GSR 2013 Discussion Paper

TV WHITE SPACES: MANAGING SPACES OR BETTER MANAGING INEFFICIENCIES?

Work in progress, for discussion purposes

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1. Introduction

This discussion paper reviews relevant regulatory aspects concerning the operational implementation of Television White Space (TVWS) devices in the television broadcast spectrum. Trials and tests are currently underway in several countries and some commercial applications are emerging, looking at maximizing the use of the highly valued UHF[1] spectrum resource through sharing its use with the primary terrestrial television service. Wireless broadband applications are the main focus of trials, nonetheless, the usefulness of this highly sought-after spectrum bands is also being considered for other applications, such as machine-to-machine communications (M2M). The low-power nature of all these alternative wireless applications is being proposed as appropriate for operation under a license-exempt[2] regulatory framework, in compliance with technical and operational specifications.

As the title of this paper suggests, there are different approaches and considerations currently being reviewed on TV white spaces. From the operational and technical aspects of accessing varying degrees of idleness of UHF television spectrum through – *managing the spaces* – to aspects concerning long-term international planning of the UHF spectrum resource as part of national ICT strategies through – *better managing inefficiencies*. These approaches are intended for improving the efficiency of the spectrum resource use, through accessing idle spectrum to deliver low-cost user applications and/or by planning a harmonized spectrum use from which economies of scale can be obtained.

The paper also examines aspects of wireless markets and sustainable development of ICTs in relation to TVWS implementation, international regulatory developments of the spectrum bands in question, spectrum management and licensing frameworks. Also, industry feedback has been received independently from several spectrum users and other industry stakeholders, which provides additional information on the ongoing trials and reflects a wider range of views. Finally, the paper raises regulatory and policy questions for regulators and stakeholders to reflect on and proposes a regulatory checklist for exploring regulatory choices in relation to TVWS implementation.

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[1] UHF: Ultra High Frequency (range of 300-3000 MHz). These frequencies are used by a variety of wireless services including TV broadcasting, military, mobile telephony, public safety communications, satellite and short-range devices amongst others. The UHF TV broadcasting band (excluding digital dividend spectrum bands) is located in the frequency range around 470-698 MHz. Including the Digital Dividend, the frequency ranges approximately between 470-790 MHz.

[2] License-exempt framework refers to devices operating on a non-interference/non-protection basis in compliance with technical specification and/or band rules without the need for an individual device license.

2. Overview to the development of TV White Spaces (TVWS)

What is TV White Space?

According to the ITU report "Digital Dividend[3]: Insights for spectrum decisions[4]", TV white spaces (TVWS) are *"portions of spectrum left unused by broadcasting, also referred to as interleaved spectrum"*. Widely, TVWS are also referred to as those currently unoccupied portions of spectrum in the terrestrial television frequency bands in the VHF and UHF TV spectrum (be it analogue or digital, generally in the UHF band). These TV spectrum "gaps", with advantageous propagation properties inherent to UHF spectrum (excellent outdoor and indoor coverage and non line-of-sight propagation properties) have been identified in some administrations as an alternative for providing commercial wireless services other than broadcasting. Some of the wireless technologies being explored in TVWS are low-power, machine-to-machine (M2M[5]) communication devices and low-power wireless broadband applications, capitalizing on the longer coverage ranges achievable with UHF spectrum.

Finding the White Spaces: instances of TVWS availability

There are different ways in which TVWS can arise at any given location. Nonetheless, the amount of spectrum available in the form of TVWS can vary significantly across different locations and will depend on various factors, including: geographical features, the level of interference potential to the incumbent TV broadcasting service, TV coverage objectives and related planning, and television channels utilization. These and other instances of TVWS availability can be categorized (not restricted to) as follows:

a. Frequency: idle channels of a TV band plan in some geographical areas due to interference avoidance techniques by means of frequency separation (guard channels).

b. Height: defines the availability of TVWS at a given area in terms of the height of the TVWS transmission site and its antenna height, in relation to surrounding TV broadcasting coverage reception. Basically, the higher the TVWS transmission site/antenna, the higher the likelihood would be of the TVWS device's signal being perceptible by TV receivers in surrounding areas

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[3] Digital Dividend: refers to the amount of spectrum made available by the transition of terrestrial television broadcasting from analogue to digital.

[4] Digital Dividend: Insights for Spectrum Decisions: http://www.itu.int/ITU D/tech/digital_broadcasting/Reports/DigitalDividend.pdf

[5] Further details about M2M communications can be found at: http://www.itu.int/en/ITU-T/focusgroups/m2m/Pages/default.aspx and a technical paper on M2M: http://www.itu.int/pub/T-TUT-IOT

(the primary service), and therefore conducive to a situation where a potential level of harmful interference could reach the primary broadcasting service (especially if there is no geographical obstruction in between to somewhat lessen a potentially interfering emission). Under such conditions of high interference probability, TVWS devices would then be unable to operate using incumbent TV frequencies.

c. Space: geographical areas that are outside the current TV coverage and therefore no broadcasting signal is currently present. Also, those geographical separation areas (planned) between locations using the same TV channels.

Moreover, instances of TVWS in case A above (frequency) are usually linked to legacy analogue television broadcasting. In the case of digital terrestrial television (DTT), "frequency separation" cases of TVWS can be found less often if the digital broadcasting network uses the adjacent channel rejection capabilities of digital technology at its full extent (less guard channels would be available). Furthermore, a third domain of TVWS could also be found if one considers the time domain. In the time domain, a TVWS could become available when a broadcasting emission is off-air; hence the licensed broadcasting transmitter is not using the assigned frequency channel during a specific period of time (i.e. nighttime). On this note, it is important to mention that the UHF television broadcasting service has been allocated as a *primary service* across all regions of the world, within the ITU's International Table of Frequency Allocations (part of the International Radio Regulations[6], "RRs"). As per Radio Regulations, a primary service must not receive harmful interference from other services not classified as primary and operating in the same frequency bands (i.e. a *secondary service*)

Also, the use of digital TV systems permits the use of Single Frequency Networks (SFNs), in which several transmitters can use the same frequency channel without interference. The increasing use of SFNs is becoming a key element in frequency planning of television broadcasting to enable the allocation of the digital dividend(s) to mobile services. As a result, a channel that may be available at one time for TVWS may become unusable as a result of the introduction of new TV transmitters in the same SFN.

Lastly, there are also instances where complete idleness of TV frequency bands can be found – fully available large blocks of UHF spectrum – rather than the sporadic smaller spectrum gaps identified for use on shared basis in an opportunistic way by TVWS devices. These instances are due to very low levels of terrestrial television demand, found either in very low population density areas (vast rural zones), or in highly developed metropolitan areas where the TV broadcasting market has been fully dominated by subscription TV services (i.e. cable, fiber, IPTV and satellite television) causing a subsequent de facto phase-out of free-to-air UHF terrestrial television. In such cases, it can be said that a *digital dividend* is likely available for its reallocation to higher value uses (subject to successful planning and coordination for compatibility with adjacent wireless services)

[6] Radio Regulations are available for download for free at: http://www.itu.int/pub/R-REG-RR

Main drivers for the research of alternative forms of spectrum utilization

In general terms, there are several drivers behind the research of alternative forms of spectrum utilization in recent years. All such drivers are indeed important and are a direct result of the increasing demand (see figure 1 below) for wireless connectivity[7] as part of the evolution of ICTs in the "digital information era". Securing access to *efficient and sustainable* ICT infrastructure has become a major goal worldwide, especially considering the vital role that ICTs play across all areas of human life, such as education, health, science, financial markets, security and civil protection, media, entertainment and business development, amongst others. ICTs continue to shape societies and its contribution to global development very much support every other input to economic growth and social development. ICTs have been acknowledged within the targets of the UN Millennium Development Goals[8], for its capacity to act as an effective tool in alleviating poverty, improving the delivery of education and health services, as well as empowering citizens.

With a steep increase in the demand for mobile connectivity[9], comes the inevitable pressure on the supply side of the resource, being the radio spectrum the necessary resource to enable wireless technologies to transmit and receive data. Noting that, while levels of spectrum demand are likely to vary across different regions depending on factors such as population density and scale of development of broadband fixed networks, the rise of advanced consumer mobile devices and data-demanding mobile applications has considerably increased the usage of bandwidth in mobile spectrum bands in both, carrier-grade level mobile networks (i.e. 3G & 4G networks) and license-exempt local area networks (i.e. Wi-Fi access). Also, emerging economies are embracing more and more the benefits of wireless broadband communication (and therefore realizing more value from the radio spectrum as a national infrastructure resource), which provides a more affordable and flexible alternative for providing internet access to citizens and contributes in a more expedite way in reducing the digital divide[10]. Thus, one could also ascertain that the increase in demand for mobile wireless access and the consequent growth of mobile networks could also be a contributing factor to an increase in demand for ancillary wireless platforms in other frequency bands, intended to support the operation of mobile networks, such as microwave links used for backhaul.

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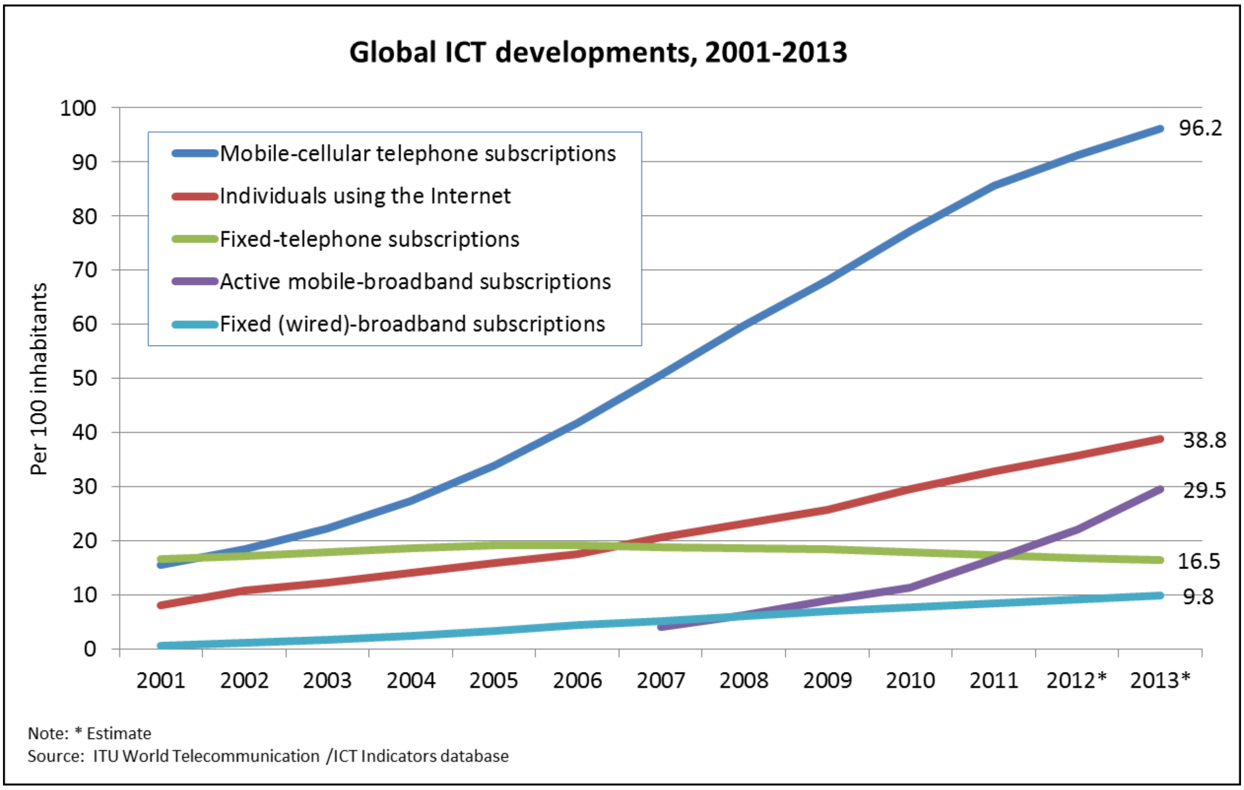
[7] **According to ITU ICT statistics 2013, mobile-cellular subscriptions will reach 6.8 billion (world population is 7.1 billion)**

[8] Details on the role of ICTs in achieving the UN Millennium Development Goals can be found at: http://www.itu.int/wsis/documents/background.asp?lang=en&theme=im

[9] See appendix 2 for statistical data on growth of mobile broadband subscriptions per region.

[10] UN article on the digital divide: http://www.un.org/apps/news/story.asp?NewsID=43265&Cr=digital+divide&Cr1=#.UbRciLSxblI

Figure 1. Global ICT Developments, 2001-2013



Source: ITU.

Taking into account the previously described ICT ecosystem, one could also describe the need for more efficient forms of spectrum utilization according to the level of market development:

a. **Mature markets with highly developed infrastructure:** the need for more efficient forms of spectrum utilization is driven here mainly by factors such as increasing bandwidth bottlenecks caused by the growing uptake of data-intensive applications (see figures 2 and 3 below) and rapid consumer absorption of novel mobile products. In the presence of bandwidth bottlenecks, potential regulatory choices for addressing such issue would strive to achieve maximum spectrum efficiency through exploring forms of dynamic spectrum access (i.e. cognitive radio[11], spectrum aggregation), sound alternatives for spectrum sharing, and forward-looking spectrum planning and refarming (and avoidance of spectrum fragmentation)

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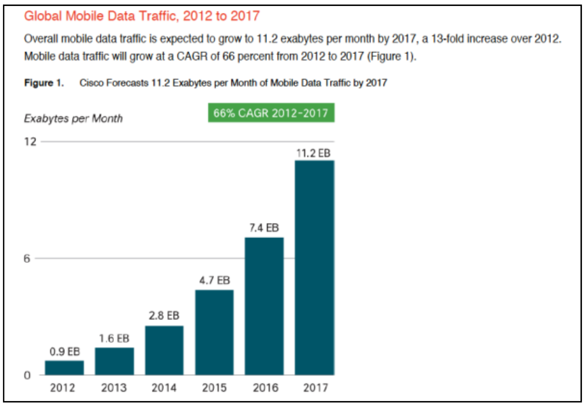
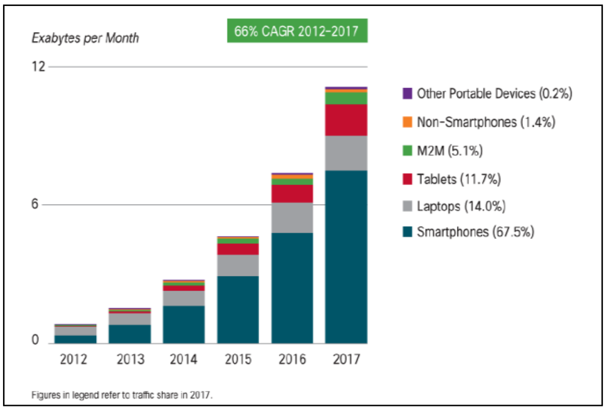
[11] Cognitive radio system: "radio system employing technology that allows the system to obtain knowledge of its operational and geographical environment, established policies and its internal state; to dynamically and autonomously adjust its operational parameters and protocols according to its obtained knowledge in order to achieve predefined objectives; and to learn from the results obtained". Definitions and details of cognitive radio (CR) can be found in ITU Report SM.2152 at: http://www.itu.int/pub/R-REP-SM.2152

Figures 2: Global mobile data traffic forecast and 3. Smartphones lead the data growth





Source: Cisco.

b. **Emerging and developing markets with expanding infrastructure:** the situation in these markets is driven in most cases by high population densities in main urban centers and the level of fixed broadband infrastructure, which due to its higher cost, may not be sufficiently widespread to comfortably absorb most of the connectivity demand. Then, regulatory alternatives for meeting demand would rely on options for facilitating cost-efficient and larger-scale mobile access solutions (i.e. prompt release of digital dividend spectrum, economies of scale advantages though spectrum harmonization and policies that encourage competition and allow new entrants)

c. **Rural regions with sparsely distributed population:** the low consumer base characteristics of such regions, along with potentially more challenging geographical features, has contributed to the lack of connectivity in such areas. Reaching these regions by means of fixed-line infrastructure is capital-intensive; therefore low short-term ROI levels would discourage providers from considering such an option. A wireless alternative is a more viable choice; especially those alternatives than can achieve large coverage areas with fewer base stations (and therefore lowering the cost of infrastructure). Such alternatives can include mobile networks in lower frequency bands (i.e. the UHF bands below 1 GHz, which propagate further, thus achieving larger coverage) as well as satellite-based solutions, and lower-frequency fixed broadband wireless access (or combinations of all these alternatives).

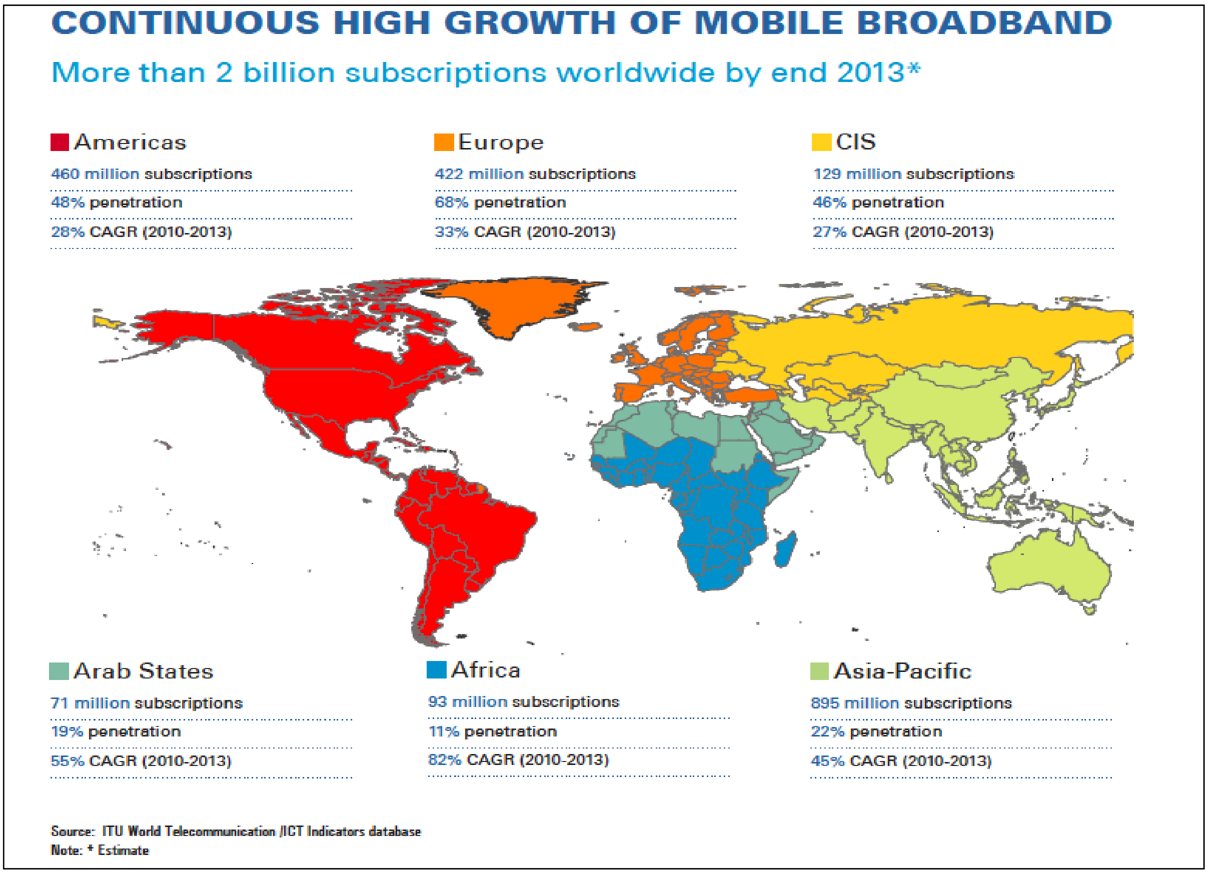
While it could be said that the spectrum resource is less scarce in these regions (and therefore minimum entry barriers would be found for accessing the spectrum resource), some other relevant factors can influence the deployment of wireless networks. Firstly, the varying levels of population income in these regions (ranging from extreme poverty to more well-off farming communities) would have an impact in terms of affordability of end-user devices or service subscription (be it mobile or satellite). In these cases, different forms of subsidies can be an alternative for funding some of the connectivity costs in rural areas; these are often carried out by means of Universal Service Obligations[12] (USO). Secondly, there are also varying degrees of access to electrical power

[12] Details on Universal Service Obligation can be found at: http://www.ictregulationtoolkit.org/en/Section.1740.html

sources at these locations, which is necessary to power-up base stations and backhaul links as well as charging battery-operated devices. Finally, availability of suitable hardware to operate in region-specific niche spectrum bands can be an issue due to the related lack of economies of scale as a result of a lack in spectrum harmonization.

Within the above market situations, TVWS are being considered in some countries as an option for addressing connectivity needs ranging from spectrum-congested zones in highly developed metropolitan areas (with high degrees of UHF TV spectrum idleness) to vast geographical rural areas lacking access infrastructure and needing lower-cost deployment alternatives (and with low UHF TV broadcasting usage). Considering the similar trend of increasing demand for mobile spectrum across mature markets as well as in emerging and developing markets, the search for alternative ways of achieving maximum spectrum efficiency becomes extremely important for policy makers, regulators and the private sector. Collaboration of all these stakeholders is necessary for achieving not only efficient use of the spectrum resource but also to ensure sustainability of the ICT ecosystem. ICTs will continue to face increasing demand in terms of spectrum access in congested areas, as well network expansion demands in developing regions needing to breach connectivity gaps (see figure 4 below).

Figure 3: Mobile broadband growth figures per region



Source: ITU.

3. Current standards for TVWS devices

Currently, the development of standards for devices intended to operate in TV white spaces is centered on two major types of applications:

1) Wireless Regional Area Network (WRAN): refers to the development of standards for low-power devices capable of delivering broadband connectivity mainly in rural areas, intended for operation on a non-interference/non-protected basis. Such development has taken place under the IEEE 802 family of standards (which covers Wi-Fi devices), being IEEE 802.22[13] the specific version for devices operating in TVWS. One of the objectives of this technical standard focuses on interference protection of the incumbent television broadcasting service (digital and analogue), considering the shared-basis operation of TVWS devices with the primary TV broadcasting service. There is also a draft specification not yet finalized under the standard 802.11af, which focuses on cognitive radio techniques for TVWS.

There is also a consideration of interference protection of other legacy authorized radio transmitters which operate in the band, such as wireless microphones, used on-site during a wide range of events, locations and public gatherings. An important aim of this standard centers on the development of cognitive radio technology[14] for implementing non-interfering opportunistic spectrum use in a shared-spectrum environment with the primary and protected TV broadcasting service. Moreover, WRAN devices would be mainly available in fixed and mobile modes, for which a database assignment mechanism has been proposed for operation, in order to prevent harmful interference to the TV service. This database assignment approach adopted in the US (mandated by FCC[15]) consists of a geo-location capability embedded in devices operating in TVWS. This geo-location capability is to be coupled to an approved frequency database system, which serves as a form of look-up table for the TVWS device to identify and use those TV broadcasting channels not in use at its geographical location (and performs calculations of the power level required and appropriate antenna height to achieve protection of TV reception in distant areas).

2) Machine-to-machine communications: also referred to as M2M communication, it consists of very low-power radio transmitters used for low-data rate industrial and commercial applications such as monitoring, tracking, metering and control (a realization of the concept of "smart machines"). Recently, a proprietary open specification for M2M devices, intended for operation in TVWS, has been agreed at a preliminary stage in the United Kingdom under the umbrella of a Special Interest Group (SIG): Weightless SIG[16]. This group released in April 2013 a draft specification for low-

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[13] Details about IEEE 802.22 can be found at: http://www.ieee802.org/22/

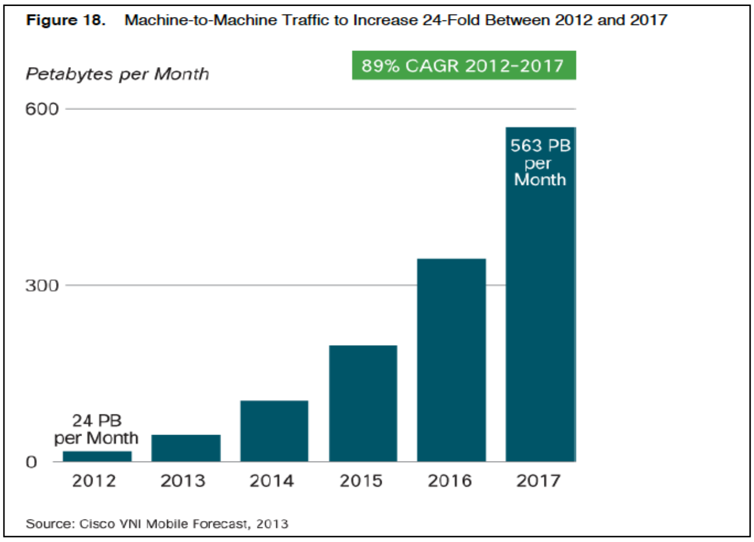
[14] Current international regulatory provisions allow cognitive radio systems to operate provided that Administrations observe their obligations set in the ITU Radio Regulations (See appendix 6)

[15] FCC's Second Memorandum Opinion and Order on the use of TVWS (FCC 10-174) can be found at: http://www.fcc.gov/document/unlicensed-operation-tv-broadcast-bandsadditional-spectrum-unlicensed-devices-below-900-m-0

[16] Draft standards specification for M2M by Weightless SIG can be found at: http://www.weightless.org

data rates M2M devices (hence the name "weightless") to operate in the terrestrial television bands, transmitting data over idle television frequency channels in geographical areas where TVWS can be found (also querying a master frequency database). Similarly to the case of the WRANs above, Weightless M2M devices are intended for operation on a license-exempt framework under a non-interference/non-protection basis. As the use of M2M devices grow, and more applications connect to the "internet of things", it is expected that numbers of M2M devices deployed will grow exponentially (see figure 4 below), especially considering the higher coverage ranges offered by the terrestrial television frequency bands.

Figure 4: projected growth of M2M devices



Source: Cisco.

3. Regulatory perspectives: impact of international spectrum planning and spectrum management

Spectrum planning aspects

The progress made in digital technologies has permitted the evolution of terrestrial television, making it more spectrally efficient by allowing, through digital compression techniques, the transmission of multiple high-quality TV programmes in one single spectrum channel (where before it was possible to transmit only one programme per channel). Such advancement resulted in the opportunity to reallocate the available TV spectrum (the *Digital Dividend*) for higher value uses, namely the mobile service, in response to the rapidly growing demand for mobile bandwidth[17]. This

[17] The ITU report "Exploring the Value and Economic Valuation of Spectrum" provides further insights into the economic value aspects of spectrum: http://www.itu.int/ITU-D/treg/broadband/ITU-BB-Reports_SpectrumValue.pdf

digital dividend is realizable once the transition from the analogue TV service to the digital TV service is completed and the "switch-off" of the analogue service is carried out. Only then, the vacated TV bands can be deployed for use by the mobile service, as the nature of the mobile service (bidirectional) is not compatible with the TV broadcasting service (unidirectional). If both services were to operate in the same frequency band, harmful interference would occur, rendering both services useless.

The above situation highlights well the importance of technically sound spectrum management[18], which has been achieved over the years through the collaborative efforts of countries in adopting coordinated spectrum decisions at regional level and in revising and updating the International Radio Regulations and related International Table of Frequency Allocations. Such revisions and updates are conducted by means of collaborative technical studies (ITU-R Study Groups[19]) carried out jointly between regulators, the private sector and other stakeholders. Thereafter, agreements or changes in allocations and updates to the RRs are made by consensus between Member States at the World Radio Conferences[20] (WRCs). Due to the large number and the different nature of radiocommunication services, such studies are grouped separately according to the nature of the services in question and are carefully treated in order to ensure that changes in spectrum allocations will not result in harmful interference to existing services. International spectrum planning of radiocommunication services involves commercial services as well as critical safety-of-life systems (i.e. aeronautical, maritime, defense, public safety and disaster relief communications, radionavigation and radiodetermination systems), important scientific and medical systems (i.e. space research, meteorological monitoring and medical imaging), satellite communications and mission critical industrial applications (i.e. telemetry and control systems)

Such a complex ecosystem of radiocommunication services, whose number continues to grow as technology advances, makes the task of international spectrum planning extremely important. Moreover, within this ever-evolving industry one thing is certain: the public value of the radio spectrum resource depends directly on the ability to prevent interference, in order to remain a useful resource from which society can benefit.

[18] Definition of spectrum management (as per Study Group 1 brochure): Spectrum management is the combination of administrative and technical procedures necessary to ensure the efficient utilization of the radio-frequency spectrum by all radiocommunication services defined in the ITU Radio Regulations and the operation of radio systems, without causing harmful interference.

[19] Information on ITU-R Study Groups can be found at: http://www.itu.int/en/ITU-R/study-groups/Pages/default.aspx

[20] Information on WRCs can be found at: http://www.itu.int/ITU-R/index.asp?category=conferences&rlink=wrc&lang=en

Box 1: International planning of the spectrum: directly supports the rational and efficient national administration of the spectrum

ITU Member States recognize each other's national rights and obligations for the purpose of ensuring the harmonious and sustainable use of the spectrum resource. In doing so, they can enjoy the right of protection of their radiocommunication services from harmful interference by coordinating spectrum use at their borders and respecting internationally agreed technical parameters for using radiofrequencies (as radiofrequency propagation cannot be physically "cut-off" at country borders). Moreover, as countries have the sovereign right to manage the radio spectrum within their territorial borders, such right can only be exercised successfully through a reciprocal agreement to not cause harmful interference to other states. This set of internationally agreed rights and obligations is contained and specified within the Radio Regulations of the International Telecommunication Union - the international treaty through which countries ensure the orderly and sustainable use of the radio spectrum. These regulations are based on several principles, of which principle 0.3 and 0.4 of the Radio Regulations stand out:

0.3 *"In using frequency bands for radio services, Members shall bear in mind that radio frequencies and the geostationary-satellite orbit are limited natural resources and that they must be used rationally, efficiently and economically, in conformity with the provisions of these Regulations, so that countries or groups of countries may have equitable access to both, taking into account the special needs of the developing countries and the geographical situation of particular countries"* (No. 196 of the ITU Constitution)

0.4 *"All stations, whatever their purpose, must be established and operated in such manner as not to cause harmful interference to the radio services or communications of other Members or of recognized operating agencies, or of other duly authorized operating agencies which carry on a radio service, and which operate in accordance with the provisions of these Regulations"* (No. 197 of the ITU Constitution)

Hence, based on the common interest of States to ensure the sustainability of their wireless infrastructure resources, it is in direct interest of countries to plan the allocation of the spectrum resource in a collaborative manner (at national, regional and, to the extent possible, global levels) and guaranteeing such outcomes is therefore an important element of national public policy objectives.

Furthermore, spectrum management, through the international planning of spectrum, provides certainty for investment and results in higher market harmonization. The constant technological changes require the continuous review of spectrum allocations, which is carried out in a planned and predictable manner in order to benefit industries through balancing efforts between encouraging innovation and providing stable regulatory frameworks to stimulate investment, while safeguarding existing wireless services from harmful interference. Moreover, the benefits of collaborative international spectrum planning translate into economic benefits in that internationally harmonized spectrum bands enhance the interoperability of systems across or within regions as well as maximize economies of scale. Some clear examples of this can be found in the broadcasting industry, license-exempt local area networks and the mobile communications industry (and non-commercial services, such aeronautical and maritime radiocommunications).

Regulatory developments at international level

The rapid uptake of mobile cellular services has led to an increase in demand of bandwidth for mobile telecommunication services. In addition, the rise of mobile devices with high computing power capable of supporting advanced applications (i.e. broadband internet & multimedia) has contributed to the increasing pressure on the bandwidth capacity of mobile networks. Consequently, a common focus of the international community has been, and continues to be, the identification of suitable spectrum bands that can be allocated for mobile services (i.e. International Mobile Telecommunications, IMT[21]) in order to meet current and expected future mobile broadband demands.

Identification and allocation of spectrum is carried out collaboratively through the World Radio Conferences. Such process has resulted, for instance, in regional reallocations of portions of the upper UHF TV broadcasting bands - on primary basis – to the mobile service (better known as Digital Dividend). This Digital Dividend (suitable for the delivery of mobile broadband) has varying sizes, depending on the specific world region and related band configuration. Generally speaking, these variants of the digital dividend are represented by the band configurations of 3 regions: the one adopted by the US, the EU and Asia Pacific[22]. These three digital dividend configurations are: the regionally harmonized option corresponding to the European band plan for ITU-R Region 1[23] (790-862 MHz) which has two blocks of 30 MHz (2x30MHz), the US band (698-806 MHz) which has blocks making up a total of 2x22 MHz, and the Asia Pacific regionally harmonized option for ITU-R Region 3 (698-806 MHz) which has the broadest bandwidth blocks with 2x45 MHz (technical gains can result from allocating larger channel bandwidths for the purpose of accommodating advanced mobile broadband services)

At the last World Radio Conference (WRC-12), countries in ITU-R Region 1 (Europe, Africa and Middle East) agreed on planning an extension of their digital dividend band (790-862 MHz), allocating the band 694-790 MHz for mobile services on primary basis, and to start its operation in 2015 (WRC-12, Resolution 232[24]). Such decision echoes other discussions and studies carried out in Europe and the US after WRC-12 on the long-term approach for reallocation of UHF spectrum, in order to respond to the increasing bandwidth demand of mobile services. For instance, the United Kingdom released in March 2012 a consultation paper[25] titled "*Securing*

[21] Details on the agreed IMT-Advanced standards can be found at: http://www.itu.int/net/pressoffice/press_releases/2012/02.aspx#.UbR4rLSxblI

[22] ITU-R Recommendation M.1036-4 provides the frequency arrangements for implementation of IMT and can be found at: http://www.itu.int/rec/R-REC-M.1036-4-201203-I/en

[23] Appendix 2 provides a detailed view of the ITU-R World Regions as per Radio Regulations.

[24] WRC-12 Resolution 232 can be found at: http://www.itu.int/oth/R0A0600004B/en

[25] UK's Ofcom consultation paper can be found at: http://stakeholders.ofcom.org.uk/consultations/uhf-strategy/summary

long term benefits from scarce spectrum resources: a strategy for UHF bands IV and V". In the paper, Ofcom stated that, as part of the proposed strategy, positive long-terms outcomes would be achieved, amongst other points, through *"enabling the future release of potentially valuable harmonized mobile broadband spectrum in the 700 MHz band to meet the growth in demand for mobile data capacity*".

Similarly, in the US, the 2013 FCC's[26] Mobile Wireless Competition Report[27] (section 87) states that, in response to the growing demand, the National Broadband Plan recommended the FCC to make available additional 500 MHz of spectrum within 10 years for broadband use, of which 300 MHz should be made available in the frequency range 225 MHz-3.7 GHz (mostly in the UHF spectrum). Moreover, UHF TV spectrum has been further sought for in the US for its reallocation to wireless broadband through incentive auctions[28]. The FCC was directed to implement a reversed auction to "*determine the amount of compensation that each broadcast television licensee would accept for voluntarily relinquishing some or all of its spectrum usage rights"*. Such policy decisions clearly signal the increasing concerns with regard to the projected demand for spectrum and its optimal utilization, and the importance of long-term strategies for identifying and allocating the UHF spectrum for broadband. Moreover, the US President Barack Obama has recently released a memorandum[29], which directs government agencies to encourage and implement more spectrum sharing into their spectrum management practices and provides other directives for the purpose of achieving higher spectrum efficiency and for advancing wireless broadband.

Further, at WRC-12, it was agreed to consider and to take appropriate action on Agenda item 1.1 of WRC-15[30], which states: *"to consider additional spectrum allocations to the mobile service on a primary basis and identification of additional frequency bands for International Mobile Telecommunications (IMT) and related regulatory provisions, to facilitate the development of terrestrial mobile broadband applications, in accordance with Resolution 233 (WRC-12)"*. These regulatory developments are significant indicators of the ongoing international revision of UHF spectrum utilization, requiring due consideration in terms of planning UHF allocations in the mid to long terms.

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[26] Federal Communications Commission

[27] FCC 13-34 Annual and analysis of competitive market conditions with respect to mobile wireless. It can be found at: http://www.fcc.gov/document/16th-mobile-competition-report

[28] US Public Law document 112-96, Feb. 2012, section 6403 on incentive auctions can be found at: http://www.gpo.gov/fdsys/pkg/PLAW-112publ96/pdf/PLAW-112publ96.pdf

[29] US White House memorandum can be found at: http://www.whitehouse.gov/the-press-office/2013/06/14/presidential-memorandum-expanding-americas-leadership-wireless-innovatio

[30] WRC-15 Agenda item 1.1 can be found at: http://www.itu.int/ITU-R/index.asp?category=study-groups&rlink=rcpm-wrc-15-studies&lang=en#{C4B1254B-0A2F-4AED-9668-3D91F9613047}

Box 2: Questions for regulators and stakeholders

1) What would be the situation for TVWS service providers and users with regard to TVWS deployments in the recently agreed digital dividend extension 694-790 MHz in ITU-R Region 1? What would be the situation in ITU-R Regions 2 and 3 in their digital dividends?

2) Should new digital dividends occur in the remaining UHF TV bands, what would be the impact on TVWS service providers and users in bands that can be identified for primary services other than broadcasting?

3) Would an incoming primary service different from broadcasting be capable of co-existing with widespread TVWS devices?

4) Which party (or parties) would be accountable for funding the costs of TVWS service providers and users in potential scenarios of migration or reallocation of TVWS devices?

Technical and operational characteristics of licensing frameworks at national level

Different mechanisms for licensing spectrum at national level have been used as part of national spectrum management frameworks, which define the rights and the obligations of spectrum users and provide a framework for user accountability. These mechanisms include:

Table 1: Spectrum licensing mechanisms

Model	Typical Users	Typical Uses
Administrative licensing	• Government agencies – Military – Public safety – Resource managers – Transport operators • Broadcasters • Professional users • Earth station operators	• Radars • Aeronautical and maritime • Tactical radios • Remote sensing • Terrestrial television broadcasting • Professional mobile radio • Point-to-point links • Satellite telecommunications
Property Rights (Flexible Rights of Use)	• Commercial terrestrial wireless operators • Satellite operators	• 2G and 3G mobile services • Satellite broadcasting and telecommunications • WiMax or fixed wireless
License-exempt (Class license, General User License)	• Internet hotspot providers • Individuals	• WiFi (WLANs) • Other Low-power devices (key fobs, garage openers)

Source: author and ITU report *Exploring the value and economic valuation of spectrum*.

The objectives of these licensing frameworks include:

- Coordinating an orderly use of the spectrum resource through licensing and registry (national and international)
- Avoiding instances of harmful interference through the establishment of license parameters.
- Ensuring technical compatibility between different services within a band and with services in adjacent bands.
- Mitigating harmful interference into safety-of-life systems.
- Ensuring that the finite spectrum resource is appropriately valued (and not hoarded), through taxation.
- Enabling equitable, rational, efficient and economical forms for allocating the resource when demand exceeds supply.
- Avoiding monopolies and enabling competition for the benefit of consumers.
- Providing a stable regulatory environment for spectrum users in order to encourage investment and innovation.

In general, licensing regimes[31] function in different ways to accommodate different types of services. For example, administrative licenses can cover higher power transmitters at a fixed location, making it easier for coordination and planning purposes (as the case of broadcasting and fixed links); property rights frameworks provide more licensing flexibility (and tradability) for larger-scale deployment of commercial mobile services requiring high QoS margins in order to meet service expectations (both regulatory and customer based expectations; i.e. emergency calling and coverage objectives). Lastly, license-exempt frameworks have been established across several frequency bands to accommodate the deployment of large numbers of ubiquitous low-power devices, for which individual licensing would be impractical. Nevertheless, license-exempt devices are subject to compliance with technical specifications and/or operational requirements of the license exemption clauses (in some countries specified as a *General User License or Class License*) in order to ensure their non-interference/ non-protection operation. An example of devices operating under license-exemption or class license is Wi-Fi devices. TVWS devices are also being proposed for operation under a license-exempt framework.

In order to ensure technical compatibility of TVWS devices operating on secondary basis, when sharing the spectrum with the primary television broadcasting service, some impact assessment of the policies behind the licensing deserve due consideration. For instance, terrestrial television broadcasting has been considered along the lines of a public service resource, and therefore it has operated for many years under licenses encompassing clear coverage protection parameters[32] (such as protection ratios and maximum permitted levels of unwanted signals).

In light of the importance of protecting TV broadcasting, several studies have taken place in different regions to assess the level of technical compatibility between TV broadcasting and TVWS broadband devices. One such study was undertaken in Europe, through the European Conference of Postal and Telecommunications (CEPT), which conducted extensive studies[33] to ascertain the level of compatibility between TVWS devices operating in the band 470-790 MHz and the UHF TV service, as well as with other forms of radiocommunications in the same frequency bands. The report concluded that the most feasible option for avoiding interference into the TV service is the geo-location database technique, since available sensing techniques alone are not reliable enough yet to guarantee interference protection.

Traditionally, some sharing of the licensed UHF TV broadcasting service has been already implemented, allowing, for example, the use of wireless microphones. It can be said that this band sharing between the TV broadcasting service and wireless microphones was achieved successfully because

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[31] The ITU document "Spectrum Management for a Converging World" provides in depth analysis and further details on spectrum licensing and spectrum assignment at national level. It can be found at: http://www.itu.int/osg/spu/ni/spectrum/RSM-BG.pdf

[32] Planning criteria for DTT can be found in ITU-R BT.1368 at: http://www.itu.int/rec/R-REC-BT.1368/en

[33] ECC Report 159 (Electronic Communications Committee within CEPT) provides the sharing studies performed in Europe to assess the compatibility levels between TVWS devices and other services in the UHF TV band. The report can be found at: http://www.erodocdb.dk/docs/doc98/official/pdf/ECCRep159.pdf

of the operational nature of wireless microphones: wireless microphones are also used by the television industry as a tool for its production of contents and therefore there was a direct interest from the broadcasting industry in achieving technical compatibility.

In order to achieve a degree of technical coordination between the primary broadcasting service and the ubiquitous nature of wireless microphones use, countries opted for either some form of wireless microphones usage register (a kind of temporary/short-term licensing) or some form of license-exemption with operational conditions. Then, band sharing between the primary TV broadcasting service and a secondary service operating under a license-exempt regime has been achieved already. This sharing is subject to technical coordination, specifying operational conditions (coordination) and establishing equipment parameters to guarantee the absence of harmful interference to the primary service. Notwithstanding this, once the digital dividend spectrum became attainable and it was reallocated to the mobile service, licensing clauses for the operation of wireless microphones in those bands needed reconsideration[34]. A plan to cease their operation in the digital dividend bands became necessary, due to the risk of harmful interference into the incoming mobile service set to operate on primary basis. Such migrations of radio devices from reallocated bands require compensation schemes or other forms of funding in order to cover the costs of the users for either re-tuning equipment, acquiring new hardware capable to operate in a different band or to absorb costs related to service disruption. Later, some other costs may also arise in the case of incidents of interference cases needing investigation and resolution, caused by devices that for some reason did not migrate and remained operating in the reallocated band.

Therefore, considering the possibility of appropriate coordination, achieved by a combination of database-managed channel assignment, geo-location and a compatible set of technical specifications, TVWS operating on secondary basis in the TV UHF bands should not necessarily represent an unmanageable hurdle in terms of licensing. There are already various international spectrum allocations that include secondary allocations, which are subject to operational coordination and interference management measures in order to allow co-existence between the services occupying the same spectrum bands. Then, a well-defined license-exempt regime (on a non-interference/ non-protection basis) for TVWS could well serve as viable option for co-existence of TVWS with the incumbent service, *provided that the nature of the primary service remains the same and technically compatible to allow its operation free of harmful interference.* If the nature of the primary service changes, let's say from broadcasting to mobile as it has in the digital dividend, then it will be necessary to assess the interference risk from TVWS devices into the new primary service and their potential reallocation to another band.

[34] Example of policy adopted in the US, prohibiting the use of wireless microphones in the digital dividend bands 698-806 MHz after June, 2010: http://www.fcc.gov/guides/wireless-microphones-700-mhz-band-prohibition-after-june-12-2010

Operational characteristics and on-going deployment of Digital TV broadcasting

The operational nature of the TV broadcasting service, requiring fewer high-power transmitters at known fixed sites and receive-only user equipment (the TV receiver sets), makes up the current scenario for technical co-existence between potentially license-exempt TVWS devices (with geo-location and database-managed channel use) and the incumbent service. A change in nature of the primary service, from broadcasting to mobile (where simultaneous transmission and reception takes place from base stations and ubiquitous end-user devices), would require analysis and studies to assess the level of compatibility achievable under such scenario.

Further, a change in nature of the coverage objectives of the broadcasting service would also require some assessment. For instance, Digital Terrestrial Television (DTT) in the UHF bands has been implemented fully in some countries, but in others the implementation process has been slower or has not started yet. For regions or countries where channel utilization by the primary DTT service is still undergoing planning and coordination, there is still a degree of uncertainty with regard to the "final" DTT coverage footprint. An example of such situation can be found in the African continent, part of the Geneva 06' agreement[35] for regional coordination of digital broadcasting, and where DTT transition is still ongoing. Such situation implies that, since the full coverage objectives of DTT have not been reached or implemented yet in some areas, a TVWS that appears as currently vacant might not be available later on.

Also, as TV broadcasting services are being squeezed into a smaller amount of spectrum to make room for the digital dividend allocation to mobile services, they are forced to increase their spectrum efficiency, in particular by the use of Single Frequency Networks (SFNs) making more intensive use of the same channels, hence reducing the availability of white spaces.

Similarly, as the benefits of digital television are still being explored and more value-added applications arise, it would not be surprising that DTT service providers can try to squeeze in more consumer alternatives through their available spectrum, which may require using more of the vacant broadcasting channels. Then, the long-term availability of TVWS would not be guaranteed in such cases and potential situations of service disruption of TVWS devices – or permanent unavailability – could arise.

[35] Geneva 06 agreement can be found at: http://www.itu.int/ITU-R/terrestrial/broadcast/plans/ge06/

Box 3: Questions for regulators and stakeholders

5) What studies would be necessary to assess the level of compatibility between license-exempt TVWS devices and licensed mobile services, should further allocations be made for the mobile service in the UHF TV band?

6) Is it possible to guarantee a continuity of service for TVWS service providers in UHF TV spectrum bands in regions where DTT deployment is still ongoing?

7) What will happen with TVWS networks using analogue TV channel gaps once digital TV is fully deployed?

8) What are the risks and benefits for TVWS service providers and users if early adoption of TVWS takes place in regions where DTT transition has not been finalized?

9) Is there a need to consider some form of spectrum *security of tenure* for TVWS service providers in order to provide them with a minimum "spectrum pool" for successful service

Operational characteristics of license-exempt devices, bandwidth availability and capacity considerations

License-exempt frequency bands, as those used by Wi-Fi devices (i.e. ISM bands), have been implemented to host large numbers of ubiquitous devices, which share those frequencies collaboratively (using low power levels and channel control schemes) and operate without an expectation of QoS. As mentioned earlier, no individual license is required for operation in these bands, but compliance with technical and operational parameters is necessary in order to avoid harmful interference to other services. Moreover, increases in transmit power exceeding the limits prescribed for license-exempt devices would either reduce the number of users at a given area or cause interference intra-service or to licensed services in adjacent bands.   Therefore, the usefulness of license-exempt bands relies on the ability of low-power devices to contain their emissions within the prescribed limits (power limits and frequency boundaries)

Several frequency bands have been allocated worldwide to operate on license-exempt basis (i.e. ISM bands) across different spectrum frequencies. These bands accommodate a variety of devices and applications, being wireless LANs (aka. Wi-Fi) one of the most commonly known. Wireless LANs operate mainly in the 2.4 GHz band (with a total of 100 MHz of bandwidth) and in the 5 GHz band (5.150-5.350 MHz and 5.470-5.725 GHz, with a bandwidth of approximately 455 MHz[36]). There is also an allocation in the 900 MHz band in ITU-R Region 2 (Americas) between 902-928 MHz (totaling 26 MHz of bandwidth). This 900 MHz allocation has also been adopted by some countries in ITU-R Region 3 (Asia Pacific). The combined total for all three license-exempt bands used by wireless LANs

[36] Based on FCC's 5 GHz license-exempt regulation FCC 13-22, found at: http://www.fcc.gov/document/5-ghz-unlicensed-spectrum-unii

is around 581 MHz of bandwidth. TVWS device specifications for Regional Wireless Access Networks (IEEE 802.22, WRANs) have been designed for operation on similar basis (but set to operate in the UHF TV spectrum); low-power devices operating ubiquitously and sharing the band with other TVWS applications, such as those proposed for machine-to-machine communications (M2M) devices. Differently to the license-exempt bands mentioned above, the amount of bandwidth available for license-exempt TVWS devices is not currently internationally harmonized; it will vary across countries and also regionally within countries, depending on the degree of channel utilization by the terrestrial television service.

Further, it is expected that the deployment of TVWS M2M devices will involve very large numbers of devices scattered across different regions and serving different purposes, and therefore, some assessment will be necessary to determine the levels of interference that a combined deployment scenario would represent, and its impact on TVWS bandwidth availability. Moreover, it has been suggested by CEPT (ECC Report 159) that more studies are needed to understand the impact of TVWS devices operating at the band-edge adjacent to mobile services in the bands adjacent to 470-790 MHz (and therefore also at the band edge 698 MHz from 2015 as per WRC-12 Res. 232 for ITU-R Region 1), which will require consideration specially in cross-border situations.

The potential wireless ecosystem in the UHF TV spectrum would then involve the primary service (television broadcasting) sharing the band with wireless microphones, TVWS devices for Regional Wireless Access Networks, TVWS devices for M2M and any other TVWS application that may arise, all occupying idle TV channels. In addition to this, countries will face different situations depending on the progress of their transition to digital television. Countries going through a phase of simulcasting (when both, the analogue and the digital television service operate simultaneously) will need to account for potential changes in the available bandwidth of TVWS.

Box 4: Questions for regulators and stakeholders

10) What studies would be necessary to assess the level of availability of TVWS in a combined deployment scenario including TVWS Wireless Regional Access Networks, wireless microphones and TVWS M2M devices? Would there be an impact on service provision due to bandwidth bottlenecks in cases of low TVWS availability?

11) Will TVWS be deployed for backhaul alternatives? Would there be potential bandwidth bottlenecks for TVWS backhaul service providers?

12) What would be the impact on TVWS service providers and users should numbers of TVWS Wireless RANs and TVWS M2M devices grow rapidly at any given area? Could such situation result in interference for TVWS devices given the greater coverage ranges possible in UHF spectrum?

13) Could the above situation in question 12 find some alternatives through the implementation of licensing arrangements other than a license-exempt framework?

4. ICT strategies and market development: how would TVWS fit into national ICT strategies and what would be the role of TVWS in enabling local markets?

One aspect of international spectrum planning, in terms of allocating spectrum, relates to the potential impacts that such planning can have in driving local markets. These impacts can be expected to translate into long-term benefits (i.e. overall advancement of the ICT sector and related contribution to GDP, job market creation and support to innovation and entrepreneurship). Then, it is significant, from the regulatory perspective, to identify the potential trade-offs of TVWS spectrum decisions in relation to the outcomes set within the national ICT strategy.

Certainly, bridging connectivity gaps between rural and urban areas is of high priority in the strategic agendas of regulators. Connectivity, as an enabling platform for rural economies, can integrate rural business into national and global markets. Through this, it is possible to empower rural enterprises, providing them with the tools to explore and benefit from ICTs. For instance, some countries have opted for implementing tailored policies into their licensing frameworks of mobile broadband infrastructure, by means of applying different forms of coverage obligations to spectrum licensees; and hence, prioritizing the connectivity needs of rural and underserved areas. There is also a sustainability aspect of ICTs (as part of a national strategy) which is based, amongst other aspects, on its capacity to effectively handle user demand, being flexible enough to adapt to growing demand and maintaining geographical scalability. Then, a long-term national ICT strategy, including the planning of wireless broadband connectivity, will need an assessment of *costs, scalability, resiliency and reliability* of the countries' national wireless access infrastructure, if this is set to support communities and enterprises.

Costs: a country's ICT infrastructure resource includes several access platforms for achieving connectivity across urban and rural scenarios (i.e. wireline/fiber, fixed wireless, mobile and satellite solutions); the last mile is only one section of the connectivity chain. Although the end-user wireless access portion (i.e. TVWS wireless RAN) could be made at a relatively lower cost, there are other significant connectivity costs down the chain. For instance, backhaul options are relatively low cost in comparison to fiber or wired options but there are costs of interconnection and data traffic from the backhaul to the ISPs[37] or the telecommunication infrastructure provider's core network. Then, the costs of all the transmission components need to be considered in order to establish the overall level of funding required for subsidizing the service costs incurred by the rural customer base.

Scalability: ventures to provide connectivity in rural areas may start with a low number of users but one would expect that, as the rest of the network matures onto newer or updated platforms, the last mile component will also experience changes in demand in terms of user density or application-based bandwidth demand. The critical factor here would be to ensure that future bandwidth bottlenecks are avoided at the last mile level, in order to prevent potential disruptions or to restrict users to a sub-optimal access solution due to lack of planning.

[37] ISP: Internet Service Provider

Resiliency: this aspect involves having an access infrastructure that can endure potentially disrupting and critical situations, by means of system redundancy, prompt turnaround in front of system failures and appropriate user support services.

Reliability: a reasonable level of reliability would be expected throughout the national network and its outreaching branches, in order to support national economic objectives that would include, amongst other objectives, *attaining and maintaining* a *competitive position amongst regional and global economies, in order to attract foreign and local investment.* If emerging rural businesses are to be supported by new infrastructure and investments are to be made, then rural communities and entrepreneurs will expect to have a reliable wireless infrastructure (one that will not create more costs for users in comparison to other available solutions)

As deployments of advanced mobile networks move forward, for example, through the use of the digital dividend spectrum, it is expected that markets with high levels of spectrum harmonization of their digital dividends will benefit from increasing economies of scale, while ensuring that connectivity platforms evolve in tandem with user demands. Moreover, cost efficiencies (and innovation) are more likely to occur where investment opportunities can find a market environment with future projections, through the adoption of scalable ICT platforms. Further, trading strategies for the mid and long-terms are also closely linked to harmonized spectrum allocations, in the sense that a closer alignment with regional and international standardization will enable access to global markets (i.e. more hardware choices and sourcing of expertise). Further, spectrum harmonization simplifies cross-border coordination, allows interoperability and reduces instances of spectrum inefficiencies at border areas due to interference caused by mismatch of dissimilar wireless systems operating in the same geographical area.

Therefore, it is important to recognize that, while the wireless component of the national ICT strategy will most certainly include a variety of models to reach out to communities, the mid and long-term strategic goals need to be taken into consideration, in order to avoid implementing short-term solutions that could result in unnecessary costs socially and economically in the long-term. It is then a matter of public policy to ensure an effective spectrum regulatory framework that nurtures a balanced, economic and scalable ICT ecosystem. This all-encompassing framework (technical, legal, economic and social) needs to be sufficiently versatile and adaptable to industry and regulatory changes, as well as capable of providing choices (through incentivized competition) and avoiding the formation of infrastructure monopolies (with its consequent costs and inefficiency issues)

Box 5: Questions for regulators and stakeholders

14) Could infrastructure monopolies arise in connectivity services provided through TVWS? Are there competition issues that need consideration?

15) Can local mobile operators and small rural ISPs benefit from opportunities through TVWS? What types of services are expected to be offered by TVWS service providers after the pilot projects?

16) In terms of TVWS service provision and TVWS central database management. Would there be a need to review the legal framework and propose new regulatory arrangements or assess the possibility of conflicts of interest between these two service areas?

17) What is the potential level of scalability, resiliency and reliability that TVWS service providers can offer? Will these levels be sustainable in front of increases in demand and increased sharing of TVWS? Is TVWS a short-term solution or a long-term connectivity strategy?

18) How does TVWS broadband connectivity fit into a long-term national ICT strategy?

5. Conclusions

This paper intends to provide an in-depth discussion on the implementation of TVWS as an alternative for providing wireless broadband connectivity, operating on secondary basis within the UHF television spectrum bands. While tests and trials are still taking place, the evaluation of different regulatory approaches seek to strike the fine balance of achieving and ensuring a rational, equitable, efficient and economical use of such important resource as the radio spectrum.

Numerous policy and regulatory alternatives can arise in the area of TVWS. As examined throughout the document, several factors need to be taken into account to appropriately balance the early adoption of a novel technology and the long-term benefits and costs at stake within a changing regulatory environment. Notwithstanding this tension, there is certainty about what is expected as the outcome of the policy decision-making process: avoiding sub-optimal utilization of the high-value spectrum resource and obtaining the greatest benefit from it.

Early adoption, test bed only or further regulatory planning required for TVWS?

These are potential avenues that policy-makers and regulators will need to consider in making TVWS regulatory decisions, which main goal will be to achieve optimum results in terms of efficiency, costs, risks and benefits. Early implementation (without regulatory safeguards) through the use of idle TV spectrum presently available would endeavor to obtain immediate benefits of connectivity. Some benefits can include reaching earlier those small communities in need of connectivity, and their earlier familiarization with wireless platforms and applications. Some risks could include DTT transition not being completed, leading to uncertain levels of future availability of channels for TVWS service providers and users. Also, there can be uncertainty with regard to potential changes in the regulatory environment and security of tenure, should there be a redefinition of the current primary service in the mid to long-term, which could result in financial losses for TVWS broadband service providers and users.

An early adoption with some form of regulatory safeguards is another policy avenue. Regulatory measures could be thought for minimizing uncertainty, burdens and service disruptions by applying, for example, a time limit safeguard for implementation of TVWS stating that, should the primary service change to non-broadcasting, incompatible TVWS devices should cease operation or should reallocate to another band. While this policy approach would provide some level of flexibility for future change, it presents some risks. There is a risk that consumers relying on TVWS broadband services would experience temporary or permanent service disruptions and that measures for the removal of license-exempt TVWS products from the market could be very costly. Such measure may not be effective enough either to guarantee a spectrum free of harmful interference to the incoming primary service and can lead to unforeseen costs for users.

The above situations could result in lack of interest to invest in these frequency bands or legal battles between a potentially new non-broadcasting primary service and those providing broadband services under the provisions set for TVWS license-exempt secondary service. Such outcomes would be sub-optimal and would result in a detrimental position for those affected markets and potentially leading to an inefficient use of the spectrum resource.

Could some form of security of tenure be needed to provide predictability and a long-term space for TVWS applications?

Perhaps, other regulatory approaches could consider alternatives for creating a regulatory environment and a space where TVWS wireless broadband applications can access spectrum not only in the short-term but also in the longer-term. The challenge is that TVWS applications are "what they are" while they operate opportunistically within the currently available gaps in spectrum allocated to television broadcasting but, what would happen if this changes or if digital TV broadcasting networks expand their coverage? Would TVWS broadband applications be adaptable enough to continue serving consumers or would they require regulatory measures to ensure their long-term success?

In order to explore solutions for longer-term security of tenure, some key regulatory aspects at the technical, economic and legal levels will need to be considered. Consideration of these aspects can help regulators and policy-makers in identifying options to provide an adequate regulatory environment where TVWS broadband applications can develop sustainably over time. Some of these key areas are summarized below:

Table 2: Examples of policy areas needed in the assessment of sustainable planning for TVWS applications

Technical level	Economic level	Legal level
Can new digital dividends take place in the near future in the UHF TV bands?	What are the total costs for the connectivity chain linked to TVWS rural broadband and who pays?	Could competition issues arise in the provision of TVWS wireless broadband services?
Has the transition to digital TV been finalized and is there a certain level of future TVWS availability? Are there regional/ international border coordination issues to be considered?	Can national operators and/or small local ISPs access TVWS? What are the long-term economic gains from implementing TVWS in comparison to other wireless choices?	Is there a potential for legal disputes between different service providers of TVWS in cases of limited TVWS availability?
Could bandwidth constraints affect the broadband service provision through TVWS in the near future?	Are there risks of monopolies arising in TVWS broadband service provision?	What parties would be accountable for the costs of potential spectrum reallocations of UHF TV spectrum?
Would a potential future expansion of digital TV networks restrict the service delivery of TVWS broadband?	Can potential regulatory changes result in increased costs for TVWS service providers and users?	Is there a need to assess legal requirements for the provision of TVWS database services?

There are many views on the TVWS subject and, through this discussion paper, we intend to convey as many as possible, hoping to contribute in the advancement of alternatives for TVWS by industry and regulators, in order to achieve the greatest benefit from the spectrum resource for society as a whole. Considering that spectrum regulation is a complex and interwoven mix of disciplines (policy, legal, economic and technical), there is definitively no silver bullet to tackle all the challenges. Notwithstanding this, sustainable development of ICTs is a necessary goal as we move forward with new developments, such as dynamic spectrum access and TVWS.

Another relevant area for discussion relates to the issues of spectrum security of tenure for TVWS broadband service providers. Any investment and business case needs to have a stable regulatory environment where wireless technologies can develop in a scalable way, for the benefit of users and service providers. Evolutionary changes in the regulatory environment for wireless, which we are experiencing specially in the highly sought-after UHF spectrum, can have massive impacts on services that are not planned to adapt to those changes or not planned within a forward-looking regulatory framework. This particular aspect needs to be addressed; otherwise regulatory and policy decisions can result in costly short-term outcomes and not in economically sound outcomes for the long-term. Comprehensive spectrum strategies and policies need to be developed towards the mid and long terms; or else we will face similar spectrum bottlenecks as we are experiencing today. TVWS needs to be an integral part of such a strategy.

As always, collaborative efforts between all stakeholders are the best way forward to ensure that the finite spectrum resource is optimally used, while encouraging social and economic growth through technological innovation. In order to achieve such outcomes, consensus and participation in the decision-making processes will continue to support a sustainable development of ICTs, from which society can continue to benefit from.

Regulatory checklist for TVWS implementation

1) What would be the situation for TVWS service providers and users with regard to TVWS deployments in the recently agreed digital dividend extension 694-790 MHz in ITU-R Region 1? What would be the situation in ITU-R Regions 2 and 3 in their digital dividends?

2) Should new digital dividends occur in the remaining UHF TV bands, what would be the impact on TVWS service providers and users in bands that can be identified for primary services other than broadcasting?

3) Would an incoming primary service different from broadcasting be capable of co-existing with widespread TVWS devices?

4) Which party (or parties) would be accountable for funding the costs of TVWS service providers and users in potential scenarios of migration or reallocation of TVWS devices?

5) What studies would be necessary to assess the level of compatibility between license-exempt TVWS devices and licensed mobile services, should further allocations be made for the mobile service in the UHF TV band?

6) Is it possible to guarantee a continuity of service for TVWS service providers in UHF TV spectrum bands in regions where DTT deployment is still ongoing?

7) What will happen with TVWS networks using analogue TV channel gaps once digital TV is fully deployed?

8) What are the risks and benefits for TVWS service providers and users if early adoption of TVWS takes place in regions where DTT transition has not been finalized?

9) Is there a need to consider some form of spectrum *security of tenure* for TVWS service providers in order to provide them with a minimum "spectrum pool" for successful service provision?

10) What studies would be necessary to assess the level of availability of TVWS in a combined deployment scenario including TVWS Wireless Regional Access Networks, wireless micro-phones and TVWS M2M devices? Would there be an impact on service provision due to bandwidth bottlenecks in cases of low TVWS availability?

11) Will TVWS be deployed for backhaul alternatives? Would there be potential bandwidth bottlenecks for TVWS backhaul service providers?

12) What would be the impact on TVWS service providers and users should numbers of TVWS Wireless RANs and TVWS M2M devices grow rapidly at any given area? Could such situation result in interference for TVWS devices given the greater coverage ranges possible in UHF spectrum?

Regulatory checklist for TVWS implementation (Continued)

13) Could the above situation in question 12 find some alternatives through the implementation of licensing arrangements other than a license-exempt framework?

14) Could infrastructure monopolies arise in connectivity services provided through TVWS? Are there competition issues that need consideration?

15) Can local mobile operators and small rural ISPs benefit from opportunities through TVWS? What types of services are expected to be offered by TVWS service providers after the pilot projects?

16) In terms of TVWS service provision and TVWS central database management. Would there be a need to review the legal framework and propose new regulatory arrangements or assess the possibility of conflicts of interest between these two service areas?

17) What is the potential level of scalability, resiliency and reliability that TVWS service providers can offer? Will these levels be sustainable in front of increases in demand and increased sharing of TVWS? Is TVWS a short-term solution or a long-term connectivity strategy?

18) How does TVWS broadband connectivity fit into a long-term national ICT strategy?

Appendices

Appendix 1: Recommendation 76 (WRC-12) on Cognitive Radio Systems

RECOMMENDATION 76 (WRC-12)

Deployment and use of cognitive radio systems

The World Radiocommunication Conference (Geneva, 2012),

considering

a) that a cognitive radio system (CRS) is defined as *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* (Report ITU-R SM.2152);

b) that a method of spectrum management to be used for aiding frequency assignment for terrestrial services in border areas can be found in Recommendation ITU-R SM.1049;

c) that ITU-R is studying the implementation and use of CRS in accordance with Resolution ITU-R 58;

d) that studies on regulatory measures related to the implementation of CRS are outside the scope of Resolution ITU-R 58;

e) that there are plans to deploy CRS in some radiocommunication services,

recognizing

a) that any radio system implementing CRS technology needs to operate in accordance with the provisions of the Radio Regulations;

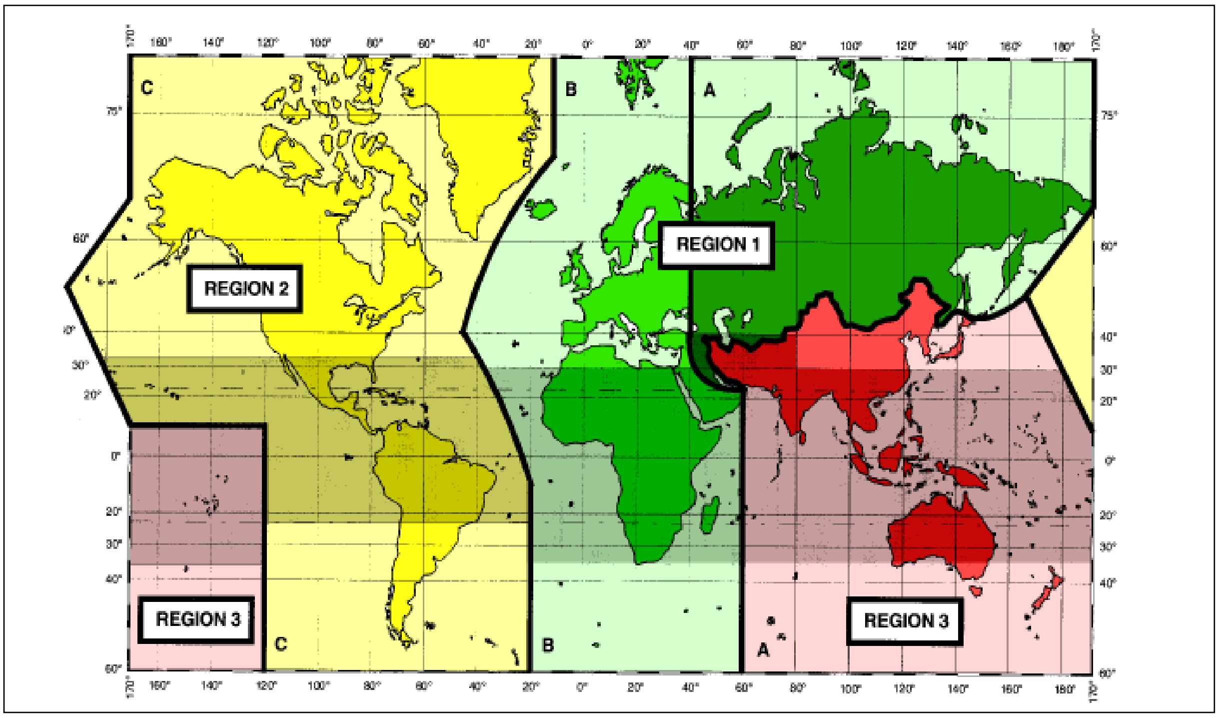
b) that the use of CRS does not exempt administrations from their obligations with regard to the protection of stations of other administrations operating in accordance with the Radio Regulations;

c) that CRSs are expected to provide flexibility and improved efficiency to overall spectrum use,

recommends

that administrations participate actively in the ITU-R studies conducted under Resolution ITU-R 58, taking into account *recognizing a)* and *b)*.

Appendix 2: ITU-R World Regions as per Radio Regulations



Annexes

Annex 1: Industry feedback on TVWS

The following annex contains a number of case studies and feedback provided by diverse sector groups involved in the development of TVWS devices, spectrum users and spectrum management entities. The aim of this annex is to widen the understanding of the status of development of TVWS, providing the reader with implementation examples and also to provide a broader mix of industry angles.

These case studies are presented in alphabetical order as follows:

1. Agence Nationale des Fréquences (ANFR, France) : Case study by ANFR
2. European Broadcasting Union (EBU) : Case study by EBU
3. Google : TV White Spaces trial in Cape Town, South Africa
4. GSM Association (GSMA): Case study by GSMA
5. Intel: Case Study by Intel Corporation Inc.
6. Microsoft: Connecting the unconnected in Rural Kenya: Can TV White Space technology help increase digital inclusion?

ITU wishes to kindly thank the above entities for their timely work and willingness to share their knowledge and suggestions on TVWS development. ITU notes that the views and opinions expressed shall aim to generate positive discussion and do not represent ITU's views.

Case Study from Agence Nationale des Frequences, ANFR – France

Vision on white spaces

The white spaces concept represents an opportunity where spectrum use is optimized. In a period where finding a frequency band for new applications is more and more challenging, the white spaces approach may provide opportunities to share spectrum dynamically while ensuring the protection of the current users of the frequency bands, the incumbents.

The white spaces approach is already used by some applications such as professional wireless microphone (PMSE) in the UHF band, using the unused TV channels in a given location in order to avoid self-interference in the TV network. Today, the channels for PMSE are selected by the user which has to avoid the channels used for television in the area under consideration and, together with the low power and low density of terminals, this is sufficient to ensure the protection of broadcasting.

The development of the database strategy in association with geolocation capability may allow the devices to know automatically and dynamically these conditions, e.g. with one "master" station being connected through other means to database and broadcasting the available conditions to all "slave" device. Nevertheless, this approach raises also several challenges in terms of spectrum, database management and update, standardization, database licensing, control of the devices, etc.

The white space concept follows the principles of "opportunistic spectrum access". From a regulatory point of view, it implies that WSD shall not cause interference to primary incumbent services nor claim protection from these services. There are uncertainties concerning future spectrum available for WSD as it depends upon the evolution of primary services uses.

Spectrum challenges

One of the spectrum challenges consists in the respect of the appropriate level of protection of incumbent services. Compatibility studies carried out in CEPT have shown that protection of broadcasting in adjacent channels would severely restrict power level of white space device (WSD), including in adjacent channels and maybe in other channels.

NRAs have also to consider the possibility of evolution of a frequency band before introducing white space devices. A decision to reduce significantly the size of white space few years after having authorized them could lead to legal issues.

Economic potential and business case

The business case depends on the spectrum available which will depend on the type of application and the rules to protect broadcasting and PMSE. For example, the rules defined in United States are resulting in no spectrum available in large cities such as New-York or Los Angeles for 100 mW Wi-Fi device, although a large bunch of spectrum is available in rural areas.

Considering severe sharing condition, the business case seems to be limited either to low power device (e.g. Wi-Fi) or to broadband access in rural areas

The cost and difficulties for practical implementation and the interest of WSD market create uncertainty which may discourage its development.

Social impact

The white space concept developed in the UHF band takes advantage of the fantastic propagation conditions of this frequency band and could help to reduce the digital divide by providing internet access to rural areas if compatibility with broadcasting and PMSE is ensured.

Recommendations

The white space concept offers new opportunities for spectrum management. Nevertheless challenges should be studied appropriately: process to authorize database, process to ensure that WSD will connect only to authorized database, devices security in order to avoid uncontrolled transmissions or connection to fake database, or the technical feasibility of the devices in terms of protection of the incumbents.

In order to accumulate experience in this concept, experiments are encouraged. Some experiments are ongoing in France using fixed stations in order to provide internet access in rural areas.

Case Study from European Broadcasting Union, EBU

The EBU believes that when the possibility of using the interleaved spectrum for cognitive radio systems is considered, the following issues need to be addressed:

- Cognitive radio systems could be introduced in the broadcasting frequency bands only on a non-protected non-interfering basis with respect to terrestrial broadcasting and SAP/SAB services that are already operating in these same frequency bands. Appropriate technical criteria and conditions need to be established.
- Deployment of cognitive radio systems must not hinder the technology and service evolution of the incumbent services, such as DTT and PMSE. This is particularly relevant in the case of the licence exempt operation of cognitive radio systems.
- The overall benefits that are expected from the introduction of cognitive radio systems in the white spaces need to be assessed. In that respect, it may be useful to establish some general criteria and guidance. This would help the industry when developing equipment and services and would assist administrations in making the necessary regulatory provisions. In addition, well defined assessment criteria would add transparency in evaluating different deployment scenarios and sharing models on a case by case basis.
- Appropriate performance indicators of cognitive radio systems need to be identified.
- The amount of 'white spaces' in the UHF band is considerably reduced by the digital switch-over and the allocation of the band 790-862 MHz to electronic communications services. It is therefore necessary to reassess the amount of the 'white spaces' that may be available for the cognitive radio devices in the future.

Background

The interleaved use of UHF spectrum (between 470 and 790 MHz) by terrestrial broadcasting networks leaves some spectrum locally available for use by a range of other applications. Research & Development organisations as well as regulators inside and outside Europe have been working for several years on the possible usages of these so-called Television white spaces.

While white space devices (WSDs) are being implemented in the TV white spaces in the USA, in Europe they are still at the definition stage. The CEPT (Conference of European Post and Telecommunication Administrations) has recently finalized two reports on technical and operational requirements for the operation of WSDs (ECC Reports 185 and 186). One major agreed feature in these requirements is the required use of geolocation databases (Fig. 1) to ensure the protection of DTT (Digital Terrestrial Television) services, PMSE (Programme Making and Special Events) applications and other incumbent services. Geolocation is the capability of a WSD to know its geographical position and to transmit it to a database which identifies the suitable channels and communicates to the device the operational parameters that it can use in its location.

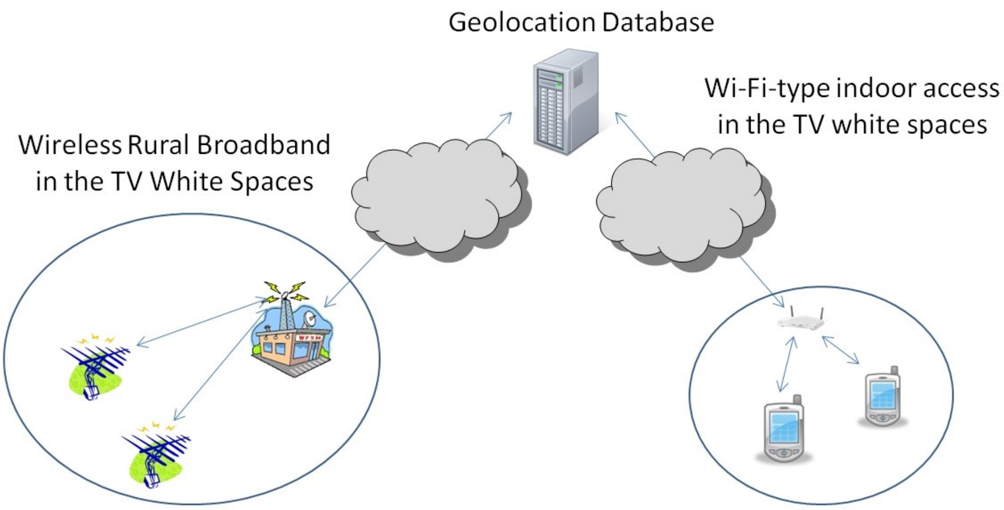


Figure 1: White space devices applications using a geolocation database.

The challenge for broadcasters

The challenges for broadcasters are twofold: firstly, ensuring protection of the DTT services and PMSE applications that use the UHF spectrum; and secondly, making use of the opportunities offered by this possible use of TV White Spaces.

On the first subject, the CEPT project team SE43 has defined the technical basis for the operation of the WSDs but has left a large degree of freedom for national regulators to define the actual level of protection that should be afforded to their incumbent services and applications. Therefore broadcasters need to ensure on their national level that the afforded protection is adequate when the time comes to implement regulations for WSDs.

On the second subject, broadcasters need to investigate those applications that could be implemented in the TV white spaces and would provide added value to broadcasters and their audiences.

What is EBU doing?

The EBU has actively participated in the CEPT work defining the technical and operational conditions for the operation of WSDs, within the project team SE43. Technical studies and proposals made by the EBU within this project team have been well received and many of these proposals have been included in the above mentioned ECC Reports 185 and 186.

Another work stream has been set up in the CEPT, in the newly created project team FM53, to deal with further requirements related to white space devices in the TV white spaces but also with implementing the Licensed Shared Access (LSA) and defining general objective on reconfigurable radio systems (RRS). This work stream will also establish a link with the current standardisation activities in ETSI.

The EBU continues to be involved in this important and complex area on behalf of its Members.

Some EBU Members, like BBC and IRT, are also actively involved in the CEPT work and in European projects dealing with the subject of WSDs. Broadcast Network Operators like Arqiva and Abertistelecom are also involved in studies and field trials of WSDs.

Case Study from Google: TV White Spaces Trial in Cape Town, South Africa

Vision: At Google, we support policies that enable robust, ubiquitous, affordable, and open broadband access. We believe that license-exempt access to television white spaces (the vacant spectrum that separates broadcast television channels) has the potential to deliver broadband access in rural and hard-to-reach areas as well as increase ubiquity in urban areas.

To that end, Google recently launched a trial deployment offering broadband over TV white spaces in South Africa. We are working with ICASA (the national communications regulator) and several local partners, including the Tertiary Education and Research Network of South Africa

(TENET), the Council for Scientific and Industrial Research, the eSchools Network, and Stellenbosch University's Faculty of Medicine and Health Sciences. Carlson Wireless and Neul have provided radios and software. Google provides a spectrum database that identifies channels unoccupied by television broadcasters and available for wireless broadband transmissions. The exact white space channels available at a particular location depend on what broadcast channels are being used there the available white spaces are not the same everywhere. Therefore, a wireless device that is configured to use the white spaces will query Google's database to determine which channels are available based on the device's coordinates. The project is truly a partnership between public, private, and nonprofit stakeholders and a model for future collaborative technical experimentation and policy development.

The trial became operational on March 25, 2013. Ten installations located on Stellenbosch University's campus in Cape Town will deliver broadband Internet service to ten primary and secondary schools within a 10 kilometer radius. It is planned that each school will receive dedicated 2.5 Mbps service with backup connectivity. Through the trial, Google and its partners hope to demonstrate to South African policymakers, regulators, and potential users that broadband can be delivered over TV white spaces in this urban area at an affordable price, without causing harmful interference to broadcast services.

Spectrum challenges and solutions: As more and more users consume increasing amounts of mobile data, the demands placed on existing spectrum allocations for mobile broadband will increase. Spectrum is a finite resource, and auctioning spectrum can only be on part of solution for meeting this increased demand. Database-controlled spectrum sharing enables use of spectrum that would otherwise lie fallow while protecting existing users. Delivering broadband over TV white spaces is one example of such use of database technology. Other potential applications include enabling sharing between civil/commercial users and government incumbents. Incumbents that do not use the entirety of a given spectrum band can be granted priority and protection from interference when and where they are using the band, while allowing nongovernmental use if the spectrum is vacant.

Economic potential and business case: We hope that the Cape Town trial will demonstrate to South Africans that broadband access can be delivered effectively and affordably over TV white spaces. In the US and abroad, many wireless Internet service providers are optimistic that this form of broadband can be delivered at affordable costs to areas that were previously impossibly expensive to serve including but not limited to rural areas and emerging markets.

Similarly, license-exempt access to spectrum presents opportunities for low-cost innovation. Hundreds of devices and applications use license-exempt spectrum, including wireless routers, Bluetooth devices, baby monitors, remote controls, cordless telephones, security alarms, and smart grid systems for electric utilities. Because the creators of these devices and applications do not have to seek permission from a license holder to develop their products, barriers to entry and transaction costs are reduced. As such, license-exempt spectrum serves an important incubator for emerging and innovative technologies.

Social impact: license-exempt access to white spaces has the potential to bring broadband to some of the 5 billion global citizens who remain unconnected to the Internet. It also may lower network operators' costs of provisioning broadband by enabling greater reliance on offloading to Wi-Fi networks, and extend the range of Wi-Fi within homes. Indeed, innovators have been using this spectrum in a range of socially beneficial ways. For example, white spaces technology has enabled smart grid applications improve efficient energy usage, municipal applications to enable traffic management and improve public safety, and rural healthcare applications improve care in remote areas.

Recommendations:

- Support spectrum sharing to make efficient use spectrum. In particular, recognize that databases enable sharing between protected incumbent users and opportunistic users. Databases may also be useful in circumstances where international harmonisation lags --a database can use a device's location information combined with known spectrum allocations to identify available spectrum in any given place.

- At a national level, regulators should pursue balanced spectrum policy. They should support a mix of licensed and license-exempt uses above and below 1 GHz. Licensed uses are one key to delivering mobile broadband, but license-exempt uses (like the use of TV white spaces) provide an important complement. Enabling both licensed and license-exempt uses below 1 GHz is especially important because the lower frequency spectrum has better propagation characteristics, making it easier to serve remote and high- cost areas.

- Favor innovation and heterogeneity of networks (including fixed, mobile, and nomadic; licensed and license-exempt) a variety of approaches will necessary to bring the remaining 5 billion online.

Case Study from GSM Association, GSMA

1. It is important to consider how to use the Digital Dividend most effectively to benefit citizens and businesses. The licensing regime should not jeopardize the future of the UHF band, especially in the case of reallocation for exclusive mobile use.

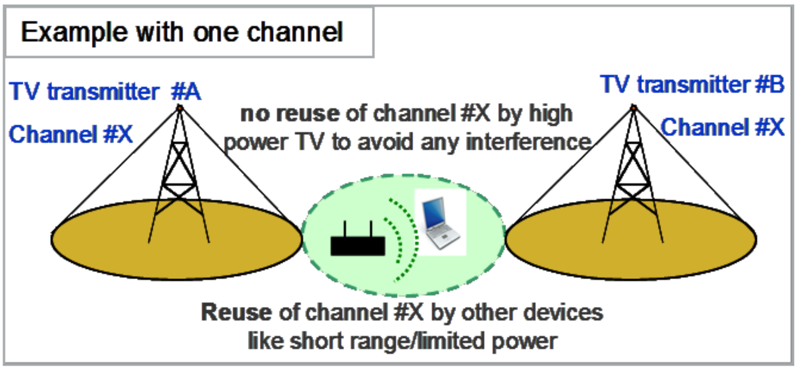
2. The use of TV white spaces must not distort the market through inappropriate regulation. Eliminating the cost of acquiring licensed spectrum and providing cellular-type mobile services could create an unfair advantage.

3. TV white space is currently based on the concept of a spectrum-use database combined with geo-location to the spectrum resource for which quality of service and spectrum availability is not predictable. For TV white space, there is no *a priori* determination of the spectrum to be eventually accessed.

4. Interference management remains a top priority, and that creates some confidence. The use of TV white spaces, on a secondary unlicensed basis, requires careful interference avoidance towards primary users such as existing TV broadcasters, as well as services in adjacent bands.

Background

The expression “white spaces” is used to define the parts of the spectrum that are not used at a particular time and geographical location. Typically white spaces, or “TV white spaces,” consist of unused spectrum in the television broadcasting bands (470-790 MHz in Europe and 470-698 MHz in USA). There is unused spectrum mainly because of the geographical separation required between television stations of the same channel and also part of the spectrum dedicated to the regional TV stations which remain unused in certain areas. For example, because of interference, you could not have one Channel 4 station broadcasting from Paris and Channel 4 broadcasting from Versailles. Microsoft is advocating globally for use of the white spaces for license-exempt services (like Wi-Fi). It is worth noting that desirable/potential geographic area, such as major urban and suburban areas, typically have little, if any, TV white space at all. The image below illustrates where white spaces devices could operate.



The TV white space scenario relies on the licence-exempt model with “no individual rights of use” as well as “no individual frequency planning/coordination”. As a consequence, users can only expect best-effort service. TV white spaces are in the television UHF band below 1GHz, often referred to as Golden Spectrum. However, it should be noted that the white space concept is frequency agnostic and could be expanded to any band where the spectrum is not uniformly used and therefore could be ‘shared with’ (made available to) other applications.

Rationale for the position

1. **It is important to consider how to use the Digital Dividend most effectively to benefit citizens and businesses. The licensing regime should not jeopardize the future of the UHF band.**

The use of TV white space should not impact the preparation process for WRC-15. Deployment of TV white space systems should not distort the possible evolution of use of the TV UHF band, especially when considering the discussions on the Digital Dividend 2. TV white space systems need to have the capabilities to adapt any change of use of the band (i.e., network evolutions in band and in the adjacent band) without asking for compensation (i.e., financial compensation or refarming in alternative bands). Finally, due to their regulation status, the TV white space systems should not claim for any protection (even to the primary mobile service) and should not create any interference, including in the adjacent bands.

Although we acknowledge it to be hard work, bands that are well-suited to mobile should be cleared and reallocated. Even if the band cannot be fully cleared, we must explore exclusive licensing models that protect incumbents on the basis of temporal, geographical or frequency-based exclusivity, rather than moving directly to more uncertain options. The risks of being wrong about an unproven approach are too high.

It is also important to note that TV white spaces would not guarantee high-quality mobile broadband data services due to:

- Non-homogeneous geographical coverage and fragmented bandwidth availability, as it is impossible to have sufficient bandwidth to mobile broadband service everywhere and with the necessary quality of service;

- lack of availability of a single, well-standardized technology solution, usable in all nations/regions, implying a lack of scale economies and related high costs for network and user equipment due to needed customization of proprietary solutions, e.g., for a single or few markets;

- Lack of coexistence studies to evaluate interference effects between mobile broadband systems using TV white space and digital TV reception.

All this would be directly translated into design complexity and into extremely inefficient use of the bandwidth due to very extended guard bands to be adopted (TV signal–guard band–TV white space for mobile broadband use–guard band), resulting, from a marketing point of view, into scarce equipment availability and very high costs for the final customer.

2. **The use of TV white spaces must not distort the market through inappropriate regulation. Eliminating the cost of acquiring licensed spectrum and providing cellular-type mobile services could create an unfair advantage.**

TV white space services intend to use unused TV spectrum to provide non-broadcasting services that could be provided by mobile networks, from broadband to M2M, smart metering, TV, etc. In principle, one of the main advantages of this technology is to use parts of spectrum licensed to existing terrestrial TV networks — at lower heights — where most of the broadcast coverage is provided by a few high masts. Another advantage is that it would use unlicensed spectrum, eliminating the cost of acquiring licensed spectrum. In this case, white spaces networks are not seen as complementary networks, but substitutive for cellular mobile services. As both networks will compete in providing the same services, it is relevant to state that white space will use free spectrum that could create an unfair advantage and distort the market.

3. **TV white space is currently based on the concept of a spectrum-use database combined with geo-location to the spectrum resource for which quality of service and spectrum availability is not predictable. For TV white space, there is no *a priori* determination of the spectrum to be eventually accessed.**

With the concept of a spectrum-use database combined with geo-location, there is no *a priori* determination of the spectrum to be eventually accessed by the secondary user. In this scenario, secondary user may access parts of unused spectrum which is shared with other radio systems without causing harmful interference to the incumbent users. It involves significant technical challenges such as continuous monitoring of the incumbent activities for reliable detection of the unused (idle) periods, rapid evacuation of the occupied channels once the incumbent activity restarts, etc. In this scenario, the selection of spectrum to be eventually accessed is made on a real-time basis following a radio environment analysis.

Furthermore, recent studies estimating TV white space availability in some countries such as Italy and France show that it can be fragmented and more abundant in rural areas, with larger contiguous blocks of unused channels available, as TV broadcasting priorities are linked to higher population density.

4. **Interference management remains a top priority, and that creates some confidence. The use of TV white spaces, on a secondary unlicensed basis, requires careful interference avoidance towards primary users such as existing TV broadcasters, as well as services in adjacent bands.**

TV white spaces are portions of spectrum unused by digital TV, characterized by an unpredictable allocation in bandwidth, time and space. Their possible use, on a secondary unlicensed basis, requires careful interference avoidance towards primary users such as existing TV broadcasters, as well as services in adjacent bands, under the control of a ruled database providing a list of available channels within the geographic area of operation. In practice, unlicensed TV white space devices have to contact an authorized database system to obtain a list of channels that are available for their operation (e.g., channels not occupied by authorized primary TV services) at their individual locations and have to operate only on those channels.

The GSMA acknowledges the importance of interference policy as long as there is no relaxation in this critical issue. MNOs, among others, need feedback on this issue.

Case Study from Intel Corporation, Inc.

The White Spaces Vision

"White spaces" generically refers to unlicensed spaces or gaps in spectrum allocations, especially in the broadcast TV bands. In the US, broadcasters are licensed to use a particular channel within contours surrounding cities. If one considers a given frequency on a nationwide basis, co- and adjacent channel limitations create "encumbered" areas that are not available for use. The white spaces reform envisions the use of data base or sensing technologies to free up otherwise unavailable frequencies improving overall spectrum efficiency. The Federal Communications Commission promulgated rules allowing whites spaces spectrum in the broadcast band to be used on an unlicensed basis subject to tight technical parameters. This analysis explains why the results in the US thus far have not been encouraging and why other spectrum reforms represent better solutions to the mounting challenge of spectrum scarcity for mobile broadband use.

Economic Potential and Business Case for White Spaces

The US experience with white spaces spectrum has not been encouraging. In response to incumbent broadcasters' concerns about potential interference, the FCC set strict adjacent channel emission limits and other measures to protect the neighboring broadcast channels. The resulting narrow "white spaces" channels are most suitable for low bandwidth use cases. Meanwhile, new Wi-Fi standards are going to wider channels for higher bandwidth uses. For example, the IEEE 802.11ac standard will use 80 and 160 MHz channels.

In urban areas where most broadcasters operate and spectrum is most scarce, the available white spaces spectrum will be quite limited. Not surprisingly, the major Wi-Fi vendors have shown little interest in the white spaces spectrum and relatively little equipment is currently available. Instead the Wi-Fi ecosystem is focusing on freeing up additional unlicensed spectrum at 5 and 60 GHz. Another problem with unlicensed use on broadcast frequencies is that it would not effectively exploit their excellent propagation characteristics. Unlicensed, wide area network use would lead to suboptimal quality of service and investment incentives because of "tragedy of commons"[38] problems.

Spectrum Challenges

Given the growth in mobile broadband, it is clear that new innovative ways are required to release more spectrum for licensed wide area use. Several approaches have been used successfully in the US, such as creating technology neutral and service flexible allocations and permitting wider channels and license aggregation (subject to a competition review). These approaches give licensees the opportunity (and given marketplace pressures the challenge) to choose those technologies and service that will best satisfy consumers. To the extent they succeed, they reduce spectrum scarcity and improve spectrum efficiency.

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[38] *See* Hazlett, Thomas W., and Evan T. Leo, "The Case for Liberal Spectrum Licenses: A Technical and Economic Perspective," 2011, available at http://btlj.org/data/articles/26_2/1037_1102_Hazlett_112111%20Web.pdf

Also, new approaches are receiving serious consideration in the US. The FCC is conducting a rulemaking that would utilize "incentive auctions"[39] to buy out broadcasters to clear and license broadcast spectrum for mobile broadband use. Intel, leading carriers and other interested parties have provided detailed comments on how to structure the band plan and auctions. By sharing a portion of the auction proceeds with incumbent broadcasters to induce them to voluntarily vacate their spectrum, incentive auctions should make more spectrum available for higher bandwidths and quality of service. The incentive auctions will address growing consumer needs and generate an estimated $24 billion dollars.[40] Finally, governments and technologists are looking at ways that commercial users could share spectrum with existing military or other government users. One approach is called Licensed Shared Access (LSA).[41] One form of LSA proposed by Intel, Cloud Spectrum Services (CSS), would identify and manage dynamic access to shared spectrum resources.

Social Impact & Recommendations

Given the burgeoning demand for mobile broadband use, technology and other solutions to increase existing capacity are not sufficient. Freeing up more spectrum for wide area mobile use will pay big dividends. In the US, economists estimate that additional spectrum suitable for mobile broadband use would generate societal benefits approximately 10 times the auction revenues paid by the winning mobile operators.[42] The market-based reforms discussed above appear most likely to maximize spectrum efficiency. Accordingly, Intel supports:

1. **<u>Clear spectrum for use on an exclusive licensed basis.</u>** Wherever possible, government should implement voluntary mechanisms to clear commercial and federal spectrum for high-value uses and technologies (*e.g.,* commercial mobile broadband) on an exclusive licensed basis, to enable efficient long range, wide area network uses. Commercial licensees should be granted service flexibility and technology neutrality and permitted to resolve interference problems with their frequency and geographical "neighbors" through negotiations.

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[39] *See* "The Broadcast Television Spectrum Incentive Auction: FCC Staff Summary," available at: http://transition.fcc.gov/Daily_Releases/Daily_Business/2013/db0116/DOC-318455A1.pdf

[40] *See* http://broadbandbreakfast.com/2013/01/fcc-chairman-genachowski-touts-incentive-auction-as-big-win-from-broadcasting-to-wireless-broadband/

[41] *See* DIGITALEUROPE Position Paper on Licensed Shared Access (LSA) Common Understanding, Status and Next Steps, February 14, 2013, available at :

http://www.digitaleurope.org/DocumentDownload.aspx?Command=Core_Download&EntryId=519

[42] Thomas W. Hazlett & Roberto E. Muñoz, *A Welfare Analysis of Spectrum Allocation Policies*, RAND Journal of Economics, Vol. 40, No. 3 (Autumn 2009), , at 425 available online at:

http://mason.gmu.edu/~thazlett/pubs/Hazlett.Munoz.RandJournalofEconomics.pdf). Empirical research undertaken a decade ago found the annual consumer surplus associated with U.S. cellular telephone licenses (issued in the 1980s) at least 10 times as large as annual producers' surplus (Hausman, 1997; Rosston, 2001).

2. **Share spectrum on a licensed basis.** Where clearing is not possible, governments should look for sharing opportunities between federal users and commercial users on a licensed basis if wide area network use is feasible. This will foster efficient market incentives for high quality of service as well as infrastructure and technology investment, and encourage voluntary, market-driven negotiations between the federal user and the commercial licensee to increase the value of the spectrum (*e.g.*, utilizing filters or other mechanisms that permit operation in specific geographic areas, at specified frequencies, or during specified times).

3. **Share spectrum on an unlicensed basis.** Where wide area network service use of spectrum is not feasible on a shared licensed basis (*e.g.*, 5 GHz band), government should look for sharing opportunities between federal users and commercial users on an unlicensed basis.

Case Study from Microsoft: Connecting the Unconnected in Rural Kenya: Can TV White Space Technology Help Increase Digital Inclusion?

"We need to take broadband from the urban areas to rural areas and be able to change the livelihood of many, many people." - Dr. Bitange Ndemo, Permanent Secretary, Government of Kenya, Ministry of Information and Communications.

Vision

Consumers have access to an increasing range of connected devices, for use in and out of the home – the vast majority relying on wireless technologies. Consumers expect instant access to their favorite services regardless of which device they happen to be using, where they happen to be, and what time it is. Whether it's a school in a remote village connecting to teachers in the capital or a group of friends watching the latest high-definition movie on a phone, broadband-quality wireless connectivity is essential. Some have even concluded broadband access is a human right.

Unfortunately, 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. In addition, hundreds of millions of wirelessly-connected devices are coming online, all requiring wireless connectivity and bandwidth and further increasing demand for spectrum resources.

Microsoft believes that major innovation and investments in Dynamic Spectrum Access and TV White Spaces can be a bridge to a digital future where billions more people and billions more devices wirelessly connect to the Internet and continue to drive global economic growth, social engagement, and improvements in health, education, and government service efficiency.

In February of 2013, as part of its 4Afrika Initiative, Microsoft announced a partnership with the Government of Kenya's Ministry of Information and Communications and industry partners Indigo Telecom, a Kenyan ISP, and Adaptrum, a pioneer in white space technologies. The project – called Mawingu or "cloud" in Swahili – will test the commercial feasibility of delivering low-cost, high-speed wireless broadband access to locations previously underserved by even basic electricity. Areas that had been unconnected for reasons ranging from geography, population density, rates of poverty, and lack of electrical infrastructure, are now being targeted for wireless broadband.

Spectrum Challenges (aka Spectrum Opportunities)

While they have ample unused radio spectrum, the areas of Kenya chosen for the Mawingu pilot lack access to affordable or reliable broadband options. Most of these locations lack basic infrastructure, such as electricity or paved roads. These areas are simply uneconomic to serve with existing wire line and wireless technologies. To serve these areas more affordably, a new approach is needed.

In an effort to overcome these challenges, the Mawingu network relies on a combination of "unlicensed" or "license-exempt" wireless technologies, including Wi-Fi and TV White Space base stations and end user devices. To maximize coverage and bandwidth, while keeping costs to a minimum, these radios use several complementary spectrum bands available to license-exempt devices, including 13 GHz, 5 GHz, 2.4 GHz, and unused UHF TV band spectrum. The network typifies the transition from homogenous to heterogeneous networks. To reduce operating expenditures and to address the huge challenge of delivering broadband access to the 75% of Kenyans who lack access to electricity where they live, the Mawingu project is leveraging solar energy, which will power the base stations and enable consumers to charge devices.

Economic Potential and Business Case

Globally, broadband connectivity remains unaffordable for much of the world's population. Fixed broadband access is unaffordable for 3.9 billion people spread across every country in the world. Mobile broadband is unaffordable for over 2.6 billion people. These estimates assume that people can afford broadband if is it less than five percent of their annual income. Availability and affordability gaps are disproportionately impacting people in Africa, Asia, and Latin America.

The key challenge for the Mawingu project participants then is finding ways to reduce the cost of access such that many more of the world's consumers can affordably come online. Consider a family making US$1,200 per year. In order for that family to afford broadband access, it would need to be less than US$5 per month. Now consider a family subsisting on US$480 per year. In order for that family to afford broadband access, it would need to cost less than US$2 per month. Through this project, Indigo Telecom, along with Microsoft and the Kenyan Government, may find out whether these technologies and new business models can enable such low-cost, affordable Internet access.

Social Impact

In addition the economic opportunities created by the new network, the social impact will also be significant. From e-health to education to improved access to vastly improved inbound/outbound communications, the Mawingu project is designed to deliver positive change to the region. The project partners are working with community leaders, global NGOs and local Kenyan partners to identify the most crucial services and insure their delivery and deployment. Computer labs, new tablet computers, teacher training and other educational benefits are part of the total solution.

According to Ms. Beatrice Nderango, Principal, Gakawa Secondary School, "Let me say that we have hard working students and given this opportunity they are going to improve their academic performance . . . now they can get information from the Internet." Direct reports from the first few months of the project are attesting to these changes. Teacher training is underway and students are already accessing the boundless opportunities that connectivity to the Internet provides.

Recommendations

The Mawingu project partners strongly believe that successful implementation could lead directly to more broad scale deployment of TV White Spaces networks. But, none of these benefits will be realized without new regulations allowing for "unlicensed" or "license-exempt" access to unused TV band and other white spaces spectrum. We look forward to working with other African countries as well as governments around the world to implement needed regulatory change and unlock this technology's potential for expanding the capacity and reducing the cost of broadband access.

In addition to the work in emerging economies such as Kenya, there is also tremendous opportunity in deploying these technologies globally and helping to usher in a better world of connectivity. From rural Kenya to wired Singapore and beyond, a future with billions of connected devices and billions of connected people depends on innovative spectrum approaches such as the use of Dynamic Spectrum Access and TV and other white spaces spectrum.