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Next Generation of Radio Spectrum Management: Licensed Shared Access and the trade-off between Static and Dynamic Efficiency

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Next Generation of Radio Spectrum Management

Licensed Shared Access and the trade-off between Static and Dynamic Efficiency

Draft Paper

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Abstract

Increasing demand for access to the radio spectrum is setting the stage for a revision of existing radio spectrum management practices, mainly oriented towards exclusive use of frequency bands. A new wave of policy reforms is envisaged, with a potential shift of policy focus from static to dynamic efficiency.

A previous wave of policy reforms promoted the implementation of market mechanisms for a more efficient distribution and use of radio frequencies, i.e. static efficiency. This second wave of spectrum policy reforms might translate into a new generation of spectrum management more centred on spectrum sharing solutions. Spectrum sharing could ensure more flexibility in spectrum use and certainty of radio spectrum access thanks to technology advances, thus promoting investment and innovation, i.e. dynamic efficiency.

Among several forms of spectrum sharing solutions, collectively referred to as Dynamic Spectrum Access (DSA) systems, the concept of Licensed Shared Access (LSA) has recently been under scrutiny, in particular in the European Union (EU) and in the United States (US). LSA is an authorisation scheme that allows for shared use of already assigned but underused spectrum bands between incumbent(s) and new user(s) by means of exclusive individual spectrum rights of use. The adoption of the LSA regime would contribute to spectrum efficiency by making underused spectrum bands available for new users. The use of Reconfigurable Radio System (RRS) technologies, such as Software Defined Radio (SDR) and Cognitive Radio (CR) would minimise the risk of harmful interference.

Against this background, this paper is intended as a progress report on the discussion upon the LSA regime, based on an extensive bibliography, which includes official documents, academic papers, position papers and reports.

Several studies agree on the contribution LSA could bring in terms of spectrum efficiency. In this regard, selected elements of the LSA regime are assessed in terms of potential contribution to dynamic efficiency, taking into consideration the dichotomy between static and dynamic efficiency. These elements are: contract length; sharing arrangements; assignment procedure for LSA licences; implementation of RRS technologies; monitoring and enforcement.

Although priority has historically been given to exclusive assignment of radio spectrum rights of use, the authors recognise the potential of LSA as a complementary regime that could promote spectrum efficiency. However, the authors advocate further exploration to clarify whether and to what extent LSA would be beneficial in terms of dynamic efficiency, i.e. promotion of investment and innovation and, thus, economic growth, taking into consideration the potential trade-off between static and dynamic efficiency.

Keywords: Licensed Shared Access, spectrum sharing, static efficiency, dynamic efficiency

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1. Introduction

Demand for access to the radio spectrum is constantly and rapidly growing. In particular, more radio spectrum is needed to cope with a tremendous growth of wireless data traffic volume (Khun-Jush et al., 2012). According to a recent forecast, global mobile data traffic is expected to increase nearly 11-fold between 2013 and 2018. With a compound annual growth rate (CAGR) of 61 per cent, global mobile data traffic will reach 15.9 exabyte per month by 2018, compared to 820 petabytes per month at the end of 2012. Consumer demand is oriented towards spectrum-hungry services, such as video. Over two-thirds (69 per cent) of global mobile data traffic will be video by 2018, registering a 14-fold increase between 2013 and 2018 (Cisco, 2014).

Along with data traffic volume, device penetration is dramatically increasing. By the end of 2014, the number of mobile-connected devices will exceed the world's population, and there will be over 10 billion mobile-connected devices by 2018. The growing need of wireless connectivity is not only due to usage of smartphones, tablets and other similar devices (RSPG, 2013), but also because of machine-to-machine (M2M) communications. By 2018, 2 billion M2M connections (e.g. GPS systems in cars, asset tracking systems in shipping and manufacturing sectors, medical applications, etc.) are expected to connect devices, machines and people (Cisco, 2014).

These trends in technology and market conditions are putting pressure on the existing spectrum assignment procedures, which seem to hinder an efficient use of the spectrum resource. In fact, current spectrum assignment procedures are mainly based upon exclusive assignment of frequency bands (e.g. Faulhaber & Farber, 2002; Faulhaber, 2006; Durantini et al., 2013). Over time, this has determined large portions of assigned spectrum being underutilised in certain geographical areas and/or points in time (Nicita & Rossi, 2013). Exclusive assignment of frequency bands has been an efficient way of managing radio spectrum, until the increasing density of wireless services has threatened the capability of existing exclusive assignment procedures to protect from harmful interference without jeopardizing efficient spectrum use (Peha, 2009).

The current radio spectrum environment, characterised by fast changes in technology and market conditions, is setting the stage for a potential shift of policy focus from static to dynamic efficiency. New trajectories of radio spectrum management and assignment tools need to be defined to facilitate spectrum reallocation through time and ensure proper incentives for investment in new equipment, services, processes and applications.

In this regard, academia, policy makers and radio spectrum users are investigating the possibility of implementing spectrum sharing solutions, collectively referred to as Dynamic Spectrum Access (DSA) systems (ITU & InfoDev). Spectrum sharing solutions could ensure more flexibility in spectrum use and certainty of radio spectrum access thanks to technology advances (Khun-Jush et al., 2012).

Among several emerging DSA models, an approach that is recently attracting interest is called Licensed Shared Access (LSA). LSA is an authorisation scheme that would allow for shared use of already assigned frequency bands between an incumbent and a limited number of new users by means of exclusive individual spectrum rights of use. In this way, underused spectrum bands could become available for new users.

Against this background, the aim of this paper is to prompt the debate on LSA, by providing a preliminary assessment of the potential impact of LSA on dynamic efficiency. This paper is based on an extensive bibliography on LSA, which includes official documents, academic

papers, position papers and reports. The intention of this paper is to start a debate on the potential contribution that implementing the LSA regime could bring in terms of dynamic efficiency, proposing a preliminary assessment of some of its characteristics. As LSA is in an emerging phase, further exploration is necessary to clarify whether and to what extent this sharing solution would be beneficial in terms of dynamic efficiency. The authors share the idea that there is no one-size-fits-all spectrum management approach. Rather, different regimes can coexist and be applied depending upon spectrum bands and radio-based services under consideration (e.g. Freyens, 2009; Lehr, 2014).

The rest of this paper is structured as follows: in section 2 the concepts of static and dynamic efficiency are described with regard to radio spectrum management; in section 3 the idea of a potential shift of policy focus from static to dynamic efficiency is introduced. This might lead to the emergence of a third generation of spectrum management, which would rely less on exclusive spectrum use and look at spectrum sharing as a way forward to spectrum efficiency; in section 4 the main features of the LSA regime are described; in section 5 elements of the LSA regime are selected and a preliminary assessment is conducted in terms of potential impact on dynamic efficiency. These elements are: contract length; sharing arrangements; assignment procedure for LSA licences (auction); implementation of RRS technologies; monitoring and enforcement; section 5 concludes this paper with some final remarks on the importance of promoting spectrum-sharing solutions and in particular LSA as a complementary regime that could promote dynamic efficiency.

2. Static versus dynamic efficiency in radio spectrum management

The concept of efficiency has been widely investigated in spectrum literature in its multiple facets (Burns, 2002; Cave, 2002; Cave et al., 2007 and Freyens, 2011). Furthermore, several regulatory authorities have conducted studies proposing different definitions of efficiency (e.g. FCC, 2002; ITU, 2006; CSMAC, 2008). Generally, what is referred to as core principle in radio spectrum management is the concept of economic efficiency (Cave, 2007: 169).

Economic efficiency can be observed from two perspectives: static and dynamic. From a static perspective, economic efficiency has two components: productive and allocative efficiency. Productive efficiency, also intended as technical efficiency (e.g. Flacher & Jennequin, 2008: 365), occurs when a given level of production of goods or services is undertaken by using the minimum amount of inputs (Flacher & Jennequin, 2008: 365) or, alternatively, the lowest possible cost of all inputs, including radio spectrum (Cave et al., 2007: 169). When it comes to spectrum, technical efficiency is defined as the fullest possible use of all available spectrum that existing technology allows for, taking into account the problem of interference (Cave, 2002: 58).

Allocative efficiency is realised when a scarce resource – the radio spectrum – is allocated to users and uses that derive the highest economic value from it. In other words, allocative efficiency occurs when the Pareto criterion is met (Cave, 2002: 58; van Dijk & Mulder, 2005; Cave et al., 2007: 170). The neo-classical concept of Pareto Optimality has profoundly influenced the literature on allocative efficiency (Cordato, 1980: 393). A Pareto Optimum describes a situation where no one can be made better off without making someone else worse off (Stiglitz, 1991: 2). This means that there is no other way to conduct economic activity that would improve the well-being of one individual without lessening the well-being of at least another individual (Cave et al., 2007: 169).

Dynamic efficiency is a much more vague concept, which considers the use of a scarce resource through time (Cave et al., 2007, 169). In a nutshell, dynamic efficiency occurs when investment and innovation are incentivised (Bauer & Bohlin, 2008: 38).² This means that dynamic efficiency is realised when the radio spectrum is used in such a way that investment and innovation in technologies, services, equipment and processes are encouraged (Cave, 2002: 103; Cave et al, 2007: 170; Bauer & Bohlin, 2008). Cave (2002: 102) points out the importance of pursuing dynamic efficiency in radio spectrum management, going beyond the goal of static efficiency, seeking for management practices that promote investment and innovation.

Schumpeter is considered one of the most influential authors of the literature on dynamic efficiency. He emphasises the importance of innovation as trigger of economic advancement. In his thoughts, Schumpeter reconciles the concepts of static and dynamic efficiency picturing the economic process as a sequence of changes and static equilibriums (Bauer, 1997). Indeed, there might be a trade-off between static and dynamic efficiency as “under some circumstances dynamic efficiency requires conditions that adversely affect static efficiency. If innovation requires large investments, high post-innovation profits are needed to recover the costs of innovation” (van Dijk & Mulder, 2005: 7).

3. Third generation of radio spectrum management

As long as there was abundance of radio spectrum, there was no need to regulate access to the radio spectrum and defining conditions for its use. However, since the number and variety of radio-based services increased, interference became an evident problem that led to the definition and adoption of specific management practices (Prasad & Sridhar, 2014). Three generations of radio spectrum management can be identified, which build upon different spectrum assignment mechanisms.

The first generation of spectrum management (Marcus et al., 2013) was characterised by exclusive assignment of radio spectrum licenses to single users issued by National Regulatory Authorities (NRAs). This administrative approach, known also as command-and-control regime, was introduced with the intent to internationally coordinate spectrum use and avoid interference problems (McLean Foster & Co, 2007). For many years, the traditional assignment process has been occurring on a first come-first served basis, by comparative hearings or beauty contests (Melody & Lemstra, 2011).

A first wave of spectrum policy reforms has arisen during the past twenty years to overcome the weaknesses of administrative mechanisms. The goal of these policy reforms has been enhancing what is theoretically defined as static efficiency, meaning a more efficient allocation and use of radio spectrum (Lie, 2004). The command-and-control approach, characterised by central planning and rigid regulations, has caused long delays and scarce flexibility in the assignment of radio frequencies. Furthermore, the assignment process has inevitably required subjective judgements from NRAs.

A second generation of spectrum management has emerged, which relies on the use of market mechanisms, in particular auctions (Bauer, 2002). Spectrum auctions are means of using market-generated prices to assign licenses. They are considered a more efficient, transparent, fairer and faster mechanism of assigning spectrum licenses, in particular when demand exceeds supply, compared to administrative assignments (Lie, 2004). In an auction, licenses

² The concept of dynamic efficiency does not have to be confused with the category of spectrum sharing solutions denominated “Dynamic Spectrum Access”.

are awarded on the basis of bidding among competing applicants and go to the bidders offering either the highest monetary sum, or a different sum depending of the auction design (ITU, 2012). The key advantage heralded for auction procedures consists of the assignment of licenses to the users that bid the most, meaning to the ones who assign the spectrum the highest value. Moreover, if the auction process is properly designed and conducted, the winning bidders are clearly identified (Cave, 2002).

Yet, Noam (1998) and Oniki (2009) anticipated the limitations of market mechanisms as an efficient spectrum assignment tool. Although market mechanisms are considered more efficient compared to other assignment procedures, they have shown their drawbacks. In particular, auctions have often led bidders overpay for licenses. Moreover, spectrum auctions could translate into a routine way for incumbents to preserve their status quo and fend off new entrants or a mere government instrument to accumulate revenues (Noam, 2003; ITU, 2014). The current radio spectrum environment, characterised by fast changes in technology and market conditions, is setting the stage for a second wave of spectrum policy reforms, with a potential shift of policy focus from static to dynamic efficiency. New trajectories of radio spectrum management and assignment tools need to be defined to facilitate spectrum reallocation through time and ensure proper incentives for investment in new equipment, services, processes and applications.

In this regard, a third generation of spectrum management might rely more on spectrum sharing solutions (Noam, 2003), which could ensure more flexibility in spectrum use and certainty of radio spectrum access thanks to technology advances (Khun-Jush et al., 2012). Increasing attention is devoted to various forms of spectrum sharing, which are collectively referred to as Dynamic Spectrum Access (DSA) systems (ITU & InfoDev). Both the EU and the US are engaged in finding possible spectrum sharing opportunities.

In the EU, a spectrum inventory process has been set up as part of the Radio Spectrum Policy Programme (RSPP), to detect frequency bands eligible for spectrum sharing (EP & the Council, 2012). In 2011, the Radio Spectrum Policy Group (RSPG) published an Opinion on cognitive technologies, highlighting the importance of intelligent technologies to share radio frequencies (RSPG, 2011a). In the same year, the RSPG published a report bringing forward a dynamic approach to spectrum sharing (RSPG, 2011b). Moreover, the European Commission (EC) Communication on “Promoting the shared use of radio spectrum resources in the internal market”, delivered in 2012, recognised shared spectrum access as the solution at the forefront to the problem of lack of available spectrum for new spectrum needs (EC, 2012).

In the United States, the idea of spectrum sharing has been extensively discussed since 2006, when the National Telecommunications and Information Administration (NTIA), in coordination with the Federal Communications Commission (FCC), examined the feasibility of spectrum sharing between federal and non-federal users (Nicita & Rossi, 2013).

The use of Reconfigurable Radio System (RRS) technologies, such as Software Defined Radio (SDR) and Cognitive Radio (CR) would enable new forms of spectrum sharing by preventing from harmful interference (Peha, 2009; CEPT, 2013). These intelligent technologies coupled with frequency, location and time sharing conditions, would allow a number of different users to coexist within the same frequency bands, through power and interference reduction techniques (Nicita & Rossi, 2013). RRSs are a combination of radio equipment and software capable of analysing the radio environment (spectrum sensing) and detecting unused frequencies, which could then be employed for other services. RRSs can

reconfigure their own parameters, including frequency and power, self-adapting to an ever-changing environment (ETSI, 2015; ITU, 2012).

Among several emerging DSA models, an approach that is recently attracting interest is called Licensed Shared Access (LSA), initially known as Authorised Shared Access (ASA). LSA is an authorisation scheme that would allow for shared use of already assigned frequency bands between an incumbent and a limited number of new users by means of exclusive individual spectrum rights of use. In this way, underused spectrum bands could become available for new users.

4. A new way of licensing spectrum: the LSA concept

The LSA authorisation scheme for spectrum rights of use is gradually attracting the attention of academia, policy makers and radio spectrum users. It was initially proposed as Authorised Shared Access (ASA) by an industry consortium composed by Qualcomm and Nokia. The aim was to promote shared use of certain spectrum bands by International Mobile Telecommunication (IMT) services, whenever and wherever they were unused by incumbent users (Ingenious Consulting Network, 2011). The ASA concept has been then extended to the notion of Licensed Shared Access (LSA) by the RSPG, which recognised several sharing opportunities, in addition to the case put forward by Qualcomm and Nokia (CEPT, 2013).

The RSPG Opinion on LSA, approved in November 2013 (RSPG, 2013), defines the LSA concept as 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 approach, the additional users are authorised to use the spectrum (or part of the spectrum) in accordance with sharing rules included in their spectrum rights of use, thereby allowing all the authorised users, including incumbents, to provide a certain Quality of Service (QoS)” (RSPG, 2013).

4.1. The LSA concept in the existing spectrum policy framework

With the LSA regime, the access to already assigned but underused spectrum bands would be guaranteed to a limited number of new spectrum users, named LSA licensees, by means of individual spectrum rights of use. In this way, existing spectrum users would share spectrum with one or a limited number of LSA licensees, in accordance with a set of sharing arrangements imposed on both groups of users (Khun-Jush et al., 2012). Assigned spectrum could be shared in terms of time, geography and/or frequency on a long-term basis (Plum Consulting, 2013; Faussurier, 2014).

NRAs are responsible for defining sharing conditions. These should include specific technical and operational requirements, for instance compatibility criteria, limitations of use in terms of frequency, timing and/or location and spectrum masks (RSPG, 2013). NRAs should develop these sharing rules considering national policy objectives, along with international obligations and regional requirements (CEPT, 2013). Moreover cooperation is needed with all parties involved. In fact, LSA is a voluntary approach: the sharing terms and conditions are to be agreed between incumbents, LSA users and NRA, taking also into account interests of users in adjacent bands (RSPG, 2013; Khun-Jush et al., 2012; Plum Consulting, 2013).

It is important to underline that the LSA regime does not challenge the existing radio spectrum regulatory framework. In fact, the LSA concept is based on different principles than existing spectrum authorisation schemes. Broadly speaking, three categories of spectrum authorisation

schemes can be distinguished on the basis of the degree of exclusivity in the assignment of radio frequencies to different users. At one extreme of the range, assignment schemes are close to exclusive use, with clear geographic limitations and time restrictions. At the opposite extreme, licence-free or unlicensed users obtain general authorisations to use certain spectrum bands under defined common rules, without any protection from harmful interference. LSA stays in the middle, as it combines the two concepts of spectrum sharing and spectrum licensing.

The LSA approach does not have to be considered as an alternative to the current spectrum authorisation schemes of exclusive licensed and license-exempt spectrum, but as a complementary regulatory approach to increase efficient spectrum utilisation, by providing new services with access to assigned but underused spectrum (e.g. Ingenious Consulting Network, 2011; Parcu & Associati, 2011; Khun-Jush et al., 2012; Nicita & Rossi, 2013; Carciofi et al., 2013; Nicita & Parcu, 2013; Durantini et al., 2013; Bangerter et al., 2014; Lehr, 2014).

4.2 Incentives for the parties involved

A fundamental prerequisite for the implementation of LSA is the definition of sharing conditions, which need to be attractive for all the parties involved: incumbent users, LSA licensees and NRAs.

First of all, protection from harmful interference must be ensured to both incumbents and LSA users. This contributes to guarantee a predictable level of QoS. Incumbents may incur in costs due to implementation of improved technologies necessary to ensure good QoS for new users. In this case, financial compensations might be agreed between the parties, as well as in the case when incumbents are subject to spectrum pricing (RSPG, 2011b and 2013).

Secondly, both incumbent users and LSA licensees require regulatory certainty over the conditions governing the shared use of spectrum. These sharing conditions should be sufficiently concise, attractive and predictable to engage both LSA licensees and incumbents in the implementation of LSA. LSA licensees would be attracted by the availability of spectrum, in a timely manner, for a sufficient period of time and in a certain geographic area and incumbents would be interested in receiving financial or other forms of compensations (e.g. access to new services) from LSA licensees, while maintaining control over spectrum use in the long term (Khun-Jush et al., 2012; CEPT, 2014b).

LSA can be conceived not only as an alternative assignment scheme to provide shared access to spectrum, but also as a temporary solution prior to spectrum re-farming (RSPG, 2011b; Deloitte, 2014). Furthermore, the application of the LSA approach might occur when existing spectrum right holders are unable, for different reasons, or lack the incentives to make unused spectrum frequencies available (Nicita & Rossi, 2013).

The nature of incumbent users is not clear yet. They might be both governmental entities and commercial operators. However, it is believed that the LSA model would be more functional if incumbents and LSA users belong to different categories (non-commercial versus commercial), so that they are subject to different regulatory requirements (RSPG, 2013; CEPT, 2014a).

4.3. Implementing LSA to share public spectrum with mobile operators

The current interest in LSA is driven by the opportunity to open public spectrum (e.g. used for defence) for commercial uses, in particular for mobile services. The 2.3 GHz band and the

3.5 GHz band are currently under scrutiny, respectively in the EU and the US, to verify whether LSA can be implemented (FCC, 2012; Khun-Jush et al., 2012; EC, 2014). LSA is viewed as an authorisation scheme that can ensure long term public use, while enabling spectrum access to mobile broadband services, in a timely manner, when exclusive allocation may be impractical (ETSI, 2012). In fact, spectrum re-farming can be a controversial, lengthy and time-consuming process over time (Khun-Jush et al., 2012), in particular in bands characterised by fragmented incumbent uses (CEPT, 2013).

4.3.1. Candidate bands for sharing

Spectrum bands internationally allocated to the mobile service, but still not assigned due to incumbent usage represents an opportunity for implementing LSA. In fact, the EU is conducting studies on the 2.3 GHz band to examine the possibility of shared spectrum between incumbent users, such as telemetry and PMSE, and mobile services (EC, 2012; ETSI, 2013; CEPT, 2014b; CEPT, 2014c;).

In the US, the candidate band for sharing is the 3.5 GHz band, whose main incumbent uses are Radiolocation Service (RLS) and Aeronautical Radio Navigation Service (ARNS). The 3.5 GHz band was identified for shared federal and non-federal use in 2010 by NTIA. The current incumbent uses are mainly localised around the coasts and this offers great sharing opportunities. Thus, in 2012 the FCC proposed to implement a three-tier system of spectrum access to manage the shared use of the 3.5 GHz band (FCC, 2012). This system called Spectrum Access System (SAS) resembles the LSA architecture, although with some differences (Youell, 2014).

4.3.2. Economic benefits of LSA

A study conducted by SCF Associates Ltd shows that additional shared spectrum for wireless broadband could create significant net economic benefits for Europe. With an increase of between 200 to 400 MHz in shared access spectrum for wireless broadband, the European economy gains net benefits of the order of several hundred billion Euros by 2020 (EC, 2012). In December 2013, Plum Consulting published a study including a cost-benefit analysis of the adoption of LSA in the 2.3 GHz band in Europe. According to this study, making spectrum available with LSA on a harmonised basis across Europe would bring net benefits of 6.5-22 billion Euros. Moreover, the Plum study highlights the fact that the amount of benefits that can be gained is considerable because of the ability to implement LSA concept in a short time period (Plum Consulting, 2013).

Furthermore, the GSMA study proposes a comprehensive framework for spectrum valuation, in particular from the view point of MNOs, which is then applied to the 2.3 GHz band in Europe and the 3.5 GHz band in the US. According to this framework, the adoption of the LSA in the 2.3 GHz band in Europe would generate up to €86 billion of incremental value added, while the US adoption of LSA in the 3.5 GHz band would generate up to \$260 billion in economic benefits (Deloitte, 2014).

5. Implementing LSA: impacts on spectrum efficiency

Having elaborated on the LSA concept, in this section the intention is to provide a preliminary assessment of selected elements of the LSA regime to understand whether the LSA regime would actually contribute to dynamic efficiency, taking into consideration the dichotomy between static and dynamic efficiency.

5.1 LSA and the trade-off between static and dynamic efficiency

Several studies agree on the contribution spectrum sharing solutions could bring for a more efficient spectrum use (e.g. Eli Noam, 2003; Peha, 2009; Bunel & Lescop, 2012; Werbahe, 2014; Rysavy, 2014). With regard to the goal of promoting spectrum efficiency, an issue regulators have to face is the possible trade-off between static and dynamic efficiency (Dijk & Mulder, 2005). To stimulate dynamic efficiency, policy and regulatory interventions should be designed in a way that ensures proper incentives for investment and innovation in equipment, services, processes and applications (Bauer & Bohlin, 2008). However, risky investment and innovation usually violate the conditions of static efficiency, at least temporarily (van Dijk & Mulder, 2005; Bauer & Bohlin, 2008). Keeping in mind the potential trade-off between static and dynamic efficiency, the following elements of the LSA regime are assessed:

- Contract length
 - Sharing arrangements
 - Assignment procedure for LSA licenses
 - Implementation of RRS technologies
 - Monitoring and enforcement
-
- Contract Length

The length of the contract between incumbent and LSA licensees could impact on the capability of the LSA regime to prompt investment and innovation. The European Telecommunications Standard Institute (ETSI) states (ETSI, 2013): “The possibility of lower cost, shorter-term, licensing options provided by the LSA regime could foster new innovative ideas and contribute to economic growth throughout the CEPT countries”. However, to promote dynamic efficiency, LSA licensees need a time horizon sufficient to realise returns on investments. The contract has to have a length sufficient to make LSA attractive to potential LSA users. Likewise, it is unclear whether setting the contract length is an NRA’s responsibility or it is a decision left to the parties of the contract. Furthermore, it is necessary to investigate the consequences of the incumbent’s right to renegotiate or terminate a sharing agreement prior to the end of the contract with LSA users.

- Sharing Arrangements

Werbahe (2013) states that forms of spectrum sharing increase static efficiency because of a reduction of spectrum waste. On the contrary, it is unclear to what extent LSA would promote or inhibit innovation and investment, i.e. dynamic efficiency and, thus, economic growth. Many authors see the LSA regime as a mechanism for innovation (e.g. v Nicita & Rossi, 2013; Werbahe, 2014). However, the authors of the Deloitte study (2014) advise there might be negative impacts to the economy if spectrum sharing is totally or partially unsuccessful. Spectrum sharing, and in particular LSA, might be a failure as it brings some limitations of use that might undermine the willingness of both incumbent users and LSA licensees to invest and innovate. It has been recognised a potential for the innovation process to be locked into legacy technology or added complexity. This is because sharing spectrum requires development of new sharing architectures and devices, which will inevitably influence the trajectory that innovation in services and technologies will take in the future (Rysavy Research, 2012).

- Assignment Procedure for LSA licenses

The ITU and the EU state that the assignment of LSA licenses must be done in a fair, transparent and non-discriminatory manner. Moreover, incumbents should act in an objective way for the definition of LSA sharing conditions and LSA users should not obstruct the long-term innovation process held by incumbents. In addition, fair competition and consumers' interest should always be guaranteed (RSPG, 2012; Faussurier, 2014).

Yet, few studies have explored possible awarding procedures for LSA licenses. For instance, in Parcu & Associati (2011: 22), the implementation of LSA is envisaged as a commercial transaction between incumbent(s) and new user(s). NRAs should not interfere with the definition of the monetary or non-monetary agreement between users. NRAs would be responsible for assigning licenses to new users once the negotiation phase between incumbent(s) and new user(s) is concluded. The fact that NRAs would have a mere supervision role over the commercial transaction could ensure LSA users a timely access to spectrum without going through lengthy authorisation schemes. As a consequence, LSA users might be more willing to invest.

As an alternative, the authors of the Deloitte study (2014) predict that LSA licenses will be awarded by means of auctions. In recent years, auctions have become well known and established approaches among many NRAs in the world (ITU & InfoDev). Auctions are meant as a reliable way to ensure that spectrum is employed for the most productive uses, as the users who are willing to pay the most should be the ones who are willing to manage the asset more efficiently. However, the results of several auctions uncovered the potential fallibility of this assignment process to select the actors who ensure the most efficient use of radio spectrum.

A final remark is that LSA has been subject to detailed technical considerations, without however a proper valuation and pricing discussion. In this regard, the authors denounce little emphasis upon an appropriate assignment procedure for LSA licenses and encourage further examinations of valuation and pricing methodologies for shared spectrum and in particular LSA.

- Use of RRS technologies

A successful implementation of the LSA regime is based on the use of RRS technologies, in particular SDR and CR, which would facilitate spectrum sharing without causing harmful interference (e.g. Peha, 2009). These technologies should be able to scan and detect actual assigned but unused radio frequencies, which are then assumed to be usable for other services. This function, called spectrum sensing, would find opportunities for spectrum access without interfering with incumbent users. However, spectrum sensing is a very delicate activity, which could actually fail to detect signals. In case of active but undetected transmissions, new services might interfere with existing services. If, from a dynamic perspective, it is important to encourage the introduction of new spectrum-saving technologies, from a static perspective, the problem of interference must be taken into consideration. For instance, potential degradation of incumbent public services, which could be defence or public safety, would also bring up national public policy considerations. Despite years of research efforts, technology seems not to be ready yet (Rysavy Research, 2012; Medeisis et al., 2013;).

- Monitoring and Enforcement

Enabling forms of spectrum sharing, as in the case of LSA, requires developing mechanisms to ensure that new equipment comply with sharing conditions. In addition, there is a need for a constant monitoring to verify that sharing conditions are always met. This raises issues related to definition of enforcement procedures (Rysavy Research, 2012).

Cui et al. (2014) point out that sharing of radio spectrum would imply a rearrangement of rights which would have consequences not only on the behaviour of spectrum users, but also on the enforcement process. The aspects of monitoring and enforcement are critical for a successful implementation of the LSA regime and need to be carefully designed.

6. Conclusion

Spectrum sharing is seen as an opportunity to increase spectrum efficiency. There is no single definition of efficiency, as it requires a “multidimensional analysis involving technical and subjective considerations” (CSMAC, 2008: 5). However, as stressed by Rysavy (2014: 386), efficiency depends upon “the various types of services and uses for which spectrum is needed” (CSMAC, 2008: 2).

In particular, LSA could be a complementary regulatory approach to be applied in those parts of the spectrum where incumbents do not fully use spectrum in terms of geography, time and/or frequency and consequently where exclusive use is not necessary to prevent interference (CSMAC, 2008: 15).

However, the LSA regime is still in an emerging phase. Therefore, several of its aspects need to be further investigated to be actually able to promote investment and innovation. In this regard, the intention of this paper is to start a debate on the potential contribution that implementing the LSA regime could bring in terms of dynamic efficiency, proposing a preliminary assessment of some of its characteristics.

A shift of policy focus from static to dynamic efficiency is envisaged. Although clearing spectrum from old to new uses has historically been the core element of spectrum management (Werbahc, 2014; OECD, 2014), it is worth exploring new spectrum sharing arrangements, such as LSA. The authors share the idea that there is no one-size-fits-all spectrum management approach. Rather, different regimes can coexist and be applied depending upon spectrum bands and radio-based services under consideration (see Lehr, 2014).

References

- Bangerter, B.; Talwar, S.; Arefi, R. & Intel, S. (2014), *Networks and Devices for the 5G Era*, IEEE Communications Magazine, February 2014.
- Bauer, J. M. (1997), *Market Power, Innovation, and Efficiency in Telecommunications: Schumpeter Reconsidered*, Journal of Economic Issues, Vol. XXXI, No. 2, June 1997.
- Bauer J. M. (2002), *A comparative Analysis of Spectrum Management Regimes*, paper presented at the 30th Research Conference on Communication, Information and Internet Policy, Alexandria, VA, USA, 28-30 September.
- Bauer, J. M. & Bohlin, E. (2008), *Form static to dynamic regulation. Recent Developments in US Telecommunications Policy*, Intereconomics, January/February 2008
- Bunel, A. & Lescop, D. (2012), *Shared Access, Cognitive Radio and Transition Issues*, paper presented at: 19th Biennial ITS Conference, November 2012, Bangkok, Thailand.

- Burns, J.W. (2002), *Measuring spectrum efficiency—the art of spectrum utilization metrics*, paper presented at the IEEE conference – getting the most out of the radio spectrum, London, 24–5 October 2002.
- Carciofi, C; Guiducci, D.; Barbiroli, M. & Castrucci, R. (2013), *Analysis of different authorization approaches for the shared access to radio spectrum*, paper presented at 24th European Regional ITS Conference, Florence 2013.
- Cave, M. (2002), *Review of Radio Spectrum Management. An independent review for Department of Trade and Industry and HM Treasury*.
- Cave, M.; Doyle, C. & Webb, William (2007), *Essentials of Modern Spectrum Management*, Cambridge Wireless Essentials Series.
- CEPT (2013), Licensed Spectrum Access opens new opportunities, ECC Newsletter, October 2013.
- CEPT (2014a), Trends and principles in spectrum management, CEPT Workshop on European Spectrum Management and Numbering, 4 June 2014, PowerPoint Presentation.
- CEPT (2014b), Draft ECC Decision (14)BB, Harmonised technical and regulatory conditions for the use of the band 2300-2400 MHz for MFCN.
- CEPT (2014c), ECC Report 205 Licensed Shared Access (LSA).
- Cisco VNI Forecast (2014), *Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2013-2018*, Cisco Public Information.
- Cordato, R. E. (1980). *The Austrian Theory of Efficiency and the Role of Government*, The Journal of Libertarian Studies, Vol. IV, No. 4, Fall 1980.
- CSMAC (2008), *Definitions of Efficiency in Spectrum Use*, Working Group 1, October 1, 2008.
- Cui, L.; Gomez, M. M. & Weiss, M. B. H. (2014), *Dimensions of cooperative spectrum sharing: rights and enforcement*, in New Frontiers in Dynamic Spectrum Access Networks, 1 April 2014 - 5 April 2014, Arlington VA.
- De Soto, J. H. (2009), *The Theory of Dynamic Efficiency*, Routledge, New York, NY.
- Deloitte (2014), *The Impact of Licensed Shared Use of Spectrum*, a report for the GSM Association prepared in collaboration with Realwireless.
- Durantini, A. & Martino, M. (2013), *The spectrum policy reform paving the way to cognitive radio enabled spectrum sharing*, Telecommunications Policy, 37 (2-3), pp. 87-95.
- EC (2012), Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Promoting the shared use of radio spectrum resources in the internal market, COM(2012) 478 final.
- EC (2014), Mandate to CEPT to develop harmonised technical conditions for the 2300-2400 MHz (2.3 GHz) frequency band in the EU for the provision of wireless broadband electronic communications services, Ref. Ares(2014)1103207 – 08/04/2014.
- EP & the Council (2012), Decision No. 243/2012/EU of the European Parliament and of the Council of 14 March 2012 establishing a multiannual radio spectrum policy programme.
- ETSI (2013), Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference Document (SRdoc); Mobile broadband services in the 2300 MHz-2400 MHz frequency band under Licensed Shared Access regime, ETSI TR 103 113 V.1.1.1, http://www.etsi.org/deliver/etsi_TR/103100_103199/103113/01.01.01_60/tr_103113v010101p.pdf (accessed May 27, 2015)
- ETSI (2015), Annual Report April 2015.
- Faulhaber, G. (2006), *The Future of Wireless Telecommunications: Spectrum as a Critical Resource*, Information Economics and Policy 18, pp. 256-271
- Faulhaber G. & Farber, D. (2002), *Spectrum Management: Property Rights, Markets, and the Commons*, Working Paper 02:12, AEI-Brookings Joint Center Publications, Washington.

- Faussurier, E. (2014), *Introduction of new spectrum sharing concepts: LSA and WSD*, ITU-R SG 1/ WP 1B Workshop: Spectrum Management Issues on the use of white spaces by cognitive radio systems, 20 January 2014.
- FCC (2002), Report of the Spectrum Efficiency Working Group, November 15, 2002.
- FCC (2012), In the Matter of Amendment of the Commission' s Rules with Regard to Commercial Operations in the 3550-3650 MHz Band, Notice of proposed rulemaking and order.
- Freyens, B. (2009), *A policy reform for spectrum economics*, Information Economics and Policy 21, pp. 128-144.
- Freyens, B. P. & Yerokhin, O. (2011), *Allocative vs. technical spectrum efficiency*, Telecommunications Policy, pp. 291-300.
- Ingenious Consulting Network (2011), *Authorised Shared Access (ASA) An evolutionary spectrum authorisation scheme for sustainable economic growth and consumer benefit*, paper presented at the 72nd Meeting of the WG FM, Miesbach, Germany.
- ITU & InfoDev, ICT Regulation Toolkit, <http://www.ictregulationtoolkit.org/5> (accessed May 26, 2015).
- ITU (2006), Definition of spectrum use and efficiency of a radio system, Recommendation ITU-R SM.1046-2 (05/2006), SM Series Spectrum Management.
- ITU (2012), Economic Aspects of Spectrum Management, Rep. ITU-R SM. 2012-1, Geneva, Switzerland, 2012.
- Khun-Jush, J.; Bender, P.; Deschamps, B. & Gundlach, M. (2012), *Licensed shared access as complementary approach to meet spectrum demands: Benefits for next generation cellular systems*, ETSI Workshop Reconfigurable Radio Systems, Cannes, France, Dec. 2012.
- Lehr, W. (2014), *Toward More Efficient Spectrum Management, New Models for Protected Shared Access*, White Paper MIT Communications Futures Program.
- Lie, E. (2004), *Radio Spectrum Management for a Converging World*, background paper prepared for the ITU Workshop on Radio Spectrum Management for a Converging World, Geneva, Switzerland, ITU New Initiative programme, 16-18 February 2004.
- Marcus, J. S.; Pogorel, G. & Pujol, F. (2013), *The Radio Spectrum: A Shift in Paradigms? Introduction*, Communications & Strategies, No. 90, 2nd Quarter 2013, pp. 11-16.
- McLean Foster & Co. (2007), *Radio Spectrum Management*, Module 5, ICT Regulation Toolkit, Executive Summary, in collaboration Cave, M. & Jones, R. W.
- Medeisis, A. & Minervini, L. F. (2013), *Stalling innovation of Cognitive Radio: The case for a dedicated Frequency band*, Telecommunications Policy 37, pp. 108-115.
- Melody, W. H. & Lemstra, W. (2011), *Liberalization in radio spectrum management*, in Finger, M. & Kunneke, R. W., International handbook of Network Industries. The liberalization of Infrastructure, Cheltenham, UK: Edward Elgar, pp. 123-143.
- Nicita, A. & Rossi, M. A. (2013), *Spectrum crunch vs. spectrum sharing: exploring the "Authorised Shared Access" model*, Communications & Strategies, No. 90, 2nd Quarter 2013, pp. 17-40.
- Nicita, A. & Parcu, P. L. (2013), *Spectrum Sharing: the case for Authorised Shared Access*, Network Industries Quarterly, 15(3), pp. 1-7.
- Noam, E. M. (1998), *Spectrum Auctions: Yesterday's Heresy, Today's Orthodoxy, Tomorrow's Anachronism*, Journal of Law and Economics.
- Noam, E. M. (2003), *The Third Way for Spectrum*, FT.com, retrieved from http://www.citi.columbia.edu/elinoam/articles/Third_way_for_Spectrum.pdf (accessed May 27, 2015)
- Peha, J. M. (2009), *Sharing Spectrum Through Spectrum Policy Reform and Cognitive Radio*, Proceedings of the IEEE, 97 (4), pp. 708-719.
- OECD (2014), *New Approaches to Spectrum Management*, OECD Digital Economy Papers, No. 235, OECD Publishing.

- Oniki, H. (2009), *Designing a System for reallocation of Spectrum: Implications for a Conceptual Study*, Osaka-Gakuin Review of Economics, 23(2), 2009, pp.1-82, paper presented at the 36th Research Conference on Communication, Information, and Internet Policy (TPRC 2008), Arlington, VA, USA, September 26-28, 2008; and at Workshop on Spectrum Valuation for 3G Services: Application of the 1900 MHz band, Bangkok, Thailand, November 14, 2008.
- Parcu, P. L.; Nicita, A.; Corda, G.; Rossi, M. A. & Bravo P. L. (2011), *Authorised Shared Access (ASA). An innovative model of Pro-competitive Spectrum Management*, Available at SSRN: <http://ssrn.com/abstract=2174518> or <http://dx.doi.org/10.2139/ssrn.2174518>
- Pastukh, S. (2012), *Software-defined radio and cognitive radio systems*, ITU News No. 2, 2012, <https://itunews.itu.int/en/2076-Software-defined-radio-%20and-cognitive-radio-systems.note.aspx> (accessed May 27, 2015).
- Plum Consulting (2013), *The economic benefits of LSA in 2.3 GHz in Europe*, a report for Ericsson, NSN and Qualcomm.
- Prasad, R. & Sridhar, V. (2014), *The dynamics of Spectrum Management. Legacy, Technology, and Economic*, Oxford, UK.
- RSPG (2011a), Opinion on Cognitive Technologies.
- RSPG (2011b), Report on Collective Use of Spectrum (CUS) and other spectrum sharing approaches.
- RSPG (2013), Opinion on Licensed Shared Access.
- Rysavy, P. (2014), *Challenges and Considerations in Defining Spectrum Efficiency*, invited paper, Proceedings of the IEEE, Vol. 102, No. 3, March.
- Rysavy Research (2012), *Spectrum Sharing The Promise and The Reality*.
- Stiglitz, J. E. (1991). *The Invisible Hand and Modern Welfare Economics*, Working Paper No. 364, NBER Working Paper Series, March 1991.
- van Dijk, M. & Mulder, M (2005), *Regulation of telecommunication and deployment of broadband*, CPB Memorandum, CPB Netherlands Bureau for economic Policy Analysis.
- Werbahc, K. & Mehta, A. (2014), *The Spectrum Opportunity: Sharing as the Solution to the Wireless Crunch*, International Journal of Communication 8, pp. 128-149.
- Youell, T. (2014), *Firms offer contrasting visions for 3.5 GHz spectrum sharing*, PolicyTracker The spectrum management newsletter.