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Conference Paper

Shared access, cognitive radio and transition issues

19th Biennial Conference of the International Telecommunications Society (ITS): "Moving Forward with Future Technologies: Opening a Platform for All", Bangkok, Thailand, 18th-21th November 2012

Provided in Cooperation with:

International Telecommunications Society (ITS)

Suggested Citation: Alison, Bunel; Denis, Lescop (2012) : Shared access, cognitive radio and transition issues, 19th Biennial Conference of the International Telecommunications Society (ITS): "Moving Forward with Future Technologies: Opening a Platform for All", Bangkok, Thailand, 18th-21th November 2012, International Telecommunications Society (ITS), Calgary

This Version is available at:

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The 19th ITS Biennial Conference 2012

“Moving Forward with Future Technologies: Opening a Platform for All”

21 November 2012, Thailand

Shared Access, cognitive radio and transition issues

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Shared Access, cognitive radio and transition issues

During the last decade, consumers have largely benefited from technological advances in the telecom sector: broadband has increased, access to the network became mobile/ubiquitous, the prices of services and terminals have become much more affordable, the usage of technology is more users friendly. Today, the usages continue to evolve and the demand for bandwidth is becoming more and more important. Tomorrow, billions of objects will be connected: people (Phone, digital health, Body Area Networks), cars (Smart Cars, Intelligent Transport Systems), smart cities, etc. These connections will not be wired: most of them will be wireless. This raises the issue of overcrowding and congestion of the wireless networks.

Far beyond the technology development and under the pressure of increasing usage, the question arose as to the effective and efficient use of spectrum and through it, the issue of competition and innovation in sectors using spectrum (including mobile). Numerous studies have shown the existence of white space, "holes" in spectrum use, and thus as a corollary the existence of potential social and economic inefficiencies. Technically, technologies for managing dynamic spectrum emerge: this is for example the case of cognitive radios.

The theoretical issues underlying dynamic spectrum management are important: Should one share its spectrum with others? Under which conditions? How? What collaborative models should be used? What rule of risk sharing? What incentives for the owner of the infrastructure? Shall we move towards a new vision of spectrum regulation? How to adapt the regulatory framework for electronic communications in Europe?

After a demonstration of the inefficiency of the actual system in Europe, our paper explores the regulatory reform required in the transition towards a 'shared access spectrum'. It introduces the new spectrum management system paradigm based on recent emerging concepts, i.e. Collective Use of Spectrum (CUS), Authorized Shared Access (ASA), Licensed Shared Access (LSA), which have been developed to allow a more efficient use and management of the spectrum resource. Then, we determine objectives to reach to sustain future connected world and we analyze the different obstacles that prevent the transition. The main objectives are: dynamic and collaborative use, non discriminatory use, incentives to promote efficient use from spectrum holders. To conclude we explore the importance of competition policy in transitioning spectrum management system. This may create a tool for government intervention in the transition to a collaborative spectrum use.

1. Introduction

Our wireless world is rapidly changing. Tomorrow, billions of devices connected to internet will be able to communicate with each other and with minimal human intervention to deliver new services. This interconnected world will enable new business models in transport systems, health (such as medical appliances, phone, digital health, Body Area Networks), research, civil protection, and in environment and energy (including smart energy grids and smart metering systems). Increases in world population and wireless services demand in the next few decades are expected to cause a substantial rise in world spectrum use. Global mobile data traffic will increase 26 % annually by 2015 (CE, 2012). By then, there will be 50 billion of intelligent connected devices in 2020 according to the European Commission¹, or 100 billion, according to economist Richard Thanki (2012). These intelligent connected devices will make up Internet of Things (IoT).

Internet of Thing refers to future communication between a wide variety of sensors and control mechanisms supporting a variety of applications for people, for cars, or for cities. It is a collection of inanimate objects that can communicate with each other electronically. They can exchange information at any time (day, night, on the move), anywhere (traveling, inside and outside, with PC or not PC) and in different and varied way (PC to PC, person to person (without PC), person to object, object to object). The Internet of Things is the connection between the real and virtual world. This concept gathered steam since the development of new technologies, such as RFID, wireless sensors, nanotechnology, etc., which enable to extend the use of the Internet to real objects.

Growing spectrum needs for wireless connectivity is becoming increasingly important in the economy. The manner of allocation and regulation of radio spectrum is a key issue for the development of the Internet of Things. The Europe 2020 Strategy sets environmental objectives for a sustainable, energy-efficient and competitive economy. Wireless technologies can play a key role in meeting these objectives. The interconnectedness of different spectrum functions reflects the increasing complexity of our modern society. Economic functions (navigation, transport and energy wireless applications), ecological functions (smart grids and smart cities applications) and social functions (safety and security) are of critical importance to our modern society. Reinforcing number of frequencies allocation for one particular function may have adverse effects on others under an individual use regime. Policy-makers, as well as spectrum managers cannot afford to be ignorant about one of these functions; for this, they should implement collaborative use regime. New use and business models induced emerging technologies are expected to have profound consequences on spectrum management. Especially the impacts on use – upon which many industries depend - pose a considerable threat to current and future allocation. Bearing this in mind, spectrum managers are now analyzing the possibilities to create systems to collective use of spectrum that are more efficient to increase capacities. Spectrum inefficiencies not only affect the spectrum management strategies, but also change the nature of spectrum-related problems. To meet growing demand we should understand current regulatory barriers of the current system and establish the principles of efficient use and effective management of spectrum.

Radio spectrum is a key resource which today supports 3.5 million jobs and more than €250 billion of economic activity each year in Europe (CE, 2012). Finding additional spectrum could create more job and considerable economic gains. That is why politics are studying varied ways to maximize spectrum value. But spectrum is a complex resource; each of the four dimensions (political, economic, institutional and physical dimension) interacts with implementation of new measures, policies or architectures.

¹ Digital Agenda: Commission consults on rules for wirelessly connected devices - the "Internet of Things"

Cisco (2012) Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2011-2016

OECD (2012) Machine to Machine Communications: Connecting Billions of Devices. OECD Digital Economy Papers, no.192

2. Inefficiencies in the European System of Spectrum Management

Most of the studies relating to spectrum management agree on one fundamental issue: such static spectrum allocation policies lead to inefficient use of spectrum. How can we define “*inefficient use of spectrum*”? This section describes the varied explanations found in the literature to argue on inefficient use and spectrum management.

Fact 1: Lack of innovation

The first reason of inefficient spectrum management advanced by regulatory policy is that actual system does not promote innovation. Lack of innovation is assumption-based because it is difficult to value something which not exists. However, the famous example to justify this lack of innovation is the WiFi band which has been open because nobody wanted them, and which has allowed several innovations through a shared access model. Today 69% of smartphone and tablet traffic is supported by the WiFi (Thanki, 2012). Behind collective use of spectrum and new concepts developed by government we can see the desire to bring innovations, new business models and new wireless services, but, the current spectrum management seems inappropriate to promote the rapid development of these new technologies.

Fact 2: No flexibility

Flexibility involves the relaxation of constraints on usage and technologies. The lack of flexibility is one of the causes of inefficient spectrum management system. In fact frequency bands are attributed to one specific technology or application that is prevents optimal use. Moreover spectrum management depends of technologies dating back over one hundred years is no longer up to date or applicable. Mark Gorenberg (2012), member of the President’s Council of Advisors on Science and Technology (PCAST) working group, has recently pointed out in an interview “*we’re living with spectrum that is of a policy that was really set in motion by technology of 100 years ago, that’s led to a fragmentation of the spectrum that has led to inefficiency and artificial scarcity*”². Current issues are not only technical problems, and finding way to transition away from older technologies is equally important that finding way to transition away from older management system.

Fact 3: Underuse of spectrum

While licence-exempt bands have fostered innovation in radio technologies as well as business models, licensed bands are full of “spectrum holes”. These holes in frequency bands reflect social inefficiencies. Underuse of resource is becoming an increasingly concern for European countries and the world. Underuse of frequency bands, e.g. “white spaces”, “spectrum holes”, means that some parts of spectrum are unused at sometimes or some geographical areas (McHenry, McCloskey, Roberson, & Macdonald, 2006). There are several types of white space - white spaces which result of an unbalance between supply and demand, i.e. in rural areas offer exceeds demand, and in urban areas/rush hours demand exceeds offer; - white spaces which result of incumbent’s anticompetitive behavior like hoarding – and white spaces TV which result of regulatory failure (Werbach, 2011). However, whether of an anticompetitive, regulatory, economic or technical nature, white spaces remain economic and social inefficiencies to resolve.

Fact 4: Anticompetitive behaviors

Anticompetitive behaviors, like hoarding, concentration, or dominant position, are a great example of the system spectrum management not working efficiently. Anticompetitive behavior concerns are heightened when spectrum available to the market is limited (Crocioni, 2009). RSPG defines anticompetitive hoarding as market players individually or jointly acquiring or retaining spectrum quantities greater than

² Source: New York Time article, By JOHN MARKOFF, Published: May 25, 2012, “Presidential Panel Urges More Flexible Use of Spectrum”, Available at: <http://www.nytimes.com/2012/05/26/technology/presidential-panel-urges-better-use-of-spectrum.html?pagewanted=all>

their foreseeable technical needs, with the effect of distorting competition (RSPG & ERG, 2009). Hoarding spectrum creates entry barriers (accumulation of individual rights of use spectrum could lead to a dominant position), increase price in the downstream market (exclusive rights confer to spectrum holders a monopoly exploitation which allows them to increase price), or can be an important insurance against future state of the wireless market trend. RSPG distinguish two notions: “hoarding” and of “speculative hoarding”. Speculative hoarding, i.e. acquiring spectrum for speculative reasons, isn’t anticompetitive behavior, and speculative reasons can be the intention of providing services in a few years time with new technology. Recently, European Commission called on Member States *“to take appropriate measures, such as financial penalties, incentive fees tools or the withdrawal of rights to prevent accumulation of spectrum which may create dominant positions as well as undue failure to use acquired spectrum”*³.

Fact 5: Failure of secondary market

Spectrum secondary markets are unsuccessful and showed disappointing performance (Stanforth, 2010). In 2010, in his presentation «Why Haven’t Secondary Markets Been Successful? » Stanforth introduced reasons why secondary markets fail. Shortly after, Benkler (2011) accepts these reasons to explain why secondary markets in licensed spectrum have been anemic. Both authors identified the following as reasons for failures of the secondary spectrum market: wrongly defined economic rights; lack information on prices and products available to all participants; absent mechanisms for bringing buyers and sellers together to make transactions with a minimum of administrative costs and delays; lack of incentives against hoarding; and fear of interference. All of these prevent secondary markets fluidity and efficiency of frequency bands market.

Fact 6: Negative relation between investment and numbers of licence

Another problem related in the sector is the lack of infrastructure investment. It has been demonstrated that carriers had less incentive to invest in infrastructure when they can obtain frequency bands. Benkler (2011) argues: *“Carriers are willing to pay for spectrum at auction because it is cheaper to use public spectrum than to invest in building more private cell towers”*. In the UIT-R SM.2012 report, International Union of Telecommunication has shown inverse relationship with capital investment and bandwidths. In fact, buy frequency bands can likely to cost less than infrastructure investment. So, in addition this negative relation implies a lack of investment in mobile network. In the recent interview Martin Cooper (2012) explain that *“for carriers, buying spectrum is the easiest way for them to expand their network, but newer technologies, like improved antennas and techniques for offloading mobile traffic to Wi-Fi networks, could multiply the number of mobile devices that carriers can serve by at least tenfold”*⁴. Moreover, Thanki (2012) argues in this latest report *“To increase capacity whilst maintaining their sparse architecture, mobile networks will require increasingly large quantities of spectrum”*. The possibility to buy exclusive rights of spectrum for carriers not incentives them to invest in their networks. Carriers hold monopoly right on the exploitation of the spectrum resource and to avoid both hoarding and lack of investment incentive measures should be taken against.

3. Collective use of spectrum: some prospective issues

3.1. Efficient spectrum management system: which criteria?

Most politicians, researchers, engineers, and economists agree that shared spectrum access will be better than current individual use of spectrum. So shared spectrum access seems to be the solution to meet an efficient spectrum management system. Goal of this section is to define the key concepts behind “shared access”

³ Decision No 243/2012/EU of the European Parliament and of the Council of 14 March 2012 establishing a multiannual radio spectrum policy programme.

⁴ The New York Time, April 17, 2012, “Carriers Warn of Crisis in Mobile Spectrum”, By BRIAN X. CHEN

“collective use of spectrum” and to analyze them in light of inefficiencies mentioned before. The idea is to establish a clear and global definition of a collective and dynamic use of spectrum. What is behind all of this? What do we mean by collective use of spectrum?

Growing concern over growing need in frequency band have revived interest in sharing and collective use of spectrum for some time now. In 2002, the Spectrum Policy Task Force report recommends spectrum sharing and introduces white space sharing concept. In 2008, the Radio Spectrum Policy Group (RSPG) adopted in this report⁵ a transition approach aiming at shared access. It claimed that a *“coherent approach to Collective Use of Spectrum (CUS) can stimulate the development of sharing technologies in Europe, resulting in more sophisticated sharing possibilities and more efficient use of spectrum”*. Collective use of spectrum is based on the principle of a shared access of frequency bands between two or more users. Requirements to meet spectrum sharing are not well explicit in the literature. In 2006, Collective use of spectrum is defined, in a study for the European Commission, as *“one of three main approaches to management of radio spectrum, the other two being the administrative model, (...), and the market based...”* (p.9) that means CUS is referring to commons approach. But, later in the document, (p.22), CUS is defined as *“all spectrum management approaches allowing more than one user to occupy the same range of frequencies at the same time, without the need for individual (exclusive) licensing”*. So, this second definition open the way to new approaches, not referring only to the common approach. In this way, in 2011, Qualcomm and Nokia, in a joint response to the RSPG consultation on cognitive technologies, proposed a new approach, Authorised Shared Access (ASA), which is a mix between Command&control Model and Market- based Model, and includes in this scheme cognitive radio techniques. ASA propose shared access to IMT spectrum under a licensing regime in order to offer services with a certain quality of service, and is taken like starting point by another concept developed by RSPG in the same time: Licensed Shared Access concept (LSA). These two authorization schemes are in line with the current approaches for spectrum sharing. Unlike the ASA concept, LSA is not limited to the IMT bands, providing an alternative to permanent segmentation or refarming of a band when there is a need to find new spectrum. The LSA concept allows continued use of spectrum for the incumbent. LSA and ASA are new regulatory-based modes and show the political desire to map a transition pathway. Moreover they differ from traditional band sharing because they are not a static arrangement set by the regulator (SCF, 2012).

Whatever the new regime, it shall respect some basic criteria which define an efficient management and use of the radio spectrum resource. The following are interconnected: dynamic spectrum access needs use of agile technologies; we need to adopt no discriminatory access and improve flexibility to support innovation; and we must for example in the case where we will renounce exclusive rights of use to ensure protection against harmful interference.

A shared access spectrum offers one way in which regulatory responses and efficient use ambitions can be linked, and in this context a collaborative use of spectrum should be viewed as part of but not synonymous with efficient spectrum management. A variety of definitions of collaborative use (or collective use of spectrum (CUS) or dynamic spectrum access (DSA) that would results from this plan) have been developed. Here we suggest that a Collaborative Use of Spectrum should:

- Take actions that are compatible with the principles of fair and efficient use of spectrum ensuring that the development wireless needs of all groups within society are met;
- Make an equitable contribution towards reducing anticompetitive behaviors
- Demonstrate a high level of spectrum efficiency and use shared access spectrum and cognitive technologies;
- Adopt models that are consistent with low levels of harmful interferences.

⁵ «Aspects of a European Approach to “Collective Use of Spectrum”»

For this we define essential criterions in line with our conception of a collaborative use of spectrum, these criterions are following:

Criterion 1: "Dynamic" approaches

Static approach allows long term stable usage. Today, short term spontaneous usage is not possible. But it should be. Dynamic approach could support diverse demands, and unlimited number of independent users could share spectrum in the same range of frequencies at the same time. Dynamic spectrum access (DSA) encompass various approaches to spectrum reform like dynamic spectrum access versus dynamic spectrum allocation, spectrum property rights versus spectrum commons, opportunistic spectrum access versus spectrum pooling, spectrum underlay versus spectrum overlay (Zhao & Sadler, 2007). To summarize, DSA is a set of techniques which optimize spectrum use by making individual devices cooperate with each other. In fact dynamic approach represents an essential requirement because it implies maximizing spectrum utilization. Dynamic use of spectrum is considered today like the better way to maximize spectrum use. European Commission requires the removal of current regulatory barriers to deploying innovative radio access technologies and the active facilitation of sharing to meet the full benefits of sharing spectrum (CE, 2012).

Criterion 2: Foster innovation

The current system cannot sustain a high enough level of innovation. One of the objectives of future spectrum management system will be to foster innovation. Politics and engineers opt to use of agile radio and to allow unlicensed access in some frequencies bands. WiFi model is an example of innovation success. The European Commission recently announced it will take steps to free up radio frequencies for emerging technologies (Criterion3). Low access barriers to the spectrum will enable wireless innovation.

Criterion 3: Use of Cognitive Technologies

Technological advances have allowed evolution of the spectrum management approaches, increasing wireless services benefits and capacities of spectrum use. In the past, new technologies have lead to increase valuable spectrum like the switchover from analogue to digital terrestrial television. Today, recent technical developments are paving the way of sharing spectrum between licensed and unlicensed users. Cognitive radio system (CRS) technology, also called "smart radio," "software defined radio," "dynamic access technology" and doubtless many other terms, should allow more flexible and efficient spectrum use by identifying when frequencies are not in use by other applications. United States are the pioneer in regulation of CRS applications with their notice of proposed rulemaking and order⁶ adopted in 2003 which examine regulatory structures. Technological progress enables to share simultaneous rights of access to a specific frequency band. Increasing number of spectrum users is possible, but policymakers must foster the development of current and new technologies. One solution is to incentive actor to invest in the new technologies. This way is not easy because almost of the carriers haven't advocated for the newer technologies because they want to retain their monopolies⁷. Devices which allow to access spectrum in the same range of frequencies are often referred under the 'agile technology' term. Shared access implies to identify bands which provide the best sharing benefit and identify position of the low use of spectrum (time, duration, frequency, location). More generally new authorization classes or shared assignments like ASA, LSA, and DSA are grounded on the use of cognitive radio.

⁶ FCC 03-322

⁷ Idem Mr Reed, vice president at SAP Labs)

Today, it is essential to avoid what we could be called a "spectrum efficiency gap." Spectrum efficiency gap can be defined as the lack of spectral efficiency, that is, the difference between the current supply in frequency bands and the supply that we would have with more efficient equipment and technologies. Agile radios technologies improve both spectral efficiency and technical efficiency. However, even if dynamic spectrum access technologies still need to be improved, policymakers should be asking themselves, how avoid a "spectrum efficiency gap" in the future? For this moment, cognitive technologies i.e. cognitive radio, seem to be the best technological solution and sharing spectrum seems to be the best approach.

Criterion 4: Non-discriminatory access

A regulatory regime must to be established to ensure access to the resource on non-discriminatory terms. Principle of non-discriminatory access is necessary to provide the basic foundations for future competition in the frequency bands market. Promoting efficiency and non-discriminatory procedures for all users are necessary to foster innovation. Main objectives should be a non-discriminatory, transparent, and open access to the frequency bands.

Criterion 5: Fairness

A good allocation scheme also needs to provide fairness across devices and users. Future model shall define the form of a spectrum management model that describes efficient and fair access in open spectrum systems. Idea is to consider at the same level global needs - e.g. both developed and developing countries needs. Next policy should be combine efficient spectrum utilization and fairness.

Criterion 6: Maximizing revenue

Auctions maximize direct state revenue. Objective of maximizing revenue is always a main criterion in the future spectrum management system but the nature of income could consider differently. With a more efficient use of spectrum, revenue of innovation, of new business model and of the creation of new jobs will replace auction revenue. Revenue will not be the direct revenue of auctions but would derive from wireless services, economic growth and innovation.

Criterion 7: No deterioration of QoS

Interferences were considered a motivation of exclusive rights of use in spectrum. If we want promote a shared access we must controlling harmful interference. Applications in the same range of frequencies should not interfere with each other; minimizing interference should remain a priority. In the ever growing shared access model we see three dimensions of sharing, integrated with a diversity of options, used to share frequencies geographically, temporally and economically. Idea behind new concepts considered by CEPT, e.g. Authorised vs. unlicensed - Licensed/ authorized secondary user type (LSA concept-based) or unlicensed secondary white spaces users (PMSE in UHF band), is to maximize spectrum utilization but ensure that there is no deterioration in the quality of services provided.

Criterion 8: Flexible use and shared allocations

License auctions have allowed granting a license from 10 years to 35 years, which means that licenses are similar, for carriers, to monopoly rights allowing individual exploitation of a frequency band during this long-term period. Moreover, with the strong certainty of renewal following expiration, competition through auctions is one-shot. So even if long-term auctions are necessary to enable long-term investments in the networks, exclusive rights are not desirable to promote competitive and efficient use between users and revoke them to allow shared access between primary and secondary users with incumbent acceptance could promote efficient use of spectrum. However, incumbent users will need to have confidence that dynamic sharing of the spectrum will not cause harmful interference to their existing systems.

3.2. Advantage of collective use vs. actual system

Three different research reports recently published have shown the growing interest and advantages of sharing spectrum compared to the actual system.

- As of February 2012, the SCF associate report “Perspectives on the value of shared spectrum access” shows the significant net economic benefits of additional shared spectrum resources for wireless broadband for the EU;
- As of June 2012, in this report “The Economic Significance of Licence- Exempt Spectrum to the Future of the Internet”, Thanki argues that an increased, globally harmonized supply of licence-exempt spectrum is necessary to meet three main connectivity challenges. These challenges are (1) Delivering universal and affordable broadband access; (2) Enabling the machine-to-machine networks of the future; and (3) Ensuring that communications networks are resilient, particularly in the face of natural and manmade disasters;
- And finally as of July 2012, the President’s Council of Advisors on Science and Technology’s Report untitled “Realizing the Full Potential of Government-Held Spectrum to Spur Economic Growth” concludes that the traditional practice of clearing government-held spectrum of Federal users and auctioning it for commercial use is not sustainable, and proposes to pass from scarcity to abundance without a loss of revenue to the Federal Government, but a plus revenue thanks to economic growth and innovation. This report open the way to realizing a new spectrum architecture which could “multiply the effective capacity of spectrum by a factor of 1,000”, and argues that the essential element of this future spectrum architecture should be shared use, not exclusive use.

Collective use of spectrum through a shared access seems to be better than actual system. The question is: how collective use can resolve current inefficiencies in actual system? Figure 1 shows how spectrum sharing will allow to resolve current inefficiencies?

Figure 1: Advantage of collective use vs. actual system

Assessment	Current system management	Future system management
Lack of innovation	Exclusivity Static allocation prevent the dynamics of innovation Long procedures	Growth of unlicensed bands will allow to support Internet of Things and others many applications
No flexibility	Specific service for specific frequency and specific technology	Choice of technology and service Large blocks of spectrum shared among compatible but not necessarily identical services
Underuse of spectrum	Fragmentation of spectrum Discontinuity and exclusive use Regulatory failure	New technologies allow to share spectrum and detect unused frequency bands
Anticompetitive behaviors	Individual use Monopoly right on the resource (false competition with auctions)	Incentive measures to shared access spectrum Introduce concurrence, new entrant in the oligopolistic market
Failure of secondary markets	Complex right of use and no flexibility No fluidity No incentive to resell spectrum due to the dominant position of carriers	Dynamic spectrum trading amongst small cognitive users Dynamically trade like stock market Dynamic double auctions
Lack of network investment	No competition (long term license renewable) Inefficient duplication of networks	Sharing infrastructure Merge networks

4. An Overview of Scenario-Based Studies: transition issues and regulatory challenges.

Some of the above-mentioned studies include scenario-based analysis but there is yet no academic work which compares the techniques used in these studies. The aim of this section is therefore to examine these studies in more detail in the context of the development of spectrum access system.

Profound changes are underway in the global spectrum management system. A substantial overhaul and review of current use and allocation practices is desirable. The set of inefficiencies and access constraints experienced by independent users are now encouraging extensive reviews of the current spectrum market model: new solutions are expected, but which solutions? Regulating is about creating new market structure with good characteristics. First issue is to ensure a good transition towards the targeted market structure by implement the correct framework. Currently, we can't know where the transition of spectrum management system will stabilize it, but we can study several possibilities of emerging new architecture and analyze them in light of new needs to allow a regulatory vision. Spectrum shortage results from the spectrum management policy rather than the physical scarcity of usable frequencies, so main questions become, which new spectrum architecture and management adopt to avoid spectrum shortage?

Having explored inefficiencies of current system and looked at how shared access can improve this suboptimal situation, we now consider three scenario options. The scenarios capture different visions and way as related in various recent reports as mentioned above. These scenarios are used to summarize a range of offered solutions for the regulator.

4.1. Toward a new market structure

The introduction of market mechanisms in the spectrum has shown the need for designing this market. This part first introduces three scenarios which discuss different design concerning spectrum market design. We conclude this paper with different possibilities relative to the design of spectrum marketplace which could be a more or less flexible and efficient instrument. Three scenarios appear in the literature like a solution to resolve spectrum scarcity and allow future needs. The first is the less disruptive. It concern finding additional bands for unlicensed use and to pass from traditional regime to a new regime promoting shared use. The second is based on the American scenario introduced by PCAST in July 2012 and which is based on "rental" and "lease" options to foster the promotion and validation of highly innovative ideas through short term and low cost access to spectrum⁸. And the third is researcher or engineer scenario which opts for an opportunistic use of spectrum.

4.1.1 European scenario: Additional shared spectrum resources

Scenario description

The idea is to allow different users to share a given frequency band through Collective Use of Spectrum (CUS) model or through Authorized Shared Access (ASA) / Licensed Shared Access (LSA). The European Commission seems to be in the line of direction to foster the collective use and the shared use. Commission has proposed a common approach to identify beneficial opportunities to share spectrum (BSO)⁹. EC promotes the shared use of

⁸ http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast_spectrum_report_final_july_20_2012.pdf

⁹ http://ec.europa.eu/information_society/policy/ecomm/radio_spectrum/sectorial/shared_use/index_en.htm

Brussels, 3.9.2012, COM (2012) 478 final 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.

spectrum resources in the UE, arguing agile technologies are desirable to share spectrum more efficiently. Additional spectrum resource can be found by sharing access or by freeing-up bands to unlicensed use.

First objective is finding additional shared spectrum resources for wireless broadband¹⁰. This additional resource could create significant net economic benefits (CE, 2012). In fact broadband has become a key priority of the 21st Century. With growing need in access internet it become more and more difficult to meet growing user demand in wireless broadband. EC argues for *"a coordinated European approach to sharing spectrum will lead to greater mobile network capacity, cheaper wireless broadband, and new markets such as tradable secondary rights for a given spectrum allocation"*¹¹. Two main measures is proposed by EC:

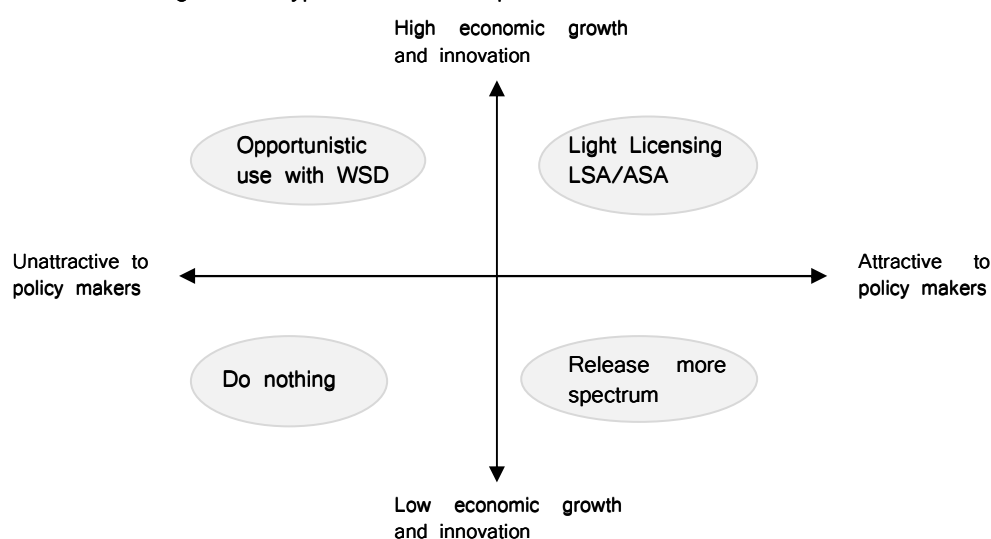
- Encourage national regulators to monitor and extend the harmonized license-exempt bands in their markets
- Foster consistent regulatory approaches across the EU for shared rights of use.

By then, three solutions will allow Europe to pact with shared access, these solutions are finding additional bands to unlicensed use, light licensing or opportunistic use. The first is based on the necessity to promote wireless broadband. In an independent report for European Commission the value to the European economy of an increase of between 200 to 400 MHz in shared access spectrum for wireless broadband is estimated significant returns in net increases in GDP by 2020¹². The second exploits the benefits of authorizing licensed shared access – e.g. light licensing through LSA and ASA concepts, and the needs of new tools for shared use in the internal market. And the third is a more complex solution implying behavioral changes. It implies no-cooperation between licensed user and unlicensed users that is why it is more complex to implement in the light of harmful interference management and cooperation between primary and secondary users.

Obstacle

Incremental approach of identifying and releasing new bands for mobile broadband is probably unsustainable in long term (Marsden, 2012). In fact a clearer vision should be define and must be flexible given the long-term horizons. Obstacle will be to deploy technology equipment to support efficient use and to identify dynamically underused spectrum. Moreover, NRAs should implement sharing rules and sharing coordination for creation of broad ranges of frequencies and to avoid fragmentation and discontinuity use of spectrum.

Figure 2: Types of Shared Spectrum Access (SSA)



¹⁰ http://ec.europa.eu/information_society/policy/ecom/radio_spectrum/_document_storage/com/com-ssa.pdf

¹¹ Digital Agenda: Maximising radio spectrum efficiency by sharing it

¹² See: Perspectives on the value of shared spectrum access, SCF Associates, February 2012 (SCF 2012).

Other issues like interoperability and roaming, spectrum efficiency and cross border frequency coordination must be resolved to meet international harmonization (SCF, 2012).

Legal

Here we distinguish “releasing and reframing spectrum” solution to “sharing spectrum under LSA / ASA models” solution. The former is not an alternative to the latter, but a complementary source of spectrum resources for European Union. LSA allow to incumbents to have reassurances and legal certainty to agree with the shared use of spectrum.

Figure 3: Type of shared spectrum access

Type of Shared Access Spectrum (SSA)	Focus and approach
Do nothing Focus on the stagnation of spectrum sharing and no regulatory intervention to avoid saturation of spectrum and this various negative effects	Focus on: <ul style="list-style-type: none"> ▪ No change in regulation ▪ Keep today's spectrum conditions of use Approach: No change
Releasing and reframing spectrum Focuses on meeting more spectrum frequencies for wireless broadband in unlicensed bands rather than overall future growth and wireless-connected society challenges.	Focus on: <ul style="list-style-type: none"> ▪ Struggle to make new spectrum available, released some existing bandwidth for wireless data use ▪ Create new unlicensed bands for a shared use ▪ Reevaluate spectrum allocated to the public sector many years ago Approach: Regulatory effort, when deciding which bands to release, how and when
Light licensing under LAS / ASA models Focus on the need to support growing wireless-connected society and Internet of Things (IoT) through low spectrum access barriers and the creation of more license-exempt shared bands	Focus on: <ul style="list-style-type: none"> ▪ Missing element in the internal market framework ▪ Need reassurance and legal certainty to agree with shared use of spectrum ▪ Grant shared spectrum access rights ▪ Guarantee quality of service requirements Approach: Regulatory changes, technological change, behavioral change
Opportunistic sharing Focuses on secondary sharing with no-cooperative use. It leads to easements and opportunistic use, so implies behavioral change and mechanism change (opportunistic secondary use).	Focus on: <ul style="list-style-type: none"> ▪ Use spectrum when the primary user is not doing ▪ Foster entry of new players in the market, foster innovation and new uses ▪ Require to mandate dynamic sharing of radio frequencies Approach: Mechanism changes, behavioral changes, use changes

The first two types of SSA (releasing and light licensing) assume that economic growth is possible with significant shared use of spectrum. The opportunistic sharing approaches put an emphasis on enabling more efficient use through technological change and no-cooperative behavior whilst the light licensing and releasing spectrum approaches focus on meeting demand through rules and contractual agreements between users.

4.1.2 American scenario: Short, medium and long term spectrum access

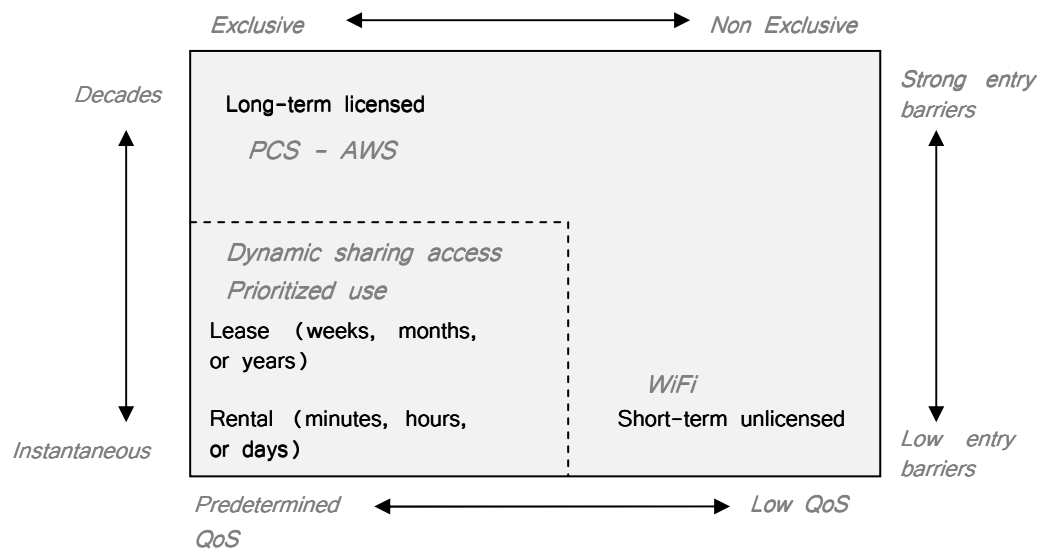
Scenario description

This scenario is based on the acknowledgment of unsustainable clearing and reallocation of Federal spectrum due to the high cost and lengthy time to implement (PCAST, 2012). Government calls for a new spectrum architecture relying on sharing rather than exclusivity and which allow fulfilling two main objectives: (a) create the first shared-use spectrum superhighway (b) identify 1000 MHz of Federal Spectrum in which to implement new architecture.

In this report President's Council of Advisors on Science and Technology conscious of the necessity to move to a dynamic sharing model proposes new range of spectrum application models. This wider range of options, concerning duration of authorized spectrum access, seeks to foster a vibrant marketplace. In fact, acknowledgment of two extreme durations of authorized spectrum access (longer-term licenses or unlicensed access) shows a willingness to add a variety of "rental" and "lease" options to foster both short term and low cost access spectrum.

Thus, new spectrum management principles combine new short and medium term spectrum license models with the current licensed and unlicensed models. Adding two new possibilities will enable to sustain new spectrum use i.e. phone, body area network, smart grid communication, Smart Cars, Intelligent Transport Systems... These licence model approaches are based on dynamic sharing spectrum between users.

Figure 4: Types of access spectrum



Obstacle

Regulators do not know the potential level of demand for short term and medium term for these new ranges of spectrum acquisition. System should support diverse demand that vary over time e.g. traditional long-term stable usage and short-term spontaneous usage¹³. Consequence of these new models is that the structure of revenues should change, but PCAST expectation is on the value of products and applications.

Legal

Scenario implies creation of large frequency bands and use of "smart," "agile," or "cognitive" radios and regulatory framework should provide sharing technology and implement a database system.

¹³ For occasional events like sports and conferences which will create a peak of demand for a short period of time.

4.1.3 Engineer scenario: Real time use of frequency bands

Scenario description

New technologies open up new opportunities for efficient use of spectrum, and today property rights appear incompatible with future wireless-connected world, competitive mobile market, and innovation. Economists have recognized the benefits of a real-time use of spectrum but they have often been puzzled about how technology and coordination will allow this. However, improving spectrum market efficiency is one of the most important challenges in the wireless telecommunication sector today, and trend seems to be moving toward a “real-time allocation” (based on market mechanism) with a dynamic spectrum allocation governed by a central entity - i.e. “Spectrum Broker”. Spectrum sharing is seen as an unproven concept by many actors but for engineers some of the foundational technologies are already in place – i.e. Database management of spectrum - Small-cell technology to facilitate spectrum sharing – or database to allocate spectrum dynamically. Moreover recent system have been developed enabling real-time dynamic spectrum allocation and creating a transparent market for recycling surplus spectrum¹⁴.

In the economic literature, real time market has often been viewed as an optimal solution facing spectrum shortage, i.e. *“Agile radio users could negotiate long-term use of a band (“forward contract”) or negotiate band use at the moment of use (“spot market”)”* (Faulhaber & Farber, 2003) - *“spot and futures markets for spectrum access would emerge (...) establishing multiple and competitive clearinghouse for different spectrum bands would add still further openness”* (Noam, 1998, p.19) - *“spot market for spectrum would be a more flexible an efficient instrument”* (Cramton, 2012) – *“A first important refinement (...) would have replaced them (auctions for big swaths of spectrum) with spot markets in spectrum clearance rights”* (Benkler, 2011), and, in technical literature many papers have studied dynamic spectrum use models, i.e. study of a real time spectrum markets which permit users to exchange spectrum use and involve cooperative sharing of licensed spectrum between existing licensees and new users who would pay for permission (Marcus, 2005) – study of a real-time secondary spectrum utilization which can follow a negotiated or opportunistic access strategy (Attar & al. 2008) – Another study proposes real time secondary market in spectrum (Peha & Panichpapiboon, 2004). This growing interest about real-time access constitutes the starting point of this scenario. Over the next twenty years many improvements in flexible hardware will be introduced and will allow organizing the spectrum market much like the electricity market. So, policy makers must consider more seriously the possibility of a real-time spot spectrum market and establish rules that will result in improved implementation of it.

Real-time spot spectrum market will require transparency, real-time information on prices, and motivated buyers and sellers who will be willing to trade. This market structure will stabilize the variation in utilization of spectrum bands allowing dynamic white space use. In the case where real time option is limited to secondary market, one spectrum broker could behave as an intermediary for both pooling the resources and matching the supply and demand. Spectrum is an ideal resource for spot market, this good does not need to be product and stock, and it is instantaneous available if nobody uses it. However since spectrum cannot be stored, system should maintain an ongoing balance between supply and demand to avoid blackouts.

¹⁴ CFRS launches real-time spectrum monitoring and network network <http://www.cfrs.com/news/2012/4/cfrs-launches-real-time-spectrum-monitoring-and-network>

Obstacle

Many obstacles must be resolved to move toward a real-time use of resource. These include: significant transactions costs (the transaction costs of owners should be less than the value of the spectrum to lessors) – defining a price for use - enable devices for spot markets, e.g. improve hardware, especially the handset to enable real time spot market - anticipating business models surrounding spectrum sharing – and overcome the fear of change, fear for many carriers to lose their current profits and position.

Legal

The real-time market could be a spot market to procure spectrum and manage congestion in the real-time. This market provides frequency band access to balance instantaneous demand. The process of restructuring a spectrum market therefore involves some basic tasks needed to build the infrastructure of a competitive market. Key exhaustive aspects of a competitive spot spectrum market are:

- The separation of monopoly activities and those exposed to competition. European mobile markets are oligopolistic markets today. Oligopoly is suboptimal because this kind of market does not compete with each other at European level but within each country on the one hand, and on the other hand the market is dominated by a small group of companies to ensure distribution of the service market. Mobile network operators (MNOs) possess infrastructures, spectrum and most of all a direct relationship with final users. Most of the time, they are vertically and horizontally integrated firms. Entry in the market appears difficult even in the event of the availability of the new band of spectrum (digital divide). Moreover in most markets there are today multiple operators with overlapping coverage, so there is a need to consolidate the basic mobile coverage and focus on sharing infrastructure. Network sharing could be the solution e.g. one optimal network developed by an independent entity (public or private), and the theoretical issues behind this concept are important: What to share? Whom to share with? Where to share? How to share?
- The tariff system for both non-exchange trade and exchange operating a spot market should be characterised by the following: - congestion level – time of use – duration – geographical area – quality of frequency band
- A system for avoiding spectrum congestion
- European rules for maintaining the real-time balance between demand and supply
- An access to frequency bands on equal terms for all market participants, and, low transaction cost

To conclude, real time spot markets exist for electricity, where the time scale is as small as a few minutes. There is no real time spot marketplace for frequency bands. Real time spot spectrum market could be operated over the Internet. It will allow meeting supply and demand and negotiating prices within milliseconds and deliver wireless services to the customer just a few minutes later. The spot market for spectrum will allow using the same auction-style bidding systems used by stock markets.

A spectrum clearing house could facilitate allocation between users and need to be implemented to facilitate the centralized approach. In fact, centralized clearing houses can help make markets thick and uncongested, and avoid unraveling (Roth, 2007). Thus there would an opportunity for licensed to maximize their profits by selling the current unutilized spectrum.

4.2. Challenges on the path to new architecture

These various scenarios propose new market architecture and will need to implement a new approach to spectrum policy. The definition of a clear and consistent market regulation framework by the EC appears to be a fundamental step. In all case, regulators should deal with the spectrum sharing concept. Spectrum sharing has already been advanced from concept to reality in 2008 in the USA when the FCC has ruled that unused wireless American TV spectrum be open for free and unlicensed use¹⁵. The transition toward a new architecture will imply main regulatory changes and transition challenges. Figure 4 summarizes different obstacles and regulatory response according market architecture.

Figure 4: Scenarios issues and regulatory challenges

Scenario	Market architecture	Obstacles	Regulatory response	Level of transition issues
Scenario 1: European scenario: Additional shared spectrum resources	Market based model and open access	<ul style="list-style-type: none"> - Establish a mechanism to manage the sharing - Finding additional bands - Regulators should grant shared spectrum access rights - High cost of clearing and reallocating spectrum 	<ul style="list-style-type: none"> - Share underutilized spectrum - Keep long-term license to support long-term investments - Implement ASA / LSA approaches - Make available megahertz (MHz) of new spectrum for wireless broadband - International harmonization 	Low
Scenario 2: American scenario: Short, medium and long term spectrum access	Trial licensing models	<ul style="list-style-type: none"> - Create three term licensing: Long-term licensing, medium-term licensing, short-term licensing - Collect revenue 	<ul style="list-style-type: none"> - Create intermediate durations, depending on the application, and QoS access - No automatic right of renewal - Short term auctions to provide temporary access to spectrum that is not being used. 	Middle
Scenario 3: Engineer scenario: Real time use of frequency bands	A real time spot market	<ul style="list-style-type: none"> - Long term auction with strong expectation of renewal following expiration - Level of hardware flexibility - Fixe real time price which will reflect the value of the frequency at the specific location, congestion level and time of delivery 	<ul style="list-style-type: none"> - Creating an incentive system - Encourage government spectrum users to retrofit their current systems to allow sharing in the near-term - Incent users to replace or move of systems to operate in the new architecture - Spectrum broker, spectrum database, 	High

¹⁵ FCC 08-260, Second report and order and memorandum opinion and order, Adopted: November 4, 2008

5. Conclusion

Over the last years there has been a growing awareness regarding spectrum management issues and the necessity to share spectrum. The scarcity of spectrum furthermore adds to the pressure on existing regime. Yet development of alternative spectrum use technologies and alternative visions allow to envisage a change. Worldwide needs for additional spectrum and spectrum sharing lead all countries to seek to move in a new innovative direction which encompasses new technology and policy challenges for a better use of the resource (Ofcom, 2012). Today policy makers and economist must opt to the level of this challenge and possible strategies to accelerate and guide such transition. In this context, spectrum transition management could be defined as a long term global and collaborative process to realize a different spectrum system based on shared access and to realize common criteria of an “efficient spectrum management system”. The main drivers for this transition are: (a) public and private concerns about scarcity and new needs, (b) government policies (new models, research and innovation programs¹⁶) aimed at a shared spectrum access, (c) wireless industry innovation strategies (Internet of Things, Smart grids, etc.), and (d) technological innovations (cognitive radio, small cells, sensing, geo-location databases, etc.). It is difficult to predict which technology will win but cognitive radio (CR) seems to be the best among existing technologies. CR will be able to allow spectrum sharing needed to meet supply and demand. The “agile technology” niche is likely to expand, because it is pushed by powerful companies, embraced by politics, and promises efficiency improvements of the existing spectrum management system. However incumbent acceptance and political will be the greatest uncertainties for this new way.

We have seen exclusive frequency assignment should not be a reason to accept underutilized capacity which could be shared. What are some of the policy implications? First it is not to stop exclusive rights, but finding additional spectrum bands to open up access and removing regulatory barriers to the use of spectrum for broadband in several bands. However freeing up spectrum is a costly and lengthy process so it may be combined with a further evolution in policy. LSA and ASA are examples of evolution.

Second, electronically rent or lease spectrum for periods of time as short as seconds coupled with long-term licenses and unlicensed bands should be expand the sharing spectrum concept and enable the development of innovative applications over the next decade.

Third, real-time spot markets should be encouraged to rent or lease spectrum to service providers via a spot market run by spectrum brokers. This market for spectrum should be separated from the market for wireless services. A real-time spot market will allow efficient and flexible allocation of spectrum, and low entry barriers for wireless service providers. So policy makers should be adopt an approach and should be ready for the next step e.g. the wireless-connected society.

A shift toward a new spectrum management requires to deal with uncertainties through the use of scenarios. So the key step is to choose a scenario and to interest in how to achieve an efficient spectrum management. Scenarios imply trade-offs between economics benefits, political and technical development. The requirement is to have a long-term orientation which could be used for short-term policies.

¹⁶ European Commission: ICT Research in FP7, <http://cordis.europa.eu/fp7/ict/>

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