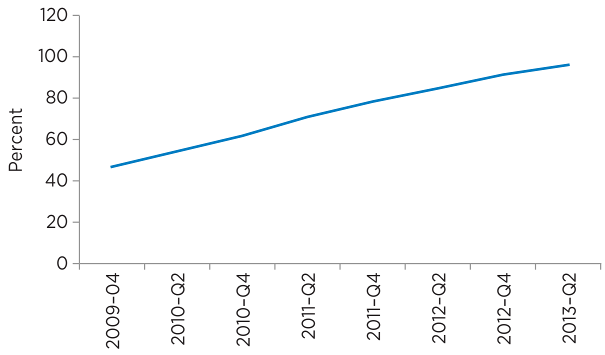
According to the President's Council of Advisors on Science and Technology (2012), annual investment in U.S. wireless networks grew more than 40 percent between 2009 and 2012, from US$21 billion to US$30 billion, while wireless investment in Asia rose only 4 percent. Projections for 2013 indicate an annual wireless network investment of US$35 billion. Table 6 confirms the robust penetration of mobile broadband.

Broadband basic speed is currently defined at 3 Mbps downstream and 768 Kbps upstream (3 megabytes/768 kilobytes), with regulatory decisions defining basic service as 4 Mbps downstream and 1 Mbps upstream (President's Council of Advisors on Science and Technology, 2012). This is, however, a progressive baseline that reflects a growing need for increased bandwidth, given the reliance U.S. citizens placed on broadband for personal and work communications and a wide variety of services. The penetration rate of mobile is considerably high and it has increased in the past few years, reflected in Figure 9.

8.1.2. *Institutional, Policy, and Regulatory Frameworks*

The responsibility for the institutional framework for frequency management in the United States is divided between the FCC and National Telecommunications and Information Administration (NTIA). The FCC, which is an independent regulatory agency, administers spectrum for nonfederal use and the NTIA, which is an operating unit of the

FIGURE 9. Wireless Broadband Penetration Rates in the United States, 2010–13



Source: OECD (2014).

U.S. Department of Commerce, administers spectrum for federal use.

The FCC also undertakes the management and licensing of spectrum for commercial and noncommercial users, including state, county, and local governments. Within the FCC, the Office of Engineering and Technology provides advice on the technical and policy issues that pertain to spectrum allocation and usage, as well as frequency allocation and assignment.

Under the Freedom of Information Act promoting transparency, relevant information can be found online. This includes frequency allocation and assignment, as well as the policies and activities of the authorities.

A sound regulatory framework for spectrum management needs to be in place in order to democratize access to the benefits that spectrum can offer. Such a framework is also essential to support the vast investments in wireless networks that are being made. The United States completed its digital switchover in February 2009 nationwide, with US$19 billion being raised through the 700 Mhz band auction.

Spectrum management is essential to achieve universality of access and services, given the need for mobile broadband to reach underserved areas and the use of mobile technologies. Universal service is a concept that was introduced in the United States by the Communications Act of 1934. The Telecommunications Act of 1996 to include spectrum allotment and broadcasting, including the Internet, expanded it. According to the Act, the FCC bases its policies for the preservation and advancement of universal service on the principles of (i) quality and rates; (ii) access to advanced services; (iii) access in rural and high-cost areas; (iv) equitable and nondiscriminatory contributions; (v) specific and predictable support mechanisms; and (vi) access to advanced telecommunications services for schools, health care, and libraries (FCC, 1996).

Aufderheide (1999) indicates out that the new version of universal policies, released in 1996, corresponds not only to a shift in technology since the 1934 Act, but also to the transition from a regulated monopoly to deregulated competition. While this adaptation made the United States the envy of the world for some (Aufderheide, 1999), it represented a legal atavism for others (Mueller, 1997). The universal service section of the Telecommunications Act provided the FCC the ability to create a durable system whereby the price for a basic phone would remain low. It would also ensure that existing companies and new entrants to the market share the burden of providing an affordable service (Aufderheide, 1999). Universal service thus, for the first time, included advanced services such as broadband Internet for all consumers at fair, reasonable, and affordable rates.

Subsequent to the Act of 1996, the Universal Service Fund (USF) was created and the FCC designated The Universal Service Administrative Company (USAC) as its administrator. USAC is an independent, not-for-profit corporation that receives, since 2013, 15.5 percent of end-user revenue received by companies from USF fees (FCC, 2013). The fee applies to telecommunications carriers, including wireline and wireless companies, VoIP providers, and cable companies that provide voice service, and is based on an assessment of interstate and international end-user revenues (USAC, 2013).

Spectrum caps ceased to be applicable in 2013. Instead, the FCC instituted a policy, referred to as spectrum screening, to evaluate spectrum holdings on a market-by-market, case-by-case basis. This allegedly caused a "steady consolidation and a dramatic decline in competition to the detriment of consumers" (Feld, 2013). In any event, the debate on whether to adopt caps or not continues. The FCC has reviewed its mobile spectrum holding policies and the DoJ advocates that "rules that ensure the smaller nationwide networks, which currently lack substantial low-frequency spectrum, have an opportunity to acquire such spectrum" as the FCC prepares to auction the 600 MHz spectrum. Civil society groups issued a petition to support the DoJ position and to support the capping of spectrum caps as a means towards "increasing auction revenue by attracting a wider base of potential bidders—bidders that might otherwise be deterred from participating. Just as important, pro-competitive spectrum holdings limits will increase downstream competition, investment and innovation in the wireless marketplace" (FCC, 2014b).

A more recent step towards universality is the National Broadband Plan released in March of 2010. It highlights ways in which the U.S. Government can stimulate the broadband ecosystem and reform universal service, for which a total of US$4.5 billion a year was allocated from the USF. The plan sets the following recommendations: (i) to ensure greater transparency concerning spectrum allocation and utilization; (ii) to expand incentives and mechanisms to reallocate or repurpose spectrum; (iii) to make more spectrum available for broadband within the next ten years; (iv) to increase the flexibility, capacity, and cost-effectiveness of spectrum for point-to-point wireless backhaul services; (v) to expand opportunities for innovative spectrum access models; and (vi) to take additional steps to make U.S. spectrum policy more comprehensive (FCC, 2010).

These recommendations are interlinked and relate to a decade of high-level debates on spectrum policy held within the Federal Government. Since 2002, the Spectrum Policy Task Force has advised the FCC on how to evolve from the command-and-control model of spectrum management to a model with less regulatory intervention, as well as on prevalent spectrum issues. The report that was issued by the Spectrum Policy Task Force in November 2002 indicates that in some bands, the spectrum was not fully used. It stated that one of the reasons for this was due to how spectrum is regulated and that "increased flexibility will be a key component of any policy that successfully promotes the efficient use of spectrum" (FCC, 2002).

8.1.3. *Spectrum Availability*

Among the countries assessed in this study, the United States ranks as second from the top, followed by Germany, in terms of the amount of spectrum dedicated to mobile broadband with an allocation of 608 MHz. Table 7 shows the bands that are allocated.

TABLE 7. Licensed Spectrum Available for Mobile Broadband: United States, 2013

Band	Allocation (in blocks)
Below 700 Mhz	N/A
700 MHz	70
800 MHz	64
900 MHz	N/A
1,500 MHz	N/A
1,700/1,800 MHz	N/A
1,900 MHz	130
2.1 GHz	130
2.3 GHz	20
2.6 GHz	194
TOTAL	608

Source: Authors, with data from FCC (2013h).
Note: N/A = not available.

Despite the United States having allocated a larger amount of spectrum than in most countries, there is yet more need for capacity to satisfy the steep increase in consumer and business broadband demand. The country, therefore, is now seeking additional spectrum and is repurposing spectrum that is already allocated.

Accordingly, the National Broadband Plan has established various spectrum recommendations. Among them are the expansion of (i) incentives and mechanisms to reallocate or repurpose spectrum; and (ii) opportunities for innovative spectrum access models. These objectives have been at the center of the spectrum policy debate. Highlighted below are the main innovations that correspond to each of the recommendations.

8.1.4. *Innovative Policies*

8.1.4.1. Incentive Auctions

Incentive auctions are essential to expand incentives and mechanisms to reallocate or repurpose spectrum, as described in the National Broadband Plan. These auctions are a market-based means through which licensees are encouraged to voluntarily renounce their usage rights in exchange for a share of the values paid for new licenses to use the repurposed spectrum. The proceeds would contribute to the funding of a new US$7 billion public safety network, in addition to paying the broadcasters that renounce their licenses.

The U.S. Congress, in February 2012, authorized the FCC to use spectrum for incentive auctions. An NPRM was adopted in September 2012 to develop a broadcast TV spectrum incentive auction in the 600MHz band, the first of its kind, worldwide (FCC, 2012d).

In May 2014, the FCC adopted rules to implement the First Ever Broadcast Television Incentive Auction, four parts of which include the (i) reorganization of the 600 MHz Band, including repacking and unlicensed operations; (ii) auction process and design; (iii) post-auction transition for all incumbents in the 600 MHz band; and (iv) post-transition regulatory issues, including channel sharing. The auction is planned for mid-2015.

8.1.4.2. TV White Spaces

Unlicensed spectrum currently generates between US$16 billion and US$37 billion each year to the U.S. economy (Clyburn, 2012), since exclusively licensed spectrum occupies five times the spectrum in the 500 MHz to 1 GHz frequencies as unlicensed usage does (Cooper, 2012). This is not sufficient to meet the fast rising demand for wireless data. By using Wi-Fi, providers offload over one third of their traffic into the unlicensed spectrum, saving over US$25 billion in OPEX and CAPEX (Cooper, 2012).

Wi-Fi is a success in terms of unlicensed spectrum use, and recent studies suggest that "the share of mobile device traffic offloaded over unlicensed spectrum onto residential and business wireline networks is likely to surpass two-thirds over the next several years" (Calabrese, 2013). The United States is aware of this and has been undertaking steps to advance unlicensed spectrum regulation, in particular the use of TVWS.

The idea of having fixed and portable unlicensed devices to operate in one or more TV contiguous channels has been under discussion since 2004, when an NPRM was issued. Subsequently, the FCC ran two series of tests on TVWS prototypes, the results of which were found to be varied when the prototypes were found to work well in sensing TV signals but not so well in sensing wireless microphones (Saeed and Shellhammer, 2012). The FCC "Report and Order" (FCC, 2014a) and a memorandum for opinion, issued in 2010, set the rules under which an unlicensed device can be certified and allowed to operate in the TVWS.

Fixed devices operate with high power and antennae that are mounted on buildings or masts, and they are likely to be used for commercial Wi-Fi Hot-Spots. On the other hand, portable devices are for short distances through rural broadband distribution or cellular-type installations. These are suitable for Wi-Fi access points, tablets, and smartphones (Google, 2013). White space devices are considered still in their infancy (Benkler, 2012), since the FCC approved the first device only in 2011 and its initial deployment occurred in 2012 in Wilmington, North Carolina. The rules for sharing fixed and portable white space devices have been established (FCC, 2013g) and are set forth in the Code for Federal Regulations.

The FCC has also recently advanced the pilot tests for database systems. In March 2013, a 45-day test of Google Inc.'s TV band database system began with the granting of public access and, as specified in the rules, to ensure that it correctly identified the channels available for unlicensed radio transmission devices to (i) operate in unlicensed TV band devices; (ii) register radio transmitting facilities that are entitled to protection; and (iii) provide protection to authorized services and registered facilities. In June 2013, Google, Inc. was granted approval by the FCC's Office of Engineering and Technology to operate the database system, providing the public with a service to support unlicensed radio devices that transmit on TVWS (FCC, 2013h).

8.1.4.3. Innovative Types of Licensing Spectrum

The light-licensing model is a nonexclusive scheme used for licenses in the 3,650 MHz band and can well be applied for existing federal services (FCC, 2013i). As explained by Webb (2008):

> "Light licensing is an approach where users do require a license (unlike license-exemption) but this license is typically very low cost and available on request to anyone. Users then have to register their use of the spectrum in some way, such as through a database containing parameters of each of their transmitters such as their location and power levels. Varying degrees of control are then possible. (…) Light licensing does not attempt to control interference through technical license terms, instead relying on resolving any interference after it has occurred."

Under this light type of licensing scheme, users must comply with specific service rules but do not have to obtain individual station licenses. Operators are expected to only pay a small registration fee to operate in the 50 MHz between the 3,650 MHz and 3,700 MHz spectrum. Furthermore, various operators are allowed to register on a nonexclusive basis. By the FCC having removed the barriers for entry, more players are able to enter the market, thus progressing towards universality.

ASA/LSA. In 2010, U.S. President Obama unveiled an initiative to reform spectrum policy and improve America's wireless infrastructure. In collaboration with the FCC, he signed a Memorandum calling for the NTIA to make available 500 MHz of spectrum—used for other federal and nonfederal services—within the next 10 years. Based on this, the NTIA assigned the 3.5 GHz band, which applied to military and satellite operations, as a band that can potentially modernize spectrum access models (NTIA, 2010).

The ASA/LSA model is currently being proposed for this band. It builds upon the efforts of the NTIA; the report of the President's Council of Advisors on Science and Technology (2012) and the U.S. experience with spectrum sharing in TVWS. The ASA/LSA approach is viewed as a new way in which to share spectrum, combining elements of traditional spectrum management with the new and enabling it to be shared at certain times and in particular places. The FCC considered has this technique since December 2012 as part of its NPRM for a new Citizens Broadband Service in the 3,550–3,650 MHz frequency band (3.5 GHz band). The small cells and spectrum sharing, together, will improve the efficient use of radio spectrum (FCC, 2012c).

The NPRM proposes that "the Citizens Broadband Service be managed by a spectrum access system incorporating a dynamic database and, potentially, other interference mitigation techniques. The spectrum access system would ensure that Citizens Broadband Service users operate only in areas where they would not cause harmful interference to incumbent users and could also help manage interference protection among different tiers of Citizens Broadband Service users" (FCC, 2012c).

There are three tiers of service proposed: (i) Incumbent Access; (ii) Priority Access; and (iii) General Authorized Access (GAA). What differentiates each of these tiers is the level of interference protection each have:

> Incumbent Access users would include authorized federal and grandfathered FSS users currently operating in the 3.5 GHz Band. These users would have protection from harmful interference from all other users in the 3.5 GHz Band. In the Priority Access tier, the NPRM proposes that the Commission authorize certain users with critical quality-of-service needs (such as hospitals, utilities, and public safety entities) to operate with some interference protection in portions of the 3.5 GHz Band at specific locations. Finally, in the GAA tier, users would be authorized to use the 3.5 GHz Band opportunistically within designated geographic areas. GAA users would be required to accept interference from Incumbent and Priority Access tier users (FCC, 2013b).

The FCC is now analyzing how rights should be assigned among users. Some stakeholders have proposed a two-tiered sharing structure that essentially removes the GAA tier and others have defended a more traditional framework, whereby exclusive access to spectrum would be assigned geographically (FCC, 2013b). The FCC is also considering expanding ASA/LSA into an adjacent 50 MHz of spectrum in the 3,650–3,700 MHz band. This would total 150 MHz available for shared wireless broadband access. On November 2013, the FCC determined that it would be in the public interest to solicit further comment on specific alternative licensing proposals (FCC, 2013c).

ASA/LSA is a framework that increases spectrum sharing and the use of small cell networks, thus raising data capacity within available spectrum resources. It is considered vital to pursue small cell spectrum-sharing strategies in parallel with other efforts to increase the amount of exclusively licensed spectrum for more widespread connectivity at affordable prices. The global small cell market is expected to grow to US$2.7 billion by 2017 (Infonetics, 2013).

8.1.5. *Analogue Switchoff/Digital Switchover*

Overview: The digital switchover was completed in February 2009 across the United States. As a result, 108 MHz in the 700 MHz band were vacated. From the 108 MHz, 24 MHz were allocated to public safety. The rest has been auctioned.

Subsidies: The U.S. Government has subsidized the cost of transitioning by offering coupons to those affected, totaling US$1.5 billion. The program was administered by the NTIA and coupons in the amount of $40 were mailed to household addresses through the U.S. Postal Service. One aspect of this scheme is that the NTIA included all U.S. households due to the uncertain demand.

Public Safety/Private Partnership: A framework between licensees in commercial spectrum blocks and those in public safety blocks was created, under which the public safety licensee has priority access to a commercial licensee in the case of an emergency. This interoperability provides a secondary use of spectrum and the maximization of public safety.

Auction: In 2008, US$19 billion was raised through the 700 Mhz band auction. The main aspects of the auctions were:

- Technology and service neutrality.
- Coverage obligations: Thirty-five percent of the geographic area of the license within four years and 70 percent within ten years. Failing to meet these requirements automatically will make the unserved portions of the license available to other potential users. Due to interoperability issues, however, the four-year deadline was extended (FCC, 2013k).
- Split in two major ranges: lower and upper 700 MHz.

Delay: The initial date that had been established for the switchover was February 2009. Analogue broadcasting, however, did not cease entirely by this deadline.

8.2. United Kingdom

8.2.1. *Overview*

Following global trends, the UK also faces the rising demand for mobile data as a result of the proliferation of connected devices and changing consumer behavior. According to information from Ofcom, the volume of data more than doubled in the 18 months preceding January 2012, and the average time spent on mobile data services was 2.1 hours a month in 2011—25 minutes (24.7 percent) a month more than in 2010 (Ofcom, 2013c). Smartphone ownership rose to 39 percent of UK adults and tablet ownership now stands at 19 percent. Ofcom estimates that by the end of 2017, almost the entire UK population will have access to 4G mobile services (Ofcom, 2013c).

The market penetration of mobile broadband is considerably high, at almost 75 percent, primarily relating to 3G. Table 8 summarizes some of the indicators relating to the UK:

TABLE 8. Mobile Broadband Indicators: the UK, 2013

Indicator	
Population	63.0 million
GNI/capita	US$37,780
Connections	77.6 million
Market penetration – Mobile Broadband	74.79%
Market penetration – 3G	80.22%
Market penetration – 4G	1.09%
Market penetration – LTE	1.09%
OPEX/revenue, annual	80.95%
CAPEX/revenue, annual	14.30%
Herfindahl-Hirschman Index	2,757

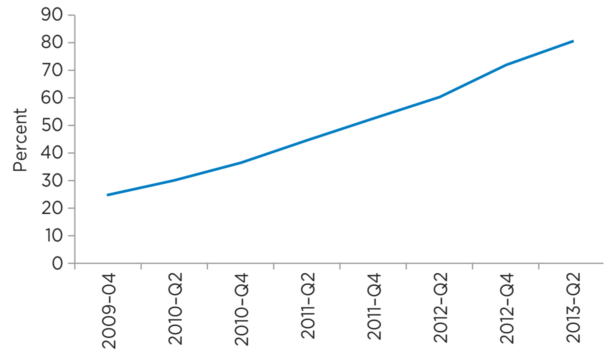
Source: Authors with data from GSMA (2013a).

Figure 10 below indicates the wireless broadband penetration rates between 2009 and 2013.

8.2.2. *Institutional, Policy, and Regulatory Frameworks*

Under the Communications Act 2003, Ofcom became the UK's independent unified regulator and competition authority for the UK electronic communications sector. It took over the responsibilities of the previous separate regulators and it manages civilian use of the spectrum. The Communications Act 2003 and the Wireless

FIGURE 10. Wireless Broadband Penetration Rates: UK, 2009–13



Source: OECD (2014).

Telegraphy Act 2006 give Ofcom the authority over spectrum management.

Within Ofcom, the Spectrum Policy Group clears, awards, and licenses the UK's radio spectrum, ensuring that wireless communications operate efficiently and without interference. In turn, the Spectrum Clearance and Awards Management Board manages Ofcom's Spectrum Clearance and Awards Programme for the 800 MHz and 2.6 GHz frequency bands.

8.2.3. *Spectrum Availability*

The table below shows that the UK has already allocated a high amount of spectrum to mobile broadband.

The National Broadband Policy, released in December 2010, will provide access to broadband speeds of at least 2 Mbps and superfast[15] broadband to at least 90 percent of the population by 2015. In terms of spectrum management, the principal legal instruments are the Communications Act 2003 and the Wireless Telegraphy Act 2006. The legal framework includes the 2009 *Digital Britain: Final Report* (Government of the UK, 2009), which came into legislation through the Digital Economy Act 2010 (Government of the UK, 2010).[16] Among the provisions of the Act are the digital switchover, regulation of TV and radio services, and access to electromagnetic spectrum. The Wireless Telegraphy Act 2006 was also amended.

TABLE 9. Available Licensed Spectrum Available for Mobile Broadband: UK, 2013

Band	Allocation (in blocks)
Below 700 Mhz	N/A
700 MHz	N/A
800 MHz	60
900 MHz	70
1500 MHz	N/A
1,700/1,800 MHz	143
1,900 MHz	20
2.1 GHz	120
2.3 GHz	N/A
2.6 GHz	185
TOTAL	598

Source: Authors, with data from Ofcom (2013f).
Note: N/A = not available.

8.2.4. *Innovative Policies*

Ofcom has articulated a market-led approach to spectrum management since 2005, when its last strategic review took place. A series of objectives around the introduction and extension of market mechanisms were set, including (i) auctions as a means to assign new spectrum access rights for large blocks of spectrum; (ii) spectrum pricing to create incentives for users to make efficient use of spectrum; (iii) spectrum trading and leasing for spectrum access rights that are already assigned to change hands; and (iv) greater license flexibility (liberalization) as a principle to enable change of use, wherever possible, without recourse to Ofcom to vary the technical license conditions (Ofcom, 2013g). As a result of this strategy, the following has taken place:

- The 4G auction at 800 MHz and 2.6 GHz has been undertaken.
- Spectrum pricing has been extended to most major license classes.
- A total of 84 percent of relevant spectrum is now tradable.
- A total of 21 percent of spectrum is highly flexible, including the liberalization of mobile licensees, deploying 3G and 4G technologies in all mobile bands and changes to business radio licensing.

[15] Defined as 24 Mbps.
[16] Broadband is not included in the Universal Service Obligations; it is part of a broader national broadband plan launched in 2010.

In October 2013, the authority released a consultation document relating to a proposed strategy to fulfill the country's spectrum management over the next ten years (Ofcom, 2013g). Ofcom also released its long-term and annual plans. Among the priorities set for 2013/2014 is to secure optimal use of spectrum. Activities under this priority are the following:

- Timely spectrum clearance in 800 MHz and 2.6 GHz to enable new awards, while mitigating co-existence issues.
- Implementation of the UHF strategy to enable a potential release of 700 MHz for harmonized mobile use.
- Support of the release of 2.3 GHz and 3.4 GHz bands to meet spectrum demand.

In addition to the above, the use of TVWS was identified for potential broadband use. Ofcom is shifting towards a more flexible management of the spectrum and it has opted for neutrality in terms of services and technologies in its future spectrum assignments.

Furthermore, the regulator has identified alternative bands that can be used for mobile data in the future, such as the 2.7 GHz band currently used for radar and the 3.6 GHz satellite band. The total amount of spectrum would boost mobile data capacity by more than 25-fold between today and 2030 (Ofcom, 2013c). The main steps for each of the activities are summarized below.

8.2.4.1. Timely Spectrum Clearance in the 800 MHz and 2.6 GHz Bands

In February 2013, Ofcom auctioned 245 MHz in two separate bands: (i) that which was freed as a result of the analogue switchoff and the 800 MHz that was part of the digital dividend; and (ii) the 2.6 GHz band. This is equivalent to two thirds of the radio frequencies currently in use by wireless devices.

This refarming process was an effort to liberalize mobile licenses so as to remove the regulatory barriers to deploying the latest available mobile technology. This decision, according to Ofcom, is aligned with the public interest, since operators will be able to plan the deployment of 4G services without engaging in a further regulatory process. Operators, therefore, will not be required to deploy 4G services in the immediate future (Ofcom, 2013b).

The auction generated £2.3 billion, £1.2 billion less than the Treasury had predicted and £3 billion less than the assumed maximum. In 2000, 3G licenses were sold for £22.5 billion, ten times more than that for 4G spectrum. Ofcom neither set a maximum figure for the proceeds nor did it forecast the proceeds ahead of the auction. Instead, the authority wishes to maintain competition in the mobile telecommunications market and to maximize consumer benefits, estimated at £20 billion. The difference between the estimate and the actual amount has raised the suspicion of the National Audit Office, which is currently preparing a report of an assessment of auction outcomes, while taking into account the experience of other countries (UK, 2014).

8.2.4.2. Implementation of UHF Strategy to Release 700 MHz

As a result of the ITU World Radio Conference 2012, the ITU has allocated additional UHF spectrum to mobile services in the 694 MHz to 700 MHz frequency band in ITU Region 1.[17] This is expected to take place in 2015 and, in the meantime, the UK is releasing its mobile broadband to the 700 MHz band. Ofcom, in parallel, is ensuring that current users of the 700 MHz band—primarily digital terrestrial TV (DTT), as well as those of program-making and special events (PMSE)—will be able to continue to provide services in the event of this change. A call for public comment was made in April 2013 to assess the benefits of mobile broadband in the 700 MHz frequency band (Ofcom, 2013d).

[17] ITU Region 1 includes Europe, Africa, and parts of the Middle East.

No final decision has been taken to date at the international, European or UK levels with regard to the release of this frequency band. In fact, coordination at the international level will significantly influence this undertaking in terms of timing, usage, and the DTT band plan to be adopted. The procedure should be completed by 2018 at the earliest (Ofcom, 2013c).

8.2.4.3. Support the Release of 2.3 GHz and 3.4 GHz Bands

Since March 2011, the UK Government, through its Department for Culture, Media and Sport, announced its intention to release 500 MHz of public spectrum by 2020 (Government of the UK, 2011a)—below 5 GHz. As part of its plan, the Ministry of Defence (MoD), under its Defence Spectrum Reform, will open up some military spectrum bands to share with public and private users. The UK Government will release further spectrum in the 2,310–2,400 MHz and 3,410–3,600 MHz frequencies in 2013/14 and 2015/16, respectively (Government of the UK, 2011b).

In addition to the call for public comment, Ofcom requested a consultation concerning the award of licenses to use frequencies in the 2.3 GHz and 3.4 GHz frequency bands at the time the MoD released 190 MHz of radio spectrum in these bands to Ofcom for an award process. The spectrum being made available comprises:

- 2.3 GHz band: 40 MHz of spectrum between 2,350 MHz and 2,390 MHz.
- 3.4 GHz band: 150 MHz of spectrum above 3,410 MHz and below 3,600 MHz.

The principal license conditions proposed are the following:

- Initial license period of 20 years.
- Fully tradable, subject to Ofcom giving consent to trade prior to it being implemented.
- Requirement to provide general information regarding equipment and use of frequencies for the rollout of networks.
- No coverage obligations.

Ofcom considers that “spectrum is most useful if it can be as unencumbered as possible.” Its initial view was that such bands will be used to develop 4G networks, although other possibilities are under consideration. The regulatory authority is expecting to award this spectrum in FY2015–16.

Harmonization of the 2.3 GHz band is taking place in Europe, based on the ITU’s World Radio Conference 2007, which established the 2,300 MHz to 2,400 MHz band for use by IMT. In addition, the 3.4 GHz band has been allocated by the ITU for fixed, mobile, fixed satellite, and radiolocation services. Both bands are undergoing harmonization in Europe. With regard to the 2.3 GHz band, CEPT—through the ECC—is expected to issue a nonbinding agreement to make the band available for mobile and fixed communication. With regard to the 3.4 GHz band, the European Commission’s Radio Spectrum Committee considered the CEPT Report in December 2013 and the decision in March 2014, which is binding on Member States (Ofcom, 2013a).

8.2.4.4. Mobile Infrastructure Project

In October 2011, the UK announced the Mobile Infrastructure Project (MIP) with a £150 million capital expenditure to improve mobile coverage and quality. The project is managed by Broadband Delivery UK, a unit within the Department for Culture, Media and Sport. The objectives of MIP are to (i) improve the coverage and quality of mobile network services for the 5–10 per cent of consumers and businesses that live and work in areas of the UK where existing mobile network coverage is poor or nonexistent; and (ii) extend coverage to 99 per cent of the UK population. The project will be implemented in 2015 (Government of the UK, 2012) and already has the clearance of the European Commission.

The MIP is part of a larger plan of the UK Government to improve broadband in the country—evidence that, despite the high penetration of Internet, the UK Government is including the underserved. It is expected that the £150 million investment will deliver approximately £340 million in economic benefits by extending coverage to remote and rural areas across the country (Government of the UK, 2013b). Under the MIP, the Government will cover the OPEX—over a period of 20 years—of four mobile operators that provide coverage for certain areas. The program will also consider ways in which it can support the sharing of infrastructure among operators in lieu of installing four sets of equipment.

8.2.4.5. Unlicensed Spectrum Sharing

Another example of the shift towards a more flexible use of spectrum promoted by Ofcom is the diversification of bands of radio spectrum allowed in the UK for unlicensed use. These bands contain a variety of applications (e.g., telemetry, broadband wireless communications, and short-range radar and relays). The license-exempt frequency bands are 2.4 GHz; 5.1 GHz; 5.5 GHz; and 60 GHz (Government of the UK, 2011b).

BT Fon is an initiative between BT and FON to provide its clients with an innovative way to access wireless broadband globally in terms of TVWS. It has a network of 7 million Wi-Fi hotspot locations around the world (Deloitte, 2013) and the UK is one of the countries undertaking this process. The launch of the industry pilot project in Cambridge in June 2011 by a consortium of companies was completed in April 2012.[18] It was designed to evaluate the technical capabilities of the technology and the potential user application scenarios. The trial took ten months and included urban and rural areas in and around Cambridge. Based on the results, the consortium requested that Ofcom complete the development of its regulatory framework to enable the commercialization of the technology.

Ofcom's TV White Spaces Pilot, launched in October 2013, tested the interactions between devices, databases, and Ofcom. This provided an opportunity for the industry to (i) conduct further trials using the proposed framework; and (ii) gain further information on the extent of interference to DTT and PMSE[19] users.

The Ofcom pilot ended in March 2014. The purpose was to test (i) device operations; (ii) database contract qualification; (iii) database operation and calculations; (iv) the provision of Ofcom's qualifying database listing; (v) Ofcom's DTT calculation results and provision of PMSE data; and (vi) interference management. Under the current pilot scheme, there is no charge for services; however, a different license for charging may be granted by Ofcom on request.

More than 40 expressions of interest to receive a nonoperational pilot license (Ofcom, 2013e) were received. Ofcom will undertake tests to ensure that the proposed co-existence parameters will result in low interference to DTT and PMSE. To participate in the test, a master white space device must discover active qualifying white space database broadband by consulting a device-readable list provided by Ofcom (Caines, 2013). To ensure that there is no undue interference with existing spectrum users, the database will provide updated information on where the TVWS are and the level of power limits that the devices would be required for use.

8.2.5. *Analogue Switchoff/Digital Switchover*

Overview: Digital UK's Programme Office in partnership coordinated the switchoff process with various stakeholders, including government and

[18] The consortium includes Adaptrum Inc., Alcatel-Lucent, Arqiva, BBC, BSkyB, BT, Cambridge Consultants, CRFS, CSR Plc., Digital TV Group, Microsoft Corp., Neul, Nokia, Samsung, Spectrum Bridge Inc., The Technology Partnership Plc., and Virgin Media.

[19] Wireless cameras and wireless microphones are examples of PMSE.

broadcasters. Most of the spectrum used for analogue TV was set aside for DTT: 256 MHz from a total of 368 MHz.

Stakeholders: In addition to the UK Government, various stakeholders played a vital role during the transition process (e.g., UK broadcasters, operators of six digital multiplexes) with the establishment of a forum. A cross-industry agreement on the challenges of the switchoff was reached and, while not considered an easy process, it ultimately led to a smooth and successful transition. Digital UK coordinated the undertaking.

Subsidies: It is a challenge in any switchover process to include the most vulnerable and isolated populations. The UK Government, under an agreement with the BBC, initiated the Switchover Help Scheme from 2007 to 2012, which reached 1.3 million eligible people older than 75 years of age, as well as the disabled, during the transition.

Communications: A major communications strategy was put in place by way of a website (http://www.digitaluk.co.uk) for the public to inform them of the transition taking place in their respective areas. More than 60 million visits were made to the website. Viewers of TV were also informed via broadcast messages.

Regional approach: The transition was designed around the 15 regions and more than 1,150 transmitting stations were upgraded. The first switchover to digital TV took place in Whitehaven over a period of a month, including 25,000 households. The community outreach resulted in 23 million emails, 6 million phone calls, the engagement of 6,000 statutory organizations, and the recruitment of 100,000 community supporters (Government of, 2013a).

Auction: The transition to the 800 MHz and 2.6 GHz bands was completed in 2013. The five companies that received the awards were Everything Everywhere Ltd., Hutchison 3G UK Ltd., Niche Spectrum Ventures Ltd., Telefónica UK Ltd., and Vodafone Ltd. The auction included the following aspects:

- Technology and service neutrality.
- Rollout or coverage obligations in the new licenses.
- Coverage obligations.
- Spectrum caps: overall spectrum cap of 2 x 105 MHz and sub-1GHz spectrum cap of 2 x 27.5 MHz.

8.3. Australia

8.3.1. *Overview*

Australia has been shown to be significantly ahead in mobile broadband penetration. Table 10 shows that Australia also has a high penetration rate of advanced technologies.

Australia's mobile broadband penetration rates stands at 108.92 percent. This is reflected in Table 10 below.

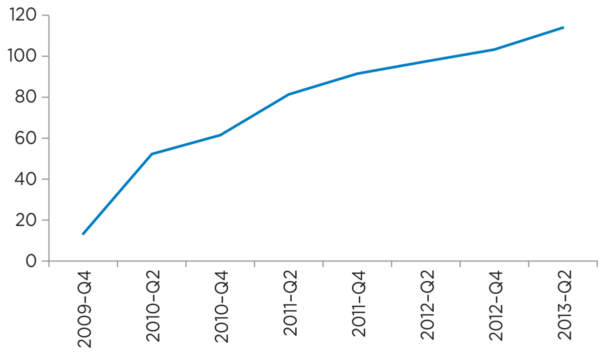
There are three mobile network carriers in Australia: Telstra, Optus, and Vodafone Hutchinson Australia, with 46 percent, 31 percent, and 23 percent, respectively. The share of the telecommunications industry revenue has recently increased, reaching more than 50 percent (Deloitte, 2013).

TABLE 10. Mobile Broadband Indicators: Australia, 2013

Indicator	
Market penetration – Mobile Broadband	108.92%
Market penetration – 3G	92.24%
Market penetration – 4G	16.69%
Market penetration – LTE	16.69%
OPEX/revenue, annual	75.43%
CAPEX/revenue, annual	11.69%

Source: Authors with data from GSMA (2013a).

FIGURE 11. Wireless Broadband Penetration Rates in Australia, 2009–13



Source: OECD Broadband statistics 2014 (OECD, 2014).

8.3.2. *Institutional, Policy, and Regulatory Frameworks*

In Australia, the authority responsible for managing the spectrum is the Australian Communications and Media Authority (ACMA), governed by the ACMA's Act of 2005 (Government of Australia, 2005), its Radiocommunications Act 1992, and its Broadcasting Services Act 1992. The key principles for its spectrum management are the following (Government of Australia, 2009):

- Allocate spectrum to the highest value usage.
- Enable and encourage spectrum to move to its highest value of usage.
- To the extent possible, promote both certainty and flexibility.
- Balance the cost of interference and the benefits of greater spectrum utilization.

The allocation of frequency bands occurs every few years. A new version was launched in 2013 in response to the ITU's World Radio Conference 2012 recommendations.

8.3.3. *Spectrum Availability*

Table 11, below, indicates the amount of spectrum allocated to mobile broadband. This is in spite of the fact that 478 MHz are allocated (Government of Australia, 2011):

TABLE 11. Available Licensed Spectrum Available for Mobile Broadband: Australia, 2013

Band	Allocation (in blocks)
Below 700 MHz	N/A
700 MHz	N/A
800 MHz	40
900 MHz	50
1,500 MHz	N/A
1,700/1,800 MHz	150
1,900 MHz	20
2.1 GHz	120
2.3 GHz	98
2.6 GHz	N/A
TOTAL	478

Source: Authors, with data from FCC (2013h).

Despite the allocated 478 MHz, it is estimated that Australia has located an additional 130 MHz–150 MHz of spectrum to support mobile access services by 2015, supplemented by 150 MHz by 2020. The ACMA has determined several possible bands, as follows:

- 850 MHz expansion band.
- 1.5 GHz mobile band.
- 3.3 GHz band (3,300–3,400 MHz).
- 3.4 GHz band (3,400–3,600 MHz).
- Bands above 4.2 GHz have not yet been identified but might be an option in the near future.

8.3.4. *Innovative Policies*

The Australian Government bases its policy decisions and regulatory interventions on a total welfare standard. Whenever regulatory options are evaluated, "the benefits to the community of the recommended option exceed its costs and have the greatest net benefits (benefits minus costs) to the community of all alternative approaches considered" (Australia, 2007). A total welfare standard requires that, to the extent possible, (i) all significant benefits and costs arising from the regulatory proposal will be given the same weight, regardless of the identity of the recipient; and (ii) the approach expected to generate the greatest net benefits is the preferred approach (Government of Australia, 2008). Despite possible antitrust issues, the ACMA has taken this approach with the result that wireless penetration has proved to be significantly successful.

The licensing regime adopted in Australia relates to three categories: (i) apparatus licensing; (ii) spectrum licensing; and (iii) class licensing, the last of which corresponds to the unlicensed approach used in other countries. Spectrum licensing has a market-based approach and is normally issued following a price-based distribution. Spectrum licenses are issued as a property right and a means to manage interference. There is evidence that these have been successful to "provide a workable compromise between maximizing flexibility and certainty in usage, channeling spectrum supply toward market demand and minimizing the need for ex post regulatory intervention" (Saeed and Shellhammer, 2012). The licenses are technology neutral, but the degree of service neutrality varies depending on the band.

8.3.4.1. Spectrum Trading and Sharing

Spectrum licenses can be traded. Some of the bands, however, are underutilized (e.g., 500 MHz, 2.3 GHz, 27 GHz), and a portion of the valuable spaces (e.g., 800 MHz and 3.4 GHz) is being traded at a suboptimal level (Saeed and Shellhammer, 2012).

The issuance of a class license is a distinct way in which to minimalize the operational conditions of the spectrum, which are not tailored to specific users. Aeronautical mobile stations, citizen band radio stations, and cordless communications systems, among others, instead, use these. The ACMA is looking at ways in which to facilitate increased access to shared spectrum and it plans to engage with industry players as further technical and regulatory developments are explored.

The ACMA views the development and deployment of Dynamic Spectrum Access "as evolutionary rather than revolutionary" and that "arrangements to address spectrum management issues associated with these technologies will be the subject of further work by the authority". It also considers that TVWS cannot yet be regulated. Nevertheless, the Australian Parliament has agreed to amend the legislation to allow class licenses within the spectrum's licensed spaces to enable usage of TVWS (Saeed and Shellhammer, 2012).

In any event, some wireless devices licensed under the class license use TVWS. These devices include radio microphones, biomedical telemetry transmitters, and transmitters used for underground communications. The technologies are categorized as potentially low-interference devices.

8.3.4.2. Infrastructure Sharing

Further developments have recently taken place with regard to infrastructure sharing, since various stakeholders are interested in deploying wireless networks within a large geographic area. As a result, the ACMA is considering an area-wide license for the mining and transport sectors and other entities, with a trial private park arrangement in a designated location. The trial is to see whether participants can be given the opportunity to test the equipment and technologies, as well as to determine whether spectrum sharing and coordination agreements can be negotiated between industry players in close geographic proximity within the framework of the private park.

8.3.5. *Analogue Switchoff/Digital Switchover*

Overview: The switchoff process on the 694–820 MHz band was challenging because of the prevalence of DTT channels on that band. It took time to move them to below channel 52, following the analogue switchoff. The process was completed in December 2013, but the task of restacking the channels was completed in 2014. The project amounted to US$37.9 million in addition to the subsidies indicated below.

Communications: A communications strategy was formulated. A website was also created (http://www.digitalready.gov.au/).

Regional approach: A region-by-region timetable was put in place. This was considered, rather than one based on license areas.

Coordination: The Australian Government established the Digital Switchover Taskforce within the Department of Broadband, Communications and the Digital Economy with an allocation of US$16.9 million. In addition, a Digital Switchover Liaison Officer Program was created to fund non-profit organizations or government entities within each of the switchover regions to develop and implement a community engagement strategy, designed to help viewers in those regions transfer to digital TV.

Subsidies: The Household Assistance Scheme was designed to provide practical assistance to older Australians, veterans, and people with disabilities. The Satellite Subsidy Scheme provides a subsidy for the installation of the equipment for populations in areas that are reliant on analogue retransmission services from a self-help TV tower not converted to digital. Moreover, funding for the private sector was provided in FY2012–13 up to the amount of US$143.2 million over five years and up to US$26.578 million in FY2013–14. These subsidies are for commercial and national broadcasters to restack the digital TV service channels. Restacking involves changing the frequencies of approximately 1,500 national and commercial digital TV channels across Australia at approximately 440 transmission sites.

Auction: Auctions of the digital dividend in the 700 MHz band and the 2.5 GHz band were conducted in April and May 2013. This has resulted in total revenues of US$2 billion for the Federal Government from three winners. Companies are expected to begin to be able to use LTE 4G networks in 2015. The main aspects of the auctions were:

- A spectrum cap was established and a single bidder could not acquire more than 2Ð25 MHz (50 MHz in total) in the 700 MHz band and more than 2Ð40 MHz (80 MHz in total) in the 2.5 GHz band. This cap was informed by advice from the Australian Competition and Consumer Commission.
- Applications for licenses for the 700 MHz band began on January 1, 2015. In most cases, applications for the 2.5 GHz band commenced on October 1, 2014.
- Bidders are allowed to bid for any combination (or package) of the spectrum on offer that is best suited to their business requirements.
- The auction raised AU$929 million less than expected, and 30 MHz in the 700 MHz frequency band remains unsold.

8.4. Germany

8.4.1. *Overview*

As shown in Table 12, Germany has a very high percentage of mobile connection. Its mobile broadband penetration, however, is lower than those of the UK and the United States. The table also indicates a high CAPEX and OPEX.

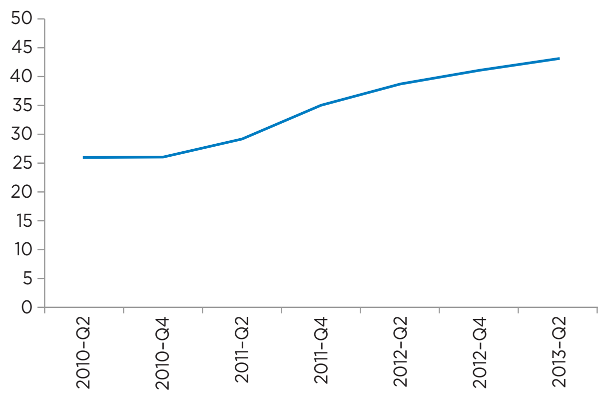
Germany is a sound market with five operators: E-Plus, Netcologne, O2 (Telefonica), Telekom, and Vodafone. In terms of investment and despite the low levels of CAPEX over the past decade in Europe, Deutsche Telekom AG will increase capital expenditure by approximately 10 billion Euros over the next three years (Musey, 2013). Such an

TABLE 12. Broadband Mobile Indicators: Germany, 2013

Indicator	
Population	82.8M
GNI/capita	$43,980
Connections	113.2M
Market penetration – Mobile Broadband	63.06%
Market penetration – 3G	66.44%
Market penetration – 4G	3.49%
Market penetration – LTE	3.49%
OPEX/revenue, annual	85.12%
CAPEX/revenue, annual	18.16%
Herfindahl-Hirschman Index	2,649

Source: Authors with data from GSMA (2013a).

FIGURE 12. Wireless Broadband Penetration Rates in Germany: 2010–2013



Source: OECD (2014).

increase in CAPEX offers the potential for spectral efficiency gains and increase in penetration.

The target for broadband speed will be a minimum of 50 Mpbs by 2014. This will be available for 75 percent of households nationwide by 2018 (Government of Germany, 2012).

8.4.2. *Institutional and Regulatory Frameworks*

In Germany, the Federal Network Agency (Bundesnetzagentur (BNetzA)) is responsible for the regulation of the electricity, gas, telecommunications, post, and railway sectors. It falls under the scope of the Federal Ministry of Economics and Technology.

The mandate of the BNetzA is to (i) promote effective competition and efficient infrastructure to secure nondiscriminatory network access; (ii) guarantee compliance with statutory requirements for universal service throughout the Federal Republic of Germany; and (iii) manage the spectrum, including frequency planning and distribution and the collection of spectrum fees, as well as standardization and numbering. The Telecommunications Act, Radio Equipment and Telecommunications Terminal Equipment Act, Amateur Radio Act, and Electromagnetic Compatibility of Equipment Act established these responsibilities.

The Telecommunications Act created a framework in which to structure a more flexible system of spectrum regulation. Sections 1 and 2 of this Act include the principles of technology neutrality, promotion of competition, and efficient infrastructure in telecommunications and the guarantee of appropriate and adequate services throughout the country.

The German Federal Council (Bundesrat)–a part of the advisory council of the BNetzA–represents Germany's sixteen federal states and stands in for them in national legislative and administrative processes. In some cases, however, the decisions of Bundesrat are not aligned with those of the BNetzA (Standeford, 2013).

With regard to TV broadcasting, each federal state has its own authority, which could be a challenge in terms of policy and regulatory discussions on the use of frequencies. As an example, while the digital switchover process was successful, it was difficult to coordinate the various state administrations. This should be taken into account with respect to TVWS, which use the same bands.

8.4.3. *Spectrum Availability*

Germany is a leader of spectrum dedicated to mobile broadband. Table 13 shows the bands that have been allocated for this.

TABLE 13. Licensed Spectrum Available for Mobile Broadband: Germany, 2013

Band	Allocation (in blocks)
Below 700 Mhz	N/A
700 MHz	N/A
800 MHz	60
900 MHz	70
1,500 MHz	N/A
1,700/1,800 MHz	140
1,900 MHz	35
2.1 GHz	120
2.3 GHz	N/A
2.6 GHz	190
TOTAL	615

Source: Authors, with data from FCC (2013h).
Note: N/A = not available.

Despite having allocated the amount of spectrum reflected in Table 13 to mobile broadband, the country is still seeking ways in which to satisfy the rapid increase in the demand for broadband. The Federal Government's Broadband Strategy, launched in 2009, included the allocation of new spectrum among its priorities.

8.4.4. *Innovative Policies*

Germany is in its initial stages of considering a second digital dividend that would create another large band of low frequency spectrum. This decision follows the decision at the ITU's World Radio Conference 2012 to allocate additional UHF spectrum to mobile services in ITU Region 1. Germany thus will allocate frequencies to the 700MHz spectrum used by broadcasters as follows:

- It is expected to award spectrum in the 900 MHz, 1,800 MHz, 700 MHz, and 1,452 MHz-1,492 MHz (1.5 GHz) bands for wireless access.
- The BNetzA is deciding on the future allocation of spectrum licenses of the 900 MHz and 1,800 MHz bands, which will expire in 2016, in addition to the allocation of the bands for mobile broadband.

In 2009, the BNetzA decided to make flexible the frequency usage rights for wireless access in terms of application and technology for telecommunications services in the 450 MHz, 900 MHz, 1,800 MHz, 2 GHz, and 3.5 GHz frequency bands. A study was commissioned in 2005 and based on this, the BNetzA has harmonized the approach for flexible frequency regulation.

TVWSs are under way in Germany, similar to the trials being undertaken in the UK, the United States (Consortium, 2012), and other countries. A recent study estimates that Germany has the highest market potential for TVWS in Europe, followed by France, Italy, and the UK (Saeed and Shellhammer, 2012). As previously indicated, Germany does not have a sole authority to deal with broadcasting—highlighted in the study as a reason for the delay in the deployment of TVWS.

Unlicensed use of spectrum is a well-known resource for broadband access, and Germany has one of the highest penetrations of Wi-Fi in households in the world (Marcus and Burns, 2013), using the following frequencies: 2,400.0 MHz–2,483.5 MHz; 5,150 MHz–5,350 MHz; and 5,470 MHz–5,725 MHz. The use of Wi-Fi as a way to offload mobile data is becoming increasingly relevant in Germany.[20]

8.4.5. *Analogue Switchoff/Digital Switchover*

Overview: Cable and satellite reception are extensive in Germany, so analogue terrestrial TV has played a limited role, facilitating the simulcast at the time the digital transition took place on a

[20] Deutsche Telekom is building up its Wi-Fi offering, while continuing with its LTE rollout for 85 percent coverage across Germany by the end of 2016. In partnership with FON, it is expected that more than 2.5 million additional hotspots will be available.

regional basis. The transition, begun in 2002, was completed in April 2012.

Market dominated by cable: The German TV market has been dominated by cable. From 36.2 million households, only 2.6 million rely on terrestrial TV, with cable penetration higher at 20.6 million households, followed by satellite at 13 million homes (Government of the UK, 2006). As such, the transition to digital in Germany has affected fewer people in comparison to most countries.

Regional approach: The switchover process was undertaken on a regional basis, aggregated in large conurbations. The process was launched in Berlin in October 2002 with a legislative framework in place and was completed in 2003. Other large urban areas with high population densities followed suit. Commercial TV ceased analogue transmission in 2005 and, in 2008, the last public service broadcasts were transmitted over analogue capacities.

Coordination: Government entities were responsible for coordinating the terrestrial broadcasters in each region, bringing together key stakeholders for communication campaigns. In Berlin, for example, the Media Institute Berlin-Brandenburg (Medienanstalt Berlin-Brandenburg (MABB)) undertook this role. In 2002, MABB signed an agreement with broadcasters to complete the switchover and by the end of 2003, all commercial channels, including public service channels, had been switched off.

Communications Strategy: A neutral communications strategy to raise the awareness of the population regarding the transition was implemented. Consumers of satellite and cable were unsure whether to make the change or whether it applied to them (MABB, 2009). The principal outlets for the communication campaign were the TV channels and a letter that was sent to households, while MABB partnered with tenant associations and consumer interest groups. The cost for the communication initiative was 1.1 million Euros, borne jointly by the broadcasters and MABB (MABB, 2003).

Auction: The German auction of May 2010, assigning 60 MHz in the 800 MHz band, raised proceeds of EUR 3.57 billion, or EUR 60 million per MHz. It resulted in four winners: Telekom with 95 MHz; Vodafone with 95 MHz; E-Plus with 70 MHz; and Telefonica O2 with 99 MHz. One player was left out without a share of the 800MHz spectrum. The objectives of the auction were as follows:

- Technology and service neutrality.
- Coverage obligations: 800MHz licensees obliged to roll out to rural areas before rolling out to urban areas.
- Spectrum caps.

9

Spectrum Management in LAC Countries: Current Status and Key Challenges

Countries in the LAC region differ from other countries in relation to broadband access, use, and adoption. Despite the disparities between and within countries, the region faces a widespread increase in mobile-cellular penetration. In 2011 alone, more than 30 million mobile broadband subscriptions were issued in the LAC region (ITU, 2012). By the end of the same year, penetration surpassed 100 percent and 20 of the 33 countries in the region had more subscriptions than inhabitants (ITU, 2012).

Accelerating broadband deployment and services in LAC is essential to achieve the benefits associated with the development of the Internet. Economic growth is one of the most important impacts, and has been closely correlated to broadband penetration. A recent study, conducted by the IDB, found that an average of 10 percent increase in penetration was associated with a 3.19 percent increase in GDP in the region, 2.61% increase in productivity, and 67,016 new jobs (García-Zaballos and López-Rivas, 2012).

Following the trend observed in developed economies, LAC countries have commenced developing national broadband plans to improve access to Internet high-speed connection. They have set targets, encouraged private investment, and promoted broadband Internet access to consumers and businesses (OECD, 2011). Many of these plans include guidelines on how the electromagnetic spectrum should be managed in upcoming years and they set the goals to promote access, including in terms of speed and coverage. Table 14 below illustrates some of these plans in selected LAC countries.

Regardless of recent improvements, broadband penetration in the LAC region remains one of the lowest in the world. On the demand side, access is limited by economic constraints (e.g., low income and high access fees). The limitation relates to usage disparities. Those subscribers (1.0 percent) who use network resources the most account for 28.1 percent of upstream, 28.0 percent of downstream, and 28.8 percent of aggregate bytes each month (Sandvine, 2013). On the supply side, the lack of an adequate regulatory framework constrains the participation of potential service providers.

TABLE 14. Projected Smartphone Usage Growth in Latin America, 2012–17

	2012	2013	2014	2015	2016	2017
Mexico	103.0%	48.2%	22.4%	21.4%	17.0%	15.1%
Brazil	70.8%	40.2%	36.0%	27.0%	16.0%	16.1%
Argentina	46.3%	29.4%	22.7%	16.4%	12.1%	10.8%
Other	64.4%	51.5%	27.9%	25.4%	18.6%	14.8%
Latin America	71.1%	45.3%	28.3%	24.1%	17.0%	14.9%

Source: eMarketer (2014).

A study undertaken by Galperin (2013) found that, on average, the relative effort that LAC mobile broadband users have to make so as to afford the same service package is six times greater than in OECD countries, ranging from US$30 in Brazil to US$4 in Costa Rica. Despite these limitations, the affordability of broadband has improved over the past years. Galperin (2013) also discovered the following:

- To access a broadband connection in LAC, the minimum expenditure by household has dropped to an annual rate of 4 percent between 2010 and 2013.
- Half of the countries in the region are spending less than 2 percent per capita income on broadband access.
- Mobile access is helping the region achieve universality, despite low-income populations having access to plans with low data caps.

Internet penetration has tended to favor mobile access, mainly due to real-time entertainment, accounting for 29.0 percent of peak downstream (Sandvine, 2013). A trend that is taking place in various markets is the differentiation of applications, where access is limited to a certain variety, such as social networks and content portals (Galperin, 2013).

Under current growth rates, the number of mobile broadband subscriptions is expected to reach twice the number of fixed subscriptions in the next few years (García-Zaballos and López-Rivas, 2012). Broadband operators require additional spectrum for mobile technologies, setting the stage for effective spectrum management, and strategic regulation if countries are to succeed in lowering service costs and progress towards universality of broadband services.

9.1. Mobile Data Traffic and Connection Broadband in LAC

The LAC region has experienced a steep rise in mobile connections throughout the past few years, with 164 million subscribers as of June 2013. This number is expected to grow by 30 percent annually over the next five years (GSMA, 2013a). Smartphone penetration will be close to 20 percent of the population at the end of 2013, and is expected to rise to 44 percent by 2017 (GSMA, 2013a).

Moreover, by 2015, approximately 44 percent of Latin American subscribers may use smartphones (GSMA, 2013a). On the other hand, data traffic will grow at a slower pace than in other regions, excluding mature economies. This suggests that LAC countries are not taking full advantage of improved Internet infrastructure.

Mobile usage is a key to economic growth in LAC and, according to GSMA, will contribute to the following:

- Generate over 3.7 percent of the region's GDP in 2012, with an expected increase of 4.5 percent by 2020.
- Support over 350,000 direct jobs.

TABLE 15. Broadband Access Initiatives[a, b, c]

Country	Program (launch)	Estimated investment	Main goals	Other characteristics
Argentina	Plan Nacional de Telecomunica-ciones Argentina Conectada (2010)	• ARS$8 billion, of which ARS$3.7 billion will be allocated for fiberoptics backbone	• Cover 97 percent of the total population by 2015 • Expand coverage and improve broadband access services, especially in areas underserved by the private sector	• National Fiberoptics network of 50,000 km • Digital Inclusion through public access points and capacity building (Núcleos de Acceso al Conocimiento y Puntos de Acceso Digital)
Brazil[d]	Plano Nacional de Banda (2010)	R$12.8 billion[e]	• 40 million households by 2014 • Minimum speed of 1 Mbps	• South-American fiber optical ring (part of UNASUR initiative) • Backbone of 23 km administered by Telebras • 2.5 GHz for 4G • 250 MHz for mobile phone and broadband • Regulation and infrastructure standards • Tax incentives • Productivity and technology policies • National backbone network
Chile	Todo Chile Comunicado (2010)	US$110 million	• By 2011, to provide Internet access to 3 million rural households • By 2014, 100 percent of school and 70 percent of households to have broadband • By 2018, 100 percent of households to have broadband	• Fund of Telecommunications Development, created to promote access to undeserved rural areas • US$30 a month, 1 Mbps • Law No. 20.453 enshrines the principle of net neutrality for consumers and Internet users
Colombia	Plan Vive Digital (2010)	COP$415 million (approx. US$237 million)	• In five years, triple number of municipalities connected, connect 50 percent of SMEs and households, and quadruple Internet connection (reaching 8.8 million in 2014) • Expand fiber optics coverage to 62 percent of all municipalities (90 percent of population)	• Creation of a legal regulatory framework for convergence

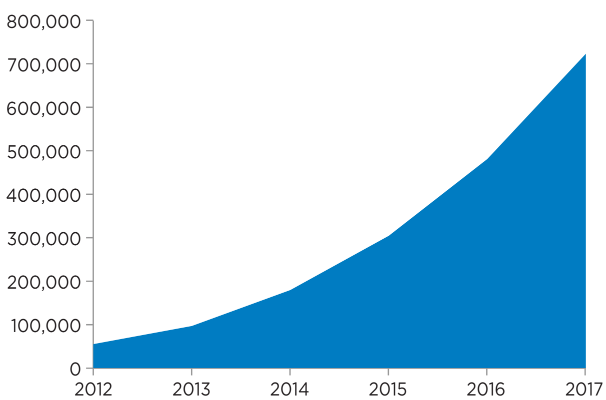
(continued on next page)

TABLE 15. Broadband Access Initiatives[a, b, c] *(continued)*

Country	Program (launch)	Estimated investment	Main goals	Other characteristics
Mexico	Acciones para el Fortalecimiento de la Banda Ancha (2012)	N/A	• Incentivize telecom services through public and private investment in infrastructure • By 2012, 22 percent broadband penetration.	• Broadband access set as a national priority in Digital Agenda • Design of a National Broadband Plan under development with IDB
Peru	Plan Nacional para el Desarrollo de la Banda Ancha en el Perú (2011)	N/A	• In 6 years, 100 percent of municipalities and main rural areas with broadband connection of 2 Mbps • 4 million connections, of which 5 million at 4 Mbps	

Source: Authors' elaboration.
[a] See Galperin, Mariscal, and Viecens (2012).
[b] See Katz (2012).
[c] See OECD (2011).
[d] See Brazil. (2013).
[e] See G1. (2011).

FIGURE 13. Mobile Data Traffic in LAC, 2012–2017



Source: Authors, with data from Cisco (2013).

- Contribute to over US$39 billion to public funding in Latin America (GSMA, 2013a)

In 2012, 4G connection (including WiMAX and LTE technologies) generated almost 20 times more traffic than non-4G connection, even though the former represents less than 1 percent of total connections (Cisco, 2013). Table 16 shows a growing rate of connection, although it is still limited in comparison to other regions and it is below the global average.

It is estimated that by 2017, 4G penetration in Latin America will be one third and one fifth of those achieved in Western Europe and North America, respectively (Cisco, 2013).

9.2. Spectrum Management in LAC

9.2.1. *Institutional, Policy, and Regulatory Frameworks*

The TRGI, developed by Waverman and Koutroumpis (2011), is a global index that includes countries in the LAC region. It assesses (i) regulatory transparency, (ii) independence, (iii) resource availability, (iv) license enforcement, and (v) per capita income. The global and regional rankings for the Americas are shown in Table 17.

As shown in the table above, countries in LAC vary widely with regard to global ranking. While Chile, Costa Rica, Panama, and various other

TABLE 16. Estimate of Regional 4G Connections

Region	Number of 4G connections 2012	Percent of total connections	Number of 4G connections 2017	Percent of total connections
Middle East and Africa	168,536	0.00%	28,437,977	2%
Central and Eastern Europe	903,123	0.20%	50,913,035	6%
Latin America	326,212	0.00%	51,772,961	6%
Asia Pacific	24,143,897	0.70%	425,094,836	8%
North America	31,329,522	6.80%	264,618,277	31%
Western Europe	3,544,454	0.60%	171,013,933	18%
Global	*60,415,743*	*0.90%*	*991,851,020*	*10%*

Source: Cisco (2013).

TABLE 17. Telecommunications Regulatory Governance Index: Ranking of the Americas versus Australia, Canada, Germany, and UK

Country	Score	Americas Regional Rank	Global Rank (out of 140)
Germany	**0.71**	**—**	**2**
United States	**0.7**	**1**	**3**
U.K.	**0.65**	**—**	**7**
Canada	0.65	2	7
Australia	**0.63**	**—**	**10**
Costa Rica	0.53	3	27
Panama	0.52	4	28
Chile	0.51	5	29
St. Vincent and the Grenadines	0.5	6	31
Peru	0.49	7	34
Jamaica	0.49	7	34
Dominican Republic	0.47	9	43
Brazil	0.46	10	45
Bahamas	0.46	10	45
Argentina	0.45	12	54
Nicaragua	0.45	12	54
Barbados	0.44	14	59
Colombia	0.42	15	68
Ecuador	0.4	16	78
Trinidad and Tobago	0.4	16	78
Uruguay	0.39	18	85
Venezuela	0.37	19	93
Paraguay	0.36	20	96
El Salvador	0.35	21	98
Mexico	0.34	22	101
Haiti	0.33	23	104
Bolivia	0.29	24	112

Source: Waverman and Koutroumpis (2011).

countries are classified as relatively good, overall, others such as Bolivia, Haiti and Mexico score poorly.

Another study, undertaken by Montoya and Francesc (2007), includes an analysis of the regulatory independence of countries in LAC over time. The conclusion is that countries in the region are benefiting from growing regulatory independence with a positive impact on fixed line penetration rates.

Despite this overall progress, the region faces many institutional challenges. Afonso and Valente (2010) indicate that spectrum awards in Brazil often lack transparency—a reality that exists in other countries in the region in addition to the challenges of independence and coordination with other agencies.

In terms of spectrum policies, LAC countries are considered to be fairly conservative. The Hazlett and Muñoz (2009) study shows that in 2006, the regulatory authorities in most countries constrained access to spectrum, not only due to rigid regulatory schemes in place but also due to significant restriction on bandwidth. This restriction could reflect a lack of demand, although such was not the case, since demand will increase seven-fold by 2017, as indicated above. The efficiency of networks and services can only be achieved by the sensible deployment, allocation, and assignment of spectrum.

In the LAC region, the 850 MHz and 1.9 GHz spectrum bands have been assigned to most markets. Eight of them have been assigned the 900 MHz band; nine have tenders for AWS 1.7/2.1 GHz spectrum bands (1,710–1,755 MHz matched with 2,110–2,155 MHz); and three have completed the allocation of 2.5 GHz (2,500 MHz to 2,690 MHz) spectrum for the provision of mobile wireless services (4G Americas, 2013).

Hazlett and Muñoz (2009) discovered that higher spectrum allocations are directly linked to lower average prices for services. LAC countries, however, are far from the spectrum recommended by the ITU. The ITU report (ITU, 2006) on spectrum bandwidth requirements estimates that the minimum spectrum bandwidth requirement for the Radio Access Techniques Groups (RATG1 and RATG2) for 2015 and 2020 are 1,300 MHz and 1,280 MHz, respectively, with regard to International Mobile Telecommunications-2000 and International Mobile Telecommunications-Advanced (ITU, 2006). To date, LAC countries are far from reaching this goal. Brazil, Chile, and Colombia have achieved 30 percent; Costa Rica, Nicaragua, Puerto Rico, Peru, and Uruguay, 20 percent; and the other countries, between 10 percent and 20 percent (4G Americas, 2013). Table 18 provides a summary of how countries in the region have allocated their bands.

Opportunities for additional sources of spectrum exist, as indicated above. The 1.7/2.1 GHz band, used for advanced wireless services (AWS) to provide mobile voice and data services, video, and messaging, is assigned in several countries, although many are still outstanding. Furthermore, the 2.5 GHz (2,500–2,690 MHz) frequency

TABLE 18. Current Spectrum Usage in Latin America and the Caribbean

450 MHz	• Multiple uses: Rural, fixed, mobile telephony, public and private safety, point-to-point and point-to-multipoint distribution services
700 MHz	• Broadcasting services – TV • Planned for TV broadcasting, fixed and mobile services
850/900/1,800/ 1,900/2,100 MHz	• Mobile services
1700/2100 MHz	• Advanced wireless services (AWS)
2,500/2,690 MHz	• TV and MMDS services • Assigned to mobile services since 2010
3,400/3,600 MHz	• Fixed services • Point-to-point and point-to-multipoint distribution services

Source: Authors, with data from Rojas (2012).

band is only used by Brazil, Chile, and Colombia. Refarming frequency bands (e.g., 2.5 GHz band) is expected to occur in various LAC countries for mobile wireless services.

The fact that all bands have not been allocated is not the only factor constraining wireless broadband in the LAC region. A further issue is spectrum hoarding—the underutilization of spectrum by operators holding licenses. This creates an artificial shortage of spectrum and this needs to be addressed.

9.3. Analogue Switchoff/Digital Switchover

In the case of the Americas (ITU Region 2),[22] World Radio Conference 2007 determined the 698 MHz–806 MHz (700 MHz) frequency band, which are typically under-utilized in most countries in the region. It proposed the freeing up of this band for IMT.

In 2011, GSMA commissioned a report to evaluate the impact of this transition in Latin America. The scope was limited to the 700 MHz band (upper segment of UHF), currently allocated for TV broadcast. The report contends that the economic and social impacts are in favor of the 700 MHz band for mobile broadband, which would contribute to the following:

- Increase coverage by 31.5 percent.
- Generate between US$11.7 billion and US$14.8 billion from the acquisition of goods and services.
- A seven-fold rise in the direct (additional revenues of the industry) and indirect (positive externalities) contributions to GDP, amounting to US$3.1 billion, and the addition of 5,540 jobs compared to TV broadcasting.
- An increase in annual tax collection over a period of eight years to US$325 million—more than four times that which is expected in the absence of mobile broadband.

TABLE 19. Amounts Related to the Award of the 700 MHz in Selected Countries in Latin America and the Caribbean

Country	Price (US$)	Band
Argentina	2.23 billion	700 MHz and AWS (1.7–2.1 GHz) bands
Brazil	2.39 billion	700 MHz
Bolivia	23 million	700 MHz
Chile	250 million	700 MHz
Honduras	31.5 million	700 MHz

Source: Authors.

- A consumer surplus of US$645 million, measured in terms of the difference between willingness to pay and the price paid for a good or service (GSMA, 2011).

It is expected that prices will differ during the auctioning process of the digital dividend bands in the region (see Table 19).

9.4. Band Plan Options for Latin America and the Caribbean

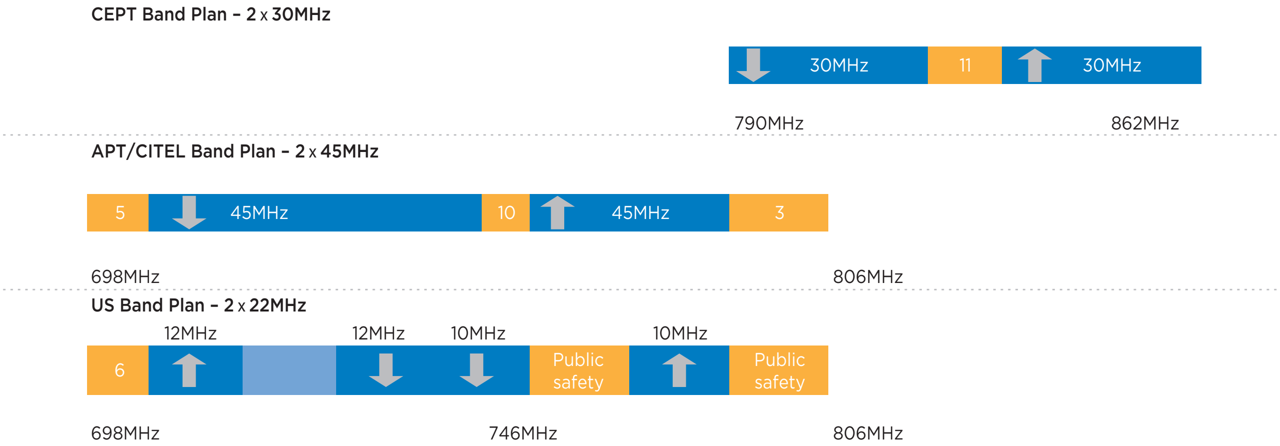
While the ITU has set the guidelines for transition, countries nevertheless have considerable flexibility to establish national policy to include the recommendations of the ITU-R framework. The band plan alternatives for the LAC region are described below.

9.4.1. *APT/CITEL*

In September 2010, the Asia Pacific region, through APT, adopted a band plan where the 700 MHz frequency for Region 3 was allocated to expand mobile services as a result of the digital dividend. In terms of harmonization, the plan was designed with the three following principles: efficient usage of the spectrum, maximum spectrum block size, and appropriate protective measures for services

[21] For a list of ITU BDT Regions and Region 2, see ITU (2013).

FIGURE 14. Band Plans for the Digital Dividend



Source: GSMA (2013b).

in adjacent bands (APT, 2010). The FDD mode, which is the focus of the APT band plan, establishes two bands of 45 MHz and includes a 10 MHz center-band gap. CITEL approved a plan with similar FDD segmentation for Region 2, specifically for the 700 MHz band for broadband mobile services (OAS, 2011).[23]

9.4.2. *U.S. Band Plan*

In the United States, the digital dividend has accelerated since the Digital Television Transition and Public Safety Act of 2005 (DTV Act) was passed. The deadline date established was February 17, 2009, for transition (FCC, 2007).

The 700 MHz band was freed up as a result of the analogue switchoff. It is divided into three segments: a broadband (763 MHz-768 MHz/793 MHz-798 MHz), a narrowband (769 MHz-775 MHz/799 MHz-805 MHz), and a 1-MHz guard band to minimize interference between them (FCC, 2013a). The FCC has divided the 700 MHz into two parts that are treated independently. In both the upper and lower portions, two paired blocks of 11 MHz have been made available for mobile broadband commercial use. Figure 14 shows the main band plans adopted in different regions.

The LAC region appears to lean towards harmonization around the APT band plan, with the exclusion of Ecuador and Bolivia. Those that are committed to APT include Brazil, Chile, Colombia, Costa Rica, Mexico, Panama, and Venezuela, while Argentina, Peru, and Uruguay are likely to follow suit (GSMA, 2013b).

As mentioned, the use of the same band plan at the regional level is advantageous. Harmonization across the region by adopting the APT band plan will contribute to economies of scale, lower the cost of mobile devices and network equipment, reduce interference along borders, and allow for international roaming.

9.5. Spectrum Caps

Spectrum caps, as previously indicated, are an ex ante measure to prevent a monopoly of spectrum, which could cause market failure. There are different approaches to spectrum caps in LAC. As indicated in Table 20, some countries impose spectrum caps, while some do not, with the total cap varying from 50 MHz to 115 MHz (4G Americas,

[22] The less commonly used Time Division Duplexing (TDD) segmentation option was also approved by APT and CITEL.

2013). Colombia and Peru have band-specific and cumulative caps and in Brazil, the cap excludes the 450 MHz and 2.5 GHz. There is a strong presence of state-owned operators in various countries, with the state having allocated between 30 MHz and 130 MHz in Argentina, Bolivia, Costa Rica, Ecuador, Honduras, Paraguay, Uruguay and Venezuela (4G Americas, 2013). In the case of Ecuador, for example, spectrum caps do not apply for its state-owned operation, the National Telecommunications Corporation (Corporación Nacional de Telecomunicaciones) (4G Americas, 2013).

In September 2013, Jamaica created an Aggregate Spectrum Cap Policy in the 700 MHz, 850 MHz, 900 MHz, 1,800 MHz and 1,900 MHz bands, totaling 80 MHz. The decision to implement caps does not imply that the operator is denied the opportunity to enhance network services, since 4G services can be deployed in bands that are not included in the aggregate cap calculation (Government of Jamaica, 2013).

9.6. Neutrality

Regulators and administrators should promote, to the extent possible, their technology and service neutrality to ensure an optimal level of service quality and to foster innovation in a constantly changing market. LAC countries still have disparate approaches towards neutrality and most

TABLE 20. Latin America's Mobile Spectrum Cap

Country	Spectrum cap	Comments
Argentina	50 MHz	Spectrum currently allocated
Bolivia	None	Spectrum currently allocated
Brazil	85 MHz	Excludes 450 MHz or 2.5 GHz (MMDS, WiMAX, LTE)
Chile	60 MHz	Only applies for AWS spectrum in combination with 850 MHz & 1.9 GHz
Colombia	115 MHz (85 MHz + 30 MHz)	85 MHz for > 1 GHz & 30 MHz for < 1 GHz
Costa Rica	None	Spectrum currently allocated
Dominican Republic	None	For AWS 40 Mhz
Ecuador	65 MHz	Does not apply to state-owned operator AWS or 700 MHz spectrum
El Salvador	None	Spectrum currently allocated
Guatemala	None	Spectrum currently allocated
Honduras	None	Spectrum currently allocated
Mexico	80 MHz	Spectrum currently allocated
Nicaragua	None	Spectrum currently allocated
Panama	None	Spectrum currently allocated
Paraguay	None	Spectrum currently allocated
Peru	100 MHz (40 MHz + 60 MHz)	60 MHz for 800 MHz, 900 MHz & 1,900 MHz and 40 MHz for 1.7 GHz/ 2.1 GHz
Puerto Rico	None	Spectrum currently allocated
Uruguay	None	Spectrum currently allocated
Venezuela	None	Spectrum currently allocated

Source: Authors, with inputs from 4G Americas (2013).

maintain service-specific licensing arrangements. The ITU Connect Americas 2012 report (ITU, 2012) indicates, nevertheless, that some nations in LAC have, indeed, adopted a unified licensing system, reflected in Table 21.

TABLE 21. Service Neutrality of Licensing Arrangements in Latin America and the Caribbean

Service-Specific Licensing	Unified Licensing
Barbados	Argentina
Brazil	Bahamas
Chile	Colombia
Cuba	Costa Rica
Dominican Republic	Honduras
Ecuador	Peru
El Salvador	Trinindad & Tobago
Grenada	
Guyana	
Jamaica	
Mexico	
Panama	
Paraguay	
Venezuela	

Source: ITU (2012).

Endeavors in Argentina, Colombia, and Peru are in place to adopt technology and service neutral licensing frameworks throughout the region. Details of this are outlined in Table 22.

National regulations in terms of neutrality are pending in most countries in the region. El Salvador and Guatemala are the only ones to have fully liberalized their spectrum, resulting in higher penetration and lower prices. Box 12 below reflects the experience of Guatemala.

9.7. Secondary Markets

Countries in LAC still lag behind in terms of secondary markets. Most lack licenses for trading, leasing, or selling, and the management model adopted in the region is based somewhat on that of command and control. Argentina and Chile are designing more modern approaches to develop secondary markets.

Chile is undertaking legislative and regulatory measures to create secondary markets through its SubSecretariat of Telecommunications (Subsecretaría de Telecomunicaciones (Subtel)). A study conducted by Subtel in 2013 found out that the lack of mechanisms, such as spectrum pricing and trading, are one of the main flaws in Chilean spectrum management (Subtel, 2013). It also gives the experience of the UK as a base to create

TABLE 22. Unified Licensing Regimes in Selected Countries

Country	Instrument	Type	Details
Argentina	Decree No. 764/00	Service and Technology, with exception of broadcasting services	Licenses do not expire, and there is no limit to licenses that can be issued
Colombia	Law No. 1341/2009	Technology, but spectrum and numbering resources must be applied for separately	Law states that technology neutrality should follow international guidelines
Peru	Law No. 28737	Service and technology, including paid television services	Law states that it is intended to promote the convergence of networks and services, as well as to facilitate the interoperability of different network platforms and provide various services and applications over a common technology platform.

Source: Elaboration of authors, with information from ITU (2012).

Box 12. Spectrum Liberalization: Guatemala

Guatemala is an example of spectrum liberalization in the LAC region. The country underwent a major reform in 1996 by granting private parties exclusive control of the use of wireless bandwidth. It also obliged regulators to define, issue, and protect requested spectrum rights.

Prior to the enactment of the General Telecommunications Law, the electromagnetic spectrum was a public good, licensed by the Federal Government to private parties, as occurs in most of Latin America. The Law now requires the allocation of the spectrum to have a bottom-up approach so that all users, including foreign companies, can request any spectrum band that is not assigned to others.

There are three types of allocation: (i) one reserved for government use; (ii) one reserved for amateurs; and (iii) the regulated bands. A total of 1,331 MHz was assigned to the Government, mainly in the bands from 3 KHz to 3,000 MHz. For amateur use, a total of 4,761 MHz was assigned, distributed between 1.8 MHz and 250 GHz (Velásquez, 2006). The authorization granted under these three types of assignments cannot be sold or transferred.

For regulated bands, the reform generated the right of usufruct which, according to the country's Civil Code, permits the title holder to enjoy the property of another to the extent that such use and enjoyment does not destroy or diminish its essential substance. The title, Title to Frequency Usufruct (Título de Usufructo de Frecuencias), has generated a market-driven structure whereby titles can be totally or partially leased or sold for a period of 15 years, with extensions for equal periods. Applications are submitted to the Telecommunications Superintendency (Superintendencia de Telecomunicaciones), an entity established as a result of the General Telecommunications Law, responsible for administering and supervising spectrum usage, managing the registry, resolving disputes related to access and use of spectrum, and other spectrum issues (Government of Guatemala, 2013). In addition, the law allows for private negotiation and agreement of price and access conditions in the lease and sale of titles within 40 days of application to the superintendency, subject to extension if both parties agree.

The outcome of the reform has been considered positive, given that spectrum usage has become more efficient. Urizar (2007) states that there is evidence that these changes have developed the telecommunications market in Guatemala, and that the Title to Frequency Usufruct has provided economic incentives and conditions for innovation. Furthermore, the reform has lowered the price of telephone services considerably—by two thirds—from what was a monopolistic market to one of competition (Urizar, 2007). Finally, mobile penetration has taken place at a fast pace. In 2009, for fixed telephony, there were only 10 lines for every 100 inhabitants; it is now 12 times more (Elbitar, 2010).

secondary markets, where leasing is made possible; that is, the secondary user has the option to be the main licensee when the primary license expires or is revoked.

Brazil has been evaluating the issue for some years. The Secretariat for Economic Monitoring (Secretaria de Acompanhamente Econômico (SEAE)) has defended a hybrid model, whereby traditional command-and-control mechanisms are combined with secondary markets that are created, together with other parts of the spectrum, managed as a commons (Fiuza Lima and de Matos Ramos, 2006).

9.8. Unlicensed Spectrum and TV White Spaces

Wi-Fi has been widely adopted in the region. A recent study by the Brazilian National Telecommunications Agency shows that there are more than 158,000 Wi-Fi hotspots in Brazil (ANATEL, 2014). A significant number of other countries allow Wi-Fi on an unlicensed basis (openspectrum.info, 2014). Identifying and making unlicensed spectrum available for Wi-Fi will assist LAC to offload data and reduce the CAPEX and licensed spectrum capacity of operators, increasing connectivity and decreasing the cost for consumers. The freeing up of unlicensed spectrum in the 700 MHz band, however, is still outstanding in most of the area.

On the basis of a survey made of each LAC country, it was evident that none has deployed TVWS. Nonetheless, Microsoft has provided TVWS demonstrations during an IDB Annual Meeting, held in 2012 in Montevideo, and at the Rio+20 Conference in Rio de Janeiro, held during the same year.[23] In 2010, Microsoft Research, together with Brazil's Telecommunications Research and Development Center (Centro de Pesquisa e Desenvolvimento em Telecomunicações (CPqD)), signed an agreement for the research and testing of TVWS, for which the IDB will provide technical support.[24] Since the initiation of this partnership, CPqD has attended discussions in Europe but, to date, there has been no further progress.[25]

An ANATEL ordinance in November 2013[26] failed to include the option of shared unlicensed spectrum. While this could change, telecommunication experts in Brazil argue that broadcasting in the 700 MHz frequency band will be very unlikely. A new ordinance in September 2013,[27] however—enacted by Brazil's Ministry of Communications (Ministério das Comunicações)—will seek to allocate spectrum bandwidths for unlicensed use.

As a result of the 2012 Microsoft TVWS demonstration at the IDB Annual Meeting in Uruguay, a small pilot project was launched in Uruguay in 2014 in collaboration with the Regulatory Agency of Communications Services (Unidad Reguladora de Servicios de Telecomunicaciones (URSEC))—the regulating authority that provided the license for the demonstration. The Government of Uruguay and Microsoft are also discussing the use of TVWS for connectivity in schools located in rural parts of the country. This will be a part of Plan Ceibal,[28] an initiative that intends to introduce ICT in public primary and secondary schools.[29] Chile is also in the process of normalizing the use of TVWS. This should be complete by 2015, if not before (Basaure, Casey, and Hämmäine, 2012).

Finally, the use of TVWS is currently under discussion under the auspices of the Permanent Consultative Committee II: Radiocommunications including Broadcasting (PCC.II) of the Organization of the American States at the Inter-American Telecommunication Commission (Comisión Inter-Americana de Telecomunicaciones (CITEL)).

[23] See TVWS' pilot projects and demonstrations at http://research.microsoft.com/en-us/projects/spectrum/pilots.aspx.
[24] See http://www.cpqd.com.br/midia-eventos/fatos/fatos-177/cpqd-microsoft-firmam-acordo-cooperacao-tecnica-area-radios-cognitivos.
[25] Information provided by the Innovation Specialist at CPqD.
[26] Resolução nº 625, de 11 de novembro de 2013. Available at http://legislacao.anatel.gov.br/resolucoes/2013/644-resolucao-625.
[27] Portaria n. 275, de 17 de setembro de 2013. Available at http://www.mc.gov.br/portarias/28256-portaria-n-275-de-17-de-setembro-de-2013.
[28] See www.ceibal.edu.uy.
[29] Information provided by Microsoft in an interview.

10
Lessons Learned

In view of the challenges faced by countries in LAC now and in the future, some key lessons can be drawn from the experiences of Australia, Germany, the UK, and the United States. The three key strategic challenges in spectrum management that are incorporated within these lessons are (i) institutional, policy, and regulatory frameworks; (ii) efficiency and flexibility; and (iii) competition.

10.1. Challenges: Institutional, Policy, and Regulatory Frameworks

Challenges assessed in LAC: Transparency and stakeholder engagement for institutional strength

Lessons Learned: Transparency and the engagement of stakeholders are especially important activities to strengthen institutions. The experiences of the reference countries indicate that changes in policy and regulation should involve a wide range of actors in public consultation. This will not only facilitate better outcomes; it will ensure transparency.

Challenge assessed in LAC: Strengthening of leadership and coordination

Lessons Learned: In Germany—where each state has a different body to manage broadcasting frequencies—it has been a challenge as well as an advantage. Coordination efforts were possible and the digital switchover process was undertaken. The structure now in place encourages the deployment of technologies, state by state. The independence of each state, however, could have been detrimental, even though Germany has a potentially high rate of TVWS availability. Its experience shows that strong governance and adequate coordination needs to be in place in advance to be able to transition to new technologies.

Challenge assessed in LAC: Lack of harmonized frequencies

Lessons Learned: Harmony is a key to the interoperability and cost effectiveness of frequency bands. In 2009, countries within the European Union adopted a regionally harmonized band for mobile at 800 MHz, following the recommendations of CEPT. Spain's experience underlines the example that by following international harmonization guidelines, countries can avoid problems that may arise in the future. In Spain's case, it had to refarm frequency bands twice at a cost as a result of its initial process not being compatible with the CEPT harmonization plan.

10.2. Challenges: Efficiency and Flexibility

Challenge assessed in LAC: The ITU's estimated spectrum bandwidth requirements for 2015 and 2020 are far from being met. The amount of spectrum allocated to wireless broadband is much lower than that recommended by the ITU. Demand may not be met by 2020.

Lessons Learned: The four reference countries have taken various measures to guarantee that spectrum demand is met. They have completed the switchoff process and have auctioned the dividend bands with high spectral efficiency of wireless broadband access. Moreover, they are also freeing new bands and allowing the use of unlicensed spectrum. Countries in LAC should consider pursuing a strategy that involves short- and long-term ways to release spectrum.

Challenge assessed in LAC: Spectrum hoarding is making markets significantly less accessible to new entrants and it is thwarting competition among providers.

Lessons Learned: The United States is promoting incentive auctions to free parts of the spectrum not used by current incumbents. This innovation will motivate incumbents to release these spectrum parts on a voluntary basis by reimbursing them. This market-based approach can benefit operators and consumers alike as more spectrum becomes available.

Challenge assessed in LAC: Service and technology neutrality are not yet part of the regulatory framework in many countries.

Lessons Learned: In the Unites States, "increased flexibility will be a key component of any policy that successfully promotes the efficient use of spectrum"(FCC, 2002). Making flexible the usage rights for wireless access is essential to achieve more efficient usage of spectrum. Germany is taking the harmonization approach towards flexible frequency regulation by prioritizing service and technology neutral licenses. The UK has committed likewise with the objective of reaching 21 percent of spectrum that is flexible.

Challenge assessed in LAC: As technology has evolved, parts of spectrum formerly reserved for government purposes are now available for award or to be shared with the private sector. The mechanisms, however, are not yet in place.

Lessons Learned: Ofcom considers that spectrum is most useful if it can be as unencumbered as possible. Ofcom is expected to release 500 MHz of public spectrum, formerly used by the MoD, by 2020. These bands may be used to develop 4G networks, although there are other possibilities under consideration. The United States is also making some federally used frequencies flexible so as to create a Citizens Broadband Service.

10.3. Challenge: Need for More Innovative Frameworks

Challenge assessed in LAC: The command-and-control inheritance of regulatory frameworks in the region may be a barrier for modernizing spectrum assignment arrangements.

Lessons Learned: The United States has implemented a licensed-light spectrum to be shared with existing federal services. Operators will pay a small registration fee to operate in the 50 MHz band that exists between 3,650 MHz and 3,700 MHz. Under this light type of licensing scheme, users must comply with specific service regulations, although they will be exempt from having to obtain individual station licenses. Another approach being considered in the United States and in Europe is the ASA/LSA approach, although approval is still pending. It combines the elements of traditional spectrum management with the new, so that spectrum can be shared at certain times and in certain places. Both approaches indicate that it is possible to encourage more efficient use of spectrum by way of relatively simple regulatory variations.

Challenge assessed in LAC: The application of unlicensed spectrum has been a success in the LAC region and Wi-Fi is now widely available. The regulatory frameworks, nevertheless, continue to lag behind in terms of alternative technologies. Being unable to install technologies using TVWS is an example of the regulatory limits that hinder the regional advancement towards universality.

Lessons Learned: The United States has revised its regulatory framework to include TVWS. Australia, the European Union, Germany, and the UK are in the throes of similar reforms, with pilots now in place. As TVWS is based on the use of unlicensed spectrum, there will be more players entering the market, which will lower CAPEX costs, in addition to more widespread coverage. In sum, TVWS technologies can include rural areas, provide services to a more diverse market at less cost, improve efficiency, and provide faster connection.

Challenge assessed in LAC: In most cases, there are no secondary markets.

Lessons Learned: While secondary markets are not a substitute for additional spectrum, they can alleviate the shortage of spectrum by making the unused or underutilized spectrum held by existing licensees more readily available to other operators. The four reference countries have established various forms of secondary markets under the authority of the regulators.

10.4. Challenge: Competition

Challenge assessed in LAC: Despite the increasing penetration rate in the LAC region, CAPEX and OPEX costs remain high in remote areas. Many people are underserved as a result.

Lessons Learned: The UK plans to inject £150 million in CAPEX to improve mobile coverage and quality. It will also cover the OPEX of its four mobile operators over 20 years. The operators, in turn, will provide coverage to rural areas, thus extending coverage to 99 percent of the population. The program will support infrastructure-sharing agreements among operators. It is clear that by establishing coverage obligations and creating partnerships between the public and private sectors, the reference countries are closer to their objective of universal access. Their experience shows that government intervention will create the necessary incentives to achieve affordability and universality.

Challenge assessed in LAC: To assess the various bidding mechanisms and to balance fiscal and social benefits can be challenging when awarding frequencies to meet the demand for spectrum.

Lessons Learned: In the UK, the 245 MHz auctions held in 2013 in the 800MHz and 2.6GHz frequency bands generated £1.2 billion less than anticipated and £3 billion less than the estimated maximum. The regulating authority aims to maintain competition within the mobile telecommunications market at the same time as maximize consumer benefits. Australia has experienced a similar case when it raised AU$929 million less than anticipated and 30 MHz in the 700 MHz band remained unsold. Australia applied the total welfare standard for maximum net benefits. These instances reflect that Australia and the UK are aware that it is necessary to balance their fiscal objectives with the longer term goal of universality and affordability, when they each set the bidding price.

Challenge assessed in LAC: Concentration in some markets may be a problem that is worsened by the lack of mechanisms to limit the number of operators that hold spectral resources.

Lessons Learned: Australia, Germany, the UK, and the United States have discovered that there are various ways to tackle the concentration in their markets while, simultaneously, establishing spectrum caps. The United States has not applied caps for some years, although it has similar mechanisms to avoid market failures and foreclosures. The lesson that can be drawn from this is that it is necessary for countries to be aware of the competitive effects of awarding frequencies. In addition, they should seek ways to address concentration issues without distorting competition.

11

Policy Recommendations

Governments have a leading role to encourage more affordable broadband services and bridge the digital divide. Overcoming the obstacles relating to connectivity depends on a wide range of factors, and it is indispensable to understand the importance of sound policy and regulatory frameworks with regard to electromagnetic spectrum. The recommendations outlined below can guide countries in the LAC region in some of the key regulatory and policy challenges they may face in their efforts to achieve universal access to the Internet. These recommendations are a result of the lessons learned from an assessment of the experiences of Australia, Germany, the UK, and the United States. It is important to highlight the importance of abiding by the guidelines of the ITU and regional telecommunications agencies.

11.1. Promote Sound Institutional, Policy, and Regulatory Frameworks

Strong markets are a result of strong institutions that are able to adequately enforce regulations without unnecessary interference. Excluding the appropriate precautions can be detrimental to consumers, investors, and the regulators themselves and lead—ultimately—to higher prices and a lower penetration of services. To meet universality, each country should include the following:

- Promote transparency. Engage academia, civil society, and the private sector in decisions that relate to spectrum management.
- Engage stakeholders. Seek approaches to enable commercial and government users to engage in discussion and share the knowledge of market dynamics, spectrum usage, future constraints, and other essential information relating to spectrum management.
- Promote a sound policy and regulatory framework. Timing is essential to enable markets to meet the demand for spectral resources. Countries need to recognize the technological changes that are necessary, to have in-depth knowledge of the industry, and to be able to predict the challenges that may arise.
- Set clear and appropriate policy goals. In their efforts to protect and promote competition and welfare, regulators should not impose regulatory limitations unless absolutely necessary.
- Follow international standards and guidelines. Countries must follow the ITU guidelines and those set by the regional telecommunications organizations for Latin American and Caribbean countries (CTU, CITEL, and CANTO). This is essential to promote sustainable policies and regulations.
- Harmonize spectrum bands. Effective national and international coordination depends

largely on the harmonization of bands at the regional and global levels.

11.2. Ensure Efficiency and Flexibility

In a world where technology is evolving at an exponential rate, the societal welfare deriving from its use also is increasing steadfastly. Regulators and administrators need to ensure that the decisions made now do not hinder the growth of the Internet ecosystem. They should encourage a market-based approach towards spectrum management. Regulators and policymakers should, therefore, consider the following:

- Accelerate spectrum release. Most countries have not yet met the ITU's spectrum bandwidth requirements for 2020. Governments should dedicate time and effort to refarm frequencies, license new spectrum, and make available unlicensed spectrum. New spectral resources should be sought and supplied through awards, refarming bands, or assigning the use of unlicensed spectrum.
- Consider the social benefits when establishing bidding mechanisms, in addition to the fiscal objectives. Bidding mechanisms should take into account short-term fiscal policy objectives, when considering the balance between an efficient allocation of resources and the long-term goal of universality and affordability.
- Follow the steps set in the roadmap for digital switchover. Review the roadmap for specific guidelines relating to the transition process.
- Adopt a technology- and service-neutral approach. Neutrality promotes innovation, and the efficient utilization of spectrum depends on industry flexibility to apply appropriate technologies. Service neutrality should be promoted to the extent possible without interference.
- Ensure that spectrum is being utilized. Spectrum underutilization makes markets significantly less accessible to new entrants and thwarts competition. Incentives should be in place to free underutilized frequencies, including those of government which, in many cases, can be shared with the private sector or be refarmed.
- Motivate incumbents to free the spectrum they are not using. The incentive auctions designed in the United States are exemplary in how governments can avoid the underutilization of spectrum.
- Promote a flexible licensing regime. Instead of a one-size-fits-all solution, countries should continue to implement a mix of policies for a more efficient use of spectrum and attract new players into the market.

11.3. Enable Innovative Solutions

In addition to providing regulatory confidence to attract investment and create a competitive market, countries should remove the barriers that are essential to meet the short-term increases in demand. An innovative market results from the entry of new providers to the spectrum and when new technologies and services are introduced. As indicated, the ability to access unlicensed spectrum can create innovation without authority, reduce entry barriers, enable experimentation, permit the use of open standards, and establish a more competitive market, thus lowering the cost of service and bridging the digital divide. The main steps for innovation to occur are the following:

- Create market-based mechanisms to find more spectrum. The incentive auctions held in the United States are an example of how new spectrum can be made available to meet the growing demand for licensed spectrum. This method of repurposing spectrum is an example of how market-based incentives can lead to its better utilization.
- Allow access to spectrum for testing purposes. TVWS pilots are now taking place in

various countries, as previously mentioned. These tests are essential for the further development of technologies as well as a way to encourage local digital ecosystems to be aware of new trends and consider them in their objectives.

- Promote the use of unlicensed spectrum. The use of unlicensed spectrum is generating high economic benefits as a result of new DSA technologies. Wi-Fi is a positive example of how to reduce the CAPEX by offloading traffic and leave licensed spectrum capacity for other connections. Its success has been confirmed for some years and the trend will continue to foster societal benefits as unlicensed spectrum is made available.
- Ensure that the unlicensed spectrum made available is within the bands with high spectral efficiency. Technologies using TVWS have multiple applications and attract newcomers into the market; they facilitate the use of advanced applications that are not fully supported by existing technologies; and they expand existing applications for improved performance.
- Facilitate the use of TVWS. Many countries are now undertaking steps towards the use of TVWS. These markets will soon be leaders in terms of the application of advanced technology. It is essential to regulate these changes to make TVWS an actuality.
- Support secondary-market and licensed spectrum sharing. Create or strengthen the secondary market by seeking new methods, such as allowing more freedom to stakeholders to decide which license to use/trade. Regulators should adapt to encourage competition, such as licensed spectrum sharing.

11.4. Promote Competition and Infrastructure Deployment/Sharing

To recognize that spectrum is a public and finite resource is a first step to promote competition. As markets become increasingly vertically integrated, operators become anticompetitive. Affordability and universality can only be possible if there is competition.

- The importance of promoting competition should not be underestimated. The convergence of products and services creates new opportunities but additional obstacles. It is essential for relevant regulators, government ministries, and competition authorities to engage in sharing information and align their interests and approaches to foster competition.
- Establishing limits on overall spectrum auctions should be considered. Regulators and administrators should be aware that spectrum caps may encourage competition. In parallel, an estimate of the amount of spectrum and bands that can be held by each operator should be made so that spectrum usage can be efficiently managed.
- Resources should be used to further develop national digital ecosystems. Countries at the forefront of wireless penetration have invested in capacity building, research and development, and capital and human resources to understand national, regional, and global demands, and to implement modern regulatory approaches.
- Infrastructure sharing should be encouraged. In order to be competitive, companies need to reduce costs. Regulators should guarantee that infrastructure can be shared and make the necessary regulatory adaptation.

12

Roadmap for the Digital Switchover

The roadmap below sets out the general steps for governments to maximize the net benefits of the digital dividend that results from the analogue switch off. It is based on the information provided in the previous chapters.

Step A. Create sound policy and regulatory frameworks

This initial step includes strengthening the regulating authority so that it can act independently and impartially. It is important to create a sound legal and regulatory framework to provide confidence and improve transparency in terms of spectrum allocation, thus helping to improve mobile broadband access. Defining how and when spectrum will be freed entails realistic and clear deadlines, milestones, and various stages in the process. There should be flexibility to accommodate regional variances; for instance, the transition may occur at a faster pace in more developed areas compared to poor ones, requiring additional time to comply with new rules.

Costs should not be underestimated

The cost of a digital switchover will vary from country to country. It is essential for governments to calculate sufficient resources to support communication and marketing activities and assist

TABLE 23. Creating Sound Regulatory and Policy Frameworks: Challenges, Risks, and Actions

Challenge	Risk	Actions
Independence and empowerment of regulatory agency	Political factors Insufficient resources	Shield agency and nominate technical personnel for key positions Define stable and continuous source of funding
Staff possess technical skills	Staff unprepared	Hire appropriate staff and provide adequate training
Offer of certainty	Uncertainty relating to dates	Establish deadlines
Execution within expected timeframe	Delays	Obtain prioritization in the political agenda

the vulnerable segments of the population. Costs can be faced not only by the individual but also by the industry. As occurred in Spain, the Spanish Government had to compensate broadcasters for the additional costs they incurred when simultaneously broadcasting during the transition. It also had to subsidize those in multifamily buildings to ensure continuity of reception of free-to-air channels. Subsidies have been part of the transition process in other countries and they need to be considered when assessing the economic implications on policy and regulatory modifications.

Step B. Engage key stakeholders

The digital dividend spectrum can be used in a number of ways, including digital TV transmission, voice communication, and mobile broadband access. Together, government, the private sector, and civil society should decide how best to allocate usage. To prioritize the increase of Internet speed, evidence is needed that the net benefits from mobile broadband access can be offset. In addition, the issues that can arise from interest groups taking over the policy agenda should be avoided. For a successful transition, it is mandatory to engage the various relevant organizations and stakeholders, such as broadcasters and nongovernmental organizations. The larger the number of interested parties involved in the process, the more likely that the process will be smooth.

Reach out to targeted audiences

Some households require more support than others to prepare for analogue switchoff. In the UK, for example, the Switchover Help Scheme reached 1.3 million persons with disabilities and those older than 75 years of age. It is important to have efficient methods to reach out to specific audiences and be aware of their needs and constraints. Australia, Germany, the UK, and the United States

TABLE 24. Engage Key Stakeholders: Challenges, Risks, and Actions

Challenge	Risk	Actions
Reconciliation of priorities of various stakeholders	Impossibility of reaching common ground	Maintain open communication Preserve rights of incumbents (and include compensation if necessary) while freeing up spectrum Utilize bottom-up approach
Expectations of stakeholders to be met	Frustration due to slow or lack of progress	Establish realistic goals and timeframe
Agenda not dominated by few stakeholders	Collective action	Create mechanisms of checks and balances to ensure smooth switchover transition

TABLE 25. Ensure Harmonization: Challenges, Risks, and Actions

Challenge	Risk	Actions
Meeting established deadlines	Missed opportunities due to slow progress	Promote regional phasing out
Resolution of cross-border interference	Delays in reaching common ground	Prioritize issue in discussions about harmonization in regional fora

created websites and communications campaigns to ensure a smooth transition.

Step C. Ensure harmonization

Countries in the LAC region should have a consistent and harmonized approach to the band plan they select. Economies of scale that are created through harmonization result in (i) lower equipment production costs, (ii) increased competition in an attractive market and the launch of more and less expensive products; and (iii) the adoption of common frequencies and relevant international protocols for disaster management and emergency communications, among other benefits.

Timing and Harmonization: The Case of Spain

Spain's experience has shown countries should be aware of the legal and regulatory limitations that are in place when implementing policies related to the digital switchover. This includes the international rules and standards that may be applicable. Spain experienced a major change when CEPT harmonized the 790 MHz-862 MHz frequency bands. The country had only just completed its digital switchover process a month before CEPT's decision. As a result, Spain had to go through the process twice.

Step D. Award the digital dividend

Using the digital dividend spectrum for mobile broadband has the advantage of servicing a larger area with fewer base stations: with the same number of stations, coverage can increase by a factor of 10 at 800 MHz, when compared to 2.6 GHz. To harness the power of the digital dividend, administrative processes and delays should permit governments to auction licenses sooner rather than later. The experience of the four reference countries demonstrates their commitment to awarding the frequencies in a short period of time subsequent to the transition.

Technology and Service Neutrality

Australia, Germany, the UK, and the United States auctioned the digital dividend license on a service- and technology-neutral basis. This left the private sector free to evaluate how the frequencies should be used and encouraged them to ensure that their cost-effectiveness will ultimately result in more affordable services.

TABLE 26. Auction the Digital Dividend: Challenges, Risks, and Actions

Challenge	Risk	Actions
Meeting spectrum demand	Frequencies left unused	Expedite the award process
Deploying technology	High CAPEX	Promote infrastructure-sharing and partnerships among operators Promote technology and service neutral licenses
Infrastructure deployment in remote areas	Perpetuation of underserved areas	Consider establishing coverage obligations
Competitive markets	Suboptimal distribution	Define clear competitive criteria

13

Spectrum Management Index

The SMI measures the ability of a country to create opportunities for more efficient usage of its electromagnetic spectrum. The index raises awareness of the importance of policies and regulations to promote broadband access through a well-managed electromagnetic spectrum and create a more competitive market.

Universal access to broadband can contribute to the achievement of the MDGs. Countries that consider themselves committed to universal access should adhere to how spectrum—a scarce resource—is managed. Governments can ultimately contribute to achieving affordable broadband access towards universality by promoting efficient usage.

Australia, Germany, the UK, and the United States were selected as the benchmark for this study. At the forefront of efficient spectrum management, lessons can be drawn from their experience in terms of institutional, policy, and regulatory frameworks. For the LAC region, Argentina, Brazil, Chile, Colombia, Guatemala, Mexico, Peru, and Uruguay were selected as a reference for the status of spectrum management development. These countries appear in the spider charts below.

The presence of strong regulators, sound policies, adequate infrastructure, innovative regulatory approaches, and a competitive environment are necessary for efficient use of spectrum. The four categories of the index are (i) Government Institutions; (ii) Policy and Regulation; (iii) Infrastructure; and (iv) Competitiveness and Innovation. Each category comprises a different set of indicators (see Table 27).

The methodology of the SMI is based on that applied in the IDB's Broadband Development Index for Latin America and the Caribbean (IDB, 2013). This is a socioeconomic index that measures the current level of broadband development in the LAC area by country.

Variables are either qualitative or progress from a points range of 1 (minimum) to 8 (maximum). For example, to the variable existence of spectrum caps, the number 1 is attributed to countries where caps are not applied, and the number 8 is attributed to countries that do apply caps. In the case of the variable progress of analogue switchoff, different numbers are attributed, depending on the date set by each country as the deadline for the switchoff. Each of these four pillars receives equal weight (25 percent). Likewise, within any component, the indicators are equally weighted.

Most of the data below comes from the ITU's ICT Eye, a one-stop-shop website that compiles data the ITU collects on each country. While the dates of each variable will differ, 2012 is used whenever possible. Some of the variables derive

TABLE 27. Spectrum Management Index Pillars

Index	Pillars
Governmental institutions	• Existence of an entity in charge of frequency allocation and assignment • Existence of an entity in charge of universal service/access
	• Enforcement power of the regulator
	• Autonomy of regulator in decision making
	• Transparency of decisions (Decisions reported on the regulatory authority's website)
	• Publicity of the information on spectrum
Policy and regulation	• Technology neutrality of spectrum licenses
	• Existence of spectrum caps
	• Adoption of a national broadband plan
	• Progress of analogue switchoff
	• Operators under universal access/service obligation
	• Creation of a universal service fund
	• Adoption of an universal access/service policy
	• Monitoring and enforcement of spectrum
Infrastructure	• Percentage of spectrum allocation recommended by the ITU completed by 2015
	• Assignment of spectrum for 3G
	• Assignment of spectrum for Long-Term Evolution • Assignment of spectrum for WiMAX
	• Number of active mobile broadband subscriptions
	• Percentage of the population covered by a mobile-cellular network
	• Availability of commercial LTE services
Competitiveness and Innovation	• Level of competition of the Wireless Local Loop
	• Level of competition on the wireless market • Level of competition on International Mobile Telecommunications (3G, 4G, etc.)
	• Regulation/legislation on the use of TV white spaces in place or planned
	• Band migration allowed
	• Secondary trading allowed • Change of spectrum use permitted on transfer
	• Mobile broadband competitor index
	• Infrastructure sharing for mobile operators allowed

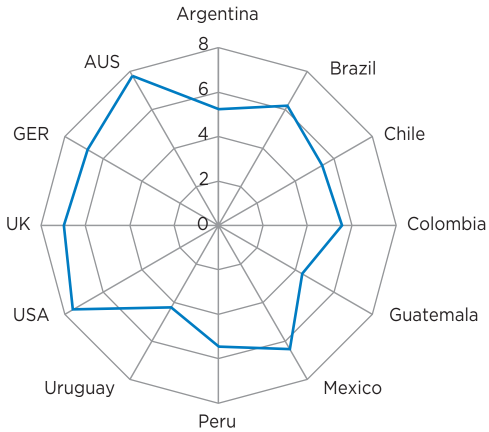
from the collection of data from cited authors—one specifically from 4G Americas (2013).[30]

13.1. Brief Discussion of the Results

The four indicators of the SMI show that in the Government Institutions category, LAC countries fare well; in particular, Mexico and Peru stand out because of their strong and autonomous

[30] The variable"percentage of spectrum allocation recommended by the ITU completed by 2015" was taken from the 4G Americas publication, "Analysis of ITU Spectrum Recommendations in the Latin American Region: Understanding Spectrum Allocations and Utilization" (4G Americas, 2013).

FIGURE 15. Spectrum Management Index for Selected Countries



regulating agencies. In terms of Policy and Regulation—and in addition to Mexico and Peru—Brazil has developed a framework in line with the best practices that exist in more developed economies. On the other hand, Guatemala and Uruguay need to take bigger strides to reach the levels of their peers.

Unsurprisingly, Infrastructure is the weakest link among the selected LAC countries, where Peru has the biggest gap to bridge. With regard to the Competitiveness and Innovation category, Chile and Guatemala have made the most progress in the region.

13.1.1. *Government Institutions*

Most of the LAC countries in the sample have the necessary institutions in place to manage the spectrum efficiently. On the positive side, all countries have assigned agencies responsible for radio frequency allocation and assignment, and information on spectrum policy is publicly available.

On the other hand, three of the eight countries have no reported decisions on their respective regulating authority website. This indicates a lack of transparency that needs tackling. Regulators in Brazil and Chile are reported to have limited powers, which can undermine their authority, while Colombia is constrained by its own agency's limited enforcement power.

13.1.2. *Policy and Regulation*

Spectrum management policy and regulation in the LAC area is in line with most developed economies, with particular emphasis on spectrum monitoring and enforcement, including the establishment of universal service funds. Moreover—with the exception of Guatemala—national

FIGURE 16. SMI Pillars

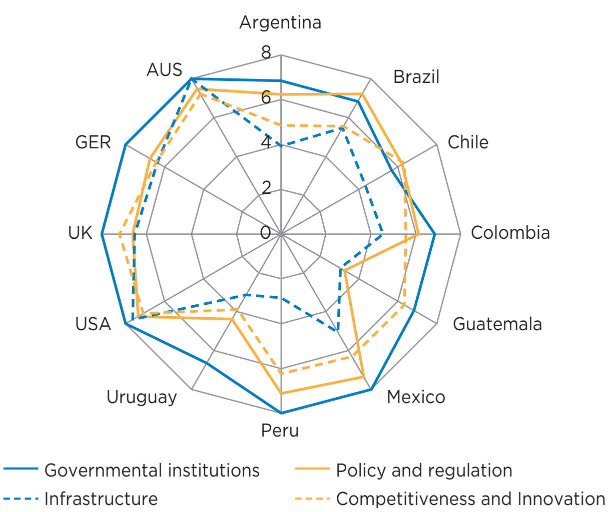
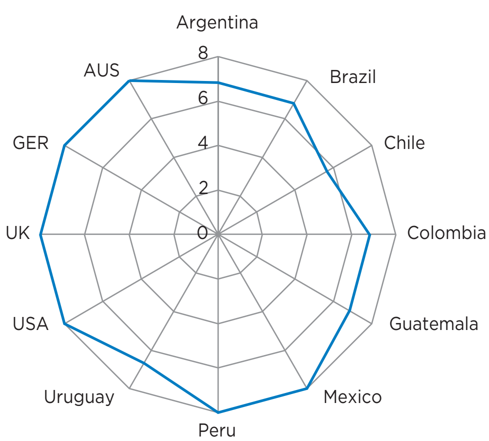


FIGURE 17. Governmental Institutions



broadband plans, technology neutral spectrum licenses, and spectrum caps have largely been adopted across the region.

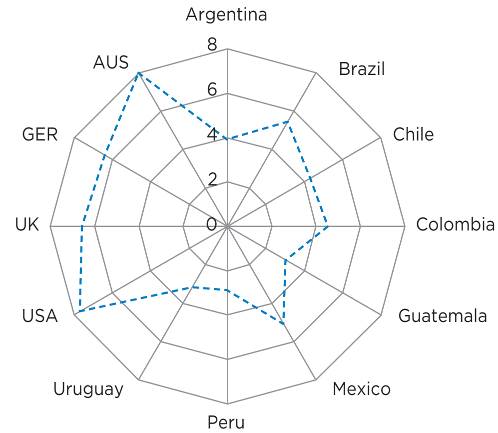
The region is falling behind with regard to the digital switchover compared to the rest of the world. The transition from analogue to digital TV has been faster in Mexico and Uruguay and slower in Colombia and Peru.

13.1.3. *Infrastructure*

All countries in the LAC sample have had spectrum for 3G assigned to operators. The same has occurred for WiMAX services, with only Peru and Uruguay as exceptions. The population covered by a mobile-cellular network is also high in the region, ranging from 76 percent in Guatemala and 83 percent in Colombia, to almost 100 percent in all other countries.

Despite the fast growth rates, mobile broadband subscriptions remain low, reaching less than 2 percent of the population in Peru, compared to rates of 79 percent in the United States and more than 100 percent in Australia. Argentina and Brazil, with 23 and 21 percent of fast mobile Internet access, respectively, show the best performance in the region.

FIGURE 19. Infrastructure



13.1.4. *Competitiveness and Innovation*

In the Competitiveness and Innovation category, LAC countries do well in infrastructure-sharing for mobile operators. They lag behind, however, in some of the cutting-edge regulatory changes that have been promoted in the reference countries, such as the use of TVWS and secondary spectrum markets, which have been extensively discussed in this document.

FIGURE 18. Policy and Regulation

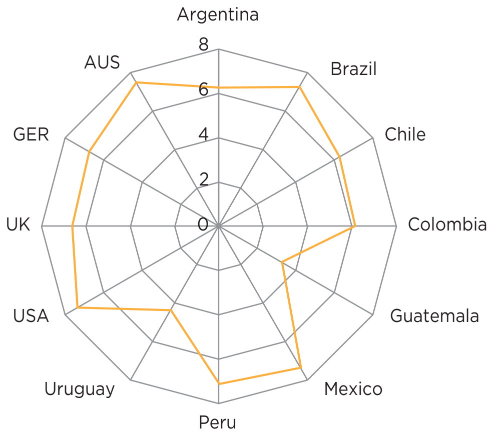
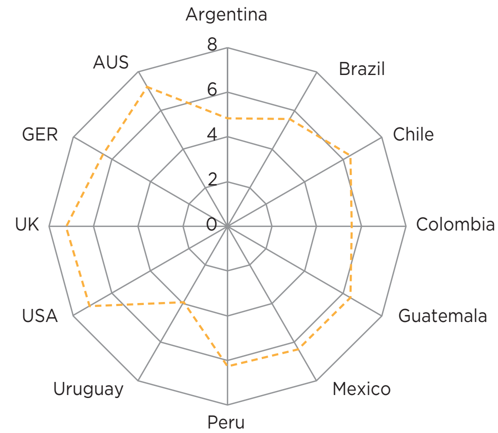


FIGURE 20. Competitiveness and Innovation



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Annexes

Annex 1: Economic Benefits of Allocating Bands and Using Unlicensed Spectrum

Country/ Region	Technology affected	Regulatory highlights	Economic benefits	Value created	Source	Year
Asia-Pacific	Mobile broadband	Allocation of harmonized 700 MHz band	Subscription price decrease of 6–10% to consumers as a result of service cost reduction. Increase in rural household benefits by 10–20%. New jobs: 2.7 million by 2020	US$1 trillion (2014–20)	The Economic Benefits of Early Harmonisation of the Digital Dividend Spectrum & the Cost of Fragmentation in Asia-Pacific (BCG/GSMA) http://www.gsma.com/spectrum/wp-content/uploads/2012/07/277967-01-Asia-Pacific-FINAL-vf11.pdf	2011
Australia	Mobile broadband	Harmonization of the Digital Dividend. Allocation of 80 MHz and 120 MHz frequencies	Maximum net economic benefit to society will be realized if 120 MHz of useable UHF spectrum is allocated to mobile services	A$7–10 billion (2008–28)	Getting the most out of the digital dividend in Australia: Allocating UHF Spectrum to Maximise the Economic Benefits for Australia (Australian Mobile Telecom Association, Spectrum Value Partners, Venture Consulting) http://www.gsma.com/spectrum/wp-content/uploads/2012/07/277967-01-Asia-Pacific-FINAL-vf11.pdf	2009
Brazil	Mobile broadband	Allocating the 700MHz band to mobile broadband	Increased availability of mobile broadband would increase to 95%, reduction of CAPEX of US$1.6 billion compared to deployment of infrastructure in higher frequency bands, an extra US$1.3 billion in tax. Jobs created: 4,300	US$5.3 billion	Brazil Mobile Observatory 2012 (Deloitte, GSMA) http://www.gsma.com/spectrum/wp-content/uploads/2012/10/gsma_brazil_obs_web_09_12-1.pdf	2012
China	Mobile broadband	Allocation of additional 1,200 MHz for international mobile technology (spectrum range: 800 MHz, 900 MHz, 1,800 MHz, 2,300–2,400 MHz, 2,500–2,960 MHz; spectrum band: 687)	Jobs created: 22.6 million (18.6 million direct jobs)	2.41% of the GDP by 2016 (RMB 4.4 trillion). RMB 7.8 trillion (by 2020)	The Socio-Economic Impact of Allocating Spectrum for Mobile Broadband Services in China (China Academy of Telecommunication Research — CATR/GSMA) http://www.gsma.com/spectrum/wp-content/uploads/2013/01/SOCIO-ECONOMIC-IMPACT-OF-SPECTRUM-IN-CHINA.pdf	2013

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Annex 1: Economic Benefits of Allocating Bands and Using Unlicensed Spectrum *(continued)*

Country/ Region	Technology affected	Regulatory highlights	Economic benefits	Value created	Source	Year
Europe	Mobile technology	Digital Dividend (release of the 800 MHz band to mobile broadband)	EUR 55 billion of tax revenues and 80,000 new businesses. Jobs created: 156,000	EUR 119 billion by 2020	Mobile Economy Europe 2013 (BCG / GSMA) http://gsma.com/newsroom/wp-content/uploads/2013/12/GSMA_ME_Europe_Report_2013.pdf	2013
	Wi-Fi	License exempt at 2.4 GHz and possible expansion of 5 GHz band	Enhance the value of fixed broadband, avoid mobile costs through offloads, and enable machine-to-machine applications	EUR 95 billion in 2023	Valuing the Use of Spectrum in the EU: An Independent Assessment for the GSMA (Plum/GSMA) http://www.gsma.com/spectrum/wp-content/uploads/2013/06/Economic-Value-of-Spectrum-Use-in-Europe_Junev4.1.pdf	2013
	Mobile services (including broadband)	Spectrum authorities have recently auctioned significant quantities of spectrum at 800 and 2600 MHz. Countries typically have access to over 500 MHz of spectrum at frequencies below 3 GHz	Transition of users from basic phones to smartphones and from 2G to 4G, *Internet of Things*	EUR 269 billion per annum (2013); EUR 477 billion per annum (2023)		
United Kingdom	Mobile wireless and broadband (Public mobile communications)	Release 500 MHz of spectrum for commercial use by 2020	Economic welfare due to access to services provided using spectrum (consumer surplus) and surplus that producers earn from offering these services (producer surplus). Roll out of 4G networks will result in an investment of GBP 5.5 billion, supporting 125,000 jobs for one year.	GBP 273–341 billion (2012–21)	Impact of Radio Spectrum on the UK Economy and Factors Influencing Future Spectrum Demand (UK Department for Business, Innovation and Skills — BIS/and the Department for Culture, Media and Sport — DCMS) http://www.culture.gov.uk/images/publications/Impact_of_radio_spectrum_on_the_UK_economy.doc	2012

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Annex 1: Economic Benefits of Allocating Bands and Using Unlicensed Spectrum *(continued)*

Country/ Region	Technology affected	Regulatory highlights	Economic benefits	Value created	Source	Year
United States	Mobile broadband	Not specified	More efficient management and documentation; health care efficiency enhancements; enhancements in field service automation; improved inventory management and reduction of inventory loss; sales force automation; replacement of landline desk phones with wireless devices, etc.	US$127 billion by 2016	The Increasingly Important Impact of Wireless Broadband Technology and Services on the U.S. Economy (CTIA-The Wireless Association / Ovum) http://files.ctia.org/pdf/Final_OvumEconomicImpact_Report_5_21_08.pdf	2008
	Mobile broadband	Reassignment of 300 MHz of spectrum to mobile broadband and potential release of additional 200 MHz	US$75 billion in CAPEX. Jobs created: 300,000 new jobs (with additional 200 MHz: another 200,000 new jobs)	US$230 billion within five years (US$385 billion considering additional 200 MHz)	Private Sector Investment and Employment Impacts of Reassigning Spectrum to Mobile Broadband in the United States (Sosa, D. and M. Van Audenrode/Analysis Group) http://www.analysisgroup.com/uploadedFiles/News_and_Events/News/Sosa_Audenrode_SpectrumImpactStudy_Aug2011.pdf	2011
	Mobile broadband	Voluntary incentive auctions; additional 500 MHz of spectrum available for wireless broadband	US$28 billion in tax revenue over ten years	Not specified	Winning the Future through Innovation — The Federal Budget FY2012 (OMB) http://www.whitehouse.gov/omb/factsheet/winning-the-future-through-innovation	2012
	Mobile broadband	Ensuring sufficient spectrum	Investment in 4G networks could fall in the range of US$25–53 billion (2012–16). Jobs created: 371,000–771,000	US$73–151 billion (2012–2016)	The Impact of 4G Technology on Commercial Interactions, Economic Growth, and U.S. Competitiveness (Deloitte Development) http://www.deloitte.com/assets/Dcom-UnitedStates/Local%20Assets/Documents/TMT_us_tmt/us_tmt_impactof4g_081911.pdf	2011

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Annex 1: Economic Benefits of Allocating Bands and Using Unlicensed Spectrum *(continued)*

Country/ Region	Technology affected	Regulatory highlights	Economic benefits	Value created	Source	Year
	Mobile broadband	Reassignment of 300 MHz to mobile broadband	US$75 billion in new investment. Jobs created: 300,000	US$230 billion in five years	Private Sector Investment and Employment Impacts of Reassigning Spectrum to Mobile Broadband in the United States (Sosa, D. and M. Van Audenrode/Analysis Group) http://www.analysisgroup.com/uploadedFiles/News_and_Events/News/Sosa_Audenrode_SpectrumImpactStudy_Aug2011.pdf	2011
	Mobile broadband	Not specified	CAPEX of US$84.2 billion; jobs created: 205,000 (2010–15)	US$242 billion (2010–15)	The Economic Impact of Broadband Investment (Crandall and Singer/ Broadband for America Coalition) http://internetinnovation.org/files/special-reports/Economic_Impact_of_Broadband_Investment_Broadband_for_America_.pdf	2010
	White Spaces (unlicensed)	Allocation of unlicensed spectrum	Reduce cost of connectivity	US$0.8–4.3 billion	The Economic Value Generated by the Current and Future Allocations of Unlicensed Spectrum: Final Report http://apps.fcc.gov/ecfs/document/view?id=7020039036	2009
	Wi-Fi	Allocation of unlicensed spectrum	Greater potential for innovation than licensed spectrum	US$16–36.8 billion (selected WI-Fi applications)		
	Mobile wireless	Incentive auctions and spectrum sharing freeing	Expand coverage, saving US$18 billion over a decade due to sharing	US$150 billion	FCC Chairman Julius Genachowski Prepared Remarks to International CTIA Wireless 2012 New Orleans, May 8, 2012 (transcription) http://transition.fcc.gov/Daily_Releases/Daily_Business/2012/db0508/DOC-313945A1.pdf	2012

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Annex 1: Economic Benefits of Allocating Bands and Using Unlicensed Spectrum *(continued)*

Country/ Region	Technology affected	Regulatory highlights	Economic benefits	Value created	Source	Year
	Wi-Fi (offloading)	Allocation of unlicensed spectrum	Cellular broadband providers were offloading over one third of their traffic into the unlicensed spectrum. Avoiding the construction of over 100,000 cell sites, they avoided incurring annual capital and operating costs of over US$25 billion. Instead, the initial hop to the Internet was provided by Wi-Fi networks at less than one tenth the cost.	US$50 billion	Efficiency Gains and Consumer Benefits of Unlicensed Access to the Public Airwaves (Mark Cooper) http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2030907	2012

Annex 2: Spectrum Management Index: Indicators and Variables

Pillar	Variable	ARG	BRA	CHI	COL	GUA	MEX	PER	URU	USA	UK	GER	AUS
Government institutions	Are decisions reported on the Regulatory Authority's website?	1.00	8.00	1.00	8.00	1.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
	Entity in charge of radio frequency allocation and assignment	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
	Regulator autonomous in decision making	8.00	1.00	1.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
	Entity in charge of universal service/access	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
	Information on spectrum is publicly available	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
	Regulator has enforcement power	8.00	8.00	8.00	1.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Policy and regulation	Spectrum licenses technology neutral	—	8.00	—	—	8.00	8.00	8.00	—	8.00	—	8.00	8.00
	Spectrum caps	8.00	8.00	8.00	8.00	1.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
	National broadband plan adopted	8.00	8.00	8.00	8.00	1.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
	Progress of switchoff	2.00	2.00	2.00	1.00	—	3.00	1.00	3.00	3.00	5.00	5.00	4.00
	Operators under universal access/service obligation	8.00	8.00	8.00	8.00	—	8.00	8.00	—	8.00	8.00	8.00	8.00
	Has your country established a Universal Service Fund?	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	1.00	8.00
	Universal access/service policy adopted	8.00	8.00	8.00	8.00	—	8.00	8.00	—	8.00	8.00	8.00	8.00
	Spectrum Monitoring and Enforcement	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Infrastructure	Percentage of spectrum allocation completed (ITU by 2015)	1.17	3.09	2.43	2.54	1.30	1.50	1.87	1.66	8.00	8.00	8.00	8.00
	Operators assigned spectrum for 3G (IMT)	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
	Operators assigned spectrum for LTE services	—	8.00	1.00	8.00	1.00	8.00	1.00	1.00	8.00	8.00	1.00	8.00
	Active mobile broadband subscriptions	2.49	2.35	2.09	1.16	1.19	1.22	1.00	1.53	6.11	5.88	3.74	8.00
	Percentage of the population covered by a mobile-cellular network	8.00	7.97	8.00	3.25	1.00	7.97	7.25	8.00	7.54	8.00	8.00	8.00
	Operators assigned spectrum for WiMAX services	8.00	8.00	8.00	8.00	8.00	8.00	1.00	1.00	8.00	8.00	8.00	8.00
	LTE services commercially available	—	1.00	1.00	1.00	1.00	1.00	—	1.00	8.00	—	8.00	8.00

(continued on next page)

Annex 2: Spectrum Management Index: Indicators and Variables *(continued)*

Pillar	Variable	ARG	BRA	CHI	COL	GUA	MEX	PER	URU	USA	UK	GER	AUS
Competitiveness and Innovation	If Yes, is a change of spectrum use permitted on transfer?	—	—	1.00	1.00	—	1.00	1.00	1.00	—	8.00	1.00	8.00
	Wireless Local Loop	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	4.50	8.00	8.00
	Mobile (wireless market competition)	4.50	8.00	8.00	8.00	8.00	8.00	8.00	1.00	8.00	4.50	8.00	8.00
	Regulation/legislation in place regarding the use of white spaces	1.00	8.00	1.00	1.00	1.00	1.00	1.00	1.00	8.00	8.00	1.00	8.00
	Band migration allowed	8.00	8.00	8.00	8.00	1.00	8.00	8.00	—	8.00	8.00	8.00	8.00
	Secondary trading allowed	1.00	1.00	8.00	1.00	8.00	8.00	8.00	1.00	8.00	8.00	8.00	8.00
	Mobile broadband competitor index	6.25	8.00	8.00	8.00	8.00	8.00	6.25	8.00	8.00	8.00	8.00	8.00
	IMT (3G, 4G, etc.)	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
	Is infrastructure sharing for mobile operators permitted (e.g., Mobile Virtual Network Operators)?	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00

Annex 3: Spectrum Management Index Calculation

The SMI is calculated as follows:

$$SMI = P_{GI} * SIP_{GI} + P_{PR} * SIP_{PR} + P_{IN} * SIP_{IN} + P_{CI} * SIP_{CI}$$

Where,

P_x. Relative weigh of dimension x

SIP_x. Pillar sub index x

$$x \in \{GI, PR, IN, AC\}$$

Where,

GI Governmental Institutions

PR Policy and Regulation

IN Infrastructure

CI Competitiveness and Innovation

The dimensions are calculated according to the following formula:

$$SIP_X = \frac{\sum_{i=1}^{N_x} Variable_i}{N_X}$$

Where,

$Variable_i$. Variable is the ith of pillar x

N_x. Number of variables comprising pillar x

Normalizations are performed for aggregation. The SMI range has been set between 1 (worst) and 8 (best). The variables have been grouped here by the type of nature of its unit of measure. The methodology for normalizing each variable will be different, according to those types in Table 29.

Where,

$I_{i,j}$: is the normalized value of variable i for country j

$x_{i,j}$: is the value of vale of variable i for country j

$min_j x_i$: is the minimum value of variable i of the 12 countries

$max_j x_i$: is the maximum value of variable i of the 12 countries

The weight of the indicators, variables, and pillars in the SMI are outlined in the table below.

TABLE A3.1. Variable Type of Normalization

Percentage variables	Those that are expressed in any type of percentage	$I_{i,j}=7 * \frac{x_{i,j} - \min_j X_i}{\max_j x_i - \min_j x_i} + 1$
Variables associated to a range	Those obtained from a survey that had a different range	
Special case: variables associated to a range	Those that have been built by consulting various telecom operator websites and institutions.	Their value will be set directly with the same range as the IDB range
Fixed variables	Those that have a fixed value (e.g., Mbps, km^2, number of households)	$I_{i,j}=7 * \frac{\log10(x_{i,j}) - \log10(\min_j x_i)}{\log10(\max_j x_i) - \log10(\min_j x_i)} + 1$

TABLE A3.2. SMI: Indicators and Weights

Pillar	Weight	Number of variables	Indicator weight in SMI	Variable weight in SMI
Government institutions	20%	6	20%	3%
Policy and regulation	25%	8	25%	3%
Infrastructure	40%	7	40%	6%
Competitiveness and Innovation	15%	9	15%	2%

This study examines the experiences of spectrum management in four countries with a high percentage of wireless broadband penetration (Australia, Germany, the United Kingdom, and the United States). What actions have they undertaken to achieve an efficient management of spectrum? How have they have shifted toward more modern management approaches? These answers can be used as a benchmark for good regulatory governance. Governance is a key issue in decisions related to spectrum management in the LAC region. Sound policy and regulatory frameworks should be able to address issues such as the allocation of the digital dividend bands, the refarming of frequencies, the availability of unlicensed spectrum, and the adoption of new technologies. These decisions will ultimately have an impact on the quality and cost of future broadband services. The occasion for this publication is opportune, and the knowledge gained from it will ultimately contribute to a proactive agenda by the decision makers in the region.

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