Cognitive Radio: aligning the regulatory environment with the technology, a business case perspective

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Abstract: This paper proposes to use the perspective of the business case to deal with the alignment between the introduction of new technology and the regulatory environment. Although this perspective can be used more generally this paper deals with this perspective in the context of the alignment between the introduction of Cognitive Radio technology and the regulatory environment for the use of the radio spectrum. The value of this approach is demonstrated through a review of historical cases of changes in radio spectrum management and introduction of new (radio) technology. It proposes to use this approach to explore Use Cases within a Community of Practice as a possible way forward for coordination between the actors involved to allow successful deployment of cognitive radio and to realise the goal of improved utilisation of the radio spectrum.

Keywords: Cognitive radio; technology introduction; regulatory environment; coherence; business case

1 Introduction

Cognitive Radio (CR) is a promising innovative technology that can be used to improve spectrum utilization. Especially the ability of a Cognitive Radio to provide access to spectrum that is already assigned to other user(s), but partly unused when considered on a time or geographical basis holds an interesting promise. This CR capability is considered as highly valuable for the introduction of new radio communication services, as essentially all (usable) radio spectrum has been allocated and assigned. However, there still is a large degree of uncertainty associated with CR that will have to be mitigated before successful, large scale deployment may be expected and the potential economic and social value can be realised.

One of the reasons for this uncertainty is that the current regulatory model is not compatible with this new technology. In the current model, radio spectrum is divided into fixed and non-overlapping blocks, which are exclusively assigned to different users, services or wireless technologies. Regulatory provisions are needed to align the regulatory model with the new capabilities of CR technology of more efficient and flexible utilisation of the radio spectrum.

The dilemma that governments are now facing is that, since the liberalization, prevailing policy suggest a technology neutral assignment of radio spectrum, while enabling the

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deployment of a specific technology, i.e. cognitive radio technology, is of public interest to achieve more efficient utilisation of the radio spectrum. It appears that in this light, regulation to allow deployment of a specific type of CR technology in parts of the radio spectrum that would otherwise be underutilised or not used at all is justified (Lemstra, Anker et al., 2011).

As CR encompasses a very versatile set of technologies, the subsequent challenge governments are facing is the choice among some of the more fundamental features of CR technology, such as the technology used to make a CR aware of its radio environment and the band in which the CR is allowed to operate. In making these choices there is a need to match the regulatory environment with a specific set of capabilities related to CR technology.

The literature on technological change and institutional alignment, including the research strands focussing on co-evolution and coherence, is not very clear in how to ensure that the introduction of new technologies will be accompanied by a set of institutions supportive of its functioning.

This paper proposes to use the perspective of the entrepreneur to deal with this issue of alignment. Although this perspective can be used more general this paper deals with this perspective in the context of the alignment of Cognitive Radio technology with the regulatory environment for the use of the radio spectrum. Eventually it is through the actions of the entrepreneurs, individually and collectively, that the goal of more efficient radio spectrum utilization is realized.

This contribution is structured as follows. It starts with the general concept of ‘coherence’ between technology and institutions. It expands this concept with a business case perspective as a means to match institutions with new technology. The value of this approach is demonstrated through a review of historical cases of changes in radio spectrum management and changes in technology. This is followed by applying the business case approach in an assessment of the so far best known business case for the deployment of CR technology, the BuC for white spot access in the TV bands.

It is proposed to use this approach to explore Use Cases within a Community of Practice as a possible way forward for coordination between the actors involved to allow successful deployment of cognitive radio and to realise the goal of improved utilisation of the radio spectrum.

2 Researching technological change and institutional alignment

The exploitation of the radio frequency spectrum for the provision of products and services such as communication and broadcasting services can be regarded as a complex technical system with very specific technical, economic and political characteristics. Complex technical systems pose challenges to the institutional governance of those systems. The application of traditional market oriented solutions is often not possible due to severe forms of market failures. This includes both negative and positive external effects in the form of collective good problems, increasing returns and network effects. Moreover, these systems often serve major societal objectives. Hence, politics are directly or indirectly involved in monitoring or even controlling the performance of the services provided by these systems. Since the liberalization of the radio spectrum, electricity, air transport and other infrastructures, these systems are governed by a market orientated approach supported by

regulations in order to perform satisfactorily, in economic, societal and technical terms (Finger, Groenewegen et al., 2005).

The liberalization process was aimed at the introduction of markets to create competition and increase efficiency, quality-of-service and customer satisfaction. Although the liberalization as such was done from a non-technical perspective, it had its effect on the evolution of the technical system, the sector and the industry. A good example of this is the development of mobile telephony (Finger and Varone, 2009).

Nelson (1994), Tunzelmann (2003) and others have shown that this linkage between changes in institutions and changes in technology runs in both directions. If technology changes, there is a need to have institutions compatible with and supportive of them. The ones suitable for an earlier set of fundamental technologies may be quite inappropriate for the new (Nelson, 1994). This linkage between changes in institutions and changes in technology has become know as co-evolution. Two or more units in a system are said to co-evolve if they both have a significant causal impact on each other (Murmann, 2003).

This concept of co-evolution explains the need for changes in institutions if technology changes and vice versa, but this co-evolution does not shed any light on the characteristics of the institutions appropriate to a particular technology (Saviotti, 2005). Let alone, how institutions should be changed as a consequence of changes in technology.

Finger, Künneke and Groenewegen (2005) brought this concept of co-evolution one step further. They positioned that the economic, social and technical performance of infrastructures is dependent on the degree of "coherence between the technical and the institutional coordination". Non-matching institutions and technologies affect performance negatively. They identified four technical functions that need to be performed satisfactorily for a given infrastructure to function properly: interoperability, interconnection, capacity management and system management (Finger, Groenewegen et al., 2005).

Although they found a need for coherence between technology and institutions, the concept of coherence does not provide a full answer to the question how institutions should be changed in response to changes in technology. It is a concept that can be used to analyse the (mis)match between a given technology and the institutional arrangement surrounding it in a static comparative approach.

In an effort to try to answer the question above, we start with taking a closer look at the relationship between technology and institutions. This relationship is not direct, technologies do not shape institutions and institutions do not craft technology. It is in the interaction between actors that technology will have an influence on institutions and vice versa.

In this respect, Koppenjan en Groenewegen (2005) introduce the notion of the unruly nature of technology. By this, they mean that technology is important but does not determine the governance structure in its totality. Technology can drive a transformation towards a new governance structure, but there remains a range of possible institutional arrangements. It is a matter of choice by the multiple (groups of) actors which governance structure will be in place. This choice is influenced by both technology and the surrounding institutional setting, such as market forces and government regulation (Koppenjan and Groenewegen, 2005).

This interaction between technology, institutions and actors for complex technical systems is shown in Figure 1.

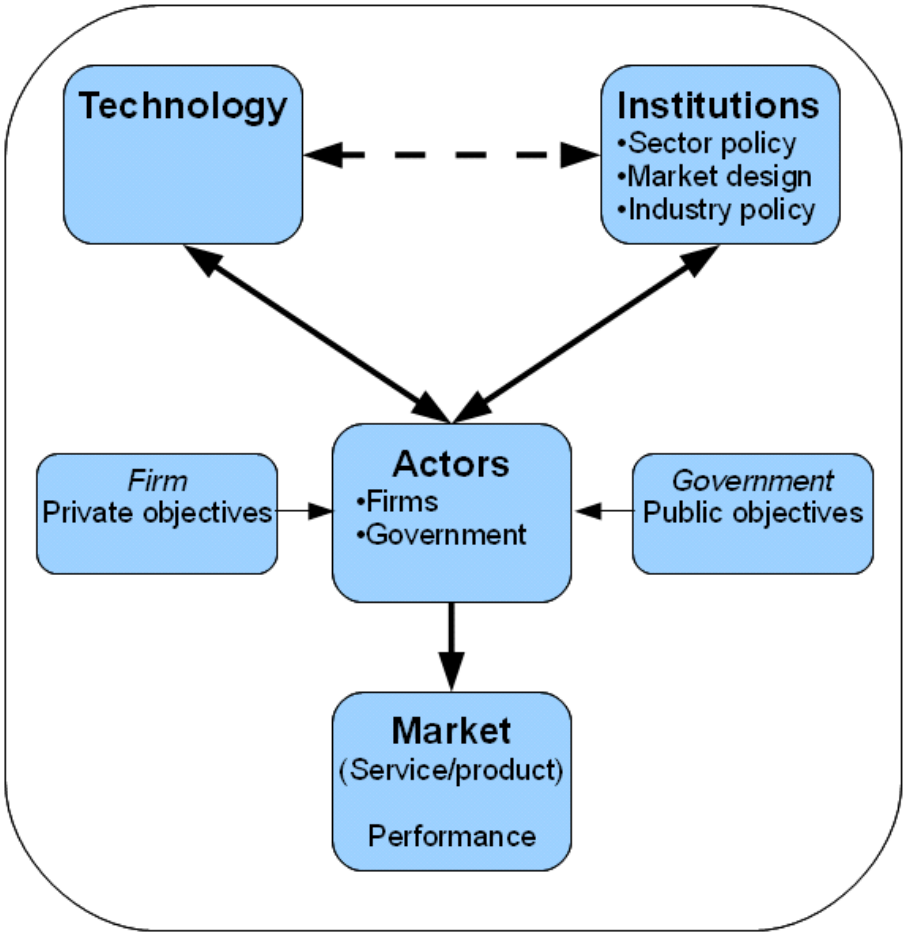

Figure 1 A dynamic model of interaction between actors, institutions and technology.

The actors will intentionally enter in interaction among each other to try to achieve specific outcomes. In their interaction the actors are guided by the structure, being both institutions and technology. They will try to influence and change the structure if this contributes to the realization of their objectives. In the interaction among actors there is not necessary an overall goal. Each actor has its own reasons to participate and is performing behaviour in order to pursue its own interests (Scharpf, 1997).

Two important actors in our case of technology changes and institutional change in complex technical systems are the government and the entrepreneurial firm. These two actors have different objectives. In a somewhat simplistic view of the world, governments have since the liberalization above all an objective of economic efficient use of the complex technical systems. This is accompanied by societal objectives, such as universal service delivery, and in some cases also by industry policy. Governments rely on a market design and associated regulations to serve this mixture of economic and societal objectives. In the case of mobile communications, radio spectrum policy is used to create a market for mobile telephony. Specific auction rules may be used to allow new entrants and to define the number of players on the market. Specific obligations are attached to the licenses to serve societal objectives, e.g. a coverage obligation.

Firms on the other hand have a completely different objective. They want to invest in (new) technology to develop products and services with the aim to maximize profit. In general

firms will only decide to invest in new products and/or services if they can expect a future return. These investment decisions are driven by three major considerations: (1) the prospective demand and willingness to pay for new products and/or services; (2) the magnitude of the investments required; and (3) the degree of risk or uncertainty involved.

The profile of the business case, in terms of depth of investment and the recovery period required, will influence the ability to obtain the necessary (external) funding. As such the business case is especially challenging for service provisioning that requires a huge up front investment, e.g. an infrastructure roll-out to provide mobile telephony. In these cases the right to exploit the radio spectrum or any other infrastructure which requires substantial up front investments, over a significant period of time and on an exclusive basis will contribute to the willingness of entrepreneurs to invest, as it may make the business case more viable (Lemstra, Anker et al., 2011).

The government and the firm are highly interdependent in the realisation of their objectives. The institutional arrangements that are set up will have to give the certainty to entrepreneurial firms to invest in new technology and the exploitation thereof. If as a result of profit maximisation considerations firms decide not to use the system as intended, the government fails in realising its governance objectives.

In setting up the institutional arrangements, governments will steer technology and possible business cases into a certain direction. Ostrom (1990) showed that the specificities of the entry and authority rules will favour certain types of usage over other types of use.[2] This is also true the other way around, certain types of perceived usage will require particular entry and authority rules.

Hence, decisions made by governments on the market design and associated regulations will have an influence on the viability of possible business cases. For example, decisions made in spectrum policy on the amount of spectrum allocated, whether the spectrum is made available on a license exempt basis or not, the number of licenses issued, the roll-out and other obligations attached to the licenses and the award mechanism for the licenses (e.g. an auction or a beauty contest) will all influence the required investments and the possibilities to exploit a certain business case. This is quite well demonstrated by mobile communications (GSM) that could flourish under a strict licensing regime and Wi-Fi that could develop after a license exempt regime was set up.

Governments will need to be very well informed to make the right decision in order to let the intended business case flourish. Lessons learned from the past seem to suggest that a too “pushy” approach from governments may be counterproductive and retard or stall technological development (Haug, 2002). Governments will need to take decisions that are not only in line with their own goal(s), but also make it possible for entrepreneurs to realize their goals. After all, it is through the actions of the entrepreneurs, individually and collectively, that the governmental goals will be realized. Use of the new technology in such a way that both the government and the entrepreneurs can realize their goals is what we call a “sweet spot”. A “sweet spot” is only possible if the use of certain technology and the associated institutional arrangements are aligned in such a way that the intended business opportunity can be realized.

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[2] Ostrom made this observation in the investigation of common pool resources. As Künneke and Finger (2009) show the problems associated to infrastructures are quite similar. They argue that infrastructures (including energy, communication, transport, and postal services) can be perceived as common pool resources providing essential services to society.

Hence there is need for cooperation between the actors to find a business opportunity that can serve the public objectives of the government but at the same time is viable enough for the firm to realize its private objectives. A possible way forward to find this "sweet spot" is the exploration of possible Use Cases. The government can facilitate this review through the initiation of close cooperation between the equipment industry, the service providers and the government itself.

There are several reasons why the government is in a good position to take the first step in this cooperation effort. First of all, as stated, the government has a clear goal in mind for the use of this new technology. However, for the realization of this goal it is dependent on the industry and service providers. Secondly, the government has a greater degree of freedom. The government can directly influence the developments that are taking place in technology as well as developments on the market through institutional arrangements and industry policy. Thirdly, regulation is about giving certainty. Not only by restricting usage, but also by enabling and facilitating innovative use (Baldwin and Cave, 1999; Anker, 2010a).

A Community of Practice (CoP) can be used to explore Use Cases and to find a "sweet spot". The participants of this CoP should be well aware of the influence that both certain new technologies and the associated institutional arrangements will have on certain types of usage.

The exploration of Use Cases within a CoP will require a few steps to take. First, one has to realize that the use of new technology will come with additional costs. The questions to be posed are: What is the added value of using this new technology? Is the intended business case attractive enough to recoup the necessary investments in this new technology? If there is an added value, the follow on question to be answered is about the relation between the use of the new technology and the existing usage of the complex technical system. Does the new technology have an effect on existing usage of the complex technical system? In other words, how can the interoperability within the existing system be assured if this new technology is used? Thirdly one has to asses possible implications of the intended use of this new technology on the institutional arrangements and the other way around. Are there any requirements that the intended business case puts on the institutional arrangements, e.g. a need to have assurances about a time span over which the intended service can be provided that is long enough to recover necessary upfront investments? When a "sweet spot" is identified, the government should set up the associated institutional arrangements to enable it.

3 Evidence from the past

Evidence for the relevance of a business case orientated approach can be found in the coordination of radio spectrum use in the past and the development of radio spectrum regulations resulting from these coordination efforts. Until now, most of the advancements that have been made in the coordination of radio spectrum usage were triggered by problems with a specific service. This will be illustrated in the four cases to be discussed in the following subsections. Given the limited scope of this paper the narratives are in summary form. Each case is concluded with an assessment that places the observed coordination efforts in the relevant business case context.

3.1 Marconi and the birth of spectrum management

At the time of Marconi, spectrum was like an open and untouched pasture. Marconi was the first to enter this pasture to exploit this common resource. He started his business by selling wireless stations for use onboard of ships. As others also started to enter the business, he changed its strategy. He decided to sell not only the equipment but wireless telegraphy as a service. For that purpose he set up a new company, the Marconi International Marine Communications Company in 1900. He built his own land based radio stations along the sea-trade routes on the shores of Britain, Ireland, Belgium, Italy, Canada and New Foundland. He trained his own radio telegraphists and placed them on all ships he equipped with a wireless radio station. These radio telegraphists, or marconists as they were called, were only allowed to communicate with Marconi wireless stations both land based and onboard of other ships (ITU, 1965). By doing so, he created a very successful, private business using radio waves.

The behaviour of the Marconi Company led to governmental involvement in the use of radio waves. In 1902, Prince Heinrich of Prussia tried to send a courtesy telegram to President Roosevelt on his way back from a visit to the United States. However, his ship was equipped with a wireless station of German make. His radio telegraphist did not succeed to get through to the land based station which was operated by Marconi (Bertho Lavenir, 1991).

This event triggered the start of the international coordination of the use of the radio spectrum, as Kaiser Wilhelm of Germany convened an international conference on the use of radio telegraphy. Representatives of nine countries gathered in 1903 in Berlin for the *Preliminary Conference on Wireless Telegraphy* (Kirby, 1995). Complete agreement was not reached, but the Conference drafted a protocol that served as the basis for a future international agreement on the use of wireless telegraphy. Among the articles of the protocol was the requirement that all coastal stations were required to exchange messages with all ships without distinction as to the system of radio being used (Robinson, 1985).

Although interconnection was the main problem on the table for the Conference, the reasons for the German government to convene the conference was broader and had also to do with industry politics. The refusal to interconnect by the dominant player, Marconi, made it harder for competitors, such as the German company Telefunken, to enter the market.

This preliminary Conference was followed in 1906 by the *first Radio Telegraph Conference of Berlin.* Twenty nine countries adopted the first *International Radiotelegraph Convention*. Two important provisions of the Convention were a requirement to accept all messages from coastal stations and ships regardless of the system used and priority for distress calls. The annex to this Convention contained the first regulations governing wireless telegraphy. It was decided to use two wavelengths corresponding to 1000 kHz and 500 kHz for public correspondence.

The interconnection among radio operators was considered of public interest to support the safety of the man at sea, and the continuous availability of the service should be assured at all times. This need for rules of engagement and international coordination was strengthened at the next Radio Telegraph Conference which took place in London, shortly after the Titanic disaster in 1912 (Codding, 1952; ITU, 1965).

Case assessment

To conclude, it was not the introduction of new technology – radio– as such that made it necessary to coordinate the use of the radio frequency spectrum and design new regulations. It was the use of this new technology by Marconi which triggered it. Marconi used this new technology in such a way that a conflict became apparent between his efforts of realizing private objectives and the realization of the newly identified public objectives.

Regulations were used as the institutional arrangement of choice to safeguard the public interests in the use of maritime communications. The regulations allowed for as much (business case) freedom as possible for the maritime service with the exception of a few standardized channels for the exchange of public messages and as an emergency signalling frequency. The outcome of the coordination efforts provided the support for a public service using a commercial incentive scheme, i.e. combining the public and private interests in a creative new combination.

3.2 The uptake of broadcasting

In the following years the use of the radiotelegraph expanded considerably. The radiotelegraph was a commercial success and had clear safety advantages. World War I led to a suspension in the progress of international regulations, but considerable progress was made in radio technology. It was the first war in which wireless played a significant role (Bertho Lavenir, 1991; Austin, 1995).[3] The advancements made in radio technology gave a big boost in the development of radio communications for other purposes; land mobile services, regular broadcasting services and aircraft radio communication services were established. Radio navigation services were developed for maritime and aeronautical use.

Regular broadcasting services started to flourish in the early 1920s. The broadcasting of the Dutch radio-pioneer Henricus Schotanus à Steringa Idzerda on the 6th of November 1919 is by some regarded as the start of the first radio broadcasting program in the world (Wijfjes, 1985; Rollema, 1995). In 1925 there were already over 500 broadcasting stations in the United States and almost every European country had one or more regular broadcasting services (Woolley, 1995). But the existing international and national regulations were not adequate to cope with this uptake. Interference became widespread with a chaos in broadcasting as a result (Coase, 1959; Woolley, 1995). A “tragedy of the commons” occurred in spectrum.

To solve this tragedy, the government took the role of supreme coordinator of the spectrum. The allocation of frequencies for broadcasting was one of the most pressing items at the *Washington Radio Conference* of 1927 (Tomlinson, 1945). This Conference marked the beginning of a new era for international radio regulations. At this Conference, the frequency range from 10 kHz to 23 MHz was divided into different frequency bands which were allocated for specific services. Each service, at that time being broadcasting, maritime, aeronautical, land mobile, point to point fixed and amateur services, was assigned its own parts of the radio spectrum to ensure greater efficiency of operation in view of the increase in the number of radiocommunication services and the technical peculiarities of each service. The international co-ordination and band harmonisation, whereby services with the

[3] The Boer War of 1899-1902 was the first war were wireless telecommunications was used. However, wireless communications did not meet the expectations of the British Army, but it did draw the attention of the British Royal Navy.

same characteristics are grouped together were aimed at reducing the phenomenon of interference and increased technical efficient use (Kirby, 1995). It also eased interoperability, because each service uses its own, internationally agreed, set of frequencies. Capacity management within each service was done through a requirement for a license. The process of licensing itself was left to the national administrations.

Case assessment

The case of à Steringa Idzerda shows the first use of broadcasting as a means to promote the primary business of selling radio receiving apparatus. In a next step, the use of radio waves obtained a political dimension, as a means of 'spreading the word', be it the words of a political party, a religious organisation or other groups representing a special interest.

The newly developing institutional arrangements now had to cater to political interests next to economic interest, which have no currency in common. As such, it re-enforced the role of governments in the governance of the radio spectrum, as the only party that is positioned to address and resolve these diverse and often conflicting interests in society, by establishing a certain degree of equity between these diverse interests.

Fortunately at that time the much broader and intensive use of radio spectrum was made possible by the advancements in technology, in particular the discovery of short-wave propagation by the radio amateurs greatly increased the available spectrum capacity for the various radio services. Without this increased capacity, it would not have been possible to assign all services their own part(s) of spectrum (Tomlinson, 1945; Codding, 1952).

The Washington Conference marked the establishment of the basic principles for the process of coordinating the use of radio spectrum at the global level, as it is still in use today. At the global level the use of the radio spectrum is governed under the hospices of the International Telecommunications Union (ITU). The Radiocommunication Sector of the ITU (ITU-R) develops and adopts the Radio Regulations, a binding international treaty between nation states, with a voluminous set of rules, recommendations and procedures for the regulation of radio-communications. The Radio Regulations are based on avoidance of radio interference through the division of spectrum in bands which are allocated to one or more services out of some 40 different radio services[4]. A wide range of regulatory, operational, and technical provisions ensure that the radio services are compatible with one another and harmful interference among services of different (neighbouring) countries is avoided. The Radio Regulations are updated on a regular basis in response to changes in needs and to new demands at World Radiocommunication Conferences (WRC), which are held every three to four years (ITU, 2004).

As such, the agreements made at the Washington Conference completed the process of institutional formation. A process of periodic alignment of technology and institutions has been established, allowing for a 3-4 year update cycle that enables new technologies and new usage to be accommodated. The global arrangement with regional and national implementations accommodates the objectives of the governments in terms of efficient use of the radio spectrum. It facilitates economies of scale to be realized by the radio entrepreneurs, in the provision of equipment and services.

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4 These radio services include services such as fixed, mobile, satellite, amateur, radio navigation and radio astronomy. Most bands are shared among primary and secondary services. Primary services have priority in case of conflicts resulting in harmful interference.

However, the coordination and decision making process has become (far) removed from the business practice of the entrepreneurs. The coordination process has become rigid and indirect as change requests need to be handled by government representatives and become subject of diverging interests, which culminate when the national delegations confer in a World Radio Conference. Fortunately, national governments have some degree of freedom in the allocation of radio spectrum usage rights at the domestic level, as long as no harm is done to legitimate spectrum usage in neighbouring countries. This of course favours large nation states over small ones.

3.3 Spectrum auctions

Hence, it should not come as a surprise that economist Ronald Coase (1959) posed that the allocation of spectrum should be determined by the forces of the market rather than as a result of government decisions. Radio licenses should be bought and sold like any other scarce resource in our economy, such as land or labour. Rights should be assigned to individual users via an auction with the provision that these rights can subsequently be traded in an open market. The market should not only decide who will have the licence, but also what services should be provided. If a business model would fail the rights to the use of the radio spectrum could be bought by another operator with a different, more successful model or by a new entrant. The problem of interference could be solved by delimiting the rights. These delimitations should not only come from strict regulations but also as a result of transactions on the market (Coase, 1959).[5]

Case assessment

At that time, Coase's idea was taken as a *big joke* by the FCC (Hazlett, 2001). Nonetheless, the idea of a model based on trading of the property rights has since been discussed among economists[6], but a property rights model was only considered seriously by spectrum management authorities in the early 1990s. At that time a broad consensus in politic thinking had emerged in support of deregulation; the introduction of market forces was considered for a number of infrastructures that had been heavily regulated in the past, including mobile telephony (Hazlett, 2001).

Deregulation changed the set of objectives pursued by the government. One of the new objectives pertaining to mobile communications became the creation of a market for radio spectrum usage rights for mobile communications. The institutional change that was already proposed in the late 1950's by Coase perfectly fitted the new objectives for mobile telephony. Various countries chose to auction the spectrum rights for mobile telephony (Cave, Doyle et al., 2007). [7]

The proposed institutional change was aimed at 'moving the government out of the equation of coordination in the use of the radio spectrum', to allow the entrepreneur to directly deal directly with the acquisition of radio spectrum usage rights as an input to his

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[5] Coase generalized this idea in his Noble prize winning easy "The Problem of Social Cost" (Coase, 1960).

[6] See note 6 of Baumol and Robyn for an overview of references (Baumol and Robyn, 2006).

[7] New Zealand was probably the first country that experimented with the definition of long-term, tradeable property rights to radio channels, and the first country to auction these rights to the highest bidder (Mueller, 1993).

business model. If and when the market would function properly, these rights would end up in the hands of the entrepreneur who values these rights most. It would require the initial auctioning of the rights and the possibility for subsequent trading in the secondary market. It would bring back the business case approach at least for those frequency ranges that were considered suitable for transaction in the market. Typically the government would retain the oversight for spectrum intended for public use, such as reserved for the military and for broadcasting.

An alternative to the property rights approach to deal with coordination outside the scope of the government is to consider the radio spectrum as a common pool resource. This is the topic of the last case example.

3.4 Wi-Fi and license exempt use of spectrum

In 1942 a new technology was invented: spread spectrum.[8] Spread spectrum is a technology whereby the signal is intentionally spread over a much wider bandwidth than strictly necessary. Spreading makes the signal inherently more resistant to interference. Until 1981 this technique remained classified as military technology because a spread spectrum signal is also difficult to intercept and hard to jam. It was not allowed to be used in civil applications (Anker and Lemstra, 2010). On the other hand, there was also no reason to use it. The institutional setting for the use of spectrum was based on exclusive rights. There was no need to use a technology that made communications more robust for interference at the expense of the use of a wider range of frequencies.

This changed in 1985. In that year, the FCC decided to allow the public use of spread spectrum for communication purposes, in three bands designated for Industrial, Scientific and Medical (ISM) applications (900 MHz, 2.4 GHz and 5.8 GHz) (FCC, 1985). This where bands that could be used without the need for a license but applications should have to tolerate interference from other users as well as from ISM applications.

The (for civil applications) new technology of spread spectrum and the introduction of regulations to support it triggered NCR Corporation to use spread spectrum for a nagging issue from their sales force; the lack of ‘mobility’ in the cash register product portfolio. Through their involvement in IEEE, as a leading standards developing organization, NCR becomes the de facto leader in the IEEE 802.11 Working Group resulting in a highly successful Wireless-LAN standard (Lemstra, Anker et al., 2011).

Case assessment

Since then, specific frequency bands are assigned on a license-exempt basis for specific types of communication equipment. These bands can be used as long as some specific rules (e.g. maximum power level and usage restrictions) are obeyed. These unlicensed bands have attracted new types of applications where the communications is generally short range and the devices are numerous. The spectrum commons provides the lowest possible barriers to the use of the radio spectrum. However, not all types of services (e.g. long-distance communication, broadcasting) and applications fit the operating conditions in a commons.

[8] At that year, a patent was granted to actress Hedy Lamarr and composer George Antheil on a “secret communication system” through the use of a spread spectrum technology called Frequency Hopping. See e.g. (Lemstra, Hayes et al., 2011) and the references in there for more information on the history of spread spectrum.

Nonetheless, it is great example of shared use of the radio spectrum. It is up to the radio equipment manufacturers to optimize the business case. The Wi-Fi case shows the power of industry actors effectively coordinating the efficient use of the radio spectrum, including graceful degradation of service levels under increasing load conditions and avoiding interference. This coordination was triggered by an industry actor with a compelling business case. The Wi-Fi case also shows that governments can be pro-active in the release of radio spectrum for use and thereby enable new business cases to be developed and implemented.

3.5 Conclusions

The review of four historical cases has revealed the need for re-alignment of institutions and technology, almost at a continuous basis. The cases have provided evidence of the value in applying a business case perspective to the process of alignment, in particular when it concerns the commercial use of the radio spectrum. Each of the cases described above were triggered by problems related to private actors on the one hand and public actors on the other hand pursuing the realization of their private respectively public objectives.

A successful outcome can be concluded when private and public actors can realize their objectives simultaneously, by designing a business opportunity in theory and allowing it to be transformed into a viable business case in practice.

Having established the business case perspective as a valuable instrument in achieving alignment between technology and institutions in the past, we will now apply this perspective to a case of which its resolution lies in the future. It concerns the introduction of cognitive radio technology. First we will analyse the intended application of CR in the so-called white spots in TV-bands. By applying a business case approach, we will conclude a misalignment between technology and institutions and hence predict a failure of policy. Secondly, we propose and discuss an alternative approach to achieve alignment, using the business case perspective in a community-of-practice environment.

4 Analysing the case of misalignment of white spot access in the television broadcasting band

The first application for CR that was put forward was the use of white spots in the TV broadcasting bands. The US Federal Communication Commission (FCC) made these white spots available for unlicensed broadband internet. Its intended use is –above all– to provide more affordable broadband deployment in rural areas (FCC, 2010).

In this case CR technology is intended to share the TV-band with the legitimate primary users, the TV broadcasting stations and low power auxiliary service stations (notably wireless microphones). Given the latter, it is understandable that the FCC removed sensing from the original requirements and took alternative measures to guarantee access to spectrum for wireless microphones and to prevent wireless microphones from being subjected to interference from CR devices. First of all, at the current state of technology sensing is not sufficiently reliable. More importantly, to prevent interference to the primary user, the output power of the CR device should be low relative to the primary users. These primary users are not only TV broadcasting stations but also these low power wireless microphones. Restriction of the output power of CR devices to a level that is low

compared to the wireless microphones would have been detrimental for the business case of rural broadband access. This puts restrictions on the use of white spots by CR devices.

In applying the business case perspective, the first question to be asked is: Why is there no service provided at the moment? There certainly is no scarcity of radio spectrum, the 2G/3G bands are under-utilized in these rural areas. The main reason appears to be that the costs to provide the service are too high in relation to the willingness to pay for the provided service (this applies not only for mobile broadband access but certainly also for fixed broadband access).

The second question to be asked is: How will the business case for CR improve the situation? For the business case to become viable either the willingness to pay for the CR enabled services has to become higher or the cost reduction needs to be bigger than the additional costs associated with the new (more capable and sophisticated) cognitive technology. Combined they need to bridge the gap between the provision of service based on the current technology and the current willingness to pay.

Under the FCC white spot ruling, rural broadband access is made more feasible due to the fact that a lower frequency range is made available, which extends the coverage area of a base station, compared to the existing alternatives to provide the service. However, existing mobile networks operate at frequencies that are just above the television band. This means that the gains of using a lower frequency are very limited.[9] Therefore the business case for deployment of a wide area network in rural areas based on white spot access remains highly questionable. It is much more likely that white spot access will be used to provide localised access to the Internet at specific backbone nodes. This is a business case that is comparable to Wi-Fi hot spot access, although over larger distances.

The next question is whether the capacity that can be supported by white spot access is high enough to support the demand of the users. In areas where the required demand for capacity is bigger, the coverage area of the base station may have to be made smaller. This conflicts with the reasoning to make these lower frequencies available. This means that the business case will be restricted to areas with a population density below a certain limit. This limit will be lower if the demand per customer is higher. It remains to be seen whether the assigned band will have enough white spot capacity available for the intended application – broadband internet access – to support a successful business case.

Studies performed on the use of the UHF broadcasting bands for cognitive radio in Europe showed that the amount of white space is limited, because of the tight digital broadcast planning. Moreover, the TV band is already heavily used “opportunistically” for Program Making and Special Event services, especially wireless microphones. Furthermore, the upper part of the band has to be made available as a harmonized subband for mobile use (ECC, 2008). Hence, the amount of available spectrum for white space devices is far less than in the United States (ECC, 2008; Beek and Riihijarvi, 2011). This amount may be even further reduced in Europe through the decision of the World Radio Conference 2012 to extend the possibility of the use of the TV band for mobile services to the 694 - 790 MHz band.

[9] As the use of white spots is considered to be free of charge, this represents a benefit compared to the business case for existing 2G/3G deployments, which may be subject to the recovery of a hefty auction fee. However, in serving the rural areas, economists will consider the auction fee as sunk costs and will calculate the business case on marginal costs.

To conclude, the white spot access regulations appear to be a technological fit instead of a BuC fit, driven by the regulator to realize a social goal. Whether the BuC is viable remains highly questionable. It would explain why the intended service providers are relatively absent in the standardisation activities and other discussions around white spot access in the TV band. Moreover, it may explain why there is as yet no viable business model for the commercial operation of a database in support of sharing the spectrum with wireless microphones.

5 Next steps: Finding a sweet spot for Cognitive Radio

Although there are possibilities to use cognitive radio under the current radio spectrum management regime, there is still no compelling business case apparent. When governments want to enable the use of Cognitive Radio, they will have to make certain choices on the specific CR technology and the regulatory environment. The choices will have an influence on the business opportunities for CR. The specific CR technology and the regulatory environment that is chosen should match. The business opportunities that are enabled by the specific choice should serve the objectives of both the entrepreneur and the government.

To assure development and deployment of CR technologies, it is worthwhile to review potential product-market combinations where CR functionality provides a 'value add' and determine whether these cases are attractive enough to be taken up by the industry as first applications of CR, as first steps on the road toward broader deployment of CR technologies.

The government can facilitate this process through the initiation of a platform in which the equipment industry, the service providers and the government itself closely cooperate with an aim to find a "sweet spot". This sweet spot serves as a catalyst to realize the ultimate goal of governments: more efficient use of spectrum.

The RSPG (Radio Spectrum Policy Group) already recommended to create a platform to allow researchers, academia, manufacturers, operators, service providers and regulators to coordinate research activities. This platform could build upon already existing platforms with comparable purposes, notably COST-TERRA (RSPG, 2011a). As COST-TERRA is focused on research activities, it will be necessary to extend the membership to include the user communities and service providers to have a successful and well informed discussion on the deployment of CR technology.

To facilitate coordination by the actors a Community of Practice (CoP) related to CR has been established in the Netherlands (CRplatform.NL). This CoP aims to identify the uncertainties surrounding potential deployment areas of CR and through discussion among stakeholders to find ways and means of addressing and reducing these uncertainties; thereby facilitating the successful deployment of CR-based products and services. This initiative evolved from the regular interaction between representatives of the Ministry of Economic Affairs and the industry.

In addressing uncertainties and finding ways towards resolution, the CoP organizes workshops to explore potential application areas of CR, the so-called Use Cases. The following application areas have been the topic of a Use Case Workshop during the past two years: Container Terminals in the Rotterdam harbour; Special Events capture by broadcasting organisations; Public safety communications by the police force; High intensity communications at airports; and CR facilitating Domotica. Each Workshop

brought together potential users, potential suppliers, policy makers and regulators, as well as academic researchers.

The Use Cases as discussed suggest that CR functionality adds most value in situations that are typically niche applications or are a small segment of the overall market for wireless technologies. One of the reasons is the fact that CR technology is basically a technology to (more efficiently) share the radio spectrum. As CR provides additional functionality compared to current radio technology this will come at increased costs, at least initially. Situations of high intensity demand are expected to provide the highest willingness-to-pay by the end-users.

Each Use Case discussed so far addressed a specific market segment, or even a market niche. Hence, potential market volumes are (relatively) low to moderate, which impacts the viability of the CR business case. Nonetheless, the Use Cases also show similarities, in particular if CR-based solutions are considered as variants of a more generic CR-platform solution. Especially the combined business case of the communication needs of the public safety services in case of an emergency and the registration of this emergency and other news gathering seems to be logical and promising. This became apparent during the Use Case Workshop on Special Events, as during (ad-hoc) events the needs of public safety and broadcasting converge at the same place and time. The type of communication needs show a strong parallel. Hence, pursuing solutions for one group of actors (broadcasters) should best be done cognisant of the needs of the other group of actors (public safety).

This example shows that finding a sweet spot for CR might be easier if the solutions for one group are similar to the solutions for the other group, at least on the platform level. This increases the addressable market and hence the viability of the business case. The unresolved issue is the capacity issue. How much capacity is available for CR use and is there enough capacity available to support the (combined) business case?

The Use Cases further show that a viable business case for CR will require economies of scale. This extends the need for coordination to the European Union level, if not at the global level. Such coordination may still be left to be organized by the industry actors. However, the use case experience suggests that lacking a very compelling business case the likelihood that industry actors will take the lead is expected to be low. The discussions within the CoP confirmed the role of the regulator to facilitate this search for a sweet spot.

6 Conclusions and recommendations

The interaction between technological change and institutional change is not a direct one. Through the intermediation of the actors changes applied to one will lead to changes to the other. In making these changes, the various actors will have a certain goal in mind. The goals of the various actors are not always in line. Exploring Use Cases can be a good instrument to bring all interested parties together and in an explorative modus find and enable a “sweet spot” for the use of new technology. A “sweet spot” is enabled if the institutional arrangements and the characteristics of the new technology are aligned in such a way that an intended business opportunity can be realized. The regulator is in a perfect position to initiate and facilitate such an exploration in a Community of Practice.

In these explorations, one of the first questions to be asked is: what are the gains from the use of this new technology, and are these gains high enough to cover the increased cost of the use of this technology compared to the alternatives?

An exploration of possible business cases for the introduction of Cognitive Radio revealed that the type of CR technology to be used and the appropriate regulatory regime to support it depend on the specifics of the intended business case and the specifics of the users with which the bands will be shared. Once, there is an initial business case in sight, the question is whether enough unused spectrum can be made available through the use of CR technology. When a viable combination is found, the regulator should set up the specific regulations to facilitate the CR deployment and thereby make an important step towards a more efficient utilisation of the radio spectrum.

7 References

ANKER, P. and LEMSTRA, W. (2010) "10 The governance of radio spectrum: licence-exempt devices", *The Innovation Journey of Wi-Fi*. pp. 288.

AUSTIN, B. A. (1995) "Wireless in the Boer War", IEE International Conference on 100 Years of Radio. London.

BAUMOL, W. J. and ROBYN, D. (2006) Toward an Evolutionary Regime for Spectrum Governance - Licensing or Unrestricted Policy. AEI-Brookings Joint Center for Regulatory Studies.

BERTHO LAVENIR, C. (1991) *Great discoveries: Telecommunications*. Geneva: International Telecommunications Union.

CAVE, M., DOYLE, C., et al. (2007) *Essentials of Modern Spectrum Management*. Cambridge: Cambridge University Press.

COASE, R. (1959) "The Federal Communications Commission", *Journal of Law and Economics*, 2 (October): 1-40.

COASE, R. (1960) "The Problem of Social Cost", *Journal of Law and Economics*, 3 (1): 1-44.

CODDING, G. A. (1952) The International Telecommunication Union. An experiment in international cooperation. Leiden: Brill.

FINGER, M., GROENEWEGEN, J., et al. (2005) "The quest for coherence between institutions and technologies in infrastructures", *Journal of Network Industries*, 6 (4): 227-259.

FINGER, M. and VARONE, F. (2009) "Regulatory practices and the role of technology in network industries: the case of Europe", In R. Künneke, J. Groenewegen and J. F. Auger (eds), *The Governance of Network Industries - Institutions, Technology and Policy in Reregulated Infrastructures*. Cheltenham: Edward Elgar Publishing Limited. pp. 87-101.

HAUG, T. (2002) "A commentary on standardization practices: lessons from the NMT and GSM mobile telephone standards histories", *Telecommunications Policy*, 26 (3-4): 101-107.

HAZLETT, T. (2001) The Wireless Craze, The Unlimited Bandwidth Myth, The Spectrum Auction Faux Pas, and the Punchline to Ronald Coase's 'Big Joke': An Essay on Airwave Allocation Policy. AEI-Brookings Joint Center Working Paper No. 01-2. Available at SSRN: http://ssrn.com/abstract=286932.

ITU (1965) *From Semaphore to Satellite*. Geneva: International Telecommunications Union.

ITU (2004) "Radio Spectrum Management for a Converging World", Workshop on Radio Spectrum Management for a Converging World. Geneva, 16-18 February.

KIRBY, R. C. (1995) "History and Trends in International Radio Regulations", IEE International Conference on 100 Years of Radio.

KOPPENJAN, J. and GROENEWEGEN, J. (2005) "Institutional design for complex technological systems", *International Journal of Technology, Policy and Management*, 5 (3): 240-257.

KÜNNEKE, R. and FINGER, M. (2009) "The governance of infrastructures as common pool resources", Workshop on the Workshop 4. Indiana University Bloomington, June 3-6, 2009.

LEMSTRA, W., ANKER, P., et al. (2011) "Cognitive Radio: Enabling technology in need of coordination", *Competition and Regulation in Network Industries*, 12 (3): 210-235.

LEMSTRA, W., HAYES, V., et al. (2011) *The Innovation Journey of Wi-Fi: The Road To Global Success*. Cambridge: Cambridge University Press.

MUELLER, M. (1993) "New Zealand's revolution in spectrum management", *Information Economics and Policy*, 5 (2): 159-177.

MURMANN, J. P. (2003) Knowledge and Competitive Advantage: The Coevolution of Firms, Technology, and National Institutions. Cambridge: Cambridge University Press.

NELSON, R. R. (1994) "The co-evolution of technology, industrial structure, and supporting institutions", *Industrial and corporate change*, 3 (1): 47-63.

OSTROM, E. (1990) Governing the Commons: The Evolution of Institutions for Collective Action. Cambridge University Press.

ROBINSON, J. O. (1985) Spectrum Management. Policy in the United States: An Historical Account (15).

ROLLEMA, D. W. (1995) *Vijftig jaar VERON Honderd jaar Radio*. Arnhem: Stichting Servicebureau VERON.

SAVIOTTI, P. P. (2005) "On the co-evolution of technologies and institutions", In M. Weber and J. Hemmelskamp (eds), *Towards Environmental Innovation Systems*. Heidelberg: Springer. pp. 9-31.

SCHARPF, F. W. (1997) Games real actors play: Actor-centered institutionalism in policy research. Boulder: Westview Press.

TOMLINSON, J. D. (1945) *International Control of Radiocommunications*. Ann Arbor: J.W. Edwards.

TUNZELMANN VON, N. (2003) "Historical coevolution of governance and technology in the industrial revolutions", *Structural Change and Economic Dynamics*, 14 (4): 365-384.

WIJFJES, H. (1985) Hallo hier Hilversum: driekwart eeuw radio en televisie. Weesp: Unieboek bv.

WOOLLEY, F. M. (1995) "International frequency regulation and planning", *EBU Technical Review* (Spring): 45-62.