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COgnitive radio systems for efficient sharing of TV white spaces in EUropean context

D2.2
Policies to enable efficient spectrum sharing over TVWS at European level

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Abstract:

This Deliverable D2.2 summarises the results of Task 2.2. The objective of this task is to identify the spectrum policies that are suited to the cognitive acess to TVWS at European level. The most promising Regulatory Policies investigated in this task will be included and evaluated in the WP7 spectrum broker data base.

Keyword list: TVWS, Secondary Spectrum Trading, Policies, Regulation.

Executive Summary

This Deliverable D2.2 summarises the results of COGEU Task 2.2 “TV White Spaces policies to enable efficient spectrum sharing”. The main objective of Task 2.2 is to make suggestions with respect to the regulation that is needed towards the realization of secondary spectrum market of TVWS at European level.

While EU level organisations such as the RSPG promote a harmonised, 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 varies 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 and industry players to invest in TVWS technologies is immature regulatory policies concerning the technology. Hence, this deliverable concerns the policies necessary to enable efficient spectrum sharing in TVWS at a European level that are supportive to technological innovation as well as 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 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 it 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 licences 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:

1. Flexible geographic interleaved awards (Ofcom UK use the formal term ‘geographic interleaved awards’ to refer to licensed lots of TVWS spectrum)
2. Band managers (TVWS broker)
3. 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). This Primary TVWS licensee could operate as a Band Manager of its own spectrum (COGEU broker). It would have the right, and associated responsibilities, to lease its spectrum to third-parties (secondary users) without recourse to the NRA allowing an automatic spectrum trading process.

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1- Introduction

The COGEU project aims the efficient exploitation of the geographical interleaved spectrum (TVWS) through the introduction and promotion of secondary spectrum trading and the creation of new spectrum commons regimes.

The role of regulator to create secondary spectrum market within TVWS is crucial for COGEU. In fact, 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.

This Deliverable D2.2 summarises the results of COGEU Task 2.2 "TV White Spaces policies to enable efficient spectrum sharing". The main objective of Task 2.2 is to make suggestions with respect to the regulation that is needed towards the realization of secondary spectrum market of TVWS at European level.

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, this deliverable reports a set of regulatory needs and COGEU recommendations to support an efficient use of TVWS in Europe.

The arrangement of the rest of this deliverable is as follows.

Chapter 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. It is assumed to be an extension and update of D2.1 reporting recent developments in this area. Also a SWOT analysis for the TVWS exploitation in the current regulatory scenario is presented.

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

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

Chapter 5 concludes the deliverable and contains a set of recommendations.

2- Current status of the regulatory framework for the use of cognitive TVWS systems

This chapter describes the current status in the regulatory bodies regarding the adoption of Cognitive radio (CR) and Software Defined Radio (SDR) systems, namely in TVWS spectrum. A special focus is given to the European regulatory bodies either centralised ones or per each member state.

This chapter is an update of D2.1 reporting recent developments in the regulatory framework for the use of TVWS. A SWOT analysis (Strengths, Weaknesses, Opportunities and Threats) for the TVWS exploitation in the current regulatory scenario is also presented.

2.1- Global trends on secondary spectrum trading

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 of ITU – and international regulatory body; and the USA FCC, and NTIA is given, citing their perspectives and approaches in addressing spectrum sharing.

2.1.1- International Telecommunication Union

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 radio communication 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 (CR) 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 (Rev. WRC.07) [1] 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 [1]:

- Keeping the current practice as it is;
- 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 related 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 radio communication technologies may enable sharing possibilities and may lead to more frequency-agile and interference-tolerant equipments and consequently to a more flexible use of spectrum.

Moreover, in ITU Resolution 956 (WRC-07) [2] (item 1.19) ITU considers relevance in the introduction of SDR and 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 utilisation, dynamic spectrum management, and flexible spectrum use.

Finally, report ITU-R M.2064 [3] 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 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.

2.1.2- Federal Communications Comission

The 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 has two initiatives: in the first initiative, broadcasters voluntarily repay part of the 500 MHz spectrum through auctions of incentive. The spectrum would be auctioned 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 white spaces that exist between the TV bands (470-698 MHz) have faster speeds, valuable propagation characteristics and easily penetrate walls, covering large areas. 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 combined with geo-location access to a database of existing spectrum use to determine if a channel is available [4]. 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) [4].

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 [5]. In [6] the FCC took additional steps to facilitate the development of spectrum usage arrangements that employ advanced technologies that more efficiently share/use licensed spectrum.

Towards the end of January 2011, the FCC designated nine entities, namely, Comsearch, Frequency Finder Inc., Google Inc., KB Enterprises LLC and LS Telcom, Key Bridge Global LLC, Neustar Inc., Spectrum Bridge Inc., Telcordia Technologies, and WSdb LLC; as TV bands device database

administrators [7]. 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.

2.1.3- National Telecommunications and Information Administration

The NTIA announced that they have identified two spectrum bands totalling 115 MHz wide as candidates to be made available for public and commercial use in order to continue the drive of finding the 500 MHz to alleviate the growing shortage of available spectrum.

The 115 MHz includes 100 MHz of federal radar bands in regions of the U.S. that are beyond the reach of radars currently used by the federal government. The other 15 MHz can be made available by consolidating spectrum bands, currently used for meteorological observation systems.

The NTIA will work with FCC and other U.S. agencies to make the full 500 MHz of spectrum available while protecting vital government uses. The Commerce Department also noted that commercial interests, like operators and other companies using spectrum, can share in proceeds from spectrum auctions when they agree to give up some or all of their bands.

Regarding the SDR and CR systems, the U.S. does not believe that changes to the radio regulations are needed to address these technologies. With respect to the definitions, description, or characterisation 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, non-interference basis after being authorised by an administration [8].

NTIA will need to modify the U.S. table of allocations to reflect any reallocation of spectrum to 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 [9].

2.2- 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 neighbouring 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 use [11].

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 neighbours 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 – the trading of spectrum rights after the primary assignment – is possible. 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.

2.2.1- The European Commission

Generally, the European Commission has the competence to propose legislation, Council and Parliament have the legislative function and the European Commission then supervises compliance of national laws with the Directives. European Directives themselves are not applicable law in the member states; they have to be transformed into national law. The application of European Harmonised Standards is a means for manufacturers, resp. persons putting equipment on the market, to give presumption that their products are in conformity with the essential requirements of the relevant Directive. This legal framework aims to foster competition and to strengthen the single European market.

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 [16], 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 colours 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 [17]. 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 harmonised 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 licence 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 fulfil 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 harmonised standards. These specificities need to be described in a guide to be addressed to ETSI. This guide should therefore also be brought to the attention of the notified bodies.

The RSPG opinion [12] 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 regulations' aim is to make the products, e.g., 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 fulfil 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, harmonised 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 authorisation 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 [11].

2.2.2- CEPT and ETSI

CEPT ECC had launched a number of activities in relation to CR [13]:

- 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 harmonised 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 pro-active 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 from the ECC Spectrum Engineering Working Group (SE43) is defining technical and operational requirements for the operation of cognitive radio 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" [15].

- 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 ECC PT 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 [13].

ETSI have initiated various work items and project teams (e.g. TC RRS, ERM, BRAN etc) to look at standardisation issues around CR and SDR. A detailed view of the relevant project teams and their responsibilities are described in Table 1 [12]:

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 standardisation for present and future broadband radio access networks, including:* - 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: - 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: - System Aspects - Equipment Architecture - Cognitive Management and Control - Public Safety	responsible of standardisation activities related to Reconfigurable Radio Systems encompassing system solutions related to Software Defined Radio (SDR) and Cognitive Radio (CR); - to collect and define the related Reconfigurable Radio Systems requirements from relevant stakeholders; - to identify gaps, where existing ETSI standards do not fulfil the requirements, and suggest further standardisation 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.

2.2.3- RSPG

In February 2010 the RSPG published a first report on cognitive technologies [13]. The report also highlighted that the use of so-called '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 Software Defined Radio (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 [12][1], 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, licences 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 standardisation body to develop harmonised 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;
- harmonisation of CPC at European level should remain on standardisation 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;
- there does not seem to be any discernable support at this time to introduce harmonised 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 [12]:

- 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,

[1] 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 [14].*

- 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 behaviour and output signal radio characteristics which will allow ETSI to develop harmonised standards,
- any CR harmonised 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.

2.2.4- European Countries

2.2.4.1 UK

In 2005, the UK's Ofcom published a report that described, in general terms, the approaches that Ofcom would take to address the reform and liberalisation of spectrum management. That report, the Spectrum Framework Review [18], stated that Ofcom had the objective of moving the control and management of spectrum from a traditional system which was highly centralised, 95.7% was under command & control management then, to a situation where over 70% of the spectrum would be managed by market mechanisms.

To achieve this shift Ofcom has engaged in a number of distinct, but complementary endeavours. Initially Ofcom focused on releasing spectrum quickly through competitive auction processes and, where appropriate, making the licence awards flowing from those auctions tradable. One feature of most of these new licence awards was that the terms of the licence, i.e. the rules describing how radios and services should operate, were described in technology and service neutral form. Such neutrality increases the tradability of the licence as it enables a buyer to use technologies that best fit its economic objectives. Such neutrality has not been universally applied however; the geographic interleaved awards of DTV spectrum in Manchester and Cardiff were issued with technology specific, i.e. DVB-T, terms and conditions [19]

To further increase the tradability of spectrum, Ofcom allows for the aggregation and disaggregation of spectrum lots; *original* licences may be split along geographic and/or frequency lines if it suits the market. Conversely, separate adjacent licences may be aggregated to provide more geographic coverage or bandwidth. Again, however, these rules are not universally applied and for certain categories of licences Ofcom places restrictions on the degree to which a licence may be fragmented or partitioned along geographic or frequency lines.

Furthermore, apart from legislating for spectrum tradability which in itself does not create a market or promote trading per se, Ofcom have progressed the concept of the band manager, a mechanism which actively sets about creating and supporting a secondary spectrum market. They have done this in two distinct ways. Firstly, following on from the Digital Switchover, Ofcom investigated means by which they could accommodate the remaining PMSE users in a more controlled fashion but using market-based techniques which would incentivise the most efficient use of the spectrum set aside for PMSE use. An application-specific model of a band manager was proposed using a market-oriented Alternative Incentive Pricing system. In Section 4.5.2 of D2.1 we described the manner in which this system is intended to operate; as yet no award has been made and it looks likely that no further progress will happen until after the 2012 London Olympic Games. In essence, such a PMSE band manager will allow for the short-term leasing of spectrum by PMSE users.

While this example is limited in its scope, many of issues have been teased out and the process of consultation with industry has been extensive. A more generic band manager concept, which relies on a

more simplified spectrum trading regime, which will be enabled under the new EU Framework Directive, has been proposed more recently; there is further discussion of this Section 3.8 of this deliverable.

More recently, Ofcom has also opened a consultation which should result in the existing cellular network licences, or *mobile spectrum* as they term it in the consultation document, being made tradable [20]. To date, activity in any secondary spectrum trading in the UK has been light. The opening up of mobile spectrum to the secondary market may see a significant change as this spectrum is clearly some of the most commercially exploitable, directly revenue-generating spectrum. One of the key differences that arise here is that Ofcom considers it will be necessary to have more oversight of the trades which take place in this spectrum. Whereas heretofore Ofcom have considered the *ex post* application of competition law to be sufficient to guard against market distortion, in the case of trading mobile spectrum Ofcom are disposed to introduce *ex ante* competition checks as they are of the view that 'there is a material risk that concentration of mobile holdings could affect downstream competition..". Basically, as spectrum suited to mobile use is relatively scarce it is a strategic asset in the mobile market. Without offering evidence, Ofcom opine that a reliance on the application of *ex ante* competition law is required as it may be difficult to detect anti-competitive behaviour and there is no guarantee that an *ex post* intervention will be successful. Of course, in the general cut and thrust of commercial litigation, *ex post* judicial interventions can be, and are regularly, used specifically to frustrate a business competitor rather than to actually achieve a *fairer* outcome.

In summary, the regulatory environment for secondary spectrum trading is maturing in the UK and the opening up of the mobile spectrum to secondary trading may be the catalyst that sees a vibrant market emerge.

2.2.4.2 Germany

Germany has a three-level system of assigning radio frequencies and making them available to the users. The primary, legally-binding instrument is the national Frequency Allocation Ordinance (Frequenzbereichszuweisungsplanverordnung, FreqBZPV) containing the national Frequency Allocation Table. The second instrument issued by the Federal Network Agency (Bundesnetzagentur, BNetzA) is the Frequency Usage Plan (Frequenznutzungsplan), which is based on the provisions laid down by the Ordinance. Finally, frequency assignment procedures, being usually tender procedures, are conducted by the Federal Network Agency in order to grant stakeholders rights of spectrum use. Secondary spectrum trading is not provided for in this process.

If WSD should be allowed in Germany, an adoption of the current state of the regulation would be required, including negotiations between the Federal Ministry for Economics (BMWi) and the Ministries of Culture Affairs of the individual German federal states. Thus actually BNetzA is not allowed to grant any channels within the TV bands for TVWS use. However BNetzA is interested in the actual developments related to TVWS and is also active at different platforms, e.g.:

- Participating in regulatory groups like CEPT SE43
- Participation in standardization groups like ETSI RRS
- Contributing to European research projects e.g. E^3 or Quasar
- BNetzA held workshops on Cognitive Radio and Software Defined Radio
- BNetzA commissioned studies on Cognitive Radio

So due to legal situation in Germany the BNetzA is currently not authorized to play an active role in enabling spectrum commons use within the TV broadcast UHF bands or even promoting secondary spectrum trading. However, according to its engagement in various activities BNetzA is well prepared to be able to react in a due time if German legislation might be adapted.

2.2.4.3 Portugal

The Portuguese National Regulatory Authority on Communications, ANACOM (*Autoridade Nacional de Comunicações*) considers secondary spectrum trading as a means of moving forward in finding ways which provide for flexible and efficient management and use of the radio spectrum. In principle, the rights of use set out in the NFAP (National Frequency Allocation Plan) are transferable in accordance with the regime set forth in article 37 of the LEC (Law of Electronic Communications) [21]. In respect of the transfer of rights of use of frequencies, ANACOM plans to establish an approach in the near term which clarifies the relevant rules and conditions associated with secondary spectrum. To this end, one of the items in the 15 actions planned for reaching the two objectives of the 2010–2012 triennium

strategic goals [22], namely (1) *to promote open and competitive markets*; and (2) *to uphold and protect the interests of users and citizens in general;* is to: *"Define spectrum management policies concerning the possibility of transmitting usage rights, particularly establishing the modes and phases associated with the introduction of secondary spectrum trading."* Moreover, the Portuguese regulator considers aligning its strategies with the rest of EU member states through the CEPT and RSPG as important. Therefore, it can be concluded that, the secondary spectrum trading is still under establishment in Portugal, while harmonization with the rest of EU member states is given priority.

2.2.4.4 France

In French law, spectrum belongs to the State exclusively, which provides precarious and revocable rights of usage. Those rights can be associated with exploitation rights, and French case law admits those rights can not be revocated without counterparts. Results from the French "Immaterial Economy Comity" [23], listed a few recommendations on a more efficient spectrum usage. This includes an harmonized spectrum assignment authority, a more flexible spectrum allocation, and introduced the great benefits coming from a secondary spectrum market in France.

In France, the National Frequency Agency (ANFR) is responsible to manage, plan and control the uses of frequencies, in conjunction with nine assignee, which shall include the Authority regulation of electronic communications and postal services (ARCEP), the Supreme Council of Audiovisual (CSA) and some ministries (including the Ministry of Defense). These assignee have access to one or more frequency band they use either for their own use (departments), or to attribute it to other users, especially for telecommunications operators (ARCEP) or audiovisual (CSA).

On Flexibility of spectrum allocation: the degree of precision and services of technology authorized (at the time of licensing) to operate in a given frequency has traditionally been really strong in France, but also in continental Europe, while it wasn't the case in other countries, including the United Kingdom or the United States. While this choice had certain advantages by fostering the emergence of a common technology for GSM and UMTS, it may lose technological opportunities, freezing over too long periods - a license is granted for an average of more than 10 years - the use that can be made of the frequency bands. Indeed, technological developments in the field of radio technology tend to increase in number and to be more and more to rapid to evolve.

On Secondary spectrum market and spectrum resale: the major recent innovation in spectrum management in France is the secondary market. This new tool has been implemented by DGE and ARCEP: the ability to transfer (or provision) permissions is thus now available to players in a very large part of the frequency band managed by ARCEP. It thus concerns including recent approvals issued for wireless local loop, which transfers of rights have already taken place. This pragmatic approach seems also consistent with report [23] which recommend a thoughtful and contextual usage of auction mechanisms.

Moreover, report [23] emphasizes that "the management of frequencies is strongly influenced by its international dimension". Indeed, what is decided at EU level, to CEPT or ITU-R is sooner or later needed in French and opportunities for national decisions are increasingly rare. Same things apply to the specialized groups or organizations (SFCG or ICAO for example).

2.2.4.5 Ireland

Ireland's progression towards creating a system which would enable secondary spectrum trading has been slow when compared to some EU Member States. Indeed, when it comes to the primary disposal of spectrum, Ireland's regulator, ComReg, has favoured techniques such first-come-first-served (e.g. Fixed Wireless Access Local Area awards), comparative selection (beauty competitions, i.e. the fourth 3G licence) as well as auctions (e.g. an All-Island Spectrum award). Such is the size of Ireland, and the consequent size of its markets, that competition for spectrum outside of the mobile spectrum is limited; auctions are only necessary when demand exceed supply. ComReg's 'Spectrum Management Strategy Statement' of 2008 does acknowledge the role that secondary trading may play in the future [24]. However, as yet, there is no regulatory basis for such trading in Ireland.

Such is the size of the market in Ireland, competitive trading of spectrum may only initially occur in mobile spectrum should that be made tradable, as we noted in Section 2.2.4.1.

2.2.4.6 Greece

According to specific reports of EU [25], [26] regarding conditions and options in introducing secondary trading of radio spectrum in Europe, a number of countries including Greece are considering to adopt spectrum trading via the relevant spectrum management authority or the Ministry responsible for spectrum management. These reports also contain case studies of five non-European countries and describe the regulatory and market situation regarding spectrum trading in those countries as different examples. If a secondary market for spectrum trading is adopted, it is beneficial to have a public register specifying not only the allocations of frequencies but also their assignment (i.e. what users are assigned to a spectrum band). All EU countries, including Greece, studied to publish an electronic national allocation table but they also publish information on the actual owners of different spectrum bands. In this context, a number of countries have already incorporated into national legislation the related EC Directive that allows for the possibility of a secondary spectrum market. Greece is included in the countries that are investigating whether spectrum trading will be allowed, depending on consultation. In general, most of the countries are not intending to predefine any detailed ruling as to the circumstances under which a trade will or will not be approved. Instead, most trades will be dealt with on a case-by-case basis, meaning that regulators intend to deal with trades as and when they occur. Many countries have given some thought already to the criteria they would take into account when approving a trade.

Greek spectrum regulator considers that with the implementation of spectrum trading, the competition will be increased and spectrum will be more optimally used. Its main concerns are related with QoS issues due to the transfer of specific license obligations and possible interference issues, resulting in a general quality problem. Greek spectrum regulator also considers that GSM bands are the first areas where trades in spectrum rights will occur. In a general context, Greece considers that recommendation and guidance from the EC on how to handle spectrum trading issues is very welcome. Member States should be given room to accommodate differences in local circumstances and conditions. The EC should adopt a voluntary approach as the market will move toward the best way for implementation.

2.2.4.7 Cyprus

In Cyprus the organisation responsible for the spectrum usage policies is the OCECPR (Office of the Commissioner of Electronic Communications and Postal Regulation). Currently it appears that there is no progress regarding the secondary spectrum trading. Although the digital switchover is to be completed in July 2011, it still has to be decided how the released spectrum will be used. A number of public consultations have been released regarding the spectrum but none yet for the secondary spectrum trading. The fact that the DVB-T broadcasts will be organised into only two SFN (Single Frequency Network) networks, will allow the availability of a large amount of spectrum, creating opportunities for secondary spectrum trading and COGEU concept to be applied. Cyprus regulators await the EC to form a policy in-order to form their own views and directions regarding the use of released spectrum and the possible adoption of secondary spectrum trading trends and possibilities.

2.2.4.8 Poland

In Poland, there is a traditional, commonly known as "*command and control*", administrative model of spectrum management based on the principle that individual rights and obligations are granted in the scope of a given spectrum usage within a band allocated to specific radiocommunication services. According to this solution, the administrative body shall point to networks and/or services which can be used in allocated frequencies.

According to the Telecommunications Law, Article 122, it is possible to make changes in a general exclusive frequency license within the authorized entity to which the license had been granted, after meeting a number of conditions. Among them, there are: **written** application of the license holder and **written** agreement of the entity to take over rights and obligations resulting from the change.

In [27], President of the Office of Electronic Communications (UKE), the Polish regulator, is guided by the necessity to support equal competition while making changes in frequency licenses. However, there are no regulations regarding settlements between license holder and entity, which will become authorized after the change.

The President of UKE specifies her strategic tasks in this respect in the following way:

- Activities aiming at establishment of appropriate legal basis that will enable trading in frequency rights.
- Specifying of frequency bands and types of radiocommunication systems that can be subject to frequency trading as well as conditions for such trading.
- Establishment of efficient mechanisms that make it impossible to hold and sell frequencies without their actual use in provision of telecommunications services.

On the other hand, in the introduction to the above-mentioned report, the President of UKE presents a very conservative approach to this issue stating that: '*In its nature and under modern technological possibilities, radio frequency spectrum is a scarce resource in short supply. Thus,* ***frequency usage must not be merely subject to a free game of market factors,*** *but it requires prospective, non-discriminatory and far-reaching regulations from the regulators'* [27].

In [28], which was published in September 2009, the President of UKE stated that the Polish Telecommunications Law allows the regulator to change entity that holds frequency license. Such a provision that enables transfer of frequency rights under the rules specified in the Act and with respect for the conditions of creating competitive market, is included in every decision issued by the President of UKE. **However, there is little interest in transfer of frequencies. By the time the report was published, only a few entities turned to the President of UKE in that matter.**

In [29], which was presented in April 2008, it is stated that in order to boost efficiency of radio spectrum usage, it is recommended to undertake a number of activities that are beyond the scope of authority of the President of UKE. Among such activities there are:

- Introduction of the possibility of organizing auctions for frequencies (in the form of multistage tenders) – implemented by an Ordinance of the Minister of Infrastructure (MI), who is responsible for electronic communications in Poland, in 2009.
- Introduction of an intermediate mechanism between license exempt and a general exclusive frequency license: light licensing system would largely facilitate procedures for operators trying to gain access to frequency bands – legislative changes aim at introduction of this mechanism in 2011.

The latter solution will consist in the obligation of a telecommunications entrepreneur to inform UKE about the intention of occupying a free band for frequency bands included in this mechanism. Such a solution would enable **significant reduction of time and costs** concerned with initiation of usage of a given frequency.

In order to implement these changes, involvement of other state bodies, including the Council of Ministers and the MI, is essential. President of UKE is to initiate and support all works over legal changes required for their implementation as far as possible.

The Minister of Infrastructure can see the need, inspired by the European Commission's initiative, to prepare a long-term program of frequency spectrum management policy. Moreover, following EC's intentions, the MI would like to introduce the option of secondary frequency trading. Entrepreneurs would be absolutely free to conclude such deals. They would only have to notify the President of UKE about transfer or lease of individual rights to radio frequency usage by license holders to other entities. The regulator could veto such deals only in certain specified cases. The bill which is to amend the current Act is in the phase of inter-ministerial consultations [30].

2.3- Commercial perspective of TVWS

For Google utilising TV white spaces is good for the country and can increase the company's revenues by 30%. White spaces sit between broadcast TV channels and can potentially be used for high speed wireless access. Google along with Microsoft and Motorola have been lobbying the FCC for the unlicensed use; but broadcasters, operators, wireless microphone makers, and even music performers have been adamantly opposed on grounds that it may interfere with nearby spectrum.

However, Google and other companies do not just have altruistic reasons for wanting unlicensed white spaces, as having easy access to high speed Internet presents multiple revenue opportunities. Google sees various business models and opportunities for companies of all sizes, and they point to the success of Linksys and Netgear with unlicensed Wi-Fi. And even the FCC's request for the white

spaces devices (WSDs) that will have to use geo-location technology is not an obstacle because it could be easily taken from similar technology in modern devices.

Moreover, FCC adopted rules to ensure the neutrality of the Internet. This is, the web traffic receives the same treatment regardless its source, and thus operators are prevented to give preference to some content over others. However, exceptions have been established for the mobile Internet.

The regulation of net neutrality has gained great projection, not only in America but also in Europe. The FCC decision came after a process of discussion and approval of shrouded in controversy, so it was expected that would be challenged by the operators. There is great fear on neutrality namely by operators. However, Google and Verizon published a framework in order to preserve the open Internet and the vibrant and innovative markets it supports, to protect consumers, and to promote continued investment in broadband access [10].

The advocates of neutrality argue that the Internet is required to ensure balance and innovation, enabling small businesses receive the same treatment that multinational corporations online, with Google and Facebook being appointed as two good examples of this kind of potential neutral environment.

A company already operating in the white space field in UK is Neul [31] that started in 2010. They claim that their network enables the “Internet of Everything” with the aim of building a reliable, full coverage global network around the open Machine-to-Machine (M2M) communications standard, over the TV white spaces bands. The reasons to choose the white space spectrum along with being license-free are stated in their web site: *These frequencies are ideal for data use, enable better propagation deep indoors, longer range outdoors and reduced infrastructure costs*.

The principle of net neutrality is defined in many ways, but we can summarise it this way: if we and someone else pay for Internet access with the same quality then the data packets of our activities on the network should be treated the same way by respective service providers, i.e. without interference from them.

The principle of net neutrality is not properly regulated in the world; however the net neutrality may be applied to COGEU in the scope of spectrum trading: if two players pay the same money for the same TVWS bandwidth they shall be equally treated by the broker.

2.4- SWOT analysis for the TVWS exploitation

In this section, a SWOT analysis for the TVWS exploitation in the current regulatory scenario is presented. SWOT analysis is a strategic planning method used to evaluate the Strengths, Weaknesses, Opportunities and Threats involved in a project or in a business venture. It involves specifying the objective of the business venture or project and identifying the internal and external factors that are favourable and unfavourable to achieve that objective. Details are presented in subsequent sections and illustrated in Figure 1.

Figure 1: SWOT analysis for the TVWS exploitation.

2.4.1.1 Strengths

Strengths included the positive internal factors. These are the qualities, trumps which positively distinguish themselves in the environment and the competition. Within COGEU model the following positive factors can be identified:

- **Spectrum efficiency**
  A market-based approach for spectrum management might be considered as a way to improve the efficient use of the radio spectrum. This mechanism would imply that under-utilised spectrum assets could be transferred to individuals or organisations, deriving in greater economic returns from their use. In this way, it would lead to an optimum use of the radio spectrum.

- **Spectrum flexibility**
  The introduction of spectrum trading involves a more flexible way of managing this scarce resource. Instead of the traditional assignment methods, spectrum trading considers the possible dynamism, both in demand and offering, inherent to the telecommunications sector itself. Moreover, it is given to the market a greater role in the allocation and assignment of spectrum, which also reduces the administrative burden on regulations. Besides, spectrum trading could be seen as a flexible way to manage spectrum, for example to satisfy spectrum demand "peaks" to cover particular and specific events, for example, the Olympic Games (by means of leasing spectrum rights for a specific time period).

- **Innovation promotion**
  Spectrum trading could be considered as incentive to accelerate innovation in wireless communications technologies. In this sense, it favours possible change in use and/or users over time in response to shifts in market demand and technological innovations. For example, M2M and smart metering applications over TVWS.

- **Competition**
  The possibility of secondary access to radio spectrum would lead to more competition, both between market players and between wireless technologies themselves, in relation with innovation promotion among such technologies. This makes it possible and opportunities for companies of all sizes, for example the success of Linksys and Netgear with unlicensed Wi-Fi.

- **Spectrum pricing**
  A spectrum management approach based on spectrum trading would help participants in the spectrum market to have access to pertinent information about the different trades. This would involve more fairness when establishing true market values for spectrum, based on real demand.

- **Transparency promotion**
  As a result, the introduction of spectrum trading relies on making available to the public all information related to spectrum usage (existing spectrum ownership, individual trades, area and population coverage, technologies, services and applications, spectral efficiency, etc.). Regarding this issue, there should be strong support by the NRA's (National Regulatory Agencies) for providing online registries including information on licence conditions, rights and obligations.

2.4.1.2 Weakness

Weaknesses include the negative internal factors. They are limiting the efficiency aspects of the project. Potential weaknesses of COGEU approach are as follows:

- **Legislative underpinning**
  It is necessary to establish clear procedures for disputes resolution and other concerns. Moreover, it is also to be taken into account the establishment of policies in relation to existing licenses.

- **International harmonisation and coordination**
  Regarding spectrum trading practical implementation across EU Member States, two main issues that need to be taken into account are the potential for interference in border regions and the need for regulations to govern the repossession of spectrum that has been harmonised for a new service. There is general support for an EU approach based on promotion of discussion and exchanges of national experience, identification and promulgation of best practice, including ad hoc events and encouraging the development of a level playing field.

- **Interference control**
  Spectrum trading, specifically if it considers "change of use", could cause serious problems related with interferences among different services/applications, which should surly be considered. This should be taken into account specifically in cross-border interference if there is no previous harmonisation among different EU Member States.

- **Fragmentation in spectrum usage**
  Along with the problems related with interference control, the implementation of "change of use" approach could lead to a fragmentation in the spectrum usage. This would surely mean a more difficult spectrum management approach and could have negative impact on ensuring scale economies in equipment production, and in the introduction of new services and applications as it could be needed continuous blocks of spectrum of a specific size.

- **Hoarding of spectrum**
  A specific practice that must be avoided is the possibility by which spectrum user applicants may be motivated to demand more spectrum than the necessary in order to prevent in a generous way their own spectrum needs for the longer term, as well as on the understanding that they might be able to recover initial investments by the way of trading the spectrum rights they got. The general way to prevent the above should include, at least, the application of generic EU competition policy, complemented by specific case-by-case rules.

2.4.1.3 Opportunities

Opportunities to external factors included positive. This occurrence and tendencies, which is used in an appropriate manner will be an impulse for the development or weaken the threat. COGEU opportunities include:

- **Regulatory certainty**
  Regulatory certainty will be key to the success of any market. Markets can thrive under the uncertainty of supply and demand of the good being traded – however, they strongly dislike any regulatory uncertainty as it is something over which they have no control and cannot hedge against. Therefore, clarity of definition of spectrum rights within the TVWS or the tradable spectrum access mechanism will be a key requisite for a successful trading system.

So for, the objective will be to provide clear guidance to the European regulators on how to regulate trade in the TVWS context such that industry has the confidence to develop consumer systems that can exploit that market.

- **Positive examples from other countries**
  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 secondary trading – the trading of spectrum rights after the primary assignment – is possible. it is they give positive incentives to accelerate action to implement the regulatory changes. Examples from other countries are 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.

- **Geographical distribution**
  The rules on geographical distribution are not universally applied, so to further increase the tradability of spectrum, for example Ofcom allows for the aggregation and disaggregation of spectrum lots; original licenses may be split along geographic and/or frequency lines if it suits the market. Conversely, separate adjacent licenses may be aggregated to provide more geographic coverage or bandwidth.

2.4.1.4 Threats

Threats included the negative external factors. These are all the external factors that are seen as barriers to the development of the project. Threats which may occur in connection with COGEU approach are as follows:

- **Regulatory delays**
  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. They need to understand the relevant (business) requirements, industrial costs, potential size of the market and investment profitability, in order to be able to advice on effective regulation. At this stage, there is a common European interest in establishing some form of partnership between European standardisation bodies and spectrum regulators (e.g. through CEPT), where possible, on the basis of initial business plans from industry.

  Therefore, from the European perspective, for cognitive access in the UHF band, we can see that there are numerous challenges facing both regulators and industries. 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.

- **The impact on interference**
  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 harmonised 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.

- **Inertia/Resistance from the main players**
  It should be emphasized that one of the main and important requirements of COGEU system is protection of primary users. Geo-location database approach can also protect future developments of DVB. Even if the broadcasters generally agreed that geo-location database is the best way to protect DVB from potential interference with WSDs they are against use of TVWS. The main concern from broadcasters side is that WSDs can block the evolution of DVB technology in EU.

  From other hand, it may be argued, that MNOs (Mobile Network Operators) do not like the cognitive access of TVWS. They simply want to have spectrum for them exclusively; and in

order to achieve that goal, they act on a political ground. A request for more spectrum allocation to the Mobile Service (IMT) within the broadcasters' UHF band 470-790 MHz may be most likely expected.

- **Low market liquidity**
  One of the main concerns for the implementation of a secondary spectrum market is the low market liquidity, for instance due a limited number of players (such as MNOs) competing for spectrum in a given area. Currently COGEU considers one (as an example) application scenario using secondary spectrum market - LTE extension over TVWS. If we assume that most of TVWS use comes from LTE network operators and if we considerer 3-4 LTE operators per country and if as expectable its TVWS allocations are medium or long term, the secondary spectrum market will be not very dynamic.

  From other hand, it should pointed out that COGEU model allows also small players enter in the spectrum market, buying spectrum for temporary use such as telemetry applications, M2M applications or WiFi-like applications with QoS guarantee. WiFi network operators will benefit from entering secondary market instead of spectrum commons. It would be possible for Public Safety systems to operate in secondary market as well. In this case, priority features was especially introduced into COGEU broker to prioritize access to secondary market for these systems.

2.5- 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 in 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 below in the form of a list of trends and impact.

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.	• Realization takes long time (years). • ITU considers relevance in the introduction of SDR and CR systems as a good approach for achieving better spectrum utilisation, dynamic spectrum management, and flexible spectrum use. • ITU foreseen that there will be no need to change the radio regulations to address CR and SDR technologies. In this sense, with the support of regulators, the introduction of these technologies may be strait forward.
USA (FCC)	• Emergence of companies involved in the US. • Geo-location is considered enough to protect incumbents. • Database operators.	• Regulator's participation has enabled the emergence of startups in using TVWS. • Standardization efforts are underway through IEEE DySPAN Standards Committee, 802.22, 802.11af, etc. • Nine entities were designated as TV bands device database administrators so far.
Europe	• The usage of TVWS is fragmented among member states. • Need for harmonization. • R&TTE directive.	• 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 harbour" concept for PMSE, etc. • ETSI have initiated various work items and project teams (e.g. TC RRS, ERM, BRAN etc) to look at standardisation issues around CR and SDR. • Under the amended framework directive, Member States have the right to establish secondary spectrum market (art. 9b). • In the UK, Ofcom have progressed the concept of the band manager, a mechanism which actively sets about creating and supporting a secondary spectrum market.

3- Policies for free and efficient spectrum markets

In this chapter, policies for free and efficient spectrum market are discussed in general. The specific policies to enable the COGEU secondary spectrum market of TVWS will be detailed in Chapter 4.

3.1- Definition of the rights to the spectrum for 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 neighbourhood interference).

In the secondary spectrum market foreseen by COGEU [D32] the spectrum selling by the broker is based on auctions. Thus prices of spectrum depend on the supply and demand, location, frequency and 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.

3.1.1- 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 an 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 (as shown in Figure 2). However, it is up to the broker in primary instance, to check the correctness of the allocation.

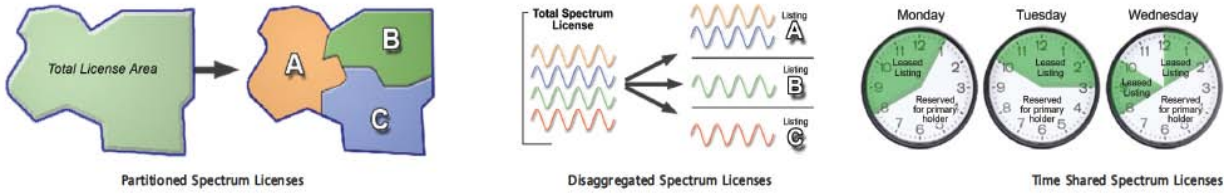

Figure 2: Spectrum availability (location, bandwidth, time) [73].

In the context of COGEU, the secondary spectrum market is related with the availability of TVWS (geographical dimension, TVWS maps [D6.1]), the coexistence of different players with different radio access technologies or modes in a non-interference basis (bandwidth dimension) and focus on temporary allocations (time dimension, trading of secondary exclusive rights).

3.1.2- Buyer

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 behaviour. 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.

3.2- Buyers validation

Trade in radio spectrum requires at a minimum enforceable and identifiable property rights. The reason for this can be seen by looking at the long-established markets in property in many countries. These work well partly because there tends to be a land registry scheme which details ownership records for

definable parcels of land. Without a land registry scheme, trade in property would involve considerable additional costs as ownership would need to be investigated more closely [11].

The operation of registry schemes helps operational efficiency by lowering the transaction costs associated with trade, and also improves the security of transactions. From a policy perspective the costs of operating registry schemes have to be weighed against the benefits associated with lower transaction costs.

Market forces are more effective when traders are better informed about the nature of products traded and about the valuations of traders in a market. While the identity of traders is not essential for efficiency to hold in many markets, the identity of traders in spectrum markets may provide a very strong signal about the use to which spectrum is to be put. As spectrum usage can generate interference adversely affecting other users, which in some instances can be very costly, it is essential that as much information about spectrum assignments is made public prior to the conclusion of trades. This requirement is particularly important in situations where the costs due to possible interference are not known, or are known with imprecision, and where they are considerable. **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.** Since public bodies utilise substantial numbers of frequencies, it is desirable that they participate as far as possible in such information disclosure.

The most important piece of information for buyers and sellers to obtain a better understanding of the value of the spectrum they are either buying or selling is the price paid in similar transactions. To the extent that the availability of spectrum transaction prices contributes to reduce the amount of private information, this could increase the efficiency of spectrum markets.

3.3- Legal protection for users

The use of market forces could significantly enhance the value derived from radio spectrum, and one of the key ways to enable these forces is through a trading regime that also allows change of use. Achieving this requires a clear definition of users' rights, often termed "property rights". Defining these property rights in the world of spectrum is complicated because of the many different uses of spectrum and the wide range of different technologies adopted. When considering possible forms for property rights it is worth remembering that the reason for rights is to protect neighbours from interference. In this case, neighbours can be both geographical and in frequency terms. In such a system property rights are defined in terms of the interference that can be caused to neighbours. Any change of use or technology is allowed as long as it does not increase these levels of interference. Finally, by considering the property rights of its neighbours, a licence holder is able to deduce the level of interference that it might suffer and design its network accordingly.

The mechanism for setting the limits in the first place needs to be defined. There are two options.

- Set all the limits in all licences to the same levels (which would probably be restrictive) and then allow licence holders to negotiate them to more appropriate levels.
- Set the limits to the status quo, where it exists such that operators do not immediately need to embark on a negotiation process. Where the status quo is not defined, estimate it through modelling and consultation.

The end point for both approaches will be the same. It seems more appropriate to provide limits in line with the status quo and avoid unnecessary negotiation for current licence holders. Conversely, for an operator, once they have a licence in property right terms, they need to work out what network they can deploy. This is not as simple as a more conventional licence where they need only to ensure they are using an approved technology. Now the operator needs to ensure that they will not exceed their interference allowance (e.g. maximum transmit power in TVWS). Just in the same manner as the licence terms are set, described above; they will likely do this through modelling. By using a propagation model and inputting the parameters of their preferred technology and likely deployment density they can determine if this will likely be within the limits of their licence terms.

The technical issues associated with the formation of property rights that would assist trading and allow change of use:

- A set of property rights is critical to facilitate trading and enable change of use.

- The key components of property rights comprise limits on the levels of interference that can be caused in three cases: in-band, out-of-band and at geographical boundaries. From these limits, neighbours will be able to calculate their likely interference levels.
- These rights and obligations will need to be carefully defined since the interference experienced by one user depends on the rights granted to other users.
- COGEU approach to the TWS can fit within this framework of property rights; however, the regulator will need to make a decision, likely based on the economic case, as to whether it should be allowed.

If the rights created are perpetual ones, it is a "once and for all" chance. If the rights are confined to a period, the resource may revert to the government which can then reshuffle the associated rights and reissue them to others, for example by an auction. One starting point is that in defining rights for spectrum, the government or regulator should be guided by considerations of economic efficiency. The underlying logic for this criterion is that spectrum is an input, and that – whatever interventions governments want to make on the composition of final outputs, by taxing or subsidising marketed goods or by direct public provision – they should always seek to use inputs efficiently.

A system of property rights will lead to an efficient allocation of resources provided that:

- the property rights are fully and precisely defined - requires that there be no ambiguity about who owns what;
- there are no transaction costs – transactions costs refer to the costs of, or impediments to, the transfer of property rights. Most obviously these are monetary, such as legal costs, but they also include instances where conflicting objectives among trading partners make it impossible to carry out a trade which improves efficiency;
- efficiency is defined without reference to the distribution of income - we are equally prepared to recognise as efficient a regime in which all assets are held by a few large corporations and their shareholders as one where they are more equally held.

This means that the design of property rights is a non-problem – owners will quickly unpick any mistakes the government makes. The alternative pessimistic version goes as follows:

- many changes will affect a large number of spectrum users, and it will be very costly to get them to agree;
- where only a few spectrum users are involved, each will try to appropriate the gains from trade, so no agreement will be reached.

There is a need to focus on the optimisation of ownership before the market opens. This is anything but easy. Basically three non-exclusive approaches exist:

- Calculate and establish an optimal configuration of rights; this might involve, for example, putting the onus to avoid interference on the so-called "least cost avoider";
- Where that is not possible – or simultaneously – invoke a principle designed to minimise transactions costs; here the main candidate in the case of interference is to distribute rights away from the party that can most economically incur the transactions costs to rectify any mistakes;
- Anticipate and manage the risks associated with failure to reach the optimum solution, by causing the right to revert periodically to the government or regulator.

When defining the property rights of spectrum, the regulator will encounter some practical problems. Spectrum licences in many countries have traditionally been finite, but indefinite. The regulator has exercised its right to give notice to licensees, sometimes offering to transfer them, at the regulator's expense, to another band. Governments are naturally cautious about making irrevocable decisions about public assets, but in this case the arguments for doing so seem strong.

In principle, there is nothing to prevent a spectrum licensee, which has leased spectrum to another firm, selling its licence to a third party, subject to the protection of the rights of the lessee. This is a natural and, in other areas, conventional form of transfer of property rights. In a transition phase, the government may also find it desirable to auction long-lasting or perpetual rights in spectrum subject to existing licensees with time-limited rights. It would then be up to the successful bidder to negotiate with these licensees over the repurchase of their rights, or to allow the licences to run their course. No further regulatory intervention would necessarily be required.

Under a tradable regime, however, spectrum licences can be issued to firms without restrictions on use or resale. As a result, licences could be issued for all spare spectrum, allowing the market to leave it vacant or apply it in some use over time. The acquirer of such spectrum, whether as intermediary or a final user, would then have an incentive to undertake development work on new technologies – work which it might not undertake without guaranteed access to the spectrum.

This analysis has enabled us to reach a clear recommendation – **a new property right should be established for spectrum trading, or more precisely the trading of spectrum licences**. Our conclusions flow in part from technical consideration and in part from economic consideration, the latter relating to transaction costs and investment incentives.

- Rights should be assigned in ways which take account of the economic value, and interference potential, of new underlay technologies such as cognitive radio over TVWS.
- Vacant spectrum should be placed in the market place (subject to international agreements).
- A compulsory purchase power for spectrum should be sharply confined, possibly to national security needs.
- Spectrum licensees should not be subject to any other restrictions that discourage efficient trading.

The rights and obligations of tradable license must be sufficiently clear: duration, area and interference restrictions. Obligations for the owner of the spectrum or broker have the following points [D3.2.]:

- Coverage requirements;
- QoS requirements;
- Interoperability requirements (e.g. handover, roaming);
- Minimum service offering (e.g. location-based services, high speed data transfer, etc.);
- Social aspects and universal service obligations, for instance special services for the disabled;
- The licensee's obligation not to interfere with other spectrum user‘s rights;
- The licensee's degree of protection from other users;
- The band which is available for use;
- The geographical area in which it can be used;
- The period for which the license is entitled.

3.4- Means of determining prices

Based on the recommendations of the ITU, spectrum prices should follow a set of principles [33].

- All spectrum users should pay a charge.
- Non-discrimination – the spectrum charge should be calculated fairly, i.e. if two users are using the same amount of spectrum in the same way, both should pay the same charge.
- The spectrum charge should be proportionate to the amount of bandwidth used.
- The charges should reflect the spectrum’s value to society, i.e. if need be, frequencies used for public services should be subject to lower charges.
- The cost of spectrum regulation should not be borne by the state.
- Spectrum users should be consulted about intended adjustments in spectrum charges.
- The pricing structure should be clear, transparent and comprehensive, without unnecessarily lengthening the licensing process.
- The pricing structure should reflect the scarcity of available spectrum and the level of demand for spectrum in different frequency bands.
- The spectrum charge should be calculated so as to recover the costs of spectrum regulation. Spectrum pricing should not seek to maximise revenue for the government.
- The ability to levy spectrum charges should be anchored in law.

The broad goals and objectives associated with spectrum pricing are:

- Covering the costs of spectrum management activity borne by the spectrum management authority or regulators;
- Ensuring the efficient use of the spectrum management resource by ensuring sufficient incentives are in place;
- Maximizing the economic benefits to the country obtained from use of the spectrum resource;

- Ensuring that users benefiting from the use of the spectrum resource pay for the cost of using spectrum;
- Providing revenue to the government or to the spectrum regulator.

The general theory of prices emerging through an authentic market transaction such as an auction or secondary trading. involves assumptions regarding economic behaviour of consumers of resources concerning rationale preferences for outcomes, utility (maximizing efficiency and profit) and information availability and access. From these assumptions, economists developed a structure to help in understanding how the allocation of scarce resources among alternative ends occurs in markets.

Another aspect is the way of setting prices in the auction model. Therefore, the pricing aspects of the selection process are addressed below.

In an auction, contestants for a licence make competitive bids and the licence goes to the highest bidder. It is normal for the bids to be made in monetary term, the competitor offering the largest monetary sum getting the licence.

There are several circumstances where an auction can be considered as a means of assigning licences:

- The simplest case is one in which a single license is offered for auction in a self-standing process.
- When two or more identical or complementary licences are offered, they can be offered sequentially or simultaneously. Where each licence is local, a simultaneous auction can allow firms to piece together local licences to provide broader coverage.
- The licence(s) can be assigned on the basis of a so-called 'open bidding' or public process, with bids visible to other parties, or on a 'sealed tender' system, under which each party marks a single private offer; there are numerous alternative variants of open auctioning, one of which is the so-called clock auction.
- The auction can have a minimum acceptable bid or 'reserve price'.

The choice of auction mode will vary with the nature of licences made available, the number and nature of firms with an interest in theirs and the regulator's or government's objectives.

A successful auction requires a clear understanding by participants of what rights and obligations are available to the winner or will be imposed upon them. If there is uncertainty about this, it will discourage competitive bidding. Auctions differ in two main ways: in the number of lots (or licences) made available and the way the auction is conducted. There has been a significant number of mobile licenses grant by auction around the world and they form a good basis for analysis and understanding. In relation to these wireless communication licences, some the key variables in designing the auction are [33]:

- The number of licences to be offered to the service and in which band: this decision is of fundamental importance, since it determines the structure of the services market. The objective of maximizing consumer welfare suggests the harnessing of competitive forces to the maximum – i.e., issuing, subject to spectrum availability, as many licences as the market will be able to support (plus one or two extras to permit freedom of entry into the market);
- Any commitments made at the time of the auction relating to restrictions on the award of subsequent licences;
- Whether **national or local regional licences** are issued; here the regulator may find it helpful to anticipate the kind of business plans (national or regional) firms are likely to have and make licences available, accordingly there is nothing to preclude a mixture of national and regional licences;
- **How long the licences will last: too short a period may discourage investment in the services, while too long a period may allow the spectrum in question to stagnate if it cannot be sold on for another purpose**;
- Any obligations a licensee may have to make periodic payments in the course of the licence;
- Any network roll-out obligations or 'use it or lose it' clause;
- Any foreign ownership restrictions.
- All these aspects influence the expected revenues from the auction, and their expected impact on consumer welfare.

The trading mechanism could be realized through an auction mechanism in which the broker collects bids to buy from the service providers, bids to sell from the geolocation database, and subsequently determines the allocation along with the price for each spectrum asset. The auction would then be repeated as spectrum assets become available (i.e., as they are released by supplying players).

Alternatively, the COGEU Broker could announce a set of reference prices for the available TVWS, and adjust the prices based on time, location, bandwidth required and other factors to maximize expected revenue or to clear the market periodically. This approach is generally simpler, and requires less overhead (information exchange) than an auction mechanism. However, a well-designed auction mechanism can achieve either a higher efficiency or more revenue depending on the intended objective.

The choice between these two approaches should depend on the size of the market. When is a few buyers and sellers, an auction mechanism may be preferred to simplicity in implementation and the chances for higher revenue. However, when the market is with a large number of buyers and sellers, the pricing mechanism should be preferred due to decreased loss in terms of efficiency or revenue.

As it was already introduced in previous reports [D3.2], the COGEU broker supports pricing mode and auction mode for allocating spectrum. In the pricing mode, the price is decided by the allocation procedure which considers various factors which influence the value of TVWS in a given place. In the auction mode, the auctioned band has a benchmark price, then each demand has an associated price and the winning bid decides the final price. In this case, spectrum is sold in terms of first come first serve basis in the pricing approach, or the most valuable bidder wins the band depending on the auction mechanism.

3.5- Dispute resolution mechanisms between market players

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.

3.5.1- Disputes Definition

Before going into detail in the dispute resolution mechanisms, it is useful to define “dispute”. A dispute may be viewed as a class or kind of conflict which manifests itself in distinct, justiciable issues. It involves disagreement over issues capable of resolution by negotiation, mediation or third-party adjudication. The differences inherent in a dispute can usually be examined objectively, and a third party can take a view on the issues to assess the correctness of one side or the other.

Herein we do not limit the exploration of dispute concepts to disputes occurring only where one party has filed a formal claim against another. It goes further, exploring situations where conflicting interests

among parties are blocking sector development, even though no formal dispute process is under way.

Policy-makers and regulators are recognizing that effective dispute resolution is an increasingly important objective of telecommunications policy and regulation. Failure to resolve disputes quickly and effectively can:

- Delay the introduction of new services and infrastructure;
- Block or reduce the flow of capital from investors;
- Limit competition, leading to higher pricing and lower service quality; and
- Retard liberalization – and with it, general economic, social and technical development.

3.5.2- Overview of Dispute Resolution Techniques

In this section various types of techniques available to resolve disputes in the telecommunications sector are presented. It identifies features of the various dispute resolution techniques that are relevant for the sector and highlights organizations that deal with dispute resolution.

Herein some dispute resolution techniques are presented, however other methods and a deep explanation can be found in [35].

3.5.2.1 Regulatory and Court Adjudication

Regulatory adjudication refers to methods regulatory authorities use, exercising their legal powers, to make decisions resolving disputes brought before them.

Most regulatory bodies adjudicate disputes. They decide between the positions of disputing parties, typically after a formal process that involves the presentation of arguments by those parties. Adjudicated decisions are often subject to review within a regulatory agency and eventually by the courts or government officials. Regulatory adjudication can have the following advantages:

- There are well-structured channels for decision-making;
- It provides accountability on the part of official decision-makers;
- There are established mechanisms for coordinating decisions among agencies with related responsibilities; and it makes available the full force of the government's enforcement mechanisms.

On the other hand, regulatory adjudication can bring the disadvantages of delays, abuse by competitors, and lack of necessary economic, legal and financial expertise to resolve disputes efficiently and finally.

The court adjudication is an alternative dispute resolution methods and it remains an important final recourse for many types of disputes, particularly those that are less policy-related. It has the advantage of bringing finality and official enforcement mechanisms to bear upon a dispute. However, the high costs and delays in some jurisdictions and a perceived lack of telecommunications-specific expertise to deal with many complex industry disputes.

The alternative dispute resolution (ADR) involves less formal or official means of dispute resolution, such as negotiation, mediation and arbitration. Parties have traditionally pursued ADR processes voluntarily, sometimes by contractual commitment. Regulators are now turning to ADR approaches to help them deal with excessive pressures and demands on their limited resources available for resolving industry disputes. Moreover, ADR can produce settlements and save costs, resulting in solutions that benefit all parties.

3.5.2.2 Negotiation and Mediation

Negotiation and mediation are flexible, consensual approaches that have the advantage of encouraging parties to identify common interests and "win-win" solutions.

Negotiation and mediation processes can, however, be subject to abuse by disputing parties who seek to delay adverse resolution of disputes or to obtain information about the other party's case.

The fundamental key to all consensual ADR activity is negotiation. The key characteristic of negotiation is that it is a consensual process that may allow the parties to arrive at a mutually agreeable solution without third-party entities.

The main advantage of negotiation is that it may result in a solution that is favourable to each party, which may be very valuable to an ongoing business relationship. Reaching agreement by negotiation avoids the more adversarial processes found in other types of ADR.

Mediation is a consensual process that involves a neutral third party in facilitating dispute resolution.

Regulators often require parties to try negotiation or mediation before bringing their disputes before the regulator. Some regulators or their staffs perform the role of mediator. Some parties prefer to use independent mediators instead. The involvement of regulators can induce parties to behave more reasonably. But it can also reduce parties' incentives to negotiate in a candid, constructive manner, because parties may see the presence of regulators as a precursor to a formal regulatory proceeding.

3.5.2.3 Arbitration

Arbitration is a method of dispute resolution (sometimes preceded by mediation) that takes the place of conventional litigation. It is a consensual process in which disputing parties agree to refer a dispute to a neutral third party arbitrator or panel of arbitrators for resolution. A commitment to arbitrate disputes is often included at the outset of commercial agreements, binding the parties to seek arbitration of any future disputes that may arise. The parties also may choose arbitration when the dispute arises, as an alternative to litigation or regulatory adjudication.

The advantages of arbitration include:

- Confidentiality;
- The parties' control over the design of the process;
- Speed, compared with most regulatory or judicial procedures; and
- In international arbitration, the neutrality of the forum (compared with the national courts of either of the parties).

Regulators are increasingly encouraging parties to use arbitration as a way to resolve disputes. There are numerous, well-established arbitration institutions around the world that have developed their own procedures and trained arbitrators. Where individual countries lack such resources, they are often able to find them somewhere in their region.

Figure 3 presents the level of participation of parties in each dispute resolution technique. This classification is also done according to reactive or proactive procedures. As long as possible, proactive procedures are favourable.

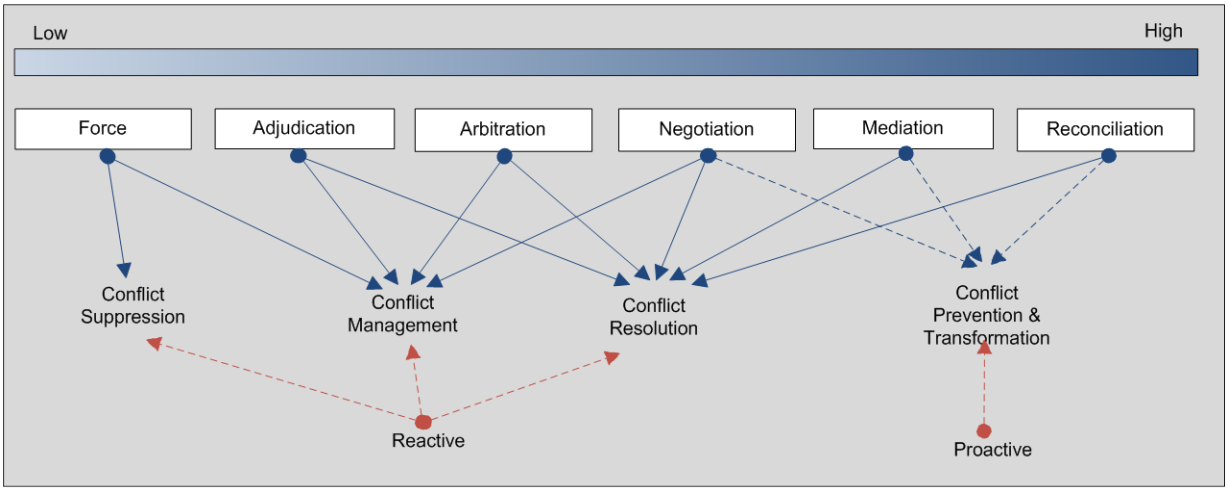

Figure 3: Level of mutual participation in search for solution

3.5.3- 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;
- Punishment, in its own office, companies for which it has found the non-compliance; 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.

To the extent that the official sector recognizes advantages in developing non-official dispute resolution approaches, it can take affirmative steps to strengthen.

4- Proposals of regulatory policies to enable the COGEU model

COGEU reference model presented in D3.1 envisage secondary spectrum trading of TVWS through a centralized broker. This chapter presents a list of spectrum polices and regulatory requirements that will incentivise 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 4.

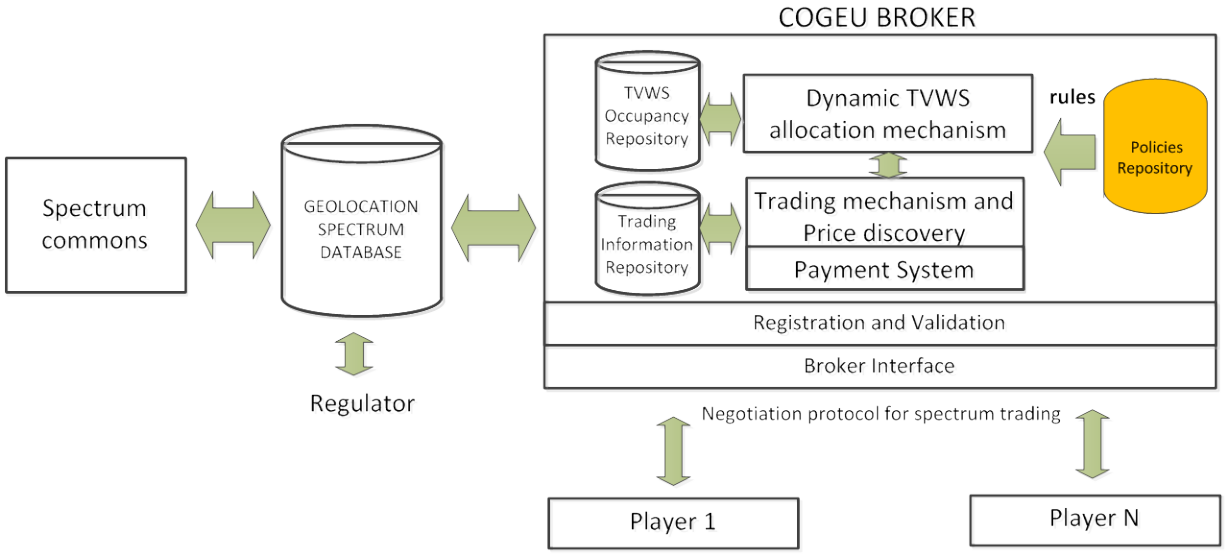

Figure 4: COGEU reference model for secondary spectrum trading of TVWS [D3.1].

4.1- Policies to allow and promote secondary trading of TVWS in Europe

In deliverable D3.2 we introduced a model 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 (as shown in Figure 4).

Combination of commons with trading is a key innovation of 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.

We propose 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 awards (Ofcom use the formal term ‘geographic interleaved awards’ to refer to licensed lots of TVWS spectrum.)
- Band managers (COGEU broker)
- Simplified spectrum leasing

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). This Primary TVWS licensee could operate as a **Band Manager of its own spectrum**. It would have the **right, and associated responsibilities,** to lease its spectrum to third-parties without recourse to the NRA. Such an approach has a number of distinct benefits:

1. The Primary TVWS user would have a license in which to operate its own services which could be low-power DTT services or non-DTT services.
2. The Primary TVWS user would have the legal authority to act as the Band Manager of its own licensed spectrum; the degree to which it leases its own spectrum, and the manner in which it arranges these leases, to third-parties would be at its sole discretion.

3. 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.

In the following paragraphs, we describe the ongoing development of these 3 necessary elements of a real-time spectrum trading regime for TVWS in Europe; geographic interleaved awards, Band Managers and simplified spectrum leasing.

Flexible geographic interleaved awards, or flexible TVWS licenses, can be seen as a prerequisite for the introduction of a secondary-trading regime in TVWS. Ofcom (UK) has conducted extensive rounds of consultation and review to select the means by which the UK TVWS will be managed. Two separate rounds of consultation, one in 2008 [41] and a subsequent one in 2010 [19], examined the likely uses of the TVWS. In the UK, as in the rest of Europe, the interleaved spectrum exists at various geographic locations at various frequencies in the 256MHz that has been assigned to national DTT multiplexes.

Ofcom's early consultation with industry on the use of the TVWS focused on identifying uses of the spectrum for which it could award licenses, specifically 'geographic interleaved awards'. It is clearly evident that this NRA's approach is to license as much of the TVWS as is feasible; the remainder being left open for unlicensed, cognitive radio access, among other uses. Initially, in 2007, it had been the objective of Ofcom to reserve the economically viable lots of TVWS for local television services. However, it was then decided that other potential uses for the TVWS should be investigated to ensure that the regulator's decisions did not displace higher value services. In 2008, Ofcom proposed to industry the use of the TVWS for DTT services over a wider (non-local) area, which would involve packaging fragmented lots of TVWS into one licence, and also mobile broadband and PMSE. While Ofcom were open to new services, the initial geographic interleaved awards were still made ostensibly for local TV services at sites identified by Ofcom as being economically viable. The metropolitan areas of Manchester and Cardiff are two areas for which awards have been made. In the case of the Cardiff TVWS license there was only one bidder, Cube Interactive, which only paid the reserve price of £10,000 for their licence.

Even though Ofcom discussed the idea of allowing alternative uses, i.e. non DTT uses, of these awards the licence conditions imposed by Ofcom were in the form of DTT (DVB-T) transmission masks. These masks were designed in such a way to protect the incumbent national DTT (DVB-T) multiplexes. However, Ofcom have stated that, in theory, these awards were not restricted to DTT services. If the licensees wish, in future, to pursue the development of other services which would have different network topologies, i.e. more dense networks for broadband provision, Ofcom would be open to changing the licensing conditions to allow for this.

A number of companies in the UK objected to this form of licencing. They called on Ofcom to develop more flexible geographic interleaved awards that use technology and service neutral Spectrum Usage Rights to define the technical licence conditions. BT, Vodafone and JFMG (the band manager discussed in Section 4.5.2 of D2.1) objected to Ofcom's seeming unwillingness to facilitate non-DTT uses of the spectrum. They stated that there was no guarantee that a variation of the licence would be granted and therefore there was a risk in investing in such an award.

COGEU strongly endorses the requirement to define TVWS licences 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 technology neutral form. Regulatory certainty is a necessary prerequisite for market participation. Ofcom's current approach to use technology specific licence 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 [42]: It is generally understood to be an organisation that engages in activities that go beyond simply trading spectrum. These activities include some or all of the following:

1. *planning the use* of a block of spectrum, which is defined by the scope of its licence;
2. *packaging the spectrum* for disposal through trading but not necessarily exploiting the spectrum operationally itself;
3. *engaging with the market* to dispose of it permanently or temporarily through trading;

4. *serving end-users*, who will be the band manager's customers, with contacts covering their relationship;
5. acting as first port of call to *investigate and resolve interference* caused by its customers.

Any holder of a tradable licence could potentially function as a band manager, even if this was not its main commercial activity. **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 licence transfers to a system of spectrum leasing is required.

The revised European Framework Directive [44], finalized at the end of 2009, contains a number of decisions that facilitate and, indeed, direct that Member State NRAs to develop more flexible trading systems. Up until this revision Article 9 of the old 2002 Framework Directive [43] 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.

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 5, 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 licence transfer, even if it is an automatic consent, then the transfer proceeds and the original licence, 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.

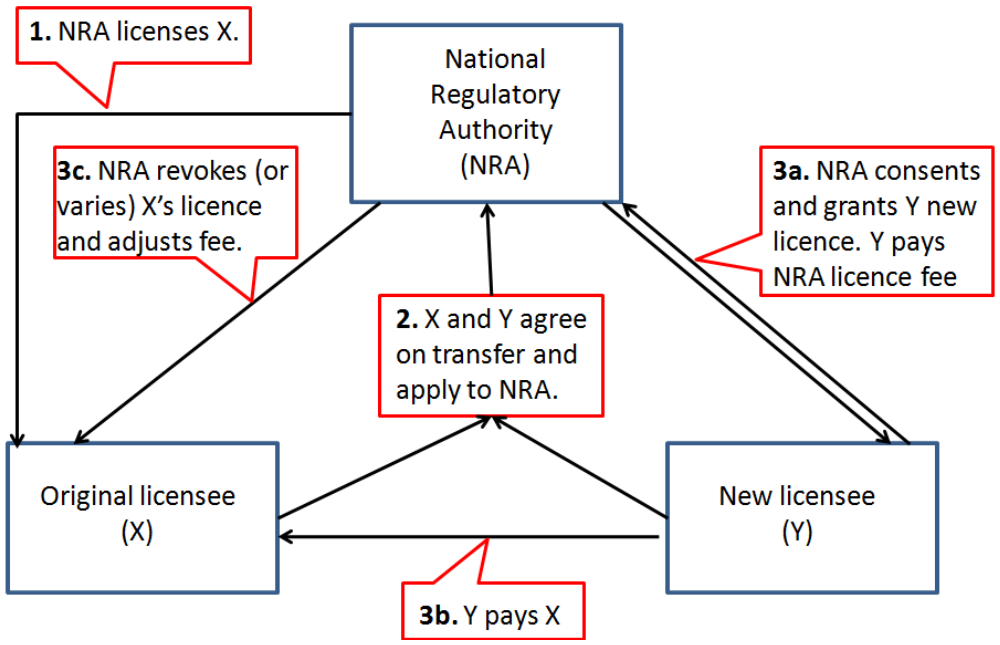

Figure 5 Article 9 Spectrum Transfers

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 though the

development of a spectrum leasing, sub-leasing and private commons regime [45], 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 in D2.1.

However, the revised Framework offers the possibility of developing a leasing system. Article 9(b) of the revised 2009 Framework Directive [44] 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.

Spectrum leasing differs significantly from spectrum licence trading through transfers as it removes the NRA from much of the bureaucracy of the trading process and it enables the Original Licence, i.e. the Primary TVWS, to contract with lessors on its own terms, as illustrated in Figure 6. Spectrum leasing is the process by which an original licensee can authorize a third-party lessor to exercise its Original licencee rights, but without transferring those rights to the third-party.

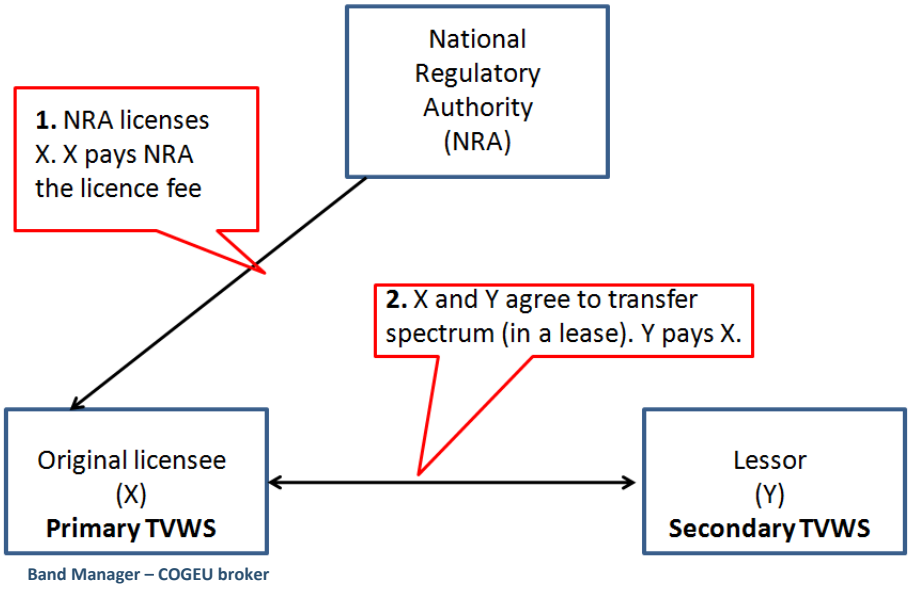

Figure 6 Spectrum Leasing (COGEU approach): removes the NRA from much of the bureaucracy of the trading process, developed under Article 9(b) of Directive 2009/140/EC [44].

The issue of confidence in the leasing process is an important one. Under the spectrum licence transfer process a new licensee has a direct relationship with the NRA who guarantees the quality and enforceability of the licence. Under a leasing arrangement, the Original licensee and 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 licence, as such, if the NRA has built in a clause that allows it pre-empt Original licencees' spectrum rights or to demand that the licensee cease transmissions, these demands will also follow to the lessor, or 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, of the kind described in Figure 6, which detaches the NRA from involvement in the execution of every single trade should be brought forward.

4.2- Use Administered Incentive Pricing to promote efficiency in the TVWS

In this section, we discuss the use of administrative incentive pricing to promote efficient secondary spectrum market in the TV white spaces. **COGEU investigates the usage of AIP as a way to provide benchmark price in the Broker, or to be used as an alternative to auction**. The use of AIP as a spectrum pricing method need to consider dynamic market conditions and static situations, as well as anticipate changes in the long run in order to be effective in promoting efficiency in the TV white spaces. Therefore, in order to effectively approximate the equilibrium value of the TV white spaces, the use of AIP has to take into consideration market specific situations such as the demand versus supply for a specific spectrum band in a given geographical location.

The aim of estimating the price of spectrum is to create incentives for spectrum users to provide high-value services at least cost – leading to efficient spectrum usage. When the market sets spectrum prices, as in auctions, equilibrium is automatically reached, forcing system designers to optimize the usage of resources. Therefore, artificial price setting, as in AIP, can only emulate the efficiency and incentive effects of market-based pricing. Such market emulating prices are based on the economic principle of opportunity cost.

Opportunity cost is defined as the highest value alternative forgone. The opportunity cost of the marginal unit of the good or service in a market equals the clearing price of an efficient market. Hence, when intermediary entities seek to emulate the efficiency of the market in allocating spectrum, prices should be determined based on the principle of opportunity cost. According to [60]:

"*The fundamental mechanism by which the spectrum management regime could contribute to economic growth is through ensuring that users face continuing incentives towards more productive use of this resource [i.e., spectrum]. … [T]hese incentives should be financial and based on the opportunity cost of spectrum use. In this way, spectrum would be considered as any other input into the production process. Price signals about the cost of using spectrum would be disseminated throughout the*

economy. This information should enable dispersed economic agents to make their own judgements about their use of spectrum and the alternatives open to them to meet their organisational goals."

The opportunity cost of a particular block of spectrum is the cost of denying spectrum to any other use or user. If the value of the spectrum to the incumbent use/user is less than the opportunity cost, then the distribution of spectrum can be said to be sub-optimal in the sense that more value would be created by re-allocating the spectrum. If users are faced with the opportunity cost of spectrum, they will have incentives to increase/decrease their use if they value spectrum more/less than the opportunity cost [53]. In theory, current users would therefore be willing to transfer rights to use spectrum if the opportunity costs of using spectrum, reflected through administrative incentive pricing, are higher than the economic value to the user.

COGEU deliverable D6.1 summarizes the different approaches that can be used for estimating opportunity costs pricing within a band based on the objectives that the broker want to achieve, which could be to estimate the call price for an auction, or the reference rate for trading mechanism.

The development of a broker based TV white space allocation mechanism in the COGEU project for the European context is motivated by several factors, which include, the need of an intermediary in developing a viable spectrum market. However, pricing is an important aspect of developing a viable market. Therefore, in line with the development of the broker, the following are some of the reasons that motivate the investigation of AIP as a tool to facilitate a viable secondary market for the TV white spaces:

- ***Maximising spectrum utilization through trading:*** In spectrum usage, market models have been identified as a key to maximize spectrum utilization and create social value [56]. An effective market can be established if trading transaction's costs are low. In such a market traders can find a trading partner, agree on terms, settle the trade and monitor performance of the contract without incurring substantial costs or delays in the process [54]. Therefore, COGEU takes a step toward establishing a viable spectrum exchange market through a broker model. A broker, which links buyers and sellers wishing to trade spectrum but do not actually own spectrum itself during the trade, is like an estate agent in the residential property market. A broker, therefore, can achieve the function of matching and assigning frequency resources to frequency users who value it the most and hence maximising the social value of the spectrum. However, one of the key challenges for the broker is determining the price of spectrum bands.
- ***Counter-marketing experiences in other countrie*s:** Hazlett in [51], [55] finds that, for countries implementing ambitious spectrum liberalizations, wireless license sales prices are observed to be about 61% lower than in other countries. He argues that: relaxing license restrictions may increase profits by allowing enhanced productivity, yet liberalization across a class of licensees can reduce the expected profits by increasing competitiveness. This evidence gives caution in developing and implementing spectrum secondary spectrum trading. As Crocioni points out in [53], allowing spectrum trading alone is not enough, other micro-levels factors need to be considered to make the market produce intended social benefits. In this context, the use of AIP as a pricing mechanism for a broker model could help in providing a healthy secondary spectrum market.
- ***Suppression of windfall profits in spectrum trading***: During the initial allocation of spectrum property rights, if a licensee has received a license at a price below the market-clearing price, this firm will receive a windfall gain. However, windfall profits are faced with corporate taxation and political decisions about equity, and hence seen as having a negative effect on secondary spectrum trading [58]. Furthermore, there are two key ways of spectrum pricing, including Cost-Recovery Pricing (CRP) and Administrative Incentive Pricing (AIP). CRP aims to recover the overall costs of the spectrum administration and AIP provides a means to price licenses to reflect the value of the spectrum. Compared with AIP, the fee based on CRP is usually low, which makes the economic value of spectrum not fully reflected so that it may result in windfall profits in secondary market. However, AIP can be used to reduce windfall profits, by which managers try to charge the opportunity cost of spectrum in order to promote its efficiency. Although there may be windfall profits in secondary market, it only means the transfer of profit and does not affect the spectrum efficiency [57], [58], [59]. As Song et al concludes in [57]: "initial spectrum allocation based on Cost-Recovery Pricing may bring about the realization of windfall profits in secondary market while the one based on AIP may suppress it." Therefore, the use of AIP could alleviate the effect of counter-market forces such as windfall profits.

Therefore, AIP is an important tool for promoting efficient spectrum management. This is because AIP signals to the spectrum user the opportunity cost of using the resource. The rationale for AIP is to promote the efficient use of spectrum (where it is congested) by allocating it to those who value it most. Those users to whom spectrum is worth more than the AIP fee will keep the spectrum they hold (or buy any that becomes available), and those to whom spectrum is worth less will sell any spectrum they hold.

The notion of opportunity cost can play a crucial part in ensuring that resources are being used efficiently, however there are complexities in determining the appropriate opportunity costs and basing fees on these costs. To this end, COGEU will continue to investigate the methods for determining the opportunity costs as a tool to facilitate efficient TV white space usage in the European context. These further studies will be reported in D2.3.

The following points should be taken into account when using the AIP to promote the efficiency of the TV white space:

- Efficient usage of the spectrum could be hindered by fixed regulatory constraints. The use of AIP will allow regulators to dynamically adjust spectrum licence prices to reflect the current value of spectrum, hence facilitate the movement of the licences from low value usage to high value usage.
- In order to ensure efficient functioning of the secondary spectrum market, especially in case where auctions are not as effective, AIP comes as a handy tool for pricing the spectrum based on opportunity cost. The opportunity cost approximates the market value of the spectrum leading to maximal efficiency.
- The growth of the secondary spectrum market in the EU member states could be affected by absence of incentives for spectrum usage. The use of AIP is strongly recommended in the development of secondary spectrum market in the EU member states so as to counter-balance such negative effects by appropriately adjusting the price of the spectrum to give incentives for spectrum usage. This could be achieved in conjunction with the adoption of a broker model (like the one proposed by COGEU) to enable the establishment of a sizeable customer base while lowering transaction costs among other things.
- It has to be remembered that the use of AIP does not involve an entity such as broker, some intermediary, or government agent explicitly choosing use or users; but rather based on set AIP, spectrum users self-select for spectrum administrative price.
- AIP setting is an important aspect of spectrum allocation. It affects allocative efficiency, productive efficiency, and dynamic efficiency. A well functioning market should exhibit the three dimensions of efficiency. Therefore, innovation in spectrum usage and derived products should be encouraged to enable interaction of supply and demand over time to optimize allocation and technical outcomes.
- Since AIP affects the choice of users, it influences total welfare of society; therefore, it should be set such as close to the market equilibrium price as possible to ensure efficiency.

4.3- Policies for automation of spectrum trading process

As we move from a system of low volume transactions to a system, which processes large volumes of smaller value trades, the reliance on paper-based processes will no longer suffice. Not only will the use of human processing of paper applications and issuing not persist in a high-volume, low value market, but the nature of players acting in the market will change. A move from human market-agents buying large, long-term licences to machine- or computer-agents buying small, short-term licences requires that policies are put in place to facilitate the automated filing, processing and issuing of licences through the COGEU Broker. The next sections describe policies, which will facilitate this transition.

4.3.1- Policies for market intermediaries such as the COGEU broker

Market intermediaries such as the COGEU broker have a number of basic requirements which are not dissimilar to the role played by the National Regulatory Authorities in the existing trading regimes. Indeed, while the COGEU broker, and similar or competing brokers which operate in different spectrum bands, may be developed independently there will need to conform to some national or international standards so that a European market can operate.

Identity of traders. The COGEU broker will need to be able to uniquely identify traders that engage in its market. Unique identification is necessary for both enforcement and competition reasons. As the

market envisaged by COGEU may involve high volume, short duration, low-value trades, buyers/traders will enter and leave the market in a dynamic manner. Traders may move from one licenced area to another, whether within a Member State or between Member States. From the perspective of enforcing licence/lease conditions it will be necessary for the COGEU broker to tie the identity of a trading entity to an actual legal entity, i.e. a real person or a corporate entity. Furthermore, from the perspective of competition law, which the new Framework Directive envisages as being the sole determinant of market behaviour in future, the COGEU broker will need to be able to ascertain the current spectrum holdings of individual trading entities. To address this identity issue it may be necessary for each NRA to mandate that all traders are issued with EU-unique trading identities, e.g. the use of a PKI (Public Key Infrastructure) system would facilitate the authentication of traders' identities.

Enforcement of Competition law. As stated, it is stated in the revised Framework Directive that in future spectrum trading and leasing will be subject only to normal competition law, except where there is a justifiable cause to exempt a particular spectrum band such as for reasons of supporting cultural or linguistic diversity. In order to effect elements of competition law which prohibit abuse of the market, the broker should have access to quasi real-time information on the spectrum holdings of all entities with which it is negotiating. To this end, the ex post notification of all changes in leases or licences should be mandatory. Brokers, and other trading intermediaries such as the NRA itself, should be required to remit completed trade information to an EU-wide accessible database which would allow NRAs and brokers across the EU to verify the current spectrum holdings of all traders.

4.3.2- Ontology-based policy description

The interaction between the trading parties in an automated manner is complex. The COGEU broker, acting as a band manager, will choose the kinds of offers, i.e. leases, which it puts to the market. The form of these leases may change over time or they may change as the demands placed on the spectrum change, e.g. a move from purely vertical sharing of the spectrum to horizontal sharing may be appropriate, or a mix of the two may be chosen. In order to allow such complexities to be managed the use of automated, policy-based management systems is recommended.

The dynamic spectrum access community has already investigated the requirements of systems that allow for the management of spectrum access. In general, ontology-based policy management is the preferred choice. An ontology is simply a formal representation of knowledge, within a given domain, using a set of concepts. The ontology also describes the relationships between those concepts. According to [48], "it is useful to define the common vocabulary in which shared knowledge is represented." As radio and network engineering is a well understood domain, we already have a shared and agreed understanding of the concepts underpinning the operation of systems. We describe spectrum usage in terms of bandwidths, centre frequencies, and geographic locations. As such, the formal definition of an ontology for spectrum/radio is not a complex task. **Spectrum policies can be described using a machine readable Extensible Markup Language (XML).**

Using an agreed ontology, policies for the management of spectrum and radios may be formed. Policies are rule based statements consisting of conditions and actions, i.e. a spectrum licence can be simply represented as a policy which lists conditions. Policy actions can indicate what a radio, or other automated entity, should do if it encounters a specific situation. For example, in an unlicenced scenario a dynamic frequency selection scheme could be triggered if a radio senses another user on its current frequency. In the TVWS scenario, a policy action to protect DTT transmission could mandate a radio to cease transmissions if it senses a primary signal.

As an example of such a system, the DARPA XG Policy Language Framework is a system which provides machine understandable policies which can be defined in a flexible, traceable manner [49]. An overview of the XG Policy language is given in [50] where the authors have identified some of the short-comings of that framework and propose the use of a community-based policy management scheme which would be suited to a disaggregated ecology of policy making authorities. Community-based policy-management systems, such as that described in [50] illustrate the type of system which will be required to enable an automated broker. The community-based policy-management system is a hierarchical system which allows entities within a domain, e.g. the EU, Ireland, ITU Region, to delegate control over spectrum resources to lower-level domains, e.g. brokers. Using a unified community-based policy-management system, each superior domain in a community hierarchy can definitively construct policies which constrain the lower-level domain. Such community-based policy-management systems lend themselves to application to the type of spectrum management being proposed by COGEU.

Specifically, the type of system described in [50] provides a template for the kind of system which could be used to support the COGEU broker concept.

4.4- Policies to protect competition in COGEU model

Commercial services are sold into a market, which makes it necessary to oversee that problems of anti-competitive behaviour do not arise. Competition in spectrum-using services generally benefits consumers by offering them lower prices and higher quality of service, as well as choice of supplier. There are, therefore, good grounds for adopting a spectrum management regime, which allows competition to develop.

If the objective is to maximize spectrum revenues, this may best be achieved by auctioning a single license to provide. Consumers then pay the price by being over-charged for the relevant service. Other regulators may pursue a goal of promoting competition. This will involve them at the time of assignment of licenses in:

- forming a conjecture about how many firms will be able to compete, using their own wireless networks, in the market place for services to end users,
- prohibiting any operator from being given more than one license.

This is necessary, because the most profit can be made out of the downstream services market by a monopolist. Hence the highest total bid for all licenses would be made by a firm which expected to acquire all of them [11].

After the initial assignment of licenses under a command-and-control spectrum management regime, the industry structure is highly constrained. Some licensees may not build out their networks and either retain their licenses or be obliged to give the spectrum back under. In the latter circumstances, the regulator can do the following:

- Create a new competitor, by using either a beauty contest or an auction. Its freedom of manoeuvre may be constrained, however, by obligations it owes to existing licensees not to lower the price for the re-issued licenses, as existing licensees will not want a new competitor to get access to a cheaper license.
- Assign returned spectrum to existing licensees; this removes the possibility of further entry at a later stage.
- Reserve the spectrum for other purposes.

The regulator may also, when auctioning a fixed number of licenses, have explicitly or implicitly accepted a legal obligation not to issue any more licenses for the same purpose for a specified period.

After the grant of licenses, the regulator may have powers to authorise the transfer of a license to another owner, or to an existing operator. Regulatory approval may be required for any merger between operators, and the return of some spectrum may also be entailed. The outcome in terms of efficiency of spectrum use and benefits to end users depends on how the service market develops.

In summary, command-and-control gives the spectrum regulator the opportunity to shape the structure of a market by choosing the number of licenses to issue. A firm which controls the spectrum suitable for (or allowed to be used for) a particular service can monopolise supply of that service, raise prices above the competitive level and make excessive profits. Monopolists also find it more profitable to sweat their existing assets rather than introduce innovations, so end users suffer additionally from that effect.

In COGEU model, the risks of monopolization are diminished by extending the frequencies over which a flexible choice of spectrum can be exercised through dynamic access to TVWS. To avoid competitive problems associated with existing spectrum allocation under a market framework is to ensure an extensive scope for market operation. This removes barriers to entry. However, further measures can be taken to avoid any adverse effects, via regulatory intervention. The task here is to strike a **balance between allowing abuses of market power and penalising firms which, through their own efforts and innovation, have established a strong market position**, but are still subject to competitive threats. This is a traditional problem in the application of competition law and policy, which seeks both to protect consumers from abuses and to encourage competitive investments by firms. A competition policy analysis of a particular concentration of spectrum ownership can be broken down into three stages:

- Define the market – i.e. the set of frequencies which are interchangeable in the provision of services to defined end user markets.
- Does the operator in question (now, or after a merger) exercise a high level of market power (In the European Union, the test under competition law is whether the operator is dominant, in the sense that it can behave to an appreciable extent independently of its customers and competitors, and ultimately of consumers.
- Has the operator abused market power by refusing to sell or lease "hoarded" or underutilized spectrum, or by abusing market power in any services markets.

This suggests a systematic way forward to investigate potential problems in spectrum markets. The problems include: hoarding or under-utilisation of frequencies; refusal to supply spectrum to competitors – thus foreclosing their entry into services markets – or achieving the same aim by excessive pricing of spectrum; abuse of market power in the services market, via excessive pricing or other conduct. Depending upon the specific legislative frameworks in particular jurisdictions, this approach can be applied:

- under competition law, in the course of an inquiry into alleged abusive conduct by an operator;
- under competition law, in the course of a forward-looking inquiry into the consequences of a merger between operators, or the acquisition of a spectrum license by the holder of another;
- under specific legislation relating to spectrum management, which gives the spectrum regulator the right to scrutinise the change of ownership of a license, either in advance, or to investigate it afterwards.

Concentration of spectrum holdings in the hands of one or a small number of operators in commercial markets can provide a means to monopolise service markets. The extent of the risk depends on policies adopted at the time of a spectrum award, and the rules governing spectrum holdings thereafter. There are grounds for designing award rules in ways which will prevent any operator from immediately gaining market power in a services market. This applies to both command-and-control and market spectrum management regimes. Moreover, intervention by the spectrum regulator or by a competition or communications services regulator can reduce the risk of market failure associated with abuse of power in spectrum markets. For these reasons, **concerns about competition are not a sufficient basis for rejecting secondary spectrum markets. Instruments to combat monopolisation of spectrum in a market context are available, and the alternative command-and-control methods can have equally deleterious effects on competition.**

The case of FCC approach to the TVWS administration may serve as an example of the policy against market abuse or anti-competitive behaviour. As already mentioned in Section 2.1.2-, FCC designated nine entities (Comsearch, Frequency Finder Inc., Google Inc., KB Enterprises LLC and LS Telcom, Key Bridge Global LLC, Neustar Inc., Spectrum Bridge Inc., Telcordia Technologies, and WSdb LLC) as TV bands device database administrators. While the operation of multiple database administrators may present some coordination challenges, we find it is in the public interest to have multiple parties developing business models for this new mechanism. The value of this exercise extends beyond databases for the TV bands, as the FCC is also considering employing similar database approaches in other spectrum bands. This regulatory approach aims to create/encourage a competitive environment. Entities designated as TV bands database administrators are subject to the set of conditions in order to establish safeguards against market abuse. Among them, "*database administrators must agree that they will not use their capacity as a database manager to engage in any discriminatory or anti-competitive practices or any practices that may compromise the privacy of users*". FCC prohibit all database administrators from using the information collected to engage in anti-competitive practices, either by using the information themselves or providing it to third parties as well [7].

In order to protect competition, COGEU must apply the following rules:

- The spectrum price should be calculated fairly, i.e. if two users are using the same amount of spectrum in the same way, both should pay the same charge;
- The pricing structure should be clear, transparent and comprehensive, without unnecessarily lengthening the licensing process;
- The spectrum regulator are entitled to scrutinise the change of ownership of a license, either in advance, or to investigate it afterwards, this can be implemented through the COGEU trading information repository;

- Maintaining a public register providing information about the price and ownership of TVWS spectrum;
- Considering multiple geo-location database administrators and/or multiple spectrum brokers in order to create a competitive environment and apply policies against market abuse.

4.5- Policies to protect the primary users

COGEU will follow CEPT definition of TVWS as a part of the spectrum, which is available for a radio-communication application (service, system) at a given time in a given geographical area on a "*non-interfering non-protected basis with regard to primary services and other services with a higher priority on a national basis*". Therefore as stated in D3.1 protection of primary users (DVB and PMSE) is the first requirement of COGEU system.

Therefore, for reliable access to the TV white spaces and the guarantee of the QoS for wireless service providers, **COGEU envisions a regulatory scenario where geo-location database access and safe harbor channels for nonregistered PMSE will be required. Within this scenario we assume that sensing is not necessary.**

The proposed solution is to consider that Europe has implemented safe harbor for the exclusive PMSE usage, i.e., number of TVWS channels for reserved PMSE usage only in which no TVWS devices would be permitted. The safe harborbands are flexible and it may change from country to country. These channels are excluded by the geo-location database and therefore out of the market. In this case the broker doesn't need to consider sensing (only database access) and system doesn't need backup channels to guarantee QoS and increasing spectrum efficiency. The rationale for this scenario is aligned with CEPT ECC Report 159:

"... it appears that the identification by national administration of at least one (or more) safe harbor channel, not used by DTT and which would be reserved for PMSE use would be helpful for the protection of PMSE, in particular for casual or unplanned usage by PMSE which would not be registered."

Therefore, COGEU considers this regulatory scenario assuming that the TVWS in channels 21-40 are reserved for PMSE use (here just non-predictable ENG use is relevant as the other predictable systems can be registered in a database). This is in line with COGEU assumptions where only channels 40-59 are considered. This gives a stable situation for COGEU considerations.

Reserving some channels (e.g. the available TVWS in channels below 40) for unpredictable PMSE applications such as ENG (Electronic News Gathering) would stabilize the available TVWS in the (other) channels considered by the COGEU broker.

This solution to clean TVWS from PMSE unpredictable activity comes with reallocation costs. For instance, recently Ofcom UK go-ahead to begin making grants to the Programme Making and Special Events (PMSE) sector to support its migration from channel 69 to channel 38. On 28 July 2010, the UK Government announced that it will be providing a contribution towards the cost of new equipment. Following this, on 23 September a funding scheme was launched, which resulted in more than 66% of eligible licensees registering claims for a contribution to the cost of modifying or purchasing equipment.

The safe harbor concept smoothes variation of TVWS availability and, to some extent, has impact on the cost of available TVWS for secondary use. The benefit for TVWS secondary use is that it is known which channels are reserved.

4.6- Policies to control the geo-location spectrum database

The geo-location spectrum database (see Figure 7) plays the most important role in architecture proposed by regulators such as FCC, Ofcom and CEPT for the management of TVWS (only unlicensed use\commons). This is also true for the system architecture proposed in COGEU (commons and secondary market). The database holds and processes all the required information, in order to manage TVWS band and their usage, from users, players and systems. In an effort to implement and deploy services in the current bands, the policies described below are designed to ensure maximum performance and availability when operating in the TVWS bands.

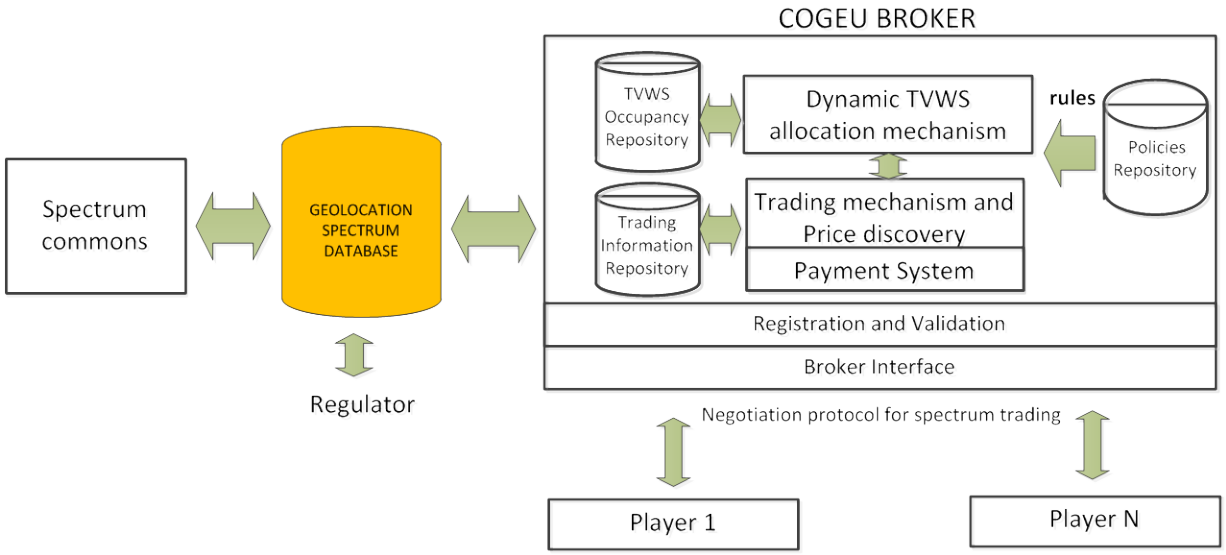

Figure 7: COGEU reference model for secondary spectrum trading of TVWS [D3.1].

4.6.1- Policies in populating the database

For the purpose of populating the geo-location database, a minimum amount of information has to be provided. This information includes:

- Incumbent systems,
- Regulatory framework information,
- Location specific regulatory policies,
- Adjacent systems,
- Services.

Furthermore, cross border incumbent systems information is also required for the calculation of the TVWS availability on the border areas.
Information is made available through interfaces that have been defined in D4.1, and allow the protections and confidentiality of incumbent system's parameters, along with the realistic calculation of available TVWS.

For security purposes, only the geo-location database administrator is allowed to authorise the database contents; this policy is designed for protecting data integrity. Also, consistency of information is important and thus having the regulatory body to populate or control the contents of the database will ensure that a single methodology is used for the population, regardless of a national or a localised geo-location database. COGEU recommends that the regulators will not supply the sensitive data concerning broadcast transmitter parameters. Therefore, the regulator would convert the incumbent's data (confidential raw data) into a list of allowed frequencies and associated transmit powers by performing TVWS calculations.

Protection ratios and common assumptions are to be used to protect the incumbent systems. These protection ratios are possible to be altered by the regulatory body that controls and administers the database.

Involvement of regulators in the population of the database also limits the over-conservative calculation or over-estimation of TVWS which is possible to undermine the COGEU operational concept, since is dependent on the available TVWS.

According to the COGEU operational model, another important aspect is the obligation of the regulator that controls the database to identify which bands are available for trading and which bands are to be used in commons, thus allowing both operational categories envisage in D3.2.

4.6.2- Policies to ensure the integrity of the database

Database integrity ensures that data entered into the database is accurate, valid, and consistent. Any applicable integrity constraints and data validation rules must be satisfied before permitting a change to the database.

The three basic types of database integrity constraints are entity integrity, domain integrity and referential integrity:

- **Entity integrity** prevents more than one row from having the same identity within a table. This is achieved by creating unique keys that characterise each record in a database table.
- **Domain integrity** ensures that the type of information is as defined and the types of data are in accordance with the database tables' structure.
- **Referential integrity** controls the communication between the tables and ensures that a Foreign Key field is valid and refers to an existing record on the referred table.

These constraints need to be part of the database design and internal structure.

4.6.3- Access security and privacy policies

The Geo-location database acts as the central information hub of the **COGEU system and is required to guarantee uptime of at least 99%**. To achieve this one can consider mirroring and parallel operation of each geo-location database. Such deployment will ensure that in a commercial environment the **database will be available through redundancy** taking into account any unscheduled or scheduled downtimes.

Each entity accessing the database will have specific access rights related to the operations that the entity is allowed to perform on the database. Entities will have access only to the specific tables of functionality that is necessary; with regards to the access to the geo-location database, the need to know policy needs to apply. The fact that there are different interfaces for each accessing entity, makes the application of this policy easier, since it can be controlled through the exposed function of the web services.

The broker access will only involve reading and downloading relevant information within the area of operation. Furthermore, the broker entities will be able to request updates periodically from the geo-location database. The geo-location database will also trigger the broker when an update takes place.

With public access only the display of information regarding the availability of TVWS in a specific location will be allowed.

Devices communicating with the database will use encryption for the purpose of securely downloading operational information from the database.

Any communication protocol must ensure the authorization and authentication of the accessing party.

All devices and entities that are to use the geo-location database need to be accredited by an authority, ensuring that, protocols and restraints/constraints are implemented and are available on any WSD device, to complying with the database instructions and limitations. This is important since if only accredited devices are allowed and authorized, the possibility of piracy and unauthorized use of available TVWS bands and band emissions in the bands will be limited.

Data security, access security and physical security policies need to apply to protect all the stakeholders of the system. The database is to be physically located in a secure location with reasonable security and identification use, and **under the supervision of the regulatory body**. Access of each database user will be able to access the database using a secure set of credentials that will be unique and logs will be kept. In case of an unauthorised access, the geo-location database will revert any changes. Alteration logs will also be available and will identify the user that committed the alterations.

Regarding access security, the database will only be accessible (except local entry) through web-services. This policy allows secure access since access rights can be granted to specific functionality with embedded security credentials. It is also possible to differentiate access right for each interface and

provide a different set of accessible web-services. Data security can be ensured through the use of relational schema and data relationships between data entities. Furthermore, validation rules will run during insertion or alteration sessions.

Following each change the database will be backed up on its current state. This will ensure that even if there is a problem during an update, the database will be able to return to the current state, notifying at the same time the entity that attempted and authorised the update that it was not successful, in order to check and resubmit the update. Furthermore, regular and scheduled backups will take place including database health checks. Continuous testing and monitoring of the system through an automated process will ensure that any problems regarding software or hardware will be detected early enough to minimize chances of database inaccessibility. These procedures will be under the control of the system administrators. It is considered at this point that the system administrators will be the regulators and authorities at the geo-location operation area.

The privacy of the users that are using a White Space Device (WSD) needs to be considered and addressed according to the local and EU law directives. The Geo-location database must secure the **confidentiality of personal and financial information of the users**, players and devices that use the geo-location database for services. All portable WSD devices will be registered in the database only while a session lasts. Furthermore, the WSD devices that operate under a master scheme must be registered with contact information. This information will be stored in the database and will be encrypted, and only the regulatory body will be able to access the information for policy reasons or misconducts of WSD's. The information exchange between the database and all accessing entities is to be encrypted as well.

4.7- Emergency policies to control TVWS

The term "major crisis" is generally used to define the circumstances described in various organization of European country Defense. To summarize, this term is used:

- for the case of general mobilization,
- when warning of taking measures to ensure government liberty of action, decrease the vulnerability of populations (or critical infrastructure) ensure safe operations of mobilization or implementation of the military,
- with respect to threats targeted on a portion of territory, an area of the national life or a fraction of the population.

Depending on the EU country considered, various number of laws and regulations specify the general organization of the Defense. Addition to the orders cited above, we note in particular:

- Decrees on the operation of stations Radio in the circumstances of major crisis, that could be applied to ensure public order and security inside and outside the state, ensure the availability of frequency bands necessary for the proper operation of transmission defense and communications essential to the life of the nation.
- Procedures for the operation of the stations other than military radio and TV-broadcasting.
- Decrees on the establishment and operation of audiovisual communication networks over the air in the circumstances of major crisis.

Under those circumstances, provisions in favor of opening rights for governments to require radio stations (stations of the state or from private actors) and to control radio spectrum allocation. Actions may include issuing prohibitions, obligations to protect, or transfer of spectrum rights to specific national forces transmissions.

However, these conditions do not apply to situations that could be considered "pre-crisis" or for use of frequencies by the armed forces and services safety and rescue at the implementation of specific plans of action.

To allow more intensive and dynamic sharing of frequencies between civilian systems and civil security, a procedure for the preemption of frequencies (or in the form of exclusivity, or quality deterioration of impacted systems) normally used by civilian systems before the implementation of Ordinance would require to be reviewed in order to make investments in appropriate equipment and manage the frequency when the need for exceptional use arises. In this perspective **it will be necessary for the**

COGEU system to allow national regulators (or the responsible trusted agency) to control the TVWS spectrum assignments. To address this control issue it is necessary for the COGEU broker (or geo-location Database) to provide a clear interface dedicated for this task. Moreover, it is necessary to define priority levels of certain types of transmissions, allowing either pre-emption of frequencies or the preemptive priority access to networks.

Service priority can be introduced into the COGEU broker, with each secondary system having an assigned priority level. In general, channel availability for equal priority services is determined on based on the trading mechanisms described in D6.1. In this manner, secondary TVWS systems will avoid selecting channels that are already in use by other secondary systems, enforcing coexistence.

The concept of service priority can be a complementary solution to allow some systems (e.g., emergency public safety systems) to operate with higher priority over other services. For example, the database can provide differing channel lists (and/or other radio operating parameters, such as maximum allowed transmit power levels) based on service priority. In order to react to an emergency incident, the broker may allocate channels to public safety systems that were previously allocated to other lower priority services or simply prioritize access to them during the allocation of frequencies. When the public safety systems arrives on scene, it would access the broker, and the broker would have the option of assigning channels that are currently utilized by lower priority systems. The lower priority systems would also receive a new set of channels/radio operating parameters for the new spectrum usage scenario. **While priority based broker should preferably be operated on a near real-time basis, even hourly broker updates could potentially provide much more efficient usage of available spectrum**. Another possibility is to re-open the market (and related auction and trading mechanism) when a major crisis happens. All players re-enter the auction game but Public Safety systems have a better chance to win due to higher priority.

Geo-location database information might be unavailable or corrupted in case of emergency situation. For example, an earthquake triggering a situation of crisis management might have damaged existing TV broadcast stations making the database information not up-to-date nor relevant. In this very specific case TVWS devices to be used by emergency systems need additional functionalities in order to operate with a corrupted or unavailable geo-location database. **TVWS devices targeting extreme emergency and lifesaving purposes should be allowed to adopt an "independent rescue mode" in order to operate without the need to request geo-location database access**. This mode is exclusively dedicated to extreme emergency situation and when the database is explicitly known to be corrupted. In this specific situation devices should mandatory be able to local sense for Primary Users before to be able to transmit (opportunistic use of TVWS).

4.8- Impact of COGEU model on the Service Level Agreement

The Service Level Agreement (SLA) is part of service contract, where the level of service is formally defined. It is defined as a negotiated agreement between two parties where one is the service provider (which can be the network operator) and the costumer that will consume the service.

The level of demand by customers in the secondary spectrum market is highly dependent on the quality of service (QoS) vs. price trade-off achievable with TVWS opportunity. That is, a communications service with lower QoS may still generate significant end-user demand if it is cheap enough. Such price/QoS tradeoffs are a hallmark of competitive markets.

At first, it seems that the QoS for the services that would require TVWS channels in secondary spectrum market is lower than the ones that enjoy guaranteed spectrum access (primary users). This assumption comes from the fact that the channel's assignment is done in a temporary basis and shall be released if a primary user is detected. However, it is better to say that TVWS channels will offer different QoS (which does not mean to be lower). The challenge comes more about the fact of finding the right novel applications or architectures that would improve the communications capabilities of CR technology itself. The better TVWS propagation conditions are well known in respect to, for example, coverage or wall penetration and may be exploited in a complete new approach.

As for many prior innovations, the "killer application" for TVWS spectrum access is likely to be unforeseen. However, the change that one or more will appear is enhanced by the lower entry costs for new service providers that are enabled by COGEU approach.

4.8.1- Legacy Applications or Services

For legacy applications, the perceived reduction in QoS associated with the DSA (Dynamic Spectrum Access) may impede the commercial success. Although, the use of a broker to temporary sell spectrum with exclusive access rights may deploy new kind of opportunities even for legacy applications, keeping the QoS at proper levels. The COGEU approach foresees a secondary regulatory scenario, where the COGEU broker is able to sell 8 MHz wide free channels in TVWS band with exclusive access rights in a temporary basis.

In longer term, however, even desirable bands like the vacant TV channels may suffer from QoS challenges for legacy applications due to competition among multiple secondary users, which may increase the level of interference. Therefore, techniques to improve QoS in TVWS band are an active and important topic of research (e.g. spectrum masks).

Other non-technical solutions may also be used, for example, for the time that the channels are sold. Or alternatively, a service provider may choose to bundle a dynamic spectrum access service together with one that has guaranteed spectrum access, perhaps as two operating modes of a single end-user device, so legacy application requirements are met despite the QoS limitations on TVWS band.

Other types of applications or services even being legacy, like the e-mail, that do not have restricted QoS constraints, are suitable for this band.

4.8.2- Service Level Agreement

Talking about the level of a service is a synonymous of talking about quality of service. Therefore it is important to define quality of service (QoS). At a high level of abstraction, “quality of service” refers to a set of service requirements to be met by the network while transporting a connection or flow and the ability to deliver network services according to the parameters specified in a Service Level Agreement (SLA). “Quality” is characterised by service availability, delay, jitter and packet loss ratio [38].

The SLA is part of service contract, where the level of service is formally defined. It is defined as a negotiated agreement between two parties where one is the service provider (which can be the network operator) and the costumer that will consume the service. The agreement is related with the services that costumer receives and not how the service provider delivers the service. The SLA may specify the levels of availability, guarantees, warranties, performance, operation, or other attributes of the service, such as billing. The level of service (QoS) may also be specified as “target” and “minimum”, which allows customers to be informed about what to expect (at least the minimum). In some contracts, penalties may be agreed upon in the case of non-compliance of the SLA.

The specification of the service level parameters and metrics represents the common understanding of the parties. The SLA parameters are specified by metrics. Metrics define how to measure an item or how to aggregate metrics to composite metrics. A metric description includes which party is in charge of measuring and aggregating and how metrics can be retrieved.

Structure

The SLA may be exchanged using a XML schema. The Web Service Level Agreement (WSLA) language specification [39] presents three sections: a section describing the parties, a section containing one or more service definitions, and the section defining the parties’ obligations. These sections are better explained next:

- **Parties**: describes the parties involved in the management of the service. This includes the signatory parties as well as supporting parties that are brought into the SLA to act on behalf of a service provider or costumer but cannot be held liable on the grounds of this SLA.
- **Service definitions**: describe the services that the SLA is applied to. The service definition represents a common understanding of the contracting parties in the structure of the service, terms of operation, service’s parameters and metrics that are the basis of the SLA.
- **Obligations**: define the service level that is guaranteed and the obligations of each party (e.g. perform measurements).

The SLA can be based on time, day, source and destination addresses, application ID values, etc.

4.8.3- Service Level Agreements in COGEU model

COGEU established two regulatory scenarios: the first, where both geo-location database access and spectrum sensing are required for the protection of incumbents; and the second, where only geo-location database access is required for the protection of the incumbents [D3.2]. In the first scenario, the information about vacant channels is retrieved from the geo-location database by the master, which further requests the sensing information on those channels from the slaves or itself in order to ensure that the channels are really vacant and not being used by, for example, an unregistered PMSE. In the second scenario, the geo-location access ensures protection for the registered incumbents, while the TVWS occupancy repository within the COGEU broker ensures protection for the secondary users; furthermore, a certain number of TVWS channels are reserved (in a safe harbour concept) for the unregistered incumbents.

Taking the above text into account, it may be established the corresponding between legacy applications and second regulatory scenario or new applications and first regulatory scenario (see Figure 8).

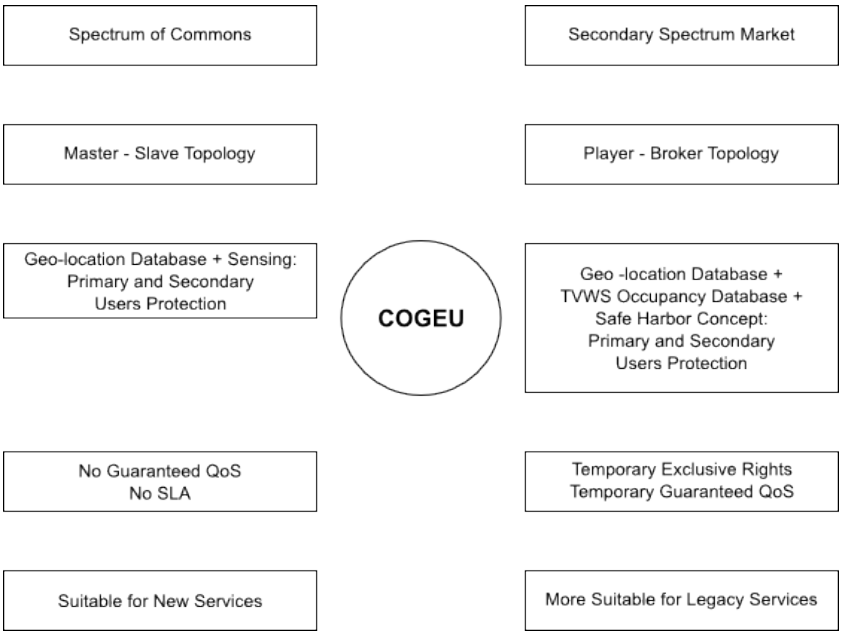

Figure 8: COGEU ecosystem

As it is easy to conclude, that only the secondary regulatory scenario may offer QoS because all the spectrum players are protected, this means that once the TVWS channel is allocated in the secondary spectrum to a secondary user, there is no need to release the channel for a primary user (as in the first regulatory scenario) because unregistered primary users have exclusive vacant channels per region, which is known as safe harbour concept, that do not make part of the secondary spectrum market. Thus the SLA shall only be considered in the second regulatory scenario.

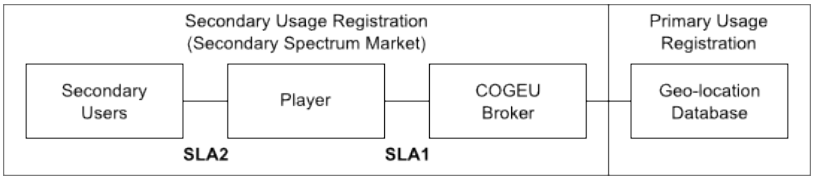

Figure 9: Service Level Agreement per connection

From now, we will consider Figure 9. In the secondary usage of TVWS, three entities must be considered: COGEU broker, the player, and secondary users. In LTE example, the COGEU broker is the broker itself; the player is the LTE operator (or service provider) from the core network to the access network; and secondary users are the LTE users (WSDs) that are able to operate in legacy carries and TVWS carriers.

When there is a provider and a consumer, it shall be considered a new SLA. On this case, two SLA shall be considered: one between the player and secondary users, SLA2, as in legacy systems; and a new SLA, between the COGEU broker and the player, SLA1. In fact, there will be N SLA2 for N secondary users, SLA2i i=1...N.

The novelty introduced herein is the fact that the COGEU broker will in fact deliver a service (spectrum) that is paid by the player, and thus shall be governed by a SLA (SLA1). Formally speaking, the SLA1 is not different from SLA2 from the conceptual point of view (or other SLA in mobile communications), however it has some particularities, that are attached with the flexibility of COGEU concept.

Namely, it shall be considered the type of service, that is a TVWS channel(s) which is available in a concrete location (geographical region) and time (years, months, days, hours) basis; the obligation, apart from others, of non-interference with primary and secondary users and release the channel(s) when the leasing time is expired; and penalties for the non-compliance of the SLA. **For example, if there is an update in the geo-location database and a vacant channel that was occupied by a secondary user becomes occupied by a primary user, the channel must be released by the secondary device and the player (or secondary user) shall receive an appropriate compensation.**

In the SLA definition, metrics assume an important role, since they are the ones that allow both service providers and services consumers to check if the SLA is being respected. These metrics are often called KPIs (or quality performance indicators) and their average values are defined by the parties when the service is negotiated. KPIs may encompass throughput, delay, jitter, packet loss, service availability, network availability and maximum time to restore the service. If the measured average values of KPIs are lower than what was contracted, alarms may rise and penalties may be applicable [40]. It is then recommended that the measurement of these indicators shall be based on daily traffic (detailed figures concerning only the peak hour traffic can be taken into account) and when required, SLA shall be re-negotiated.

This specification assumes an abstract model of the runtime management of a COGEU SLA, which is outlined in Figure 10. We assume that the measurement and management functionality is divided in three groups of functionality and closely follows the specification presented in [39]:

- The ***measurement*** functionality receives the measured metrics from the system's instrumentation. Instructions on how to measure a particular system parameter are defined in the measurement directives of a SLA. The role of the measurement functionality is also to implement and compute composite metrics (data that results from the combination of other simpler metrics).
- The ***evaluation*** function evaluates the guarantees of QoS as depicted in the SLA. Guarantees are defined as predicates over SLA parameters. The value of these parameters can be obtained from the measurement function. The evaluation function must implement the relevant predicates to perform the guarantee evaluation. In the case of violation, an action is invoked on the management function.
- The ***management*** implements actions that are invoked upon guarantee violations. The subsequent course of action to remedy the problem is not treated here. We assume that this is implemented as appropriate.

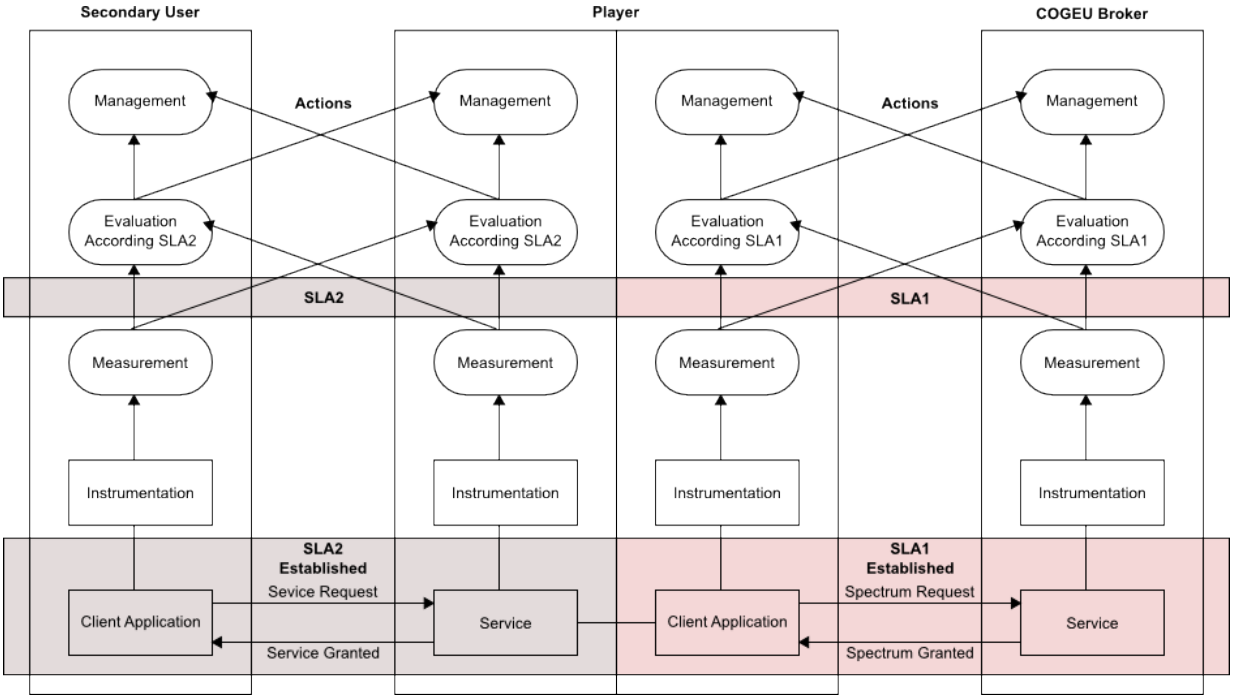

Figure 10: COGEU SLA runtime management

The Figure 10 illustrates that interactions between parties may occur at various function levels, if required. Measured (resource) and high level metrics may be exchanged by the measurement function and management actions may be triggered from both provider and customer. Moreover, the SLA1 may somehow be a limiting factor when defining SLA2.

4.9- Policies to promote a single market in the TVWS

There are significant benefits in adopting a harmonised approach regarding TVWS utilization. The timely availability of spectrum across Europe and the harmonised specification of cognitive devices will exploit economies of scale and encourage industry investment, thus enabling new cognitive applications that could bring significant benefits to European markets by maximising the effective and efficient use of spectrum. This will only be achieved if common technical conditions can be agreed at the European level on identified frequency bands, which provide sufficient certainty and stability to industry within an appropriate timeframe.

Following Wikipedia, a single market is “a type of trade bloc which is composed of a free trade area (for goods) with common policies on product regulation, and freedom of movement of the factors of production (capital and labour) and of enterprise and services. The goal is that the movement of capital, labour, goods, and services between the members is as easy as within them. The physical (borders), technical (standards) and fiscal (taxes) barriers among the member states are removed to the maximum extent possible. These barriers obstruct the freedom of movement of the four factors of production. To remove these barriers the member states need political will and they have to formulate common economic policies.”

COGEU envisions a scenario where geo-location database access and “safe harbor” channels for non-registered PMSE will be required [D3.2]. Within this scenario we assume that sensing is not necessary. The proposed solution is to consider that Europe has implemented “safe harbor” for the exclusive PMSE usage, i.e., number of TVWS channels for reserved PMSE usage only in which no TVWS devices would be permitted. The “safe harbor” bands are flexible and it may change from country to country. These channels are excluded by the geo-location database and therefore out of the market. In this case the broker doesn’t need to consider sensing (only database access) and system don’t need backup channels to guarantee QoS and increasing spectrum efficiency.

Mapped to the considered UHF channels 40 to 60 the single market would be the unused channels, available for new applications (the TVWS). The different possible TVWS systems can be considered as the goods and the factors of production and the barriers mentioned in the definition above may be seen as follows:

Physical

- The TVWS systems shall be operated in free channels in the UHF band. Depending on the occupation of adjacent channels there are limitations to the system parameters (e.g. transmit power) of the TVWS systems.
- The considered frequencies cover the range of 622 to 790 MHz. As the antenna aperture is proportional to the square of wavelength, the propagation characteristic for lower channels is better by a factor of max. 1.56. On the other side lower channels with longer waves require larger antennas.
- For very special systems it might be the case that the amplifier of the system can operate only on some few channels (as is the case for some PMSE equipment).

Technical

In a market, certain regions may be protected by specialized standards. In the TVWS channels, this may be caused by adjacent channels:

- For TVWS devices operated in channels close to channel 40 it may be necessary to take special care for possible PMSE operation in safe harbor bands below channel 40 (second COGEU regulatory scenario [D3.2]).
- At the other edge of spectrum range, LTE equipment operated in the TV channels 61 and above may require additional protection and therefore may influence technical parameters of TVWS equipment.
- Also for the channels within different treatment may be required, depending on the occupation of neighbor channels by incumbent systems.

Fiscal

In a non-open market, a country can protect its market by introducing protective duties. Within the TVWS use different prices for different systems may cause a similar effect: some systems might be given priority over other systems. To avoid discrimination of some systems comparable fees for the different systems using TVWS have to be determined. (The difficulty lies in finding an appropriate method to monetary describe and compare different systems.)

Surmounting the barriers

For the first sight it seems as if there is a lot of potential for barriers resisting single TVWS market. In most cases however, the barriers can easily be surmounted.

- For the physical and technical aspects possible limitations, caused by frequency range, “broadband” amplifiers and broadband antenna covering the considered frequency range can easily be used. (It should be mentioned that the limitation to channels 40 to 60 was made due to this reason.) If the number of units in the market increases, the cost for amplifier and antenna drops and operational frequencies do not favor certain systems.
- Operational parameters depending on the used channels are specified by the broker who has all the information to guarantee protection of other systems – systems in adjacent bands as well as incumbent systems. In this way **it is in the responsibility of the broker that all possible TVWS systems are treated equal.**
- It may be possible to define a set of ‘minimal’ parameters which do not require an inquiry at the database.
- Equal treatment of TVWS systems related to costs is probably more crucial than the aspects described before. As COGEU proposes spectrum commons use as well as secondary spectrum trading this is primary a matter of regulation and of the broker. In a first step the channels reserved for spectrum commons might be defined and the broker may auction the remaining channels. This split-up is a decision of national policy and does not contradict the free market idea, instead it enables the coexistence of free-of-charge spectrum use (the spectrum commons) by at the same time abdicating QoS and a guaranteed QoS transmission by some kind of exclusive use which causes on the other hand costs to the licensee. At the time of auction different systems with e.g. different bandwidth requirement may bid for the available channels. The market mechanism is one mean to distribute the available channels. However, the broker may use other aspects to assign spectrum to spectrum seekers (example: emergency systems).

When TV receivers and TVWS applications have to share frequency resources, it must be ensured in any case, that these TVWS devices comply with the technical requirements, bound to the use of the spectrum to avoid interference.

Introduction of new radio systems and equipment
The certification process in the USA and in Europe differs essentially. In the USA products can only be put on the market when they comply with the requirements set out by the Federal Communications Commission (FCC). In contrast, in Europe the manufacturers themselves declare the conformity with the relevant standards. Thus in the USA, a presumption of conformity of the devices on the market is more reliable. On the other hand, this leads to significantly higher administrative costs than in Europe.
Approval of new radio devices on a national basis has been repealed within the EU. Now the R&TTE Directive (Radio & Telecommunications Terminal Equipment) [62] and their corresponding national implementation regulate the placing on the market of these devices. According to this, the manufacturer himself declares the conformity with the essential requirements of the directive by using harmonized standards.

Market surveillance
Radio devices which are classified according to the R&TTE Directive as so-called class 1 devices [63] may be operated only in frequency ranges which are harmonized in the EU. So moving them from one EU country to another and operate them there is easy.
Class 1 devices are:

- Devices operating in a frequency band, to which the same radio interface is assigned in each Member State, in the following ways:
  - there is a Europe-wide uniform radio frequency allocation
  - and within this frequency range assignment and/or allocation of radio frequencies or radio frequency channels follows a community-wide uniform plan or regulation
  - and for the devices community-wide uniform parameters apply (such as power, bandwidth, duty cycle)
- devices that do not send (i.e. pure receivers)
- devices that can send only under the control of a network

Class 1 devices require only a declaration of standard conformity. Information of the national regulatory authority on the intended distribution and operation of these devices is not required.
Appropriate market surveillance is organized by the individual Member States. If a standard violation is noticed the following measures can be taken:

- to request improvements
- to impose fines
- to take devices off the market
- to impose sales restrictions
- to force revocation

If a national authority takes such measures, according to article 9 of the R&TTE Directive, the Commission must immediately be informed. Then the Commission shall consult with the TCAM Committee (Telecommunications Conformity Assessment and Market Surveillance Committee). If the measures are considered as appropriate, the Commission shall inform all other Member States. If not, the national authority is informed and asked to revoke their actions.

At European level the TCAM Committee coordinates the required compliance with the standards. It consists of representatives of the relevant national competent authorities and/or ministries. Furthermore the ADCO Group (Group of Administrative Co-operation under R&TTE Directive 99/5/EC) supports and complements the work of the TCAM Committee.

The extent of the market surveillance and the verification that equipment is compliant with the standards varies from one Member State to another. Thus by the free movement of goods within the common market in Europe devices can come on the market that are definitely not compliant with the relevant standards. Therefore, the harmonization of market surveillance and conformity assessment is a relevant factor for a decision on a possible introduction of TVWS in Europe.

5- Conclusions and recommendations

COGEU identifies one of the causes for the lack of confidence in current spectrum users and industry players to invest in TVWS technologies is immature regulatory policies concerning the technology. Hence, this deliverable concerns the policies necessary to enable efficient spectrum sharing in TVWS at a European level that are supportive to technological innovation as well as 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.

From other hand, COGEU team is convinced that unlicensed use of TVWS bands is not fully adequate solution for all possible applications which may apply in Europe. Therefore we strongly promote the combination of spectrum commons regimes and temporally exclusive rights for use within Europe.

The successful implementation of secondary spectrum trading requires a commitment to change the current views of regulatory bodies, giving them a solid understanding of the new technologies and systems that will underpin TVWS usage. Spectrum policies must address the incentives for innovation in order to promote spectrum's assignment flexibility whilst clearly establishing the usage rights and obligations of those who use the spectrum to transmit or receive information. Furthermore, increasing spectrum flexibility will demand new approaches and practical methods for compliance monitoring, enforcement and conflict resolution.

Globally, various stakeholders have been moving to lay the regulatory ground work for the exploitation of TVWS by means of spectrum trading, SDR and CR. In the US, both the FCC and NTIA have both advanced the regulatory space for both TVWS devices and secondary trading. In particular, the FCC's 2010 authorisation for unlicensed TVWS devices provides a basis for other authorities to emulate or improve upon. The regulations for secondary markets are less specific; it is harder to create a market through regulation, but a space can be made in which a market can emerge. The NTIA are minded that SDR systems do not require specific regulations and can be covered by existing radio regulation.

While EU level organisations such as the RSPG promote a harmonised, 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 varies significantly. The UK and France have taken different approaches to the introduction and promotion of secondary trading whilst other Member States such as Ireland and Germany have yet to give their spectrum regulators primary legislative authority to engage in such measures. 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 analysis leads to a set of policy recommendations necessary to implement market-based spectrum sharing of TVWS in Europe:

- 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 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 it 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 licences 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 technology neutral form.

- Regulatory certainty is a necessary prerequisite for market participation. (Ofcom's recent approach to use technology specific licence conditions in TVWS auctions which *may* be changed denies the market any certainty and creates risk.)

- Clear spectrum rights and obligations must be defined. Spectrum rights are defined primarily in terms of three parameters: geographical coverage, duration and time of use, and then in terms of protection against interference.

- Transparency in TVWS 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.

- Publish spectrum prices: In fact, the most important piece of information for buyers and sellers to obtain a better understanding of the value of the spectrum they are either buying or selling is the price paid in similar transactions. To the extent that the availability of spectrum transaction prices contributes to reduce the amount of private information, this could increase the efficiency of spectrum markets.

- The three necessary elements of a real-time spectrum trading regime for TVWS in Europe are: geographic interleaved awards, Band Managers and simplified spectrum leasing:

    - 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 (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 may provide a means to manage this balance which is dynamic in nature.

    - Simplified spectrum Leasing, of the kind described in Figure 11, which detaches the NRA from involvement in the execution of every single trade should be brought forward.

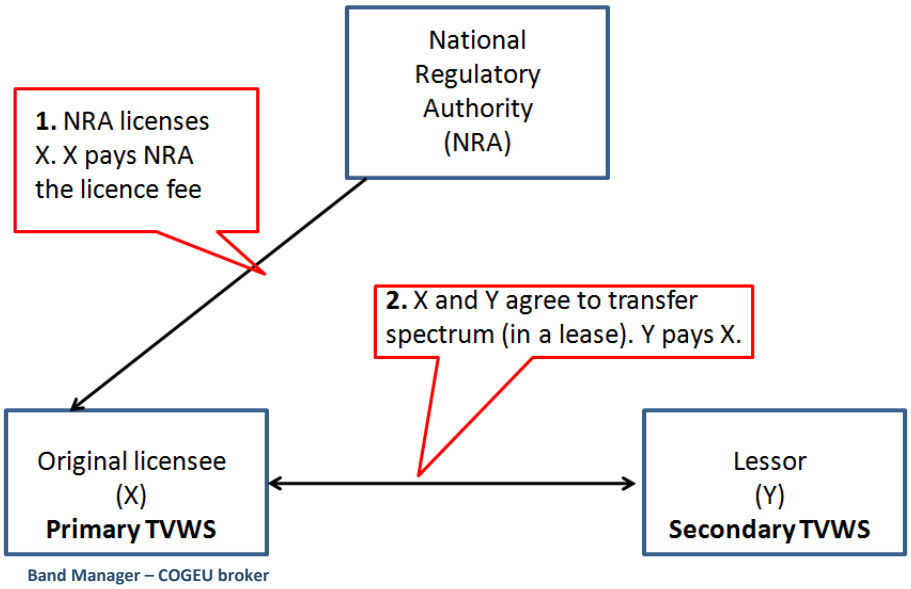

Figure 11 Spectrum Leasing (COGEU approach): removes the NRA from much of the bureaucracy of the trading process. Developed under Article 9(b) of Directive 2009/140/EC [44].

- In order to protect competition in spectrum markets, COGEU recommends the following rules:
  - The spectrum price should be calculated fairly, i.e. if two users are using the same amount of spectrum in the same way, both should pay the same charge;
  - The pricing structure should be clear, transparent and comprehensive, without unnecessarily lengthening the licensing process;
  - The spectrum regulator are entitled to scrutinise the change of ownership of a license, either in advance, or to investigate it afterwards, this can be implemented through the COGEU trading information repository;
  - Maintaining a public register providing information about the price and ownership of TVWS spectrum;
  - Considering multiple geo-location database administrators and/or multiple spectrum brokers in order to create a competitive environment and apply policies against market abuse.

- Recommendations for spectrum geo-location database policies
  - COGEU recommends that the regulators will not supply the sensitive data concerning broadcast transmitter parameters. Therefore, the regulator would convert the incumbent's data (confidential raw data) into a list of allowed frequencies and associated transmit powers by performing TVWS calculations.
  - Involvement of regulators in the population of the database limits the over-conservative calculation or over-estimation of TVWS which is possible to undermine the COGEU operational concept, since is dependent on the available TVWS.
  - For the geo-location database, it will be desirable to have European standardised protocols/languages to access the database and format of data within it.
  - The need of concertation and common approach to protect incumbents in cross border areas should be matter of special interest. Cross-border issues have to be considered in the specification of the database.
  - These policies will have to take account of existing EU data protection and privacy directives.
  - All devices and entities that are to use the geo-location database need to be accredited by an authority, ensuring that, protocols and restraints/constraints are implemented and are available on any WSD device, to complying with the database instructions and limitations.

- COGEU recommends that TVWS devices targeting extreme emergency and lifesaving purposes should be allowed to adopt an "independent rescue mode" in order to operate without the need to request geo-location database access.

- Efficient dispute resolution mechanisms between primary and secondary users and among secondary users of TVWS: 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.

- Certification and harmonized standards: COGEU supports the EC position 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 fulfil 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 harmonised standards. These specificities need to be described in a guide to be addressed to ETSI. This guide should therefore also be brought to the attention of the notified bodies. Harmonization of market surveillance and conformity assessment is a relevant factor for a decision on a possible introduction of TVWS in Europe.

To sum up, in this deliverable, policies to enable efficient spectrum sharing over the TVWS at the European level have been presented. In the course of the project, the policies recommended in this deliverable will provide the basic assumptions for the development and analysis of economic models of TVWS secondary markets to be presented in D2.3. TVWS policies will be further detailed and tested through simulation (T2.3, T2.4) and finally will be include in the "*Policies Repository*" of the COGEU system demonstrator developed and validated in WP7.

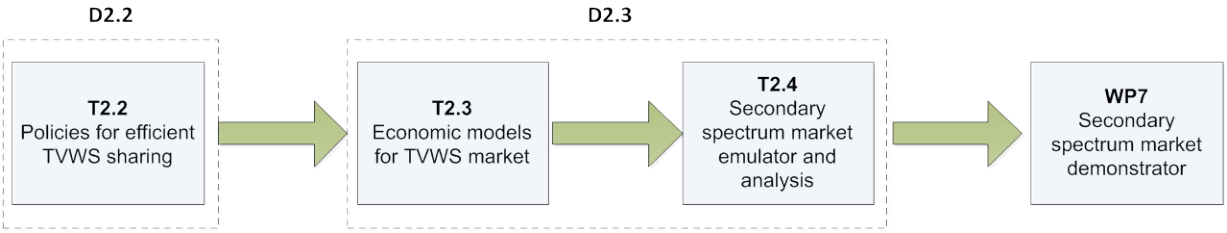

Figure 12: The relationship between Task 2.2 and other COGEU activities.

6- References

[1] Resolution 951 (Rev. WRC-07) Enhancing the international spectrum regulatory framework, The World Radiocommunication Conference, Geneva, 2007.

[2] ITU, 2012 World Radiocommunication Conference Agenda and References (Resolutions and Recommendations), 2010.

[3] WRC-12 Agenda Item 1.19: Shaping the International Regulatory Framework for Software Defined and Cognitive Radio Systems, 2009.

[4] In Matter of Unlicensed Operation in the TV Broadcast Bands (ET Docket No. 04-186) and Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band (ET Docket No. 02-380), Second Memorandum Opinion and Order, 2010.

[5] In Matter of Promoting Efficient Use of Spectrum Through Elimination of Barriers to the Development of Secondary Markets (WT Docket No. 00-230), Report and Order and Further Notice of Proposed Rule Making, 2003 (http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-03-113A1.doc).

[6] Secondary Markets Second Report and Order, 19 FCC Rcd at 17545-54, pp. 85-99.

[7] In the Matter of Unlicensed Operation in the TV Broadcast Bands (ET Docket No. 04-186) Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band (ET Docket No. 02-380), Order, January 2011.

[8] U.S. Preliminary Views on WRC-11, Agenda item 1.19, 2009

[9] Plan and Timetable to Make Available 500 Megahertz of Spectrum for Wireless Broadband, U.S. Department of Commerce, October 2010

[10] Verizon-Google Legislative Framework Proposal, August 2010

[11] M. Cave, C Doyle, W. Webb, "Essentials of modern spectrum management", Cambridge University Press, Cambridge 2007.

[12] RSPG, "RSPG Opinion on Cognitive Technologies", RSPG 10-348 Final, 10 February 2011.

[13] RSPG, "Radio Spectrum Policy Group Report on «Cognitive Technologies»", RSPG 10-306 Final, 11 February 2010.

[14] "COGEU response to the call for public input on the draft RSPG Opinion on Cognitive Technologies (RSPG 10-348)", January, 2011, (http://rspg.groups.eu.int/consultations/consultation_cognitiv_2010/cogeu_0115.pdf).

[15] ECC Report 159, "Technical and operational requirements for the possible operation of cognitive radio systems in the 'white spaces' of the frequency band 470-790 MHz", Cardiff, January 2011.

[16] European Commission, "A market-based approach to spectrum management in the European Union", COM(2005)400 Final, 14 September 2005.

[17] European Commission, "Communication on the Review of the EU Regulatory Framework for electronic communications networks and services", COM(2006)334 final, 29 June 2006.

[18] Ofcom (UK), "Spectrum Framework Review", June 2005.

[19] Ofcom (UK), "Digital Dividend: 600MHz band and geographic interleaved spectrum. Consultation of potential uses", February 2010.

[20] Ofcom (UK), "Notice of proposals to make 900MHz, 1800MHz & 2100MHz public wireless network licences tradable", February 2011.

[21] ANACOM, National Frequency Allocation Plan 2009/2010, April 2010

[22] ANACOM, Strategic goals and actions for the triennium 2010-2012, October 2009

[23] M. Levy, J.-P. Jouyet, Rapport de la commission de l'économie de l'immatériel, novembre 2006. www.minefi.gouv.fr/directions_services/sircom/technologies_info/immateriel/immateriel.pdf

[24] Commission for Communication Regulation (Ireland),"Spectrum Management Strategy Statement 2008 - 2010", July 2008.

[25] Study on conditions and options in introducing secondary trading of radio spectrum in the European Community, Final Report for the European Commission, (http://ec.europa.eu/information_society/policy/ecomm/radio_spectrum/_document_storage/studies/secondary_trading/secontrad_final.pdf).

[26] A. Gonzales, D. Rojo, C. Feijoo, S. Ramos, "Secondary Spectrum trading. Opportunities and difficulties in EU", ITS 15th Biennial Conference, Berlin 2004, (http://userpage.fu-berlin.de/~jmueller/its/conf/berlin04/Papers/rojo_paper.pdf)

[27] UKE, "The UKE President's regulatory strategy on spectrum management", April 2007, in Polish.

[28] UKE, "The Report on implementation of UKE President's regulatory strategy on spectrum management announced in April 2007", September 2009, in Polish.

[29] UKE, "The UKE President's Regulatory Strategy 2008-2010", April 2008, in Polish.

[30] T.Boguszewicz, L. Dec, "Amendments to the Telecommunications Law are coming – an interview with the vice-Minister of Infrastructure, Ms. Magdalena Gaj," in Rzeczpospolita (newspaper), 11 October 2010, in Polish.

[31] Neul Ltd., "The Internet of Everything", England, 2011. Information available at: http://www.neul.com/about.php.

[32] ITU, "Spectrum Pricing Study", Communication Study Groups, ITU-RSM.2012, 1993.

[33] ITU, ICT Regulation Toolkit, Module 5: Radio spectrum management, Chapter 5: Spectrum Pricing, http://www.ictregulationtoolkit.org/en/Section.2662.html

[34] Smith–NERA, "Study into the use of spectrum pricing", report for the Radiocommunications Agency by NERA and Smith System Engineering, April 1996.

[35] ITU and World Bank, Dispute Resolution in the Telecommunications Sector: Current Practices and Future Directions, October 2004

[36] WTO Reference Paper on Basic Telecommunications, 1998 (http://www.itu.int/newsarchive/press/WTPF98/WTORefpaper.html)

[37] J. M. Chapin and W. H. Lehr, The Path to Market Success for Dynamic Spectrum Access Technology, IEEE Communications Magazine, pp. 96-103, 2007

[38] GSMA, Guidelines for Service Level Agreement Between Mobile Operators and Carriers for TDM Voice, July 2010, Version 1.0

[39] Web Service Level Agreement (WSLA) Language Specification, IBM, 2003, Version 1.0

[40] GSMA, Guidelines for end to end GRX Service Level Agreement between Mobile Operation and Carriers, Official Document IN.10, June 2010, Version 1.3

[41] Ofcom (UK), "Digital Dividend Review: geographic interleaved awards 470 - 550 MHz and 630 - 790 MHz", Consultation on detailed award design, June 2008.

[42] Ofcom (UK), "Simplifying spectrum trading: Regulatory reform of the spectrum trading process and introduction of spectrum leasing", September 2009.

[43] Directive 2002/21/EC of the European Parliament and of the Council of 7 March 2002 *on a common regulatory framework for electronic communications networks and services (Framework Directive)*, OJ L 108, 24.04.2002, pp. 33‑50.

[44] Directive 2009/140/EC of the European Parliament and of the Council of 25 November 2009 *amending Directives 2002/21/EC on a common regulatory framework for electronic communications networks and services, 2002/19/EC on access to, and interconnection of, electronic communications networks and associated facilities, and 2002/20/EC on the authorisation of electronic communications networks and services,* OJ L 337, 18.12.2009, pp. 37-69.

[45] FCC, Promoting Efficient Use of Spectrum Through Elimination of Barriers to the Development of Secondary Markets, FCC 04-167, September 2004.

[46] Electronic Communications Committee (ECC) within the European Conference of Postal and Telecommunications Administrations (CEPT), "CEPT Report 19: Report from CEPT to the European Commission in response to the Mandate to develop least restrictive technical conditions for frequency bands addressed in the context of WAPECS", Report approved on 21 December 2007 with editorial revisions on 17 March 2008 and 30 October 2008.

[47] Ofcom (UK), Spectrum Usage Rights: A statement on controlling interference using Spectrum Usage Rights", December 2007.

[48] T. R. Gruber, **"**A translation approach to portable ontology specifications", Knowledge Acquisition – Special issue: Current issues in knowledge modeling, Vol. 5, No. 2, June 1993

[49] DARPA XG Working Group "DARPA XG Policy Language Framework, Request for Comments", version 1.0, prepared by BBN Technologies, Cambridge MA, USA, April 16 2004

[50] D. Lewis et al. “Managing Policies for Dynamic Spectrum Access”, 1st International IFIP TC6 Conference on Autonomic Networking (AN2006).

[51] T. W. Hazlett, Property Rights and Wireless License Values, The Journal of Law and Economics, August 2008, Vol. 51, No. 3: pp. 563-59

[52] M. M. Bykowsky, M. Olson, W. W. Sharkey, Efficiency gains from using a market approach to spectrum management, Information Economics and Policy, Volume 22, Issue 1, Wireless Technologies, March 2010, Pages 73-90

[53] P. Crocioni, Is allowing trading enough? Making secondary markets in spectrum work, Telecommunications Policy, Volume 33, Issue 8, September 2009, Pages 451-468,

[54] Ofcom (UK), SRSP: The revised Framework for Spectrum Pricing, Proposal following a review of our policy and practice of setting fees, March, 2010

[55] T. W. Hazlett, Property Rights and Wireless License Values (March 2004). AEI-Brookings Joint Center Working Paper No. 04-08. Available at SSRN: http://ssrn.com/abstract=519602 or doi:10.2139/ssrn.519602

[56] P. Xavier, D. Ypsilanti, Policy issues in spectrum trading, Info, Vol. 8, no. 2, 2006, pp: 34-61

[57] Qizhu Song, Meimei You, Tingjie Lv; Incentives to spectrum trading," IC-NIDC'09: IEEE International Conference on Network Infrastructure and Digital Content, pp.948-952, Nov. 2009

[58] T. M. Valletti, Spectrum trading, Telecommunications Policy, Volume 25, Issues 10-11, October-November 2001, pp: 655-670,

[59] U. Stumpf, L. Nett, The economics of frequency trading, Wik-Consult Conference Paper. Bad Honnef, 2003

[60] M. Cave, Review of Radio Spectrum Management, for the UK Department of Trade and Industry and H M Treasury, March, 2002.

[61] CEPT Report 30, Report from CEPT to the European Commission in response to the Mandate on “The identification of common and minimal (least restrictive) technical conditions for 790-862 MHz for the digital dividend in the European Union”.

[62] Directive 1999/5/EC of the European Parliament and of the Council of 9 March 1999 *on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity,* OJ L 91, 7.4.1999, p. 10–28.

[63] European Commission, Commission Decision of 6 April 2000 establishing the initial classification of radio equipment and telecommunications terminal equipment and associated identifiers (notified under document number C(2000) 938), 2000/299/EC, OJ L 97, 19.4.2000, pp. 13-14.

[64] European Commission, Communication from the Commission of 1 June 2005 to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions entitled “i2010 - A European Information Society for growth and employment”, COM(2005) 229 final, 1.6.2005.

[65] European Commission, “i2010 eGovernment action plan progress study”, Summary report, November 2009

[66] European Commission, “Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - Europe’s Digital Competitiveness Report: main achievements of the i2010 strategy 2005-2009”, COM(2009) 390 final, 4.8.2009.

[67] CEPT sharing studies in the UHF band, European Communications Office, July 2010.

[68] C. Feijóo-González, J. L. Gomez-Barroso, S. Ramos-Villaverde, D. Rojo-Alonso, “Public Policies For Broadband Development In The European Union: New Trends For Universalisation Of Services”, Public Utilities Research Center / London Business School Conference on “The future of broadband: wired and wireless”, Gainesville (US), 24-25 Feb. 2005.

[69] A. Lebeau, “Digital divide and public policy initiative”, Report available at: http://telecom.esa.int/telecom/media/document/lebeau-London-final.pdf.

[70] Spectrum Bridge Inc., “Analysis of FCC Secondary Spectrum Markets Positions, Policies and Comments”, White Paper, August 2008.

[71] A. Stirling, White Spaces – the New Wi-Fi?, UK-based Consultant, International Journal of Digital Television. Vol. 1, No. 1, 2010

[72] P. Bahl, R. Chandra, T. Moscibroda, R. Murty, M. Welsh, White Space Networking with Wi-Fi like Connectivity, Proceedings of ACM SIGCOMM, August 17-20, 2009.

[73] New Spectrum Solutions Allowed by the FCC's Secondary Market Initiative. Spectrum Bridge (blog). February 2010. Available at: http://spectrumbridge.blogspot.com/2010/02/new-spectrum-solutions-allowed-by-fccs.html

Previous COGEU deliverables used as references:

[D2.1] "European TV White Spaces Analysis and COGEU use-cases", April 2010.

[D3.1] "Use-cases Analysis and TVWS Systems Requirements", August 2010.

[D3.2] "Initial Architecture for TVWS Spectrum Sharing Systems", January 2011.

[D4.1] "Spectrum measurements and anti-interference spectrum database specification", November 2010.

[D6.1] "Dynamic Radio Resource Management algorithms for an efficient use of TVWS", January 2011.

7- List of Tables

8- List of Figures

9- List of Abbreviations

ADCO	Group of Administrative Co-operation (R&TTE Directive)
ADR	Alternative Dispute Resolution
AIP	Administrative Incentive Pricing
ANACOM	Autoridade Nacional de Comunicações (Portugal NRA)
ANFR	French National Frequency Agency
ARCEP	Autorité de régulation des communications électroniques et des postes (French NRA)
ARD	German public TV broadcaster
ART	Autorité de régulation des telecommunications (former French NRA)
BMWi	Federal Ministry for Economics (Germany)
BNetzA	Bundesnetzagentur (German NRA)
BT	British Telecom
CENELEC	European Committee for Electrotechnical Standardization
CEPT	Conference of European Postal & Telecommunications
ComReg	Commission for Communications Regulation
CPC	Cognitive Pilot Channel
CR	Cognitive Radio
CRP	Cost Recovery Pricing
CRTC	Canadian Radio-television and Telecommunications Commission
CSA	Supreme Council of Audiovisual (France)
CT	Cognitive Technologies
DAA	Detection And Avoidance
DARPA XG	Defense Advanced Research Projects Agency neXt Generation program
DFS	Dynamic Frequency Selection
DGE	Direction générale des entreprises (France)
DSA	Dynamic Spectrum Access
DSSS	Direct Sequence Spread Spectrum
DTV	Digital Television
DVB	Digital Video Broadcasting
DVB-T	Digital Video Broadcasting - Terrestrial
EC	European Commission
ECC	European Consumer Centre
EMC	ElectroMagnetic Compatibility
ETSI	European Telecommunication Standards Institute
EU	European Union
FCC	Federal Communications Commission (US)
FHSS	Frequency Hopping Spread Spectrum
FIRE	Future Internet Research and Experimentation
FP7	Seventh Framework Programme
GATS	General Agreement on Trade Services
GDP	Gross domestic product

GSM	Groupe Spécial Mobile (also, Global System for Mobile communication)
HDTV	High Definition Television
HS	Harmonised Standards
ICAO	International Civil Aviation Organization
ICT	Information and Communications Technologies
IEEE	The Institute of Electrical and Electronics Engineers
IMT	International Mobile Telecommunications
IPv6	Internet Protocol version 6
ISM	Industrial Scientific and Medical (band)
ISP	Internet Service Providers
ITU	International Telecommunication Union
ITU-R	International Telecommunication Union – Radio Communication Sector
JFMG	Joint Frequency Management Group
JRC	Joint Research Centre
KPI	Key Performance Indicators
LEC	Law of Electronic Communications
LTE	Long Term Evolution
M2M	Machine-to-Machine
MI	Minister of Infrastructure (Poland)
MNO	Mobile Network Operator
NFAP	National Frequency Allocation Plan
NRA	National Regulatory Agency
NTIA	National Telecommunications and Information Administration (US)
OCECPR	Cyprus NRA
OFCOM	Office of Communications (UK)
PAL	Phase Alternating Line
PKI	Public Key Infrastructure
PMSE	Programme Making and Special Events
QoS	Quality of Service
R&D	Research and Development
R&TTE	The Radio and Telecommunications Terminal Equipment Directive
RF	Radio Frequency
RLAN	Radio-based Local Area Network
RSPG	Radio Spectrum Policy Group
SDR	Software Defined Radio
SE	Spectrum Engineering Working Group
SECAM	Sequential Color with Memory
SFCG	Search for Common Ground
SFN	Single Frequency Network
SLA	Service Level Agreement
SME	Small and medium enterprises
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
TV	Television
TVWS	TV White Spaces
UHF	Ultra High Frequency
UK	United Kingdom
UKE	Urzad Komunikacji Elektronicznej (Polish NRA)
UMTS	Universal Mobile Telecommunications System
US	Unites States of America
UWB	Ultra-wideband
WAPECES	Wireless Access Policy for Electronic Communications Services
WG FM	Frequency Management Working Group
WiFi	IEEE 802.11
WiMAX	Worldwide Interoperability for Microwave Access
WRC	World Radiocommunication Conferences
WSD	White Space Device
WSLA	Web Service Level Agreement
WTO	World Trade Organization
XML	Extensible Markup Language
ZDF	German TV broadcaster

Annex I. Glossary of Terms

- **Secondary frequency trading**

  *The above-mentioned mechanism which is popularly referred to as **secondary frequency trading**, enables license holders to transfer the rights to use a part of or the whole allocated spectrum, usually in turn for certain material gain. This trade may have various forms, applied individually or combined together, e.g. partial sale of spectrum may or may not require reconfiguration or a change in the manner of usage, depending on the currently effective regulations and expectations of the parties.*

- **Transfer of obligations**

  includes transferring of the rights to use a spectrum from one entity to another, under effective regulations. Transfer of obligations does not require a change in the license conditions such as the date of expiry or obligations specified in a general exclusive frequency license, e.g. coverage, pricelist or quality of services. In the case of large radiocommunication networks which use scarce frequency bands (e.g. GSM or UMTS), there may be additional issues concerned with competitiveness, for instance when an operator wants to merge with or take over its rival.

- **Reconfiguration**

  refers to a situation in which the right to use a spectrum is transferred to a new entity which wants to change some working conditions. All changes resulting from reconfiguration should concern exclusively the conditions specified in frequency license, not the manner of spectrum usage (type of service or radiocommunication system).

- **Resale**

  of a part of spectrum may take place when an entity holds the rights to bigger amount of spectrum than it needs or has too little spectrum and wants to acquire more of it. In such situations, the option of 'sharing' one's spectrum and reselling rights to a part of spectrum to another entity can be a profitable solution.

- **Leasing/loaning**

  of a spectrum is an option of short- or long-term leasing or loaning of rights to spectrum usage by a license holder to another user. Such a form of management of the rights to a spectrum may enable this user to generate profits from access to radio spectrum without the necessity to apply for his own license. A license holder who does not need to have access to the whole of 'his' spectrum all the time, may be interested in the possibility of making a part of it available to other users and deriving material gain from it. Lease may also make it possible for new users to acquire access to a radio spectrum under conditions that have been agreed on by the parties, without the necessity for the previous holder to waive the right to the spectrum.

- **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.

- **Transactions costs**

  refer to the costs of, or impediments to, the transfer of property rights. Most obviously these are monetary, such as legal costs, but they also include instances where conflicting objectives among trading partners make it impossible to carry out a trade which improves efficiency

- **Regulatory adjudication**

  refers to methods regulatory authorities use, exercising their legal powers, to make decisions resolving disputes brought before them

- **Negotiation**:

  *The key characteristic of **negotiation** is that it is a consensual process that may allow the parties to arrive at a mutually agreeable solution without third-party entities.*

- **Mediation**
  is a consensual process that involves a neutral third party in facilitating dispute resolution

- **Arbitration**
  is a method of dispute resolution (sometimes preceded by mediation) that takes the place of conventional litigation. It is a consensual process in which disputing parties agree to refer a dispute to a neutral third party arbitrator or panel of arbitrators for resolution.

- **Band manager**:
  The **band manager** has been loosely defined in the following way [42]: It is generally understood to be an organisation that engages in activities that go beyond simply trading spectrum. These activities include some or all of the following:

  1. *planning the use* of a block of spectrum, which is defined by the scope of its licence;
  2. *packaging the spectrum* for disposal through trading but not necessarily exploiting the spectrum operationally itself;
  3. *engaging with the market* to dispose of it permanently or temporarily through trading;
  4. *serving end-users*, who will be the band manager's customers, with contacts covering their relationship;
  5. acting as first port of call to *investigate and resolve interference* caused by its customers.

  Any holder of a tradable licence could potentially function as a band manager, even if this was not its main commercial activity.

- **Spectrum leasing**
  is the process by which an original licensee can authorize a third-party lessor to exercise its Original licencee rights, but without transferring those rights to the third-party.

- **Opportunity cost**
  is defined as the highest value alternative forgone.

- **Quality of service**
  *At a high level of abstraction, "**quality of service**" refers to a set of service requirements to be met by the network while transporting a connection or flow and the ability to deliver network services according to the parameters specified in a service level agreement (SLA). "Quality" is characterised by service availability, delay, jitter and packet loss ratio [38].*

- **Service level agreement (SLA)**:
  *The **service level agreement (SLA)** is part of service contract, where the level of service is formally defined. It is defined as a negotiated agreement between two parties where one is the service provider (which can be the network operator) and the costumer that will consume the service. The agreement is related with the services that costumer receives and not how the service provider delivers the service. The SLA may specify the levels of availability, guarantees, warranties, performance, operation, or other attributes of the service, such as billing. The level of service (QoS) may also be specified as "target" and "minimum", which allows customers to be informed about what to expect (at least the minimum). In some contracts, penalties may be agreed upon in the case of non-compliance of the SLA.*