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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. A new wave of spectrum policy reforms can be envisaged, with a potential shift of policy focus from static to dynamic efficiency. This might translate into a new generation of radio spectrum management tools more centred on spectrum sharing solutions. Spectrum sharing could ensure more flexibility in spectrum use and certainty of radio spectrum access, which might eventually encourage investment and innovation, i.e. dynamic efficiency. Among several forms of spectrum sharing, the concept of Licensed Shared Access has recently been under scrutiny, in particular in the European Union and in the United States.

Against this background, this paper is intended as a progress report on the discussion upon the LSA regime. This paper is based on an extensive bibliography on LSA, which includes official documents, academic papers, position papers and reports. Given the shift of spectrum policy focus from static to dynamic efficiency, the aim of this paper is to provide a preliminary assessment of the impact of LSA on dynamic efficiency. In this regard, selected elements of the LSA regime are assessed in terms of potential contribution to dynamic efficiency. These elements are: contract length; sharing arrangements; assignment procedures for LSA licences; implementation of RRS technologies; monitoring and enforcement.

The preliminary assessment presented in this paper shows that the LSA regime needs to be refined to ensure that dynamic efficiency is promoted, in particular aspects of enforcement have to be carefully designed.

The authors of this paper would recommend further studies on the LSA regime, which could represent a valuable element of the regulatory toolkit for spectrum management under a radio spectrum regulation aimed at increasing dynamic efficiency. The authors share the idea that different regimes can coexist and be applied depending upon spectrum bands and radio-based services under consideration.

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 (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, 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 technological trends are putting pressure on the existing spectrum management procedures, which seem to hinder an efficient use of the spectrum resource. In particular, 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. In fact, the current debate among policy makers is to reform the way radio spectrum is managed to facilitate spectrum reallocation through time and ensure proper incentives for investment in new equipment, services, processes and applications.

A previous wave of spectrum policy reforms promoted the implementation of market mechanisms for a more efficient distribution and use of radio frequencies, i.e. static efficiency. The upcoming wave of spectrum policy reforms might translate into a new generation of radio spectrum management and assignment tools more centred on spectrum sharing solutions. In particular, academia, policy makers and radio spectrum users are investigating the possibility of implementing spectrum sharing solutions. 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 forms of spectrum sharing, the concept of Licensed Shared Access (LSA) has recently been under scrutiny, in particular in the European Union and in the United States. The Radio Spectrum Policy Group defines LSA as a regulatory approach 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. These individual radio

spectrum rights of use would include sharing rules to allow both incumbent(s) and new user(s) to provide a certain quality of service. In the United States, a three-tier system of spectrum access is proposed, which resembles the LSA architecture, although with some differences. Several studies argue that the adoption of LSA would contribute to spectrum efficiency by making underused spectrum bands available for new users.

Against this background, this paper is intended as a progress report on the discussion upon LSA. This paper is based on an extensive bibliography on LSA, which includes official documents, academic papers, position papers and reports. Given the shift of spectrum policy focus from static to dynamic efficiency, 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. To this end, selected elements of LSA are assessed in terms of potential contribution to dynamic efficiency, taking into consideration the dichotomy between static and dynamic efficiency.

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 spectrum 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, selected elements of the LSA regime are assessed in terms of potential impact of LSA 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 refining some aspects of the LSA regime in order to ensure a concrete contribution to dynamic efficiency.

2. The Concepts of Static and Dynamic Efficiency in literature

The concept of efficiency has been widely investigated in spectrum literature in its multiple facets (Burns, 2002; Cave, 2002; Cave et al., 2007; Freyens, 2009 and Freyens & Yerokhin, 2011). Furthermore, several regulatory authorities have conducted studies proposing different definitions of efficiency (e.g. FCC, 2002; ITU, 2006; CSMAC, 2008). According to a taxonomy of 2008 (CSMAC, 2008) there cannot be a single definition of efficiency, because this concept requires a “multidimensional analysis involving technical and subjective considerations” (CSMAC, 2008: 5). Furthermore, the type of efficiency that is relevant would vary according to “the various types of services and uses for which spectrum is needed” (CSMAC, 2008: 2). What emerges is lack of common understanding on the concept of efficiency and acknowledgement of the complexity of efficiency as a goal in spectrum policy and regulation.

This paper focuses on the concept efficiency from a static and dynamic perspective. To the best knowledge of the the authors of this paper, there is no systematic literature on static and dynamic efficiency in radio spectrum policy and regulation. A stating point for a systematic literature on static and dynamic efficiency in radio spectrum policy and regulation could be to draw upon three main groups of studies.

Firstly, several studies have been conducted on the implications of static and dynamic efficiency in telecommunications policy and regulation (e.g. Bourreau & Dogan, 2001; Quigley, 2004; de Bijl & Peitz, 2004; Bauer & Bohlin, 2008). Secondly, there are a number

of studies which focus on the relation between public policy and regulation on one hand, and the innovation process on the other (e.g. Christiansen, 2001; Lewis & Yildirim, 2002; Pelkmans & Renda, 2014; OECD, ____). Thirdly, Cave (2002) and Cave et al. (2007) have elaborated on the concept of static and dynamic efficiency in radio spectrum management. In particular, he combines the concepts of static and dynamic efficiency with the concepts of economic and technical efficiency.

From a static perspective, economic efficiency has two components: productive and allocative efficiency. Productive efficiency occurs when a given level of production of goods or services is undertaken by using the minimum amount of inputs or, alternatively, by ensuring the lowest possible cost of all inputs, including radio spectrum (Cave et al., 2007: 169). 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). Likewise, technical efficiency in radio spectrum use, from a static perspective, 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).

Dynamic efficiency is a much vaguer concept. Cave (2002: 58) emphasizes the dynamic aspect of efficiency, describing economic efficiency as “provision of responsiveness and flexibility to changes in markets and technologies, accommodating new services as these become technically and commercially feasible” and technical efficiency as “development and introduction of new spectrum-saving technologies where the cost of such technologies is justified by the value of the spectrum saved”.

Although there is no clear definition of static and dynamic efficiency as radio spectrum regulatory principle, it could be said that dynamic efficiency occurs when the radio spectrum is managed and 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).²

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 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

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

distribution 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, it was exposed to the risk of being biased by 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, compared to administrative assignments (Lie, 2004). In an auction, licenses are awarded on the basis of bidding among competing applicants and go to the bidders that offer either the highest monetary sum, or a different sum depending of the auction design (ITU, 2012). The key advantage of auction procedures is that licenses are assigned to the users that bid the most, meaning to the ones who assign the spectrum the highest value.

Yet, Noam (1998 and 2003) 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 sometimes 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.

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. The current debate among policy makers is to reform the way radio spectrum is managed 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). 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 (ITU, 2012; ETSI, 2015).

Increasing attention is devoted to various forms of spectrum sharing, in particular in the EU and the US. 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”, published 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 US, 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). Among several forms of spectrum sharing, an approach that is recently attracting interest is called Licensed Shared Access (LSA), initially known as Authorised Shared Access (ASA).

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

The LSA authorisation scheme for spectrum rights of use 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 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, location and/or frequency on a long-term basis (Plum Consulting, 2013).

NRAs would be 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 licensed and license-exempt spectrum. 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 the LSA regime is the definition of sharing conditions, which need to be attractive for all 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. Likewise, 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, 2014a).

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).

4.3. Implementing LSA to share public spectrum with mobile operators

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, 2014b).

The current interest in LSA is driven by the opportunity to open public spectrum (e.g. defence spectrum) 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, 2013). 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 for IMT, but still not assigned due to incumbent usage, represent an opportunity for implementing the LSA regime. 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, LSA would favour harmonisation of spectrum harmonisation. In particular, 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

This section is based on the assumption that there is an increasing interest in incorporating the concept of dynamic efficiency in radio spectrum policy and regulation and that this interest would drive towards implementation of spectrum sharing arrangements. Several studies suggest that spectrum sharing arrangements could contribute to a more efficient spectrum use (e.g. Eli Noam, 2003; Peha, 2009; Bunel & Lescop, 2012; Werbach, 2014; Rysavy, 2014).

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

With regard to the goal of promoting spectrum efficiency, an issue policy-makers and regulators have to face is the possible trade-off between static and dynamic efficiency (van Dijk & Mulder, 2005). 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”, for instance in terms of initial large investments required in the process of innovation and of high post-innovation profits needed to recover the cost of innovation (van Dijk & Mulder, 2005: 7).

Against this background, the aim of this section is to provide a preliminary assessment of the impact of LSA on dynamic efficiency. The following elements of the LSA regime are assessed:

1. Contract length;
2. Sharing arrangements;
3. Assignment procedure for LSA licenses;
4. Implementation of RRS technologies;
5. Monitoring and enforcement.

5.1.1. Contract Length

A contract must be signed between incumbent and LSA users and the length of the contract between incumbent and LSA licensees could impact on the capability of the LSA regime to prompt investment and innovation. On one hand, “the possibility of lower cost, shorter-term, licensing options provided by the LSA regime could foster new innovative ideas” (ETSI, 2013), for instance lowering barriers to entry. However, on the other hand, the contract has to have a length sufficient to make LSA attractive to potential LSA users, which require a time horizon sufficient to realise returns on investments.

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. This fact would discourage potential LSA users from adopting a shared arrangement.

5.1.2. Sharing Arrangements

Many authors recognise the potential of spectrum sharing solutions to increase static efficiency because of a reduction of spectrum left idle. Likewise, the LSA regime is seen as a mechanism for innovation (e.g. Nicita & Rossi, 2013; Werbach, 2014). However, it is unclear to what extent LSA would promote or inhibit dynamic efficiency. For instance, the authors of the Deloitte study (2014) state that 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.

Furthermore, 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).

5.1.3. Assignment Procedure for LSA licenses

If access to the radio spectrum is restricted, as in the case of shared spectrum on a licensed-basis, an approach to select those who are allowed access the spectrum is needed. Yet, few studies have explored possible conditions for awarding 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.

5.1.4 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. From a dynamic perspective, it is important to encourage the introduction of new spectrum-saving technologies. However, 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. Furthermore, despite years of research efforts, technology seems not to be ready yet (Rysavy Research, 2012; Medeisis et al., 2013;).

5.1.5 Monitoring and Enforcement

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. Implementing the LSA regime would require developing enforcement mechanisms to induce desired behaviours and ensure that new equipment comply with sharing conditions. In addition, constant monitoring is needed to verify that sharing conditions are always met (Rysavy Research, 2012).

Enforcement is key of any property rights regime and the challenge of enforcing usage property rights is not new to spectrum management. However, the transition to innovative spectrum sharing solutions and the use of technologies like SDRs and CRs brings new

challenges that need to be tackled when designing enforcement procedures for ensuring interference protection for spectrum usage rights. Furthermore, the discussion on enforcement procedures raises the question as to whether forms of private or public enforcement should be adopted (Weiss et al., 2012).

6. Conclusion

This paper is intended as a progress report on the discussion upon the LSA regime. This paper starts by envisaging a potential shift of spectrum policy focus from static to dynamic efficiency. This increasing interest in incorporating the concept of dynamic efficiency into radio spectrum policy and regulation would drive towards implementation of spectrum sharing arrangements. In this regard, this paper provides a preliminary assessment of the potential impact of LSA on dynamic efficiency.

This paper supports the implementation of the LSA regime as a complementary regulatory approach to be applied in those parts of the spectrum where incumbents do not fully use spectrum in terms of location, time and/or frequency and consequently where exclusive use is not necessary to prevent interference. This would be beneficial in terms of static efficiency as it reduces the amount of spectrum left idle. However, it is still uncertain to what extent the LSA regime would contribute to dynamic efficiency.

The LSA regime is still in an emerging phase, but has a potential that should not be held back. The preliminary assessment presented in the section above shows that some aspects of the LSA regime needs to be refined to ensure that dynamic efficiency would be promoted, in particular enforcement procedures have to be carefully designed.

Therefore, the authors of this paper would recommend further studies on the LSA regime and active discussion between policy makers and radio spectrum users, both incumbents and potential LSA licensees, to first finalise the design of this regulatory regime and then to quickly move to the implementation phase.

Although clearing spectrum from old to new uses has historically been the core element of spectrum management, 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. In this regard, the LSA regime could become a valuable element of the regulatory toolkit for spectrum management under radio spectrum policy and regulation aimed at promoting dynamic efficiency.

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