

TV WHITE SPACES: MANAGING SPACES OR BETTER MANAGING INEFFICIENCIES?

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This paper¹ reviews relevant regulatory aspects concerning the operational implementation of Television White Space (TVWS) devices in some parts of the spectrum allocated to TV broadcasting. The term TV White Spaces usually refers to unoccupied portions of spectrum in the VHF/UHF terrestrial television frequency bands in some geographical areas. Trials and tests are currently underway in several countries and some commercial applications are emerging, looking at improving the utilization of the highly valued UHF 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 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-exempt² 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 for 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 implementation and rapid development of user applications, and/or by planning an internationally harmonized

1. The text of this article is based on the ITU discussion paper of the same title, presented at the Global Symposium for Regulators 2013, Warsaw, Poland. The full text of the discussion paper is available at: http://www.itu.int/en/ITU-D/Conferences/GSR/Documents/GSR_paper_WhiteSpaces_Gomez.pdf

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.

*Disclaimer: the views expressed in this article are those of the author and do not necessarily reflect the opinions of ITU or its membership.

spectrum use from which economies of scale can be obtained (end-user devices in particular).

This paper also examines aspects of wireless markets and sustainable development of ICTs in relation to TVWS implementation, international regulatory developments of the spectrum, spectrum management and licensing frameworks. Finally, the article offers conclusions in the form of discussion of regulatory and policy questions that may need further exploration prior to implementing TVWS on a large scale, in order to take into account spectrum regulatory developments at the international level.

7.1 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/temporal features, the level of interference potential to and from the incumbent TV broadcasting service coverage objectives and related planning and utilization of broadcasting, as well as the nature of the application intended to use white spaces (receiver sensitivity, required transmitted power etc.). These instances of TVWS availability can be categorized (not restricted to) as follows:

- a. Frequency: to avoid interference within broadcasting, idle channels are purposely planned in the TV band in some geographical areas.
- b. Deployment: available TV white spaces may be used given that the height of the TVWS transmit antenna and its installation site (as well as the aggregate emissions of the numerous TVWS devices) are planned in technical compatibility with nearby or surrounding TV broadcasting reception in order to avoid interference.
- c. Space/distance: geographical areas that are outside the current planned TV coverage and therefore no broadcasting signals are currently present.
- d. Time: 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 (e.g. nighttime). However, this type of availability can be subject to change if the broadcaster decides to modify hours of operation.

Further, in the case of digital terrestrial television (DTT), white space availability by means of "frequency"(channel idleness) could vary greatly across regions. TV white spaces may be less prevalent if the

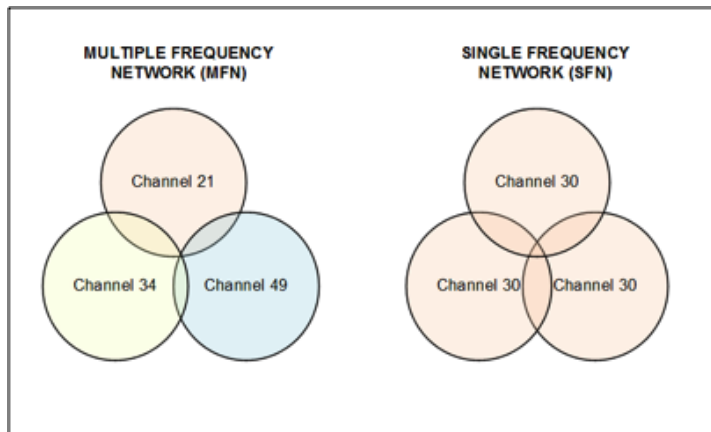


Figure 7.1: Single frequency networks use the same frequency to transmit the same programme in a given region, providing increased spectrum efficiency.

digital broadcasting network uses the adjacent channel rejection capabilities of digital technology to its full extent (and therefore fewer guard channels are needed). Also, digital TV systems permit 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. Therefore, for better utilization of TVWS spectrum and for estimating the bandwidth available in the short, medium and long terms, it would be preferable to define how this part of the spectrum will be used in the future (i.e. which part for broadcasting and which part for mobile).

It is important to mention that UHF television broadcasting 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 Regulations³, "RR"). As per Radio Regulations, a primary service is awarded protection from harmful interference arising from secondary services, or from devices not classified as primary or secondary and operating in the same frequency bands (as the case of devices using the spectrum opportunistically, such as TVWS devices). It is important to note also that, in turn, while secondary services cannot claim interference protection from primary services, they are protected from harmful interference arising from radio devices operating opportunistically. Considering this, TVWS equipment is being developed to operate opportunistically on non-interference/ non-protection basis, under a license-exempt regime, similar to low-power/ short range devices used in ISM bands (e.g. 802.11 WiFi devices). TVWS radio emissions are to be properly controlled in order to avoid harmful interference into primary

3. Radio Regulations are available for download for free at: <http://www.itu.int/pub/R-REG-RR>

4. SAB: services ancillary to broadcasting. SAP: services ancillary to programme making. See ITU-R Recommendation BT.2069-5 at: <http://www.itu.int/pub/R-REP-BT.2069>

and secondary services.

It is also necessary to take into consideration that often the usage of the UHF band is not limited to broadcasting. The Radio Regulations allocate portions of the UHF band to several other radio services, such as fixed, mobile, radionavigation either on a primary or secondary basis (also some countries used these bands for SAB/SAP⁴ devices on licensed basis). These allocations are utilized in a number of countries for various radio applications, thus in these countries, the utilization of white spaces on non-interference basis is more complex.

7.2 MAIN DRIVERS FOR THE RESEARCH OF ALTERNATIVE FORMS OF SPECTRUM UTILIZATION

The increasing demand (see Figure 7.2) for wireless connectivity as part of the evolution of ICTs in the "digital information era" is driving the research of alternative forms of spectrum utilization in recent years. 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.

With a steep increase in the demand for mobile connectivity, comes the inevitable pressure on the supply side of the resource (the radio spectrum). Noting that, while levels of spectrum demand are likely to vary across different regions depending on factors such as population density, geographic characteristics, 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 mobile networks (e.g. 3G & 4G) and license-exempt local area networks (e.g. WiFi 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 expeditious way to reducing the digital divide. Thus, one could also infer 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 terrestrial or satellite links used for backhaul.

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:

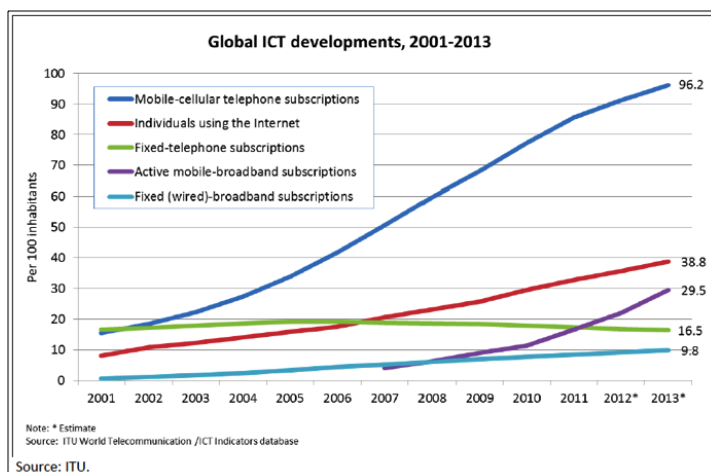


Figure 7.2: Global ICT Developments, 2001-2013

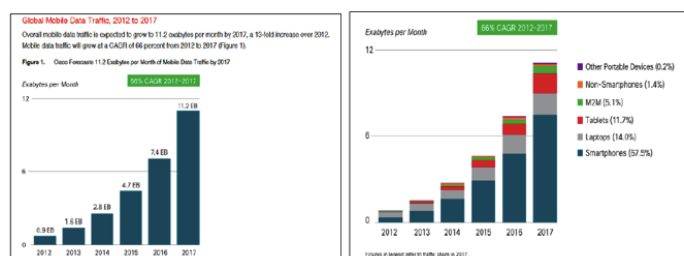


Figure 7.3: Global mobile data traffic forecast and Smartphones lead the data growth.

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 7.3 and 7.4) and rapid consumer adoption of novel mobile products. In the presence of bandwidth bottlenecks, potential regulatory choices for addressing such issue would strive to achieve improved spectrum efficiency through exploring forms of dynamic spectrum access and more efficient use (i.e. cognitive radio, spectrum aggregation), sound alternatives for spectrum sharing, and forward-looking spectrum planning and refarming (and avoidance of spectrum fragmentation). In these markets, the main objective is to match spectrum demand, given that spectrum utilization in such markets is bandwidth intensive due to the high density of users.

There are however some limitations to the use of TVWS to provide mobile broadband access to the mass consumer market (similar to cellular networks):

- Availability of TVWS spectrum in urban areas is likely to be

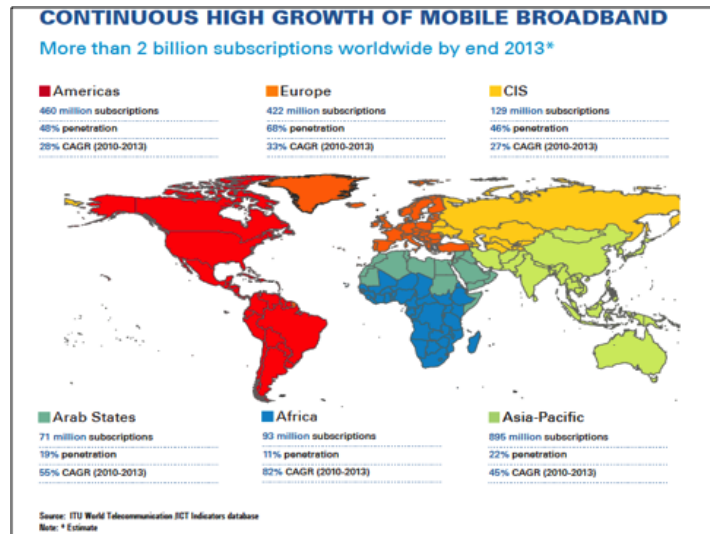


Figure 7.4: Mobile broadband growth figures per region.

small where digital television has been deployed.

- Potential for *aggregate interference* from large numbers of ubiquitous license-exempt TVWS users into the primary service (television reception).
- Self-interference within the TVWS network may also be a limitation.

Cost-benefit analyses would therefore be needed also in order to assess the relative benefits of providing only a modicum addition to the overall bandwidth pool available to users at the cost of setting up interference-limited new infrastructure for wide-area coverage. This is one of the main points of divergence between TVWS and WiFi devices used in higher frequency bands: the low-power/short range use of license-exempt WiFi devices prevents them from creating detrimental interference levels, provides for higher frequency re-use and requires a low-cost, small infrastructure footprint.

Moreover, a mismatch situation would inevitably be prevalent, where there is high demand for bandwidth but a very low TVWS bandwidth supply. Considerations in this regard would include assessing the frequency re-use capabilities of TVWS networks in bandwidth limited scenarios, balancing download and upload requirements, costs considerations for network infrastructure deployment and client's service delivery.

Costs considerations would also include an assessment of the trade-offs arising from replicating existing cellular infrastructure.

- b. **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 return on investment (ROI) levels would discourage providers from considering such an option. A wireless alternative is a more cost effective choice; especially those alternatives than can achieve large coverage areas with fewer base stations (and therefore lowering the cost of the wireless infrastructure).

Such alternatives can include mobile networks in lower frequency bands (i.e. the UHF bands below 1 GHz, where signals 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). Therefore, the rural scenario represents a challenge but also has a great potential, since in terms of spectrum availability, the reverse situation to case a) occurs here: in rural areas, depending on the coverage obligations imposed to broadcasters, a larger supply of spectrum may be available for wireless broadband delivery.

In order to provide broadband coverage through TVWS to these large rural areas, there is an inherent need to build infrastructure: base station towers and backhaul links are needed before the user can access the network through some form of end-user equipment (be it mobile, nomadic or fixed to the customer premises). While in general broadband access provided through wireless networks would be much less cost intensive than fixed-line wired solutions, investments in wireless infrastructure are not insignificant; even if a kind of license-exempt regime is used by TVWS networks, together with appropriate regulatory measures. This cost of investment aspect may have an impact in terms of ROI for commercial providers considering TVWS network deployment, given that while the spectrum supply is high, the customer demand side is low. Further concerns may arise for investors also from the viewpoint of service protection and spectrum security of tenure: such an opportunistic spectrum use has no interference protection guarantees and has no future certainty with regard to regulatory changes arising from the reallocation of the spectrum to a different primary allocated service.

In summary, TVWS alternatives are being tested in pre-identified local areas of some countries as an option for addressing connectivity needs ranging from spectrum-congested zones in highly developed metropolitan areas (with varying degrees of UHF TV spectrum idleness) to large geographical rural areas lacking access infrastructure and needing lower-cost deployment alternatives (areas with low use of UHF TV spectrum). Considering the similar trend of increasing demand for wireless broadband across mature markets as well as in developing and rural markets, the need for efficient and sustainable spectrum use be-

comes 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. The ITU Radiocommunication Sector is providing this unique global and collaborative forum for reaching international agreement on the use and harmonization of radio technologies and systems. ICTs will continue to face increasing demand in terms of spectrum access in congested areas, as well as network expansion demands in rural regions seeking to breach connectivity gaps.

7.3 ON-GOING DEPLOYMENT OF DIGITAL TELEVISION BROADCASTING AND 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 with analogue TV). Such advancement resulted in the opportunity to reallocate new available UHF frequencies as a result of the analogue TV to digital TV transition (the **Digital Dividend**) for other uses, namely by wireless broadband applications, in response to the rapidly growing demand for mobile bandwidth⁵.

5. 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

The digital dividend is more fully realizable only once the transition from analogue to digital terrestrial television (DTT) is completed and the "switch-off" of analogue TV is carried out. Only then, the vacated UHF TV frequencies can be fully deployed for use by other services such as the mobile service, as the nature of the mobile service (bidirectional) is not technically compatible to share the same spectrum with TV broadcasting (unidirectional). If both services were to operate using the same frequency bands, harmful interference could occur, rendering both services useless. The operational nature of TV broadcasting (primary service), requiring fewer high-power transmitters at known fixed sites and receive-only user equipment (the TV receiver sets, at unknown fixed and mobile locations), makes up the current scenario for technical co-existence between opportunistic license-exempt TVWS devices and the incumbent service (coordinated through TVWS geo-location and database-managed channel use). A change in nature of the primary service, for instance from broadcasting to mobile (where simultaneous transmission and reception takes place from base stations and ubiquitous end-user devices), may lead to an incompatibility with TVWS networks, with possible financial, legal and/or other implications. This is because the mobile service tends to provide continuous coverage to ensure communications at any given location, resulting in a more

difficult identification of available white spaces, as compared with TV broadcasting, in particular considering the longer-range propagation properties of UHF spectrum.

Further, modifications in coverage objectives of transitioning broadcasting networks would also require some assessment. For instance, 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. Such probability of change in DTT networks is not restricted to transitional aspects but also to the future spectrum needs of the broadcasting service in the UHF bands.

In this sense, a realistic figure of the bandwidth available for the opportunistic secondary use of TVWS can only be obtained once analogue TV switch-off is achieved and the final DTT coverage is in place (especially if DTT is deployed using SFN). An example of such situation can be found in the African continent, part of the Geneva 06' Agreement⁶ (GE06 Agreement) for regional coordination of digital broadcasting, and where DTT transition is currently ongoing. Such a situation implies that, since the full coverage objectives of DTT have not been reached or implemented yet in some areas, a white space that appears currently vacant may not be available later on. This situation is particularly relevant in border zones, where frequency coordination is critical for avoiding cross-border harmful interference.

The above situation highlights well the importance of technically sound spectrum management⁷, which has been achieved through the collaborative efforts of countries, (a) at regional level by adopting coordinated and harmonized spectrum decisions, reflected for instance in Regional Agreements (such as the ITU GE06 Agreement) and (b) at global level, by updating the international Radio Regulations. Such updates are conducted on the basis of collaborative technical studies (ITU-R Study Groups⁸) carried out jointly by the ITU Membership: Member States, and other stakeholders (operators, manufacturers, academia, etc).

On this basis, changes in spectrum allocations and updates to the RR are made by consensus between Member States at the World Radio Conferences⁹(WRCs) and also common regional frequency plans are agreed through Regional Radio Conferences¹⁰ (RRCs). ITU-R study groups also adopt technical standards and harmonized spectrum use (ITU-R Recommendations, Reports and Handbooks) as well as best practices on radiocommunication matters. Within this framework, ITU-R is currently undertaking multiple studies to develop technical recommendations on the use of new technologies such as Software Defined Radio (SDR) and Cognitive Radio Systems¹¹ (CRS), which are relevant to the development of radio systems using white spaces. Further, at the last World Radio Conference (WRC-12), the subject of SDR and CRS was addressed and it was concluded that the RR was providing enough

6. Geneva 06 agreement can be found at: <http://www.itu.int/ITU-R/terrestrial/broadcast/plans/ge06/>

7. 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.

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

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

10. Regional Radio Conferences: <http://www.itu.int/ITU-R/index.asp?category=conferences&rlink=rrc&lang=en>

11. Resolution 58 (2012): studies on the implementation of cognitive radio systems: <http://www.itu.int/pub/R-RES-R.58-2012>

flexibility at it stands to enable the use of CRS in accordance with its provisions, recognizing in particular the obligations of administrations in preventing interference (see Recommendation 76, WRC-12).

Additionally, at 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 the mobile service on a primary basis, and to start its operation in 2015 (Resolution 232, WRC-12¹²). Appropriate measures will be taken at WRC-15¹³ in response to agenda item 1.2, which states: *"to consider to examine the results of ITU-R studies, in accordance with Resolution 232 (WRC-12), on the use of the frequency band 694-790 MHz by the mobile, except aeronautical mobile, service in Region 1 and take the appropriate measures"*.

Such decisions echoes other discussions and studies carried out in Europe and the USA 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. Further, in July 2013, under the African Telecommunications Union and ITU auspices, the Sub-Saharan African countries agreed on modifications to the GEO6 Plan in order to allocate the 694-790 MHz band to the mobile service¹⁴.

Finally, it was also agreed at WRC-12 to consider and to take appropriate action on agenda item 1.1 of WRC-15, 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 the inclusion of opportunistic TVWS systems in the planning of UHF spectrum allocations in the mid and long terms.

7.4 TVWS EQUIPMENT STANDARIZATION AND SPECTRUM HARMONIZATION

Several frequency bands have been allocated worldwide in such a way that they allow the operation of devices on license-exempt basis (e.g. ISM bands) across different spectrum frequencies. These bands accommodate a variety of devices and applications, being wireless LANs (e.g. WiFi) 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 MHz¹⁵) in accordance with ITU Resolution 229 (Rev.WRC-12). There is also an allocation in the UHF band at 900 MHz in ITU-R Region 2 (Americas) between 902-928 MHz (totaling 26 MHz

12. WRC-12 Resolution 232 can be found at: <http://www.itu.int/oth/R0A0600004B/en>

13. WRC-15 agenda item 1.1 and 1.2 can be found at: www.itu.int/ITU-R/go/rcpm-wrc-15-studies

14. See <http://www.itu.int/ITU-R/terrestrial/broadcast/ATU/index.html>

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

of bandwidth). The combined total for all three license-exempt bands used by wireless LANs is around 581 MHz of bandwidth.

TVWS device specifications are for instance currently being developed for Wireless Regional Access Networks, IEEE 802.22 WRANs (point-to-multipoint), and 802.11af for lower-power operation in a "hot-spot" fashion. The development of both standards is based on similar operational characteristics of devices using ISM bands and referred to above: license-exempt devices sharing the band with other TVWS applications. The deployment of TVWS devices could involve very large numbers of devices scattered across different areas 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. Then, the potential wireless ecosystem in the UHF bands would involve the primary service(s) sharing the band with wireless microphones (and also licensed SAB/SAP devices in some countries), TVWS opportunistic devices broadband (such as IEEE 802.22 and IEEE 802.11af), TVWS for machine-to-machine communication and any other TVWS application that may arise.

Frequency bands utilized for license-exempt applications such as those used by WiFi devices, have been used to host large numbers of ubiquitous devices, which share those frequencies collaboratively (using low power levels, short range transmissions 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 into 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/short range devices to contain their emissions within the prescribed limits (power limits and frequency boundaries).

ITU-R studies are on-going in response to Resolution ITU-R 58¹⁶ on the implementation and use of CRS technologies, in particular in the mobile services, and may lead to the development of new ITU-R Recommendations or to the revision of existing ones referred to in the RR.

16. Resolution ITU-R 58 can be found at: www.itu.int/pub/R-RES-R.58

7.5 CONCLUSIONS

One aspect of international spectrum planning, in terms of harmonizing spectrum allocations, relates to the potential impact that such harmonization may have in driving local markets. This impact can be expected to translate into long-term benefits (i.e. economy of scales of devices, overall advancement of the ICT sector and related contribution to GDP,

job market creation and support to innovation and entrepreneurship). It is therefore 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.

A long-term national ICT strategy, including the planning of wireless broadband connectivity, will need an assessment of *costs, scalability, resiliency and sustainability* of the countries' national wireless access infrastructure, if this strategy is set to support rural communities and its enterprises.

17. Internet Service Providers

- **Costs:** there are significant connectivity costs down the transmission chain and the last mile is only one section of 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 ISPs¹⁷ 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 or insufficient infrastructure resources.
- **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.
- **Sustainability:** a reasonable level of long term certainty would be expected throughout the national network and its outreaching branches, in order to support national economic objectives that would include, amongst other, *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) in the medium and long terms.

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. 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.

On the basis of the above considerations, the following questions would need to be addressed in adopting national ICT strategies:

a) What can be the potential outcomes of early policy decisions on TVWS?

Early implementation (without regulatory safeguards) through the use of idle TV spectrum presently available would endeavor to obtain immediate benefits of connectivity, provided the available spectrum is properly identified and used on an interference controlled basis. Some benefits can include reaching earlier those small communities in need of connectivity, and their earlier familiarization with wireless platforms and applications. Some uncertainties would include DTT transition not being completed, leading to unclear levels of future availability of spectrum for TVWS service provision. Also, there can be uncertainty with regard to potential changes in the regulatory environment and TVWS spectrum security of tenure, should there be a redefinition of the current primary service in the mid to long-term, resulting in financial losses for TVWS broadband service providers and users. While TVWS equipment standards are still under development and economies of scale are still pending, more clarity is needed to understand the current TVWS business case and to understand the type of service that consumers are to expect.

b) What are some of the current regulatory challenges for TVWS implementation?

One of the main tasks of a national regulator with respect to deployment of TVWS devices would be to ensure their compatible operation with incumbent services and licensed applications. TVWS devices are supposed to work on a non-interference and non-protection basis, which requires the knowledge about other radio systems in operation in the

same geographical area. Initially, the acquiring of this knowledge was seen through sensing of electromagnetic environment and choosing unused frequencies. Due to the current need for the development of more advanced and reliable solutions in spectrum sensing (to handle hidden obstacles and account for the requirements posed by very sensitive and expensive receivers) the sensing function has been replaced by geo-location databases containing information of other radio applications and neighboring TVWS. Moreover, aggregate interference into the primary service, as well as intra-service, will need particular attention especially in urban scenarios.

The establishment, maintenance and dynamic update of such databases may represent an added complexity for national authorities and would require thorough studies and trials. This aspect is especially important in the border areas, where the knowledge about radio systems used in the neighboring country is necessary. Exchange of database information would also be needed to avoid cross-border interference.

c) Could some form of security of tenure be needed to provide predictability and a long-term space for opportunistic 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 the allocation 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? 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.

d) How does a potential TVWS broadband solution fit into a long-term national ICT strategy?

There are many views on the TVWS subject and, through this paper, it is 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, legislative, regulatory, economic, technical and operational), there is

definitively no silver bullet to tackle all the challenges. Notwithstanding this, sustainable development of ICTs and efficient spectrum use are necessary goals as we move forward with new developments, such as dynamic spectrum access and TVWS.

Currently "ICT underserved" rural areas represent a challenge for policy makers and regulators in terms of achieving national ICT objectives. In allocating spectrum to operators, coverage obligations have been implemented in many countries to increment the broadband capacity levels of rural regions, with the expectation that spectrum resources licensed to operators will further serve the socio-economic and developmental needs of rural communities, as well as maximizing economic benefits in urban areas. Alternative forms of spectrum utilization (such as dynamic spectrum access and TVWS) are interesting approaches to economically complement rural broadband needs, therefore their appropriate development and maturity are encouraged and envisaged for the benefit of users.

In conclusion, 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 harmonization; as well as balancing innovation and scalability of ICT ecosystems. Initiatives striving to make more efficient use of the spectrum resource through spectrum sharing, dynamic access and cognitive radio are supported and encouraged within ITU-R technical studies, with the expectation that they will provide a valuable contribution in the future of wireless. However planning of the finite spectrum resource requires all-encompassing frameworks (technical, legal, economic and social) which need 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). Comprehensive spectrum strategies and policies need to be developed towards sustainable mid and long terms, considering the international regulatory developments; or else spectrum bottlenecks will arise as demand continues to grow. TVWS utilization needs to be assessed within such strategies.