

Final Report

ITU-D
Study Group 1

**Resolution 9:
Participation of countries,
particularly developing
countries, in spectrum
management**

Evolving spectrum management tools to support development needs

6th Study Period
2014-2017



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Preface

ITU Telecommunication Development Sector (ITU-D) study groups provide a neutral contribution-driven platform where experts from governments, industry and academia gather to produce practical tools, useful guidelines and resources to address development issues. Through the work of the ITU-D study groups, ITU-D members study and analyse specific task-oriented telecommunication/ICT questions with an aim to accelerate progress on national development priorities.

Study groups provide an opportunity for all ITU-D members to share experiences, present ideas, exchange views and achieve consensus on appropriate strategies to address telecommunication/ICT priorities. ITU-D study groups are responsible for developing reports, guidelines and recommendations based on inputs or contributions received from the membership. Information, which is gathered through surveys, contributions and case studies, is made available for easy access by the membership using content-management and web-publication tools. Their work is linked to the various ITU-D programmes and initiatives to create synergies that benefit the membership in terms of resources and expertise. Collaboration with other groups and organizations conducting work on related topics is essential.

The topics for study by the ITU-D study groups are decided every four years at the World Telecommunication Development Conferences (WTDCs), which establish work programmes and guidelines for defining telecommunication/ICT development questions and priorities for the next four years.

The scope of work for **ITU-D Study Group 1** is to study “**Enabling environment for the development of telecommunications/ICTs**”, and of **ITU-D Study Group 2** to study “**ICT applications, cybersecurity, emergency telecommunications and climate-change adaptation**”.

During the 2014-2017 study period **ITU-D Study Group 1** was led by the Chairman, Roxanne McElvane Webber (United States of America), and Vice-Chairmen representing the six regions: Regina Fleur Assoumou-Bessou (Côte d’Ivoire), Peter Ngwan Mbengie (Cameroon), Claymir Carozza Rodriguez (Venezuela), Victor Martinez (Paraguay), Wesam Al-Ramadeen (Jordan), Ahmed Abdel Aziz Gad (Egypt), Yasuhiko Kawasumi (Japan), Nguyen Quy Quyen (Viet Nam), Vadym Kaptur (Ukraine), Almaz Tilenbaev (Kyrgyz Republic), and Blanca Gonzalez (Spain).

Final report

This final report in response to **WTDC Resolution 9: “Participation of countries, particularly developing countries, in spectrum management”** has been developed under the leadership of its two Co-Chairmen: Fadel Digham (Egypt) and Sergey Pastukh (Russian Federation); and four Vice-Chairmen: Amer Hassan (Microsoft Corporation, United States of America), Richard Kimasi (Autorité de Régulation de la Poste et des Télécommunications du Congo (A.R.P.T.C.), D.R. of the Congo), Scott Kotler (Lockheed Martin Corporation (LMC), United States of America), LiChing Sung (United States of America). They have also been assisted by ITU focal points and the ITU-D Study Groups Secretariat.

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Executive Summary

This Report to WTDC-17, in response to Resolution 9 (Participation of countries, particularly developing countries, in spectrum management) (Rev. Dubai, 2014), addresses national technical, economic and financial approaches to, and challenges of, spectrum management and spectrum monitoring, taking into consideration development trends in spectrum management, case studies on spectrum re-deployment, licensing processes and best practices implemented in spectrum monitoring around the world, including consideration of new spectrum-sharing. This report has been developed through close collaboration between the ITU Radiocommunication Sector (ITU-R) and the ITU Telecommunication Development Sector (ITU-D). Such joint inter-sectoral collaboration has fulfilled the target of raising awareness of and matching the ongoing radiocommunication activities and technical studies with the special and growing needs of the developing countries. Contributions made to this report encompass case studies and system level descriptions submitted by Member States and private sector members, as well as ITU-R and ITU-D activities and publications.

Chapter 1 addresses current and emerging spectrum management approaches. The mainstream approach currently, in particular for mobile broadband, is to allocate spectrum on the basis of exclusive licenses and leave operators full flexibility to deploy their networks over the national territory, subject to the license conditions. Due to imbalance between increased demand for different services and the supply of spectrum resource, spectrum sharing is an effective way in improving spectrum utilization and accommodating increased demand given available spectrum. Chapter 1 therefore provides also background on different spectrum sharing schemes.

Chapter 2 examines various economic aspects of spectrum management. This chapter also considers some of the economic benefits of using spectrum whether under the licensed or the license-exempt model use, as well as regulatory costs under spectrum sharing.

Chapter 3 addresses spectrum management activities. It considers assessment tools and guidelines to help developing countries prepare/update their National Table of Frequency Allocations (NTFA). It also considers results and preparation of World Radiocommunication Conferences (WRCs).

Spectrum monitoring is essential in order to ensure that spectrum management policies are properly implemented: **Chapter 4** describes various aspects of spectrum monitoring that may be useful for developing countries, including methodologies of setting up a monitoring system.

1 CHAPTER 1 – Spectrum management approaches

1.1 Introduction

Access to broadband drives economic growth, creates opportunities, and improves the quality of life of people everywhere.¹ However, these benefits have yet to reach many communities that are unserved by Internet access or are severely underserved due to the limitations of the available Internet access. It is estimated that the Internet is currently accessible to only 35 per cent of people in developing countries.² The situation in the 48 UN-designated Least Developed Countries (LDCs) is particularly critical, where less than 10 per cent of the population have some kind of Internet connectivity.³ The availability of ubiquitous, affordable, reliable, and robust broadband connectivity in communities across LDCs, in developing and emerging economies, and in less developed regions of developed economies would support a number of the sustainable development goals and targets in the United Nations' 2030 Agenda for Sustainable Development.⁴

Often these communities must overcome varying geographical challenges, the lack of adequate infrastructure, and seemingly unfavourable economics to gain access to broadband Internet service. Extending fixed-line fiber connections to unconnected populations is a formidable task, both because of the difficulty of undertaking and financing such projects as well as the challenge of rendering the resultant service economical for the target population. Fixed, mobile, and satellite wireless networks are all intended to provide broadband coverage across a defined geographic area. Due to the relatively less demanding infrastructure requirements, wireless technologies, may be used to provide backhaul and last mile Internet access in less densely populated areas at lower cost than fixed wireline networks. Nevertheless, it is important to note that regardless of the radio technology used to provide the last mile connectivity, the local endpoint must be able to interconnect seamlessly back to the Internet backbone for there to be broadband coverage.

Where wireless networks exist in developing countries, they may suffer from both gaps in coverage and congested nodes that drive up costs and reduce service quality. And even in the most developed economies there are gaps in wireless coverage, access points and base stations become overloaded in busy areas, and pricing presents an affordability barrier for many.

As a result, spectrum managers in developing countries face challenges of making available spectrum in, typically, lower frequency bands to provide, at a lower cost, wide-area broadband coverage in unserved and underserved areas, as well as making available additional spectrum in mid- and high frequency bands to add broadband capacity where there is already wireless broadband access.

When making spectrum management decisions, administrations should first attempt to introduce services using ITU-R Recommendations in the allocations defined by the Radio Regulations. This is likely to provide the most benefit in terms of economies of scale, roaming, interoperability and wider choice of equipment. Administrations should take into account that it may take several years between the adoption of a standard and the availability of equipment and devices at a cost which is affordable for consumers and citizens of developing countries.

¹ See generally "Internet Matters: The Net's Sweeping Impact on Growth, Jobs and Prosperity," *McKinsey*, 2011, http://www.mckinsey.com/insights/high_tech_telecoms_internet/internet_matters; "Online and Upcoming: The Internet's Impact on Aspiring Countries," *McKinsey*, 2012, http://www.mckinsey.com/client_service/high_tech/latest_thinking/impact_of_the_internet_on_aspiring_countries.

² "The State of Broadband 2015," *The Broadband Commission for Digital Development*, 2015, pp. 41-42, <http://www.broadbandcommission.org/Documents/reports/bb-annualreport2015.pdf>.

³ "The State of Broadband 2015," *The Broadband Commission for Digital Development*, 2015, pp. 41-42, <http://www.broadbandcommission.org/Documents/reports/bb-annualreport2015.pdf>.

⁴ "Transforming our World: The 2030 Agenda for Sustainable Development", Resolution adopted by the United Nations General Assembly on 25 September 2015. http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E.

If the above approach is not followed, it would typically require special equipment that may increase network and equipment costs, lead to difficulties in product availability and create challenges for long term support.

One approach to address these challenges is to redeploy spectrum for licensed mobile services that can be used for broadband.⁵ Licensing is currently the mainstream spectrum management approach for mobile broadband, providing the certainty of dedicated spectrum to support over 8.1 billion connections and almost 5 billion unique subscribers.⁶

Exclusive licensed spectrum allows for better interference protection guarantees and enables higher power output, both of which help improve coverage and incentivise network investment. The amount of spectrum that has been licensed to mobile operators – including the type of bands that are licensed – can have a major impact on the cost, quality and coverage of mobile broadband services.

The amount of spectrum that has been exclusively licensed to mobile operators varies widely around the world – this ranges from 150 MHz in numerous developing countries to over 700 MHz in more advanced mobile markets.⁷ Those countries with less spectrum licensed may struggle to support fast mobile broadband speeds and growing amounts of data traffic.

The type of spectrum that is licensed can also have a significant impact on the cost and reach of mobile broadband services. Coverage bands (i.e. below 1GHz) can cover wide areas with less infrastructure than spectrum in higher bands, so can play an important role in connecting rural populations in a cost-effective manner, while also helping to improve quality of service through improved in-building penetration.

An example of the effectiveness of this approach is the reallocation of the “Digital Dividend” spectrum to the mobile service, as a result of the spectrum efficiencies gained by the transition of analogue television services to digital terrestrial television. Re-farming of that spectrum avoided onerous requirements on radio equipment, and mobile services could be deployed without restrictions on power or coverage. This is particularly crucial in disadvantaged economic areas where the viability of a service, or the subsequent cost of service to subscribers, is often determined by the population served by each point of presence on the landscape.

Capacity of frequency bands (i.e. above 1 GHz) is important for delivering the rich, data-intensive services that consumers are increasingly using.

License-exemption of spectrum bands is now an important spectrum management tool. Administrations have found that license-exemption can generate benefit for citizens and consumers. License-exemption is generally used where the equipment has a low capacity to cause harmful interference. A wide range of economic equipment is often available in license-exempt bands and it can be rapidly deployed without the need of a license from the administration with associated costs. For example, the license-exemption of the 2.4 GHz ISM and 5 GHz bands has delivered significant benefits with a wide range of equipment being available including Wi-Fi, as an extension of the fixed network.

Another complementary approach is to make more efficient use of existing spectrum resources through application of various techniques for inter-service sharing of spectrum, as well as sharing of spectrum by primary and secondary users, where feasible. According to the [ITU-R Handbook on National Spectrum Management](#), “Frequency sharing is an effective way in improving the utilization of the spectrum. The possibility of sharing existing frequencies should be considered before a new frequency is assigned”.⁸

⁵ The major part of the spectrum in use today, both in developed and developing countries, has been allocated on a dedicated basis. This includes spectrum identified for IMT-2000 and IMT-Advanced mobile services in the UHF band.

⁶ GSMA Intelligence – see www.gsmaintelligence.com.

⁷ GSMA Intelligence – see www.gsmaintelligence.com.

⁸ Handbook on National Spectrum Management (Edition of 2015), ITU, page 139.

Spectrum sharing among different services is a common practice and can be implemented by national administrations by adopting regulations consistent with ITU Radio Regulations and ITU-R Recommendations and implemented through technical solutions developed in partnership with industry and international standards organizations. It can take place at different levels:

- Between different radiocommunication services or applications in accordance with the ITU Radio Regulations, or national level regulatory framework;
- Between different entities or type of users (e.g. governmental vs commercial use);
- Between different licensed users of the same application (e.g. PMR services, Point to point links);
- Between protected primary users and license-exempt users (e.g. radars and Earth Exploration-Satellite Service (EESS) stations vs 5 GHz Radio Local Area Networks (RLANs));
- Between different license-exempt users (e.g. short-range devices and Wi-Fi).

Spectrum sharing assumes that there are several entities seeking to use the same spectrum bands. This may be a more common scenario in areas with high population density.

The choice of policy for a proposed frequency band depends on the expectation on quality of services in that band. For example, a licensed allocation serves bands where the economic value of re-farming is palpable, and where the commercialization of a new generation of services demands a foundational certainty of rights to use spectrum, while sharing with military or public safety bands is more suited for licensed shared allocations. Unlicensed use of bands is particularly suitable for applications where quality of service is less of a concern and where the incumbent services can be protected.

Qualifying properly “spectrum sharing” from a regulatory perspective requires distinguishing the two key steps in a national regulatory process to enable access to spectrum at national level: 1) Frequency allocation, and 2) Frequency authorization.

“Frequency allocation” refers here in a broad sense to defining at national level the services and/or applications that have access to a frequency band while “frequency authorization” refers to the procedures for assigning spectrum to users for the allocated services and/or applications, as well as market regulation.

Spectrum managers in National Regulatory Authorities (NRAs) can implement a range of spectrum sharing schemes incorporating various mitigation techniques that enable access to shared spectrum as long as any National rule conforms to the Radio Regulations. Spectrum sharing can be applied through a variety of regulatory frameworks.

Not all frequency bands are equally suited for spectrum sharing due to the nature of the services already occupying a given band and the technical feasibility of protecting these services from interference through the necessary technical rules. Spectrum managers need to evaluate the potential for spectrum sharing on a band-by-band basis.

Over time, the notion of spectrum management at NRAs in both developed and developing countries has broadened from exclusively preventing harmful interference to primary users to one that also includes maximizing a given band’s spectrum utilization efficiency, as well as economic and social efficiency in order to increase connectivity – in line with public policy objectives.⁹ Maximizing the economic efficiency of a spectrum band ensures that spectrum is allocated and assigned to uses that derive the highest economic value. Maximizing the spectral utilization efficiency of a band enables the spectrum manager to achieve the most intensive use possible within the interference limits for the protection of licensed services in the country and in neighbouring countries. In order to ensure that both economic efficiency of a spectrum band and spectrum utilisation efficiency remain high

⁹ “Background Paper: Radio Spectrum Management for a Converging World”, International Telecommunication Union, Document: RSM/07, Presented at ‘Workshop on Radio Spectrum Management for a Converging World’, 16-18 February 2004.

over time, NRAs are encouraged to carry out periodical review of their adopted regulatory measures and respond to the possible needs of amendment of the relevant regulatory framework, accordingly.

1.2 ITU regulatory framework for wireless broadband

1.2.1 International Mobile Telecommunications (IMT)

The framework for the development of the third generation of mobile systems (3G) was established in 1992 at ITU's World Administrative Radio Conference (WARC-92), where, among other regulatory provisions, the radio-frequency spectrum bands were identified on a global basis for use by countries when deploying International Mobile Telecommunications (IMT) systems.

WRC-2000 and WRC-07 provided the framework for 4G by opening up the 1.8 GHz and 2.6 GHz bands and the "first digital dividend" bands (700 MHz in Regions 2 and 3 and 800 MHz in Region 1) respectively.

WRC-15 opened up the "second digital dividend" band (700 MHz) in Region 1 and the 3.4-3.6 GHz band world-wide to the mobile service (IMT), to be used for 4G and 5G¹⁰ (IMT-2020) mobile systems. WRC-19 is expected to identify more spectrum in the bands above 24 GHz for 5G mobile services. 5G is expected to accelerate the digital transformation by providing the enhanced mobile broadband capability and by integrating the Internet of Things (IoT), and vertical activities like health, transportation and retail. (See Recommendation ITU-R **M.2083**: IMT Vision – "Framework and overall objectives of the future development of IMT for 2020 and beyond").

The work on making the 600 MHz frequency band available for mobile broadband has also started in countries for which there is a footnote in Article 5 of the Radio Regulations concerning this band, based on a frequency arrangement which has been proposed in the ITU-R Study Group 5.

WRC resolutions highlight important aspects related to IMT, as per:

Resolution 223 (Rev. WRC-15), states that International Mobile Telecommunications (IMT) systems provide telecommunication services on a worldwide scale regardless of location, network or terminal used. It also notes that since WARC-92 there has been a tremendous growth in mobile communications including an increasing demand for broadband multimedia capability; and that harmonized worldwide bands for IMT are desirable in order to achieve global roaming and the benefits of economies of scale.

Resolution 224 (Rev. WRC-15), states that frequency bands below 1 GHz are important, especially for some developing countries and countries with large areas where economic solutions for low population density areas are necessary; moreover it recognizes that there is a need, in many developing countries and countries with large areas of low population density, for the cost-effective implementation of IMT, and that the propagation characteristics of frequency bands below 1 GHz result in larger cells.

1.2.2 Wireless Access Systems/Radio Local Area Networks (WAS/RLAN)

WRC-03 opened parts of the 5 GHz frequency band for RLANS subject to the use of Dynamic Frequency Selection (DFS) by RLAN devices in order to protect radars. DFS is a mitigation technique based on sensing technology.

Unlike the use of the 2.4 GHz ISM frequency band for Wi-Fi, the use of a portion of the 5GHz band by WAS/RLANS requires the implementation of mitigation techniques towards spectrum sharing between license-exempt and licensed services. While there has been a considerable growth in the demand for

¹⁰ IMT-2020 refers to the 5G standardization work at ITU.

WAS/RLAN applications in the last years, the enforcement of the regulations and mitigation techniques and harmful interference to radars (in particular meteorological radars) are challenging.

WRC-03 allocated the spectrum between 5150 and 5350 MHz and between 5470 and 5725 MHz on a co-primary basis to the mobile service for “Wireless Access Systems including Radio Local Area Networks (RLAN)s”. **Resolution 229 (Rev. WRC-12)** specifies the condition so that RLANS could not cause interference to other primary users of these frequencies- radar systems deployed on satellite, terrestrial, and maritime platforms. An RLAN seeking to access these frequencies is required to implement a mechanism called Dynamic Frequency Selection (DFS) to detect emissions from these radars and avoid causing co-channel interference into them (see also **Section 1.4.3.1**).

WRC-15, through **Resolution 239 (WRC-15)**, invited ITU-R to conduct studies concerning Wireless Access Systems including radio local area networks (WAS/RLAN) in the frequency bands between 5 150 MHz and 5 925 MHz, considering the contribution of WAS/RLAN applications to global economic and social development, the need for additional spectrum and the need to continually take advantage of technological developments in order to increase the efficient use of spectrum and facilitate spectrum access.

1.2.3 High Altitude Platform Stations (HAPS)

HAPS are defined in No. **1.66A** of the Radio Regulations as “station located on an object at an altitude of 20 to 50 km and at a specified, nominal, fixed point relative to the Earth”. HAPS is a type of radio-communication station which operate under fixed service allocation, not a type of service. The ITU Radio Regulations identify fixed service allocations for HAPS in several frequency bands:

47.2–47.5 GHz and 47.9-48.2 GHz bands

Today, there is only one globally harmonized fixed service identification for HAPS, in a band that presents challenges for broadband delivery in tropical rainy zones where many of the world’s 4 billion un-connected people live. Radio Regulations **No. 5.552A** states that the allocation to the fixed service in the bands 47.2-47.5 GHz and 47.9-48.2 GHz is designated for use by high altitude platform stations. The use of the bands 47.2-47.5 GHz and 47.9-48.2 GHz is subject to the provisions of **Resolution 122 (Rev. WRC-07)**, which establishes maximum transmit EIRP levels, antenna beam patterns and power flux-density (pfd) levels for HAPS operations.

27.9-28.2 GHz and 31.0-31.3 GHz bands

At 27.9-28.2 GHz, the HAPS identification in Radio Regulations **No. 5.537A** permits use within the territory of a number of countries. Such use is limited to operation in the HAPS-to-ground direction and requires HAPS systems to avoid causing harmful interference to, and precludes HAPS systems from claiming protection from, other fixed service systems or co-primary services. At 31.0-31.3GHz, pursuant to Radio Regulations **No. 5.543A**, the same countries mentioned above are permitted to use this band for HAPS in the ground-to-HAPS direction. Such use may not cause harmful interference to, nor claim protection from, other types of fixed service systems or mobile service systems. **Resolution 145 (Rev. WRC-12)** ensures protection of the adjacent radio astronomy service by placing a pfd limit on the HAPS ground station antenna, while adding mandatory coordination and agreement with considered neighbouring administrations.

6 440–6 520 MHz (HAPS-ground) and 6 560-6 640 MHz (ground-HAPS)

The 6 440-6 520 MHz and 6 560-6 640 MHz bands are allocated to the fixed, fixed-satellite (Earth-to-space) and mobile services on a primary basis. Radio Regulations **No. 5.457** identifies these bands in Australia, Burkina Faso, Cote d’Ivoire, Mali and Nigeria for HAPS use within each countries’ territory. Such use is limited to operation in HAPS gateway links and may not cause harmful interference to, and may not claim protection from, existing services. HAPS use must comply with **Resolution 150 (WRC-12)**.

In addition to the fixed service identifications as above, the bands **1 885 1 980 MHz**, **2 010 2 025 MHz** and **2 110 2 170 MHz** were identified for HAPS operating in the mobile service as IMT base stations at WRC-2000.

No. 4.23 of the Radio Regulations states “Transmissions to or from high altitude platform stations shall be limited to bands specifically identified in **Article 5. (WRC-12)**”.

The technological innovations and the growing urgency to expand the availability of broadband has led to a review of the current regulatory environment for HAPS. Stations operating in the stratosphere are high enough to provide service to a large footprint. Recent test deployments of stations delivering broadband from approximately 20 km above ground have demonstrated the potential of such stations for providing connectivity to underserved communities with minimal ground-level infrastructure and maintenance.

HAPS are flexible platforms that could one day be deployed rurally, utilizing a fleet of HAPS to backhaul data to an Internet point of presence where ground-based backhaul is not available.

Given recent innovation in antenna and other technologies, multi-gigabit broadband capacity might be achieved using HAPS. With the average coverage diameter of HAPS ranging from 40-100 km, operators using HAPS to supply backhaul could target a typical population density at 60 per square km. A provider using HAPS may architect its network to either optimize capacity or coverage. For instance, a fleet of HAPS may be deployed to either efficiently cover a broad area, or to provide more capacity to a medium population density area.

WRC 19 agenda item 1.14 aiming at facilitating access to broadband applications delivered by HAPS, pursuant to **Resolution 160 (WRC-15)**.

1.2.4 Satellite systems

Satellites, with their inherent ability to provide ubiquitous, wide-area coverage, are key to deliver broadband connectivity including in remote and underserved areas. Recent years have seen the deployment of numerous High Throughput Satellite (HTS) systems operating in Ka-band frequencies¹¹ in the fixed-satellite service (FSS) to provide broadband connectivity directly to end-users over small satellite user terminals. To provide high capacity and high spectrum efficiency, HTS systems implement large numbers of satellite spot beams which allows for high multiples of frequency re-use.

Within the range of Ka-band FSS frequencies in which HTS systems are generally deployed, there is 500 MHz of spectrum¹² for which satellite services do not share with other primary services in the ITU table of frequency allocations. User terminals operating in these bands can generally be deployed ubiquitously without need for individual coordination of the satellite earth stations.

However, meeting the ever increasing capacity requirements for broadband connectivity requires that HTS systems deploy ubiquitous end-user terminals in FSS frequencies also in the parts of the Ka-band where satellite services do not have an exclusive primary allocation.

Within the CEPT, for instance, significant progress has been made towards opening the FSS Ka-band for the ubiquitous deployment of uncoordinated satellite earth stations. This is reflected in a number of ECC Decisions which have been adopted and amended over the past years, including:

Decision ECC/DEC/(00)07, “*The shared use of the band 17.7-19.7 GHz by the fixed service and earth stations of the fixed-satellite service (space-to-Earth)*”, which has provisions to enable the deployment of FS stations, coordinated FSS (space-to-Earth) earth stations and *uncoordinated* FSS (space-to-Earth) earth stations in the band 17.7-19.7 GHz. To facilitate the sharing between these types of stations,

¹¹ Typically 17.3/17.7 – 20.2 GHz (space-to-Earth) and 27/27.5 – 30 GHz (Earth-to-space).

¹² 19.7 – 20.2 GHz (space-to-Earth) and 29.5 – 30 GHz (Earth-to-space)

the Decision includes in its annexes descriptions of technical and regulatory mitigation approaches to be taken and/or considered by Administrations.

Decision ECC/DEC/(05)01, “*The use of the band 27.5-29.5 GHz by the Fixed Service and uncoordinated Earth stations of the Fixed-Satellite Service (Earth-to-space)*”, which designates parts of the band 27.5-29.5 GHz also for *uncoordinated* FSS earth stations. This Decision was amended in 2013 to include provisions for license-exemption and free circulation of these uncoordinated FSS earth stations.

1.2.4.1 High-Density Fixed-Satellite Service (HDFSS) systems

WRC-03 identified portions in the above frequency bands for high-density applications in the fixed satellite service (HDFSS) through Radio Regulations No. **5.516B**, indicating that “*Administrations should take this into account when considering regulatory provisions in relation to these bands*”.

Resolution 143 (WRC-03) was also adopted at the Conference, providing “*Guidelines for the implementation of high-density applications in the fixed-satellite service in frequency bands identified for these applications*”.

1.2.4.2 Earth Stations In Motion (ESIMs)

The increasing need for broadband communications is not location specific and includes requirements on vessels, aircraft and land vehicles that operate at fixed locations and while in motion, both in developed and developing administrations, and often in very remote parts of the globe.¹³ Earth Stations in Motion (ESIM) that communicate with geostationary (GSO) Fixed-Satellite Service (FSS) networks can meet this need.¹⁴

In 2013, CEPT adopted a regional regulatory approach for harmonized use of ESIMs.¹⁵ Under the “Decision”, administrations within CEPT are supposed to designate the frequency bands 19.7-20.2 GHz (space-to-earth) and 29.5-30.0 GHz (earth-to-space) for ESIMs operation that satisfy the provisions. The two main principles embodied in the Decision are: (1) Free circulation (e.g. authorization for foreign visiting terminals with the country boundaries); and (2) Domestic terminal exemption from individual licensing (e.g. ‘blanket license’). Individual CEPT administrations may have additional national requirements for authorization of ESIM operations as part of their spectrum management activities.

WRC-15 agreed to facilitate the global deployment of ESIM in the 19.7-20.2 and 29.5-30.0 GHz frequency bands in the FSS,¹⁶ paving the way for satellite systems to provide global broadband connectivity for the transportation community. Earth stations on-board moving platforms, such as ships, trains and aircraft, will be able to communicate with high power multiple spot beam satellites, allowing transmission rates in the order of 10-50 Mb/s.¹⁷ WRC-19 will consider the use of frequency bands 17.7-19.7 GHz (space-to-Earth) and 27.5-29.5 GHz (Earth-to-space) by ESIMs communicating with geostationary space stations in the FSS.

Outside the CEPT, the national regulatory framework for domestic ESIMs varies greatly from administration to administration, and there is currently a lack of harmonized regulations at regional level. Some administrations authorize class/blanket licenses covering the entire family of terminals, while

¹³ Document 1/362, “Spectrum management approach for the consideration of earth stations in the fixed-satellite service, including Earth Stations In Motion (ESIMs)”, Inmarsat Plc. (United Kingdom of Northern Ireland and Great Britain).

¹⁴ Report ITU-R S.2357-0 ‘Technical and operational guidelines for earth stations on mobile platforms communicating with geostationary space stations in the fixed-satellite service in the frequency bands 19.7-20.2 GHz and 29.5-30.0 GHz (June 2015).

¹⁵ ECC/DEC(13)01: The harmonized use, free circulation and exemption from individual licensing of Earth Stations on Mobile Platforms (ESOMPs) within the frequency bands 17.3-20.2 GHz and 27.5-30.0 GHz.

¹⁶ Specifically, the Radio Regulations provide for ESIMs to communicate with geostationary (GSO) FSS space stations in the frequency bands 19.7-20.2 GHz (space-to-Earth) and 29.5-30.0 GHz (Earth-to-space) under certain conditions, which are specified in ITU RR. 5.527A and Resolution 156 (WRC-15).

¹⁷ https://www.itu.int/net/pressoffice/press_releases/2015/56.aspx.

other administrations require individual terminal-by-terminal licenses. In administrations where the authorization process is not entirely defined, uncertainty is created for the satellite operators, the local and multinational service providers and, ultimately, the potential end users.

Resolution 156 (WRC-15) provides the conditions under which ESIMs may be operated in the frequency bands 19.7-20.2 GHz (space-to-Earth) and 29.5-30.0 GHz (Earth-to-space). This may lead to an increase in the growth of ESIM deployments in both developed and developing administrations. A consequence is that spectrum managers should not only consider the development and adoption of national regulatory frameworks for ESIM licensing and authorization, but also if and how to approach matters of regional harmonization. Options for spectrum managers are to consider: (1) Type-approved mark; (2) Harmonized regional regulatory framework; (3) National-level exemptions; (4) National-level “blanket” licenses; and (5) Spectrum authorization.

1.2.4.3 Non-GSO systems

Due to their orbital characteristics, non-geostationary satellite systems (non-GSO) in the fixed-satellite service (NGSO-FSS) may provide broadband connectivity to any area of the world, with a much shorter propagation delay than geostationary satellite systems in the fixed-satellite service (GSO FSS).

Several non-GSO FSS systems were at the state of projects in the 1995-2003 timeframe, which led ITU World Radiocommunication Conferences in that period to open to non-GSO FSS various frequency bands already allocated to the FSS, on a shared basis with GSO FSS systems and terrestrial services, for a total of 8.6 GHz in the following frequency bands: in the space-to-Earth direction: 3.4-4.2 GHz, 10.7-12.7 GHz, 17.8-18.6 GHz and 19.7-20.2 in all Regions, and 12.5-12.75 GHz in Regions 1 and 3; in the Earth-to-space direction: 5 925-6 925 MHz, 12.5-13.25 GHz, 13.75-14.25 GHz, 17.8-18.1 GHz, 27.5-28.6 GHz and 29.5-30 GHz in all Regions and 17.3-17.8 GHz in Regions 1 and 3.

The sharing conditions imposed to non-GSO FSS systems are:

- Power flux density limits (pfd), specified in Article 21 of the Radio Regulations, to protect terrestrial services from interference caused by non-GSO FSS space stations;
- Equivalent power flux density limits (epfd), specified in Article 22 of the Radio Regulations in order to protect GSO FSS in both the space-to-Earth and Earth-to-space directions, as well as GSO systems in the Broadcasting-satellite service;
- Coordination of non-GSO FSS earth stations with terrestrial services, on a first-come-first-served basis, as in the case of GSO FSS, as specified in Article 9 of the Radio Regulations.

Recent progress in space technologies have enabled several new projects to emerge in the last two years, which include several hundreds to several thousands of non-GSO FSS satellites. The proponents of these projects have committed that the above limits will be complied with and the ITU Radiocommunication Bureau is in the process of verifying this compliance, as foreseen by Articles 21 and 22. The first deployments of these systems are foreseen in 2018, with full commercial service from 2020. They are intended to provide backhaul for broadband mobile and fixed connections.

WRC-19 will consider the regulatory framework for non-GSO FSS satellite systems to operate in additional frequency bands, totaling 9 GHz of spectrum: 37.5-39.5 GHz (space-to-Earth), 39.5-42.5 GHz (space-to-Earth), 47.2-50.2 GHz (Earth-to-space) and 50.4-51.4 GHz (Earth-to-space).

In view of the above discussion, in the development of their applicable national regulatory frameworks, spectrum managers may wish to take into consideration the role that current and future geostationary and non-geostationary satellite systems could play in complementing other telecommunications systems to provide broadband connectivity and helping to bridge the digital divide.

1.3 Spectrum management under the licensed approach

From a regulatory perspective, a “license” may be given to an operator at particular location or for defined geographical area(s) (local, regional, or national), authorizing the operation of station(s) in this(ese) location or area(s). The license secures rights for the transmission of signals and for the protection of their reception from interference, for a specified period of time. This is typically illustrated by mobile services from 2G systems to IMT systems deployed in bands below 3 GHz.

A “license” includes rights and obligations for the licensee. For example, authorisations delivered to mobile operators may include obligations to meet public policy objectives, in particular coverage obligations (e.g. mobile broadband service for indoor reception delivered to a minimum percentage of the population in a country).

Licenses should as far as possible be “technology neutral”. Frequency assignment coordination enables to optimise the use of spectrum between several licensees. It also enables spectrum sharing between different licensed services (e.g. radio relays and earth stations).

1.3.1 Spectrum management for mobile broadband

For 30 years, the cellular mobile development has been a major revolution of our societies. This development has taken place under a licensed approach. From 2000, the development of mobile broadband has relied on 3G and, since 2007, on 4G, on the basis of IMT-2000 specifications, followed by IMT-Advanced from 2012. 5G is now being developed on the basis of IMT-2020 specifications, which are expected to be approved by 2020, with large scale commercial deployment of 5G networks starting at that time.

There are currently:

- 591 commercially launched LTE networks in 189 countries. Of these, 195 networks in 95 countries employ LTE-Advanced technology. Over 4 in 5 commercially launched LTE operators (81 per cent) use 700 MHz, 800 MHz, 1800 MHz or 2600 MHz spectrum in their LTE networks.¹⁸
- At least 18 operators have now made public commitments to deployment of pre-standards ‘5G’ networks in 13 countries. Deployments are likely to employ existing IMT bands (e.g. 600 MHz, 700 MHz, 3.5 GHz and other refarmed IMT bands) as well as potential new IMT bands which will be considered at WRC-19 under agenda Item 1.13.

The exclusive licensed approach provides certainty to operators – in terms of quality of service and guaranteed access to spectrum – which helps provide security for heavy investment in mobile networks. If operators had no guarantees of spectrum access, and were vulnerable to interference, then investments would be significantly riskier.

One trend in modern spectrum management is establishing a regulatory environment that provides long-term predictability for licensees to help incentivise the large investment necessary for network roll out. This can be especially important to enable mobile broadband coverage in rural areas where the business case for service provision can be challenging due to sparse populations.

NRAs can help provide long-term predictability by consulting on and publishing a spectrum roadmap. This provides existing operators, and potential new entrants, with information about future spectrum availability so future deployment options can be considered. These roadmaps can form part of a national broadband plan which sets out future targets (e.g. for broadband adoption, speed, quality, reach and affordability), including timelines, and the policy and investment plans required to meet them.

Long-term predictability can also be supported through spectrum license terms and conditions – especially through license duration and renewal procedures. When licenses are close to expiry and/

¹⁸ GSA: “700 & 800 MHz Ecosystem Evolution” Report, 2017; “Evolution from LTE to 5G” (April 2017 update).

or where there is uncertainty surrounding license renewal, mobile operators may be less likely to invest in networks, which in turn may impact the cost and reach of services. As such, NRAs may consider longer license durations – for example the European Commission proposed 25 year licenses. Regarding licenses renewal, in the United States the FCC supports an ‘expectation of renewal’ to provide predictability to licensees.

1.3.2 Transition to digital terrestrial television broadcasting

The transition from analogue television broadcasting to digital television broadcasting is one of the major undertakings in spectrum management currently taking place in all regions of the world to provide improved broadcasting services to populations.

Once completed, this transition has enabled the release of the 700/800 MHz frequency bands as part of the digital dividend and their reallocation to the mobile service.

As of May 2017, out of 198 administrations, 56 completed the Digital Switch Over (DSO), 14 launched the process and are still going through it, 68 did not start it and the remaining ones did not communicate the information to ITU. This data is constantly updated at <https://www.itu.int/en/ITU-D/Spectrum-Broadcasting/Pages/DSO/Default.aspx>.

More details and status of the DSO and Digital Dividend can be found in ITU-R and ITU-D Reports and Handbooks, such as:

- **Report ITU-R BT.2140:** Transition from analogue to digital terrestrial broadcasting,
- The purpose of this Report is to help countries that are in the process of migrating from analogue to digital terrestrial broadcasting. It provides an overview of digital terrestrial sound and television broadcasting technologies and system migration and outlines the available options for making that transition and the route to be followed.
- **Digital Dividend insights for Spectrum Decisions:** This document provides a detailed insight into what the digital dividend process entails and to help national and internal spectrum decision makers to allocate and manage the digital dividend process.
- **Report ITU-R SM.2353:** This Report, approved in 2015, provides information agreed within ITU-R on the challenges and opportunities for spectrum management resulting from the transition to digital terrestrial television in the UHF bands, and appearance of the digital dividend, including amongst others expectations, definition of digital dividend, technical, regulatory, economic and societal aspects in the area of spectrum management.
- **Guidelines for transition from analogue to digital broadcasting (Edition of 2014):** The guidelines are intended to provide information and recommendations on policy, regulation, technologies, network planning, customer awareness and business planning for the smooth transition to Digital Terrestrial Television Broadcasting (DTTB) and introduction of Mobile Television Broadcasting (MTV). They will help develop a well-defined roadmap for transition covering national goals, strategies and key activities, helping to reach consensus on requirements and solutions, providing a mechanism to help forecast the key miles stones and a framework to help plan and coordinate the steps for the transition. The Guidelines have been prepared for Africa, taking into account the provisions of the GE06 Agreement. However they could also be applied in countries outside the GE06 planning area, but provisions of other applicable regulations, instead of GE06, should be taken into account in that case.
- **ITU-R “Handbook on Digital Terrestrial Television Broadcasting Networks and Systems Implementation”:** This Handbook, in addition to the broadcasting technologies and standards, concentrates on the new developments during the last 15 years, including the transition from analogue to digital broadcasting and the Digital Dividend.

1.3.3 Strategies and methods of migration from analogue to digital terrestrial broadcasting and implementation of new services

As new technologies, services and applications are being developed that allow for more rational and efficient use of spectrum, NRAs need to periodically adjust the regulatory framework on the use of this scarce resource to benefit from this evolution.

In this context, spectrum redeployment (refarming) is an important activity carried out at national level by NRAs and at international level by regional organisations such as APT, ASMG, ATU, CEPT, CITELE and RCC and by the ITU at global level.

The recent activities undertaken at regional and national levels in the UHF band (470-862 MHz) in conjunction with the transition of analogue to digital terrestrial television broadcasting provide a relevant example of the importance of spectrum refarming, redeployment and thorough re-planning of the usage and purpose of spectrum for the evolution of services and deployment of new services and applications in the same frequency band.

This refarming effort involved, among several activities, modifications of the allotment and assignment plans previously agreed, in order to allow the use by the mobile service of the digital dividend spectrum released by the transition to digital terrestrial television broadcasting.

It is also relevant to point out that this refarming effort involved negotiations between broadcasters inside each country and between neighbouring administrations, to modify the characteristics (frequency, effective radiated power (e.r.p.), antenna diagram, tilt, etc.) of planned and operational broadcasting networks to avoid harmful interference and to allow for equal access to spectrum.

This issue was addressed in response to ITU-D Study Question 8/1 – “Examination of strategies and methods of migration from analogue to digital terrestrial broadcasting and implementation of new services” that produced relevant case studies and grouped some best practice on refarming and redeployment for the purposes of allowing the implementation of digital broadcasting throughout the world and also for the usage of the released spectrum after the transition to digital broadcasting. The result of the discussion is reflected in **Chapter 3** “Spectrum Issues related to the Analogue Switch off Process” and **Chapter 4** “Use of released spectrum to implement new services and applications” of the Final Report of Question 8/1.

The ITU-R Handbook on “Digital Terrestrial Television Broadcasting Networks and Systems Implementation” contains some examples of Regional Groups activities on that matter.

From the discussion held in ITU on this subject, it can be highlighted that the GE06 spectrum re-planning efforts, which involved 120 countries, have enabled the implementation of digital terrestrial television broadcasting and the use of the digital dividend by the mobile service on an equal access basis and avoiding harmful interference, in Region 1. Additionally, some other case studies from countries of Asia and the Americas, such as Thailand and Brazil, can also be highlighted, the first for their approach on spectrum re-planning and the latter for their experience on performing both the digital television switchover and the release of spectrum for other services, in the re-planning and refarming effort.

Report ITU-R SM.2353-0 “The challenges and opportunities for spectrum management resulting from the transition to digital terrestrial television in the UHF bands” contains information on the transition to digital terrestrial television in UHF bands and appearance of the digital dividend, including amongst others expectations, definition of digital dividend, technical, regulatory, economic and societal aspects in the area of spectrum management. Also, national and regional experiences and practices in the spectrum management area with regard to these items are presented in **Annex 2**.

The ITU-D Report (2012) “Digital Dividend: Insights for spectrum decisions” provides a detailed insight into what the digital dividend process entails and helps national and international spectrum decision makers to manage the digital dividend process. It also provides information on spectrum

auctions in the digital dividend bands for mobile services. Beyond the amounts raised by the auctions, Administrations have included coverage obligations to extend the mobile coverage to underserved or uncovered areas. **Annex 2** includes information on the auctions in relation to the use of the Digital Dividend. It also concludes that national spectrum decision makers have an opportunity to contribute to bridge the digital divide by allocating part of the digital dividend to the mobile service. International harmonization is already well advanced in this regard and should quickly ensure the availability of low cost equipment for broadband mobile access in the corresponding parts of the UHF bands.

The bands made available for mobile broadband through the digital dividend (i.e. in some countries in the 600 MHz and in all regions in the 700 MHz and 800 MHz) are the principal bands to provide coverage for mobile broadband. Other harmonised mobile coverage bands – generally found below 1 GHz – are typically used for 2G, or in some cases 3G services (e.g. the 900 MHz band and, normally in different areas, the 850 MHz band). As such, it is normally only through the assignment of spectrum in the digital dividend bands that NRAs can enable widespread affordable access to LTE services in their country. It should be noted that the 700 MHz band enables the deployment of base stations with 7x the coverage area of the 2.6 GHz band (the original LTE band) and over 2.5x the coverage area of the 1800 MHz band (the most common LTE band worldwide).¹⁹ These large cell sizes can allow more people to be covered with a single base station. This can help bring down the cost of mobile services while also allowing 4G services to viably extend beyond city centres, into suburban and rural areas.

There are currently 104 countries with live LTE services using the 700 MHz and 800 MHz mobile bands.²⁰ This number is expected to increase significantly as a further 51 countries have committed to making the band available for mobile services. The scale of these deployments mean the equipment ecosystem for compatible mobile devices is significant and growing rapidly.

The 800 MHz band (3GPP band 20) is currently the second-most deployed LTE band globally and is supported in 2,784 compatible devices.²¹ Although the 700 MHz LTE band (3GPP band 28) is live in fewer countries, the number of deployments are now increasing more quickly than the 800 MHz band. There are currently 639 devices for the 700 MHz band (3GPP band 28)- more than double the number from one year earlier.

The scale of digital dividend deployments can support the economies of scale in the LTE equipment ecosystem that are important for giving consumers a wide choice of affordable mobile devices.

However, it should be noted that many developing countries have not yet licensed the digital dividend bands thus limiting the ability of operators to expand mobile broadband coverage. The benefits of licensing the digital dividend can be significant. For example, Sweden had only 30 per cent LTE population coverage before the digital dividend band was used – it now has 99 per cent LTE population coverage. In Ghana, LTE population coverage almost doubled in just one year – from 21 per cent to 40 per cent – once services went live in the digital dividend band.²²

It should be noted that spectrum reallocation at national level may also need to rely on harmonization efforts at regional level, in order to facilitate spectrum planning and avoid cross-border interference. The process of transition from analogue to digital terrestrial television (DTT) and the regional harmonization processes to enable the release of the 700 and 800 MHz for the mobile service, provide two examples of such a need.

Concerning the transition from analogue to digital terrestrial television broadcasting, 120 countries in Europe, Africa, Middle East and Central Asia concluded, in 2006, the GE06 Agreement which provides for an equitable frequency Plan to effectively share the UHF band with priority to analogue service until 17 June 2015 and to digital service afterwards. This agreement, developed under the auspices

¹⁹ GSA: “700 & 800 MHz Ecosystem Evolution” Report, 2017.

²⁰ GSMA.

²¹ GSA: “700 & 800 MHz Ecosystem Evolution” Report, 2017.

²² GSMA.

of the ITU, has greatly facilitated the transition to DTT by ensuring stable rights to operate DTT in each country party to this agreement.

After WRC-07, which opened the possibility of allocating the 800 MHz band in Region 1 and the 700 MHz band in Regions 2 and 3 (“first digital dividend”). This led European countries to a series of negotiations to modify the GE06 Plan in order to relocate DTT below 790 MHz, thus harmonizing the use of the 800 MHz band for the mobile service in Europe.

After WRC-12, which opened the possibility of allocating the 700 MHz band in Region 1 (“second digital dividend”), which was confirmed by WRC-15, Regional organizations in Region 1 (ATU for sub-Saharan Africa, and ASMG for the Arab States) and in Region 2 (CITEL, COMTELCA and CTU for Central America and Caribbean) and smaller regional groups in Europe, have initiated, with the technical support of the ITU, similar negotiations to modify the GE06 Plan (in Region 1) or to conclude coordination agreements (in Region 2) in order to relocate DTT below 694 MHz, thus harmonizing the use of the 700 MHz band for the mobile service in these countries.

For Sub-Saharan African countries, the process, completed in 2013, involved 47 countries and resulted, after 33 iterations to match the spectrum requirement of these countries, in the satisfaction of 97.4 per cent of the requirements. For Arab States, the process, completed in 2015, involved 17 countries and resulted in the satisfaction of 76.9 per cent of the requirements. In both cases, the degree of satisfaction was higher than achieved at the GE-06 Conference. For the Central American and Caribbean countries, the process has started in July 2016 and is expected to be completed in 2017.

1.3.4 Recent trends

Existing 4G networks and future 5G networks will offer much greater spectrum efficiency and utility to the societal needs of a nation.

The requirement for the development of the Internet of Things may be addressed under the licensed regime. It is expected that by year 2020 the Internet of Things (IoT) ecosystem will consist of billions of connections between various Machine-to-Machine (M2M) terminals. IoT can provide significant socio-economic benefits and revolutionize a wide range of industries.

Under the licensed model, Mobile Network Operators (MNOs) offer IoT services using in particular 2G and 4G technologies. Standardization activities allow new releases to address specific IoT requirements. The IoT market segment is also a key target for future 5G technologies. Spectrum regulations for Private Mobile Radio (PMR) in the 400 MHz range offer regulatory options that may enable specific network deployment to match specific requirements and satellite providers may also provide IoT applications such as worldwide tracking or sensor monitoring in remote areas.

IoT applications may also be addressed under the unlicensed regime (see **Section 1.4.1**).

1.4 Spectrum sharing

Spectrum sharing can be applied through a range of schemes that include: license-exempt, ‘lightly-licensed’, Licensed Shared Access (LSA), or licensed regulatory frameworks.

Article 1 of the Radio Regulations, Nos. **1.166** to **1.176**, defines the parameters to be taken into account in frequency sharing. Spectrum sharing is facilitated by application of technical methods that are considered on a general basis but which also can be used in the assignment of frequencies on a station-by-station basis. Some of these approaches may involve regulatory actions.

Some techniques for allowing shared access to spectrum are static, such as channelling plans and band segmentation (frequency separation), site separation and geographically shared allocation (spatial separation), and signal coding and processing (signal separation).

Other techniques are dynamic – that is they allow enabled devices sharing the same spectrum band to dynamically select a frequency and/or time slot to use to avoid causing interference to other nearby devices.²³ There are several methods available to facilitate the dynamic sharing of spectrum. These include listen before talk (LBT), dynamic frequency selection (DFS), agile systems, spectrum database, spectrum access controller, geo-location database, beacon, sensing, and licensed shared access.²⁴

1.4.1 Spectrum sharing under the license-exempt approach

License-exempt bands are inherently based on spectrum sharing among the various license-exempt users of the bands.

“License-exempt” spectrum refers to spectrum which access is permitted on the basis of “general license”: under this approach any radio device that complies with a predefined set of regulatory parameters is permitted to operate.

These regulatory parameters are defined to ensure protection of radio services (vertical sharing) and also in view of ensuring an equitable access between “license-exempt” radio devices (horizontal sharing).

“Short range devices” (SRD) commonly fall into this category. The term “SRD” allows actually labelling a family of spectrum regulations that belongs to the broader concept of “collective use of spectrum”, as opposed to “exclusive use of spectrum”. They are now encompassing wide range of innovative applications.

Effective access to spectrum by SRDs heavily relies on the principle of “frequency re-use” that is enabled by the low power operation, cluttered environment, and spectrum access mechanisms such as duty cycle limitation.

While spectrum access cannot be guaranteed in the case of “license-exempt spectrum”, it should be noted that the specified regulatory parameters define a predictable sharing environment. Administrations have a responsibility in ensuring sustainable access to SRD bands: the impact of a change in spectrum regulations have to be duly assessed prior to decision making.

With respect to the market, license-exempt approach allows to address multiple segment including that of Broadband connectivity (e.g. Wi-Fi) and of the Internet of Things (IoT).

Concerning the IoT, many solutions are deployed or investigated to address the IoT market under license-exempt rules. In particular, Low power Wide Area Network (LPWAN) systems have already been deployed worldwide in license-exempt spectrum, notably in the 800/900 MHz range. LPWAN systems seek longer range operation compared with conventional SRDs, with relatively low throughput. IoT applications can be offered using LPWAN systems or conventional SRDs based on the target capacity/coverage trade off.

A well-known example of spectrum sharing through time separation is Wi-Fi operations in the license-exempt 2.4 GHz ISM band, where multiple license-exempt devices operating in a Wireless Local Area Network (WLAN) combine a collision-based mechanism called listen-before-talk with exponential back-off to allow for sharing in time of the same spectrum within a localized area.

At present, in several countries, mobile network operators utilize Wi-Fi offload of the downlink data over license-exempt spectrum in the 2.4 GHz ISM band to improve network operations and the user experience, and are laying the groundwork for supplemental downlink in segments of the 5 GHz band.

²³ Ofcom ‘The Future Role of Spectrum Sharing for Mobile and Wireless Data Services’.

²⁴ Handbook on National Spectrum Management (Edition of 2015), ITU.

1.4.2 Dynamic spectrum sharing

In the context of this Report, temporarily unused / unoccupied spectrum is a portion of spectrum in a band designated for use by one of several applications operating under the provisions of the Radio Regulations and that is not being used at a given time and within a given geographic area. Dynamic spectrum sharing stands for the ability of a radio (possibly via implementing cognitive capabilities) to operate on temporarily unused / unoccupied spectrum and to adapt or cease the use of such spectrum in response to other users of the band.

The identification of the portions of spectrum available for dynamic spectrum sharing is under the purview of the Administrations and conditions vary on case-by-case basis. Administrations must ensure that systems applying dynamic spectrum sharing operate in accordance with the Radio Regulations.

Dynamic spectrum sharing allows for real-time adjustment of spectrum use in response to changing environment, circumstances and objectives.²⁵ More concretely, dynamic spectrum sharing techniques enable a radio device to:

- Determine or be informed of which frequencies are available for use on a non-interference basis;
- Operate on these frequencies; and
- Vacate these frequencies when required.

Radiocommunication systems relying on dynamic spectrum sharing is intended to use spectrum when and where it is available under the technical rules in bands for which such sharing is authorized by the NRA.

Dynamic spectrum sharing may be implemented between the services operating with equal rights. It may also be implemented by opportunistic access to spectrum already allocated to a service of higher category subject to not causing harmful interference to nor claiming protection from this service. This may require the opportunistic device to vacate the band at a given time.

There are many variants of the dynamic spectrum sharing techniques/mechanisms that can be implemented, with each having its own strengths and weaknesses for application in a given band based on the requirements of the services that need to be protected. Therefore, it is important for spectrum managers to consider the applicability of various dynamic spectrum sharing techniques on a band-by-band basis.

The application of appropriate dynamic spectrum sharing techniques/mechanisms could be one solution among several other existing solutions, which can assist spectrum managers in developing countries make more efficient use of their spectrum resources. Each sharing solution has its own strengths and weaknesses in relation to the incumbent service(s) that need to be protected, to the benefits that may be derived in terms of innovation and to the associated costs. Therefore, spectrum managers may want to take this into account when considering application of dynamic spectrum sharing techniques/mechanisms in a given spectrum band where this could be possible.

Finally, spectrum management issues for consideration with respect to the implementation of dynamic spectrum sharing-based application include:

- i) The need for detailed sharing and compatibility studies to be performed within ITU-R study groups of the service to be protected in both co and adjacent channels. One example of such studies was for the development of dynamic frequency selection (DFS) as a sensing method by radio local area network (RLAN) in the 5 GHz spectrum, in accordance with Recommendation ITU-R M.1652, to avoid interference to the radar systems;

²⁵ IEEE 1900.1.a-2012, Definitions and Concepts for Dynamic spectrum access: Terminology Relating to Emerging Wireless Networks, System Functionality, and Spectrum Management.

- ii) The need to take into account cross-border coordination in accordance with the Radio Regulations;
- iii) The need for mature sensing technology, if applicable, to be able to measure accurately the spectrum occupancy;
- iv) The risk for investments in opportunistic uses, associated with the uncertainties on the medium and long term availability of spectrum, either as a result of changes in the spectrum requirements of higher priority users or as a result of a change in higher priority allocations;
- v) The challenge for the regulator's ability to change the priority users' spectrum allocation at a future stage, noting that the identification of a frequency band for "license-exempt" applications may be seen as irreversible, or if feasible, may take a very long period of time to be changed to an alternative purpose. As a consequence, administrations should, in the context of their decision making-process, evaluate their long-term strategy with respect to the future of the subject frequency band prior to authorizing license-exempt opportunistic access. They should also ensure, through the terms on their regulatory decision authorizing opportunistic access, that future decisions in terms of spectrum planning can be enforced;
- vi) The challenge of ensuring the compliance of the devices with national and international regulations and the enforcement of these regulations. These compliance and enforcement aspects will need to be addressed in a satisfactory way if such spectrum sharing technologies are to be implemented in the future;
- vii) The database related issues including complexity reliability and management if applicable;
- viii) The technical challenge of developing devices that are able to operate in any channel over a wide frequency range while having to avoid adjacent channel interference into higher priority services.

1.4.3 ITU regulatory framework for spectrum sharing

Since the 1960's, the ITU has been developing and implementing spectrum sharing technologies and techniques as a management method for increasing spectrum utilization efficiency. In principle, these technologies may now enable dynamic spectrum sharing based on dimensions of time, frequency, spatial location, and/or signal separation.

1.4.3.1 Adaptive system or Dynamic Frequency Selection (DFS)

Resolution 729 (Rev.WRC-97) invited the ITU membership to use frequency adaptive systems for MF (300 to 300 kHz) and HF (3 to 30 MHz) spectrum bands.²⁶

Resolution 229 (Rev.WRC-12) specifies the conditions of use of the bands 5 150-5 250 MHz, 5 250-5 350 MHz and 5 470-5 725 MHz by the mobile service for the implementation of wireless access systems including radio local area networks (RLAN) under the condition that RLANS should not cause interference to systems of other primary services at these frequencies – radar systems installed on satellite, terrestrial, and maritime platforms. An RLAN seeking to access these frequencies is required to implement a mechanism called Dynamic Frequency Selection (DFS) to detect emissions from these radars and avoid causing co-channel interference into them. DFS performance criteria were defined separately by Recommendation ITU-R M.1652.

Other Recommendations:

- ITU-R **F.1110** Adaptive radio systems for frequencies below about 30 MHz.
- ITU-R **SM.1266** Adaptive MF/HF Systems.

²⁶ Resolution 729 (WRC-97).

1.4.3.2 Software Defined Radio and Cognitive Radio System

In preparation for WRC-12, ITU-R studied the question whether software defined radio and cognitive radio systems could operate under the existing international regulatory framework, i.e. the Radio Regulations.

ITU-R studies resulted in the following definitions:

- *Software Defined Radio (SDR)*: ‘A radio transmitter and/or receiver employing a technology that allows the RF operating parameters including, but not limited to, frequency range, modulation type, or output power to be set or altered by software, excluding changes to operating parameters which occur during the normal pre-installed and predetermined operation of a radio according to a system specification or standard.’²⁷
- *Cognitive Radio System (CRS)*: ‘A radio system employing technology that allows the system to obtain knowledge of its operational and geographical environment, established policies and its internal state; to dynamically and autonomously adjust its operational parameters and protocols according to its obtained knowledge in order to achieve predefined objectives; and to learn from the results obtained.’²⁸

Recommendation 76 (WRC-12)²⁹ and Resolution ITU-R 58 state that services incorporating these spectrum sharing technologies shall operate in accordance with the Radio Regulations and protect stations operating according to the Radio Regulations.

ITU-R Study Group 1 has approved in 2017 a new [Report ITU-R SM.2405-0](#)- Spectrum management principles, challenges and issues related to dynamic access to frequency bands by means of radio systems employing cognitive capabilities (see [Document 1/75 \(Rev.1\)](#)), which highlights situations where the coexistence scenario may be more difficult to manage and/or may require more attention include the implementation of dynamic spectrum access in the frequency allocations used for:

- i) Safety of life applications, this would pose a major risk to the safe and efficient usage of aviation and maritime services which could not be easily corrected once the devices are in general use;
- ii) Mobile satellite services and radiodetermination-satellite services, as the mobile nature of stations makes the practical implementation of databases difficult;
- iii) Earth exploration satellite services and space research services, as passive services cannot be detected by spectrum sensing etc.

Some other more technical issues related to the use of CRS technologies have also to be considered, as explained in detail in Reports ITU-R M.2330 and ITU-R M.2242, such as the implementation complexity, reliability of different methods for obtaining knowledge and interference avoidance; the need for a timely availability and good quality of service; the need for sufficient degree of protection against malicious behaviour which may arise due to any CRS operation; etc.

As for all radio applications, a regulatory framework for dynamic spectrum sharing-based applications must be defined in accordance with the provisions of the Radio Regulations. Noting that dynamic spectrum sharing is a spectrum access mechanism to facilitate the shared use of the spectrum, a dynamic spectrum sharing based application is supposed to operate within the allocated radiocommunication services and therefore the procedures of Article 15 (Interferences) apply.

ITU-R has undertaken a number of studies in recent years in particular in response to Resolution ITU-R 58-1, which are relevant to cognitive radio and dynamic spectrum solutions (see ITU-R References provided before the Annexes of this report).

²⁷ Report ITU-R SM.2152.

²⁸ Report ITU-R SM.2152.

²⁹ WRC-12 Recommendation 76 (WRC-12).

1.4.4 Licensed Shared Access (LSA)

“Licensed Shared Access” was initially introduced as an enabler to unlock access to additional frequency bands for mobile broadband under individual licensed regime while maintaining incumbent uses, has been developed in the CEPT. LSA is defined as “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 Licensed Shared Access (LSA) approach, the additional users are authorised 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 authorised users, including incumbents, to provide a certain Quality of Service (QoS)”.³⁰ LSA aims to ensure a certain level of guarantee in terms of spectrum access and protection against harmful interference for both the incumbent(s) and LSA licensees, thus allowing them to provide a predictable quality of service. Incumbent(s) and LSA licensees each have exclusive access to spectrum at a given location at a given time. LSA excludes concepts such as “opportunistic spectrum access”, “secondary use” or “secondary service” where the applicant has no protection from the primary user.³¹ LSA has been used successfully, for example to deploy GSM or 3G networks in spectrum previously allocated to military services. It is being implemented within CEPT at 2.3 GHz, based on ETSI and 3GPP standards, through coexistence rules applying between the newcomers and the incumbents, under the control of the spectrum regulator.

In the broadest sense, LSA is nothing new: introducing new services compatible with existing ones has been the spectrum manager’s practice for decades. However, smarter tools such as dynamic databases are offering new opportunities to share with incumbent users which have limited time of geographical use of the band. The LSA approach allows addressing the market demand for introduction of new applications or networks, operated under an individual license regime, in specific bands, allowing for more efficient spectrum use and security for investment.

In addition, ITU-R Study Group 1 has approved in 2017 a new **Report ITU-R SM.2404-0** – Regulatory Tools to support enhanced shared use of spectrum (see [Document 1/74\(Rev.1\)](#)).

1.4.5 Tiered access to spectrum

Access to spectrum can be authorized under tiered access models, whereby different classes of users with different rights and obligations access the same sections of spectrum. These models generally designate a primary incumbent (usually the current license holder or government agency) who maintains unfettered access to that portion of spectrum, while also allowing additional secondary and tertiary levels of users, each of which is accorded a lower level of interference protection, and who must halt transmitting if a higher tier user accesses the spectrum. Several countries have begun to develop and implement these tiered access models for spectrum bands. In fact, the standard three-tier model of primary, secondary and license-exempt use of spectrum has been practiced in many countries for several years.

The United States has adopted initial rules to permit the development of a three-tier access model for spectrum between 3550-3700 MHz, with the intent to allow one or more commercially provided “Spectrum Access Systems” (SAS) to manage access to the spectrum in almost real time.³² Implementation of the rules is in its early stages, with protocols still under development.

³⁰ See Radio Spectrum Policy Group (RSPG) Opinion on Licensed Shared Access, November 2013, ref. RSPG13-538. The RSPG is a high-level advisory group that assists the European Commission in the development of radio spectrum policy.

³¹ ECC Report “Licensed Shared Access”, February 2014, page 18.

³² Amendment of the Commission’s Rules with Regard to Commercial Operations in the 3550-3650. Band, Report and Order, 30 FCC Rcd 3959 (2015) (“3.5 GHz Order”) https://apps.fcc.gov/edocs_public/attachmatch/FCC-16-55A1.pdf.

The uppermost tier consists of “Incumbent Access” users that include authorized federal (government) and grandfathered fixed-satellite service users currently operating in the 3.5 GHz band. These users will be protected from harmful interference caused by all other users of the band.³³

The second tier consists of licensed users in a “Priority Access” tier. Priority Access Licenses (PALs) will be assigned using competitive bidding within the 3550-3650 MHz portion of the band. Each PAL is defined as a non-renewable authorization to use a 10 MHz channel in a single census tract for three-years. Up to seven total PALs may be assigned in any given census tract with up to four PALs licensed by any single applicant. Applicants may acquire up to two-consecutive PAL terms in any given license area during the first auction.

The third tier or General Authorized Access tier will be licensed-by-rule to permit open, flexible access to the band for the widest possible group of potential users. General Authorized Access users will be permitted to use any portion of the 3550-3700 MHz band not assigned to a higher tier user and may also operate opportunistically on unused Priority Access channels. Users within each tier cannot cause interference to users in the above tier(s) and cannot claim protection from users in the higher tiers.

1.4.6 TV White Spaces

Some Administrations have implemented technical and service rules or have granted temporary authorizations for license-exempt devices to opportunistically access the so-called Television White Spaces (TVWS).

The TVWS is defined as “A portion of spectrum in a band allocated to the broadcasting service and used for television broadcasting that is identified by an administration as available for wireless communications at a given time in a given geographic area on a non-interfering and non-protected basis with regard to other services with a higher priority on a national basis”.³⁴ License-exempt access to the TVWS is subject to the Radio Regulations and applicable national regulations.

Spectrum in the UHF and VHF television bands experience lower path loss and have better penetration through more common building materials and foliage than do radio waves at high frequencies. Additionally, line-of-sight operation is not required in order to achieve quality reception. To date, there have been deployments of fixed point-to-point and point-to-multipoint access points and customer premise equipment in the TVWS that can serve areas that were previously difficult to reach with traditional terrestrial infrastructure and accelerate the process of bringing high speed Internet the “last mile” to rural and remote populations. **Annex 2** summarizes the contributions from several Administrations where there have been pilot projects, technical trials, and commercial use of the TVWS.

To date, Canada, Singapore, the United Kingdom, Republic of Korea, and the United States of America³⁵ have adopted technical and service rules allowing for TVWS access to the VHF and/or UHF-band television broadcast spectrum. Each of these countries have authorized the use of geolocation databases to enable access to unused/unoccupied channels while protecting incumbent users in the broadcast television bands. As sensing technologies for TVWS application are not sufficiently mature, and have not yet been certified, geolocation databases have emerged as the means to protect incumbent

³³ Further details on protection mechanisms for the SAS can be found in FCC-15-47 and FCC 16-55.

³⁴ Report ITU-R M.2225 (2011).

³⁵ See Unlicensed Operation in the TV Broadcast Bands, ET Docket No. 04-186; Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band, ET Docket No. 02-380, Second Memorandum Opinion and Order, 25 FCC Rcd 18661 (2010); Industry Canada, Framework for the Use of Certain Non-Broadcasting Applications in the Television Broadcasting Bands Below 698 MHz (2012), available at <http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf10493.html>; Infocomm Development Authority of Singapore, Regulatory Framework For TV White Space Operations In The VHF/ UHF Bands (2014), available at: http://www.ida.gov.sg/~media/Files/PCDG/Consultations/20130617_whitespace/ExplanatoryMemo.pdf; Ofcom, Implementing TV White Spaces (2015), available at: <http://stakeholders.ofcom.org.uk/binaries/consultations/white-space-coexistence/statement/tvws-statement.pdf>.

services. For more detailed technical information on the implementation of TVWS, see **Annex 2**, which provides a summary of different country experiences with TVWS implementation.

Based upon the experiences of these countries, a few key regulatory components can be identified.

1.4.6.1 Interference protection experiences

National regulations are necessary to provide for the protection of incumbent services. These commonly make use of recognised standards to describe the level of protection afforded to a given radio service and/or technology.

Having established the protection requirements, it is then necessary to calculate the potential severity and probability of interference to incumbent services. To do this, the location of the incumbent service receivers and the TVWS transmitters is required, along with an agreed set of parameters and an appropriate propagation model for determining the level of interference.

Protection requirements may evolve with time, considering that the capabilities of incumbent service and user requirements are also evolving. This may have an impact on the necessary parameters to allow access for opportunistic services.

Existing TVWS regulations incorporate various propagation models which are used to calculate channel availability at a given location. These propagation models include signal contours, free space, FCC TM 91-1, Longly-Rice, Okamura-Hata, and the Ofcom-developed model. These models have different characteristics and use different technical means which may affect the manner in which protection criteria are calculated and specified. Setting interference protection requirements may also involve defining protected service areas and receiver protection requirements.

Annex 2, Section A2-2, includes information on national experiences relating to interference protection.

1.4.6.2 Interference avoidance methods

Once the frequency of operation and the protection requirements have been established, a system must be devised to allow White Space Devices (WSDs) to meet these requirements. As discussed above, authorizations have been given in some countries for implementing geolocation databases as a means to avoid interference.

These databases may be managed by either the regulator or by private sector companies. In the latter case, the regulator is responsible for providing certain accurate data about incumbent services, and those necessary to ensure the protection of radio systems in neighbouring countries if applicable, and defining what criteria are sufficient for certification of a database. These criteria must ensure that White Space Devices Databases (WSDBs) contain and provide sufficient and reliable information so that WSDs connected to the database can avoid causing harmful interference.

National regulatory frameworks for TVWS, where they exist, are intended to ensure no harmful interference for the continued operation of protected incumbent services. Limiting access to spectrum for WSDs under the control of geo-location database(s) reduces the possibility of interference events caused by “unknown” devices. This requires that regulations are in place to ensure that the communications between the WSDB and the WSD are secure, and that only certified WSDBs and authorized WSDs can communicate.

Annex 2, Section A2-2, includes information on national experiences relating to interference avoidance methods.

1.4.7 Case studies of broadband access in the TVWS

Contributions have been received from several Administrations in the framework of the development of this report, which provides information on pilot projects, technical trials, and commercial use of the TVWS, as follows:

- **Bhutan** implemented a pilot project to design an eHealth service delivery platform piloting the TVWS technology. The project links rural health clinics with a central reference hospital, utilizing TVWS technology for last mile connectivity.
- **Botswana** launched a TVWS pilot project to bring specialized health services to local Botswana hospitals and clinics and to overcome some rural health challenges.
- **Ghana** started commercial deployment of TV White Space enabled services with one company to provide internet connectivity to two educational institutions. This has given students access to affordable broadband internet around the campuses and their environs.
- **Malawi** conducted projects extending Internet connectivity to two schools and a rural hospital. TVWS devices were also deployed to enhance national seismic early warning systems and to connect runways and bases of the Air Wing Unit of the Malawi Defense Force to the Internet.
- **The Philippines** implemented a TVWS pilot project to support community connectivity, sustainable resource management, educational access, and disaster resilient communications in a remote province
- **The Republic of Korea** set a regulatory framework for the TVWS and allowed for TVWS commercial services in April 2017.
- **The United States of America (USA)** has pioneered the use of license-exempt spectrum in TVWS, and three case studies in the USA are addressing the deployment of commercial wireless Internet service in rural areas, the extension of the service area of libraries into communities, and the provision of university campus-wide broadband.

More information on these case studies can be found in **Annex 2**.

1.4.8 Benefits and challenges associated with the use of TV white spaces

The considerations mentioned in **Section 1.4.2** above in the general case of dynamic spectrum sharing in terms of requirements for studies, risks and challenges, also apply to TVWS.

TVWS may be used to provide Internet service to underserved areas under certain conditions.

In this context, TVWS may be used to provide a lower cost backhaul to broadband internet access. However, the UHF spectrum does not allow the use of highly directional antennas and the use of a license-exempt model for TVWS limits the power available. For these reasons, and due to the limited bandwidth available in the UHF band, TVWS may be unable to provide the type of capacity suitable for backhauling of broadband internet access.

TVWS may also be used as an extension of fixed or fixed-satellite networks to directly provide broadband internet access to customers in underserved areas, taking advantage of favourable propagation conditions of the UHF band. However, efficient frequency reuse requires a careful network planning among all access points, which may be difficult under a license-exempt regime, thus limiting the capacity offered by the network.

Also, rules applicable to license-exempt devices restrict the maximum power level of wireless broadband radios, which limits the advantage of the UHF band in providing larger coverage area. As a result of WRC-07 and WRC-15 decisions regarding the introduction of IMT in large portions of the 470-862 MHz frequency range, many administrations intend to deploy broadband mobile networks in this

range. Also, WRC-23 may consider further introduction of IMT in this frequency range. This results in uncertainty as to the future availability of TVWS in this range.

The experiences of countries having developed TV white space regulations, as shown in **Annex 2**, demonstrates the complexity of the process carried out by these administrations to put in place a satisfying regulations with all the necessary rules to protect incumbent services, the framework for selection and operation of database and the enforcement issues.

Overall, as a result of the limited number of countries having developed regulations for the use of TV white space, as well as the limited deployment in these countries, there is a low number of vendors and device models on the market and the ecosystem has not reached the level of maturity of other commercial systems, which impacts the equipment pricing.

1.5 Current ITU-R studies and investigations

Upon the request of the Radiocommunication Assemblies, ITU-R study groups are currently performing the following additional studies:

- Additional studies within Study Groups 1 and 5 in response to Resolution ITU-R 58-1 “Studies on the implementation and use of cognitive radio systems”.
- Additional studies within WP 1B in response to Question **ITU-R 208-1/1** “Alternative methods of national spectrum management”.
- Additional studies within WP 1C in response to Question **ITU-R 235/1** “Spectrum monitoring evolution”.
- Additional studies within WPs 5A and 5D in response to Question **ITU-R 241-3/5** “Cognitive radio systems in the mobile service Cognitive radio systems in the mobile service”. Additional studies by WP 5D on the revision of Recommendation ITU-R M.1036 on frequency arrangements for new IMT bands identified at WRC-15.

2 CHAPTER 2 – Spectrum economics

2.1 Introduction

Chapter 2 highlights the experiences of several administrations with respect to spectrum pricing, licensing fees, and auctions. Readers are encouraged to consult [Report ITU-R SM.2012](#), “Economic aspects of spectrum management” for detailed guidance. The Chapter also examines some of the economic aspects associated with license-exempt use and specifically license-exempt use of the TV White Spaces to provide spectrum managers information on some of the potential costs and benefits when considering such a sharing approach.

2.2 Spectrum pricing, licensing fees and auctions

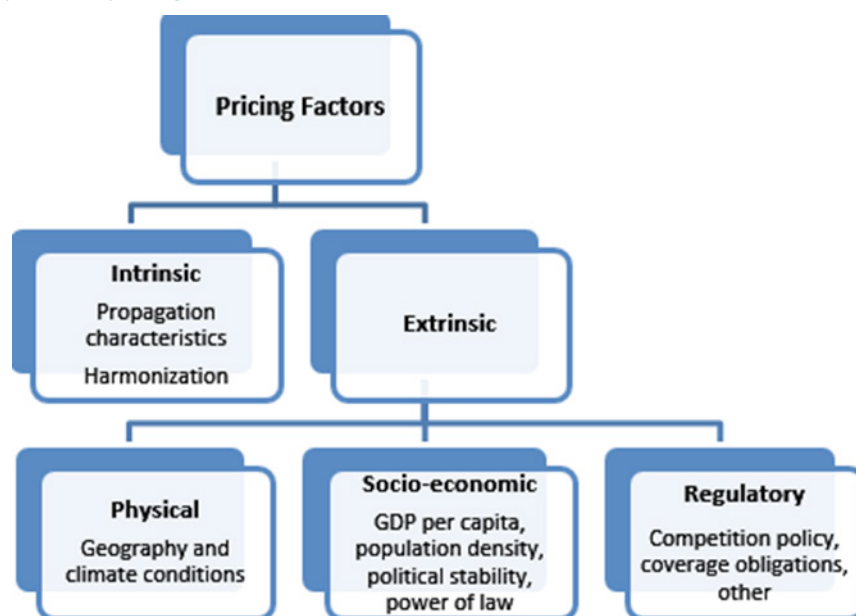
This section addresses methodologies to evaluate spectrum fees. There exist three types of spectrum fees – a one-time spectrum auction fee, annual spectrum use fees, and a non-recurring use fee (e.g. license amendment and renewal). A National Regulatory Authority (NRA) determines the specific spectrum fee by:

- a) **Setting general rules** as a function of the type of application (commercial/non-commercial, civilian/non-civilian, exclusive/shared-use, etc.);
- b) **Identifying pricing factors:** The pricing factors an NRA uses to establish the auction reserve price and associated annual royalties for mobile licensees include both intrinsic and extrinsic characteristics associated with each spectrum band. Intrinsic factors relate to the type and characteristics of the band under consideration, such as propagation characteristics. Extrinsic factors cover aspects including physical (e.g., geography), socio-economic (GDP per capita, population density, etc.), and regulatory (competition policy, etc.) ones.
- c) **Applying spectrum pricing methodologies:**
 - **Administrative Fees Recovery (Cost based):** Fees are calculated to recover different administrative costs including cost of issuing, processing and renewing licenses, spectrum planning, spectrum monitoring, international coordination, personnel, training and overheads
 - **Market-based:** Spectrum valuation is based on market needs and demands. Auctioning is one of the methods used in this context when the demand of spectrum is greater than the spectrum available.
 - **Formulas:** An administration can use certain formulas to approximate the market value of the spectrum. To do so, many parameters and factors need be incorporated and carefully assigned numerical values. Examples of such parameters include amount of spectrum (BW), type of band (Band Factor), band congestion factor (related to the opportunity cost), population density, coverage area, technology used, financial coefficient, and a socio-economic benefit coefficient. For example:

Price = (Price per MHz) x BW x Band Factor x Coverage Factor x Congestion Factor / Social Benefit Factor

Annex 2, Section A2-4, provides case studies from Côte d’Ivoire on estimating the costs of licenses and frequencies, Republic of Niger on methods to determine the frequency fees, the Russian Federation with the experience of the Russian Federation in the field of spectrum fees, and the Republic of Korea on beauty contests and auctions in spectrum management.

Figure 1: Spectrum pricing factors



2.3 Economic aspects related to improving broadband access

While there continues to be improvement, broadband access remains unaffordable in the majority of the world's poorest countries".³⁶ Based on ITU estimates, the global Digital Divide in calendar year 2016 can be characterized by the following.

Table 1: The Digital Divide in 2016

Select metrics	Country classification		
	Developed	Developing	Least Developed Countries (LDCs)
Percentage of individuals using the Internet	81.0	40.1	15.2
Percentage of households with Internet access	83.8	41.1	11.1
Mobile broadband subscriptions per 100 inhabitants	90.3	40.9	19.4
Fixed broadband subscriptions per 100 inhabitants	30.1	8.2	0.8
Broadband affordability – Price for the basic service less than five per cent of average monthly gross national income	45 of 45	88 of 106	5 of 43

At the end of 2015, 88 developing countries had achieved the Broadband Commission's affordability target set in 2011 – "By 2015, entry-level broadband services, should be made affordable in developing countries through adequate regulation and market forces (amounting to less than 5 per cent of average monthly income)".³⁷ Broadband in 18 developing countries (excluding LDCs) and 38 LDC countries, where available, is still considered unaffordable vis-à-vis the Broadband Commission's target. Even in these administrations where entry-level broadband prices, on average, is considered

³⁶ International Telecommunication Union (ITU) ICT Facts and Figures 2016. <https://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2016.pdf>.

³⁷ United Nations (UN) Broadband Commission 2011.

affordable, there are populations within, often in the less densely populated areas, where entry-level service remains unaffordable.

The most recent ITU statistics indicate that: (1) Mobile broadband services have become more affordable than fixed-broadband services; (2) The average price of a basic fixed-broadband plan is more than twice as high as the average prices of a comparable mobile broadband plan, and (3) In LDCs, fixed-broadband services are on average more than three times as expensive as mobile-broadband services.

Administrations in developing countries, including LDCs, are pursuing strategies to ensure basic broadband service is available and affordable for all its residents. Without the available broadband service being affordable, for many it has the same net effect as if there were no broadband coverage at all.

2.4 Assessing the economic benefits of using spectrum

The ITU-R Report on the Economic aspects of spectrum management, cites two methods used for quantifying economic benefits by calculating the contribution of radio use to the economy using: (1) Gross Domestic Product (GDP) and employment and (2) Consumer and producer surplus.³⁸ Each method has its associated advantages and disadvantages.³⁹

2.4.1 Economic benefits of licensed spectrum

The benefits derived by a telecommunications operator from its spectrum occupancy may be evaluated by considering, among other things, its net operating results. From the economic and accounting standpoint, the fees associated with frequency usage and applied to an operator should be in relation to its net operating result.

Some of the economic condition surrounding licensed operations include the following factors: socio-economic factors, characteristics of authorizations or licenses allocated, terms of reference of authorized operators, comparison/transportation of fee levels.⁴⁰

Additional factors affecting the value of the economic benefits that arise from the use of licensed radio spectrum include: (1) frequency availability; (2) suitability; (3) demand; and (4) country geography that incorporates regional variations and spectrum congestion.

Although the application of frequency usage fees is a legitimate approach, those fees must not be set too high in order not to discourage initiatives and hamper the development of new services. In any event, the level of the fees cannot exceed the operator's propensity to pay.⁴¹

2.4.2 Economic benefits of license-exempt spectrum

License-exempt spectrum can be considered a production factor that generates value:

- Complementing wireless and cellular technologies, thereby enhancing their effectiveness;
- Developing alternative innovative technologies, thus expanding consumer choice;
- Expanding access to communications services beyond what is economically optimal by technologies operating in licensed bands.

It proves somewhat more challenging to capture and quantify the full economic benefits of license-exempt spectrum as: (1) it is accessed by numerous heterogeneous devices and services (which makes

³⁸ Report ITU-R SM.2012-5 (06/2016).

³⁹ *Ibid.*

⁴⁰ *Ibid.*

⁴¹ *Ibid.*

calculating impacts on GDP and producer surplus more challenging), (2) it is difficult to estimate the consumers' willingness to pay as it has been done in the case of licensed spectrum (which makes calculating the consumer surplus more challenging) and (3) it is hard to establish a baseline as license-exempt spectrum is being used by technologies and services that are growing at a rate that renders obsolete any research completed even a few years ago.

Taking into account these caveats, spectrum managers may apply the two methods typically used to calculate the contribution of radio use to the economy to license-exempt spectrum. Ultimately, if the NRA decides to go forward with some fee based on its analysis, it needs to keep in mind the same consideration as with licensed operators – the level of the fees cannot exceed the operator's propensity to pay – especially to the extent where the objective is the provision of affordable entry-level broadband access.

2.4.3 Potential costs and economic benefits associated with shared use of spectrum

Sharing enables the use of spectrum in situations where it might otherwise remain unused, which may improve spectrum efficiency. This may increase consumer surplus as well as increase GDP. This may also lower barriers to spectrum access. This may facilitate new entrants, resulting in stronger competition, which may lead to a reduction of costs. Secondly, the increase in availability of spectrum may improve the quality of existing services. Citizens and consumers may also benefit from a reduction in congestion in other spectrum bands.

Opening access to any spectrum band incurs administrative costs on NRAs, whether on an exclusive or shared basis, licensed or license-exempt model. These costs arise from the required efforts to establish national policy and regulatory frameworks for how access to that spectrum is implemented and managed.

These processes are necessary to ensure compliance with the Radio Regulations, initiate cross-border coordination, and protect licensed incumbents from harmful interference. These costs may be largely one-time or one-off, but offset in part by the increased costs of monitoring capability when it is necessary to identify situations involving harmful interference. More sophisticated spectrum sharing regimes, e.g. when it is necessary to develop and maintain accurate and reliable information on the actual spectrum use, may require dedicated resources (see **Section 1.4** of **Chapter 1**).

3 CHAPTER 3 – Spectrum management activities and resources

3.1 National Table of Frequency Allocations (NTFA) guidelines

3.1.1 NTFA

In all countries and regional as well as international organizations, there are many competing demands to use valuable spectrum resource for different radio services, from government, public and private users to international systems such as maritime and aeronautical services, global or regional terrestrial and satellite telecommunications systems that require a degree of frequency harmonisation for cross-border interoperability. One of the most important tools to address the competing demands is a carefully prepared National Table of Frequency Allocations (NTFA). The NTFA will have several levels of detail. The top level should define clearly how frequency bands have been allocated in conformity with the Radio Regulations to radiocommunications services in the country concerned. The next level should define how these “service bands” are divided or shared between major uses, in particular government and non-government uses. ITU has developed guidelines which focus on the detailed preparation of an NTFA⁴² (see also document 1/56, “Guidelines for the preparation of a National Table of Frequency Allocations (NTFA)” and **Annex 3**). Recommendation ITU R SM.1265-1 “National alternative allocation methods” examines alternate allocation structures with the aim of using the radio spectrum more efficiently and providing flexible access to the spectrum by new technologies.

3.1.2 Assessing countries’ needs for spectrum management and IT tools/systems

ITU developed guidelines (Spectrum Management Assessment Guideline) provide a standard approach for national governments to self-assess national spectrum management development needs.⁴³ The International Telecommunication Union Telecommunication Development Bureau (ITU-BDT) can supply a computer program to assist the administrations of developing countries to perform their spectrum management responsibilities more effectively. This program is known as the Spectrum Management System for Developing Countries (SMS4DC).⁴⁴ Prior to the installation and operation of SMS4DC, the Administration should have in place existing legal, regulatory and technical mechanisms for national spectrum management. SMS4DC software has been designed to manage frequency assignments to the land mobile, fixed and broadcasting services and for frequency coordination of Earth stations (Radio Regulations Appendix 7 procedures). Though the system automates most of the technical assessment procedures and displays the results, the final spectrum management decision must be made by a suitably qualified radio engineer who fully understands the assignment procedures and is able to correctly interpret the results displayed. The ITU-R Handbook: Computer-aided Techniques for Spectrum Management (CAT) (2015) contains more detailed information on spectrum management tools.⁴⁵

Annex 2 provides examples/experiences of case study in Hungary, China (People Rep. of) and Tanzania on spectrum management activities, related respectively to “Spectrum Management IT System (STIR)”, “The improvement of spectral efficiency based on LTE technology” and “The legal framework on Spectrum Management in Tanzania”.

⁴² <http://www.itu.int/en/ITU-D/Spectrum-Broadcasting/Documents/Publications/Guidelines-NTFA-E.pdf>.

⁴³ See <http://www.itu.int/en/ITU-D/Spectrum-Broadcasting/Documents/Publications/Administration%20Assesment-E.pdf> and Document SG1RGQ/81 + Annex, “Assessing the spectrum management needs of developing countries”.

⁴⁴ <http://www.itu.int/pub/D-STG-SPEC-2015-V5.0>.

⁴⁵ <http://www.itu.int/pub/R-HDB-01>.

3.2 Results and preparations of World Radiocommunication Conferences

3.2.1 WRC cycle and WRC process

World Radiocommunication Conferences (WRCs) are normally convened every three to four years to update the Radio Regulations (RR) and deal with any question of a worldwide character within its competence and related to its agenda. The results of a WRC are included in its Final Acts which are signed by the ITU Member States, becomes international law for inclusion in national regulations. These final acts are incorporated in the subsequent edition of the Radio Regulations that is generally published within a year after the WRC. The Radio Regulations are complemented with the Rules of Procedure approved by the Radio Regulations Board (RRB) in order to clarify any difficulty arising from the implementation of the provisions in the Radio Regulations.

During the preparatory process of a WRC, draft items to be put on the agenda and preliminary agenda of the next and subsequent WRCs respectively are proposed and approved at the end of this WRC. Immediately after the WRC, the ITU-R Conference Preparatory Meeting (CPM) holds its first session to organize the ITU-R preparatory studies for the next and subsequent WRCs (see [Resolution ITU-R 2](#)).

The results of the ITU-R preparatory studies (e.g., sharing conditions, protection limits, transitional regulatory measures, etc.) are included in new or revised [ITU-R Recommendations](#) and/or draft WRC Resolutions, which can become mandatory if incorporated by reference in the Radio Regulations by the WRC. The assumptions made, calculations performed or other detailed information used to derive those sharing conditions or protection limits are usually described in new or revised [ITU-R Reports](#) and/or other ITU-R relevant publications.

For each item and issue on the agenda of the WRC, background information, a summary and analysis of the studies, and methods to satisfy the agenda item/issue, accompanied if necessary by draft modifications to the Radio Regulations, are consolidated during the second session of the CPM and included in the CPM Report to the WRC.

The information contained in the CPM Report is of primary importance for the ITU Member States to better understand the issues on the WRC agenda, understand also the positions and views of the other Member States and prepare proposals to the WRC. It is important to note that, during all the study cycle, the ITU-R Sector Members are able to contribute directly to the studies, while only the Member States can submit proposals to the WRC.

The regional preparations for the WRC described in [Resolution 72 \(Rev.WRC-07\)](#) as well as the ITU inter-regional Workshops on WRC Preparation are also a key element of the success of the WRCs, in particular in order to coordinate and develop as many common or multi-countries proposals as possible.

3.2.2 WRC-15

The most recent WRC (WRC-15) was held in Geneva from 2 to 27 November 2015. A total of 3,275 participants representing 162 Member States and 130 observer organizations attended WRC-15. Mr Festus Yusufu Narai Daudu (Nigeria) was elected as Chairman of the WRC-15.

WRC-15 addressed over 40 topics related to frequency allocation and frequency sharing for the efficient use of spectrum and orbital resources. WRC-15 fielded outcomes in: mobile broadband communications, amateur radio service, emergency communications and disaster relief, search and rescue, earth observation satellites for environmental monitoring, unmanned aircraft and wireless avionics systems, global flight tracking for civil aviation, enhanced maritime communications systems, road safety, operation of broadband satellite systems (earth stations in motion), universal time, fixed satellite services, maritime-mobile satellite services, and satellite procedures.

In particular regarding mobile broadband communications, WRC-15 agreed on additional allocations to the mobile service and identification for International Mobile Telecommunications (IMT) of frequency bands in the L-band (1427-1518 MHz) and C-band (3.4-3.6 GHz), paving the way for the availability of globally harmonized spectrum for mobile broadband services in these bands. WRC-15 also achieved agreement on some additional bands or portions thereof that were also allocated to the mobile service and identified for IMT in some countries (470-698 MHz, 3.3-3.4 GHz, 3.6-3.7 GHz and 4.8-4.99 GHz).

Studies are on-going for the revision of Recommendation ITU-R M.1036 on frequency arrangements for new International Mobile Telecommunications (IMT) bands identified at WRC-15. The implementation of IMT in these additional bands is expected to facilitate the deployment of mobile broadband in developing countries. It should also be noted that portions of bands below 1 GHz are identified for IMT. This should be taken into account when considering options with respect to dynamic spectrum sharing and the deployment of TVWS (TV White Space).

WRC-15 also decided to include studies in the agenda for the next WRC in 2019 for the identification of bands between 24 and 86 GHz in order to meet demand for greater capacity, notably through the implementation of **IMT-2020**. In addition, studies for WRC-19 will cover frequency related matters of WAS/RLAN in 5 GHz and regulatory actions for High-Altitude Platform Stations (HAPS), which could further facilitate access to mobile broadband applications.

WRC-15 also took a decision that will provide enhanced capacity for **mobile broadband in the 694-790 MHz frequency band in ITU Region 1** (Europe, Africa, the Middle East and Central Asia) and a globally harmonized solution for the implementation of the digital dividend, while providing full protection to television broadcasting and aeronautical radio navigation services in this band.

Thus, prior to authorizing a “license-exempt” application, the decisions made by WRC-12 and WRC-15 in allocating large parts of the UHF band to the mobile service and identifying them for IMT need to be factored in the national long-term strategy regarding the UHF band. Resolution **235 (WRC-15)** must also be taken into account when making decisions on deployment of WSD in TVWS. This is addressed further in **Section 3.2.3** below.

The modifications made to the Radio Regulations at WRC-15, including the new or revised WRC Resolutions and Recommendations as well as the ITU-R Recommendations incorporated by reference in the RR, have been included in the 2016 Edition of the Radio Regulations which is available at: www.itu.int/pub/R-REG-RR.

The most recent edition of the Rules of Procedure, which reflect the WRC-15 decisions, are available at: www.itu.int/pub/R-REG-ROP/en.

Annex 4 highlights the relevant decisions of the RA-15 and the WRC-15 which are especially important for developing countries.

3.2.3 Preparation for WRC-19 and WRC-23

The next WRC has been scheduled in November 2019 and the subsequent one in 2023. The Agenda of WRC-19 can be found in **Council Resolution 1380 (MOD C-17)** derived from **Resolution 809 (WRC-15)** and the Preliminary Agenda for WRC-23 in **Resolution 810 (WRC-15)**. ITU-R preparatory studies have been organized during CPM19-1 (see the results in **BR Administrative Circular CA/226** and its Corrigendum 1) and the latest information on these studies can be found at: www.itu.int/go/rcpm-wrc-19-studies. Activities related to the regional preparation for WRC-19 can be found at: www.itu.int/go/wrc-19-regional, and additional information can be found on the WRC-19 webpage at: www.itu.int/go/wrc-19. A brief presentation on the above-mentioned topics was provided during a WTDC Res.9 Group meeting and can be found in document 1/240, “Outcome of World Radiocommunication Conference (WRC) 2015”.

Resolution 238 (WRC-15)

In preparation for WRC-19 consideration under agenda item 1.13, Resolution **238 (WRC-15)** invites ITU-R to conduct studies on frequency-related matters for International Mobile Telecommunications identification including possible additional allocations to the mobile services on a primary basis in portion(s) of the frequency range between 24.25 and 86 GHz for the future development of International Mobile Telecommunications for 2020 and beyond. This activity will include sharing and compatibility studies, taking into account the protection of services to which the band is allocated on a primary basis, for the frequency bands: 24.25-27.5 GHz², 31.8-33.4 GHz, 37-40.5 GHz, 40.5-42.5 GHz, 42.5-43.5 GHz, 45.5-47 GHz, 47.2-50.2 GHz, 50.4-52.6 GHz, 66-76 GHz and 81-86 GHz.

Resolution 235 (WRC-15)

Resolution 235 (WRC-15) resolves to invite ITU-R, after the 2019 World Radiocommunication Conference and in time for the 2023 World Radiocommunication Conference to review the spectrum use and study the spectrum needs of existing services with the frequency band 470-960 MHz in Region 1, in particular the spectrum requirements of the broadcasting and mobile, except aeronautical mobile, services, as well as to carry out sharing and compatibility studies, as appropriate, in the frequency band 470-694 MHz in Region 1 between the broadcasting and mobile, except aeronautical mobile, services, taking into account relevant ITU-R studies, Recommendations and Reports.

The preliminary agenda of the 2023 World Radiocommunication Conference includes an item “to review the spectrum use and spectrum needs of existing services in the frequency band 470-960 MHz in Region 1 and consider possible regulatory actions in the frequency band 470-694 MHz in Region 1 on the basis of the review in accordance with Resolution 235 (WRC-15). Therefore, Resolution 235 (WRC 15) has the potential to impact the amount of TVWS spectrum available in Region 1.

Therefore the decisions made by previous conferences and the prospects of future conferences are the basis for a long-term sustainable radiocommunications ecosystem that allows for significant investments and worldwide economies of scale.

Resolution 239 (WRC-15)

WRC-15 adopted **Resolution 239 (WRC-15)**: “Studies concerning Wireless Access Systems including radio local area networks in the frequency bands between 5 150 MHz and 5 925 MHz” which requested studies to be carried out in preparation for WRC-19 and to enable that Conference to take appropriate decision on its agenda item 1.16 (see **Resolution 809 (WRC-15)**): “to consider issues related to wireless access systems, including radio local area networks (WAS/RLAN), in the frequency bands between 5 150 MHz and 5 925 MHz, and take the appropriate regulatory actions, including additional spectrum allocations to the mobile service, in accordance with **Resolution 239 (WRC-15)**”;. The studies will be conducted under the responsibility of ITU-R Working Party (WP) 5A, in collaboration with contributing ITU-R WPs 4A, 4C, 5B, 5C and 7C for the concerned satellite, terrestrial and science services, as well as with other interested ITU-R WPs.

4 CHAPTER 4 – Spectrum monitoring

This Chapter presents highlights about spectrum monitoring. As noted earlier, spectrum monitoring is an essential tool for spectrum management because of its ability to: monitor and take measurements of signals; detect and identify unauthorized stations; determine station locations for further enforcement actions; and identify the source of harmful interference. Administrations interested in establishing spectrum monitoring facilities are encouraged to read the ITU-R Handbook on Spectrum Monitoring, ITU-R Recommendations and ITU-R Reports identified in the relevant ITU-R References provided before the annexes of this report, for additional details. Furthermore, the reader is advised that the ITU Academy provides training in spectrum monitoring.⁴⁶

The international framework for the use of the radio frequency spectrum is set out in the ITU Radio Regulations and provides some flexibility to organise national spectrum management, as each country must develop its own system to meet political and legislative regimes and regional situations. ITU Recommendation ITU-R SM.1047⁴⁷ (national spectrum management) specifies the topics to be addressed for the development of national spectrum management programmes.

In this complicated task of national spectrum management, spectrum monitoring provides information on the actual use of the spectrum and to realise a usable spectrum that is as much as possible free of interference.

ITU developed guidelines to provide a standard approach to set up a new or update an existing spectrum monitoring network.⁴⁸ These guidelines do not include monitoring equipment tender documentation specifications. Such specifications will depend on the need and type of national monitoring and on the national laws and regulations. These guidelines are based on the *ITU-R Handbook on Spectrum Monitoring*,⁴⁹ which contains detailed information on monitoring system planning and tenders. Valuable information can also be found in the following ITU-R Handbooks on:

- National Spectrum Management;⁵⁰ and
- Computer-Aided-Techniques for Spectrum Management.⁵¹

These three handbooks have been developed by ITU-R Study Group 1⁵² on spectrum management. ITU-R Working Party 1C⁵³ includes international experts on spectrum monitoring related studies, including the development of techniques for observing the use of the spectrum, measurement techniques, inspection of radio stations, identification of emissions, and location of interference sources.

ITU-D has also developed “Guidelines for the preparation of a tender to set up or update a spectrum monitoring network”. Chapter 2 of these guidelines⁵⁴ provides a short introduction to the need for spectrum management, whilst Chapter 3 includes the role spectrum monitoring has in spectrum management. Chapters 4-13 further describe and discuss aspects to be considered and implemented when setting up a new spectrum monitoring network. Especially, Chapter 6 is dealing with the development of a tender document.

Current technology allows most spectrum monitoring functions, and indeed entire monitoring networks, to be highly automated, and allows spectrum monitoring systems to be highly integrated with automated spectrum management. Many activities of an automated national spectrum management

⁴⁶ For more information, consult the ITU Academy portal (<http://academy.itu.int>).

⁴⁷ <http://www.itu.int/rec/R-REC-SM.1047>.

⁴⁸ http://www.itu.int/en/ITU-D/Spectrum-Broadcasting/Documents/Publications/Guidelines_SpectrumMonitoring_Final_E.pdf.

⁴⁹ ITU Handbook on Spectrum Monitoring 2011 (especially Annex 1): <http://www.itu.int/pub/R-HDB-23>.

⁵⁰ National Spectrum Management: <http://www.itu.int/pub/R-HDB-21>.

⁵¹ Computer-Aided-Techniques for Spectrum Management: <http://www.itu.int/pub/R-HDB-01>.

⁵² <http://www.itu.int/en/ITU-R/study-groups/rsg1/Pages/default.aspx>.

⁵³ <http://www.itu.int/en/ITU-R/study-groups/rsg1/rwp1c/Pages/default.aspx>.

⁵⁴ http://www.itu.int/en/ITU-D/Spectrum-Broadcasting/Documents/Publications/Guidelines_SpectrumMonitoring_Final_E.pdf.

system will benefit from integration with automated spectrum monitoring stations, as is described in Recommendation ITU-R SM.1537-1. Spectrum monitoring is one of the essential tools of spectrum management. Spectrum monitoring techniques are developed to ensure adherence to technical parameters and standards for radiocommunication systems. In addition, spectrum monitoring can assist in assessing the efficient utilisation of the radio frequency spectrum. These systems can also be very useful to administrations for enforcing regulations of licensed stations, identifying illegal operations, and detecting and mitigating harmful interference. Spectrum monitoring techniques are different from those of a radiocommunication network in that they are carried out in non-optimal situations and, in some cases, in an unknown environment. ITU-R Handbook on Spectrum Monitoring covers all essential features of spectrum monitoring techniques and activities, including the establishment of monitoring facilities (refer to its Annex 1 on “Monitoring system planning and tenders”).

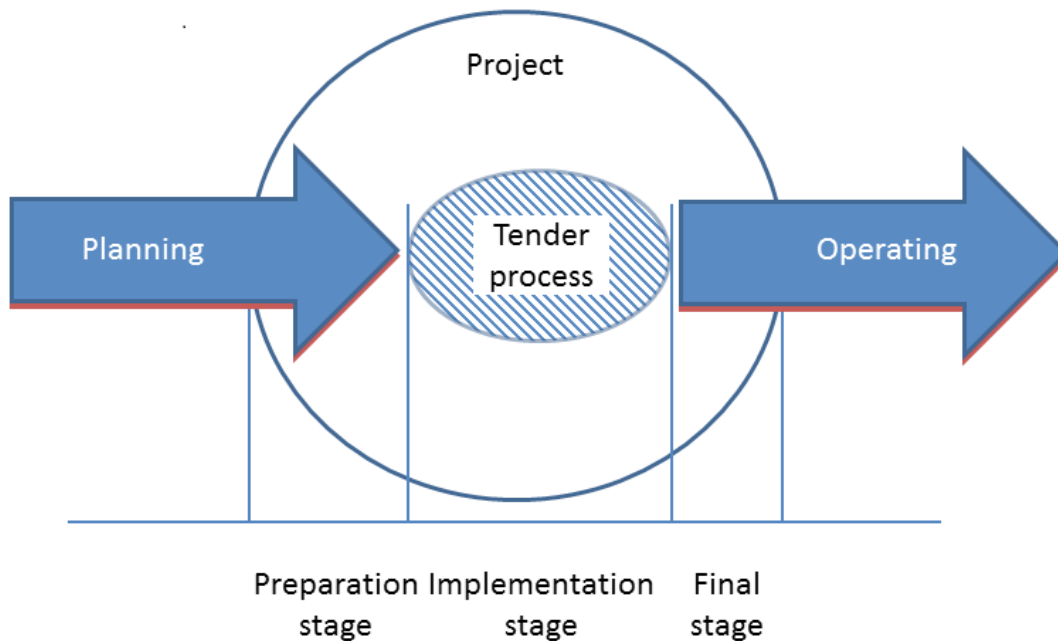
4.1 Identification of methodologies on setting up a spectrum monitoring network

4.1.1 Setting up tenders

When a national administration decides to create its nationwide spectrum monitoring network, to add a new local monitoring station, or just to make a single mobile measuring study, the work is generally divisible into three stages (see **Figure 2**):

- **Preparation stage – Planning:**
 - Concept and objectives for a radio monitoring system;
 - Feasibility study;
 - Business Plan;
 - System planning;
 - Specifications for the systems.
- **Implementation stage – Tender process:**
 - Invitation to start public purchase tender (consideration of the competence of the bidders, viewpoints of the disqualification for fulfilment of contract);
 - Invitation for bids (including clarification to the bidders);
 - Submission of proposals by the bidders;
 - Evaluation of received proposals (request for clarifications inclusive);
 - Decision for award of contract;
 - Signature and entry into force of the contract.
- **Final (termination) stage – Acceptance procedure, operation:**
 - Factory, provisional and final acceptance procedures;
 - Training, maintenance and spare parts supply;
 - Starting up of the operation.

Figure 2: Setting up tenders



Annex 1 to the ITU-R Handbook on Spectrum Monitoring describes in depth the steps for the tender process. It discusses both procedures defined by ITU and those by the World Bank.

4.1.2 Planning a spectrum monitoring network

The goal of Spectrum Monitoring Network (SMN) planning and optimization is to enable required monitoring functions across territories containing the highest density of transmitters with the minimum number of monitoring fixed stations. This is to be achieved using the lowest possible antenna tower heights while maintaining high quality RF measurements. The territory of interest may be centres of high population or industrial development.

A computerized methodology for such planning and optimization in the VHF/UHF frequency ranges (based on angle of arrival (AOA) principals) has been developed and is set out in Section 6.8 of the ITU-R Handbook on Spectrum Monitoring. Recommendation ITU R SM.1392-2 references Section 6.8, and emphasizes the potential technical and economic benefits of effective planning and optimization of SMNs in developing countries. These benefits can only be achieved using computer-aided methods and apply in full measure to both developed and developing countries.

Practical experience has shown that, with the right computer models and calculations, it is possible to reduce the number of fixed monitoring stations required for coverage of a given region in comparison with SMNs planned on the basis of assessments by human experts. On the other hand, the planning and optimization process is rather complex. It comprises many different steps and is determined by the primary requirements of the planned SMN, which have to be defined in advance. In addition, it will be necessary during the planning stage itself to tackle a number of administrative decisions to optimize the process. Annex 1 of the ITU-R Handbook on Spectrum Monitoring provides a detailed guideline and step-by-step implementation to make the entire process more effective, while minimizing the work involved.

There is a number of different methods available for geolocation processing and three methods are described in Report ITU-R SM.2356 (2015). The first combines Angle of Arrival (AOA) measurements from multiple sites using direction-finding antenna arrays to determine the emitter location. The second combines Time Difference of Arrival (TDOA) measurements from a minimum of three sites

(two pairs of TDOA measurements between the three sites are required for geolocation). The third method, Hybrid AOA/TDOA combines both AOA and TDOA measurements to perform geolocation processing. Additional cost and type of environment (rural, urban or suburban) make the selection of a combination (hybrid) system an option. In urban cores where there is a lot of multipath and limited space for big antennas, TDOA nodes can be more cost effective and efficient. But as the cost is dependent on infrastructure, planned coverage area, environs, etc., such an approach must be considered case-by-case, to ensure that it is the most effective and efficient solution.

The first step in SMN planning requires basic decisions concerning the system objectives, configuration and performance in light of the available and projected financial resources. Apart from the points identified in Recommendation ITU R SM.1392-2,⁵⁵ these decisions include:

- The size of the territory to be monitored;
- Blanket vs. local coverage of territory by fixed stations;
- AOA vs. TDOA vs. Hybrid AOA/TDOA technology;
- Categories of test transmitters and the core monitoring tasks: listening, measurement of emission characteristics, Direction Finding (DF), and estimation of emitter location;
- Relative proportions of fixed and mobile station numbers.

In the initial phase of planning, it is also important to gather as much information as possible about the region of interest. It is also important to make decisions concerning the following:

- Determining the performance requirements for radio monitoring equipment;
- The choice of radio-wave propagation model (different models are optimized for quasi-plane relief or for hilly and mountainous terrain and others for urban settings);
- Determining avoidance areas for monitoring stations (closed or secure locations, or areas with high field strength);
- Location uncertainty (for AOA/TDOA SMNs).

4.2 Challenges of detecting weak signals and solutions

Signals of modern devices operate with bandwidths that have been steadily increasing, reaching 20 MHz or wider. In order to effectively analyse these signals, most modern spectrum monitoring systems use wideband receivers. With the increase in receiver bandwidths required for these signals, an unintended side effect is that it is more likely to have both strong and weak signals present within the receiver bandwidth. The likelihood of the monitoring system being installed in the vicinity of strong nearby signals is a real-world problem driven by the fact that the number of emitters within radio reach is constantly increasing.

In order to receive a weak signal in the presence of strong signals the wideband receiver must be able to process signals with powers that can vary from weak to strong (that is, in technical terms, the receiver must have high in-band dynamic range). Note that the effects of strong nearby signals can be further reduced by using receivers that have dual receiver bandwidths, wide and narrow, where the narrow bandwidth (typically 1/10th of wide bandwidth) is used in the presence of extremely strong nearby signals.

A receiver's local oscillator is designed to produce as pure a mixing signal as possible, but in practice the achievable purity can vary widely depending on the design. The purity is measured in dB below carrier (dBc) at several offset frequencies. The problem is that local oscillator phase noise, through receiver reciprocal mixing, can mask weak signals in the presence of strong signals. The effect of

⁵⁵ ITU-R SM.1392 – Essential Requirements for a spectrum monitoring system for developing countries.

the reciprocal mixing is again equivalent to increasing the receiver's effective noise figure. In order to minimize the effects of the reciprocal mixing, receiver phase noise must be low. The phase noise specification of a modern receiver in monitoring equipment should not be less than -100 dBc/Hz at 10 kHz offset from the carrier.

More information concerning monitoring receivers is given in Section 3.3 of ITU-R Handbook on Spectrum Monitoring.

Glossary

License by Rule:	It refers to a regulatory framework in which the user is not required to obtain an individual license to operate within a particular frequency band, but the user is required to obtain a general permit from the local administrator, and it must agree to comply with rules governing the use of the frequency band. (Adapted from: FCC. “Family Radio Service (FRS)” : https://www.fcc.gov/general/family-radio-service-frs).
License-Exempt:	It refers to a regulatory framework in which the user is not required to obtain a formal license from the local administrator to operate within a particular frequency band. Users must still comply with pre-defined technical performance requirements, as well as regulatory and operational limits and their use of the spectrum is non-exclusive.
Lightly Licensed:	It refers to a regulatory framework in which the user is required to obtain a license to operate in a particular frequency band, but the license is non-exclusive. With this approach, interference is typically mediated by technical solution rather than by the local administrator. In contrast to a licensed shared access framework, licensees are not required to share specific frequency bands. (Adapted from: GSMA. “Wireless Backhaul Spectrum Policy Recommendations & Analysis”, October 2014).
Licensed Shared Access:	It refers to a regulatory framework in which multiple users share access to spectrum. With this approach, new users are allowed to obtain individual licenses to operate within a particular frequency band that is already assigned to one or more incumbent users or other LSA licensees. (Adapted from: Faussurier, Emmanuel. “Introduction of new spectrum sharing concepts: LSA and WSD”. ITU-R SG 1/WP 1B Workshop, 20 January 2014, pg. 16).
Tiered Access:	It refers to a regulatory framework in which different classes (i.e. tiers) of users with different rights and obligations access the same sections of spectrum. The different tiers typically consist of a primary incumbent (usually the current license holder or government agency) who maintains unfettered access to that portion of spectrum, while also allowing additional secondary and tertiary levels of users, each of which is accorded a lower level of interference protection, and who must halt transmitting if a higher level user requires use of the spectrum.

Abbreviations and acronyms

Various abbreviations and acronyms are used through the document, they are provided here.

Abbreviation/acronym	Description
AOA	Angle of Arrival
BDT	Telecommunication Development Bureau
BR	Radiocommunication Bureau
CAT	Computer-Aided Techniques
CEPT	European Conference of Postal and Telecommunications Administrations
CPM	Conference Preparatory Meeting
CR	Cognitive Radio
CRS	Cognitive Radio Systems
DCF	Discounted Cash Flow
DF	Direction Finding
DFS	Dynamic Frequency Selection
DTT	Digital Terrestrial Television
EESS	Earth Exploration-Satellite Service
EFIS	ECO Frequency Information System
EPOCA	Electronic and Postal Communications Act (Tanzania)
ESIM	Earth Station in Motion
ESOMP	Earth Stations on Mobile Platforms
ESSS	Earth Stations of Satellite Systems
FCC	Federal Communications Commission
FRS	Family Radio Service
FSS	Fixed Satellite Service
GDP	Gross Domestic Product
GHz	Gigahertz
GSO	Geostationary
HAPS	High-Altitude Platform Stations
HTS	High Throughput Satellite
HF	High Frequency

Abbreviation/acronym	Description
IC	Industry Canada
ICT	Information and Communications Technology
IDA	Infocomm Development Authority (Singapore)
IEEE	Institute of Electrical and Electronic Engineers
IETF	Internet Engineering Task Force
IoT	Internet of Things
IMT	International Mobile Telecommunications
ISIF Asia	Information Society Innovation Fund Asia
ITU	International Telecommunication Union
ITU-D	ITU Telecommunication Development Sector
ITU-R	ITU Radiocommunication Sector
KCC	Korea Communications Commission (Republic of Korea)
LDCs	Least Developed Countries
LMS	Land Mobile Service
LSA	Licensed Shared Access
LTE	Long-Term Evolution
M2M	Machine-to-Machine
MEST	Meltwater Entrepreneurial School of Technology (Ghana)
MF	Medium Frequency
MHz	Megahertz
MoH	Ministry of Health (Kingdom of Bhutan)
MoIC	Ministry of Information & Communications (Kingdom of Bhutan)
MSIP	Ministry of Science, ICT and Future Planning (Republic of Korea)
NRA	National Regulatory Authority
NTFA	National Table of Frequency Allocation
NTP	National Telecommunications Policy (Tanzania)
OSA	Open Spectrum Access
PAL	Priority Access License
PAWS	Protect Against Wrapped Sequence(s)
PMSE	Programme Making and Special Events

Abbreviation/acronym	Description
QoS	Quality of Service
RAPA	Korea Radio Promotion Association (Republic of Korea)
RFID	Radio Frequency Identification
RLAN	Radio Local Area Network
RR	Radio Regulations
RSPG	Radio Spectrum Policy Group
SAS	Spectrum Access Systems
SDR	Software-Defined Radio
SMN	Spectrum Monitoring Network
SMS4DC	Spectrum Management System for Developing Countries
SRFC	State Radio Frequency Commission
STIR	Spectrum Management IT System
TCA	Tanzania Communications Act (Tanzania)
TDOA	Time Difference of Arrival
TVWS	TV White Space
UDP	User Datagram Protocol
UHF	Ultra-High Frequency
UN	United Nations
UWB	Ultra-Wideband
VHF	Very High Frequency
WISP	Wireless Internet Service Provider
WLAN	Wireless Local Area Networks
WRC	World Radiocommunication Conference
WSD	White Space Device
WSDB	White Space Database
WTDC	World Telecommunication Development Conference

ITU-R references

Title	Description
WRC Resolutions	
Resolution 229 (Rev. WRC-12) – Use of the bands 5 150-5 250 MHz, 5 250-5 350 MHz and 5 470-5 725 MHz by the mobile service for the implementation of wireless access systems including radio local area networks	This Resolution contains the requirements implementation to enable wireless access systems including radio local area networks. This Resolution is incorporated by reference in the RR.
Resolution 239 (WRC-15) – Studies concerning Wireless Access Systems including radio local area networks in the frequency bands between 5 150 MHz and 5 925 MHz	This Resolution contains information and instructions for ITU-R work related to WRC-19 Agenda item 1.16.
Resolution 729 (Rev. WRC-07) – Use of frequency adaptive systems in the MF and HF bands	This Resolution contains information on the Use of frequency adaptive systems in the MF and HF bands.
Resolution 809 (WRC-15) – Agenda for the 2019 World Radiocommunication Conference	Contains the Agenda for the 2019 World Radiocommunication Conference.
WRC Recommendations	
Recommendation 76 (WRC-12) Deployment and use of cognitive radio systems	Recommends that administrations participate actively in the ITU-R studies conducted under Resolution ITU-R 58.
ITU-R Handbooks	
ITU-R Handbook on National Spectrum Management	Includes information on spectrum management fundamentals, frequency assignments and licensing, spectrum monitoring, spectrum economics, and automation.
ITU-R Handbook on Spectrum Monitoring	Includes Chapters on Equipment (Ch. 3), Measurements (Ch. 4) and the planning and execution of monitoring station equipment/facilities acquisition documents (Annex 1- Monitoring station “tenders”).
ITU-R Questions	
ITU-R 208-1/1 – Alternative methods of national spectrum management	This ITU-R question seeks to answer various questions about alternative spectrum management practices.
ITU-R 235/1 – Spectrum monitoring evolution	This question seeks to answer various questions about the required evolution of spectrum monitoring as technologies advance.
ITU-R 241-3/5 – Cognitive radio systems in the mobile service	This ITU-R question seeks to answer various questions regarding cognitive radio systems.
ITU-R Recommendations	
ITU-R SM.575 – Protection of fixed monitoring stations against interference from nearby or strong transmitters	This Recommendation specifies maximum field-strength levels at monitoring stations to ensure their interference-free operation.
ITU-R SM.854 – Direction finding and location determination at monitoring stations	This Recommendation provides classification of bearings to determine the most likely position of an emitter using direction finding at monitoring stations.

Title	Description
ITU-R SM.1050 – Tasks of a monitoring service	This Recommendation describes the tasks of a monitoring service.
ITU-R F.1110 – Adaptive radio systems for frequencies below about 30 MHz	This Recommendation provides the general functions of HF adaptive systems.
ITU-R SM.1132 – General principles and methods for sharing between radiocommunication services or between radio stations	This Recommendation provides general principles and methods for sharing between radiocommunication services or between radio stations.
ITU-R SM.1370 – Design guidelines for developing automated spectrum management systems	This Recommendation gives design guidelines for an automated spectrum management system, including the recommended functionality for such a system, and the data elements required for frequency management at national level while also ensuring that the data collected is suitable (statistically significant) for accurate characterization.
ITU-R SM.1392 – Essential Requirements for a spectrum monitoring system for developing countries	This Recommendation describes requirements for spectrum monitoring systems, including systems tasks, equipment and evaluation criteria for determining the scope of what is needed based on administration requirements.
ITU-R SM.1537 – Automation and integration of spectrum monitoring systems with automated spectrum management.	Current technology allows most spectrum monitoring functions, and indeed entire monitoring stations, to be highly automated, and allows spectrum monitoring systems to be highly integrated with automated spectrum management. Many activities of an automated national spectrum management system will benefit from integration with automated spectrum monitoring stations. This Recommendation describes recommended functionality of these systems.
ITU-R SM.1603 – Spectrum redeployment as a method of national spectrum management	This Recommendation gives guidelines for spectrum redeployment issues.
ITU-R SM.1708 – Field-strength measurements along a route with geographical	This Recommendation describes the method which should be used for field-strength measurements of vertically polarized signals along a route.
ITU-R SM.1880 – Spectrum Occupancy measurement and evaluation	This Recommendation describes frequency channel occupancy measurements performed with a receiver or spectrum analyser and includes discussions about equipment, monitoring site considerations, fixed and mobile monitoring, statistical considerations for result validity and post processing.
ITU-R SM.2039 – Spectrum Monitoring Evolution Note: This Recommendation may become relevant at a later stage after setting up an initial spectrum monitoring system	This Recommendation describes the need for improved coverage and sensitivity in monitoring networks and the extension of monitoring coverage utilizing new technologies, including the challenges and approaches for detection of weak signals.

Title	Description
ITU-R M.2083 – IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond	This Recommendation defines the framework and overall objectives of the future development of International Mobile Telecommunications (IMT) for 2020 and beyond in light of the roles that IMT could play to better serve the needs of the networked society, for both developed and developing countries, in the future. In this Recommendation, the framework of the future development of IMT for 2020 and beyond, including a broad variety of capabilities associated with envisaged usage scenarios, is described in detail. Furthermore, this Recommendation addresses the objectives of the future development of IMT for 2020 and beyond, which includes further enhancement of existing IMT and the development of IMT-2020. It should be noted that this Recommendation is defined considering the development of IMT to date based on Recommendation ITU-R M.1645.
ITU-R Reports	
ITU-R M.2117 – Software-defined radio in the land mobile, amateur and amateur-satellite services	The Report was revised based on the recent results of ITU-R studies on SDR and CRS.
ITU-R M.2225 – Introduction to cognitive radio systems in the land mobile service	This Report addresses the cognitive radio systems in the land mobile service (LMS) above 30 MHz (excluding international mobile telecommunications (IMT)).
ITU-R M.2242 – Cognitive Radio Systems specific for IMT Systems	This document addresses aspects of cognitive radio systems specific to International Mobile Telecommunications (IMT) systems.
ITU-R M. 2330 – Cognitive radio systems (CRSs) in the land mobile service	This Report addresses cognitive radio systems (CRSs) in the land mobile service (LMS) above 30 MHz (excluding IMT).
ITU-R M. 2373 – Audio-visual capabilities and applications supported by terrestrial IMT systems	This Report examines the capabilities of IMT systems to deliver audio-visual services.
ITU-R SM.2012 – Economic aspects of spectrum management	The objective of this economic study is to respond to the following issues which are divided into three categories: Strategies for economic approaches to national spectrum management and their financing; Assessment, for spectrum planning and strategic development purposes, of the benefits arising from the use of the radio spectrum; Alternative methods of national spectrum management.
ITU-R SM.2152 – Definitions of Software Defined Radio (SDR) and Cognitive Radio System (CRS)	This report contains the definition of Software Defined Radio (SDR) and Cognitive Radio System (CRS).
ITU-R SM.2256 – Spectrum occupancy measurements and evaluation	A comprehensive report covering methodology, measurement parameters, site considerations and procedures for spectrum occupancy monitoring and reporting.
ITU-R SM.2355 – Spectrum monitoring evolution Note: This Report may become relevant at a later stage after setting up an initial spectrum monitoring system	This companion Report (to Rec. ITU-R SM.2039) describes, in detail, methods for improvements in coverage and sensitivity of monitoring networks (to be able to detect weak signals) and the extension of monitoring coverage utilizing new technologies.

Title	Description
<p>ITU-R SM.2356 – Procedures for planning and optimization of spectrum-monitoring networks in the VHF/UHF frequency range</p> <p>Note: This Report may become relevant at a later stage after setting up an initial spectrum monitoring system</p>	<p>This Report outlines procedures, methods and equipment for planning and optimizing monitoring networks in the VHF/UHF range. These networks may use AOA, TDOA, or Hybrid AOA.TDOA techniques for geolocation.</p>
ITU-R Resolutions	
<p>ITU-R Resolution 58 – Studies on the implementation and use of cognitive radio systems</p>	<p>This Resolution studies the implementation and use of cognitive radio systems</p>

Other references

References for Chapter 1

- The Broadband Commission for Digital Development, The State of Broadband 2015, 2015: <http://www.broadbandcommission.org/Documents/reports/bb-annualreport2015.pdf>.
- CEPT, Electronic Communications Committee Report 236: Guidance for national implementation of a regulatory framework for TV WSD using geo-location databases, May 2015: <http://www.erodocdb.dk/Docs/doc98/official/pdf/ECCREP236.PDF>.
- CMAI Association of India, Research Paper on White Space for Digital India, 11 December 2014: https://www.whitespacealliance.org/documents/Research%20Paper%20on%20White%20Spaces_final2.pdf.
- FCC, Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band, GN Docket No. 12-354, 30 FCC Rcd 3959 ¶¶ 379-86, 2015.
- FCC, Unlicensed Operation in the TV Broadcast Bands, ET Docket No. 04-186.
- FCC, Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band, ET Docket No. 02-380, Second Memorandum Opinion and Order, 25 FCC Rcd 18661, 2010.
- ITU-D World Telecommunication Development Conference, Resolution 9 (Rev. Dubai, 2014), 2014: <http://www.itu.int/net4/ITU-D/CDS/sg/doc/rgq/2014/D14-SG01-RES9-en.pdf>.
- Industry Canada, Framework for the Use of Certain Non-Broadcasting Applications in the Television Broadcasting Bands Below 698 MHz, 2012: <http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf10493.html>.
- Infocomm Development Authority of Singapore, Regulatory Framework For TV White Space Operations In The VHF/UHF Bands 2014: http://www.ida.gov.sg/~media/Files/PCDG/Consultations/20130617_whitespace/ExplanatoryMemo.pdf.
- McKinsey, The Net's Sweeping Impact on Growth, Jobs and Prosperity, 2011: http://www.mckinsey.com/insights/high_tech_telecoms_internet/internet_matters.
- McKinsey, Online and Upcoming: The Internet's Impact on Aspiring Countries, 2012: http://www.mckinsey.com/client_service/high_tech/latest_thinking/impact_of_the_internet_on_aspiring_countries.
- Ofcom, Implementing TV White Spaces, 2015: https://www.ofcom.org.uk/__data/assets/pdf_file/0034/68668/tvws-statement.pdf.

References for Chapter 2

- Yochai Benkler, "Open Wireless vs. Licensed Spectrum: Evidence from Market Adoption," *Harvard Journal of Law and Technology* Vol. 26 No. 1 (2012): <http://jolt.law.harvard.edu/articles/pdf/v26/26HarvJLTech69.pdf>.
- Deloitte and GSMA, "The Impact of Licensed Shared Use of Spectrum," 23 January 2014: <http://www.gsma.com/spectrum/wp-content/uploads/2014/02/The-Impacts-of-Licensed-Shared-Use-of-Spectrum.-Deloitte.-Feb-20142.pdf>, pp 8, 67.
- Simon Forge, Robert Horvitz, and Colin Blackman, "Final Report for the European Commission: Perspectives on the value of shared spectrum access," *SCF Associates*, February 2012: https://ec.europa.eu/digital-single-market/sites/digital-agenda/files/scf_study_shared_spectrum_access_20120210.pdf.
- International Telecommunications Union, "Measuring the Information Society Report 2015," 2015: <http://www.itu.int/en/ITU-D/Statistics/Documents/publications/misr2015/MISR2015-w5.pdf>.

- Raul Katz, “Assessment of the Economic Value of Unlicensed Spectrum in the United States”, *Telecom Advisory Services LLC*, 2014: <http://www.wififorward.org/wp-content/uploads/2014/01/Value-of-Unlicensed-Spectrum-to-the-US-Economy-Full-Report.pdf>.
- Tony Lavender, Paul Hansell, Iain Inglis, Sarongrat Wongsaraj “Use of C-Band (3400/3600-4200 MHz) for mobile broadband in Hungary, Italy, Sweden and the UK”, *Plum Consulting*, June 2015: http://www.plumconsulting.co.uk/pdfs/Plum_Jun2015_Use_of_C-Band_for_mobile_broadband_in_Hungary_Italy_Sweden_and_UK.pdf.
- OECD, “Machine-to-Machine Communications: Connecting Billions of Devices”, OECD Digital Economy Papers, No. 192, 2012, dx.doi.org/10.1787/5k9gsh2gp043-en.
- Richard Thanki, “The Case for permissive rules-based dynamic spectrum access”, *Microsoft Research*, August 2013: http://research.microsoft.com/en-us/projects/spectrum/case-for-permissive-rule-based-dynamic-spectrum-access_thanki.pdf.
- Richard Thanki, “The Economic Significance of License-Exempt Spectrum to the Future of the Internet,” *Microsoft Research*, 2012: http://research.microsoft.com/en-us/projects/spectrum/economic-significance-of-license-exempt-spectrum-report_thanki.pdf, page 30.
- Qiang, C. Z. W. World Bank. “IC4D: Extending Reach and Increasing Impact,” *Economic Impacts of Broadband*, 2009. Chapter 3.
- *US Department of Commerce*, “An Assessment of the Viability of Accommodating Wireless Broadband in the 1755 – 1850 MHz Band,” March 2012: https://www.ntia.doc.gov/files/ntia/publications/ntia_1755_1850_mhz_report_march2012.pdf.
- *US Government Accountability Office*, “Spectrum Management: Incentives, Opportunities and Testing Needed To Enhance Spectrum Sharing”, *Report to Congressional Committees*, 2012: <http://www.gao.gov/products/GAO-13-7>.
- US President’s Council of Advisors on Science and Technology, “Realizing the Full Potential of Government-Held Spectrum To Spur Economic Growth”, July 2012: https://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast_spectrum_report_final_july_20_2012.pdf.
- *US National Telecommunications and Information Administration*, “Promoting Spectrum Sharing in the Wireless Broadband Era”, 9 January 2015: <https://www.ntia.doc.gov/blog/2015/promoting-spectrum-sharing-wireless-broadband-era>.

Annexes

Annex 1: Existing regulations on TV White Space

Inclusion of links to existing regulations from Canada, Singapore, United States of America, and the United Kingdom:

- Canada, Radio Standards Specifications-222 Issue I – White Space Devices (WSDs): <http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf10930.html>.
- Singapore, Decision Paper issued by the Infocommunication Development Authority of Singapore. Regulatory framework for TV White Space operations in the VHF/UHF bands, 16 June 2014: https://www.ida.gov.sg/~media/Files/PCDG/Consultations/20130617_whitespace/ExplanatoryMemo.pdf.
- Singapore, Telecommunications Act (Chapter 323) Telecommunications (exemption from Sections 33, 34(1)(b) and 35) (Amendment No. 2) Notification 2014: <http://statutes.agc.gov.sg/aol/search/display/view.w3p;page=0;query=DocId%3Afe1642bb-1981-4afd-a8da-322595befe8a%20Depth%3A0%20ValidTime%3A02%2F02%2F2016%20TransactionTime%3A02%2F02%2F2016%20Status%3Apublished;rec=0>.
- United Kingdom, 2015 No. 2066 Electronic Communications – The Wireless Telegraphy (White Space Devices) (Exemption) Regulations 2015: <http://www.legislation.gov.uk/uksi/2015/2066/made/data.pdf>.
- United States of America, Code of Federal Regulations Title 47, Chapter I, Subchapter A, Part 15, Subpart H – White Space Devices: <https://www.ecfr.gov/cgi-bin/text-idx?SID=f7cf9120b29f6e16a04e68c3c315be9b&mc=true&node=sp47.1.15.h&rgn=div6>.

Annex 2: Case studies and countries experiences

These case studies and countries experiences are listed below for information purposes only with no aim at defining guidelines, recommendations or conclusions.

A2-1. Digital Dividend

The tables below show information on the auctions of the Digital Dividend:

Digital Dividend (prior to 2012):

Digital Dividend spectrum allocations	USA	Germany	Sweden	Spain	France	Italy	Switzerland
Frequency bands considered in the same process	700 MHz (698–787 MHz)	800 MHz, 1.8 GHz, 1.9/2.1 GHz & 2.6 GHz	800 MHz	800 MHz, 900 MHz & 2.6 GHz	800 MHz	800 MHz, 1.8 GHz, 2.0 GHz & 2.6 GHz	800, 900 MHz 1.8 GHz, 2.1 & 2.6 GHz (FDD & TDD)
Date of licensing decision	24/1/2003-3/2/2012	12/10/2009	4/3/2011	May 2012	17/01/2012	18/05/2011	May 2012
License duration	10 years	15 years	25 years	Until 31 December 2030	20 years	17 years	12-16 years. Until 31/12/2028
Type of licensing process	Auction	Auction	Auction	Auction	Auction + weighted commitments	Auction	Auction
Packaging of DD band	Three 2x6 MHz, one 2x11 MHz, and two unpaired 6 MHz blocks = 70 MHz	3x2x10 MHz = 60 MHz	6x(2x5 MHz) = 60 MHz	6x(2x5 MHz)= 60 MHz	3 blocks of 2x10 MHz = 60 MHz	6 blocks of 2x5 MHz	Each of the 3 bidders (Orange, Sunrise, Swisscom) won a package of 2 x 10 MHz.

(continued)

Digital Dividend spectrum allocations	USA	Germany	Sweden	Spain	France	Italy	Switzerland
Amount raised for DD band	19.1 billion USD (Sum of net bids in auctions 44, 49, 60, 73, and 92)	1.212 GEUR 1.210 GEUR 1.154 GEUR Total 3.576 GEUR	2054 MSEK (220 MEUR)	3 operators got two blocks of 2x5 MHz each. For each block of 2x5 MHz: 170 MEUR 221.9 MEUR 230.0 MEUR 226.3 MEUR 228.5 MEUR 228.5 MEUR Total 1.305 MEUR	3 operators got one block each: 683 MEUR 891 MEUR 1065 MEUR Total 2.639 GEUR	3 operators got 2 blocks each: 978 MEUR 992 MEUR 992 MEUR Total 2.96 GEUR	N/A (During the auction, bidders could bid on different packages consisting of frequency blocks in different bands. Therefore the prices are per package)
Amount raised/MHz/population	0.98 USD	0.73 EUR	0.39 EUR	0.48 EUR	0.70 EUR	0.82 EUR	N/A
Coverage obligations	Three types: 1. Economic area (EA) 2. Cellular market area (CMA) 3. Regional economic area groupings (REAGs) CMA & EA: 35% coverage within 4 years of end of DTV transition. 70% coverage at end of license term. REAG: coverage based on EA; 40% of population in each EA within 4 years and 75% by end of license term.	For 800 MHz Band: List of municipalities per federal state. Priority class system: P1: pop <5k P2: pop 5-20k P3: pop 20-50k P4: pop >50k Staged rollout. P1 areas must be covered first at 90%, before moving to next priority stage areas and so on. The last areas, P4, must be covered at 90% by 2016. Total population coverage must be 50% by January 2016.	Priority to a list of households without broadband connection. To be reviewed annually. SEK 300 million of auctions proceeds comprise bids for coverage and the license holder that has won the frequency block FDD6 shall use this sum to cover those permanent homes and fixed places of business that lack broadband.	Operators who have been awarded 2x10 MHz in the 800 MHz band (Telefónica, Vodafone and France Telecom), will have to fulfil, altogether and before January the 1st of 2020, a coverage of at least 90% inhabitants of towns with less than 5 000 people with at least 30Mbit/s speed (considering offers with other technologies or in other frequency bands).	98% /99.6% population after 12/15 years + 40%/90% of priority population after 5/10 years + 90% of population of each department after 12 years + (optional but weighted in selection process) 95% of population of each department after 15 years.	For each region, five lists of municipalities with less than 3000 inhabitants have been formed; each list was associated to one spectrum lot (2x5MHz) (the first lot, the lower, assigned as specific lot, has not coverage obligations associated); the list are formed by uniform rotation of municipalities ordered by population. The coverage obligations	General obligation regarding utilisation: the licensee is obliged to use the allocated frequencies as set out in Article 1 TCA and to provide commercial telecommunications services over its own transmission and reception units. In addition, licensees who have the right to use frequencies in the 800 MHz band are obliged to ensure coverage

(continued)

Digital Dividend spectrum allocations	USA	Germany	Sweden	Spain	France	Italy	Switzerland
						<p>are: 30% of the broadband service must start within three years municipalities included in the lists associated to the assigned spectrum lots within three years, 75% within five years.</p> <p>The commercial launch (retail or wholesale) of A new entrant is allowed two additional years to reach the same objectives. Coverage obligations can also be fulfilled using frequencies in other bands. In this case the switch to 800 MHz frequency of municipalities covered with different frequencies, should be at least 50% of the obligations in 7 years and completed in 10 years.</p>	<p>of 50% of the population of Switzerland with mobile radio services via their own infrastructure by 31 December 2018 at the latest</p>

(continued)

Digital Dividend spectrum allocations	USA	Germany	Sweden	Spain	France	Italy	Switzerland
Additional obligations	Open platform requirement on the 2x11 license.	For all bands: Obligation to apply for site specific technical radio parameters for every base station before bringing into operation.	Obligation placed to only one license in 800 MHz to provide a minimum broadband service of 1Mbps to the priority list. Obligation to not cause interference to reception of terrestrial broadcasting (according to definition in license conditions).	Obligation to protect broadcasting in lower adjacent band	Obligations on infrastructure sharing, opening to MVNO and roaming. Obligation to protect broadcasting in lower adjacent band by stringent out-of-band power limitations on base stations, provision of impact studies and by “taking all necessary measures to restore previously existing broadcasting services if interference occurs”.	Obligation to accept any reasonable request of access by third parties on commercial terms after 5 years in areas where frequencies have not been used. Obligation to offer national roaming to new entrants Obligation to site sharing on commercial and reciprocal terms for at least 5 years Obligation to use all mitigation and coordination techniques, standards, methods and best practices for protecting broadcasters. Administration reserves to intervene in case of persistent problems in a justified and proportionate way	

(continued)

Digital Dividend spectrum allocations	USA	Germany	Sweden	Spain	France	Italy	Switzerland
Other obligations				Additional annual fee for spectrum use: 7.76 MEUR per year for a block of 2 x 5 MHz, applicable from effective use of spectrum (before 1st January 2015).	Additional annual fee for spectrum use: 1% of annual income every year.	Obligation to publish and maintain for at least 5 years a data offer where no traffic management technique is introduced.	

Digital Dividend (from 2012 to 2017):

Digital Dividend spectrum allocations	USA	Germany	France	New Zealand	Brazil	Peru	Mexico	Finland
Digital Dividend 1 or 2	2	2	2		1	1	1	2
Frequency bands considered in the same process	600 MHz (617-698 MHz)	700 MHz, 900 MHz and 1.8 GHz (703-733 MHz and 758-788 MHz)	700 MHz (703-733 MHz and 758-788 MHz)	700 MHz	700 MHz	700 MHz	700 MHz (703-748 MHz and 758-803 MHz)	700 MHz (703-733 MHz and 758-788 MHz)
Band Plan		APT	APT	APT	APT	APT	APT	APT
Date of licensing decision	Mar-2017 (auction closed)	May-2015 Jun-2015	Dec-2015	Aug-14	Nov-2014	Jul-16	Jan-17	Nov-2016 Feb-2017 (operation in the spectrum)
License duration	12 years (10 year renewal)	Aprox. 17 years Until 31/12/2033	20 years	16 years	15 years (renewable once)	15 years (renewable)	20 years (renewable once for the same term).	17 years
Type of licensing process	Incentive auction: Reverse auction + Forward auction	Auction	Auction	Auction	Auction	Auction		Auction
Packaging of DD band	7x(2x5 MHz)= 70 MHz- licensed spectrum 14 MHz- wireless microphones and unlicensed use.	6x(2x5 MHz)= 60 MHz	6x(2x5 MHz)= 60 MHz	9x(2x5 MHz)= 90 MHz	4x(2x10 MHz)= 80 MHz, 3 national blocks and 3 regional blocks	3x(2x15 MHz) = 90 MHz	1x(2x45 MHz) = 90 MHz One wholesale shared services network.	6x(2x5 MHz)= 60 MHz

(continued)

Digital Dividend spectrum allocations	USA	Germany	France	New Zealand	Brazil	Peru	Mexico	Finland
Amount raised for DD band	Total: 19.8 billion USD (10.05 billion USD for broadcasters and 7.2 billion USD to the US treasury).	3 operators got 2 blocks each: 166.397 MEUR 165.509 MEUR 167.847 MEUR 166.567 MEUR 171.649 MEUR 163.476 MEUR Total 1001.445 MEUR	2 operators got one block and 2 operators got two blocks each: 466 million EUR/ block of 2x5 MHz Total 2798 MEUR	1 operator got 2 blocks: 44 million NZD 1 operator got 4 blocks: 158 million NZD 1 operator got 3 blocks: 68 million NZD Total: 270 million NZD	3 operators got 1 national block (2x10 MHz) each: 1.947 billion Reais 1.947 billion Reais 1.927 billion Reais 1 operator got 1 regional block (2x10 MHz) in 29.5 million Reais Total 5.85 billion Reais	Total: 911.2 million USD		3 operators got 2 blocks each: 11.000 MEUR 11.000 MEUR 11.000 MEUR 11.000 MEUR 11.000 MEUR 11.330 MEUR Total 66.330 MEUR
Amount raised/MHz/population	0.88 (USD)	0.21 (EUR)	0.70 (EUR)	0.47 (USD)	0.19 (USD)	0.32 (USD)		0.20 (EUR)

(continued)

Digital Dividend spectrum allocations	USA	Germany	France	New Zealand	Brazil	Peru	Mexico	Finland
Coverage obligations	One license size Partial Economic Area (PEAs) Build out to 40% of the population in their service areas within 6 years and to 75% of the population by the end of their initial license terms of 12 years.	Each assignee – with the exception of new entrants– must ensure: Minimum transmission rate of 50 Mbit/s per sector Coverage of a minimum of 98% of households nationwide General availability of transmission rates of 10 Mbit/s and more Full coverage for the main transport routes (national motorways and high speed railway lines) Assignees may use their entire spectrum package to meet this target.	Spectrum CAP: 2x15 MHz in the 700 MHz band, and 2x30 MHz of lower band spectrum (700 MHz, 800 MHz and 900 MHz). 98%/99.6% metropolitan population in 12/15 years + 100% main roads in 15 years + 90%/95% of population in each metropolitan department in 12/15 years + 40%/92%/97,7% of population in the priority deployment zone in 5/12/15 years + 100% of city centres in the white zones program in 12 years + 60%/80%/90% of regional rail roads	Bidders who acquire three blocks of radio spectrum must build at least 5 new cell sites each year, for five years. Bidder having four blocks of 700 MHz radio spectrum will be required to build 10 new cell sites each year, for five years, in areas that it does not currently cover. Total of 75 new towers will be build to increase mobile coverage. All successful bidders must upgrade 75% of their existing rural cellsites to 4G using 700 MHz (to a maximum of 300 sites).	Spectrum CAP: 10+10 MHz (first round), increased to 20+20 MHz if there were remaining blocks (second round) No coverage obligations. Allowed bidders to use the 700 MHz band to accomplish the 2.5 GHz auction coverage obligations.	Coverage obligations In 1 year, after the beginning of operation: 15 specific locations In 3 years, after the beginning of operation: 129 population centres In 5 year, after the beginning of operation) : DL: 1 Mbps UL: 20% of DL speed	Until the 31/03/2018: Coverage of 30% of the aggregated national population, including at least 25% of the total pueblos magicos In 3 years: Coverage of 50% of the aggregated national population, including at least 50% of the total pueblos magicos In 4 years: Coverage of 70% of the aggregated national population, including at least 75% of the total pueblos magicos In 5 years: Coverage of 85% (Minimum Coverage Required) of the aggregated	The network pursuant to the license must be built so as to cover 99% of the population of mainland Finland within three years of the start of the license period. Ensure reasonable indoor coverage within the coverage area. Covers all the main roads, secondary roads, regional roads and connecting roads in mainland Finland and the entire rail network owned by the State of Finland or managed and operated by a state-owned company.

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Digital Dividend spectrum allocations	USA	Germany	France	New Zealand	Brazil	Peru	Mexico	Finland
			nationwide coverage in 7/12/15 years + 60%/80% of regional rail roads coverage in each region in 12/15 years.	The auction conditions are designed to ensure that at least 90 per cent of the population has access to a 4G network and faster mobile broadband coverage within five years.			national population, including 100% of the total pueblos magicos In 6 years: Coverage of 88.6% of the aggregated national population In 7 years: Coverage of 92.2% of the aggregated national population.	
Additional obligations			The frequencies, which are currently being used for digital television broadcasting, will gradually become available across the country between April 2016 and July 2019.	The direct cost of clearing the spectrum was \$147 million.	900 million Reais obtained in the auction will be used in the analogue to digital transition Commitment to purchase equipment with national technology	The service provider will assume the obligations and costs for the migration of broadcasters operating in the band. The total migration cost is of 10 million USD and it will be divided equally	The first criteria for choosing the winner will be based on the highest Populational Coverage Offer In case of a tie, the highest guarantee value will be considered as a second criteria.	

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Digital Dividend spectrum allocations	USA	Germany	France	New Zealand	Brazil	Peru	Mexico	Finland
					<p>Creation of an entity to administer the process of redistribution and digitalization of TV channels (including the distribution of Set Top Box (STB) to lower income population)</p> <p>Bidders compromise to bear the costs of redistribution of TV and repetitors and the solutions to solve harmful interference on broadcasting systems</p> <p>The use of the 700 MHz band can only begin 12 months after the analog switch off (the date can be anticipated, under certain conditions).</p>	<p>between the three winners.</p> <p>Band cleaning can take up to 12 months.</p> <p>Mobile concessionaries are obliged to provide interconnection to Mobile Virtual Network Operators (MVNOs).</p>		

A2-2. National regulations

Table 1A: Interference protection experiences

United States of America	Canada	Singapore	United Kingdom
<p>Frequencies: allows any mode of WSD operation between 470-698 MHz on available channels subject to the interference protection requirements.*</p> <p>Allows fixed WSD operation between 54-72 MHz, 76-88 MHz, and 174-216 MHz.</p> <p>Propagation model: utilizes R6602 F-curve propagation model.</p> <p>Adjacent channel power limits: -42.8 dBm conducted power for fixed WSD (-42.8 dBm at 30 dBm EIRP conducted power, -62.8 dBm at 10 dBm conducted power, linear interpolation for values in between). For personal / portable devices -52.8 dBm EIRP (at 100 mW EIRP) or -56.8 dBm EIRP (at 40 mW).</p> <p>Protected services: protection criteria granted to DTT, and digital and analog Class A TV, low power TV, TV translator and TV booster stations, MVPD receive sites, fixed BAS links, PLMRS/CMRS operations, Offshore Radiotelephone Service, wireless microphones, radio astronomy services, and Wireless Medical Telemetry Service.</p>	<p>Frequencies: allows any mode of WSD operation between 512-608 MHz and 614-698 MHz.</p> <p>Allows fixed WSD operation between 54-60 MHz, 76-88 MHz, 174-216 MHz, and 470-512 MHz.</p> <p>Propagation model: utilizes R6602 F-curve propagation model.</p> <p>Adjacent channel power limits: -42.8 dBm/100 kHz for fixed WSD, with additional limits on transmitting antennas with directional gain greater than 6 dBi; and -52.8 dBm/100 kHz or -56.8 dBm/100 kHz (low power) for portable devices</p> <p>Protected services: Specifies particular protection criterion for TV licensees, RRBS base station (downstream) transmitted protected contour, licensed LPA and developmental stations, radio astronomy observatories, and licensed (but not license-exempt) wireless microphones.</p>	<p>Frequencies: allows WSD operation (before DTT transition) between 181-188 MHz, 209-223 MHz, 502-518 MHz, 614-622 MHz, 630-710 MHz, 718-742 MHz, 750-774 MHz, and 790-806 MHz.</p> <p>Allows WSD operation (after DTT transition) between 174-188 MHz, 195-202 MHz, 209-230 MHz, 470-534 MHz, and 614-694 MHz.</p> <p>Propagation model: mandates use of Hata model.</p> <p>Adjacent channel power limits: -56.8 dBm in channels adjacent to TV broadcasters.</p> <p>Safe harbour channels: database must establish two PSME channels and may designate up to two "high priority channels".</p> <p>Protected services: currently include TV broadcast, private mobile radio, and wireless microphones (may be subject to future expansion).</p>	<p>Frequencies: allows WSD operation between 470-790 MHz.</p> <p>Propagation model: utilizes SEAMCAT extended Hata model.</p> <p>Adjacent Channel power limits: WSDs subject to different out of band emissions limits based upon emissions class (1 through 5).</p> <p>Protected services: protection currently specified for DTT, PMSE, and services in bands adjacent to 470-790 MHz.</p>
<p>* White space devices are not permitted to operate on the first channel above and below TV channel 37 (608-614 MHz) that are available until the completion of the broadcast television spectrum incentive auction.</p>			

Table 2A: Interference avoidance methods

United States of America	Canada	Singapore	United Kingdom
<p>Method: Geolocation database permitted, and Federal Communications Commission (FCC) will designate one or more administrators.</p> <p>Spectrum sensing permitted, with separate device parameters specified.</p>	<p>Method: Geolocation database permitted and Industry Canada (IC) will designate one or more administrators.</p> <p>Spectrum sensing is not permitted at this time.</p>	<p>Method: Geolocation database permitted, and Infocomm Development Authority (IDA) will license one or more administrators.</p> <p>Spectrum sensing only not permitted at this time, but sensing can be complimentary.</p>	<p>Method: Geolocation database permitted, and Ofcom will qualify and designate one or more administrators.</p> <p>Spectrum sensing not permitted at this time.</p>

A2-3. Case studies of broadband access in the TVWS

More information on these cases studies may be found in the input contributions to this report, a list of which can be found in **Annex 3**.

A2-3.1 Bhutan

Bhutan is characterised by steep, high mountains crisscrossed by rivers that form deep valleys before draining into the plains of India. Though the constitution mandates the Royal Government of Bhutan provide to its citizens free access to basic health care facilities, the majority of Bhutan's population live in settlements where health care facilities are usually more than an hour's walk away, and many villages are connected only by mule tracks.⁵⁶

With support from international development institutions and private sector stakeholders, the Ministry of Health (MoH) and Ministry of Information & Communications (MoIC) jointly implemented a pilot project to design an eHealth service delivery platform piloting TV White Space technology. The project links rural health clinics with a central reference hospital, utilising TVWS technology for last mile connectivity. By connecting rural populations, who would otherwise have to travel hours or even days to the nearest hospital, the project significantly improves their access to basic health services.

A2-3.2 Botswana

The government of Botswana has worked with a broad set of partners to deploy a telemedicine project designed to increase the quality of health services available at rural health clinics by enabling the provision of specialised care, and in particular maternal care not previously available.⁵⁷

Launched in March 2015, project Kgolagano aims to bring specialised health services to local Botswana hospitals and clinics. Telemedicine will provide a low-cost, high-impact solution to rural health challenges. In Botswana, rural hospitals and health clinics suffer from a lack of capacity, especially to offer specialised healthcare and quality maternal care that may be more available in larger cities.

Project Kgolagano provides a system to capture and send high resolution images over TVWS signals from local clinics to regional hospitals. From hospitals, they are sent via backhaul fibre networks to specialised medical personnel located in Gaborone, Botswana's capital, and to international partners such as the University of Pennsylvania, resulting in more accurate diagnoses and better care, without requiring the patient to travel.

The project not only fills a connectivity gap for dozens of local clinics, but also gives them the means to provide specialised healthcare services that are currently otherwise unavailable to rural populations. Over time, this TVWS system is expected to be expanded from clinics to other sites such as government offices and small businesses, further spreading access and its socio-economic benefits.

A2-3.3 Republic of Korea

The Korean government believes that TVWS services will help close the digital divide and make wireless broadband access more affordable for people across the country.⁵⁸ To realize this goal, the Korea Communications Commission (KCC) unveiled its "Basic Plan to Utilize TV White Space" in 2011, intending to use the 470-698 MHz band to provide: wireless internet services to rural areas, disaster prevention and management services, information delivery services for museums, stadiums, and other small areas, and smart grid services on water quality and power usage. During the same year,

⁵⁶ Document 1/223, "eHealth pilot project using TV white space technology as last mile connectivity", Kingdom of Bhutan.

⁵⁷ Document SG1RGQ/109, "Providing health care by using spectrum sharing in Botswana", Republic of Botswana.

⁵⁸ Document 1/459(Rev.1), "Update of Korea's TVWS case", Republic of Korea.

a super Wi-Fi network in Je-ju Island and emergency transmission service were introduced in the country as a TVWS pilot service.

The Korean government set the unlicensed based TVWS technical standards to build a TVWS Data Base that protects priority services of the 470-698 MHz band, such as terrestrial DTV and licensed wireless microphone.

In 2013, the TVWS DB was set up and has been managed by the government (MSIP).

In 2015, the government extended TVWS Wi-Fi services for fire detection and protection application services for cultural properties located in mountainous and coastal regions.

The government of the Republic of Korea (MSIP) made a new public notice allowing unlicensed use of the TVWS in November 2016. In April 2017, the first TVBD product that meets the regulations released and Korea began to provide TVWS commercial services.

A2-3.4 Malawi

Like many countries in Africa, Malawi⁵⁹ faces many challenges extending Internet connectivity beyond the current penetration rate of 6.7 per cent. Consequently, the government has pursued TVWS research through several different pilots to evaluate its potential. These projects extended Internet connectivity to two schools, enabling access to expanded educational resources for students, and a rural hospital, that piloted new projects in remote and virtual diagnosis. TVWS devices were also deployed by the Department of Seismology to enhance national seismic early warning systems and by the Air Wing Unit of the Malawi Defense Force to connect runways and bases to the Internet.

A regulatory framework enabling the widespread operation of white space devices is currently under development in Malawi and is expected soon.

A2-3.5 The Philippines

The Philippines is conducting the largest TVWS project so far in Asia supporting affordable community connectivity, sustainable resource management, educational access, and disaster resilient communications in a remote province.⁶⁰

Partially due to challenging topography, communities in Bohol province suffer from poor last-mile infrastructure, a gap which leaves dozens of schools and communities without Internet access. Existing infrastructure deficits are exacerbated by natural disasters, several of which have occurred in the region recently.

With a broad array of public, private, and international development partners, the project deployed TVWS technology to bring connectivity to dozens of sites across the Bohol province. The primary purpose of the Bohol project is to improve the quality of local education; by providing schools and teachers with reliable connectivity, TVWS technology allows for new forms of multimedia instruction, access to higher quality information and resources, and more effective teacher training and management.

Further, by opening broadband connections after school hours to the wider community, existing bandwidth is not wasted and a new resource is made available to the community. Residents use it to access social media and communications platforms to stay in touch with friends and family, to access government services and public information, and to engage in e-commerce. Connectivity was also provided to support the Ecosystems Improved for Sustainable Fisheries (Ecofish) ecological

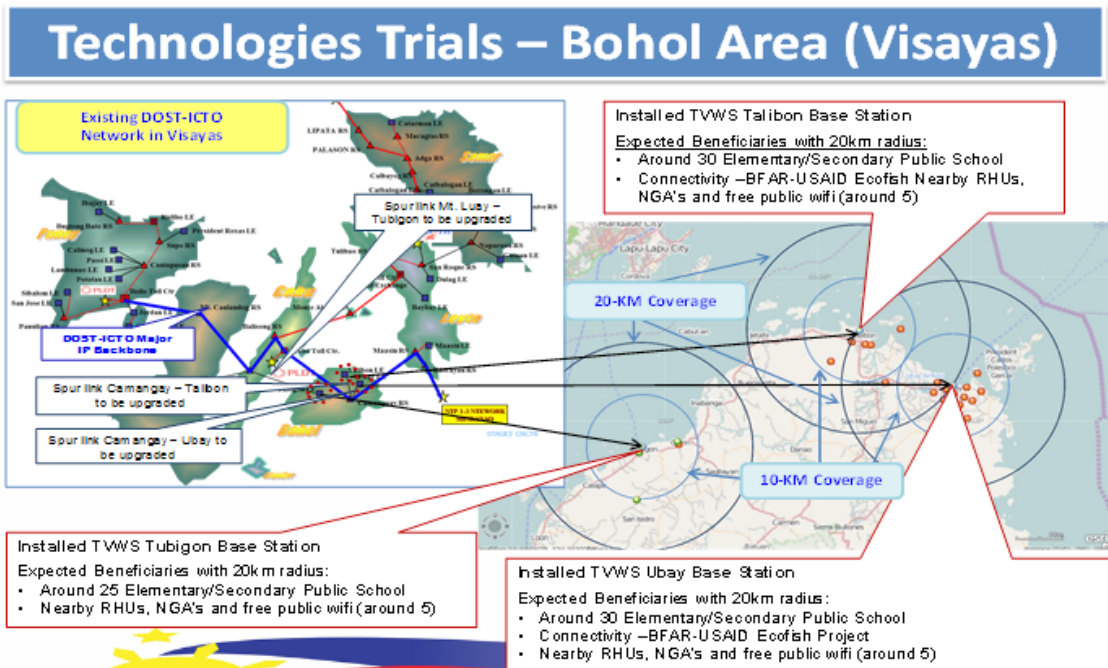
⁵⁹ Document 1/233, "Providing innovation and highly researched technologies in TV White Spaces (with applications in education, security, early warning and disaster preparedness)", Malawi.

⁶⁰ Document SG1RGQ/44, "Dynamic spectrum access case study", Republic of the Philippines.

sustainability program, where it makes local fishing more sustainable through more effective management, administration, and compliance action.

As part of separate project, the Department of Science and Technology in partnership with private sector partners, deployed TVWS transmitters in the city of Tacloban after the 2013 Bohol Earthquake and Typhoon Haiyan. By providing immediate connectivity and two-way voice communication after the destruction of other terrestrial infrastructure, this equipment provided communication capabilities for first responders and victims, improving the coordination of relief efforts. This was accomplished at less than 1/10th the cost of alternative solutions and required little to no specialised expertise to deploy. During this period, TVWS technology connected over 500 residents, enabled greater than 75,000 hours of Skype calls, and coordinated 5,000 rescue workers.

Figure 1A: Talibon, Tubigon and Ubay TV White Space area coverage



A2-3.6 United States of America

The United States of America (USA) has pioneered use of license-exempt spectrum, and three case studies in the USA are relevant to the experience of developing countries, namely the deployment of commercial wireless Internet service in rural areas, the extension of the service area of libraries into communities, and the provision of university campus-wide broadband.⁶¹

The first describes a commercial deployment in rural El Dorado County, California, a rugged region with approximately 140,000 rural residents, many of whom remained without Internet access. In 2012, the local commercial Wireless Internet Service Provider (WISP) deployed a series of five TVWS base stations, each capable of serving up to ten customers. In 2015, the WISP began the process of upgrading to the next generation of TVWS equipment, which will allow it to operate at higher power levels, higher data rates, and serve up to 30 customers per base station.

The second discusses a deployment in Delta County, Colorado. It is a hilly and tree-covered area with a rural population of approximately 30,000. Due to poor deployment of broadband, each of the county's five libraries served as a sort of community centre and Wi-Fi access point for many residents.

⁶¹ Document SG1RGQ/60, "Preliminary examples of spectrum sharing practices in the broadcast television bands", United States of America.

Beginning in 2013, one of these libraries was equipped with a TVWS base station which subsequently provided Wi-Fi access to other areas of the community. After the conclusion of the trial period, the Delta County library system raised the funds to purchase the TVWS equipment and continues to provide access for the community.

The third case highlights a project to provide high quality wireless broadband across a university campus. In 2013, a partnership of education associations, public interest groups, technology companies, and the West Virginia University Board of Governors, among others, began a multi-stage project to expand the areas of connectivity across several campuses of West Virginia University. In its first stage, two TVWS base stations and five fixed client radios were deployed in order to provide Wi-Fi access at university transit stations. Plans call for the eventual installation of TVWS radios on all cars of the transit system to provide seamless connectivity to commuting students and faculty.

A2-3.7 Ghana

Most educational institutions and rural communities in Ghana do not have access to affordable broadband Internet. To bridge this gap, several trials were made on TV White Space technology in these institutions. After the trials, one company was authorised to operate commercial TV White Space enabled services to provide Internet connectivity to two educational institutions. This has given students access to affordable broadband Internet around the campuses and their environs.

In Ghana, television services are distributed using multi-frequency network (MFN) and single frequency network (SFN) meaning that the services are transmitted using different frequencies in different parts of the country. TV broadcast network uses high power transmitters, it is therefore necessary to leave gaps to prevent TV coverage areas from overlapping which would cause interference and disrupt TV reception.

Further, the National Communications Authority (NCA) is currently developing the regulatory framework for the operations of TVWS services.

In view of the above, although the TVWS technology is still not fully mature for a full-scale deployment in Ghana, results of the trials indicate that it has the potential of delivering broadband access to rural communities in Ghana.

A2-4. Countries experiences in relation to spectrum pricing, licensing fees and auctions

In the following sections we highlight experiences of different administrations in valuing spectrum fees.

A2-4.1 Côte d'Ivoire – Estimating costs of licenses and frequencies

The capability of the National Regulatory Agency (NRA) to accurately estimate licensing costs and spectrum usage fees when renewing 2G mobile telephony licenses, allowing entry of new 2G competitors, and the granting of new licenses (3G, 4G, general license) is important both for the NRA and the telecom operators.⁶² For many administrations, such payments often represent a significant resource for public finance. These payments are based on several factors and considerations. Typically, licensing costs and spectrum usage fees vary based on the type of network and services provided and are determined by the characteristics and the amount of spectrum made available.

Côte d'Ivoire observes that NRA's in developing countries often lack the necessary capability to estimate the costs of licenses and usage fees, as telecom operators upgrade their 2G voice and data networks to 3G and 4G networks. In these circumstances, NRA's often turn to international firms to estimate the costs of licenses for both their technical expertise and to lend credibility to the process

⁶² Document 1/164, "The need to develop a method of estimating license costs", Republic of Côte d'Ivoire.

for the affected parties. The two methods used most often by these firms for estimating the economic value of the spectrum licenses are: (1) Discounted Cash Flow (DCF) and (2) benchmarking methods.

Under the DCF method, the consultant first estimates an operator's annual revenues and cost based on its business plan over the period of validity of the license to derive an estimate of the operator's free cash flow. A country's unique discount rate is applied to the estimated future free cash flow to determine its present value, which is an indicator of the license's economic value. A percentage of the calculated value, between 40 and 70 per cent, is used to estimate the spectrum price of the license. The estimate can be validated by a comparison of results with international best practices. As the analysis is based on the expertise of consultants acquired from many other similar projects rather than on country specific data, the possibility exists for under-estimating or over-estimating the cost of the licenses. Côte d'Ivoire believes these cost estimates should be adjusted to account for the conditions prevalent in developing countries so as to reflect their actual value. Further, it would be desirable for these consultants to adopt a coherent method of calculation for the sake of obtaining a clearer and fairer evaluation of the various financial costs associated with individual licenses and spectrum usage fees.

The second method, benchmarking, involves comparing values of the financial costs of licenses and frequency use. Limitations in using the benchmarking method result from the differences in licensing terms (population, areas, inflation, etc.) that prevent an apples-to-apples comparison, coupled with the fact that the methods used for estimating the costs for a given license may not be known. To improve benchmarking, Côte d'Ivoire recommends that: (1) National regulatory authorities carry out market surveys in their countries in order to better ascertain market trends and be in a position to make reasonable and fair estimates; (2) National regulatory authorities put in place mechanisms to certify the validity of data and to exchange data in real time; and (3) the ITU recommend methods of estimating costs of licenses and frequencies that are best adapted to the requirements of developing countries taking into account the shortage of data for estimating costs of licenses and frequency resources.

A2-4.2 Republic of Niger – Method to determine the frequency fees

The NRA is authorized to collect an annual spectrum usage fee, as well as fees to cover its costs for managing and monitoring the radio spectrum.⁶³ The Republic of Niger proposes a new method for calculation of spectrum usage and management fees that is less complex and more understandable to all the parties involved. The motivation for proposing the new method is that if fees are seen to be set too high, operators will increase their rates for telecommunications services which may result in fewer users and / or reduced use of the spectrum. Conversely, if fees are set too low, it may lead to a significant increase in spectrum usage, causing network congestion, among other challenges. The new method covers:

- The administrative fee paid at the time of requesting a radio frequency assignment or approval of a radio installation referred to as the 'file tax'. The value of the tax varies for different services / networks and is determined through a benchmarking process.
- The visit and control tax allows for cost-recovery for when regulatory agency staff provides services at a network user or radio service facility. It is a flat tax whose value is based on benchmarking.
- Spectrum usage fee for private sector operators can be calculated by the following formula:

$$R = D \times V \times L \times S \times C \times K$$

Where:

D = Percentage of time the frequencies are being used over a year

⁶³ Document SG1RGQ/182, "Method to determine the frequency fees", Republic of Niger.

V = Bandwidth of the frequency assignment (provided by a table that varies by radio service and the frequency band)

L = Level of demand (provided by a table that varies by frequency band and the nature of the service)

S= Optimization of the use of the spectrum (accounting for the level of complexity of the spectrum management based on different service / network type)

C = Class of use (government use, private services of general interest or public utility, networks open to the public established by licensed operators, independent private networks, radio and television, amateur use.)

K = Reference value (fee depends on the radio service)

There are also spectrum usage fees for fixed- and mobile-satellite service and for terrestrial radio and television broadcasters whose content is retransmitted over cable networks.

– Contributions to the management fee are calculated using the formula:

$$C = T \times R \times O \times G$$

Where:

T = Percentage of time the frequencies are being used over a year

R = Number of stations / links

O = Service coverage area (urban, regional, national, international)

G = Reference value (depends on service / network)

There are also fixed spectrum management fees for mobile satellite service and terrestrial radio and television retransmission over cable systems.

A2-4.3 Russian Federation – Experience of Russian Federation in the field of spectrum fees

In accordance with its Federal laws and Government decrees, the Russian Federation requires a one-time initial payment and an annual fee for use of its radio frequency spectrum. The methodology used for calculating these fees, includes rates and coefficients dependent on the frequency bands used, the number of radio frequencies (or channels used) and radio technologies applied, is described below:

Calculation of One-Time Payment

Each mobile operator must pay a one-time spectrum use fee for each frequency band assigned for its use by the State Radio Frequency Commission (SRFC) decision and (or) specified in the license granted by each Russian Federation Subject (or part of Subject). For technologies other than cellular, the one-time fee is set for each granted authorization. For both, the fee is calculated using the following formula:

$$P_{ot} = R_{ot} \times K_{band} \times K_{N} \times K_{tech}$$

Where:

P_{ot} = total one-time payment, roubles

R_{ot} = rate of tariff for one-time payment, roubles

K_{band} = coefficient depending on the frequency band used

- K_{Nf} = coefficient depending on number of used radio frequencies (radio channels)
 K_{tech} = coefficient depending on applicable technology

Details regarding the methodology for calculation of K_{band} , K_{Nf} and K_{tech} can be found in **Annex 3**.

Calculation of the Annual Fee

Each mobile operator must pay an annual spectrum use fee for each frequency band assigned for its use by the State Radio Frequency Commission (SRFC) decision and (or) specified in the license granted by each Russian Federation Subject (or part of Subject). For technologies other than cellular, the annual fee is set for each granted authorization. For both, the fee is calculated using the following formula:

$$P_a = \sum_{i=1}^4 P_{a(q)(i)}$$

where:

$$P_{a(q)} = R_a / 4 \times K_{band} \times K_{Nf} \times K_{tech} \times N_{auth(q)} / N_q$$

- P_a = annual fee, roubles
 $P_{a(q)}$ = annual fee per a quarter, roubles
 R_a = rate of annual fee, roubles
 K_{band} = coefficient depending on used frequency band
 K_{Nf} = coefficient depending on number of used radio frequencies (radio channels)
 K_{tech} = coefficient depending on applicable technology
 $N_{auth(q)}$ = number of effective days of authorization in a payable quarter
 N_q = number of days in a payable quarter

Note that the coefficients are applied per each radio frequency (radio channel) and/or frequency band.

Details regarding the methodology for calculation of K_{band} , K_{Nf} (excluding MMDS radio systems, Earth Stations of Satellite Systems (ESSS) and VSAT Hub (central) stations) and K_{tech} (for both cellular radio and other technologies) can be found in **Annex 3**.

Note 1: If a cellular operator holds a license to multiple channels within a given spectrum band, and uses different cellular radio technologies to access different channels, the annual fee per frequency band is calculated using maximum K_{tech} for radio technology used in the frequency band.

Note 2: When a SRFC decision or license assigns a frequency band to an operator not for the entire territory of the Subject but for some part of its territory, the number of used radio frequencies (radio channels) is calculated only with regards to the part of the Russian Federation Subject.

Note 3: To encourage timely registration, radio system operators that do not register within the designated period after authorization is granted, face significantly increased annual fees.

Observations regarding spectrum fees derived using this methodology

- On a per radio device basis, spectrum fees are highest for devices used for commercial cellular service and lowest for devices for scientific and government use, or are license-exempt.

- On a per megahertz basis, spectrum fees are highest for commercial cellular services and lowest for services that are for scientific and government use, or are license-exempt.

A2-4.4 Republic of Korea –Beauty contest and auction in spectrum management

Up until 2011, the Republic of Korea assigned spectrum to telecommunications service providers exclusively through beauty contests.⁶⁴ In the case of beauty contests, the economic value of the spectrum is measured by the value of the frequency band along with: (a) the efficiency of radio resource utilization; (b) the financial capacity of the assignee; (c) the technical capability of the assignee; (d) the technical characteristics of the frequency to be assigned; and (e) the impact of the corresponding frequency allocation on the telecommunications business and other factors. Korea also calculates spectrum prices based on revenue forecasts or actual revenues of telecommunications service providers as a means to promote broadcasting and ICT industry development.

Korea's first spectrum auction was conducted in 2011. Evaluations of the 2011 and 2013 spectrum auctions have shown that use of the auction method has enhanced fairness, transparency, and effectiveness of frequency management. With a beauty contest, the government can more accurately forecast its potential revenue. With the auction method, the government can no longer accurately forecast its potential revenue, as the value of spectrum for commercial use is more closely tied to the current market price, which is set by telecommunications service providers. Even so, the auction method is now considered the primary approach in assigning frequencies.

To promote competition, the Korean government has introduced a longer instalment payment system for spectrum auctions that lowers the barriers for participation by smaller, less-well capitalized companies. It is also important to note that most of the revenue generated from assigned spectrum has been spent for promoting research and development of information and communications technologies.

A2-5. Countries experiences in relation to Spectrum Management Systems

A2-5.1 Hungary – Spectrum Management IT System (STIR)

After three years of planning, the first phase of the development of the Spectrum Management IT System (STIR) was finished in 2015 in Hungary.⁶⁵ The STIR provides wide support to experts to create, edit, visualize and easily publish regulations around the use of the spectrum in Hungary, specifically the "Decree on National Frequency Allocation" and the rules of using frequency bands. This tool helps experts to undertake different analyses according to various criteria through processing the frequency management information that is available in the system. The tool is also capable to receive or send information to other systems such as EFIS (ECO Frequency Information System) and can be used in both English and Hungarian.

A2-6. Countries experiences in relation to Spectrum Management

A2-6.1 People's Republic of China – The improvement of spectral efficiency based on LTE technology

As the transition proceeds from narrowband trunked systems to broadband wireless networks, increased spectrum capacity is needed for the delivery of various public sector applications, including those requiring transmission of voice, data, image and video. In particular, public safety and

⁶⁴ Document 1/54, "The experience of beauty contest and auction in spectrum management in the Republic of Korea", Republic of Korea.

⁶⁵ Document 1/352 + Annex, "STIR (Spectrum Management IT System)", Hungary.

emergency communications require dedicated networks for use across transportation, energy, education, and environmental protection.⁶⁶

In consideration of other governments' spectrum allocation for public safety, the People's Republic of China's Ministry of Industry and Information Technology, has designated 20MHz bandwidth on 1.4GHz frequency band for a broadband dedicated trunked system to meet the needs of government use, public safety, and other public sector use.

In addition, the Chinese government conducted pilot projects in Beijing, Shanghai, Tianjin, and Nanjing to experiment with government uses for dedicated wireless networks, powered by TD-LTE technique and digital trunked technique. These technologies support high speed transmission, broadband and resource sharing, fast call technology, and command dispatch. They can also deliver services, such as original trunked voice service, broadband communication of collaborative process, and video-scheduling simultaneously. In addition, this network may be technically capable in the areas of network safety, reliability, and extendibility, which provides great potential for various applications in the fields of public safety, transportation, security, and defence. The Chinese government believes a TD-LTE technology-based government network will provide strong support for future smart city applications.

Nanjing Example: The wireless government dedicated network in Nanjing covers 11 municipal districts, with an area of about 6,597 square kilometres and a population of about 8 million. Following the network of outdoor roads, the city adopted a thin-overlay coverage pattern with the following coverage quality conditions: (1) The area where the received signal strength exceeds -100dBm, (2) is not less than 85 per cent of the planned coverage area, and (3) the edge coverage ratio is not less than 60 per cent. To ensure the coverage of the network within the city, as well as the indoor coverage in major application architectures, the network is composed of terminals, broadband wireless access subsystem, the network subsystem, and application subsystems. It includes almost 300 base stations, providing mobile information solutions for mobile office applications, emergency disposal, administrative enforcement actions and public safety. These support communication and data transmission services for Nanjing municipal government, the police department, and the urban management departments, and played a crucial role in command dispatch and communication protections in the Nanjing Youth Olympic Games. The wireless government dedicated network also supports Internet services and multimedia trunking services, which are characterized by strong anti-interference ability, high spectral efficiency, high coverage, excellent compatibility and confidentiality.

A2-6.2 Tanzania – The legal framework on Spectrum Management in Tanzania

Radio frequency spectrum is a scarce resource which must be used efficiently and effectively. In absence of a specific policy on spectrum management and for the purpose of resolving challenges in regulating spectrum, Tanzania⁶⁷ has put in place a legal framework that provides for wide powers for spectrum management, authorizing the Authority to retrieve spectrum from operators who do not use it, or are using it in an inefficient and ineffective manner. The framework can be adopted by other countries so as to put in place effective and efficient spectrum management, and to ensure that the scarce spectrum resource is used for the benefit of society.

Tanzania has two general policies to govern the ICT/telecommunications sector: National Telecommunications Policy (NTP) of 1997 and the National Information Communications Technology Policy of 2003. The NTP authorized the relevant regulators to monitor and to regulate the telecommunications sector and to allocate and monitor radio frequencies. Additionally, various legislation has governed the management of spectrum in Tanzania. In 1993, the Communications Commission (TCC) was established under the Tanzania Communications Act (TCA) as the regulator for posts and telecommunications issues. Following a legal battle on retrieval of spectrum, in 2001 the Government of Tanzania amended the TCA to enable TCC to retrieve spectrum from an operator who is occupying

⁶⁶ Document 1/356, "The improvement of spectral efficiency based on LTE technology", People's Republic of China.

⁶⁷ Document 1/155, "The legal framework on Spectrum Management in Tanzania", United Republic of Tanzania.

but not using certain spectrum. The amendment also ensured spectrum is utilized in an efficient and effective manner. In 2010, the Electronic and Postal Communications Act (EPOCA) was enacted and repealed the TCA and Broadcasting Services Act. This new law provided the Converged Licensing Framework, introduced a number of new developments in the sector including: SIM card registration, Computer Emergency Response Team, Digital broadcasting, and Postcodes.

In the regulatory space, the Radio Communication Regulations of 2001 was the first regulation covering a number of issues related to radio frequency spectrum. It was replaced with the Tanzania Communications (Radio Communications and Frequency Spectrum) Regulations in 2005, which governed a range of issues such as general licensing issues and classes of licenses using spectrum and interference with telecom equipment, station networks and systems. In 2011, the 2005 regulations on frequency spectrum were repealed and replaced with the Electronic and Postal Communications (Radio Frequency) Regulations. The above-mentioned Regulations provide:

- Where spectrum is insufficient or bands are competitive, allocation and assignment of spectrum to any successful applicant shall be on basis of beauty contest process;
- Criteria for the Authority to follow in case of competing demand: roll out commitment, financial/technical capability and public interest;
- Spectrum allocated to be used within 12 months from date of grant of license;
- The Authority may from time to time, review spectrum allocation plan with view to phase out ageing technologies and obsolete radio equipment;
- The Authority may require sharing of spectrum among users.

Annex 3: Contributions received for WTDC Resolution 9

Resolution 9 contributions for Rapporteur Group and Study Group meetings

Web	Received	Source	Title
1/465	2017-03-17	BDT Focal Point for Resolution 9	Spectrum management master plans in ASP and Caribbean
1/459 (Rev.1)	2017-03-17	Korea (Republic of)	Update of Korea's TVWS case (section 1.4.3, Chapter 1) of the Final Report
1/445	2017-01-17	ITU-D and ITU-R Co-Chairmen for the Joint Group for Resolution 9	Report for the ITU-D/ITU-R Joint Group meeting for WTDC Resolution 9, Geneva, 17 January 2017
1/420 [OR]	2017-02-10	ITU-D Co-Chairman for the Joint Group for Res. 9	Final Report for Resolution 9
RGQ/278 (Rev.1) [OR]	2016-11-18	ITU-D and ITU-R Co-Chairmen for the Joint Group for Resolution 9	Draft Final Report for Resolution 9
RGQ/276	2016-11-14	Korea (Republic of)	Modified text for Korea's TVWS case in Chapter 1
1/373	2016-09-07	France	Draft Chapter 1 and 2 – Report of Resolution 9
1/372	2016-09-07	BDT Focal Point for Question 8/1 and Resolution 9	BDT activities on broadcasting and spectrum management
1/363 +Ann.1	2016-09-07	Chairman and BR Counsellor for ITU-R Study Group 1	ITU-R Study Group 1 recent and on-going activities on spectrum management
1/362	2016-09-07	Inmarsat Plc	Spectrum management approach for the consideration of earth stations in the fixed-satellite service, including Earth Stations In Motion (ESIMs)
1/356	2016-09-07	China (People's Republic of)	The improvement of spectral efficiency based on LTE technology
1/352 +Ann.1	2016-08-25	Hungary	STIR (Spectrum Management IT System)
1/339	2016-08-05	United States of America	Spectrum Monitoring
1/327 [OR]	2016-08-05	ITU-D Co-Chairman for the Joint Group for Res.9	Draft Chapter 1 and 2 – Report of Resolution 9
1/295	2016-08-01	France	Comments of France in response to observations made by WP 1B of ITU-R Study Group 1
1/273 +Ann.1	2016-07-22	BDT Focal Point for Resolution 9	Spectrum fee guidelines
1/249	2016-04-11	Co-Chairmen for the Joint Group for Resolution 9	Report of the Rapporteur Group Meeting on Resolution 9 (Rev. Dubai, 2014), Geneva, Monday 11 April 2016

Resolution 9: Participation of countries, particularly developing countries, in spectrum management

Web	Received	Source	Title
RGQ/240 +Ann.1	2016-04-11	Radiocommunication Bureau, BR Focal Point on Resolution 9	Outcome of World Radiocommunication Conference (WRC) 2015
RGQ/238	2016-03-22	France	Consolidated text for New/Emerging Spectrum Management Approaches completed with ECC Report 236 relevant extracts.
RGQ/236	2016-03-22	ITU-D Co-Chairman for the Joint Group for Res.9	Draft Chapter 1 and 2 – Report of Resolution 9
RGQ/222	2016-03-22	Russian Federation	The experience of the Russian Federation in the field of spectrum fees
RGQ/216	2016-03-22	Korea (Republic of)	Recent TV White Space (TVWS) Policy and Pilot Projects in Korea (Republic of)
RGQ/206 +Ann.1	2016-03-18	ITU-D Co-Chairman for the Joint Group on Res.9	Report of the Expert Group meeting on Resolution 9 (Budapest, 18-19 February 2016)
RGQ/204	2016-03-18	BDT Focal Point for Question 8/1 and Resolution 9	Outcomes of RA-15, WRC-15 and CPM19-1 related to ITU-D
RGQ/203 +Ann.1	2016-03-18	BDT Focal Point for Resolution 9	BDT activities on spectrum management
RGQ/201 +Ann.1	2016-03-17	Radiocommunication Bureau	Further development of the ITU-R documents database search facility
RGQ/182	2016-03-08	Niger (Republic of the)	Méthode pour déterminer les redevances de fréquences
RGQ/137	2016-01-25	Microsoft Corporation	Consolidated text for New/Emerging Spectrum Management Approaches
RGQ/134	2016-02-02	Egypt (Arab Republic of)	Spectrum Access Schemes
RGQ/133	2016-01-25	Inmarsat	Licensing regime applicable to earth stations in motion operating in the fixed-satellite service
1/249	2016-04-11	Co-Chairmen for the Joint Group for Resolution 9	Report of the Rapporteur Group Meeting on Resolution 9 (Rev. Dubai, 2014), Geneva, Monday 11 April 2016.
1/233	2015-08-27	Malawi	Providing innovation and highly researched technologies in TV White Spaces (with applications in education, security, early warning and disaster preparedness)
1/227	2015-09-02	Dynamic Spectrum Alliance (DSA)	Technical Overview of Dynamic Spectrum Access
1/224	2015-09-01	BR Focal Point for Resolution 9	ITU-R Study Group 1 – Recent & on-going activities on Spectrum Management
1/223	2015-09-01	Bhutan (Kingdom of)	eHealth Pilot project using TV White Space technology as last mile connectivity
1/220	2015-08-31	BDT Focal Point for Resolution 9	Guidelines for setting up a new or updating an existing spectrum monitoring network

Resolution 9: Participation of countries, particularly developing countries, in spectrum management

Web	Received	Source	Title
1/183	2015-08-07	Telecommunication Development Bureau	1st ITU-D Academia Network Meeting
1/180 +Ann.1	2015-07-24	G3ict	Contribution of G3ict- The Global Initiative for Inclusive Information and Communications Technologies to the Working Party 5D (WP 5D) – IMT System
1/164	2015-07-31	Côte d’Ivoire (Republic of)	The need to develop a method of estimating license costs
1/155	2015-07-31	Tanzania (United Republic of)	The legal framework on Spectrum Management in Tanzania
1/154	2015-07-31	Microsoft Corporation	Cloud-based, open-source, low-cost experimental platform for qualitative assessment of spectrum utilization
1/151	2015-07-28	BDT Focal Point for Resolution 9	BDT activities on spectrum management
1/134 +Ann.1	2015-07-17	France	Recent CEPT publication: ECC report 236 on “Guidance for national implementation of a regulatory framework for TV WSD using geo-location databases”
1/130	2015-07-13	Radiocommunication Bureau	Further Development of the ITU-R documents database search facility
RGQ/109	2015-04-01	Botswana (Republic of)	Providing health care by using spectrum sharing in Botswana
RGQ/88 +Ann.1	2015-03-20	BDT Focal Point for Resolution 9	BDT activities on spectrum management
RGQ/81 +Ann.1	2015-03-17	BDT Focal Point for Resolution 9	Assessing the spectrum management needs of developing countries
RGQ/65 +Ann.1	2015-03-02	Hungary	Spectrum Management IT System (STIR)
RGQ/60	2015-02-27	United States of America	Preliminary examples of spectrum sharing practices in the broadcast television bands
RGQ/44	2015-02-26	Philippines (Republic of the)	Dynamic spectrum access case study
RGQ/15	2014-12-15	ITU-D/ITU-R Co-Chairman, Joint Group on Res.9	Draft work plan for Resolution 9
1/67	2014-09-08	Egypt (Arab Republic of)	Draft work plan for Resolution 9 (Rev. Dubai, 2014)
1/63	2014-09-02	Chairman, ITU-R Study Group 1, Radiocommunication Bureau	ITU-R Study Group 1 recent and ongoing activities on spectrum management (including ITU-R studies on DSA and CRS)
1/62	2014-09-02	Radiocommunication Bureau	Development of the ITU-R documents database search facility

Web	Received	Source	Title
1/56	2014-08-29	BDT Focal Point for Resolution 9	Guidelines for the preparation of a National Table of Frequency Allocations (NTFA)
1/55	2014-08-29	BDT Focal Point for Resolution 9	Resolution 9 and BDT activities in spectrum management
1/54	2014-08-28	Korea (Republic of)	The experience of beauty contest and auction in spectrum management in the Republic of Korea
1/50	2014-08-28	United States of America	Selected recent developments in U.S. spectrum management
1/3	2014-08-20	Telecommunication Development Bureau	Resolution 9 (Rev. Dubai, 2014): Participation of countries, particularly developing countries, in spectrum management

Liaison Statements

Web	Received	Source	Title
1/436	2017-03-15	ITU-R Study Groups- Working Party 5D	Liaison Statement from ITU-R WP 5D to ITU-D/ITU-R Joint Group on Resolution 9 on spectrum management principles, challenges and issues related to dynamic access to frequency bands by means of radio systems employing cognitive capabilities
RGQ/308	2016-12-15	ITU-R Study Groups- Working Party 1B	Liaison Statement from ITU-R WP1B to ITU-D/ITU-R Joint Group for Resolution 9 on Spectrum management principles, challenges and issues related to dynamic access to frequency bands by means of radio systems employing cognitive capabilities
RGQ/307		ITU-R Study Groups- Working Party 1B	Liaison Statement from ITU-R WP1B to ITU-R/ITU-D Joint Group on WTDC Resolution 9 on Resolution 9 Draft Output Report
RGQ/306	2016-12-15	ITU-R Study Groups- Working Party 1B	Liaison Statement from ITU-R WP1B to ITU-D SG1 Resolution 9 on the progress towards a preliminary draft new report ITU-R SM [Regulatory Tools]
1/268	2016-07-20	ITU-R Study Groups- Working Party 1B	Liaison Statement from ITU-R WP 1B to the ITU-D/ITU-R Joint Group on WTDC Resolution 9 on Working document towards a preliminary draft new Report ITU-R SM [CRS Spectrum Management Challenges]
1/264	2016-07-08	ITU-R Study Groups- Working Party 1B	Liaison Statement from ITU-R WP 1B to ITU-D/ITU-R Joint Group on Resolution 9 on the progress of ongoing work on WTDC Resolution 9 (Rev. Dubai, 2014) during the ITU-D Study Period 2014-2017 with respect to Chapter 1 on New/emerging spectrum management approaches

Web	Received	Source	Title
1/260	2016-07-08	ITU-R Study Groups- Working Party 5D	Liaison Statement from ITU-R WP 5D to ITU-D/ITU-R Joint Group on Resolution 9 on the progress of ongoing work on WTDC Resolution 9 (Rev. Dubai, 2014) during the ITU-D Study Period 2014-2017
1/259	2016-06-28	ITU-R Study Groups- Working Party 1C	Liaison Statement from ITU-R WP 1C to ITU-D SG 1 on new Correspondence Group on the revision of Recommendation ITU-R SM.1392-2 on essential requirements for a spectrum monitoring system for developing countries
1/255	2016-06-28	ITU-R Study Groups- Working Party 1B	Liaison Statement from ITU-R Working Party 1B to the ITU-R/ITU-D Joint Group on WTDC Resolution 9 entitled "The progress of ongoing work on WTDC Resolution 9 (Rev. Dubai, 2014) during the ITU-D study period 2014-2017, with respect to Chapter 2"
RGQ/186	2016-03-09	ITU-R Study Groups- WP 5D	Liaison statement from ITU-R WP 5D to ITU-D SG1 on Working document towards a preliminary draft new report ITU-R SM.(innovative regulatory tools)
RGQ/185	2016-03-09	ITU-R Study Groups- WP 5D	Liaison statement from ITU-R WP 5D to ITU-D SG1 Q8/1 on television distribution using terrestrial International Mobile Telecommunication (IMT) networks
1/212	2015-08-28	ITU-R Study Groups- Working Party 5A	Liaison statement from ITU-R WP 5A to ITU-D/ITU-R Joint Group for Resolution 9 on Work items during the 2014-2017 study period
1/211	2015-08-26	ITU-R Study Groups- Working Party 5A	Liaison statement from ITU-R Working Party 5A on Innovative regulatory tools to support enhanced shared use of the spectrum
1/127	2015-07-04	ITU-T Study Group 15	Liaison Statement from ITU-T SG15 to ITU-D SGs on ITU-T SG15 OTNT standardization work plan
1/123	2015-06-23	ITU-R Study Groups- Working Party 1B	Liaison Statement from ITU-R SG6 WP1B to the ITU-D/ITU-R Joint Group for Resolution 9 on Working document towards a preliminary draft new report ITU-R SM on CRS spectrum management challenges
1/120	2015-06-23	ITU-R Study Groups- Working Party 1B	Liaison Statement from ITU-R WP1B to ITU-D Study Group 1 on Working document towards a preliminary draft new report ITU-R SM on Innovative regulatory tools
1/93	2015-04-08	ITU-T Study Group 3	Liaison Statement from ITU-T SG3 to ITU-D SG1 Resolution 9 on Economic aspects of spectrum management

Resolution 9: Participation of countries, particularly developing countries, in spectrum management

Web	Received	Source	Title
RGQ/80	2015-03-17	ITU-R Study Groups- Working Party 6A	Liaison Statement from ITU-R SG6 WP6A to the ITU-D/ITU-R Joint Group for Resolution 9 on Dynamic spectrum access

Annex 4: Relevant decisions of the RA-15 and the WRC-15 which are especially important for developing countries

The Resolutions approved during the RA-15, which are relevant to the future work of the ITU-D/BDT are listed below.

Subject	Resolution	Title
Collaboration with ITU-R	Resolution ITU-R 7-3	Telecommunication development including liaison and collaboration with the ITU Telecommunication Development Sector
Bridging the Digital Divide	Resolution ITU-R 69	Development and deployment of international public telecommunications via satellite in developing countries
Spectrum Management	Resolution ITU-R 40-4	Worldwide databases of terrain height and surface features
	Resolution ITU-R 11-5	Further development of the spectrum management system for developing countries
	Resolution ITU-R 22-4	Improvement of national radio spectrum management practices and techniques
Wireless broadband	Resolution ITU-R 56-2	Naming for International Mobile Telecommunications (IMT)
Accessibility for persons with disabilities	Resolution ITU-R 67	Telecommunication/ICT accessibility for persons with disabilities and persons with specific needs
Emergency telecommunication, disaster response and relief	Resolution ITU-R 55-2 (and Suppression of Res. ITU-R 53-1)	ITU studies of disaster prediction, detection, mitigation and relief
Climate change and green ICTs	Resolution ITU-R 60-1	Reduction of energy consumption for environmental protection and mitigating climate change by use of ICT/radiocommunication technologies and systems

Other resolutions and recommendations relevant to work of ITU-D/BDT but do not explicitly require involvement of BDT

- Resolution ITU-R 66: *Studies related to wireless systems and applications for the development of the Internet of Things (IoT)*
- Recommendation ITU-R M.1036-5: *Frequency arrangements for implementation of the terrestrial component of International Mobile Telecommunications (IMT) in the bands identified for IMT in the Radio Regulations*
- Recommendation ITU-R M.2090-0: *Specific unwanted emission limit of IMT mobile stations operating in the frequency band 694-790 MHz to facilitate protection of existing services in Region 1 in the frequency band 470-694 MHz*

WRC-15 Resolutions which request actions from the Director of BDT or ITU-D

Subject	Resolution	Title	Required action
Interference in HF bands	Resolution 207 (Rev.WRC-15)	Measures to address unauthorized use of and interference to frequencies in the bands allocated to the maritime mobile service and to the aeronautical mobile (R) service	<i>resolves to invite ITU-R and ITU-D, as appropriate to increase regional awareness of appropriate practices in order to help mitigate interference in the HF bands, especially on distress and safety channels</i>
IMT below 1 GHz	Resolution 224 (Rev.WRC-15)	Frequency bands for the terrestrial component of International Mobile Telecommunications below 1 GHz	<i>invites the Director of the Telecommunication Development Bureau to draw the attention of the ITU Telecommunication Development Sector to this resolution</i>
Emergency and disaster	Resolution 647 (Rev.WRC-15)	Radiocommunication aspects, including spectrum management guidelines for early warning, disaster prediction, detection, mitigation and relief operations relating to emergencies and disasters	<i>invites the Director of the Telecommunication Standardization Bureau and the Director of the Telecommunication Development Bureau to collaborate closely with the Director of BR to ensure that a consistent and coherent approach is adopted in the development of strategies in response to emergency and disaster situations</i>
694-790 MHz in Region 1 - mobile	Resolution 760 (WRC-15)	Provisions relating to the use of the frequency band 694-790 MHz in Region 1 by the mobile, except aeronautical mobile, service and by other services	<i>invites the Director of the Radiocommunication Bureau to work, in cooperation with the Director of the Telecommunication Development Bureau, to bring assistance to developing countries wishing to implement the new mobile allocation in order to help these administrations to determine the modifications of the GE06 entries according to their needs</i>
Spectrum use in 470-960 MHz	Resolution 235 (WRC-15)	Review of the spectrum use of the frequency band 470-960 MHz in Region 1	<i>further invites ITU-R to ensure inter-sectoral collaboration with the ITU Telecommunication Development Sector (ITU-D) in the implementation of this resolution.</i>
Time scale	Resolution 655 (WRC-15)	Definition of time scale and dissemination of time signals via radiocommunication systems	<i>invites the Director of the Telecommunication Development Bureau to assist the participation of developing countries in meetings, within approved budgetary resources</i>

Subject	Resolution	Title	Required action
Palestine	Resolution 12 (Rev.WRC-15)	Assistance and support to Palestine	<i>instructs the Director of the Radiocommunication Bureau and the Director of the Telecommunication Development Bureau to encourage all concerned parties in continuing bilateral negotiations and facilitate implementing the agreements and relevant resolutions, in order to undertake additional measures required for enhancing and developing the wireless telecommunication infrastructures, new technologies and services for Palestine, further instructs the Director of the Radiocommunication Bureau to continue providing specialized assistance and support, in particular in the field of spectrum management and frequency assignment, to Palestine in collaboration with ITU-D, pursuant to the relevant ITU resolutions</i>

Detailed list of Recommendations and Resolutions which can be of special interest for developing countries

Recommendation/Resolution	Title
Recommendation 207 (Rev. WRC-15)	Future IMT systems
Resolution 5 (Rev. WRC-15)	Technical cooperation with the developing countries in the study of propagation in tropical and similar areas
Resolution 12 (Rev. WRC-15)	Assistance and support to Palestine
Resolution 49 (Rev. WRC 15)	Administrative due diligence applicable to some satellite radiocommunication services
Resolution 55 (Rev. WRC 15)	Electronic submission of notice forms for satellite networks, earth stations and radio astronomy stations
Resolution 81 (Rev. WRC-15)	Evaluation of the administrative due diligence procedure for satellite networks
Resolution 144 (Rev. WRC-15)	Special requirements of geographically small or narrow countries operating earth stations in the fixed-satellite service in the band 13.75-14 GHz
Resolution 207 (Rev. WRC-15)	Measures to address unauthorized use of and interference to frequencies in the bands allocated to the maritime mobile service and to the aeronautical mobile (R) service
Resolution 212 (Rev. WRC 15)	Implementation of International Mobile Telecommunications in the frequency bands 1 885-2 025 MHz and 2 110-2 200 MHz
Resolution 223 (Rev. WRC 15)	Additional frequency bands identified for International Mobile Telecommunications

Recommendation/Resolution	Title
Resolution 224 (Rev. WRC 15)	Frequency bands for the terrestrial component of International Mobile Telecommunications below 1 GHz
Resolution 535 (Rev. WRC-15)	Information needed for the application of Article 12 of the Radio Regulations
Resolution 552 (Rev. WRC 15)	Long-term access to and development in the frequency band 21.4-22 GHz in Regions 1 and 3
Resolution 553 (Rev. WRC 15)	Additional regulatory measures for broadcasting-satellite networks in the frequency band and 21.4-22 GHz in Regions 1 and 3 for the enhancement of equitable access to this frequency band
Resolution 555 (Rev. WRC 15)	Additional regulatory provisions for broadcasting-satellite service networks in the frequency band 21.4-22 GHz in Regions 1 and 3 for the enhancement of equitable access to this frequency band
Resolution 646 (Rev. WRC 15)	Public protection and disaster relief
Resolution 647 (Rev. WRC 15)	Radiocommunication aspects, including spectrum management guidelines, for early warning, disaster prediction, detection, mitigation and relief operations relating to emergencies and disasters
Resolution 906 (Rev. WRC-15)	Electronic submission of notices for terrestrial services to the Radiocommunication Bureau and exchange of data between administrations
Resolution 760 (WRC 15)	Provisions relating to the use of the frequency band 694-790 MHz in Region 1 by the mobile, except aeronautical mobile, service and by other services
Resolution 235 (WRC-15)	Review of the spectrum use of the frequency band 470-960 MHz in Region 1
Resolution 655 (WRC-15)	Definition of time scale and dissemination of time signals via radiocommunication systems
Resolution 810 (WRC 15)	Preliminary agenda for the 2023 World Radiocommunication Conference
Resolution 236 (WRC-15)	Railway radiocommunication systems between train and trackside
Resolution 809 (WRC 15)	Agenda for the 2019 World Radiocommunication Conference
Resolution 238 (WRC 15)	Studies on frequency-related matters for International Mobile Telecommunications identification including possible additional allocations to the mobile services on a primary basis in portion(s) of the frequency range between 24.25 and 86 GHz for the future development of International Mobile Telecommunications for 2020 and beyond
Resolution 160 (WRC 15)	Facilitating access to broadband applications delivered by high-altitude platform stations

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