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Conference Paper

Analysis of different authorization approaches for the shared access to radio spectrum

24th European Regional Conference of the International Telecommunications Society (ITS): "Technology, Investment and Uncertainty", Florence, Italy, 20th-23rd October, 2013

Provided in Cooperation with:

International Telecommunications Society (ITS)

Suggested Citation: Carciofi, C.; Guiducci, D.; Barbiroli, M.; Castrucci, R. (2013) : Analysis of different authorization approaches for the shared access to radio spectrum, 24th European Regional Conference of the International Telecommunications Society (ITS): "Technology, Investment and Uncertainty", Florence, Italy, 20th-23rd October, 2013, International Telecommunications Society (ITS), Calgary

This Version is available at:

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Analysis of different authorization approaches for the shared access to radio spectrum

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1. Introduction

In the recent decades the formulation of management models aiming at improving the efficient use of spectrum has been at the heart of the telecoms policy at national, European and international level. All proposals of approaches alternative to the traditional command-and-control and market models (e.g. unlicensed model, spectrum trading, spectrum leasing, etc.) try to answer the same need, namely. satisfying the increasing demand for spectrum and avoiding the misuse of this very valuable and scarce resource. The EU authorities have issued a number of policy statements aimed at promoting more flexible use of spectrum and greater use of market approaches to spectrum management. In particular, this approach is into the Radio Spectrum Policy Program (RSPP) established by the Decision No 243/2012/EU of the European Parliament and of the Council of 14 March 2012 [1].

In this context spectrum sharing may constitute a valid option. This is currently being discussed at EU level in order to reach a harmonised framework and relevant documents on the subject have been made available in the public domain both from public and private entities such as the RSPG “Report on Collective Use of Spectrum (CUS) and Other Sharing Approaches” (November 2011) [4] or the SCF Associates Report, “Perspectives on the value of shared spectrum access” (February 2012) [6].

Moreover, in September 2012 the EU Commission published the Communication “Promoting the shared use of radio spectrum resources in the internal market” [7] containing some key principles for the development of a common framework for shared spectrum access.

In parallel, the topic of the shared use of radio spectrum has been tackled by the industry with remarkable innovation. In particular Qualcomm, Nokia, Ericsson, Nokia Siemens Networks have proposed the so called Authorized Shared Access (ASA), a third new and complementary way of authorising spectrum rights of use in addition to licensed and license-exempt as framed under the EU Regulatory Framework for electronic communications. The incentive work on ASA has been dealt with in two independent reports produced by Ingenious Consulting Network [8] and by Studio Economico Parcu & Associati [9]. ASA has also been recognised in the RSPG “Report on Collective Use of Spectrum and Other Sharing Approaches” [4]. CEPT also studied ASA in its “Report on ASA Concept” [5].

In short, ASA was basically introduced as an enabler to unlock access to additional frequency bands for mobile broadband under individual licensed regime and represents an alternative to spectrum clearing or re-farming. ASA is addressed towards bands that have already been harmonised for mobile broadband, whilst being used for different services or applications. The possible opening of these bands to mobile broadband would benefit from economy of scale and immediate availability of equipment.

Stemming from the ASA authorisation proposal, the RSPG widened the scope towards the Licensed Shared Access (LSA) to be generically applicable to various kinds of applications and services [4]: the ASA concept is extended to cater for the potential for application to other services in addition to its application to the mobile service. The basic aim of the LSA approach is to provide additional spectrum rights of use sharing the frequency band between different categories of services and applications and allowing predictable Quality of Service for all rights holders. Nonetheless, the LSA represents also a complementary approach to meet spectrum demands with straightforward benefits for next generation cellular systems [10]. In this respect, Mobile Network Operators (MNOs) within the GSMA and technology providers within DIGITALEUROPE have expressed concordant views on LSA.

In view of the potential to improve spectrum efficiency and speed up the development of wireless high capacity networks, complementary spectrum management approaches based on LSA are currently widely under discussion at European level. Regulatory principles of the LSA concept and operational guidance for its implementation in real scenarios are currently under study in Europe as well.

A draft RSPG Opinion on Licensed Shared Access [11] is currently under the public consultation process and the final version is expected in November 2013. This opinion is likely to set the pace for future development in Europe in this area.

Within CEPT, LSA is currently under discussion in two different Project Teams set out by the Working Group on Frequency Management (WG FM):

- Project Team FM52 (PT FM52) has to develop harmonised implementation measures for mobile/fixed communications networks in the 2300-2400 MHz band, including regulatory provisions based on LSA ensuring the long term incumbent use of the band in the territory of the administrations that wish maintain such use. The group was established in September 2012 and its work has to be finalised in the first half of 2014.
- Project Team FM53 (PT FM53) works on White Space Devices (WSD), Reconfigurable Radio Systems (RRS) and Licensed Shared Access (LSA). For the LSA scope, the project team has to: analyse the procedures for the assignment of LSA individual rights of use, in conformity with the EU Framework and Authorisation Directives; develop general conditions, including possible sharing arrangements and band-specific conditions for the implementation of the LSA that could be used as guidelines for CEPT administrations; study the “level of guarantee” in terms of spectrum access under LSA that is required by an operator for network investment. The group was established in September 2012 and has currently developed a draft ECC Report [15] to be approved for public consultation.

CEPT establishes proper interactions with the European standardization body, ETSI, in order to translate relevant sharing requirements in relation with the implementation of the LSA framework into harmonised standards. ETSI has worked and finalized a System Reference Document for the introduction of mobile broadband services in the 2300 – 2400 MHz frequency band under LSA [16], showing a strong interest of the industry at large and beyond the initial ASA proponents to access this frequency band on an LSA/ASA basis.

This picture of fervid and dense activities in a very tight timeframe, makes immediately clear the enormous interest on LSA and its potential among the international community. Current work by EU and CEPT on the sharing framework for LSA has led to quite solid results and further enhancement is expected once the public consultations procedures on reports produced so far come to an end. In particular it is expected that activities with different bodies will converge and complement towards a common view, in order to define a complete LSA

framework capable to accommodate different needs from various stakeholders (e.g. national administrations, industries, spectrum users, etc.).

In this paper the state of the art of the definition of the sharing framework for LSA is described and investigated. In particular, the work is focused on discussing several specific issues that are still unresolved within the international framework, such as the concept and identification of incumbent users in a given band, which is obviously necessary to grant protection from interference to incumbents themselves and allow LSA users to access the band.

As a second step, this work focuses on the factual implementation of LSA at a national level. Country administrations/NRAs have the responsibility to apply the LSA approach at national level and it is currently accepted that, once defined a common sharing framework, administrations should be left free to define autonomously how to implement LSA, instead of applying common pre-defined guidelines. To this aim, this paper propose some practical guidance, considering that national administrations have first to establish if the application of the LSA approach in a given band is feasible and convenient, and secondly they have to decide how to implement properly LSA authorisations.

The paper is structured as follows. In Section 2 the role of global, regional/European and national institutions for the definition of spectrum management and policies is addressed; activities carried out to promote innovative methods for shared and efficient use of the spectrum under LSA are also preliminarily introduced. In Section 3 the key aspects of the LSA approach are briefly mentioned. Section 4 deals with several open issues that are still to be solved within the international definition of the sharing framework. It is advisable that such issues should be properly addressed to avoid ambiguity and facilitate the release of rights of use under LSA. Section 5 considers actions that national administration should adopt for the application of the LSA approach. Some guidelines of general applicability are developed and proposed. Finally, Section 6 summarises the major results of the work.

2. Overview of spectrum management and policy in Europe

Legal instruments to govern the use of spectrum are regulated at three different levels (Figure 1): global, regional and national levels.

2.1 Global level

At a global level, the ITU is the most important institution whose role is to provide an international framework for global harmonisation of spectrum management. The basic aim is guarantee harmonised, equitable, efficient and economical access to spectrum by all different radiocommunications services (e.g. fixed, mobile, broadcasting) in interference free conditions. This is achieved through the implementation of the Radio Regulations (RR) [2], which allocate frequency bands to radio services, while accounting for the need of global harmonisation of specific communication sectors (e.g. satellite, maritime, etc.) taking into account coexistence of different radio networks as well as physical properties of frequency bands and economies of scale.

The basic principle of the provisions of ITU Radio Regulations is that any new assignment (i.e. any new authorisation to operate a radio station) must be made in such a way as to avoid causing harmful interference to other services.

Frequency bands are allocated to different radiocommunication services (Article 5 of the RR, Section IV - Table of Frequency Allocations) on a primary or secondary basis. Secondary

services shall not cause harmful interference to primary services and cannot claim protection against harmful interference from primary services.

RR represent the most important legal instruments not directly applicable to individuals and operators for spectrum utilization: each State will implement the required measures (legislation, regulations, clauses in licenses and authorizations) to comply with RR obligations. National administrations can adopt specific harmonization measure (e.g. EU legislation) and use the spectrum for different type of radio stations without causing interference to other countries.

ITU legal instruments are updated through the processes of the World and Regional Radiocommunication Conferences (Figure1). Furthermore, ITU-R Recommendations assure the necessary performance and quality of radiocommunication systems ensuring flexibility for future expansion and new technological developments.

The improvement of efficiency of spectrum use is one of the key issues under consideration within ITU, in order to promote more flexible approaches for spectrum regulation and management. This can be achieved through the use of innovative technologies such as cognitive radio and the adoption of new regulatory approaches (e.g., LSA). However, it has to be noted that currently ITU studies are mainly focused on Cognitive Radio Systems (CRS) (e.g. in ITU-R Working Party 1A and 1B), whereas lower interest is devoted to innovative regulatory approaches for spectrum licensing, such as LSA. In specific, the ITU-R Recommendation SM.1132 [3], which treats of general principles and methods for sharing between radiocommunication services or between radio stations is under revision to include CRS.

The discussion on new regulatory provisions such as LSA for more flexible assignment of rights of use is currently mainly debated at regional level (and specifically in Europe), whereas it shall be brought to the attention of ITU in order to provide a legal basis at global level, which will allow for future implementation of the LSA approach in different countries at a global level.

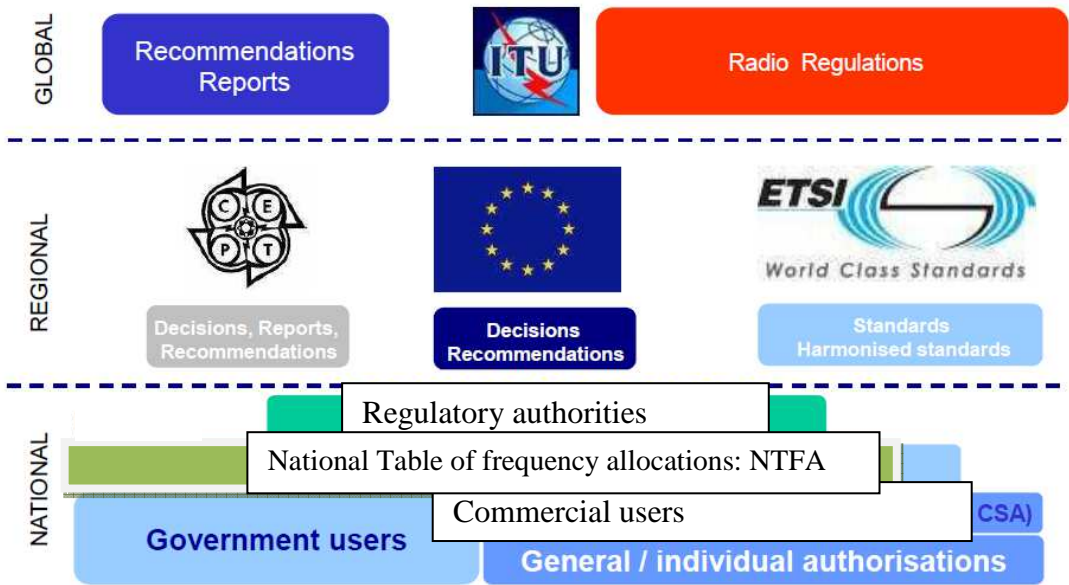


Figure1: Global, regional/European and national levels in spectrum management and policy

2.2 European level

The reference bodies playing a crucial role in spectrum management and regulation in Europe are (see Figure 1):

- the European Commission (EC): binding regulations through specific procedures
- the Electronic Communication Committee (ECC): decision for harmonised spectrum allocation and technical conditions for its use
- ETSI: equipment and system specifications including “spectrum use” characteristics

ECC has to develop harmonised European regulations for the use of radio frequencies. The implementation of ECC Decisions and ECC Recommendations by national administrations is made on a voluntary basis.

The harmonised European regulations for the use of radio frequencies provide legal framework to stakeholders on the availability of spectrum usage under specific conditions also to ensure the development of new technologies. The aim is to develop effective harmonisation measures based on consensus between the member countries: different legal approaches are possible at national level provided that the member state requests a derogation to be granted by the Commission generally for a limited time.

The EU regulatory framework for electronic communications has been issued with the Radio Spectrum Decision [14], which defines the policy and regulatory issues allowing the Commission to adopt implementing decision to achieve harmonised conditions for the availability and efficient use of radio spectrum for the internal market. The EC may decide to issue mandates to the European Conference of Postal and Telecommunications Administrations (CEPT) for the drafting of technical implementing measures.

The EC is supported by two complementary bodies:

- Radio Spectrum Policy Group (RSPG), to help the Commission developing general Radio Spectrum Policy at Community level,
- Radio Spectrum Committee (RSCOM), to assist the Commission in developing technical implementation measures. The RSCOM shall then approve CEPT Reports and associated technical implementing measures prepared by the Commission, which implementation by the administrations of EU Member States is mandatory.

The European harmonised regulatory framework for spectrum rights of use of Electronic Communications Networks and Services (ECN&S) is based on the “Framework” Directive [12] and the “Authorisation” Directive [13]. The “Framework” Directive sets the main objective for the management of radio spectrum in order to ensure that allocation and assignment of radio frequencies at national level are based on *objective, transparent, non-discriminatory and proportionate criteria*.

According to the “Framework” and “Authorisation” Directives, different authorization regimes are possible for right of use of frequencies:

- General authorization (license-exempt): when the use of radio spectrum is involved to support the delivery of electronic communication services, a legal act issued by a NRA authorising the use of spectrum with no “individual right of use” is commonly referred to as a “general authorisation[[15]]”. This regime is limited to devices that do not need coordinated use to avoid harmful interference. The regulator does not provide legal guarantee to protect users from interference.
- Individual rights of use (licensed): due to the scarcity of some frequency bands,

granting of rights of use should be limited. Individual rights of use may be granted to an undertaking time, frequency and geography, in order to avoid harmful interference, ensure technical quality of service and pursue efficient use of spectrum;

In case of “general authorisations”, the compatibility studies conducted by CEPT will allow to determine a set of regulatory parameters to ensure protection of radio services while for “individual authorisations”, “frequency assignments” may need to be coordinated, at national or international level, to ensure coexistence between existing and future systems (e.g., CEPT Recommendations on cross-border coordination).

As it will be clear in Section 3, it is considered that LSA rights of use are fully within the scope of the Authorisation Directive, and most in general in the current EU regulatory Framework for electronic communications [11].

2.3 National level

Spectrum management is the combination of regulatory procedures and tools in view of delivering regulatory solutions to accomplish for different types of use of spectrum. However, managing frequency authorisations is performed at national level identifying suitable procedures to assign spectrum.

Administrations can use different regulatory policies for spectrum right assignment to balance different interests: entry of new technologies, competition between existing players, entry of new players, consumer protection.

ITU-R radio regulations and European harmonization measures represent the basis for the National Regulatory Authorities (NRAs). Another key element for national spectrum management is the National Tables of Frequency Allocations (NTFA) and frequency assignments (Figure 2): this represents a crucial asset for national administrations to plan the allocation of frequency bands between different users, namely:

- Governmental users (Military, defence, civil aviation, maritime & waterways, public safety, meteorology, science, etc.), which have access to spectrum to perform their own duties. Spectrum rights are not directly related to Authorization Directive – NRA – possible review by the NRA of spectrum access
- Commercial use/use by citizens / non-governmental: public legal act issued by NRAs (general or individual authorization).

Based on the NTFA, frequency bands can be allocated by national authorities on an exclusive or shared basis. The latter approach offers a possible to solution to accommodate new spectrum demand, while spectrum refarming (i.e., change in spectrum use) can be adopted when sharing conditions are not feasible.

The LSA approach is under consideration also at national level in the different European countries, in order to study possible candidate bands suitable for the implementation of LSA identifying the sharing scenarios between the incumbents and the LSA users.

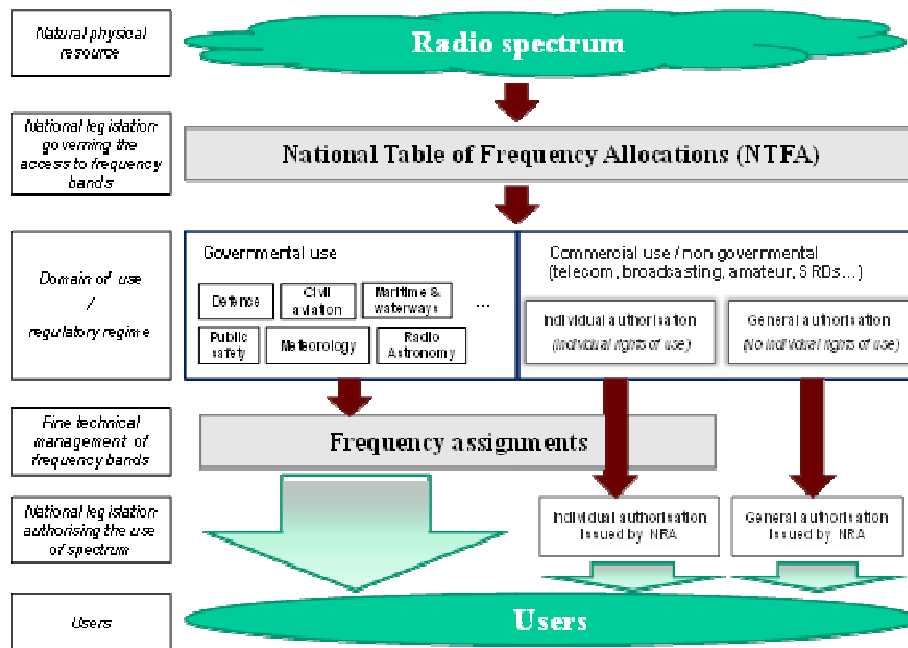


Figure 2: National legislation from the radio spectrum to users. (Source PT FM53[15])

3. Key aspects of the LSA approach

The LSA is a new regulatory framework for dynamic use of spectrum especially in bands partially un-used by the incumbent services. While guarantying national current spectrum usages, the LSA concept should provide new sharing opportunities to accomplish for spectrum demand required by wireless broadband services.

LSA is a complementary approach to traditional exclusive licensing and license-exempt approaches allowing a spectrum band to be shared between an incumbent spectrum user (i.e., incumbent) and another services (i.e., LSA licensee) with pre-determined rules and conditions and licensing agreements. A key benefit of the LSA concept is to ensure controlled predictable quality of service (QoS) levels for both incumbent and LSA licensees.

According to the draft RSPG opinion on LSA [11], currently under public consultation, the working definition of Licensed Shared Access is:

“A regulatory approach aiming to facilitate the introduction of radio communication systems operated by a limited number of licensees under an individual licensing regime in a frequency band already assigned or expected to be assigned to one or more incumbent users. Under the LSA framework, the additional users are allowed to use the spectrum (or part of the spectrum) in accordance with sharing rules included in their rights of use of spectrum, thereby allowing all the authorized users, including incumbents, to provide a certain QoS”.

LSA can provide a cost-efficient and harmonized way to utilize existing spectrum allocations and to achieve economies of scale, as results clear addressing IMT bands, which could be made available worldwide with existing user equipment and minimum modifications to the infrastructure.

LSA is a dynamic approach to enable additional user access the relevant needed portion of spectrum in a mutually beneficial way with incumbents. An LSA user can obtain “new” rights of use which allow him to share the spectrum with the incumbent in time or location or both.

This is done on an “exclusive” basis, which means that either the incumbent “or” the LSA user access the spectrum at a given location at a given time. This also means that they do not interfere with each other and they can still leverage the very best performance of their equipment.

LSA has not to be considered a new licensing regime but rather a novel regulatory approach to achieve a more efficient use of spectrum in bands already assigned (or expected to be assigned) to one or more incumbent users which are the current holders of spectrum rights of use.

It has already been recalled that the LSA approach is considered to be fully within the EU Regulatory Framework for electronic communications as LSA rights of use [11]:

- entail specific provisions to avoid harmful interference to the incumbent and ensure a certain quality of service, providing at the same time an incentive for the incumbent to accept the necessary changes in its rights;
- take into account specific national specificities (the use of the band by the incumbent);
- would be granted as individual rights of use and be associated with a number of conditions, usually defined in the LSA licence.

Another key feature of LSA is the need of a predictable quality of service for the incumbent and for the LSA user. In the LSA approach, concepts such as “opportunistic spectrum access”, “secondary use” or “secondary service”, where the applicant has no protection from primary user, has to be excluded.

The implementation of LSA need to rely on the concept of a “sharing framework” that is under the responsibility of administrations/NRAs. In particular, in order to enable alternative spectrum usage under LSA, the incumbent spectrum rights and needs has to be reviewed through a proper definition of the sharing framework at national level, which guarantees the protection of both the incumbent and the LSA services.

Different types of incumbent services can operate in the same frequency band. This implies that dynamic sharing approaches should be foreseen for the implementation of LSA.

The introduction of LSA requires the cooperation of different parties:

1. the administration/NRA;
2. the incumbent(s);
3. the candidate LSA user(s)

The administration/NRA has a strategic role to permit the introduction of LSA based on the following actions:

- promote discussion and technical studies on possible implementation of LSA considering and evaluating the proposals coming from the incumbents and LSA users,
- define the spectrum sharing framework,
- define a transparent licensing process that is compliant with the Authorisation Directive.

The administration/NRA has also to care for the proper inclusion of sharing framework conditions in the grant LSA license process and this requires addressing different key issues [15]:

- The identification of the incumbent(s) to be protected;
- The terms and conditions under which the incumbent may access the spectrum;
- The terms and conditions under which the potential LSA licensees may access the spectrum.
- Identification of frequencies, locations and times that must be protected for the incumbent, together with the level of protection;
- Mechanism for transmission of information on spectrum availability between Incumbent and LSA licensee;
- Length of the sharing framework;
- Financial terms and conditions of the sharing framework;
- Terms and conditions for the operation of the LSA repository;
- Reference to appropriate regulatory document, i.e. ECC Decisions, Harmonised Standards.

More investigation on how a country administration could implement LSA at a national level is available in Section 5.

4. Key open issues on LSA

Current work on regulatory aspects of LSA has already highlighted and clarified several key aspects of LSA as a complementary tool for spectrum management. However, there still remain several key issues that are under discussion and need to be solved in order to make the LSA approach factual and applicable.

These issues are pillars for the proper definition of the sharing framework, represented by a set of sharing conditions and rules between the incumbent and the LSA users, and are vital to enable the proper implementation of LSA. The state of the art of work in CEPT and at EU level raises a number of open questions currently under discussion by administrations and industries, namely:

- definition of incumbent users and related protection levels
- definition of sharing conditions and approaches
- cross border coordination guidelines for LSA

The mentioned topics will be treated more widely in the following paragraphs, proposing several remarks that should be taken into account for the development a proper framework.

4.1 Definition of incumbent users

The definition of the incumbents can be general or more specific and this choice has a strong impact on the implementation of LSA.

The definition given in the draft FM53 ECC Report 205 [15] is quite general: an *“incumbent”* is basically a spectrum user which enjoys at certain point in time some exclusive or priority rights on the use of a frequency band in a country. Therefore, LSA is intended a general concept that does not specify the nature of the incumbents and LSA users. LSA shall nevertheless stay focused as a spectrum management tool which aims to facilitate the introduction in a frequency band of new applications while maintaining incumbent services in the band. LSA licensees and incumbents operate different applications and are subject to

different regulatory constraints.

Based on the draft RSPG opinion on LSA [11], the incumbent is any current holder of spectrum rights of use (commercial or governmental). It is stressed that higher opportunities for the applicability of the LSA approach should be found when the incumbent is a governmental user. However, governmental rights of use are generally limited to the rights described in the National Table of Frequency Allocations (NTFA) with no individual authorizations with limited duration.

As a general view, industries and operators believe that a wide definition of incumbent users should not be supported, since it undermines the guarantee of greater certainty and predictability to the market players and the industry for the implementation of LSA.

Two particular aspects are currently of specific interest.

The first is related to the possible inclusion of secondary users, which use spectrum resources on a non-interfered and non-protected basis, as incumbents. The most common view let the administrations/NRAs decide on the services to be protected within the sharing framework (incumbent) in the light of national policy objectives, and taking into account international obligations and community law. As a general principle it should be avoided to include among incumbents, users that cannot claim protection from nor shall cause harmful interference to stations of a primary service. However, exceptional cases might be identified; for instance, one administration could decide to grant protection to Programme Making and Special Events (PMSE) applications in a specific band in view of possible difficulties to accommodate such applications in other portions of the spectrum, due to possible congestions.

Another aspect under consideration is the possibility to refer to the incumbent user limiting the definition to users that hold their rights of use, without having been through an award procedure (beauty contest, auction) for commercial use. Such a definition of incumbent service is aimed at addressing for LSA application only bands where the current users are governmental, excluding bands used for commercial services by licensees who have accessed rights of use through competitive procedures. As a matter of fact, it is actually advisable to preserve rights of use granted under objective, transparent, non-discriminatory and proportionate procedures, in accordance with the Framework and the Authorisation Directives, through either beauty contests or auctions to market players.

4.2 Definition of the sharing framework

In the definition of the sharing framework, it has to be understood that LSA is a form of Vertical Sharing corresponding to the situation when an entity which is granted spectrum rights of use for a specific frequency resource (named thereafter the incumbent), allows another entity (named thereafter the “additional” user) to benefit from access to the said frequency resource to offer a different service and/or application, when and where the incumbent does not use its resources. Under the LSA sharing framework, the services and applications provided under the spectrum usage rights of the incumbent and the LSA licensees are and will remain different and thus “vertical”.

Unlike horizontal sharing (sharing between peers proposing the same service), vertical sharing is likely to provide benefits as the incumbent and the additional user frequency requirements are complementary, i.e. they are unlikely to require the spectrum at the same time, in the same geographical area. Incumbent and new user will, in an LSA clearly defined scenario, never compete against each other. They will rather tend to develop a cooperative constructive attitude which will benefit the wide value chain as a whole (infra market, device market, software, application, content and services market).

While the sharing framework is clearly referred to vertical sharing within CEPT [15], the current draft RSPG Opinion on LSA seems to give some room also to horizontal sharing. This issue should actually be made clear and horizontal sharing should be clearly excluded.

For sake of clarity, it is here reported how vertical sharing is currently addressed within the sharing framework, under development in PT FM53[15].

Sharing conditions between LSA and the incumbent can be based on geographical, frequency or time separation. In Figure 3 an example of geographical separation is shown where the green zone corresponds to spectrum availability for LSA users taking also into account for future development of the incumbent network (grey stations in the figure).

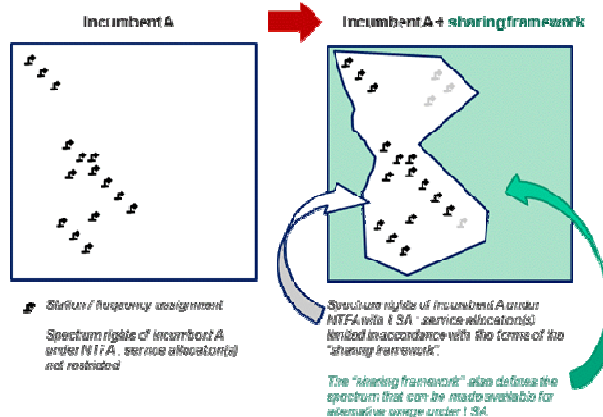


Figure 3: Sharing framework in a vertical sharing scenario (source PT FM53[15])

This sharing framework should include “Vertical Sharing” which are the conditions for LSA to access the spectrum ensuring the protection of the incumbent (FM53 report 205). The protection of the incumbent could be guaranteed through the definition of protection areas where the field strength levels generated by LSA users should be below certain thresholds. Assuming a geographical separation distance between the incumbent and the LSA user (e.g., MFCN) it could be possible to identify, based on rigorous propagation models, the allowed deployment zones for the MFCN LSA and its exclusion zones where transmission is not allowed since MFCN emissions cannot fulfil the interference criteria.

4.3 LSA cross-border coordination

Cross-border coordination is usually performed through bilateral agreements between Administrations/NRAs.

The issue of cross-border coordination has been raised within PT FM52, with respect of the possible use of the 2300-2400 MHz band for MFCN under LSA approach.

Cross-border coordination procedures seem to be of plain application in case only MFCN users are concerned, whereas some issues are still open in case cross-border coordination occurs among MFCN and non-MFCN users.

For the former, individual right of use delivered at national level request mobile networks operators to respect the terms and conditions of such agreements. In traditional MFCN bands, the CEPT may conduct studies and product guidelines in order to support administrations/NRAs in their bilateral/multilateral negotiations. Cross border coordination for MFCN services introduced in a band under LSA follows exactly the same framework. Bilateral/multilateral agreements must be contracted between relevant administrations/NRAs

and the LSA licensee will be requested to comply with such agreement under its individual right of use [15].

PT FM52 has already highlighted that bilateral/multilateral agreements should be based on devoted cross-border coordination guidelines provided for different LSA services; this work is at its very preliminary phase.

An open question is related to the degree of protection that a LSA user can claim from services in neighbouring countries. The doubt is if the LSA user can be considered a primary service as the incumbent and thus requires the same level of protection of the incumbent from other countries or if the LSA protection can be achieved only through the sharing framework with the incumbent. A more complex situation occurs when the incumbent user claiming protection is a secondary user and thus it cannot claim any protection from other services either inside or outside the country. As a general view, it can be said that administrations should work on multi- and bi-lateral basis to grant to LSA users proper protection also from services in neighbouring countries, whilst avoiding as much as possible protection of foreign secondary users.

5. Guidance for implementing LSA at a national level

The spectrum management process in Europe has been already described in Section 2, recalling that, at country level, governments and regulators manage the process of assigning spectrum to users, in accordance with the country table of frequency allocations, CEPT technical harmonization measures and EU decisions on spectrum.

Under the LSA approach, national administrations shall remain the sole responsible entity to determine the most appropriate type of individual rights of use award and of conditions attached to operate and manage LSA networks. This will increase flexibility and efficient sharing.

In this Section, it is discussed how to put into practice the conceptual role of administrations/NRAs. As it is assumed that there is no need for general guidelines to be issued at international level (see hereafter), it is advisable, if not even required that country administrations/NRAs define their own requirements and fulfilment, as a function of their specific national context.

Authorising shared spectrum access to a band refers to situations in which a number of independent users and/or devices are allowed to access the same range of frequencies under certain conditions. Although the modalities of the authorisation process to be set by Administrations/NRAs have to consider national circumstances and market demand, several principles have recently been highlighted, which should be taken into account properly in the authorisation process itself.

The European Commission, for instance, in its Communication [[7]] identifies two key general principles, in order to provide more spectrum access opportunities and incentivize greater and more efficient use of spectral resources:

- **Beneficial sharing opportunities (BSO)**, which exist in both licensed and license-exempt frequency bands, whenever the combined socio-economic benefit of multiple applications sharing a band is greater than the net socio-economic benefit of a single application, taking into account additional costs from shared use;
- **Usage rights for the shared use of spectrum**, that is shared spectrum access rights as regulatory tools to authorise licensed sharing possibilities with guaranteed levels of protection against interference.

These principles reflect into practical needs, which apply also to the LSA approach, thereof:

- Ensuring coexistence through the definition of acceptable levels of interference and appropriate mitigation strategies.
- Balancing impact and usage constraints for incumbents and additional users in terms of sharing rules and costs.
- Enabling users to share spectrum with regulatory guarantees based on individual licenses.

Therefore, national administrations willing to make available spectrum for the shared use under LSA regime have to implement proper actions to make it factual.

As already mentioned, currently the most accepted view suggests that there is no need to develop common guidelines that administrations shall follow. In other words, stemming from a common framework, country administrations may identify and develop their own implementation guidelines, to choose if authorisation under LSA is the most suitable to the national circumstances and fit the application of the LSA approach to the national context. A methodology of general validity is investigated for administrations, which have to assess the feasibility of LSA approach in specific bands and have also to determine how LSA authorisation could properly be issued.

In this work it is proposed a possible applicable way forward for administrations, willing to adopt the LSA approach at a national level. The overall process is summarized in Figure 4.

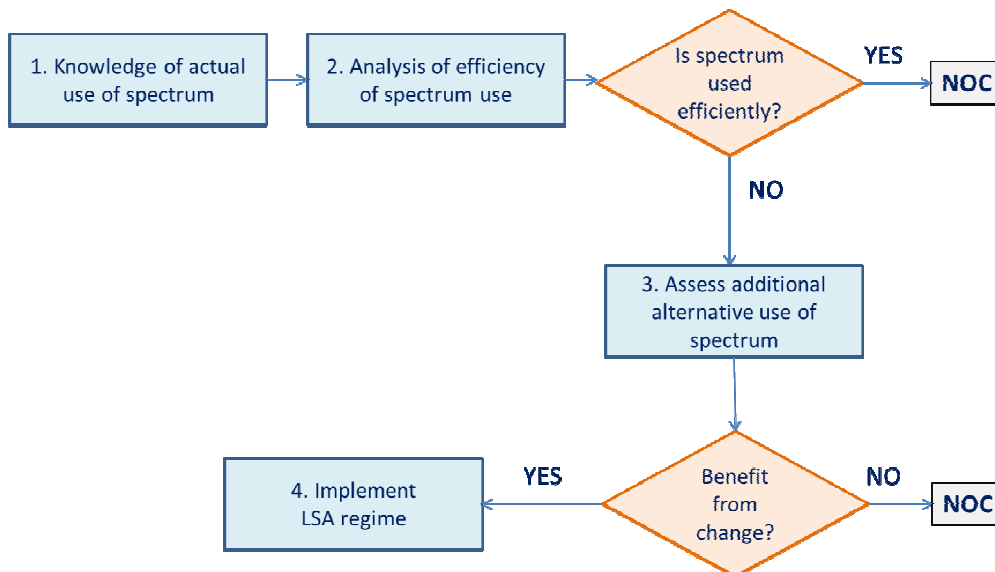


Figure 4: Conceptual flow at the basis of the application of LSA at a national level

Step 1: knowledge of actual use of spectrum

The first step (**Step 1** in Figure 4) towards the possible application of the LSA regime in a given frequency band requires the knowledge of the actual use of spectrum in that band. Although this seems a trivial issue, the preliminary experience gained at European level on the so called *spectrum inventory*, as performed in a study committed by the European Commission [17], shows that information on the actual use of spectrum is scarce or even absent for a number of frequency bands. Furthermore, it has to be noted that often the bands

where a lower degree of knowledge is accessible are generally those for governmental uses, such as defence, which are indeed addressed as the most appropriate for the application of the LSA authorisation regime. Finally, it has also to be mentioned that a proper set of data about the use of spectrum has to be collected, depending on the applications or services, which are currently using the band of interest. This issue has been addressed also at European level in the RSPP framework [1], and additional guidance and requirements can be found in the relevant implementation Act [18]. National administration may decide to employ the same dataset as provided by the European Commission or may conversely decide to adopt different data clusters, as a function of the specific context and needs in the country.

It has to be remarked that the amount and the type of information strongly depend on the definition of incumbent users: in case secondary users, such as amateur, are considered to be protected, national administrations should gather enough information to develop proper sharing conditions and guarantee due protection.

Step 2: Analysis of efficiency of spectrum use

Once the information on the actual use of spectrum is gathered, national administrations should proceed analysing how efficiently the spectrum is used (**Step 2** in Figure 4). The concept of spectrum efficiency has been also addressed at European level [18] and it is foreseen that the European Commission is in charge efficiency assessment, as a pillar of the more general goal represented by the review of spectrum use. However, in order to estimate potentialities offered by the possible application of the LSA approach in a certain band, national administrations need to assess the efficiency of spectrum use on their own, possibly adapting criteria and methodologies adopted at European level. Without going into details, it can be recalled that efficiency of existing spectrum use has to be intended in a interdisciplinary fashion, considering :

- technical efficiency η_t ;
- economic efficiency η_e ;
- social value η_s .

Technical efficiency is a broad concept, which takes into account, spectrum usage, equipment, other capital and labour. These elements should be used trying to generate the highest possible output with the minimum resources cost. Technical efficiency can be expressed as:

$$\eta_t = \text{Technical Efficiency} = \frac{\text{output}}{\text{costs of all inputs}}$$

Furthermore, the economic efficiency is aimed to create the most value for consumers with the least amount of inputs:

$$\eta_e = \text{Economic Efficiency} = \frac{\text{value of output}}{\text{costs of all inputs}}$$

The value of the output is mainly related to the type of transmitted information and its usefulness for the consumers (service value) rather than to the amount of transmitted information. As an example, some customers may give more value to a 10 minutes mobile call than to an hour of broadcast television.

Social value is referred to the social value of applications or services (e.g. achievement of public service objectives or level of benefit to the citizens, society and the environment):

$$\eta_s = \text{Social Efficiency} = \frac{\text{social value of output}}{\text{costs of all inputs}}$$

The evaluation of the above defined different terms of efficiency requires the assessment of a number of proper general Key Performance Indicators (KPIs) so that:

$$\eta_k = \sum_i w_i KPI_i$$

where η_k is one among technical, economic and social efficiency.

The weights for the combination of KPIs depend on several factors, such as the considered band, services and applications. It is advisable to identify a common set of KPIs to be applied over any spectrum interval that might be of interest. There might obviously be services or applications for which part of the defined common set of KPIs does not apply (i.e. the weight is null), without affecting the general applicability of such a methodology, as well as the weight of a specific KPI may vary significantly from application to application or service to service.

The overall efficiency of spectrum use

$$\eta = k_t * \eta_t + k_e * \eta_e + k_s * \eta_s$$

where k_t , k_e and k_s are the weights respectively of the technical and economical efficiencies and social value.

Each weight must be properly determined as a function of the application or service. For instance, safety of life applications will be presumably characterized by a higher value of k_s than other applications, in order to underline the importance of social value.

A concrete example of assessment of efficiency of spectrum use is reported in [19], where some preliminary estimations have been derived in response to a commitment from the Italian NRA, applying a methodology in line with the one introduced here above.

In case the assessment for a given frequency band leads to an acceptable or even remarkable efficiency in spectrum use, there is no need to consider any additional application or service to be introduced in that band (i.e., NO CHANGE option – NOC), otherwise alternative additional users may be admitted through the adoption of a LSA regime.

Step 3: assess additional alternative applications for the shared use of spectrum

Once the efficiency of spectrum use di analysed, opportunities of multiple applications sharing the same band has to be considered against the current use of the band. A comparative procedure has to be carried out in terms of socio-economic benefit in different use case scenarios, taking into account additional costs from shared use.

The estimate of economic surplus may be applied to classify and compare different applications, in order to discover and evaluate new opportunities for new applications in a given band. Considering the current use of the band, it would be possible to assess the current economic value of the band, through the calculation of the consumer (if any) and producer surplus of the existing services on the band, and compare this value with possible different applications. A similar approach has already been applied in several studies, including those for the so called L-Band (i.e., 1452-1492 MHz) at CEPT level [20]. In addition, the overall social benefit coming from possible alternative use of the band has to be considered. Social benefit is generally derived from indicators, which cannot be measured in a quantitative way, but which are equally important while deciding on possible uses of spectrum. These

indicators are essentially qualitative, and can measure weather and to which extent the different usage scenarios are capable of meeting social requirements, such as public service objectives or scientific worth.

Socio-economic benefits must be reiteratively assessed for all the candidate applications for the shared use in a given band, thus evaluating each usage scenario that might occur.

Of course, while revenues and costs are certain for existing products and services, those arising from new services must be estimated, taking proper assumptions. As for revenues the most important assumptions are mostly, but not exclusively, on the expected demand for services, whereas, as for costs, hypotheses on use case scenarios and network topologies (e.g. macro/micro/pico layout for Mobile/Fixed Communications Networks – MFCN) play the most important role, as infrastructure costs are strongly affected.

It is also worth noting that socio-economic evaluations, must account for several paramount aspects, in order to properly assess potential costs and benefits. For instance, it is strongly advisable to avoid sharing opportunities for those bands where rights of use have been granted through competitive awards. The shared use of spectrum would be hardly applicable and of disputable benefit in such bands for a number of reasons, among which:

- in accordance to the Framework and Authorisation Directives, competitive awards are natively performed under objective, transparent, non-discriminatory and proportionate conditions, strongly related to confidence in the regulatory regime in force. As already mentioned in the previous Section 4, the possible opening towards shared use of spectrum would introduce not negligible *a posteriori* modifications, which would be hardly acceptable and would also affect any possible issuing of new rights of use either under the LSA approach or not,
- even disregarding previous arguments, it has to be considered that, from a practical point of view, compensation measures would need to be granted to incumbent users, which would result plausibly unaffordable. Moreover possible obligations related to rights of use of incumbents might not be coped with, in case of the introduction of new users under a sharing approach.

In case the socio-economic analysis for the shared use of spectrum leads to an acceptable or even remarkable net-benefit in spectrum use, the LSA regime may be implemented in the considered band, otherwise there is no need to consider any additional application or service to be introduced in that band (i.e., NO CHANGE option – NOC).

Step 4: implementation of the LSA regime

For the proper implementation of the LSA authorization regime in a given band, the national administration may take advantage of many outputs aroused from the investigations and assessments performed in previous steps, such as information on incumbent users, revenues and cost analysis and so on.

Administrations have to define the most appropriate type of individual rights of use award, considering in particular the opportunity to carry out competitive procedures (e.g., auction or beauty contest) and setting as a consequence the most suitable rules. In this respect, administrations already have their own rules of procedure to be adopted during the preparatory phase of rights of use awards, including public consultations and interviews with stakeholders, which can be carefully adapted also to account for special requirements derived for the LSA approach.

Some general key issues that national administration should account for are given in [15] and recalled in Section 4.3. However in this paragraph only a few aspects believed of relevant interest are addressed.

Considering financial terms and conditions for the sharing framework, the administrations have to determine if compensation measures for incumbent users shall be applied or not and this significantly depends on the specific type of incumbent (e.g., compensation measures shall neither apply to secondary users nor to primary users who scarcely use their assigned spectrum) as well as on the possible additional costs, if any, that the incumbent users might incur because of sharing. In case compensation measures apply, it has to be established how incumbents have to be repaid (e.g., *una tantum* or based on the actual use of spectrum by LSA licensees).

One more key issue is represented by pricing definition for the release of LSA rights of use, which is also connected with the adoption of compensative measures for incumbent users. Some interesting considerations on pricing can be found in [21], where pricing is addressed for the so called *pluralistic licensing*, that is the issuing of rights of use in bands where the shared access to spectrum is implemented. Although in [21], opportunistic use of spectrum is particularly addressed, some general remarks could be extended and adapted to the LSA case, with special reference to the balance between tolerated interference and license fee.

Furthermore, national administrations have to determine if LSA licensees shall undergo specific obligations related to their rights of use (e.g. *use-it-or-lose-it*, coverage obligations, etc.).

It has also to be recalled that under the LSA approach, administrations have to implement proper actions, in order to give a certain level of guarantee (i.e. taking into account user requirements and sharing constraints) with respect to the spectrum that can be made available. Therefore, proper technical and operational conditions have to be set for additional alternative usage under LSA, considering QoS issues.

Whilst referring to appropriate regulatory document, if available (i.e., ECC Decisions, Harmonised Standards), on coexistence among different services of interest (e.g. mobile/fixed communication networks and fixed satellite services), administrations are advised to conduct studies at national level taking into account relevant specificities (e.g. defining an adapted propagation model including terrain, setting technical characteristics corresponding to the national situation). Such a profound understanding of the national context allows a deeper consideration of the impact of LSA network topologies (e.g. MFCN macro/micro/pico) and, consequently, a more appropriate definition of criteria and parameters for sharing conditions attached to operate and manage LSA networks.

Specific, effective and innovative tools have to be at the administration disposal in order to define, apply and monitor the terms and conditions under which either the incumbents or LSA licensees may access the spectrum. LSA implementation requires, in fact, specific skills and knowledge to identify frequencies, locations and times where spectrum use must be protected for the incumbent, together with the level of protection. Mechanism for transmission of information on spectrum availability between incumbents and LSA licensee should also be set and implemented. National administrations should overview and monitor constantly the entire process, in order to assess effectiveness, monitor the performance and possibly intervene for proper improvement, in order to increase flexibility and efficiency of spectrum sharing.

6. Conclusions

In this paper we have recalled the enormous potential offered by the adoption of LSA

approach for improving spectrum efficiency, promote competition and favour the shared use of radio spectrum while granting a predefined level of QoS to users.

The state of the art for the development of the sharing framework for the LSA approach is quite stable, even though several key issues still remain to be properly treated and solved for a thorough picture which could lead to regulatory tools clearly applicable. In this respect we have highlighted that some clarifications are needed in terms of the definition of incumbent users, as this may enormously affect bands where the LSA approach could be applied or not. We have also highlighted that the sharing framework has to make clear that LSA is a form of vertical sharing, from which different entities (incumbent and LSA licensee) may benefit for the shared use of spectrum in case they offer different services or applications. The issue of cross-border coordination has also been addressed.

Furthermore in this paper we have proposed some possible general guidelines to national administrations which have to establish if the application of the LSA approach in a given band is feasible and convenient and how to implement properly LSA authorisations.

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