RADIO SPECTRUM POLICY GROUP 2011

Report on Collective Use of Spectrum (CUS) and other spectrum sharing approaches

November 2011

Executive summary

Based on its work on Collective Use of Spectrum (CUS) and Cognitive Technologies (CT), the RSPG analyses and recommends the way forward for "dynamic" approaches to spectrum sharing in the general sense and investigates how to implement or further improve the regulatory framework for innovative sharing arrangements in Europe.

In 2011, the RSPG set itself the task:

- of revisiting the Collective Use of Spectrum (CUS) model, in order to facilitate rapid access to spectrum, given that with the development of new technologies and the emergence of different regulatory models for ensuring the most efficient use of spectrum, the CUS model appears to be a subset of spectrum sharing in a broader sense, and
- of providing the European Commission with analysis and further developments concerning Collective Use of Spectrum and other spectrum sharing approaches.

Within the scope of the RSPG work programme, while preparing this report, the RSPG has:

i. reviewed innovative sharing arrangements applicable to the frequency spectrum in general;
ii. identified that some higher frequency bands (e. g. in the millimetric wavelength range) may be appropriate candidate bands to which the CUS approach could potentially be applied, noting the need to provide appropriate protection to radiocommunication services such as the passive services (radioastronomy, Earth exploration-satellite (passive), etc.);
iii. analysed sharing techniques to facilitate the exploitation of white space spectrum (generic approach), including a review of progress on white space utilisation in the broadcasting bands;
iv. analysed the requirements for further work to be carried out by the RSPG on shared access to spectrum, in light of the above.

Content

Firstly the Report analyses Collective Use of Spectrum approaches and explores the need to identify high frequency bands (e. g., in the millimetric wavelength range) to which any redefined approach could potentially be applied. Then it focuses on the impact and challenges of innovative sharing arrangements, including those utilising Cognitive Technologies and further develops and explores the approach to promote efficient use of spectrum in the most appropriate way.

Furthermore it explores the possibilities of establishing a regulatory framework for a shared use of spectrum approaches, based on the collective use approach. Finally this RSPG report elaborates on white spaces and on the policy implications of the use of white space spectrum, notably in the UHF bands.

The main issues and objectives addressed by this report are the following:

- reviewing the CUS approach and of spectrum sharing approaches that allow an unlimited number of independent users and/or devices to access spectrum in the same range of frequencies;

- providing CUS market insight for the already designated bands;
- providing an overview of various innovative approaches for spectrum sharing, considering also those utilising Cognitive Technologies;
- developing spectrum sharing opportunities in the broader sense, including approaches for licensed sharing;
- proposing a new concept Licensed Shared Access (LSA);
- exploring policy implications of the use of White Spaces;
- evaluating different approaches for accessing White Spaces;
- identifying challenging issues which require further attention and further development.

The conclusions drawn up from this Report will assist the European Commission on a way forward to implement spectrum sharing approaches.

The RSPG Report concludes that a great part of spectrum is already shared between different applications, and at the moment there is no identified need for more dedicated spectrum. Nevertheless, there is a need to progress further on appropriate regulatory mechanisms in regard to sharing of spectrum and to foster more efficient use of it, both for the commercial and public sector. Additionally, in this way forward, it introduces a new concept called “Licensed Shared Access”. Licensed Shared Access (LSA) could provide new sharing opportunities on a European scale under a licensing regime, while safeguarding national current spectrum usages which cannot be refarmed.

A set of recommendations are proposed to the European Commission in a view to facilitate shared access to spectrum in Europe:

- strengthen cooperation between CEPT and ETSI in the CUS domain, and the development of cognitive radio, sensing and geo-localisation techniques;
- in-depth assessment of the concept of LSA so as to explore the viability of this approach and carry out a consultation amongst EU Member States.

The RSPG also intends to undertake further work on the concept of LSA in the framework of the 2012 work programme, which will be subject to a public consultation.

Index

1. Introduction

Article 2 of the amended Commission Decision[A] establishing a Radio Spectrum Policy Group states that "*the RSPG shall assist and advise the Commission on radio spectrum policy issues, on coordination of policy approaches, on the preparation of multiannual radio spectrum policy programmes and, where appropriate, on harmonised conditions with regard to the availability and efficient use of radio spectrum necessary for the establishment and functioning of the internal market*".

This RSPG Report focuses on the impact and challenges of innovative sharing arrangements. Its objective is to address Collective Use of Spectrum (CUS) and further explore and develop approaches which may promote optimally efficient use of spectrum in an appropriate manner.

Services that rely on spectrum access under a collective use model represent some of the fastest growing areas of the ICT sector. Billions of devices operate within Europe which require access to spectrum and are exempt from individual licensing requirements, often because they operate at very low power. Due to the nature of such devices, it is difficult to quantify the total number in use, and hence their value to the European economy is also difficult to quantify. However, a study undertaken in 2006 for the Commission[B] estimated it to be worth in the region of tens of billions of Euro annually, with this value continuing to grow rapidly. Moreover, low barriers to entry for such devices mean that they can be one of the main drivers for innovation in the wireless industry. Their application contributes across many different sectors, including transport, logistics and asset tracking, medical, social, energy, communications and many others, including a variety of everyday consumer devices. For examples see also Section 4 – Table 4-1 and Annex B.

The RSPG Opinion[C] on the Radio Spectrum Policy Programme (RSPP) proposed that it should consider how to "make more spectrum available under a collective use model in order to facilitate rapid access to spectrum, promote innovation and competition". Furthermore, the RSPG Opinion RSPG08-244[G] on the Collective Use of Spectrum stated: "Given the potential of the CUS model to promote innovation, the RSPG considers that further work should be undertaken to assess how this objective can best be achieved." In its Opinion[D] on Cognitive Technologies the RSPG also has considered that "promising new systems and services fostering growth and innovation are seeking access to spectrum".

Therefore, in 2011, the RSPG set itself the task of revisiting this topic, given that with the development of new technologies and the emergence of different regulatory models for ensuring the most efficient use of spectrum, the CUS model appears to be a subset of spectrum sharing in a broader sense.

The aim of the report is to reconsider the CUS approach and explore further developments in innovative approaches to sharing the spectrum resource, whilst also noting the need to provide appropriate protection to radiocommunication services such as the passive services (radioastronomy, earth exploration-satellite (passive), etc.).

2. Scope of the Report

In this Report, the RSPG explores possible approaches for the implementation or further improvement of the regulatory framework in order to enhance innovative sharing arrangements within Europe. The report also outlines proposals to promote, inter alia, intelligent spectrum sharing and the use of Cognitive Technologies (CT) to enhance the effective and efficient utilisation of spectrum.

It provides strategic input to the European Commission for the preparation of the forthcoming Commission activities on “shared use of spectrum”, which aim to address shared use of spectrum in a broader sense, covering economic, technical and regulatory issues.

Bearing this in mind, and based on its work on Collective Use of Spectrum (CUS) and Cognitive Technologies (CT) to date, the RSPG therefore analyses and recommends a way forward for "dynamic" approaches to spectrum sharing in the general sense (i. e. scenarios where several users share spectrum resources through exploitation of certain aspects of the multidimensional spectrum space (e.g., frequency, time, place, quality etc.) according to actual needs and actual availability of the resources).

In preparing this report, the RSPG has:

i. reviewed innovative sharing arrangements applicable to the frequency spectrum in general;
ii. identified that some higher frequency bands (e. g. in the millimetric wavelength range) may be appropriate candidate bands to which the CUS approach could potentially be applied, noting the need to provide appropriate protection to radiocommunication services such as the passive services (radioastronomy, Earth exploration-satellite (passive), etc.);
iii. analysed sharing techniques to facilitate the exploitation of white space spectrum (generic approach), including a review of progress on white space utilisation in the broadcasting bands;
iv. in light of the above, analysed the requirements for further work to be carried out by the RSPG on shared access to spectrum.

Furthermore, this report sets out to identify innovative spectrum sharing arrangements, including those utilising Cognitive Technologies , in addition to further exploring the policy implications of utilising white space spectrum, and also explores the need to identify high frequency bands (e. g., in the millimetric wavelength range) to which any redefined approach could potentially be applied.

The report is structured in four parts. In part one, spectrum sharing approaches which potentially allow an unlimited number of independent users and/or devices to access spectrum in the same range of frequencies are analysed. In part two spectrum sharing opportunities in the broader sense are discussed, including approaches for licensed sharing. In part three, the RSPG evaluates different approaches for efficiently utilising white space spectrum.

Finally part four concludes the summaries of the relevant part on each issue and considers the next steps necessary to facilitate shared access to spectrum in Europe. Additionally this part contains a list of questions forwarded to the RSPG, which are seen out-of-scope of this action.

2.1 Basic concept and terminology

In this Report, the RSPG reconsidered and slightly revised the definition from 2008 RSPG Opinion[G], for the term "*Collective Use of Spectrum "*, as follows:

"Collective Use of Spectrum allows an unlimited number of independent users and/or devices to access spectrum in the same range of designated CUS frequencies at the same time and in a particular geographic area under a well-defined set of conditions."

Additionally, the RSPG, in this report, also considers the *shared use of spectrum* in a broader sense (i.e., beyond CUS also covering situations in which a known number of independent users access the same range of frequencies on the basis of an agreed sharing arrangement).

The RSPG, having considered the sharing approaches for unused or unutilised spectrum, as mentioned in the RSPG Report on Cognitive Technologies (RSPG10-306), has applied the following definition for the term *white space spectrum:*

"`*White Space´*, according to the definition set out by CEPT Report 24, is a label indicating a part of the spectrum, which is available for a radiocommunication 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".

In this Report, the RSPG also considers a new concept, "Licensed Shared Access" (LSA), which it defines to be:

"An individual licensed regime of a limited number of licensees in a frequency band, already allocated to one or more incumbent users, for which the additional users are allowed to use the spectrum (or part of the spectrum) in accordance with sharing rules included in the rights of use of spectrum granted to the licensees, thereby allowing all the licensees to provide a certain level of QoS."

PART I Collective Use of Spectrum approaches

In this part of the report, spectrum sharing approaches that allow an unlimited number of independent users and/or devices to access spectrum in the same range of frequencies are explored.

3. Considerations related to applications already operating under CUS conditions

The CUS approach can be divided into 3 categories as illustrated in figure 1, below. In general, administrations consider generic applications (category C) when designating bands for CUS. The justification for adopting specific applications (category B) is the result of compatibility studies and the need to have a limited number of devices using the band at the same location and/or a higher power limit. It may also be justified when a degree of protection of an application is required (for example, where it is related to safety or security of life). In cases where there is a significant risk of harmful interference a light licensing regime may be imposed (category A).

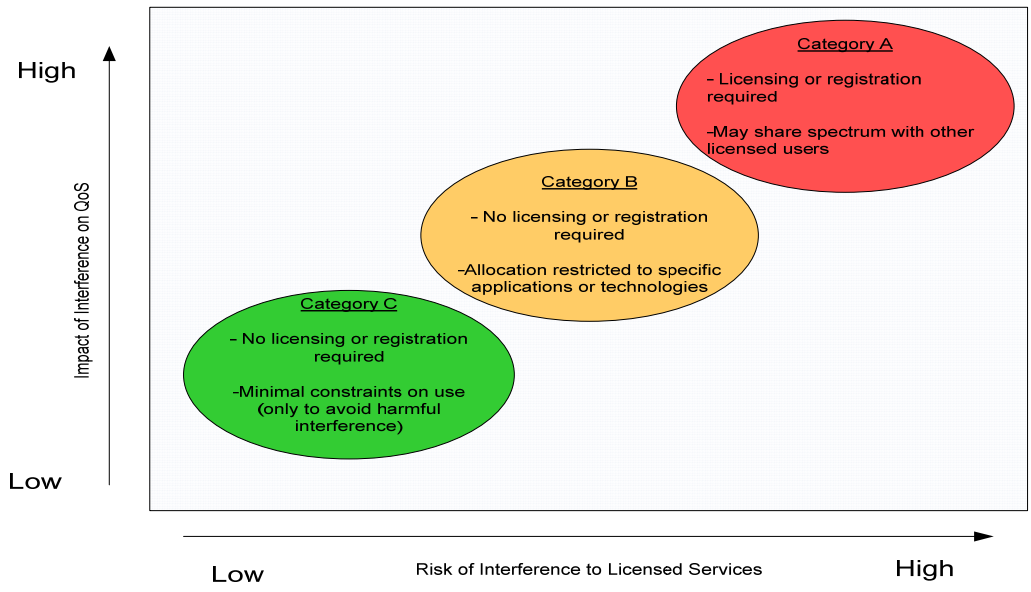

Figure 3-1: Categorisation of CUS approaches

The CUS approach applies to frequencies in the usable spectrum range, as detailed in Annex B. Many CUS applications use spectrum below 1 GHz for historical reasons, and due to the favourable characteristics of this frequency range. Much of this spectrum is allocated for specific applications (category B), but there also exist a number of generic categorisations (category C) in this range also

Spectrum in the 1 GHz to 5 GHz spectrum range has been utilised for some specific applications by a great number of devices. It should be noted that there is a certain variety of difference within the wide definition of the applications which explain the great interest of users for this frequency range. This shows that the border between generic and specific is not always very strict.

Of note, the use of equipment with cognitive capabilities has been employed in the 5 GHz to facilitate spectrum sharing. Between 6 and 40 GHz, most of the applications are concentrated in the 24-26 GHz band, while above 40 GHz, most of the applications are for the provision of broadband.

Finally, bands which have been designated for UWB applications fall under generic, specific, and light licensing regimes.

The RSPG assumes that the regulatory framework for CUS is well-known from all parties involved, in particular the industry and ETSI cooperating well with regulators in order to respond in time to new demands as far as they are reasonable and to provide the necessary input for compatibility studies.

EC Decision 2006/771/EC[E] on SRDs and the CEPT ERC Recommendation 70-03[F] both provide a list of the bands in the three categories with associated usage conditions. Alongside a list of the bands and conditions, definitions of the relevant applications are also provided within these documents.

Based on a permanent Mandate from the European Commission, the CEPT is tasked with regularly updating of the technical Annex of EC Decision 2006/771/EC. The work is undertaken by the Short Range Device Maintenance Group (SRD/MG) of CEPT/ECC, which is responsible for setting technical sharing parameters for applications suitable for CUS bands (e. g., SRD, RFID, Smart Meters etc.).

4. Opportunities and challenges for new applications

4.1 Current situation

Current radio spectrum access technologies (RAT) and related mitigation techniques enable the successful coexistence of applications, within the frequency bands identified in Annex A of RSPG08-244[G], which have been designated for CUS purposes. Perhaps the best example of successful CUS implementation can be found in the 863 - 870 MHz band. Within this band, millions of devices are in use, employed for application in several market sectors and having high societal benefit (see Table 4-1 for examples of such applications).

Category	**Non-specific SRD**	**Radio microphone applications including aids for hearing**	**Radio frequency identification applications**	**Wireless Audio Applications**	**Alarms**
Example	Remote Controls	Wireless Microphones	Payment transactions	Audio transceivers	Smoke detectors
	Building automations	Hearing aids	Access controls	Tour guides	Personal attack protections
	Sensors		People and goods tracking	2-way communications	Emergency lighting

Table 4-1: Assorted examples of applications in the 863 - 870 MHz band

The SRD/MG of CEPT stated in April 2011 that:

- existing spectrum in 863 - 870 MHz is not overcrowded, but it is evident that there is strong device population growth, and there exists the possibility that the noise environment may change as a result of new services being introduced in adjacent spectrum;
- many industry stakeholders have indicated that they may be able to share spectrum provided that the minimum technical criteria for sharing are identified in spectrum compatibility studies;
- segmentation of the spectrum by defining specific frequency spots for specific applications should be avoided as much as possible, as new frequency band segmentation or exclusivity for specific applications cannot be the common target.

Finally, the SRD/MG summarised that sufficient information for compatibility studies has been made available by stakeholders and ETSI. Some system reference documents of ETSI (SRDoc) contained valuable information for identifying input parameter for these studies; additional ETSI Specialists Task Forces (STFs) also contributed new information.

Nonetheless, the further development of approaches to enable new technologies to access spectrum and mitigate possible interference is needed and should be addressed by NRAs.

4.2 Risk of harmful interference

Given that the model for Collective Use of Spectrum is not designed to grant exclusive access to frequency bands or provide interference protection from other authorised users operating within the same bands, a number of factors need to be taken into account when considering the co-existence of the possibly numerous services and technologies which may exist within a CUS environment.

One of the main concerns with adopting the CUS approach is that, with the introduction of numerous new CUS applications to a given spectrum band, the band itself may be rendered unusable for other applications due the potential interference generated by the CUS applications. More specifically, the nature of the CUS applications means it can be difficult to refarm the spectrum if a ‘better’ use emerges in future. One must therefore ensure that a CUS approach represents effective use of the spectrum over the longer term before making any initial allocation or, alternatively, ensure that access conditions are set appropriately.

In some instances, the potential for interference may be lessened by, for example, designating a particular band for specific applications, placing technical constraints on power levels and imposing duty cycle limits, or encouraging coordination amongst users. Another alternative may be to establish regulatory controls which enable the secondary access to the band to be managed, for example through the use of databases or under a light licensing regime, which allows National Regulators identify secondary users operating within a given spectrum band.

Within spectrum bands currently designated for CUS bands in the higher frequency ranges (> 40 GHz), physical propagation characteristics such as relatively high free space attenuation could potentially lead to CUS, as interference potential within these bands is considerably less probable than when compared with lower frequency bands. This could ease the access for new entrants.

4.3 Technical and Quality of Service (QoS) aspects

The above section 4.2 identified that bands, which can potentially facilitate CUS, generally fall under the non-interference/non-protection case. As stated in the RSPG Opinion on CUS[G], QoS for users depends, inter alia, on the level of congestion existing at a certain location, within a given band and also the capability of different services and technologies within that band to coexist without negatively affecting the operation of other applications. Where off-the-shelf sharing techniques are available, such as Low Duty Cycle (LDC), Listen Before Talk (LBT), Detect and Avoid (DAA) and Transmit Power Control (TPC), they may be required in order to guarantee a certain level of QoS. In addition to the above listed cognitive capabilities, in order for users of different applications to successfully coexist, a number of "politeness rules" or "network etiquette" protocols may also need to be adhered to. Alternatively, a spectrum band can be exclusively designated for a specific application, thus making use within the band more predictable and therefore manageable. However, application-specific designation may have costs, notably in terms of spectrum efficiency if usage of the band does not develop as anticipated.

QoS may also depend on the type of CUS that is implemented. For instance, where licence-exempt SRD applications are concerned, the number of users is not regulated, which can potentially lead to congestion at certain locations, within a spectrum band. Therefore, certain controls, both through regulatory and/or standardisation processes, may need to be enforced in order to mitigate the potential for interference, thus maintaining minimum required QoS levels.

Further, the technology used can have a potentially significant bearing on QoS offered within CUS bands. Cognitive Radio is one such technology which can enable and/or improve QoS, which is enabled through equipment sensing of its surrounding spectral environment, and "choosing" appropriate unused frequencies over which data can be transmitted, thus minimising the risk of interference. As spectrum becomes more heavily used, QoS can become more difficult to maintain. Therefore, in such heavily utilised frequency bands, it is important that user equipment has such technological safeguards in order to maintain QoS. Such considerations are particularly important where safety critical applications are concerned.

Capacity requirements of users are also a consideration when assessing QoS needs, as in some instances a minimum capacity is required in order to provide an acceptable QoS. Given that current CUS bands in the higher spectrum bands (i.e., > 40 GHz) have greater bandwidth and therefore offer greater capacities to users, they may address some QoS issues which rely on higher capacities. The propagation characteristics within the bands may limit the type of applications suitable for these bands, but it should also be noted that the poorer long range propagation characteristics of the bands also makes them ideal for frequency re-use over relatively short distances. Such factors need to be taken into consideration by stakeholders when assessing opportunities for their applications.

The underlying technical requirements which are initially set out to define QoS depend strongly on the intended frequency band of operation (taking into account propagation characteristics and other applications in adjacent bands), the application type (duty cycle, capacity and bandwidth) and the geographic location. Therefore, the demands on QoS should only be differentiated by an appropriate body, supported by the stakeholders, using the results of relevant compatibility studies as well as, where appropriate, being based on e.g., ERC Recommendation 70-03.

On the other hand, the determination of criteria providing an appropriate QoS for segmented and therefore more protected use of the spectrum may potentially lead to a more static scenario by limiting the type of applications that may be deployed. Such an approach will need to be justified and balanced against efforts to introduce greater flexibility in spectrum management as set out in the new EU framework.

4.4 Reliable sharing arrangements between primary and other users

As indicated from work done by the FCC's Spectrum Policy Task Force[H] and Ofcom's Spectrum Framework Review[I], much licensed spectrum may not, at present, be utilised as efficiently as it potentially could be. Furthermore, certain frequency bands already allocated to primary users may have a relatively low signal power, indicating that the bands could possibly be shared with other users. Additionally, where other frequency bands are concerned, variation exists with regard to how spectrum is used in different geographic regions or locations.

Another factor may be the rate at which secondary usage events occur. That is, secondary usage may be stable over a lengthy time period (e.g., for a spectrum lease), whereas in other scenarios, secondary usage periods may only have intervals of activity that last for durations of time which extend from seconds to hours.

Technology utilisation of the primary service is also an important factor to consider. For example, with FDMA systems, it may be possible to have secondary use in idle channels or possibly the guard bands between channels. Technical constraints on the secondary user would then be limited to the bandwidth of the channel and the primary users' transmission power. In such an instance, there may be few restrictions when co-ordinating between primary and secondary users. For TDMA systems, however, vacant time slots in frequency channels, in addition to vacant frequency channels denote idle capacity. Therefore, closer coordination between primary and secondary users is required since time synchronisation is required in addition to the frequency restrictions. These different usage scenarios need to be given in-depth consideration when making plans to implement spectrum sharing arrangements between primary and secondary users within a given spectrum band.

Technology that the secondary service employs also needs to be taken into account. For example, the use of Software Defined Radio (SDR) and cognitive radio systems (CRS) lend themselves to more easily fitting in with primary users in multiple primary usage environments, whereas secondary users with less technologically advanced systems may need to focus more on finding a band where an appropriate primary user exists, while also having greater constraints placed on their operation.

The nature of the secondary usage also needs to be considered when assessing how secondary usage may be implemented in a frequency band that already has an existing primary designation. In some cases, sharing may only be possible when both, the primary and secondary user, are utilising similar applications, while, in other bands the primary and secondary user could use different applications. These two sharing situations can have different implications for the level of flexibility that certain frequency bands may have.

4.5 Regulatory certainty for existing users vs. access for new users

With technical progress creating further viability for the sharing of spectrum, it is anticipated that sharing between licensed and CUS applications will continue to increase, with more frequency bands being exploited for both purposes. However, as stated in the RSPG Opinion on CUS[G], this does not imply that licensed use will necessarily decline, but rather there may be further opportunity for sharing between both licensed and Collective Use of Spectrum users.

However, it is also worth noting that new CUS allocations in spectrum which already harbours existing primary users could potentially affect future flexibility of spectrum use for those primary users. This might happen as a consequence of initial compatibility studies being carried out which define a sharing scheme based solely upon the existing technologies of both the CUS and primary users, and not taking possible future technological developments into account. In such an instance, technology or service evolution for primary users may eventually become constrained, where the proposed evolved technology or service may not be protected to the same degree as the original primary usage was. Therefore, in order to mitigate such risks, rigorous compatibility studies should be conducted prior to any sharing arrangements being made, taking into account not only existing primary usage within a band, but also safeguarding for future primary use. Such actions will help ensure that collective use will not have a detrimental impact upon primary users both at present and in the future.

4.6 Identification of frequency bands

In discussing the possible identification of frequency bands for CUS in general, it is important to emphasise that in this market the manufacturer should be the driving force. As such, manufacturers, in order to provide new applications and/or new device, are expected to:

- devise their own concepts and scenarios for usage of a proposed application;
- undertake necessary market analyses related to a proposed application;
- provide information which identifies frequency bands based on physical needs;
- provide information to support related compatibility studies carried out by the appropriate bodies;
- establish standards via an appropriate standardisation body, e.g., ETSI.

These actions and provided information should be based on the existing frequency allocation table and associated regulatory frameworks. Based on the premise that a proposed application deployment is aimed at an international market, when such work is being conducted, it is also important to involve other regulatory administrations and CEPT. Otherwise, the provision of an appropriate frequency band for a newly proposed application is an obligation, which rests with the relevant National Regulatory Authority (NRA) and their organisations (e.g., CEPT and EC).

Under the CEPT process, industry demand is generally addressed to CEPT via ETSI[J]. Both bodies agreed on a co-operation process between them, started by ETSI generating a System

Reference Document (SRdoc)[1] and finalized by the ECC when establishing either an ECC Decision[2] or an ECC Recommendation.

When manufacturers consider frequency bands for CUS applications, it is critical that they minimise the risk of harmful interference by considering only the deployment of 'state of the art' technology (RSPG08-244[G]). Such an approach may mean that the identification of new frequency bands is unnecessary and, moreover, it will enhance the efficient use of spectrum under a collective use arrangement. The ongoing development of radio spectrum access technologies (e. g., CT, UWB) and mitigation techniques (e. g., LBT, LDC, DFS, TPC) will aid in facilitating this.

If it is not possible to utilise a frequency band, which has already been designated for CUS, for a particular application, the identification of potential new bands for CUS may then be explored. However, it is important to recognise that once a band has been designated for CUS, it is both difficult and time consuming to ever change this designation. This is largely due to the types of devices that will be deployed in the band which, by their very nature, cannot be tracked by the regulator and may have a lifespan of many years or decades. Therefore any decision to designate a new band for CUS needs to be given careful consideration.

It also needs to be understood that each frequency band has different entry requirements and limitations. This fact makes the search for appropriate bands within which to appropriately implement CUS difficult and time-consuming. Further, where bands above 35 GHz are concerned, current technological constraints exist, such as limitations on semiconductor development, for the production of devices appropriate for CUS applications (see CEPT Report 014[K]).

In general, the market wants to have low entry barriers through general authorisations, but also harmonisation, long term certainty, and stability of access. Identifying a band which fulfils all of these requirements presents an ideal scenario for spectrum access. In the absence of such a scenario readily arising, an alternative route to enable successful spectrum sharing may be followed when, for example, a manufacturer identifies a frequency band where a primary user may benefit from a new application, complementing the primary use, which the manufacturer wishes to place on the market. In such a scenario, both the manufacturer and the primary user could collaborate in order to find a mutual solution for coexistence, to be confirmed and agreed by the NRA.

A further option may be the development of a mechanism for sharing which could be imposed directly by the NRA. This is considered further in section 5.4 (Part II).

[1] According to the Working Procedures for ETSI, a 'System Reference Document' (SRdoc) should be produced for any new system, service or application requiring a change of the present frequency designation / utilisation within CEPT or a change in the present regulatory framework for the proposed band(s) regarding either intended or unwanted emissions

[2] ECC Decisions are measures on significant harmonization matters. It is understood that all CEPT administrations should implement measures specified in ECC Decisions

Conclusions of part I

For the effective implementation of Collective Use of Spectrum approaches based on the CUS model, the RSPG concludes that:

- Based on the analysis contained in this report, it is evident that the harmonised implementation of the sharing approaches based upon the CUS model is highly attractive for numerous applications, and the designated frequency bands for CUS are in high demand;
- The results and lessons learned, from 863 - 870 MHz[L] need to be taken into account when considering the potential application of a broader regulation. In light of this, the RSPG recommends that applications should not be narrowly defined, as this will maximise possibilities for access to spectrum, and hence minimise the potential obstruction, through segmentation of spectrum bands, of application convergence and further innovation with regard to applications. Prior to considering new spectrum bands for CUS, it should firstly be ensured that spectrum which has already been allocated for such purposes is being utilised in an optimally efficient manner.
- Spectrum scarcity, especially in the sector of social networking (hotspots etc.) is mainly an issue of high density of transmitters operating in urban areas, while rural and more remote areas are less affected;
- Legal certainty for the stakeholder already using CUS bands has to be respected in accordance to their terms of license;
- Higher frequency CUS bands offer greater bandwidth capacities to users, and facilitate frequency re-use over relatively short distances;
- Further investigations are needed on technical specifications for applications using the CUS bands above 40 GHz, with particular focus on physical characteristics, such as propagation distances, that may ease access to these bands for new entrants;
- Industry stakeholders need to provide sufficient information to support compatibility studies, with particular regard to applicable receiver parameters;
- Regulators need to take innovative technology into account when defining sharing conditions in CUS bands;
- To mitigate the risks to primary users, rigorous compatibility studies should be conducted prior to any sharing arrangements being imposed in order to ensure that collective use will not have a detrimental impact upon primary users both at present and in the future;
- Methodologies need to be defined to transparently assess the comparative benefits of safeguarding existing and future primary use and users and/or spectrum access for secondary users based on a CUS model;
- Regulators need to strike a balance between market demands for low entry barriers and the needs for spectrum harmonisation, long term certainty and stability of access;
- Manufacturers of wireless technology should be encouraged to identify frequency bands where a primary user wants to use or could benefit from an application that the manufacturer has developed, while in such cases regulators should support the manufacturer and the primary users find solutions for coexistence.

PART II Spectrum sharing opportunities and approaches

In this part, spectrum sharing opportunities in the broader sense are discussed, including approaches for licensed sharing.

5. Technical approaches

New approaches have emerged in recent years such as dynamic spectrum access[3], Ultra-wideband[4] and Spread spectrum[5], which may be suitable to facilitate shared use of spectrum.

Of these approaches, the focus of the report is on dynamic spectrum access. This advanced approach to spectrum management is closely related to other management concepts and techniques such as spectrum trading and flexible spectrum management. It involves unitizing spectrum in terms of temporal and geographical time slots and allows users to apply for access to a particular portion of spectrum for a defined time period or in a defined area, which they cannot exceed without re-applying for the resource. It permits communications to work by:

a. Monitoring airwaves to detect unused frequencies;
b. Reaching agreement with similar devices on which frequencies should be used;
c. Constantly monitoring frequency use by others; and
d. Switching frequency bands and adjusting power when this is needed to avoid interference into other devices.

Given the under-utilisation of certain frequency bands, spectrum spot markets could also provide an economic tool through which the benefits of cognitive radio can be realised. However, as this approach depends on the willingness of the initial spectrum right holder, some incentives are needed.

In order to benefit from increased access to spectrum and improved efficiency, however, several hurdles need to be overcome, including:

a. The potential for increased interference, effect on quality of service, and compliance with regulations;
b. Technical issues related to unseen devices competing for similar frequencies (the hidden node problem), and development of complex equipment.

Proposals have been made in order to adapt the regulation to these new technologies in particular Software Defined Radio (SDR). The RSPG believes that this should be taken into account in order to provide also a relevant regulatory framework for intelligent equipment.

[3] Dynamic spectrum access allows users to access spectrum for a defined time period or in a defined area. Users cannot exceed the terms of this access without reapplying for the resource, for example LBT, Duty cycle, etc.

[4] Ultra-wideband is an active underlay technology which transmits information which is spread over a large spectrum bandwidth.

[5] Spread spectrum is a technique of spreading spectrum significantly wider than the original signal, for example FHSS, DSSS, etc.

5.1 Cognitive radio

The RSPG published its first Opinion on Cognitive Technologies in 2010[D], setting out its various components, the challenges facing its future deployment and looking at the necessity for regulatory action.

The following potential capabilities of cognitive technology for spectrum access have been identified and were set out in the 2010 RSPG Opinion:

- Sensing: where devices monitor frequencies for any radio transmissions and if they do not detect any, assume that the channel is free and can be used;
- Geo-location: where devices determine their own location and query a database which returns the frequencies they can use at their current locations; and
- Beacon transmission: where a network of fixed transmitters or base stations are established and broadcast signals informing devices which channels are free to use in each relevant location.

Of these three techniques, beacon transmission has not been actively pursued because of the costly infrastructure that would likely be involved in setting up a network and the inefficiencies caused by base stations having to transmit well within the allowed usable spectrum.

5.2 Sensing

Initial development of white space technology focused on the sensing approach. The US, in particular, promoted trialling and development of these technologies to see how they would perform in environments where TV and/or PMSE were also operating. The results from those initial trials were mixed. FCC conclusions are outlined in Annex A.

Separately, in December 2007 the UK spectrum regulator, Ofcom, consulted on the use of interleaved spectrum by licence-exempt devices as part of its Digital Dividend Review[M]. It proposed that such use should be facilitated as long as existing users did not suffer harmful interference. Subsequently, it consulted in February 2009 on the threshold levels that would be needed for licence-exempt devices making use of sensing alone. It did confirm what those parameters should be in June 2009, whilst stating in its *Implementing geo-location* proposal of December 2010[N] that “sensing to very low levels is costly and possibly not achievable”.

Similarly, the 2010 RSPG Opinion on Cognitive Technologies noted the technical challenges faced by sensing technology where a wider range of frequencies or a wider range of user applications needed to be taken into account.

5.3 Geo-location

In response to the technical challenges that sensing technologies has posed, the focus for cognitive radio deployment in very recent years has moved to geo-location. The 2010 RSPG Opinion set out in detail how a geo-location device might work in terms of a structure of a database of available frequencies. That description included reference to:

- what information should be provided by the national regulatory authorities;
- what the model for managing the database should be; and

- how harmonisation and standardisation should be achieved.

The FCC moved towards introducing geo-location devices by publishing an order in September 2010 which authorised the use of white space devices in TV interleaved spectrum[O] on the basis of geo-location databases. Applications from potential database administrators were subsequently sought, whereby approved companies handed in applications which took into account the rules set out in the September 2010 notice. In March 2011, the FCC held a workshop to discuss how the database administrators could work together and set out a framework for device and database certification. A second meeting was held in Spring 2011.

The UK published its *Implementing geo-location* consultation in November 2010[P]; seeking comments from interested stakeholders, including potential database administrators (see Annex C for further information).

6. Regulatory approach: Licensed Shared Access

Shared access to spectrum exists in a number of frequency bands in most, if not all, EU countries, and is permissible under current European spectrum regulation. The RSPG believes that sharing spectrum on a European basis can improve the efficient use of spectrum, promoting economies of scale and encourage investment.

The RSPG is aware of a concept called ASA (authorised shared access) which has recently been proposed by an industry consortium[6], and which aims to provide shared access to IMT spectrum under a licensing regime in order to offer services with a certain quality of service. The RSPG has considered the regulatory aspects of such an approach, and has used this as a basis to foster the potential to share spectrum, which is not only limited to the IMT bands, in a harmonised manner within a licence regime. The RSPG refers to this as “Licensed Shared Access” (LSA).

A framework could be defined at EU level to enable the sharing of spectrum between a limited number of licensed users. Under this concept, the initial licensed user(s) utilising spectrum for a specific application would have to share spectrum with one or several new users for the same, or a different, application in accordance with a set of conditions to be defined through regulation imposed on both the initial user(s) and the new user(s). The granting of amended and new authorisations would be implemented by national authorities in accordance with their national regulation and EU Directives. The technical licensing conditions should be defined in accordance with the results of compatibility studies which have been agreed at the European level by CEPT, taking into account national particularities. They may be “static” or dynamic. In the latter case, a system for updating the conditions would need to be established.

Having ensured that there is a demand from stakeholders, National regulators and the EC would then need to agree on a strategy to share spectrum under the LSA conceptualisation. National regulators would have to define sharing conditions which take the interests of both incumbent(s) and new user(s) into account, as well as users in adjacent bands. Such sharing

[6] The consortium partners are Nokia and Qualcomm.

conditions should be based on compatibility studies which would be conducted preferably at European level within CEPT but which, in certain cases, may need to be conducted at national level when situations are specific to one country. This should be done in cooperation with the parties involved. In some cases it may be suitable to adopt an European Commission Implementing Decision in order to specify sharing conditions within a particular band of spectrum, based on the results of a Mandate to CEPT.

In order to gain the confidence of all parties involved, a progressive approach could be adopted where several bands are considered. It should be emphasised from the outset, however, that the LSA concept is not intended to be an initial or temporary phase which could lead to the refarming of a band.

An advantage of the LSA concept is that it allows more efficient use of spectrum whilst also providing an alternative to permanent segmentation or refarming of a band when there is a need to find new spectrum. The LSA concept allows continued use of spectrum for the incumbent, while also providing potential use of the same spectrum for other users. Such users could potentially provide other applications or radio services, in accordance with Chapter 5 of the Radio Regulations (ITU-R).

Another advantage of the LSA concept is that it also provides operators and industry with new opportunities on a European scale, taking into consideration the needs of the current users.

A general advantage of the LSA concept over the CUS model is that it gives some rights to a new user, thus making it possible for them to provide services where a predictable quality of service can be ensured. In this respect, spectrum sharing conditions have to be sufficiently attractive and predictable to provide incentive for new users to invest in equipment and networks.

The success of LSA, however, depends on the availability of the following critical elements, which require further study:

1. A reliable sharing agreement among primary user and LSA licensee (which is implemented under the direction of the NRA);
2. In environments where dynamic changes to spectrum access conditions are envisaged, a data base or other system for updating the conditions of spectrum access will be required.

The implementation of the LSA concept may take advantage of recent advances in cognitive technology, thereby allowing for more dynamic spectrum sharing. This is explored further in the following section.

6.1 Licensed spectrum sharing in Member States

As a common European view, it is generally considered beneficial for users, as well as NRA's, that regulation is relaxed insofar as possible with respect to issuing licences for spectrum use. Under such relaxed regulation, the Regulator may issue licences to all applicants in limited frequency bands by general assignment. When this is not possible, frequencies for particular usages may be assigned individually by the Regulator. It should be noted that an individual licensing regime should only be employed if there are no available alternative means to ensure interference-free radio transmission, or to ensure efficient use of spectrum.

Through the issue of licences, NRA's maintain information with respect to users of certain frequency bands, thereby ensuring that users can expect a good quality of service, so long as all users comply with the conditions in the licence, and coordinate their frequency use with other users when necessary.

The Regulator may, after hearing the parties concerned, release frequency bands for trading of usage rights and stipulate the framework conditions of and the procedure for trading when there is interest in trading usage rights for the spectrum concerned. The procedure shall include termination of the frequency assignment and the issue of a new assignment.

Noting that these are also basic requirements of the current European regulatory framework (e.g., Art. 9(3) Framework Directive and Art. 7 and 8 Authorisation Directive), they have been implemented in the regulatory regime of each MS.

However, as the LSA concept may require the designation of a new application in the band considered for LSA, its implementation requires additional regulatory measures compared to trading of usage rights. Therefore further information from MS is needed on the regulatory regime in order to implement the LSA concept at a European level. Furthermore, information is also needed on the dynamic evolution of conditions of use of spectrum.

Although this signifies, as implied at the beginning of the section, that a European implementation of a shared use of spectrum (here LSA) should be possible for all MS without any changes to the national regulatory environment. In this regard, a consultation requesting the views of the MS is considered needed. Thus, complete information on the license regimes of the MS, in relation to sharing, can be provided in order to support the further RSPG work on European level.

Conclusions of part II

With regard to spectrum sharing opportunities in the broader sense, including licensed sharing, as discussed in part two, the RSPG concludes that:

- Different approaches exist with regard to shared spectrum access in a number of frequency bands in many EU countries; this is permissible under current European spectrum regulation;
- Approaches to spectrum sharing which have been harmonised on a European level can serve to improve the efficient use of spectrum, promoting economies of scale and encourage investment;
- In recent years the most relevant approaches are those based on dynamic spectrum access, which are closely related to other management concepts and techniques such as spectrum trading and flexible spectrum management;
- Uniting spectrum in terms of temporal and geographical time slots and allowing users to access a particular piece of spectrum for a defined time period or in a defined area which they cannot exceed, has the potential to increase the utilisation of spectrum;
- The geo-location approach to grant shared spectrum access is a promising way to facilitate spectrum sharing and that first steps are underway to implement such an approach in Europe;

- Standardisation efforts are necessary to ensure the required economies of scale for equipment which shares spectrum;
- The implementation of the Licensed Shared Access (LSA) concept, when applied in conjunction with requirements, may allow for the sharing of spectrum in a more dynamic manner;
- The LSA concept allows incumbents to continue to use the spectrum while also providing spectrum capacities to other users, including for other applications or radio services;
- Compared to the CUS model, the LSA concept would provide some rights to the new user, making it possible for new users to provide services under a predictable QoS;
- The sharing conditions based on LSA have to be sufficiently attractive and predictable to incentivise users to appropriately invest in equipment and network;
- In order to gain the confidence of all parties involved in the sharing of spectrum, it may be necessary to adopt a progressive approach, consider several bands and to emphasise, from the outset, that the LSA concept is not intended to be an initial or temporary phase prior to the refarming of a band;

It should be noted that the current regulatory framework of electronic communications (e.g., Art. 9(3) Framework Directive and Art. 7 and 8 Authorisation Directive), enables the implementation of LSA concepts. However, further investigations would be required to identify how Member States would implement an LSA concept based on existing licensing regimes, as a first step to a European implementation.

Further analysis would also be required in order to determine more detailed considerations, such as, for example, the number of LSA licensees with a similar QoS requirement that could successfully utilise an LSA band, how competition rules would apply, and to what extent the introduction of LSA might inhibit future flexibility of spectrum utilisation for existing users.

PART III Sharing approaches to use white space spectrum

In part three, the RSPG evaluates different approaches for accessing white space spectrum.

7. Different approaches for spectrum sharing

7.1 Administrative Model

Often referred to as Command and Control, this approach to spectrum management entails National Regulatory Authorities holding responsibility for assessing and controlling how various parts of the radio spectrum should be utilised, and also who should use it. Access is typically granted to users for a frequency channel/range, with certain restrictions being imposed by the Regulator on all users of the frequency band with regard to how the spectrum can be used, thus providing protection from interference by other users of that band.

With the explosion in demand for radio spectrum in recent times, this model of spectrum management may struggle with the burgeoning and rapidly evolving requirements for access to spectrum. Supporting this view, Mott Macdonald, in their 2006 study for the EC[B], indicated that this is particularly the case for commercial services and applications, where demand for access to radio spectrum can often exceed supply.

7.2 Market Based Model

Over the past number of years, market based approaches, typically taking the form of license auctions, have been employed by National Regulatory Authorities as a spectrum management tool. When compared with both the administrative and many collective use models, there may be fewer restrictions on spectrum usage when this approach is adopted. Exclusive use of spectrum and protection from interference may also be provided under the market based model.

Further, the potential for spectrum spot markets has become more feasible with the advent of Cognitive Radio Systems (CRS). As radio equipment becomes more frequency agile, and with improvements in antenna design, spectrum could be made available for dynamic use on a real-time basis. Such spot markets may, in the future, facilitate increased ease of access to spectrum in addition to enhanced spectrum efficiency.

7.3 Collective Use Model

Under the collective use model, users are not provided with exclusive access to spectrum, nor are they afforded legal protection from radio interference. Moreover, with the exception of some light licensing approaches, where a degree of protection may be provided to the licensee, many CUS applications typically must share frequency bands with other users on a non-interference and non-protected basis. However, technical restrictions may be applied to the manner in which the spectrum is used in order to accommodate this type of spectrum sharing.

7.4 Licensed Shared Access (LSA) Model

The implementation of the LSA concept may take advantage of recent advances in cognitive technology, thus allowing sharing spectrum in a more dynamic way, utilising frequency, location and time sharing bases. Dynamic sharing does not impede predictability of operation given that a certain level of spectrum access shall be guaranteed (i.e., the primary user will have to allow access to a certain spectrum/time/location or will have to give sufficient time before significant restrictions to access are imposed). In other words, the “priority” given to the primary user is to be limited/regulated.

Any sharing arrangement would be part of the regulation and included in the authorisations delivered by the NRA.

7.5 Quality of Service for white spaces users

QoS for White Spaces has to be distinguished into two parts, related on the level where it is provided.

The first (vertical) provision is fully dependant on the incumbent's implemented technology. The basic criterion for this QoS will be the percentage of interference secondary user(s) will have to cope with. The second (horizontal) provision is dependent on the result of a related sharing agreement or to the setup of sharing criteria by the regulator. But these measures can only confirm the level of the vertical QoS for each possible user.

The definition of additional higher QoS would lead to a limitation of the usability of the band, noting that this measure will certainly limit the number of users.

7.6 Potential white spaces services and their market opportunities

White spaces in the UHF band have the potential to provide high-speed, wireless internet services on a grander scale than traditional Wi-Fi, but this requires further investigation. Use of such relatively low frequencies, which travel very well through buildings, trees, and over varied terrain can be advantageous for the provision of these services.

White Space Devices (WSD) could take advantage of wireless innovations and utilise spectrum-sensing technology to automatically detect occupied UHF frequencies, allowing the public to use spectrum that would otherwise be inefficiently used or entirely unoccupied. With the growing use of Wi-Fi and other unlicensed devices ranging from laptops to next-generation PDAs and cell phones, WSD provide much-needed additional capacity for broadband connectivity, home and community networking.

While existing use of unlicensed spectrum has driven a remarkable amount of innovation, opening low-frequency spectrum for WSD may serve to further facilitate and improve home, business, and regional wireless networks.

A potential use of the unlicensed UHF band would be to create large area wireless data networks for numerous applications (i.e., Rural Broadband deployment, metro area "White-Fi" hotspots, cellular offload networks, mobile broadband, etc.).

However, in some cases it may not be possible to plan the use of WSD in the TV bands on a large scale. One such case may arise when there is an extensive use of digital TV and/or use of single frequency networks (SFN). Another instance where large-scale planning may not be feasible may arise when a general authorisation regime for PMSE applications has already been implemented by an NRA. Local assessments should therefore be made on a case-by-case basis, which are based on national circumstances.

As also indicated in CEPT Report 24 (Report C from CEPT to the European Commission) the use of white space by PMSE under general or individual licences, depending on the category of PMSE, is expected to continue in the foreseeable future, taking into account the development of digital broadcasting in the UHF band. Introduction of new cognitive radio applications for interleaved deployment in this band has been considered based on discussions which have emerged in the United States and that is being assessed in the UK trials. This technology is still under development and these matters will need further investigation in the future also taking into account results of trials.

At the moment the feasibility of cognitive sharing schemes has not yet been conclusively demonstrated and any sharing scheme will have to be carefully assessed and confirmed, before it can be put in place on a large scale. This includes compatibility with other services such as terrestrial broadcasting but also the consequence in terms of possibility of evolution of terrestrial broadcasting planning and technology.

Based on the decisions of the RRC-06 and WRC-07 related to the UHF band, the potential for white space spectrum availability is being gradually reduced. The re-planning and move to digital broadcasting under the GE06 Plan has resulted in far less white space spectrum being available than previously under the analogue ST61 environment. Moreover, the harmonisation of a sub-band for fixed/mobile applications (digital dividend at 800 MHz) has also reduced the amount of white space spectrum available for interleaved services in the UHF band. Extensive use of digital TV and/or use of single frequency networks (SFN) will also reduce possibility to plan the use of WSDs in the UHF band on a large scale. It is recommended looking further into the requirements within the European environment for CRS devices to be deployed in white space spectrum especially if looking at UHF band and that local assessments should be made on a case by case based on national circumstances.

7.7 The use of white spaces for Programme Making and Special Events (PMSE) applications

In Denmark the frequency band 800 - 820 MHz may be used for wireless microphone applications on a licence-exempt basis. Use of the band for these applications is terminated by the end of 2012. Hence NITA (the National IT and Telecom Agency) had to find alternative spectrum to be used for wireless microphones. Within Denmark, white spaces in the frequency band 470 - 790 MHz could, until recently (October 2010), be used for PMSE, with a licence for a given frequency in a given geographical area. To make spectrum use within the band use more flexible, NITA has changed the authorisation regime so that interleaved spectrum (White Spaces) in the 470 - 790 MHz band may now be used for wireless microphones on a licence-exempt basis.

In order to make it easier for the users to identify interleaved spectrum that may be used, NITA has developed some online applications to identify the legal interleaved spectrum in 470 - 790 MHz. These applications are available at NITA's website: http://en.itst.dk/spectrum-equipment/wireless-microphones.

NITA has also developed a database, which can be accessed from the homepage and an application for smartphones (iPhone and Android), which enables users to easily identify frequencies which can be used at a given location. Available spectrum is at a given location is presented when the user enters an address or clicks on a map.

Aside from the applications made available through their website and/or smartphones applications, NITA has developed a public application programming interface (API) which can be used to integrate live, up-to-date data related to industry solutions (i.e., product specific software or private web-solutions) on interleaved spectrum in 470 - 790 MHz for wireless microphones at any given location in Denmark. This API is also used for the smartphone applications and NITA's website application.

These solutions provided by NITA provide access to professional users and other interested parties with the most up-to-date information on available interleaved spectrum for wireless microphones in the 470 - 790 MHz range.

7.8 Plans for using white spaces in the band 470-790 MHz

The table below summarises the progress that some countries have made in facilitating the use of white space spectrum in the 470 - 790 MHz range:

Country	Status
United Kingdom	Consulted on the feasibility of implementing geo-location in November 2010 and issued a statement in September 2011 which aims to establish a regulatory framework to enable White Space Devices and geo-location databases to emerge in the UK. Trials also underway in Cambridge focused on the use of TV White Space (see annex C for more information).
Ireland	PMSE licences can currently be granted in the 470 – 790 MHz band within Ireland. ComReg's test and trial licence scheme provides an opportunity for spectrum users to apply for temporary test licences within the 470 – 790 MHz band for dynamic spectrum access technology. Test licences have been granted in the past for cognitive radio testing purposes.
Denmark	White spaces in the frequency band 470 - 790 MHz could until recently (October 2010) be used for PMSE with a frequency that is not used for DTT in a given geographical area, as described in section 7.7. above.
Germany	Licensed the current white space spectrum in traditional scheme to PMSE (SAB/SAP; ENG), PMR and wind-profilers
France	White spaces in the frequency ranges 174-223 MHz, 470-790 MHz and 823-832 MHz have been designated for professional wireless radio microphones under a general authorisation regime on a non-protection, non-interference basis.

Additionally:

United States	Published an order in September 2010 authorising the use of geo-location devices in white-space spectrum.

	Held workshops in Spring 2011 with potential database administrators. Spectrum Bridge has undertaken formal tests of its database.

8. Which Model is most appropriate?

It is sometimes readily obvious as to which one of the models outlined above is the most appropriate to apply in given circumstances. For example, if high QoS service requirements are necessary for existing users within a band, and the band is heavily used, then introducing a CUS model in the band may be difficult. Conversely, in a band which has relatively low QoS requirements, it may be possible to introduce licence-exempt CUS applications (employing appropriate mitigation techniques (e.g., duty cycle) and maximum power limits) on a shared basis with existing users.

However, other situations may present themselves where it may not be immediately obvious as to which model to apply. For example, technological advances may enable spectrum users to co-exist in the same frequency band, but the level of QoS required by some of these users may demand that the number of users sharing within the band is limited. Further, technological advances, such as those seen in cognitive radio applications, could possibly be taken advantage of to enable sharing in bands which in the past could only have been allocated for use on an exclusive basis.

One important distinction between the collective use model, spectrum sharing and licensed shared access concerns control. Under the LSA approach, the regulator knows exactly who is licensed to operate in a given band, and so is well positioned to effectively deal with any cases of interference that may arise (for example, to the incumbent user). Similarly, under a CUS or other sharing approach based on a geo-location database, the regulator can manage the interference environment by controlling the emission levels permitted by the database. If necessary, the regulator can also prevent devices, registered on the database, from transmitting at all, despite the fact that the devices do not require a licence to transmit. However, under a more general CUS model, based on licence exemption without access to a database, it can be extremely difficult to make any changes to the conditions under which the devices access the band, thereby potentially making it more difficult to protect an incumbent user.

8.1 Regulatory aspects

It has been considered by several organisations, such as CEPT and ITU, that access to white spaces should not be governed through the application of an unnecessary regulatory framework. White spaces are described as parts of allocated spectrum, which are not usable or are unused due to technical, geographical or timing restrictions. These frequencies are seen as ideal candidates for further deployment of the CUS or LSA approach, irrespective the primary usage of the band.

8.2 Regulatory certainty for existing primary users

As explored in part one of the report, as technical progress creates further viability for the sharing of spectrum, it is expected that frequency bands already occupied by other users will be increasingly made available for sharing applications. Also using the same rationale prior to making spectrum available to new sharing applications, compatibility studies should firstly be carried out to ensure that existing services are protected insofar as possible. Furthermore, it should be noted that imposing mitigation rules on any new sharing applications, such as, for example, politeness protocols and transmit power limits, in addition to employing technologies such as cognitive radio, underlay technologies, and applying spread spectrum techniques, will help ensure that potential for interference is minimised.

Conclusions of part III

With regard to the possible approaches for accessing white space spectrum as discussed in part three, the RSPG concludes that:

- While technological advances may enable spectrum users to co-exist in the same frequency band, the QoS requirements of some users within that band may provide sufficient justification to place a limit on the number of users sharing the band;
- Technological advances made through the development of, for example, Cognitive Technologies, could enable spectrum sharing within frequency bands which otherwise might only be available for use on an exclusive basis (such as white spaces);
- As technical progress creates further opportunities for the sharing of spectrum, it is expected that frequency bands already occupied by other users will be increasingly made available for sharing applications;
- Ensuring compliance with mitigation rules, such as politeness protocols and transmit power limits, in addition to employing technologies such as cognitive radio, underlay technologies, and applying spread spectrum techniques, will help ensure that the potential for interference is minimised;
- Essential requirement for using white spaces are their sufficient availability and the possibility to identify its users (e.g.: through notification in a database)
- Regulators could specify a geo-location approach to control the permitted emission levels of equipment as well as to prevent the devices from transmitting at all if necessary, despite the fact that such devices do not require a licence to transmit;
- Prior to making spectrum available to new sharing applications, compatibility studies should firstly be carried out to determine whether sharing is possible and, if so, the relevant conditions to be applied in order to protect existing services.
- At the moment the feasibility of cognitive sharing schemes for using white space spectrum has not yet been conclusively demonstrated and any sharing scheme will have to be carefully assessed and confirmed, before it can be put in place on a large scale;

It must be taken into consideration that in some cases it could not be possible to plan the use of cognitive sharing schemes in the UHF bands on a large scale (i.e., based on general authorisation PMSE scheme and/or very extensive use of digital TV) and local assessments should be made on a case by case based on national circumstances.

PART IV Conclusions of the Report and next steps necessary to facilitate shared access to spectrum in Europe

In part four the RSPG considers the next steps necessary to facilitate shared access to spectrum in Europe. RSPG has studied three domains, where progresses can be made on spectrum management, and identified issues where further development could be considered. RSPG conclusions on these domains as well as the next steps which should be undertaken are presented further below.

The RSPG concludes that a great part of spectrum is already shared between different applications, and at the moment there is no identified need for more dedicated spectrum. Nevertheless, there is a need to progress further on appropriate regulatory mechanisms in regard to sharing of spectrum and to foster more efficient use of it, both for the commercial and public sector.

Collective Use of Spectrum

The situation regarding Collective Use of Spectrum is rather complex, as applications - either specific or generic - are using a great number of bands spread across the usable spectrum. Sharing techniques are also becoming more complex. Even if the legal environment indicates that the CUS approach falls under the non-interference/non-protection regime, the requests for more protection and better Quality of Service are major trends. Even if there is no obvious need for new spectrum to be made available, there is a clear request to provide better Quality of Service to certain category of SRDs (ITS, etc.). In this case and to safeguard future primary use, detailed compatibility studies need to be conducted within CEPT, in cooperation with ETSI. As spectrum above 40 GHz is rather underutilised, development of technologies in this part of the spectrum should also be encouraged.

Spectrum sharing opportunities and approaches

Different shared access to spectrum approaches exist in a number of frequency bands in most if not all EU countries under current European spectrum regulation. A number of technologies, such as cognitive radio, sensing, and geo-location, are under development, aimed at increasing spectrum sharing opportunities. RSPG has also considered that the regulatory environment, whilst already allowing spectrum sharing, should open the way to a new concept called “Licensed Shared Access”. Licensed Shared Access (LSA) could provide new sharing opportunities on a European scale under a licensing regime, while safeguarding national current spectrum usages which cannot be refarmed. It is not intended that LSA will be an initial or temporary phase prior to the refarming of any band. Consequently, general sharing conditions should be agreed at European level, taking into account national particularities in bands designated for LSA at EU level, thus offering new opportunities for providing services with a good Quality of Service in spectrum within Europe. This new concept needs to be further developed, in particular regarding the possibility to dynamically modify licensing conditions within the framework of the recently adopted EU regulation.

Sharing approaches to use white space spectrum

The report identifies four approaches; the administrative model, the market based model, the collective use model, and the newly proposed Licensed Shared Access (LSA) model. It also further explains the potential of white space services and their associated market opportunities. Designating a band for White Space Devices (WSD) requires two essential conditions; firstly,

that there are enough white spaces, and secondly, that current users can be identified, at a minimum, through a notification process. Provided that these conditions are met, such designations will provide opportunities for other applications. Regarding Quality of Service it is concluded that there is a direct dependence to the technology used by incumbent(s) and the current sharing agreement(s). In the UHF band, even if in some cases will be not possible to plan the use of White Space Devices on a large scale, these applications could include rural broadband deployment, Wi-Fi, Machine to Machine communications, etc.

Next steps necessary to facilitate shared access to spectrum in Europe

The RSPG recommends that the EC should encourage the strengthening of cooperation between CEPT and ETSI in the CUS domain, and the development of cognitive radio, sensing and geo-location techniques.

The RSPG recommends that any future work programme which explores the wider issue of Collective Use of Spectrum should also include a more in-depth assessment of the concept of LSA. In particular, further work may foster greater understanding as to how viable this approach to authorisation might be, in practice, amongst EU Member States.

The RSPG also recommends that the EC should consider the implementation of the LSA concept in order to provide access to new spectrum in the light of the future RSPP Decision. A first step could be a consultation of the MS. Thus complete information on the license regimes of the MS, in relation to sharing, can be provided in order to support the further RSPG work on European level.

Abbreviations

ASA	Authorised Shared Access
BEM	Block Edge Mask
BMA	Building Material Analysis
CEPT	Conférence Européenne des Administrations des Postes et des Télécommunications
CRS	Cognitive Radio Systems
CT	Cognitive Technologies
CUS	Collective Use of Spectrum
DAA	Detect and Avoid
DFS	Dynamic Frequency Selection
DSSS	Direct-Sequence Spread Spectrum
ECC	European Communications Committee
ETSI	European Telecommunications Standards Institute
EU	European Union
FCC	Federal Communications Commission
FHSS	Frequency-Hopping Spread Spectrum
IEEE	Institute of Electrical & Electronics Engineers
ITS	Intelligent Transport Systems
ITU	International Telecommunication Union
LSA	Licensed Shared Access
LBT	Listen Before Transmit
LDC	Low Duty Cylce
MFN	Multi Frequency Network
MS	Member States
NRA	National Regulatory Administration
PMSE	Programme Making and Special Event
PMR	Private Mobile Radio
QoS	Quality of Service
R&TTE	Radio and Telecommunications Terminal Equipment
RATs	Radio Access Technologies
RFID	Radio Frequency Identification
RLAN	Radio Local Area Network
RSPG	Radio Spectrum Policy Group
SDR	Software Defined Radio
SRD/MG	Short Range Device – Maintenance Group
SRR	Short Range Radar
SUS	Shared Use of Spectrum
TPC	Transmission Pulse Control
TVBD	TV band devices
UHF	Ultra High Frequency
UMTS	Universal Mobile Telecommunications System
UWB	Ultra Wide Band
WAPECS	Wireless Access Policy for Electronic Communications Services
WRC	World Radiocommunication Conference

Annex A: European and International activities

Relevant activities in Europe (EC, ECC, CEPT, ETSI)

On November 2008, the RSPG, upon request of the European Commission, issued an Opinion on "Aspects of a European Approach to 'Collective Use of Spectrum'", where it concluded that further work should be undertaken to assess how this objective can best be achieved. This should include investigation of the different approaches to making spectrum available for CUS, after carrying out the Impact Assessments and the necessary compatibility studies.

Based on these considerations several frequency bands had been identified to be used under the CUS model and therefore annexed to the 2008 Opinion. Only a few of them were used in the past, but those under usage (i. e. the 863 - 870 MHz band) are an example for the success of the CUS approach.

In the context of the EU2020 growth strategy and in particular the Digital Agenda, one of the key objectives for the EU spectrum policy is to enhance the quality of life of European citizens. This includes lowering access barriers to spectrum for new uses and users, in so strengthening the internal market and fostering digital inclusion and social cohesion.

In line with European initiatives such as the Digital Agenda, spectrum management can also contribute to efforts to bridge the digital divide through enabling ubiquitous broadband access, highly contributing therefore to the objectives of smart, inclusive, sustainable growth envisaged in the EU2020 strategy.

The way forward in this regard also needs to include efforts to make more spectrum available under a collective use model in order to facilitate rapid access to spectrum, promote innovation and competition. In addition, it is also necessary to create appropriate regulatory mechanisms to foster more efficient use of spectrum, both for the commercial and public sector.

In this context the RSPG considers the enhancement of the CUS model and the development of a broader approach to spectrum sharing is beneficial for new systems and services fostering growth and innovation, which are seeking access to spectrum. Therefore, in 2010 and 2011, both the RSPG and the CEPT/ECC are working to enhance the regulatory approaches to spectrum sharing. The RSPG has already covered relevant issues in its work on CUS and on Cognitive Technologies (RSPG08-244[G]). The CEPT held a workshop in April 2011 on spectrum for SRDs, RFIDs and Smart Metering, where the current situation for some of the already identified CUS frequency bands was depicted and discussed.

Also related work is done within ECC on CRS, a possible enabling technology for CUS, especially on scenarios of usage (WG FM) and regulatory framework (WG RA). Of particular interest in the context of the report is ECC Report 159[Q] of SE PT43 on the "Technical and operational requirements for the possible operation of cognitive radio systems in the 'White Spaces' of the frequency 470 - 790 MHz".

Relevant activities in USA, CANADA, ASIA, ITU

FCC has adopted an Order[R] with regard to the matter of unlicensed operation in the TV broadcast bands below 900 MHz and in the 3 GHz band (January 26, 2011). In this order, the requirement was removed that white space devices using geo-location and database access

must also include sensing technology to detect the signals of TV stations and wireless microphones.

The FCC designated Google and eight other companies to be "White Space" administrators. The TV bands databases will be used by fixed and personal portable unlicensed devices to identify unused channels that are available at their geographic locations. The FCC has asked all administrators to submit additional information about their database plans by 28th February 2011 and attend a workshop at 10th May 2011 to go over the agency's rules. Administrators will then undergo a 45-day trial period. If they pass the trial, they will be able to operate their databases for five-year terms. On the other hand one main requirement on the white spaces devices remained unchanged. A type approval is still explicitly required in order to use the TV white spaces in the US. The proceedings on database operations and attempts on are publicly available[S].

Initial development of white space technology had focussed on the sensing approach. The US, in particular, promoted trialling and development of these technologies to see how they would perform in environments where TV and/or PMSE were also operating.

The results from those initial trials were mixed. In 2008, as a result of field trials in the Washington and New York areas the Federal Communications Commission (FCC) concluded that

> *"… we (the FCC) believe that much more development work needs to be accomplished before the spectrum sensing technique can be implemented as the principal means of identifying unoccupied channels in the TV bands, even in the case of fixed devices that use outdoor antennas*
> *Thus, we are not convinced that spectrum sensing as currently presented could adequately serve as the only means to protect TV services and other fixed protected contour services from interference by unlicensed TVBDs [TV band devices] operating at the power levels proposed in the Notice"*[T]

Relevant documents:

FCC Order 04-186 (2008) http://www.naic.edu/~phil/rfi/fccactions/FCC-04-113A1.pdf
Update 2008 http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-08-260A1.pdf
Update 2010 http://www.fcc.gov/Daily_Releases/Daily_Business/2010/db0923/FCC-10-174A1.pdf
Update 2011 http://www.fcc.gov/Daily_Releases/Daily_Business/2011/db0126/DA-11-131A1.pdf
TV White Spaces Page (FCC) http://www.fcc.gov/oet/whitespace/
Proceedings on Docket 04-186 http://fjallfoss.fcc.gov/ecfs/proceeding/view?name=04-186

Annex B: Description of CUS applications/frequency band

Applications operating below 1 GHz

Applications operating in the bands below 1 GHz generally offer good propagation characteristics and a rather long range. The applications in this part of the spectrum are low power applications (generally less than 500 mW) and can be used at the same time by a great number of users. The limits are only if a great number of users are using their equipment on the same location. They are normally using a narrow channelling with a low data rate. Main applications using specific bands are: inductive applications, model control, wireless alarms, hearing aids, radio microphones, medical and biological applications, industry telemetry, PMR 446, RFIDs.

In addition a number of bands have been designated for non-specific application. The main bands are the 433 MHz and 863 - 870 MHz bands. Current regulation imposes channel segmentation, duty cycle and mitigation requirements to deliver multiple services. Spectrum designated for CUS below 1 GHz is generally harmonised and extensively used. It should be noted that such a segmentation associated to the existing regulation confers to applications a certain protection in regards of interferences and offers a reliable environment to operate.

It should be underlined that reducing the availability of white space spectrum, as it is envisaged in the UHF band in the frame of the draft Decision on RSPP, may create difficulties for some applications in particular for PMSE.

The general trend in telecommunications towards convergence of services (data/ voice/ audio/ video) is also affecting SRDs. However, the trend for some specific SRD is the request for more protection on the basis that they operate on human security such as medical implants or social alarms.

Consequently, attractive technical conditions of operation in this sub 1 GHz band is resulting in a growing demand from new applications. In particular, in the near future, new applications such as Smart Metering, Smart Grid and city automation are expected to enter the mass market.

As the interesting spectrum is not expandable, compatibility studies are more and more requested in order to assess the sharing conditions with existing services and also intra-SRD and facilitate the inclusion of new applications below 1 GHz. RSPG considers that the responsibility of conducting compatibility studies belong to CEPT in the first case (between SRDs and other radio services) as the results of these studies are reflected in the regulation, and to ETSI in the case of each intra-SRD application as the results of the studies are included in the harmonised standards. When there are several SRD applications in the same band or in adjacent bands, CEPT may give advice to ETSI (through a liaison statement from ECC).

Applications operating between 1 GHz and 5 GHz

Main applications using specific bands are: DECT, RFIDs, radio-microphones, PMSE, radiolocation, radio local area networks and wideband transmission networks.

Most of the applications, specific or non-specific, are using the band 2400 - 2483.5 MHz. The maximum power is 10 mW for non-specific application and 100 mW for some specific applications, and 500 mW in the band 2446 - 2454 MHz for specific applications. The different power limits have been evaluated in order to allow several CUS applications in the same band.

DECT is using the band 1880 - 1900 MHz. Most if not all wireless phone are using this technology.

The band 1785 - 1800 MHz has been designated for radio-microphones in some EU countries but is currently unused in those countries. Due to the reduction of availability of spectrum in the UHF band in the short term it is anticipated that the market may develop in this band in some countries. The band 2465 - 2475 MHz is also designated for ENG/OB.

Applications in these bands provide a greater data rate than applications below 1 GHz. Therefore, as the demand for spectrum for new SRD applications requires higher data rates, such a demand is concentrated in this part of the spectrum. Higher data rates can also be provided also by spectrum above 5 GHz but in that case the technology is not often available and the SRD industry has not always the capability of developing new technologies.

With regard to the ITU radio regulation all SRD applications have a status of secondary service and are in the category of mobile service as their location is unknown.

Applications operating in the 5 GHz band

The bands 5150 - 5350 MHz and 5470 - 5725 MHz have been designated for radio local area networks, the band 5725 - 5875 MHz is designated for non-specific applications and the band 5795 - 5805 is designated for intelligent transport systems. The band is shared with other radio services and in particular radars used by meteorology, civil aviation and defence. For this reason RLAN equipment is required to apply mitigation techniques, such as DFS, standardised by ETSI. It is interesting to note that the development of the harmonised standards followed an iterative process. The initial versions of the standards did not provide a suitably robust solution and some radars still suffered from interference. Several versions of standards were needed before achieving a satisfactory solution. This shows that compatibility studies can be rather complex and that the parties involved may be required to accept an increased risk of harmful interference. It also demonstrates that solutions can be found even where at first they do not appear obvious. This was possible due to the good cooperation between regulators and ETSI and may require a test period before obtaining a satisfactory solution.

Applications operating between 6 GHz and 40 GHz

Apart for radiolocation applications using different bands between 4.5 GHz and 27 GHz, most of the applications are concentrated in the bands 24 - 26 GHz.

Main applications using these bands are: intelligent transport systems and vehicle radar, inductive applications and simplex radiocommunications.

In some countries, applications in the 24 GHz band share the use of spectrum with radar speed meters which need to be protected due to the sensitive requirements of such applications (road safety and legal aspects). Technical parameters are published in ETSI standards, in conformance with compatibility studies carried out by CEPT in order to share the band with this specific application. In this way, compatibility studies have been done with automotive radars also and mitigation techniques have been found through the application of a duty cycle. Coexistence between CUS requires compatibility studies from CEPT even though parameters are included in ETSI standards.

Even if CUS are secondary services the compatibility studies aims at providing a certain guarantee to users that they will not suffer from significant interferences and that their

equipment will work properly. If a new SRD application is introduced in the same band this application should be compatible with the previous one and not create interferences to them. This means that in practice the initial SRD application has a kind of priority. This is also required by the industry to invest in the development of an application and give them the legal certainty they need.

Applications operating above 40 GHz

Applications in this upper part of the spectrum are concentrated in the bands 57 GHz - 66 GHz, 75 GHz - 85 GHz, 122 - 123 GHz and 244 - 246 GHz.

Main applications are: broadband, ITS, SRR, scientific (meteorological and EESS) and radiolocation.

Most of the applications in these bands are still under development.

Upper bands (122 - 124/244 - 246 GHz) are now open to non-specific SRD application but technology is still under development. Noting that this band is used for scientific applications, it may be necessary that compatibility studies should be carried out in the future.

UWB generic and specific applications

Generic UWB applications can use a wide range of frequency bands. That is possible due to very low power usage. In some bands for example 3.1 - 4.8 GHz, 6 - 8.5 GHz and 8.5 - 9 GHz it is possible to increase the max mean E.I.R.P if they have implemented i.e., DAA, TPC or LDC mitigation techniques.

Such equipment on board vehicles shall implement LDC mitigation techniques.

Specific application BMA (building material analysis) can use lower bands compared with generic UWB applications without mitigation techniques.

Specific application GPR/WPR (ground and wall probing radars) can use higher power than BMA due to the fact that equipment is used by professionals subject to a coordination procedure near certain locations (airports, observatories and military camps).

Annex C: Summary of Cambridge Trials (UK)

The UK published its *Implementing geo-location* consultation in November 2010[U], seeking comments from interested stakeholders, including potential database administrators. This was followed by statement published in September 2011 which set out Ofcom's intention to allow White Space Devices (WSD) to access the TV white space providing that no harmful interference is caused to existing services. In this document Ofcom explained its reasoning which included the work undertaken by Ofcom and others to define the geo-location database approach, along with the ultimate ability of the regulator to control the emission levels allowed by databases and to prevent WSDs from transmitting if necessary, so that any harmful interference is avoided. Ofcom also explained the UK's preference for a harmonised approach to WSDs across Europe, which it considered would deliver greatest benefits for citizens and consumers. Finally, the document set out next steps which aim to establish a regulatory framework to enable WSDs and geo-location databases to emerge in the UK.

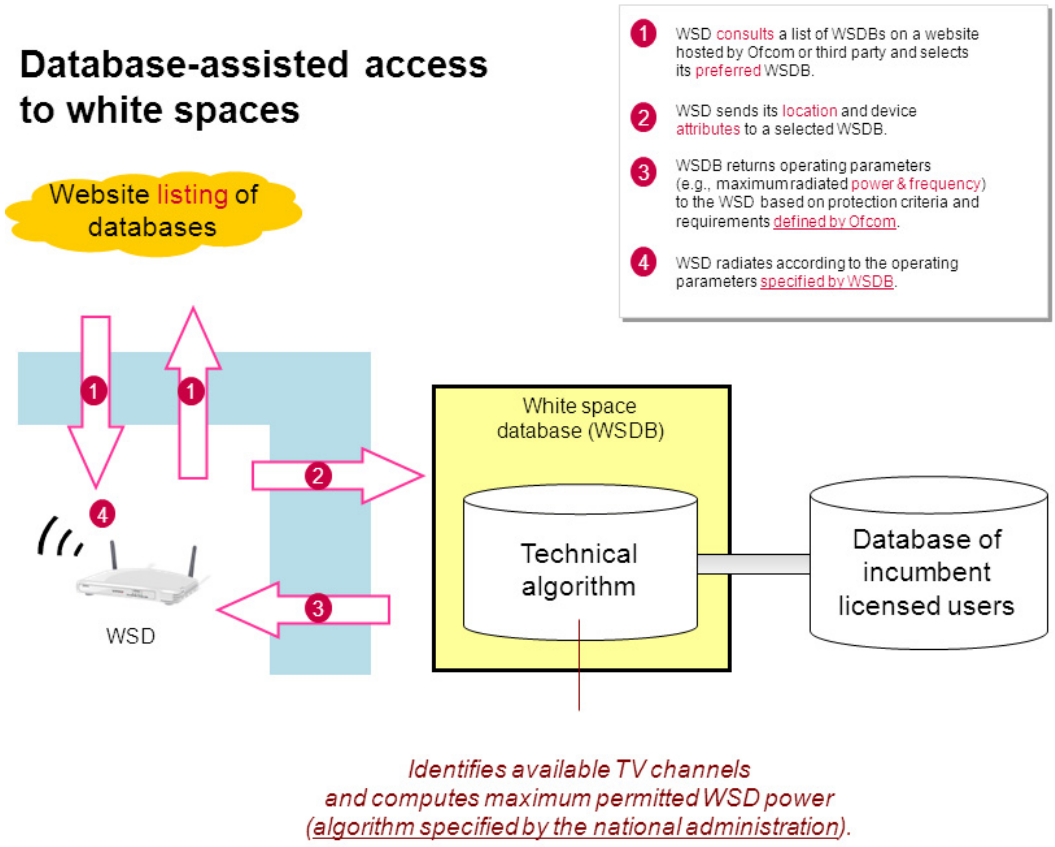

Figure 2: Depiction of database assisted access to White Spaces (UK)

In the meantime, starting in June 2011, trials got underway in Cambridge (UK) to explore how unused UHF spectrum which lies between broadcasting transmissions (i.e., TV White Space) can be utilised for other wireless applications. The trial is attempting to show how this unused broadcasting spectrum can be used to supplement existing wireless broadband and cellular networks without impacting on TV broadcast services in order to meet the increasing demand for mobile data.

The consortium involved in the trial includes broadcasters, operators, consultants, software companies and manufacturers[7]. Some of the applications they are hoping to demonstrate using white space technology include wireless data services in urban centres, home networks, mobile broadband in rural areas and support to an array of intelligent connected devices that communicate with one another (the so called “Internet of Things”).

Devices being trialled:

Wi-Fi

Wi-Fi devices operating in TV white spaces, as well as the existing allocations at 2.4 and 5 GHz. Why is TV white space spectrum attractive?

- Popularity of Wi-Fi could lead to congestion and poor performance for devices at 2.4 GHz.
- Perception that Wi-Fi operating at 5 GHz has poor range.

Rural Broadband

Using TV white spaces to provide a wireless broadband connection to rural areas. Why is TV white space spectrum attractive?

- A cost-effective means to provide broadband to areas that would be too expensive to serve by other means.

Machine-to-machine communications (M2M)

Data connections between sensors and devices used for telemetry or remote monitoring. Why is TV white space spectrum attractive?

- A more cost-effective network for M2M communications compared to using cellular networks.
- Additional range afforded by TV white spaces is attractive to reach devices deep inside buildings.

[7] The Consortium Partners are BBC, BSkyB, BT, Cambridge Consultants, Microsoft Corp, Neul, Nokia, Samsung, Spectrum Bridge Inc and TTP.

Bibliography

A Commission Decision 2002/622/EC establishing a Radio Spectrum Policy Group, 27 July 2002
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2002:108:0001:0006:EN:PDF

B Study on Legal, Economic & Technical Aspects of 'CUS' (Mott McDonald 2006)
http://ec.europa.eu/information_society/policy/ecomm/radio_spectrum/_document_storage/studies/cus/cus_rep_fin.pdf

C RSPG Opinion on the Radio Spectrum Policy Programme, June 2010
http://rspg.ec.europa.eu/_documents/documents/opinions/rspg10_330_rspp_opinion.pdf

D RSPG Opinion on Cognitive Technologies
http://rspg.ec.europa.eu/_documents/documents/meeting/rspg24/rspg_10_348_ct_opinion_final.pdf

E EC Decision 2006/771/EC of 09.11.2006on Short Range Devices (SRDs)
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:119:0032:0039:EN:PDF

F ERC Recommendation 70-03 on Short Range Devices (SRD)
http://www.erodocdb.dk/Docs/doc98/official/pdf/RE C7003E.PDF

G RSPG Opinion on "Aspects of a European approach to 'Collective Use of Spectrum' (CUS)"
http://rspg.ec.europa.eu/_documents/documents/meeting/rspg17/rspg08244_finalopinion_collectiveuse.pdf

H FCC SPTF Spectrum Efficiency Working Group Final Report, Section III, pp. 9-16.
http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-04-167A1.pdf

I Spectrum Framework Review Statement (Ofcom 2004),
http://stakeholders.ofcom.org.uk/binaries/consultations/sfr/summary/sfr.pdf

J ECC-ETSI cooperation process
http://www.cept.org//files/1051/ECC/About%20ECC/ECC-ETSI/Standardisation%20process.pdf

K CEPT Report 14 on "Develop a strategy to improve the effectiveness and flexibility of spectrum availability for Short Range Devices (SRDs)" in response to an EC Mandate (2006)
http://www.erodocdb.dk/Docs/doc98/official/pdf/CEPTREP014.PDF

L Summary of ECO Questionnaire on the Use of 863-870 MHz
http://www.cept.org/Documents/srd/mg/201/SRDMG_11_056_Summary_and_preliminary_conclusions_863-870_MHz

M Digital Dividend Review (Ofcom)
http://stakeholders.ofcom.org.uk/binaries/consultations/ddr/statement/statement.pdf

N Proposal on Implementation of Geo-Location (Ofcom)
http://stakeholders.ofcom.org.uk/binaries/consultations/geolocation/summary/geolocation.pdf

O Newsletter of FCC on "Steps to free up vacant airwaves between TV channels"
http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-301650A1.pdf

P Initial consultation on Geo-location in November 2009 (Ofcom)
(http://www.ofcom.org.uk/consult/condocs/cogaccess/cogaccess.pdf)

Q ECC Report 159 – "Technical and operational requirements for the possible operation of cognitive radio systems in the 'White Spaces' of the frequency 470 - 790 MHz"
http://www.erodocdb.dk/Docs/doc98/official/pdf/ECCREP159.PDF

R FCC Order on "Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band"
http://www.fcc.gov/Daily_Releases/Daily_Business/2011/db0126/DA-11-131A1.pdf

S Proceedings on FCC Order on White Spaces (Docket 04-186)
http://fjallfoss.fcc.gov/ecfs/proceeding/view?name=04-186

T First update to initial FCC Order on White Spaces
http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-08-260A1.pdf

U Initial consultation on Geo-location in November 2009 (Ofcom)
(http://www.ofcom.org.uk/consult/condocs/cogaccess/cogaccess.pdf)\