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TVWS policies to enable efficient spectrum sharing

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TVWS policies to enable efficient spectrum sharing

Abstract:

The transition from analogue to the Digital Terrestrial Television (DTV) in Europe is planned to be completed by the end of the year 2012. The DTV spectrum allocation is such that there are a number of TV channels which cannot be used for additional high power broadcast transmitters due to mutual interference and hence are left unused within a given geographical location, i.e. the TV channels are geographically interleaved. The use of geographically interleaved spectrum provides for the so-called **TV white spaces (TVWS)** an opportunity for deploying new wireless services.

The main objective of this paper is to present the spectrum policies that are suitable for TVWS at European level, identified within the COGEU project. The COGEU project aims the efficient exploitation of the geographical interleaved spectrum (TVWS). COGEU is an ICT collaborative project supported by the European Commission within the 7th Framework Programme. Nine partners from seven EU countries representing academia, research institutes and industry are involved in the project. The COGEU project is a composite of technical, business, and regulatory/policy domains, with the objective of taking advantage of the TV digital switchover by developing cognitive radio systems that leverage the favorable propagation characteristics of the UHF broadcast spectrum through the introduction and promotion of real-time secondary spectrum trading and the creation of new spectrum commons regimes. COGEU will also define new methodologies for compliance testing and certification of TVWS equipment to ensure non-interference coexistence with the DVB-T European standard. The innovation brought by COGEU is the combination of cognitive access to TV white spaces with secondary spectrum trading mechanisms.

JEL codes: L96, L50, L40, K23

Keywords: telecommunications, spectrum management, secondary spectrum market, regulation, TV white spaces, cognitive radio

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TVWS policies to enable efficient spectrum sharing

1 Introduction

The transition from analogue to the Digital Terrestrial Television (DTV) in Europe is planned to be completed by the end of the year 2012. The transition is done according to the ITU 2006 Frequency Plan (the so-called Geneva Agreement or GE-06) [17]. Throughout Band III (174-230 MHz) and Band IV/V (470-862 MHz), this Plan assigns each country in Europe (and beyond) channels for the broadcasting service. It also takes into account other existing primary services in these bands.

Some countries are not making use of all their assigned channels, and thus in 2007, ITU identified, at WRC-07, the sub-band 790-862 MHz (TV channels 61-69) additionally for IMT (International Mobile Telecommunications). Some European countries have already auctioned out this band to the Mobile Service, creating thus the Digital Dividend.

The broadcasting band, especially at UHF, has always been used by other services or devices on a secondary (i.e. non-interfering) basis. Typically these were wireless microphones and other TV production equipment (often referred to as PMSE). The switchover to DTV will provide additional possibilities for the usage of the so-called “white spaces” due to the fact that DVB (the DTV technical system used in Europe) is a more robust transmission format than the vestigial sideband modulation which was used for the analogue TV systems PAL or SECAM, and can thus operate at significantly reduced protection ratios².

There may be countries where the DTV switchover will release a more or less significant amount of valuable spectrum bands. There are other countries where this is not the case or where there is only very little spectrum release due to a high usage by TV services and due to the fact there must be some headroom for the further development of DTV towards higher-data rate services such as HDTV or 3DTV. Some spectrum is also needed for the second DTV switchover, i.e. the transition to the second generation of DTV (DVB-T2). But even if there is no space for a digital dividend, there will be, if properly done, additional opportunities for both licensed and unlicensed devices in the broadcast spectrum. Spectrum regulators may thus seek to achieve a balance between commons and market-oriented spectrum management regimes.

It is to be noted, that the DTV spectrum allocation is such that there are a number of TV channels which cannot be used for additional high power broadcast transmitters due to mutual interference and hence are left unused within a given geographical location, i.e. the TV channels are geographically interleaved. The use of geographically interleaved spectrum use provides for the so-called **TV white spaces (TVWS)** an opportunity for deploying new wireless services.

The COGEU project³ aims the efficient exploitation of the geographical interleaved spectrum (TVWS) [20]. COGEU is an ICT collaborative project supported by the European Commission within the 7th Framework Programme, under the project no. 248560 for the

² Part of that advantage is already compensated by the reduced transmit power of the DVB sender when compared with analogue frequency plans. Reception at a given location is always a mix of available transmit power (carrier-to-noise ratio) and governing interference by co-channel and adjacent channels of a different broadcasting service (carrier-to-interference ratio).

³ www.ict-coge.eu

years 2010-2012. Nine partners from seven EU countries representing academia, research institutes and industry are involved in the project. The COGEU project is a composite of technical, business, and regulatory/policy domains, with the objective of taking advantage of the TV digital switchover by developing cognitive radio systems that leverage the favorable propagation characteristics of the UHF broadcast spectrum through the introduction and promotion of real-time secondary spectrum trading and the creation of new spectrum commons regimes. COGEU will also define new methodologies for compliance testing and certification of TVWS equipment to ensure the coexistence with the DVB-T European standard. The innovation brought by COGEU is the combination of cognitive access to TV white spaces with secondary spectrum trading mechanisms.

Bearing in mind the absence of specific, strong regulatory guidance on the use of TVWS, but mindful of regulatory trends towards technical and service neutrality, COGEU will also identify regulatory needs to support the proposed applications, in both commons and market-based frameworks. In particular, the success of secondary markets will depend on the confidence of sellers that buyers will not misuse their temporary usage rights, therefore policies need to be investigated that provide a reasonable validation of the buyers being restricted to their TVWS in time, space and frequency. The project also investigates policies against market abuse (anti-monopoly issues); for instance, the use of clearing systems and trade registers, together with strong competition laws and their enforcement, can mitigate against the risk of market abuse.

If part of TVWS is to be traded as a commodity, the amount of policing and enforcement of illegal or accidental polluting of spectrum needs improvement from today's standard practice. Therefore this task will make suggestions with respect to the digital switchover regulation that is needed towards the realization of true spectrum sharing systems at European level.

The main objective of this paper is to present the spectrum policies that are suitable for TVWS at European level, identified within the COGEU project and broadly elaborated in [5]. The arrangement of this paper is as follows.

Section 2 summarizes the current status of the regulatory framework on the use of cognitive technologies in the TV white spaces, presenting global and European points of view.

Section 3 discusses policies necessary to establish free and efficient spectrum markets in general, including definition of the spectrum rights, validation of buyers, legal protection for users, means of determining prices, dispute resolution mechanisms between market players and the role of public agencies.

Sections 4 and 5 present the proposed regulatory policies to incentivize and enable the COGEU model for TVWS usage, including policies for secondary trading of TVWS, policies for automation of spectrum trading, policies to protect competition, policies to protect the primary users, policies to control the geo-location database and policies to promote a single market in the TVWS.

Section 6 concludes the paper and contains a set of recommendations.

2 Current regulatory framework for the use of cognitive TVWS systems

The successful implementation of secondary spectrum trading requires a commitment to change current view of regulatory bodies with a solid base in understanding new technologies and operating systems. Spectrum policies must address the incentives for innovation in order to promote spectrum's assignment flexibility while clearly establish the usage rights and obligations of those who use the spectrum to transmit or receive information. Furthermore, the spectrum flexibility also demands new approaches and practical methods for the monitoring compliance, enforcement and conflict resolution.

The spectrum is a shared and scarce resource, thus the implementation of spectrum's policies largely depends on the advances in radio technologies that are designed to facilitate spectrum sharing. A way forward is the steps to be taken by international regulatory bodies or nationwide entities in the scope of TVWS and cognitive systems. In this section, a review is given of the ITU – an international regulatory body established by the United Nations – and the frequency regulators in the USA (FCC and NTIA), citing their perspectives and approaches in addressing spectrum sharing.

2.1 Global trends on secondary spectrum trading

The governance of spectrum usage on a global basis is a core responsibility of the **International Telecommunication Union (ITU)**, in particular, their Radio Communication Sector (ITU-R). The mission of the ITU-R sector is, beyond others, to ensure rational, equitable, efficient and economic use of the radio frequency spectrum bands by all radiocommunication services.

The ITU World Radiocommunication Conference (WRC), held roughly every four years, convenes the delegates to consider amendments to international regulations and spectrum allocations, which are necessary to accommodate new technologies and applications. The agenda for the next WRC, scheduled for 2012 (WRC-12), invites delegates *“to consider regulatory measures and their relevance, in order to enable the introduction of SDR and cognitive radio systems, based on the results of ITU-R studies.”* In the ITU-R preparation for WRC-12, one of the agenda's points is the ITU Resolution 951 [18] that enhanced the international spectrum regulatory framework. This resolution establishes the guidelines used in evaluating and developing concepts related to four identified options in order to enhance the spectrum regulatory framework and prepare solutions to be discussed at WRC-12. The four options include:

- Keeping the current practice as it is;⁴
- Reviewing and possibly revise the current service definitions or add a new service to the list of service definitions, which would encompass several of the existing ones;
- The introduction of a new provision in the radio regulations enabling the substitution between assignments of specific services;
- The introduction of composite services in the table of frequency allocations.

A composite service is a conglomeration of existing web services working together to offer new value-added services. The four options aim to develop concepts and procedures to improve the Radio Regulations. The ITU Resolution 951 identifies that further studies are needed in order to develop concepts and procedures for enhancing the radio regulations to meet the demands of current, emerging and future radio applications, while taking into account existing services and usage. The studies shall consider that evolving and emerging radiocommunication technologies may enable sharing possibilities and may lead to more frequency-agile and interference-tolerant equipment and consequently to a more flexible use of spectrum. Moreover, in [16], ITU considers the relevance in the introduction of software define radio (SDR) and cognitive radio (CR) systems. The studies of ITU have shown that SDR using cognitive control mechanisms is considered to be a good approach for achieving better spectrum utilization, dynamic spectrum management, and flexible spectrum usage. Finally, [19] shows the application and implications of SDR to land mobile systems, including issues on the efficient use of spectrum using SDR techniques and adaptive control mechanisms. As a conclusion, any change to improve the flexibility of administrations in

⁴ WRC-12 is most likely to decide in line with this option as both CEPT and USA are supporting this position.

accommodating converging services has to rely on a combination of service definitions and allocations of spectrum. Improving flexibility and the timeliness of their implementation will therefore require continuation of the studies by cognitive radio for the successful implementation of secondary spectrum trading.

2.2 USA view

In the USA, the Federal Communications Commission (FCC) is committed to find 500 MHz of new spectrum for wireless broadband use in the next decade; however, so far only 25 MHz have been allocated. The FCC has planned to preserve white space as a buffer for inaccuracies in signal broadcast. However, with newer and better technology, it is believed that these tiny portions of the spectrum may not be needed any more. What the FCC has done is to defend the flexible use of spectrum without fixed owners, allowing the parties to adjust.

The FCC followed two initiatives: in the first initiative, broadcasters voluntarily repay part of the 500 MHz spectrum through auctions of incentive. The spectrum would be auctioned out and the broadcasters would receive part of their income. The second initiative was the release of vacant TV channels for unlicensed applications, such as “Super Wi-Fi”.

The so-called “Super Wi-Fi” technology is the first to receive a significant block of spectrum designated for unlicensed use in more than 20 years. As expected, the FCC approved the licensed “white spaces” but now comes the hard part: taking “Super Wi-Fi” technology to the market. The usage of white spaces that exist within the US TV band (470-698 MHz) allows for faster speeds and large coverage areas, thanks to favorable propagation characteristics (the waves penetrate walls more easily than at higher frequencies). This technology is expected to go a long way towards mitigating the looming spectrum crisis.

FCC claims that white space technology promises to be good for business, hence creating a powerful platform for innovation. More importantly, the FCC’s database approach for managing spectrum and mitigating interference on a real time basis firmly establishes a new paradigm in how spectrum can be optimally used.

The white spaces approval has shown the neutrality of FCC in the national plan for broadband wireless access. In November 2008, the FCC adopted rules to allow unlicensed radio transmitters to operate in the broadcast TV spectrum at locations where that spectrum is not being used by licensed services. The commission decided to rely on a combination of spectrum sensing with geo-location access to a database of existing spectrum use to determine if a channel is available [13]. However, in September 2010, FCC eliminated the sensing requirement for white space devices (WSDs) that include geo-location database functions (as petitioners argued that sensing technology was not sufficiently mature for consumer devices and would delay market entry) [13].

In its secondary market’s policies and rules, the FCC has sought to further enable the dynamic access and use of spectrum by licensees and other spectrum users. Specifically, FCC has established procedures to facilitate access to spectrum across various dimensions (e.g. frequency, space or time) employing advanced technologies [12]. In [15] the FCC took additional steps to facilitate the development of spectrum usage arrangements that employ advanced technologies that more efficiently share/use licensed spectrum.

Later in the end of January 2011, the FCC designated nine entities as TV bands device database. Additionally, it is also stated in the same document that TV bands databases will be used by fixed and personal portable unlicensed devices to identify unused channels that are available at their geographic locations.

Regarding the SDR and CR systems, the USA does not believe that changes to the radio regulations are needed to address these technologies. With respect to the definitions, description, or characterization of SDR, there is no need to include a definition of SDR or CR

in the radio regulations. As these technologies may also be implemented in license exempt devices, which operate on a non-interference basis after being authorized by an administration [25].

The National Telecommunications and Information Administration (NTIA) will need to modify the USA table of allocations to reflect any reallocation of spectrum to a non-federal use or to add non-federal use in cases involving spectrum sharing. For frequency bands that are to be auctioned, the NTIA will coordinate guidance concerning relocation timetables so that the auction participants are clearly notified when auction winners will have access to the auctioned spectrum. Prior to any auction, if there are geographic aspects to such access, or varying time periods, this information will be concatenated so that the FCC can make it available to prospective bidders in advance of the auction. In addition, during the relocation process, the FCC, NTIA and the federal agencies will work cooperatively to ensure that the new non-federal licensees have access to the frequencies by the established dates. For bands identified for exclusive non-federal use, the FCC also may need to identify incumbent non-federal systems that share the use of spectrum bands, define a timetable for their relocation, and ensure that those users are appropriately accommodated [22].

2.3 European trends on secondary spectrum

Regulatory control over the use of the spectrum makes it easier for the regulator to ensure that excessive interference does not occur because the regulator is able to carefully model the interaction between neighboring services and tailor the license conditions appropriately. It also allows for other regulatory goals to be achieved – for example, ensuring that a service is available on a pan-European basis, or imposing coverage requirements to achieve ubiquity of services. Finally, it can result in high technical efficiency of spectrum usage [1]. It is up to the regulator to decide which equipment to exempt, what the rules for its operation should be, how much spectrum should be set aside for its operation and where in the frequency band this should be. The current spectrum allocation process operates at both a national and international level. International coordination is essential in some cases because the zones of possible interference extend beyond national geographical boundaries. Broadly, international bodies tend to set out high-level guidance which national bodies adhere to in setting more detailed policy. In some countries, there are multi-national bodies coordinating across a region. For example, this is very much the case within Europe where the European Union (EU) and the Confederation of European Post and Telecommunication Agencies (CEPT) provide further harmonization. Broadly, these bodies can be seen as local versions of the ITU, providing further coordination. Different bodies have differing levels of power. For the CEPT their decisions, like those of the ITU, are non-binding but if a country deviates from them it is expected not to cause interference to its neighbors as a result. However, the EU has legal powers and is able to require national spectrum managers under its jurisdiction to enact decisions.

Following the initial assignment of spectrum rights and obligations to users, whether by auction or other means, circumstances may change causing initial license holders to want to trade their rights and obligations with others. Today this is not possible in many countries. However, in a few countries such as the UK, secondary trading is possible once the process of primary assignment has been completed⁵. The possibility to trade radio spectrum is argued by many commentators to be a critical factor in the promotion of more efficient radio spectrum use. Furthermore, it is increasingly recognized that the flexibility afforded by trading is helpful for innovation and competitiveness.

⁵ A review of regulatory environment in this matter is presented in [5].

In Europe, the European Commission is taking the lead in promoting harmonized trading for radio spectrum where its use has a European dimension. Emphasis is being placed on certain bands below 3 GHz, where it is estimated that the net benefits from trade may be substantial. Despite fairly widespread recognition that the current regime of spectrum management operating in most of the European Union is not sufficiently flexible to achieve the Union's objectives in promoting competitiveness and innovation, thus far the pace of reform is slow, although some necessary steps have been put in place, and the European Commission is promoting liberalization across the EU.

In September 2005, the Commission published a Communication on a market-based approach to spectrum management in the European Union [10], which noted that a fragmented approach to spectrum reform would make it more difficult to achieve the Union's objectives. Accordingly, it proposed the coordinated removal of restrictions on spectrum use in all Member States in order to promote an open and competitive digital economy. In practice it was suggested that substantial amounts of spectrum, including roughly one-third of the spectrum below 3 GHz (the spectrum best suited for terrestrial communications) could possibly be made subject to tradable and flexible use by 2010 (which did not happen). Clearly the Communication is a key document in which the Commission has nailed its colors to the liberalization mast.

In 2006 the Commission proposed that greater flexibility in spectrum management could be introduced by strengthening the use of general authorizations whenever possible [11]. Also, selected bands agreed at EU level via a committee procedure would become available for use under general authorizations, or subject to secondary trading across the EU. Common authorization conditions for the use of the radio spectrum would also be enacted with this procedure in appropriate cases. Unfortunately, this does not amount to a complete reform of spectrum regulation of the EU, in the direction of pan-European markets.

Under the framework directive, Member States have the right to set the conditions of use of spectrum which radio equipment has to meet. These conditions can include appropriate limits that aim to avoid harmful interference to other radio services. These conditions can be harmonized on a European-wide basis either through a European Commission Spectrum Decision (which is mandatory for EU member states to implement) or by implementing an ECC Decision or Recommendation. Alternatively, if no mandatory harmonized guidance is available, a regulatory deliverable can be developed on a national basis.

In all the above cases the conditions of use of radio frequencies are put in national regulations that are administered either through general or individual authorization models (most administrations manage through use of individual licenses and/or license exemption). The current regulation on spectrum usage already includes relevant mechanisms to address sharing arrangements and conditions. These existing mechanisms can also be used for the introduction of CR technologies.

It is assumed that the essential requirement of the R&TTE directive fully applies to CR devices and they do not need to be amended. All the different possible stages of configurability of an apparatus with CR support have to fulfill the requirements of the R&TTE directive. Therefore most of the test procedure and relevant measures aiming at ensuring the compliance at different stages of the CR device functioning should be included in harmonized standards. These specificities need to be described in a guide to be addressed by ETSI. This guide should therefore also be brought to the attention of the notifying bodies.

The RSPG opinion [24] assumes that the manufacturer is responsible for the CR device to be compliant with the R&TTE directive, where ETSI is expected to provide suitable guidance on how to meet compliance with the R&TTE directive for cognitive functionalities.

The R&TTE directive has been proven to be a valuable tool to reduce administrative efforts while, at the same time, it is assured that equipment brought to the market is in line with regulations. Usually the aim of regulations is to make the products safer and/or more interchangeable and such paves the way to the markets for these products. In this way, the manufacturer has a vital interest to fulfill the requirements of R&TTE directive.

In the case of CR devices, however, one aim is to protect the existing users. In this special case being fully in line with the directive may limit the functionality of the device whereas violating some of the requirements might, in the user's view, cause an "improvement" in device functionality.

German broadcasters, ARD and ZDF, therefore believe that self-certification by the application of Harmonized Standards according to the R&TTE directive is not a safe way to guarantee non-interfering operation of CR devices within the broadcast bands, especially when bearing in mind that possible interferers may be difficult to identify in the field. Hence we recommend to allow only such devices to be brought to market that were certified by a neutral institution. This is in line with the regulation of FCC which also requires such equipment to be certified for the US market.

In particular, harmonized standards should include specifications:

- For the exchange of information between the CR device and the database;
- To ensure that the CR devices will be connected with the relevant database;
- On the geo-location systems;
- On the need for the CR device to obtain the authorization to emit from the database.

Except in case of databases managed by administrations there is currently no regulatory framework requiring accreditation of databases and conditions, which the database has to meet [1].

CEPT ECC had launched a number of activities in relation to CR [23]:

- In response to industry initiatives, CEPT ECC has developed spectrum regulation and sharing conditions for pre-cognitive technologies (UWB DFS, DAA, RLAN) in strong cooperation with ETSI;
- CEPT ECC has already published a report on "white spaces": CEPT Report 24 is a preliminary assessment of the feasibility of fitting new/future applications/services into no harmonized spectrum of the digital dividend (namely the "white spaces" between allotments);
- CEPT ECC is already preparing a position for WRC-12.

Following a workshop organized by CEPT in January 2009, other initiatives are highlighted as follows:

- The majority of administrations support the view that the ECC should take a proactive role in driving the regulatory work on CR. This approach was especially supported to facilitate the introduction of CR, to respond to requests from industry and to encourage industry investments as the industry may be waiting for some regulatory signal before investing in CR. This approach calls for active cooperation between CEPT and industry;
- A project team of the CEPT Spectrum Engineering Working Group (SE43)⁶ is defining technical and operational requirements for the operation of cognitive radio

⁶ In 2009, at its 53rd meeting and following a request from the ECC, WGSE decided to set up a new project team, SE43, dealing with white spaces and cognitive radio systems (excerpt from Doc. SE43(09)01, Terms of Reference and Work Item for SE43, 10 June 2009)

systems in the “white spaces” of the UHF broadcasting band (470-790 MHz) to ensure the protection of incumbent radio users/systems and investigate the consequential amount of spectrum potentially available as “white space” [9];

- An ECC correspondence group comprising a large number of stakeholders is also active in identifying tasks to be undertaken by the ECC by taking into consideration feedback from initial investigations by SE43 and the experience gained on pre-cognitive systems;
- Finally ECC also decided to task its Frequency Management Working Group (WG FM) to start to identify possible candidate bands for cognitive radio systems [23].

ETSI have initiated various work items and project teams (e.g. TC RRS, ERM, BRAN etc) to look at standardization issues around CR and SDR. A detailed view of the relevant project teams and their responsibilities are described in Table 1 [24]:

Table 1: ETSI project teams and their responsibilities relevant to CR/SDR

Project Team	Title	Scope
TC BRAN	Broadband Radio Access Network	Responsible for all aspects of standardization for present and future broadband radio access networks, including: <ul style="list-style-type: none"> - Radio and regulatory aspects, - Lower layer protocol aspects, - Architectures, transmission and inter-working aspects of access networks, - Aspects of transport network interfaces.
TC ERM	EMC and Radio spectrum matters ERM TFES	Primary responsibility for: <ul style="list-style-type: none"> - ETSI deliverables (in whole or in part) dealing with EMC; - ETSI deliverables (in whole or in part) dealing with radio spectrum parameters concerned with inter-system characteristics; - Co-ordination of ETSI positions on the efficient use of the radio spectrum and spectrum allocations.
TC RRS	Reconfigurable Radio Systems Four Working Groups: <ul style="list-style-type: none"> - System Aspects - Equipment Architecture - Cognitive Management and Control - Public Safety 	Responsible of standardization activities related to Reconfigurable Radio Systems encompassing system solutions related to Software Defined Radio (SDR) and Cognitive Radio (CR); <ul style="list-style-type: none"> - To collect and define the related Reconfigurable Radio Systems requirements from relevant stakeholders; - To identify gaps, where existing ETSI standards do not fulfill the requirements, and suggest further standardization activities to fill those gaps; - To deliver its findings in the form of ETSI deliverables as appropriate; - To provide ETSI with a major centre of expertise in the area of Reconfigurable Radio Systems.

In February 2010 the RSPG published a first report on cognitive technologies [23]. The report also highlighted that the use of white spaces in the UHF band might be one of the first applications of CR. In this opinion it is assumed that the manufacturer is responsible for the CR devices to be compliant with the R&TTE Directive. This differs from SDR equipment where the responsibility for compliance may be divided between different hardware and software providers. However, with recognition of the role of ETSI to provide suitable

Harmonised Standards (HS) under the EC mandate, suitable guidance will have to be provided with respect to how compliance with the R&TTE Directive for Cognitive functionalities can be met.

Cognitive radio has been proposed and promoted as a technology to alleviate today's spectrum scarcity problems. Actual usage of the spectrum varies considerably, dependent on various parameters like, for example: the number of applications which are sharing the same frequency band, the number of users in a specific area and in a specific period of time, and the environment (urban versus rural with their difference in demand). Cognitive radio technologies are seen as an enabler providing more efficient use of spectrum and providing more dynamic access to spectrum. The following definition has been set by the ITU-R Study Group 1 in Recommendation ITU-R SM.2152.

In a recent report [24]⁷, RSPG addressed possible implications to the EU spectrum policy in relation to the implementation of CR technologies, including those operating in TVWS. Basic RSPG notes and considerations are as follows:

- In several European countries, licenses have been given for the provision of digital terrestrial television in the UHF bands for the next 15 to 20 years;
- The licensing period, planning requirements and use of the incumbent services in the UHF band (i. e. Broadcast and PMSE) varies between different national administrations. This will have an impact on the timing and amount of white space that could be made available for use by cognitive devices;
- CEPT is, in the first instance, the most appropriate entity to undertake any Europe wide studies in order to identify spectrum available and develop sharing conditions in order to implement CR technologies;
- Academia and researchers have already assessed the technical issues related to cognitive radio technologies;
- ETSI is the appropriate standardization body to develop harmonized standard related to devices with CR technologies;
- In case of databases, there does not seem to be any European regulatory framework applying to accreditation of databases;
- Harmonization of CPC at European level should remain on standardization level until technical and commercial uncertainties have been solved.
- The R&TTE Directive covers all of the essential requirements that can be applied to CR devices;
- The existing regulatory framework already covers devices that implement sensing techniques to enable sharing between different services;
- Technical and legislative options involved in this transition should not be determined by economic factors alone but ought also to take account of social, cultural and political factors;
- Promising new services fostering growth and innovation are seeking access to spectrum;
- The amount of spectrum available for cognitive radio use is still to be studied and evaluated;
- CR devices may enable and/or improve spectrum sharing in a number of bands;

⁷ This report was subject of a consultation at the beginning of 2011. It should be noted that COGEU prepared response to the above mentioned RSPG opinion [2].

- There does not seem to be any discernable support at this time to introduce harmonized frequency allocations to accommodate CPC, but some standard bodies have introduced the possibility of sharing with other services by recognition of beacons which could be part of the incumbent normal protocol;
- EU funded research covering the following activities: evaluation of terminal radio frequency hardware and computations constraints relevant to sensing, leading to specifications of suitable embedded hardware and computing capabilities, definition of sensing scenarios, by taking into account several radio environments, evaluation of communications resources that are necessary for interfacing sensing components in case of cooperative sensing and for connection to the database, evaluating the safety mechanism to be implemented in order to ensure a safe data communication (for database and cooperative sensing) to prevent degraded functioning.

Based on these observations and considerations, the RSPG recommends [24]:

- That implementing measures to introduce the CR technologies in some bands could be left to member states as long as border coordination issues are addressed and other recommendations from the list below are taken into account;
- A platform shall be created to allow researchers, academia and regulators to coordinate research activities;
- Administrations, when implementing CR technologies that require to utilize databases should (possibly with guidance developed in the CEPT): indicate how the databases should be certified or accredited, supplied and updated by national regulatory bodies, and to supply relevant information to CR systems, provide information to database managers on algorithms, provide information on incumbents directly or through a designated entity;
- Administrations and the EC should request ETSI to study the relevant means that could be implemented in order to secure the access from CR devices to the relevant database and the exchange of information between them;
- Administrations, in relation with the EC and TCAM, should give to ETSI relevant information on suitable data elements, equipment behavior and output signal radio characteristics which will allow ETSI to develop harmonized standards;
- Any CR harmonized standard developed by ETSI should include: compliance testing instructions under R&TTE Directive, relevant information on how CR device could access only certified or authorized databases, HS information that should be given to CR devices from the database for a given period of time, information to be supplied by the CR device to the database including appropriate geo-location information, means needed to secure transmission between the database and the CR device;
- That TCAM should keep Notified Bodies up to date regarding specific requirements under the R&TTE Directive for CR devices;
- That in order to provide some confidence to all stakeholders, EC should investigate if JRC facilities can be made available to carry out proof of concept testing on CR devices supplied by industry.

2.4 Impact in the COGEU model

The successful implementation of secondary spectrum trading requires a commitment to change current view of regulatory bodies with a solid base in understanding new technologies and operating systems. Spectrum policies must address the incentives for innovation in order to promote spectrum's assignment flexibility while clearly establish the usage rights and obligations of those who use the spectrum to transmit or receive information. Furthermore,

the spectrum flexibility also demands new approaches and practical methods for the monitoring compliance, enforcement and conflict resolution.

In the regulatory aspect, it has been shown that: spectrum regulators in most European countries (with the exception of the UK), are still in an exploring stage. Regulators will need to be satisfied that they have specified appropriate conditions of access which protect incumbent users and allow feasible operation of cognitive devices and systems, including additional regulatory considerations such as management of database solutions.

As illustrated, it can be seen that reaping the benefits of cognitive technologies in TV white spaces in the European context is an iterative process between technology feasibility, market potential and regulatory feasibility. In the light of market potential, technical feasibility and regulatory policies in the US and the UK, it follows that, the COGEU project is timely and feasible in regulatory and market as well as technical aspects. A summary is presented in the Table 2.

Table 2: Regulatory trends and their impact on COGEU

Scope	Trend	Comment
Globally	There is a need to harmonize the use of spectrum at a global stage.	<ul style="list-style-type: none"> Realization takes long time (years). ITU considers relevance in the introduction of SDR and CR systems as a good approach for achieving better spectrum utilization, dynamic spectrum management, and flexible spectrum use.
USA (FCC)	<ul style="list-style-type: none"> Emergence of companies involved in the USA. Geolocation is considered enough to protect incumbents. Database operators. 	<ul style="list-style-type: none"> Regulator's participation has enabled the emergence of startups in using TVWS. Standardization efforts are underway through the IEEE, e.g., 802.22, 802.11af, etc. Nine entities were designated as TV bands device database administrators so far.
Europe	<ul style="list-style-type: none"> The usage of TVWS is fragmented among member states. Need for harmonization. R&TTE directive. 	<ul style="list-style-type: none"> Harmonization efforts are important through regional bodies like CEPT, RSPG, ETSI. The COGEU project offers concrete approaches in achieving harmonization of the exploitation of TVWS among member states. These includes proposal of the broker, geo-location database, and "safe harbor" concept for PMSE, etc. ETSI have initiated various work items and project teams (e.g. TC RRS, ERM, BRAN etc.) to look at standardization issues around CR and SDR. Under the amended framework directive, Member States have the right to establish secondary spectrum market (art. 9b).

3 Policies for free and efficient spectrum markets

In this section we discuss what is known as good practice regarding the specific market of spectrum market. We start to discuss the rights both for buyers and sellers, next the dispute resolution mechanisms and, finally what is the role of the regulator.

3.1 Rights to the spectrum buyers and sellers

The sale of the spectrum is the same as selling goods or services. Whenever goods or services are sold, a new contractual agreement shall be established between the seller and the buyer. The buyer undertakes to pay the requested price and the seller undertakes to deliver the goods or services at that price according to the seller-buyer contract. Generally speaking, the buyer can claim for the following rights:

- If the goods are dangerous in any way, there shall be a warning;
- The goods must be of reasonable quality and undamaged;
- The goods may not be second hand (unless advertised as such); and
- The goods must be provided with the necessary, easily-understood instructions.

Sellers have an integrated view of their products and present it to the buyer. The seller is the one that is responsible for the contractual interface with the buyer to sell the products; provide the buyer with support when requested, and bill the buyer for the products supplied. The seller is responsible for acting on behalf of the value network that he represents in relationships with intermediaries as well as with the buyer.

Both buyer and seller have the right to expect the other party to act in an ethically correct manner. The seller has the right to expect that he will be paid properly for his goods or services, while the buyer has the right to expect that the seller will not try to mislead him.

When the goods are time-based, buyers and sellers require clarity over the expiry of usage right. If the duration of a usage right is uncertain, or approaching its end date, this will depress the value of the license, so the right to leave merchantable must be sufficiently clear about the use restrictions (e.g. in cellular networks, usage area or maximum allowed neighborhood interference).

In the secondary spectrum market foreseen by COGEU [4] the spectrum selling by the broker is based on auctions (more requests than offers). Thus prices of spectrum depend on the supply and demand, location, frequency and geographical time. Therefore, for a trade to occur, the needs of the buyer and seller must be conform. As a result, the number of participants in a market of the spectrum must have a reasonable number. However, the broker can increase the thickness of the market by adopting suitable negotiation mechanisms that create the opportunity and will enhance the spectrum user to conduct a negotiation.

As a legitimate business enterprise, auctions cannot be proscribed. They are not above reasonable regulation by both state and local authorities. Some states subject auction sales to taxation. In the absence of statutes, any person can act as an auctioneer, but a license, which usually restricts his or her authority to a certain region, is often required. Licensing officers can refuse to issue a license, but only if done reasonably, impartially, and to promote the interest of the community.

The following text depicts the rights of buyers and sellers and focuses the particularities of COGEU's approach namely with the secondary spectrum market.

3.2 Sellers

In spectrum sales within COGEU, transactions and other costs incurred by the parties are reduced because of the central point (broker) that mediates negotiations between the various secondary users who want to buy spectrum channels. However, this refinement also suffers from high transaction costs because the central broker needs to send several messages to the buyers (and inquire the geo-location database) informing them about the current provision of free spectrum and negotiate with each player.

The seller (broker) has to make sure that buyers will pay the spectrum usage rights of spectrum sold and the price at which the seller is willing to release the spectrum. All the

transactions shall be grounded in confidence; and preference may be given trusted users when the seller exercises its right of preemption. Preemption means the contractual right under which a party has the first opportunity to buy an asset before it is offered to a third party. The lower confidence of the seller, the less meaningful is the notion of releasing spectrum in a preemptive basis and thus lowers the distinction between the releases of spectrum in a preemptive vs. non-preemptive basis. The smaller significance of this distinction, the less likely spectrum trading may occur.

However, technology is now available that can give the public sector spectrum user's high confidence that it will be able to regain nearly instantaneous use of spectrum. On this basis, a seller may be hesitant to conduct a spectrum trade because of "performance risk". Government agencies often employ spectrum on an intermittent basis to, for example, coordinate relief efforts in the event of a natural or human disaster. It is often suggested that, because of the stochastic nature of such events, they should permanently occupy, on an exclusive basis, such spectrum. In permitting such assignment, the existing spectrum management system treats such government spectrum users as if they are "infinitely risk averse".

When a buyer purchases the spectrum he has to ensure that what was bought is in accordance with the request, in terms of location, bandwidth and lease time (see Figure 1). However, it is up to the broker in primary instance, to check the correctness of the allocation.

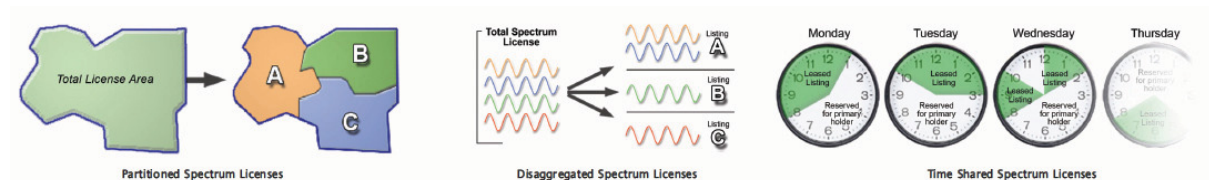


Figure 1. Spectrum availability [26]

3.3 Buyers

The broker transfers to the buyer a set of exclusive rights to be used in certain parts of the spectrum, in certain geographic areas and at certain times, governed primarily by technical rules to protect against harmful interference and by trade rules to protect against anti-competitive behavior. These rights are initially allocated to secondary users by the authority spectrum (broker). Other prospective users of these frequencies must obtain the broker approval and agree on terms and conditions. Owners may reconfigure (divide or aggregate) and trade their spectrum rights without limitation and not being limited in technologies (e. g. LTE or Wi-Fi) to comply with technical regulations and trade rules.

Trading of spectrum rights can take various forms. In a sale, the ownership of spectrum rights is permanently transferred to another party. But for the COGEU it involves the sale of spectrum rights of another party with a repurchase agreement on a temporary basis. Options establish a right to buy, or an obligation to sell spectrum rights in certain conditions (for example, a fixed price) by a fixed date.

In future contracts, to buy or sell spectrum at a later date may be determined in the terms and conditions. It is believed that once the basic framework of spectrum rights is in place, developing specific trading mechanisms can be left largely to the market.

Facilitating transparency in spectrum markets would enable market forces to steer prices more effectively towards efficient levels. This might involve, for example, maintaining a public register providing information about the ownership of spectrum.

When there are buyers and sellers, shall always be implemented efficient dispute resolution mechanisms, as next discussed.

3.4 Dispute resolution

The dispute resolution among market players has to take into account that the operation of each system can adversely affect the performance of others and the normal operation of a system may prevent the operation of another. COGEU spectrum sharing are closely related with the minimization of the negative impact that a TVWS systems causes on the performance of primary users (DVB-T and PMSE).

In the market when licenses for spectrum are being initially offered, auctions can create competition for spectrum. However it is often the case that the successful licensee is precluded from trading the license at anytime afterward. Continuous reselling of spectrum becomes possible when a secondary market operates in respect of either spectrum that has been auctioned or of spectrum initially allocated by administrative methods but which is now been cleared for trading. When a secondary market is combined with flexibility in spectrum use, licenses can be deployed by the original licensee or, after a trade, by another firm in a new innovative use. Auctions alone merely introduce an initial market-based selection by organizations that will highly exercise specified spectrum usage rights, whereas secondary trading seeks to develop a primarily market-based solution both for spectrum assignment and for spectrum allocation, on the condition that flexibility in use is allowed.

These secondary market policies and rules are intended to facilitate the use of advanced technologies, such as opportunistic spectrum usage that can be provided by cognitive radio (CR) devices, that have the potential to increase access and use of underutilized or unused licensed spectrum. As further improvements in these technologies come along, it is foreseen that licensees and other spectrum users must find ways to employ these secondary market mechanisms.

Some of the dispute mechanisms are: regulatory and court adjudication, negotiation and mediation, arbitration [5]. Next we highlight the role of regulation in the dispute resolution.

3.5 The role of regulation

The regulator plays an important role in the protection of users (namely low value users), primarily through the exercise of regulatory functions, and then with the supervision and information disclosure.

At the level of consumer disputes, the regulator has no role in arbitration, mediation or resolution of disputes between service providers and their users. In this context, and over the complaints made to it, it falls to this authority:

- Provide information to users, in particular with regard to the regulatory powers of action and reaction media that are available to them;
- Identify situations in which it is necessary to intervene at the level of regulation or supervision;
- Execute punishment of companies for which non-compliance was identified; and
- Ensure, from the register of complaints and other requests from users, production and dissemination of statistical indicators.

Given the rapid pace of change in the contemporary telecommunications sector, the challenge for regulators is to keep an open mind about the choice of process in particular situations. It is necessary continually to re-examine the assumptions behind regulatory approaches and choices of dispute resolution techniques.

Regulators in various countries seem increasingly inclined to require market participants to resolve disputes themselves as a form of self-regulation. There may be a general concern that industry participants and self-regulatory initiatives may arrive at far-reaching proposals for the sector that are not envisioned by the regulator. Regulators are well-positioned to mitigate

this concern by setting guidelines within which public consultation and other processes can occur.

Promotion of a more developed market specifically aimed at telecommunications sector dispute resolution could improve the fairness of cost-allocation in dispute resolution and reduce transaction costs to parties and to the sector as a whole. By encouraging alternative means of resolving disputes, regulators and policy-makers may promote the development of a commercial market for specialized telecommunications dispute resolution services.

The development of a dispute resolution market may help to increase efficiency, reduce companies' transaction costs, and make the market more attractive to investment and growth.

Designing consensus-building mechanisms requires addressing the competing priorities of confidentiality and transparency both from regulator and players. Significant matters in dispute frequently involve confidential strategic, technical, and marketing information of concern only to the immediate parties to a dispute. In this respect, confidentiality concerns must be fully respected to ensure credibility for the dispute resolution forum. Transparency of process is crucial to building confidence in the dispute resolution processes.

Both official and non-official adjudication decisions are generally subject to appeal or oversight procedures, which are often part of a system of checks and balances, designed to prevent arbitrary, incorrect, or procedurally flawed decisions. These procedures are often considered essential, since regulatory adjudicators ultimately are exercising the authority and power of the state to make decisions and enforce them through judicial or other means. Similarly, where parties have the right to enforce arbitration awards in the courts, arbitrators are making decisions that, indirectly, will rely upon the authority and power of the state for their implementation.

The full benefits of non-official approaches to dispute resolution can only be secured if the official and non-official sectors work together to develop their capabilities. Once such capabilities are demonstrated, both the government and the industry gain confidence in non-official dispute resolution.

Various factors are important in considering the capability of the non-official sector in resolving disputes. They include:

- The development of institutions, experts, and professional dispute resolution roles;
- The utilization of procedures, codes, and review procedures by dispute resolution institutions;
- The voluntary nature of non-official dispute resolution mechanisms and the operation of the "market" in dispute resolution; and
- The availability of ways for officials to be involved in non-official dispute resolution procedures other than through oversight and review.

4 Proposals of regulatory policies to enable the COGEU model

COGEU reference model presented in [6] envisage secondary spectrum trading of TVWS through a centralized broker. This chapter presents a list of spectrum policies and regulatory requirements that will incentivize new business models in the TVWS and are the regulatory basis for COGEU development. COGEU policies are stored in the policies repository as shown in Figure 2.

In [4], a model was introduced where the regulatory bodies assign TV white spaces for spectrum commons (free access) in given areas and where the remaining spectrum can be traded in a secondary market using a centralized broker (Figure 2).

Combination of commons with trading is a key innovation of the COGEU reference model. In fact, currently, only unlicensed access to TVWS is envisage/allowed by regulators, typically

for low power applications (CEPT, OFCOM, FCC). COGEU recommends an extension of this regulatory regime and proposes a secondary spectrum market of TVWS that can leverage the value of these underutilized bands.

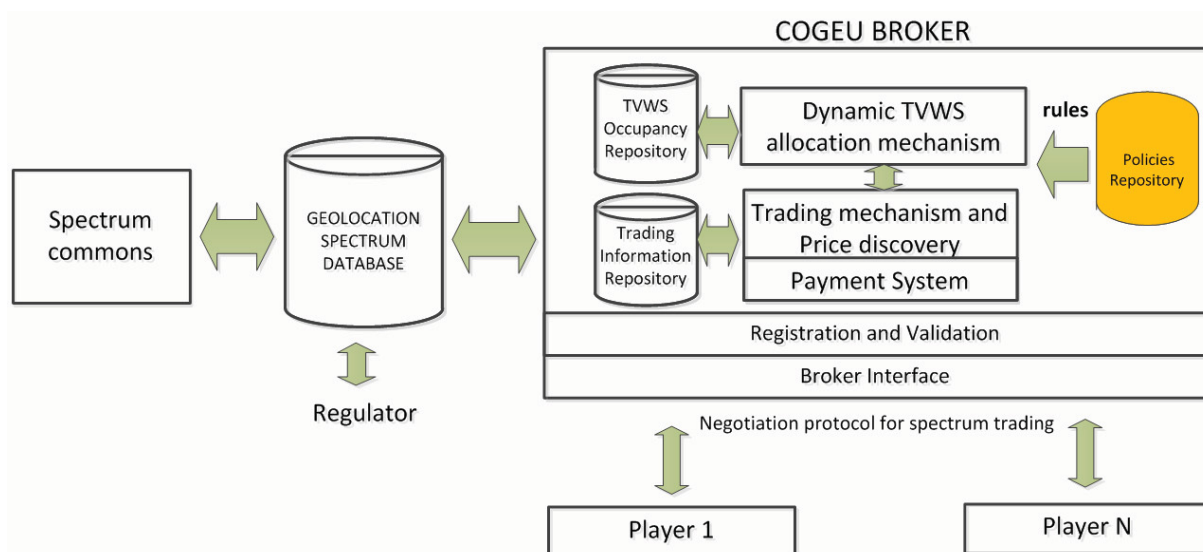


Figure 2. COGEU reference model for secondary spectrum trading of TVWS

COGEU proposes that the following policies are adopted in the European context to allow and promote secondary trading of TVWS, such that it can be exploited by advanced devices such as cognitive radios:

- Flexible geographic interleaved awards⁸;
- Band managers (COGEU broker);
- Simplified spectrum leasing.

The basic premise of COGEU's approach is that National Regulatory Authorities (NRAs) should license flexible geographic interleaved awards to Primary TVWS users/licensees, i.e. the holder of a geographic interleaved award (or TVWS license). These Primary TVWS licensees could operate as Band Managers of the spectrum assigned them. They would have the right, and associated responsibilities, to lease "their" spectrum to third-parties without recourse to the NRA. Such an approach has a number of distinct benefits:

- The Primary TVWS users would have a license in which to operate their own services which could be low-power DTT services or non-DTT services;
- The Primary TVWS users would have the legal authority to act as the Band Managers of their licensed spectrum; the degree to which the licensees would lease the licensed spectrum, and the manner in which they would arrange these leases, to third-parties would be at the sole discretion of the licensees;
- Simplification of trading rules will enable and, possibly, incentivize such a Band Manager (COGEU Broker) to invest in technologies that allow for the automation of the trading process such that real-time trading of its spectrum holding is possible.

Flexible geographic interleaved awards, or flexible TVWS licenses, can be seen as a prerequisite for the introduction of a secondary-trading regime in TVWS.

COGEU strongly endorses the requirement to define TVWS licenses in terms of flexible WAPECS-appropriate Spectrum Usage Rights. The form of these rights may vary from Member State to Member State. There are a number of approaches to describing rights in a

⁸ Ofcom UK use this formal term to refer to licensed lots of TVWS spectrum.

technology neutral form. Regulatory certainty is a necessary prerequisite for market participation. Ofcom's current approach to use technology specific license conditions which may be changed denies the market any certainty and creates risk.

COGEU believes that the band manager concept has the potential to play a useful role in making the spectrum market function more efficiently as it offers end-users an alternative source of spectrum to the NRA. The band manager has been loosely defined in the following way [21]: It is generally understood to be an organization that engages in activities that go beyond simply trading spectrum. These activities include some or all of the following:

- Planning the use of a block of spectrum, which is defined by the scope of its license;
- Packaging the spectrum for disposal through trading but not necessarily exploiting the spectrum operationally itself;
- Engaging with the market to dispose of it permanently or temporarily through trading;
- Serving end-users, who will be the band manager's customers, with contracts covering their relationship;
- Acting as first port of call to investigate and resolve interference caused by customers.

Any holder of a tradable license could potentially function as a band manager. The band manager concept closely aligns with the concept of the COGEU broker.

The last element required to create a regulatory environment suited to high-volume, low-value, short-term trading is the simplification of the spectrum trading process. Essentially, a move from the existing system of trading through full or partial spectrum license transfers to a system of spectrum leasing is required.

The revised European Framework Directive [8], finalized at the end of 2009, contains a number of decisions that facilitate and, indeed, direct that Member State NRAs develop more flexible trading systems. Up until this revision, Article 9 of the old 2002 Framework Directive [7] was the basis for the development of existing spectrum trading frameworks. The main sticking point of the old directive was that it required NRAs to be given prior notification of pending transfers and it did not facilitate the concept of spectrum leasing.

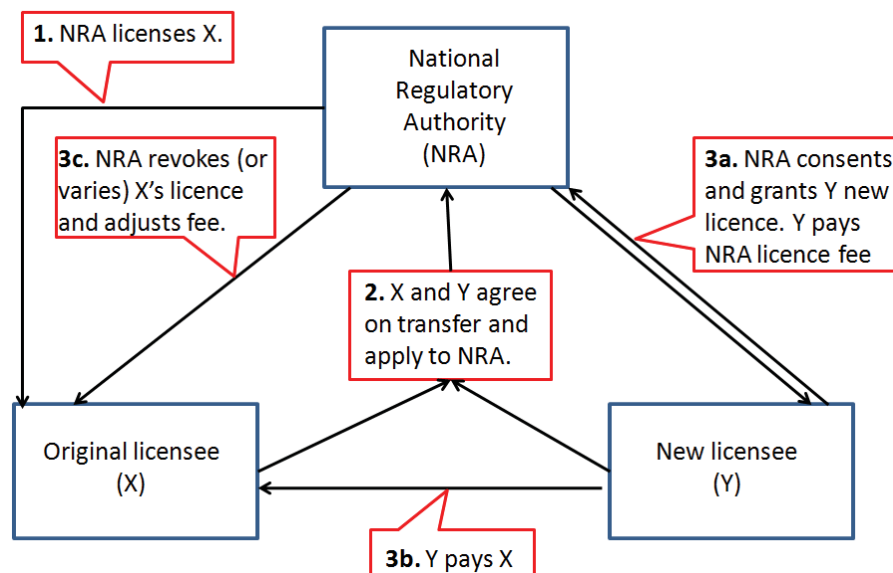


Figure 3. Article 9 Spectrum Transfers

Up until 2009, the only type of trading permitted in Europe by Article 9 of the old Framework was pre-notified spectrum transfers. Under this model, illustrated in Figure 3, an original licensee could negotiate with a potential buyer. If they came to an agreement, this trade had to

be notified to the NRA for consent. Even if the consent was to be given in an automatic manner the requirement to interact with NRA for every spectrum license transfer, even if only partial, would have an effect on the type of trading system that could be developed. **Currently, the main kind of interaction between licensees and NRAs is paper-based filing. Mundane issues such as paper-based processes, office opening hours and other human-personnel related restrictions impede the effectiveness of any trading system.**

If the NRA does consent to the spectrum license transfer, even if it is an automatic consent, then the transfer proceeds and the original license, and fee, can be adjusted. The level of bureaucracy involved in this kind of trading regime is not suited to the real-time trading envisaged for the COGEU broker.

The approach that was mandated under the old Article 9 is also the approach that has been adopted by the FCC. Even though the FCC has moved to promote a secondary spectrum trading market through the development of a spectrum leasing, sub-leasing and private commons regime [14], these regimes are still stymied by the pre-notification requirement. The spectrum leasing arrangements, both Spectrum Manager Leases and de facto Transfer Leases are not suited to real-time spectrum trading as they both require prior notification and consent from the FCC. Although these processes have been streamlined to make the process quasi immediate, there would be considerable overhead involved in such a system if the volume of trades increased in a very dynamic, liquid, high-volume, low-value market.

The Private Commons model does not offer a meaningful regulatory model for a real-time spectrum trading environment either. While the Private Commons model has been specifically developed for new devices such as cognitive radios and advanced devices that can dynamically access the spectrum, there is a specific exclusion in the rules governing Private Commons that forbids the radios operating under this to offer network-based services to end users. This exclusion makes the Private Commons model unsuitable for the types of business applications suggested by COGEU.

However, the revised Framework offers the possibility of developing a leasing system. Article 9(b) of the revised 2009 Framework Directive [8] permits the use of spectrum leases in addition to spectrum transfers. Significantly, the revised Framework does not impose the pre-notification and consent conditions on any leasing regime. The omission of this regulatory burden should allow for the development of a whole range of new, dynamic trading processes. Article 9(b) says that it is a matter for the individual NRAs to implement leasing schemes.

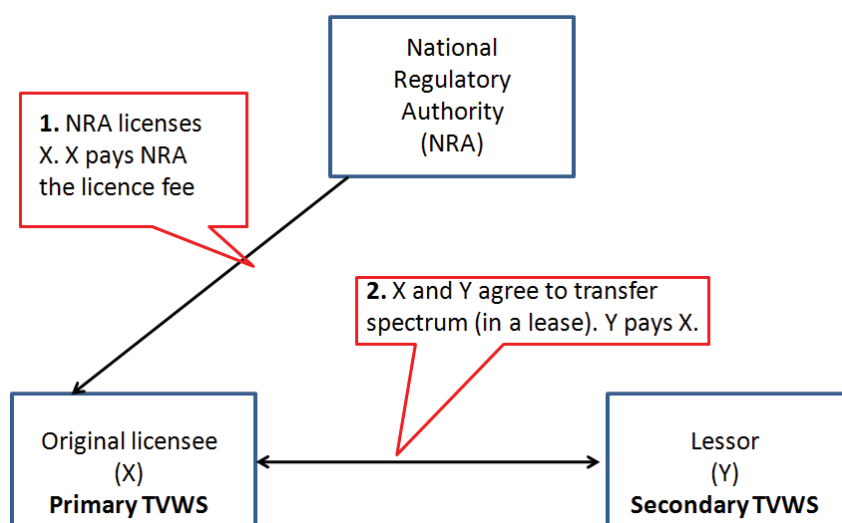


Figure 4. Spectrum Leasing (COGEU approach) based on Article 9b

Spectrum leasing differs significantly from spectrum license trading through transfers as it removes the NRA from much of the bureaucracy of the trading process and it enables the holder of the Original Licence, i.e. the Primary TVWS, to contract with lessors on its own terms, as illustrated in Figure 4. Spectrum leasing is the process by which an original licensee can authorize a third-party lessor to exercise its Original licensee rights, but without transferring those rights to the third-party.

The issue of confidence in the leasing process is an important one. Under the spectrum license transfer process a new licensee has a direct relationship with the NRA who guarantees the quality and enforceability of the license. Under a leasing arrangement, the Original licensee and the Lessor(s) come to a private contractual arrangement which is not subject to the prior scrutiny of the NRA. As such, spectrum leasing may carry risks as it requires the original licensee to draw up well written and enforceable contracts.

Nonetheless, leases will still fall under the limiting terms of the original license, as such, if the NRA has built in a clause that allows it pre-empt Original licensees' spectrum rights or to demand that the licensee cease transmissions, these demands will also follow to the lessor/lessors.

NRAs would have the option to develop leases in two forms; they could completely devolve the process to the Original licensee who could create purely privately drafted contracts or the NRA could impose the use of pro forma leases that it feels address certain basic requirements. Another challenge of the leasing approach is that the NRA does not keep records. While it may, ex post, collect notifications of leases that have been agreed, in batches or individually, the NRA's ability to monitor the spectrum utilization is reduced.

In summary, COGEU recommends that the following regulations are developed for real-time secondary trading of TVWS in Europe. The regulations do not have to make explicit provision for cognitive radio so long as they are technology and service neutral:

- Flexible awards of TVWS should be made. Such awards should use the most flexible technical conditions feasible, in accordance with the WAPECS Directive.
- Explicit regulations should be developed to support the concept of the Band Manager, namely:
 - The independence of the Band Manager (e.g. COGEU Broker) should be enshrined in regulation. Such an entity should act as a trusted third party facilitating the smooth operation of the market. As such it should be unencumbered by any financial association, i.e. shareholdings, partial ownership, etc., with either new market players or market incumbents;
 - The Band Manager should have the primary right and responsibility to record, publish and investigate all transactions such that the transparency of operation of a free market is maintained, whilst protecting financially sensitive information as a secondary objective;
 - The Band Manager should promote and provide for both existing and anticipated spectrum needs. As such, the Band Manager should manage the spectrum offerings such that they do not promote new service offerings at the expense of incumbent services, nor vice versa. The use of AIP, discussed in the next section, may provide a means to manage this balance which is dynamic in nature.
- Simplified spectrum leasing, which detaches the NRA from involvement in the execution of every single trade should be brought forward.

5 Conditions for the use of TVWS

Regulation shall permit TV white space usage on a non-interfering, non-protected basis

Eventually, the existing media and telecommunication laws would have to be updated in order to allow the usage of TVWS under predetermined legal and technical conditions. The beneficiaries of the TVWS licenses would be bound to operate according to the rules implied such that primary users would not be interfered with by the operation in the TVWS, i.e. the NRA's would have to issue rules that make interference manageable. CEPT has developed ECC Report 24 [27] that requests that TVWS applications are operated on a non-interfering basis and that these applications cannot claim protection from interference stemming from primary spectrum usage, i.e. from the broadcasting service, or from incumbent PMSE.⁹

Responsibility for interference avoidance has to be fixed

NRA's may grant exclusive access for a given TVWS to a broker. In case of interference, both, the NRA and the broker are responsible to detect and resolve the problem. In each country, there should be regulatory provisions that allow stopping the operation of interfering devices.

Use of TV white spaces require the existence of geo-location spectrum database

Within the COGEU model, management and usage of TV white spaces rely on the existence of a "Geolocation Spectrum Database" (see Figure 2). The entries to this database are the white spaces information derived from the transmitters of the primary service, i.e. the broadcasting service, as well as from the incumbent PMSE devices (typically those PMSE devices that are firmly installed in stadiums, concert halls, theaters, production studios, etc.). As these entries are relatively stable, it should be sufficient to maintain and update this database once per day.

Regulators may accept different usage scenarios

Within COGEU, two types of usage are envisaged: trading of secondary spectrum (via a broker) and the so-called spectrum commons. The first application results in paid and, hence, protected usage of spectrum whilst the latter is freely available to any user but does not guarantee any protection against interference from other spectrum common devices. Both types make use of the database.

As indicated in Figure 2, the broker contacts with the databank and then leases ("assigns") a piece of protected spectrum to a user for a certain period of time and at a certain location. This piece of spectrum is made available against payment (fixed price or as a result of an ad-hoc auction process). Users who get spectrum via a broker do not need necessarily cognitive (sensing) devices but may need to adjust the operative frequency of their devices from one usage period to the other.

This is in contrast to the usage of the spectrum commons devices. Those radio devices contact the database which indicates them usable channels at a given location. By so doing, the database protects the operation of the primary (i.e. the broadcasting) service and the operation of the incumbent PMSE systems. The spectrum commons devices should be cognitive (in one way or the other) to allow for some sort of collision detection as the databank may indicate the same TV channel to all demanding commons devices. The databank knows the white spaces available to spectrum commons and can thus list them, on demand, to non-incumbent (cognitive) radio devices on demand (at a pre-determined maximum output power).

⁹ Incumbent PMSE are tolerated applications that enjoy protection against other TVWS application as does the broadcasting service.

Geo-location spectrum database: Access rights and responsibilities need to be fixed

According to discussions in CEPT SE 43, the regulator should prepare, update and operate the geo-location spectrum database as the information necessary to build up the database represent sensitive and business-relevant data. For each transmitter of the primary service, the important technical data (location, antenna diagram, transmit power, antenna height, etc.) are stored in order to determine the size and location of the TV white spaces. In addition, the location and technical data are processed for each incumbent PMSE system. The information about the white spaces is then available upon request by any potential user:

- Indirectly through the broker in case of exclusive, paid usage, or
- Directly through the database in case of spectrum commons.

Eventually, it is a political decision, how many channels in TV white spaces are handed over to spectrum trading (via a broker) and how many TVWS channels are left to spectrum commons. It should be noted that a broker does not have a permanent right of brokering for a specific TVWS. In particular cases, the broker's usage right may be reduced, transferred to a different channel or even withdrawn temporarily. This can happen during large public events such as Olympic Games, world championships or Royal marriages when the NRA needs a high number of TVWS capacity for temporary PMSE coverage.

In practical terms, COGEU proposes that:

- All predetermined usage of white spaces, such as incumbent PMSE systems in stadiums, concert halls, etc. should be part of the geo-location database. They can be accommodated in all TV channels within the broadcasting band 470-790 MHz (Ch. 21-60).
- Except for ENG devices, all cognitive radio or PMSE devices that are not registered in the database are accommodated in white spaces within TV Ch. 40-60 after having contacted the database.
- ENG applications, that are by nature hardly predictable, that often occur ad-hoc and are thus difficult to schedule, should operate within Ch. 21-39, i.e. the part of the band that is not subject to COGEU management.

Regulations should be developed for compliance, access security and privacy

Two further requirements concern the security of access as well as the preservation of privacy. Policies are to be determined that can regulate these issues. The database must provide some sort of redundancy to achieve an availability of at least 99% of time. All radio devices that contact the database, should comply with the protocols and instructions of the database. Eventually, some kind of certification might become appropriate. As important confidential information (i.e. personal and financial data) are transferred during the access process, preservation of privacy is predominant repercussion for a successful implementation of TVWS usages.

6 Conclusions and recommendations

While EU level organizations such as the RSPG promote a harmonized, or singular, vision for Europe, the actual Directives in place leave many details and the scope of the actual implementation choices to the Member States. As such, the progress that has been achieved across the EU is uneven and the choices made by different Member States vary significantly. Nonetheless, most Member States are undertaking preparatory groundwork such as the setting up of electronic registries of licensed allocations and assignments, registries which enable stakeholders to make informed contributions to the debate on how to proceed with enabling secondary trading.

COGEU identifies one of the causes for the lack of confidence in current spectrum users by industry players to invest in TVWS technologies are immature regulatory policies concerning the technology. Hence, policies need to be determined for efficient spectrum sharing in TVWS at a European level that are supportive to technological innovation and thus boost investors' confidence. The key is in creating predictability on the availability of spectrum resources (TV white spaces). This can only be achieved through the collaboration of all stakeholders in the TV white space ecosystem.

COGEU recommends a model where the regulatory bodies assign TV white spaces for spectrum commons in given areas (promote free access and inclusion for citizens to ICT through, for example, WiFi-like services) and where the remaining spectrum can be traded in a secondary market using a centralized broker. Combination of commons and secondary trading will leverage the value of these underutilized bands.

COGEU recommends that Europe implements "safe harbor" channels for the exclusive PMSE usage, i.e., number of TVWS channels for reserved PMSE usage only in which no TVWS devices would be permitted. Within this scenario sensing is not necessary because primary users (PMSE, DVB-T) are protected by the geo-location database. The "safe harbor" bands are flexible and may change from country to country. The reallocation to "safe harbor" channels of PMSEs will allow a secondary market of clean TVWS providing services with high QoS requirements.

COGEU strongly endorses the requirement to define TVWS licenses in terms of flexible WAPECS-appropriate Spectrum Usage Rights. The form of these rights may vary from Member State to Member State.

COGEU proposes that the following policies are adopted in the European context to allow and promote secondary trading of TVWS:

- Flexible geographic interleaved awards¹⁰;
- Band managers (TVWS broker);
- Simplified spectrum leasing (developed under Article 9(b) of Directive 2009/140/EC).

The basic premise of our approach is that National Regulatory Authorities (NRAs) should license flexible geographic interleaved awards to Primary TVWS users/licensees, i.e. the holder of a geographic interleaved award (or TVWS license). These Primary TVWS licensees could operate as Band Managers of their assigned spectrum (COGEU broker). They would have the right, and associated responsibilities, to lease their assigned spectrum to third-parties (secondary users) without recourse to the NRA allowing an automatic spectrum trading process.

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List of Abbreviations

ARD	German public TV broadcaster
CEPT	Conference of European Postal & Telecommunications
CPC	Cognitive Pilot Channel
CR	Cognitive Radio
DAA	Detection And Avoidance
DFS	Dynamic Frequency Selection
DTV	Digital Television
DVB-T	Digital Video Broadcasting - Terrestrial
EC	European Commission
ECC	Electronic Communications Committee (within CEPT)
ETSI	European Telecommunication Standards Institute
FCC	Federal Communications Commission (US)
HDTV	High Definition Television
ICT	Information and Communications Technologies
ITU	International Telecommunication Union
ITU-R	International Telecommunication Union – Radio Communication Sector
JRC	Joint Research Centre
NRA	National Regulatory Agency
NTIA	National Telecommunications and Information Administration (US)
OFCOM	Office of Communications (UK)
PMSE	Programme Making and Special Events
R&TTE	The Radio and Telecommunications Terminal Equipment Directive
RLAN	Radio-based Local Area Network
RSPG	Radio Spectrum Policy Group
SDR	Software Defined Radio
SE	Spectrum Engineering Working Group
TC BRAN	Broadband Radio Access Network
TC ERM	EMC and Radio Spectrum Matters
TC RRS	Reconfigurable Radio Systems
TCAM	Telecommunications Conformity Assessment and Market Surveillance Committee
TVWS	TV White Spaces
UWB	Ultra-wideband
WAPECES	Wireless Access Policy for Electronic Communications Services
WRC	World Radiocommunication Conferences
ZDF	German TV broadcaster