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# The Future of International Radio Regulations: Transformation Towards Sharing

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## Abstract

While the international radio regulations (RR) do not prevent opportunistic access, the application of these regulations largely does not encourage such a concept. This is due to the existence of different elements of restriction within these regulations including the absence of a quantified definition of harmful interference and the lack of enforcement measures for resolving ITU-R interference procedures. It is argued that operating on a non-interference-basis within these regulations discourages the application of opportunistic access. Moreover, there is confusion among many of the ITU-R countries between the application of the RR when it comes to cross-border interference with neighbouring countries, and the application of the RR within the country.

In general, it is argued that the main problem with the RR is not only the restrictive elements within them, but also the paradigm that it has created over the course of the last century. Measures that could enable the transformation towards more sharing in the RR are having a dedicated band for opportunistic access devices, and allocating more bands for ISM applications. The second alternative is to enable opportunistic access in a more explicit way in the RR with more rights in higher bands. Having said that, if an entrepreneurial country or groups of countries advocate one of these measures, there could be a transformation at the international level, though this would require enough support from sufficient number of countries within the ITU-R. The last step is to include the regulations related to the concept of opportunistic access in the RR.

**Keywords:** opportunistic, spectrum, easements, RR, ITU-R.

## I. INTRODUCTION

For more than a century, spectrum management has been centred on strengthening the regulator's control over spectrum in what is called 'command and control', where the regulator manages spectrum by designating appropriate uses, technologies and users (OECD, 2006). Such an approach has been criticised for creating an artificial scarcity that is due to inefficient utilisation rather than spectrum shortage (Wellenius and Neto, 2005). Meanwhile, since the 1990s, there has been an intense debate over which of spectrum market, spectrum commons, or spectrum easements approaches should substitute the command and control.

In particular, while the market approach calls for treating spectrum assignments in a similar way to other property rights and allowing spectrum usage flexibility (Coase, 1959; Hazlett, 1998), spectrum commons enables spectrum open access for all users and as a result render license exclusivity and spectrum scarcity obsolete (Baran, 1995; Benkler, 1998; Gilder, 1994; Noam, 1995; Noam, 1998). Spectrum easements is an approach that is based on allowing other users rather than the spectrum owner to use the spectrum as a non-interference easement (Faulhaber and Farber, 2003).

The practice of these three alternatives has not occurred with the exception of specific concepts such as 3G auctions and technology neutrality within the International Mobile Telecommunications (IMT) standards, or for particular technologies such as Wi-Fi in the ISM bands (El-Moghazi et al., 2015). Meanwhile, in most of the world, especially in developing countries, radio spectrum is managed along the lines of traditional government administration although significant changes have been introduced into the telecommunications market (Wellenius and Neto, 2007).

Having said this, in a previous paper we investigated the influence of the international spectrum management regime on adopting the concept of opportunistic access in the TV white spaces (TVWS) (El-Moghazi et al., 2016). It was found out that the international regime does not prevent the adoption of such an approach. However, there are different elements of restriction that have an influence on a regulator's decision with respect to the deployment of TVWS.

In this paper, we will explore the main elements within the international RR that may have a negative influence on the concept of opportunistic access in general, and then we discuss the alternative remedies for these elements in the forms of modification to the RR that enable more easements in spectrum. In other words, we ask a simple question: 'what modifications are needed in the RR in order to encourage more sharing to the spectrum?'. This is important; while the international regime does not prevent TVWS, we did not find any evidence that it encourages the concept of opportunistic access in general.

The rest of the paper is organised as follows. In Section II focuses on the spectrum policy debate while Section III provides a brief overview of the RR. In Section IV, we explore the restrictive elements within the RR that have negative influences on the concept of opportunistic access. Section V is a discussion of the way forward for the RR in order to enable more sharing internationally. Conclusions are drawn in Section VI.

## II. SPECTRUM POLICY DEBATE

Broadly speaking, national spectrum management policies have four main elements: radiocommunication service allocation, technology selection, usage rights type, and assignment type (Chaduc and Pogorel, 2008). The first element, service allocation, is the distribution of the spectrum to different radiocommunication services (e.g., mobile, broadcasting) (Foster et al., 2011). Service allocation can be flexible, neutral or harmonised. The second element is technology selection, which can be neutral, restricted to standardised technologies or selective of specific technologies. The third element is usage rights. Chaduc and Pogorel (2008) define three categories of spectrum usage rights: exclusive property rights, exclusive with easement, or collective (non-exclusive). The fourth element of spectrum management policy is frequency assignment where there are three categories: administrative, market-based, or license exempt (Chaduc and Pogorel, 2008).

In general, opportunistic access is based on allowing a certain right to use the property of another without actually possessing it. Easements in spectrum were mainly proposed by Faulhaber and Farber (2003), who suggested an approach based on allowing other users rather than the spectrum owner to use the spectrum. In general, there are two main types of access within spectrum easements: overlay (opportunistic) and underlay access. Overlay devices access the spectrum at the geographical, time or frequency gaps of the licensed users' transmission as long as not causing harmful interference (e.g., TVWS). Underlay access implies that a secondary user will transmit at low power levels, within the noise floor of licensed spectrum (e.g., UWB) (Cave and Webb, 2012).

Overlay or opportunistic access is promoted by technologies such as Cognitive Radio System (CRS) that are capable of measuring the radio environment and learning from experience in order to transmit dynamically in the temporal unused frequencies without the need of exclusive allocation (Mitola, 2000). One of the main candidate spectrum bands for CRS operations is TVWS, which refers to the geographical interleaved vacant frequencies in the TV spectrum. The practice of TVWS has varied around the world with limited commercial deployments and trials with several criticisms of the concept (Almarzooqi, 2014; Ntra of Egypt, 2014).

### III. INTERNATIONAL RADIO REGULATIONS

The international RR were created in the early days of wireless communications to handle the phenomena of interference, and the refusal of the Marconi company to relay messages received from competing operators (Anker and Lemstra, 2011). Accordingly, an international conference was held in Berlin in 1903 to address the Marconi company monopoly over radio telegraphy and to enable international interconnection (Coddington, 1991). The final protocol of the conference established that wireless stations should operate in a way as not to interfere with other stations (Coddington and Rutkowski, 1982). The participants also signed the convention to regulate wireless telegraphy (Headrick, 1992).

By the mid-1920s, the issue of harmful interference became more serious as Europe and North America were full of broadcasting stations using unregulated frequencies (Savage, 1989). Accordingly, the 1927 International Radiotelegraph Conference witnessed a shift from focusing on the regulation of the radio traffic towards allocating the spectrum to separate services (Woolley, 1995), and the concept of “common use of common frequencies” gained momentum (Levin, 1971). The conference decided to establish a new committee - International Radio Consultative Committee or CCIR, which later became ITU-R - that undertakes technical studies in the intervals between radio conferences (Coddington, 1991).

The main principle of the RR is that all radio stations must not cause harmful interference to other stations which operate in accordance with the provisions of these regulations (ITU-R, 2008e). The RR have international treaty status and are binding for all the ITU-R countries (Maitra, 2004). On the other hand, ITU-R recommendations do not have legal status similar to the ITU-R RR unless they are incorporated by reference in the RR (McLean Foster & Co., 2013). The main element of the RR is the allocation of the radio spectrum to one or more radio services with equal or different rights (primary and secondary). Stations of a secondary service cannot cause harmful interference to stations of primary services, and cannot claim protection from harmful interference caused by stations of a primary service (ITU-R, 2008c). Furthermore, the ITU-R divides the world into three regions in terms of spectrum allocation (ITU-R, 2012b). If a country or group of countries want to have different spectrum use than the regional allocation in a specific band, they may add a footnote to the RR stating their particular use. However, other neighbouring countries may block such use if it will restrict their own use (ITU-R, 1995a).

Alternatively, article 4.4 of the RR enables countries to use frequencies in a way that is not in conformity with the RR on the condition that such use shall not cause harmful interference to, and shall not claim protection from harmful interference caused by, a station operating in accordance with the RR (ITU-R, 2008b).

The RR are amended at major conferences called World Radiocommunication Conferences (WRCs) that are convened every three or four years. The previous WRC was in 2015 and the next one is scheduled for 2019. WRC resolutions and recommendations are part of the RR and have international treaty status. Significantly, the agenda of the current conference is determined by the previous one. Items that could be included in the agenda include revisions to the RR and any other question of a worldwide character that falls within the remit of the conference (ITU, 2011).

There have been several attempts to review the main principles of the RR. The first step was when the 1989 Nice Plenipotentiary Conference noted that the RR were rather complex, unwieldy and difficult to apply. A Voluntary Group of Experts (VGE) was established to study the simplification of the RR in order to enable improved flexibility when using spectrum (Woolley, 1995). The recommendations of the VGE studies were introduced during WRC-95. The VGE recommendations called for retaining the main principles of the RR including maintaining a table of service allocation covering the useable radio-frequency spectrum (ICAO, 1995). The most important aspect of the VGE recommendations was that future WRCs should, wherever possible, allocate frequency bands to the most broadly defined services with a view to providing the maximum flexibility to administrations in spectrum use, and should, wherever possible, allocate frequency bands on a worldwide basis (ITU-R-R, 1995b).

The issue was also raised at WRC-03, motivated this time by the convergence of radiocommunication services as exemplified by services such as mobile-TV (ITU-R-R, 2003a). WRC-03 decided that the existing regulatory framework contained sufficient flexibility to minimise any regulatory constraints resulting from the existing definitions of services (Gavrilov, 2003). However, WRC-03 considered also in resolution 951 that segregating bands for different radiocommunication services may not achieve the best possible result in terms of spectrum efficiency (ITU-R-R, 2003d).

The issue was not resolved at WRC-07, which decided to continue to study the issue until WRC-12 under agenda item 1.2 (ITU-R-R, 2007). Following WRC-07, the ITU-R studies approached the issue from two perspectives. The first focused only on convergence between fixed and mobile services, while the second addressed spectrum allocation issues more generally (ITU-R-R, 2011a). Eventually WRC-12 decided not to change current spectrum allocation practices with regard to the two issues (ITU-R, 2012i), to end the general studies of enhancing the international spectrum regulatory framework under resolution 951 (ITU-R, 2012g) and to continue the studies on revising the definitions of fixed service, fixed station and mobile station until WRC-15 (ITU-R, 2012h).

In addition, WRC-12 also called for the ITU-R to study all aspects of interference management resulting from the impact of technical convergence on the radio regulatory environment, involving stations that may

operate under more than one terrestrial radiocommunication service, particularly cross-border interference cases (ITU-R, 2012d). WRC-12 recognised that the principles behind radiocommunication services and spectrum allocation have been adopted since the first Radio Telegraph Conference in Berlin in 1906, and that countries may adopt other approaches on the national level. However, WRC-12 also asserts that this can be done through the application of the RR article 4.4 (ITU-R, 2012e).

The studies reporting to the WRC-15 indicate that the discussions resulted in retaining the current definitions for the fixed service, fixed station and mobile station as they have been able to adapt to technology evolution, and that there is sufficient flexibility within the present RR (ITU-R, 2014). Eventually, WRC-15 decided to introduce no changes to the RR, and to keep the current service definitions.

In general, the concept of opportunistic access or spectrum easements exists in the ITU RR in three main forms. The first one is the co-existence of primary and secondary services as secondary services operate in the same spectrum bands with primary services without causing interference or claiming protection against interference from primary services. For instance, underlay devices such as short range devices (SRD) are perceived to operate on secondary basis as mobile service (RSPG, 2011).

The second form could be considered as the operation on non-interference basis (NIB) according to RR Article 4.4. One example of that is the Wi-Fi devices which operate on a non-protection, non-interference basis and with low powers (Anker and Lemstra, 2011). These devices usually operate in the what is called Industrial, Scientific and Medical (ISM) spectrum bands such as 2400-2500 MHz and 5725-5875 MHz (ITU-R, 2012b). These bands are designated for ISM applications, and radiocommunication services operating within these bands must accept harmful interference which may be caused by ISM applications (ITU-R, 2012b).

The third form is the sharing between co-primary services. One example of this is the sharing between Wi-Fi devices, which are categorised as primary mobile service, and other primary services in the 5 GHz band. Such allocation was initiated by the European countries who proposed to consider additional spectrum allocation to mobile service in the frequency ranges 5150-5350 MHz and 5470-5725 MHz to gain global harmonized frequency allocations for radio local area networks (R-LAN) (CEPT, 2000). Eventually, WRC-03 decided to allocate the bands 5150-5350 MHz and 5470-5725 MHz on a primary basis to the mobile service for the implementation of wireless access systems (WAS), including R-LANs (ITU-R, 2003c). WRC-03 agreed also on allowing sharing of the 5 GHz bands between radiolocation service (radar systems) and mobile service (R-LAN) on a primary basis upon using DFS and TPC to facilitate spectrum sharing (ITU-R, 2003b; ITU-R, 2011b).

In addition to the previous three forms of non-exclusive access, WRC-12 recommended that any radio system implementing CRS technology should operate in accordance with the provisions of the radio regulations and that the use of CRS does not exempt administrators from their obligations with regard to the protection others operating in accordance with the RR (ITU-R, 2012f).

#### IV. ANTI-SHARING PARADIGM

In the previous section we have briefly explored the different forms of opportunistic access within the RR. In a previous paper (El-Moghazi et al., 2016) we addressed the restrictions of the international spectrum management regime on the adoption of a specific application of opportunistic access, that is, on TVWS. The examination of such an issue shows that the international regime does not prevent the adoption of opportunistic access in the TVWS. However, there are different elements of restriction that have an influence on a regulator's decision regarding the deployment of such a concept. These elements are dependent on a country's relationship with its neighbouring countries, the perception of the TVWS concept and how the international regulations are interpreted. This includes not having a service allocation where TVWS devices can operate, having additional mobile allocation and the placing of broadcasting services in the UHF band.

In this section, we focus on the radiocommunication service allocation framework within the RR and the restrictive elements of introducing more sharing in the spectrum via opportunistic access. Firstly, the idea of allocating the radio spectrum into different radiocommunication services started when the WRC of 1906 that divided the spectrum into public correspondence, military and naval bands (Savage, 1989). Following this, the concept of sharing between the different services' allocations started as early as the RR of 1912. Sharing was conditioned by not causing interference to bands that are used exclusively by a certain service (e.g. broadcasting). The main rationale behind spectrum service allocation is the management of interference between radio stations (Louis and Mallalieu, 2007). Having said that, interference management is the basis of any national spectrum management approach. In particular, the command and control approach is based on granting exclusive license to control interference (Freyens, 2009). Meanwhile, within spectrum easements, not causing interference to the existing users is a condition for these opportunistic access devices.

Therefore, it is worth examining the interference concept embedded within the current RR. Firstly, the roots of the current interference paradigm go back to the first International Radiotelegraph Convention in 1906, which established the right of states to transmit on unused frequencies throughout air space without disturbing the services of other radio stations (Zacher, 1996). This was mainly because the issue of



interference was acute at the beginning of the twentieth century as radios transmitted over a wide band of frequencies due to the lack of knowledge of how to tune the transmitters and receivers. It was difficult to limit interference for several reasons. Firstly, even tuned transmitters emitted several frequencies. Secondly, measures of wavelengths could only be estimated after 1905. Thirdly, many operators preferred to transmit over a wide range of frequencies to avoid the precise adjustment of receivers. Finally, transmitters used to transmit with large power to reach long distances (Kruse, 2002).

Currently, harmful interference is defined, according to the ITU-R RR, as: “*interference which endangers the functioning of a radio navigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with Radio Regulations*” (ITU-R, 2008d). Vries and Sieh (2012) criticise the ITU’s broad definition of interference as it adds additional restrictions on new entrants and does not explicitly indicate which transmission will cause harmful interference.

The interference resolving procedures in the RR are initiated when the victim country fills a report of harmful interference (ITU-R, 2012a). The rest of the procedures are based on the goodwill of involved administrators. Most importantly, the ITU-R Bureau (BR) can assist when asked in determining the source of interference. However at the end of the day, the role of the BR is limited to forwarding its conclusions and recommendations to the administration reporting the case of harmful interference, and to the administration believed to be responsible for the source of harmful interference together with a request for prompt action (ITU-R, 2008d).

Accordingly, resolving any dispute will refer to the values of permissible interference and accepted interference based on the ITU-R Recommendations (Indepen, 2001). However, this degradation of service or limitations of interference are not accurately defined or quantified in many cases in the RR, and the ITU-R recommendations do not cover all cases of interference and thus some solutions cannot be enforced. Additionally, it is outside the authority of the ITU to enforce or bring sanctions to those who seek to operate outside its agreed procedures (Cronk, 2011). More specifically, while these recommendations are usually based on worst-case scenarios in terms of interference probability, they are not enforced as they are ‘merely’ recommendations (Indepen, 2001).

Even these recommendations do not contain any provisions related to spill over between neighbouring countries, and there is no recommendation dealing with the issue, which is mostly left for multi/bi-literal agreements. In fact, this is the main problem with the international interference management, which focus on the ex-ante procedures of interference management because the ex-post procedures are not strict or enforced effectively (Rspg, 2013). Moreover, the ITU-R does not have any mechanisms for identifying

sources of interferences or determining whether it is unintended or due to jamming. Finally, there are no measures for the ITU-R to investigate the actual spectrum use (Struzak, 2007b).

Secondly, similar to the command and control which has traditionally placed the burden on transmitters to resolve interference, even if receivers are of low performance (Vries and Sieh, 2012), the RR focus is usually on the transmitters. In particular, it is stated in RR Article 15 that transmitting stations shall radiate only as much power as is necessary to ensure a satisfactory service, and that directional antennae should be deployed when possible (ITU-R, 2008d). On the other hand, the RR state that “*the performance characteristics of receivers should be adequate to ensure that they do not suffer from interference due to transmitters situated at a reasonable distance and which operate in accordance with these Regulations*” (ITU-R, 2008a). However, there are no quantified details on either the transmitter power or the characteristics of receivers.

Thirdly, examining RR article 4.4, which allows operating on NIB, reveals that the application of such an article provides no cross border protection against interference (Louis, 2011). Thus, even if operating according to the RR article 4.4 is reasonable in terms of transmitted power and used antennas, it does not have any protection against interference from neighbouring countries, which may use exaggerated characteristics. This, of course, does not provide any type of encouragement to the adoption of flexible spectrum use models such as opportunistic access. Hence, while article 4.4 allows for non-interference operations, for many countries such an article is not used in practice or is not reliable for commercial or public sector usage as usually stated through ITU-R discussions. More specifically, in practice, when a country requires a new allocation and a neighbouring country calls for operating on a NIB according to 4.4, this implies allowing nothing in practice.

Fourthly, article 9.21 is extensively used in the RR and argues to restrict opportunistic access, especially in cases of additional allocations. Such an article requires that before an administration notifies the ITU-R Bureau or brings into use a frequency assignment for any station of a service for which the requirement to seek the agreement of other administrations is included in a footnote to the RR table of frequency allocations, it shall seek the agreement of the affected administrations by such allocation (ITU-R, 2012c). Article 9.21 is perceived to be similar to article 4.4 in several aspects in terms of discouraging more sharing of spectrum. Firstly, it indicates no interference on existing radiocommunication services or neighbouring countries. Secondly, it is becoming increasingly unpopular, as it does not guarantee protection against interference from the prospective of some of the administrations. In fact, the practice of 9.21 application indicates that it is not much used in reality (World Radiocommunication Report, 2015b).

Fifthly, another issue that is considered to be restrictive to sharing is the confusion of many of the ITU-R countries between the application of the RR when it comes to cross-border interference with neighbouring countries, and the application of the RR within the country. This issue was raised by Sweden prior to WRC-15 with respect to the differences between the RR service allocation and actual national use of radio spectrum (Sweden, 2014). In particular, it was clarified that that the RR accommodate several frequency bands that are allocated to more than one radiocommunication service, even if they are not compatible. Accordingly, the result of the sharing between existing services allocations and potential additional services allocations should be based on the possibility for cross-border interference and not on the compatibility within a given country. In other words, the RR should not be applied to services that do not cause harmful interference to the stations of another country (Jones, 1968). In fact, such perception was perceived by Coase (Negus and Petrick, 2009), one for the first to call for flexibility in spectrum use more than fifty years ago and who argued that flexibility is already accommodated in the RR on the condition of not causing interference to neighbouring countries (Coase, 1959). The issue is that this is not the dominant paradigm within the ITU-R countries.

Sixthly, WRCs usually consider additional spectrum allocations for radiocommunication services that have increasing demand (e.g., mobile service for IMT systems). However, the issue is that most of the radio spectrum is traditionally allocated to historical services. Thus, any additional service allocation or IMT identification should take into account the existing use and should not place any additional burdens on the services to which the band is currently allocated to. This is one of the reasons why in past WRCs it was not possible to agree on most of the candidate bands to be identified for IMT.

Another paradox with the RR is that while there is a recommendation within the RR to allocate spectrum to broadly defined services, it states in other parts that using a broadly defined service where its subset radio services have widely different protection ratios may result in a degradation of performance requirements (ITU-R, 2012e). Therefore, the RR do not implicitly encourage having this broadly defined services that allow for greater flexibility in spectrum use.

## V. TRANSFORMATION TOWARDS SHARING

While in the previous section we discussed the restrictions emerged from the different elements of the RR on opportunistic access and sharing in general, in this section we discuss the transformation process towards more sharing in the RR. In fact, we argue in this paper that the main problem with the RR is not only the restrictive elements within it, but rather the paradigm it has created over the last century. In particular, while the RR do not prevent national regulators from introducing opportunistic access to

spectrum, and technologies such as CRS could operate under current service allocation (Anker, 2010), the RR do not encourage opportunistic access due to many reasons. Having mentioned that, we argue that the transformation towards more sharing in the RR could be done through several measures.

The first of these measures is to have a dedicated band for opportunistic access devices. We understand that by having a dedicated band, this would be more of a spectrum commons than spectrum easements. However, opportunistic access to the spectrum occupied by dominant services, such as broadcasting, is quite restrictive. Therefore, it is suggested to have this dedicated band for these devices so that there would be no resistance from the current primary users. In fact, that was a concept embedded in the early versions of the RR where there were dedicated bands for experiments (ITU-R, 1927).

The idea of a dedicated band was largely proposed by Lehr and Crowcroft (2005), who argue that dedicated unlicensed spectrum, where all unlicensed devices are considered primary users, will gain the full benefits of spectrum commons rather than overlay or underlay. It was further argued that underlay or overlay regime are not likely to gain the full benefits of the unlicensed model, as limitations on transmitted power for underlay devices may deter their applicability. This was also supported by Tonge and Vries (2007) who pointed out that the combination of both licensed and licence-exempt allocations will result in a greater citizen benefit than each individually. Lehr (2004) also argues that it is important to allocate dedicated spectrum for unlicensed use rather than focusing only on allowing spectrum easements as the regulatory diversity enable future proof policy.

In fact, the internet provides evidence that a decentralized architecture in spectrum allocation will provide more benefits to the end users (Benkler, 1998). In addition, the 2.4 GHz ISM band already accommodates billions of ISM devices and still operates efficiently.

The second measure is to allocate more bands for ISM applications where devices could operate in a similar way to Wi-Fi operating in the ISM bands at 2.4 GHz. The issue here, however, is that the last time the ITU-R decided to allocate bands for ISM was at the WRCs of 1947 and 1959 and, more recently WRC-79 that accepted an increase in the number of bands to be designated for ISM equipment (ITU-R, 1979). One may ask why sharing and opportunistic access would be more enabled in the ISM bands. The answer is that the deployment of spectrum easements approach is challenging in practice in any other bands where there are primary services mainly because of the non-fairness of these primary users who tend to limit this secondary access to their spectrum. This occurred in the case of TVWS. In particular, broadcasters in many countries opposed the introduction of TVWS in spectrum bands where they operated. Meanwhile, the ISM application did not have the aggressive industry structure that restricted access to ISM bands. If that were the case, we would not enjoy the Wi-Fi services that are available today.

The third measure is to enable opportunistic access in a more explicit way in the RR with more rights in higher bands where there is less use of the spectrum while still being secondary to the primary services. Having said that, there is a tendency within the ITU-R to allocate more bands for technologies that require exclusive allocation such as IMT and, with the movements towards 5G, the next WRC-19 will discuss several potential spectrum bands in the higher frequencies to be identified for IMT (ITU-R, 2016). The danger of this is that it pre-judges the future of spectrum management and focuses on the exclusive allocation to the mobile industry, which is against the concept of opportunistic access. Therefore, we suggest enabling this measure in higher spectrum band where there is mostly a global allocation. Therefore, the ITU-R should encourage such a type of operation by providing it with minimum legal or regulatory status according to the RR, as this provides some sort of certainty. This is important, as the current paradigm for many ITU-R countries is that opportunistic access via 4.4 is considered as the opposite of the RR. In other words, there is a perception that the ITU-R focus is on primary services of high power high tower between countries unlike, for example, the case of TVWS.

The fourth suggested remedy for the restriction from the traditional service allocation and categorisation is to map the most common allocation in a specific band onto other bands that have similar characteristics. More specifically, sharing between the different services in the same band is already accommodated in several bands where there are allocations to more than one service. It should be noted that while sharing could be possible in one band in one region, this does not mean it is the case for the other ITU-R regions. However, many differences exist due to the historical separations between the ITU-R three regions. This is demonstrated by the observation that in the higher frequency bands there is usually a common service allocation across the world.

One application of such a remedy is to apply the co-primary allocation between the mobile and broadcasting service in the 700 MHz band to the rest of the UHF band (470-698 MHz). It is also suggested to apply the most dominant allocation in any of the three regions in the two other regions. Such a step would enable more co-primary allocation across the whole radio spectrum, and, accordingly, provide more flexibility for future radio system.

Another restriction against having more co-primary or co-secondary services in one band is the restriction from countries that are geographically separated from other countries with the same region (e.g., Russia is far away from most of the African countries that are also within Region 1) or from countries in neighbouring regions (e.g., Iran lies in Region 3 but has many neighbours in Region 1). The remedy for this could be to apply population distribution maps instead of the current separations between the three regions that was based mainly on the historical disagreement between the US and Europe (Mazar, 2009).

The fifth suggested measure to manage interference while allowing for more flexibility in service allocation is to set general service-neutral values for interference parameters across all frequencies at the geographic boundary of every country by way of a multilateral agreement, where the ITU can act as an arbitrator in the event that dispute resolution is necessary (Lie, 2004). Another method is to define generic technologies and service models based on anticipated use and reasonable expected receiver performance (Louis, 2011). We understand that this particular remedy is difficult to be applied in practice, but it is suggested here that an appropriate starting point is initially a few frequency bands that could then be expanded if successful.

The next step after considering these measures is to have an influential or entrepreneurial country (or groups of countries) promote one of them in a future WRC. In fact, that was exactly what happened with regard to the case of Wi-Fi in the ISM bands where the transformation was led by the US. More specifically, while the ISM bands were firstly allocated in the WRC of 1947 (ITU-R, 1947), that decision was taken shortly after the US adopted similar decision (USA, 1948). Moreover, that band was initially allocated to ISM in the RR of 1947 in Region 2, where the US is located, and in some countries in Regions 1 and 3. It was then allocated globally in the RR of 1982 (Ard-Paru, 2012). A major change in the use of these ISM bands was when the FCC decided in 1985 to open up three ISM spectrum bands (915 MHz, 2.4 GHz and 5.8 GHz) for Wireless Local Area Network (WLAN) (Lemstra et al., 2011a). The decision led to a similar transformation in the band 2.4 GHz in Europe (Lemstra et al., 2011b).

Another example of policy transformation was in 1992 when the spectrum band 5.150-5.350 GHz was allocated in Europe for WLAN (Cept, 1992). The industry in the US was emboldened by that decision and called, in 1995, for a similar allocation in the 5 GHz band in the US for WLAN. Consequently, the FCC allocated the spectrum bands 5150 to 5350 MHz and 5725 to 5825 MHz for the operation of the unlicensed national information infrastructure (U-NII) devices (Anker and Lemstra, 2011). Following this, WRC-03 decided to allocate the band on a primary basis for mobile services (ITU-R, 2003c). In such a case, the Wi-Fi regulations in the 5 GHz involved taking the European regulations on what they called HIPERLAN and turning them into international regulations mentioned in the RR (CEPT, 1992).

In both cases, the transformation of a particular concept was first initiated by an entrepreneur country (e.g., US), and the domestic preference of this country was adopted by other countries. The international platform of the RR was then used to promote such concept on the international level. In fact, the transformation of the international telecommunication regime has also been through similar steps (Ratto-Nielsen, 2006). Finnemore and Sikkink (1998) emphasise the role of entrepreneurs and the existence of international organisational platforms to promote new concepts. At that stage, if a critical mass of

countries supports these concepts, there could be a transformation at the international level. Ratto-Nielsen (2006) also argue that there is a 'loop effect' between domestic preferences and changes internationally in the telecommunications sector.

We suggest that for the concept of opportunistic access, the US would be the optimum entrepreneur as it lies in a separate region (Region 2) than the other main stakeholders in the ITU-R (Europe and Asia in Regions 1 and 3 respectively), which could be useful for any possible transformation in the RR. In particular, this would enable the US to be sufficiently autonomous in order to experiment with new spectrum use models and technologies.

The last step for this transformation to prevail around the globe is to include the regulations related to the concept of opportunistic access in the RR. We believe such a step is quite critical to get acceptance for the concept, and to achieve global harmonisation. In particular, many countries, especially the developing ones, need measures from the ITU-R to coordinate with their neighbours. Evidence of the influential effect of the RR is that there has been a few violations of the RR (Zacher, 1996). In fact, this extends to the ITU-R recommendations, which, although they are not treaty instruments, are still widely adopted and most countries comply with them most of the time (Ratto-Nielsen, 2006). This could be related to the fear of interference in case a country is not following the RR. However, as shown in the previous section, the ITU-R procedures are not effective in resolving actual cases of interference. Therefore, while there is hardly any enforcement of the RR, the enforcement is largely driven by the international legal status of the RR that countries sign and agree to oblige by.

Therefore, it is argued that by strengthening the role and functions of the ITU-R in terms of how it handles harmful interference, this may provide the confidence necessary for regulators and operators to introduce more opportunistic access into their service allocation in a way that is not as conservative as hitherto been the case. More specifically, the way the ITU-R is currently involved in interference resolution should be debated with one suggestion being that it should have a more enforcing role. This could be achieved via establishing regional monitoring stations to determine sources of harmful interference and identify the responsible country(s). Another suggested way to manage interference while allowing service neutrality is to set general service-neutral values for interference parameters across all frequencies at the geographic boundary of every country by way of a multilateral agreement where the ITU can act as arbitrator in the event that dispute resolution is necessary (Lie, 2004).

Having mentioned that, we believe that the transformation process would be faced with resistance from the international community. In particular, it is argued that the RR have become a tool for the main stakeholders in the international domain to block spectrum uses that are not in their interest (Kelly, 2002).

For instance, there have been several attempts to modify the current RR structure and functions during WRC-1995, WRC-03, WRC-07, WRC-12, and WRC-15, but each time there was a perception that there is a need to modify the RR to accommodate greater flexibility and to handle the deficiencies in the international service allocation framework. However, each time, it was agreed by most of the ITU-R countries to keep the current situation with largely no changes.

With respect to the industry, significant investment has been made in the existing radio system that may postpone the mass production of any other radio even if it is more spectrum efficient (Struzak, 2007a). Moreover, Benkler (2011) argued that the exclusivity advocates usually out-lobby and out-bid the commons supporters because they can internalize the full benefit of auctioning and other spectrum management measures that strengthen their exclusivity of the spectrum. For instance, the main argument of the mobile industry against TVWS was that eliminating the cost of acquiring licensed spectrum and providing cellular-type mobile services could create an unfair advantage (GSMA, 2013).

In addition, Benkler (1998) explains how the evolution of the decentralized model of spectrum allocation will face resistance from the current institutional arrangements. These arrangements are mostly enjoyed by the regulators, which, for many decades, have been strengthening their command over the spectrum. In particular, Hazlett (2001) explains that regulators usually tend to monitor inefficiency resulting from over-utilization rather than those associated with under-utilization. In addition, opportunities for new services and technologies are usually under-valued by the regulator compared to existing ones. Moreover, regulators usually favour inaction, as they do not face tangible deficits if new entrants are blocked. They also cannot anticipate or measure the benefits and cost provided by the market.

Another reason for the resistance is related to the perception on technologies of opportunistic access and spectrum easements approach. More specifically, there were high expectations and not realistic ones with regard to CRS (Forde and Doyle, 2013). In fact, this was a key problem, especially for regulators who embraced a type of management that enabled strict control on the spectrum as it limited their willingness to move towards technologies that are perceived to access any part of the spectrum and access it without the need for approval by regulators.

Furthermore, it is perceived that the current spectrum management approach is based on the historical model of wireless broadcasting. Therefore, the current allocation is based on powerful transmitters on the operator side and simple receivers on the end users side (Benkler, 1998). This is in contrast with the opportunistic access model, which is based on moderate transmitting power devices. Moreover, as the developing countries are a majority in the ITU-R, and they would probably refuse any innovative measures of spectrum sharing as it may threaten existing services.



The issue is that all these resistance forces are empowered by the current ITU-R decision-making procedures. In particular, introducing any changes required for dynamic spectrum access to the ITU-R table of allocation may take 5-10 years while nationally it may only take 6 months to 2 years (Berggren et al., 2004). This is because WRCs usually favour the protection of existing systems and applications (Radiocommunication Bureau, 2007). Accordingly, it is expected that existing services would lobby to resist any additional allocation on a co-primary or co-secondary basis. This was quite apparent in the last WRC-15 where the broadcasters industry opposes any co-primary allocation in the UHF band (World Radiocommunication Report, 2015a).

Another issue is that developing countries would almost certainly refuse any change to the rule of one vote per country as their collective numbers provide them with influence and power within the ITU (U.S. Congress Office of Technology Assessment, 1982). Therefore, although the ITU-R decision-making process is based on consensus, the ability to use voting may block the transformation process. Moreover, Lyall (2011) argues that the insistence of the developing countries on what they consider to be their rights may eventually damage the ITU as an institution as the increasing emphasis on the developing countries' requirements could distort the functionality of an organization like the ITU that focuses on the technical side of international telecommunications. In other words, the present decision-making procedures are tailored towards developing countries because it is a very slow system; this is good for these countries that need more time, or have more equipment life left in their network.

Our suggested remedy to the decision-making procedures is to have more frequent meetings of WRCs, such as, for example, every two years. Another suggestion to facilitate introducing more innovative ways of spectrum sharing is not to change the one vote per country rule to one favouring population size. As the majority of the ITU-R countries are from the developing world, it is likely that they would oppose such a move. Under such a scenario entrepreneurial countries such as the US may have more influence over discussions.

Last but not least, one must admit that the RR may be innocent from creating such paradigm as sharing has been part of the RR framework since the early days of wireless communications. For instance, only 0.8% of the European common allocations table consists of exclusive allocations (Forge et al., 2012). However, it is argued that such a paradigm has been created due to the immaturity of radio technologies during the early day of wireless communications (Horvitz, 2013). Moreover, this has led to the focus on protection against interference that is argued to cause delays to the development of more robust, interference resistant equipment for many decades (Forge et al., 2012).

Having said that, we admit that change is difficult as many bands have considerable existing infrastructure investments. Accordingly, while the suggested measures have different degrees of applicability we believe that the most applicable is the third one where, in higher bands, there is not much use of the spectrum. Moreover, mitigation techniques could enable sharing with these existing users especially in those bands where propagation distances are quite small. Furthermore, we suggest that the frequency bands where such measure could be applied should include part of the candidate bands for IMT-2020 (e.g., 50 GHz, 66 GHz).

## VI. CONCLUSIONS

Broadly speaking, national spectrum management policies have four main elements: radiocommunication service allocation, technology selection, usage rights, and assignment type. The spectrum easements approach in spectrum management is based on allowing exclusive spectrum property rights with easements. In particular, opportunistic access is based on allowing a certain right to use the property of another without possessing it.

At the international level, the main principle of the RR is that all radio stations must not cause harmful interference to other stations that operate in accordance with the provisions of these regulations. Article 4.4 of the RR enables countries to use frequencies in a way that is not in conformity with the RR on a NIB. The concept of opportunistic access or spectrum easements exists in the ITU RR in three main forms. The first one is the co-existence of primary and secondary services without causing interference or claiming protection against interference from primary services. The second form could be considered as the operation on NIB according to RR Article 4.4. The third form is the sharing between co-primary services in the same band.

In general, while the RR do not prevent opportunistic access, there is no evidence that they encourage such concept. This calls for examining the restrictive elements within the RR on introducing more sharing in the spectrum via opportunistic access. The main rationale behind spectrum service allocation is the management of interference between radio stations. The issue with the interference paradigm within the RR is that there is no quantified definition of harmful interference in many cases. In addition, international interference cases are mainly resolved due to the goodwill of the involved administrators. Resolving any dispute will refer to the values of permissible interference and accepted interference based on the ITU-R recommendations, which do not have procedures for enforcement. It is considered that the international interference management focuses on the ex-ante procedures, and the ITU-R does not have any mechanisms for identifying sources of interferences. Secondly, examining article 4.4, which allows

operating on NIB, reveals that the application of such an article in practice for opportunistic access is not encouraging. Thirdly, there is confusion among many of the ITU-R countries between the application of the RR when it comes to cross-border interference with neighbouring countries, and the application of the RR within the country per se.

It is argued that the main problem with the RR is not only the restrictive elements within it, but also the paradigm it has created over the course of the last century. Therefore, we suggest different measures to enable the transformation towards more sharing in the RR. The first of these measures is to have a dedicated band for opportunistic access devices, as most spectrum bands are currently occupied by dominant services, which restrict access to the spectrum. The second is allocate more bands for ISM applications where devices could operate in a similar way to the Wi-Fi operating in the ISM bands in the 2.4 GHz. The third suggested measure is to enable opportunistic access in a more explicit way with more rights in higher bands where there is less use of the spectrum. The fourth is to map the most broadly and commonly allocation in a specific band in one region to the other two regions in bands that have similar characteristics. Moreover, population distribution maps could be applied instead of the current ITU-R three regions system.

The next step after considering these alternatives is to have an influential or entrepreneurial country, or groups of countries, promote one of them at a future WRC. At such a stage, if a critical mass of countries supports these concepts, there could be a transformation at the international level. The last step for this transformation to prevail around the globe is to include the regulations related to the concept of opportunistic access in the RR. However, it is expected that the transformation process would be faced with resistance from the international community who benefits from the current institutional framework.

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