Response to
Request for Opinion from RSPG
RSPG10-348 on Cognitive Technologies

Dr. Ir. W. Lemstra

Ir. P. Anker, Ing. V. Hayes

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Delft University of Technology

Department Technology, Policy and Management

Jaffalaan 5

NL-2628 BX Delft

The Netherlands

Phone: +31152782695

Fax: +31152787925

Corresponding author: Dr. Ir. W. Lemstra

w.lemstra@planet.nl

+31 653 216 736

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Purpose of this document

This report is a response to the public consultation on the request of the European Commission (EC) by the Radio Spectrum Policy Group (RSPG) on the topic of 'Cognitive Radio Technologies'.

Our research into CR technologies provides the following insights relevant to the RSPG request for public opinion:

1. The successful deployment of CR technologies can be considered as an item of public interest,
2. For the promise of CR to be unlocked a certain degree of coordination is required to reduce the uncertainties that now clouds the market for CR applications,
3. The fundamental question regarding coordination is: Will the industry assume the necessary coordination efforts, if the government would reduce its coordinating efforts, as suggested by the prevailing policy direction of 'technology neutral' and 'service neutral' radio spectrum allocations and assignments,
4. The dilemma that governments are now facing is that prevailing policy suggest a technology neutral assignment of radio spectrum to improve dynamic efficiency, while enabling the deployment of a specific technology, i.e. cognitive radio technology, is of public interest to achieve higher utilization efficiency of the radio frequency spectrum,
5. It appears that in this light allowing deployment of a specific type of technologies in parts of the radio spectrum that would otherwise be under utilized or not used at all is justified,
6. The question than remaining is to what degree governments should provide coordination in the implementation of the CR technologies,
7. For the rural business case to become attractive the deployment of CR technologies should have a positive effect on the cost parameters as compared to 3G/4G technologies,
8. The CR Use Cases studied show that a viable business case for CR will require economies of scale that will need coordination at the European Union level, if not at the global level,
9. The main purpose of coordination between governments and the industry is finding and enabling the 'sweet spot' for CR deployment.

Acknowledgements

This report draws upon the research program on Radio Spectrum Governance in the Section Economics of Infrastructures of the Department Technology, Policy & Management at the Delft University of Technology (TUDelft), the Netherlands, in particular the findings from the 'Use Case Workshops', which have been organised in 2010 by the 'Cognitive Radio Platform the Netherlands' (www.crplatform.nl). Understanding the role of industry actors and government in shaping successful wireless e-communication networks and services is drawn from research into wireless technologies and systems, reported in for instance "The innovation journey of Wi-Fi" (Lemstra, Hayes and Groenewegen, 2010) and the development of mobile systems (Lemstra and Hayes, 2009).

About the authors

Peter Anker, Vic Hayes and Wolter Lemstra are Senior Research Fellows at the Section Economics of Infrastructures at the Department Technology, Policy and Management of the TUDelft.

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1 The promise of CR

We share the opinion of the RSPG that Cognitive Radio (CR) as an enabling technology holds an interesting promise for improved utilisation of the radio frequency spectrum.

CR technologies optimally align with the principle of technology and service neutral allocation and assignment of radio frequency spectrum, as by sensing the local radio environment and understanding the user's communications needs the cognitive radios are able to select and deploy the most appropriate communications profile – for instance, frequency band, access technique and modulation method – to transfer information using radio waves.

Early forms of cognition can be found in DECT terminals seeking a free (pre-assigned) channel, Wi-Fi terminals operating in the 5 GHz band sensing and avoiding radar signals, and more recently within LTE where femto-cells sense and detect neighbouring cells and adjust their operation accordingly. In these CR-based applications spectrum efficiency is improved essentially as part of existing (co-)primary allocations and assignments.

CR capabilities are considered also highly valuable for creating 'space' for the introduction of new radio communication services, as essentially all (usable) radio frequency spectrum has been allocated and assigned, while in practice the radio frequency spectrum appears to be under-utilized, when considered in time and place; hence, in expanding the cases of shared and secondary use of the radio spectrum.

Hence, the successful deployment of CR technologies could be considered as an item of public interest.

However, despite considerable research and development efforts to our knowledge no announcements of commercial implementations of cognitive radio based services have been made.[1] On the one hand this comes as a surprise given the potential of the technology, on the other hand history has shown that new technologies require considerable amounts of time to arrive a the point in time of mass market break-through, taking typically 10 years and sometimes even more.[2]

The introduction of CR may be hampered by another phenomenon: the technology is so versatile that uncertainties arise as to the best product-market combination to be selected that leads to a profitable business case for the entrepreneur. Specially recognizing that CR functionality comes at a premium compared to current day mobile technologies.

For the promise of CR to be unlocked a certain degree of coordination is required to reduce the uncertainties that now clouds the market for CR applications. The question is who should provide this coordination?

This is in our view the more fundamental question underlying a response to the public consultation of the RSPG10-348 on Cognitive Technologies. In section 2 we present our approach addressing this question. In section 3 the insights obtained through Use Case Workshops organized as part of the CRplatformNL activities are discussed. In section 4 we conclude with providing our point-by-point response to the RSPG request for public consultation.

2 The need for coordination

In a first approximation we may postulate that the 'amount' of coordination to create industry success is relatively constant, what differs is the amount of coordination performed by governments (including the RSPG) and the amount performed by entrepreneurs (operators and equipment manufacturers). Figure 1 provides a schematic representation of this hypothesis.[3]

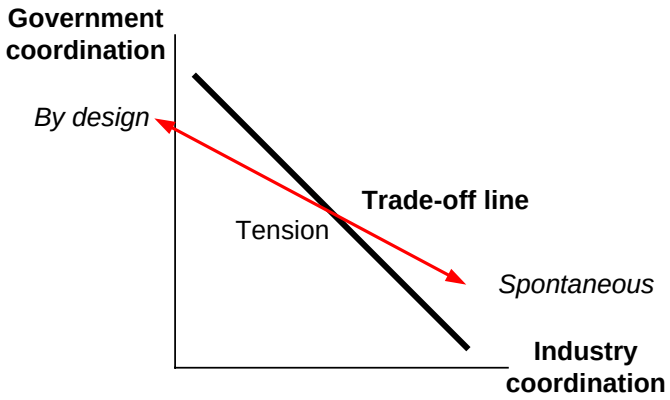

Figure 1. Coordination trade-off: Spontaneous or by design

In positioning the case in this way the major challenge or tension for governments in pursuing the efficient use of the radio spectrum is becoming apparent:

Will the industry assume the necessary coordination efforts, if government would reduces its coordinating efforts?

We should thereby recognize that the coordinating role of governments are *by design*, and in principle *ex-ante*, the coordinating role of industry can only be *spontaneous*, and thus *ex-post*. Hence there is a degree of uncertainty regarding the outcome that will be provided by the industry.[4]

The prevailing telecom reform policy doctrine suggests that governments and thus the RSPG can best leave decisions regarding choices of technology and service design to the market actors, i.e., radio spectrum allocations should be made 'technology neutral' and 'service neutral'. This drives the solution down on the trade-off line in the direction of more 'industry coordination'. Given the public interest associated with successful deployment of CR the question than becomes, provided the governments create the right boundary conditions, e.g. initial assignments of radio frequency bands where CR may be deployed:

Will the industry actors provide the necessary coordination and will they coordinate in a timely manner?

While the future can not be predicted with certainty, certain behavioural patterns from the past may inform our understanding of the future.[5] To assess the role the various actors might play with respect to industry coordination, which could lead to a successful deployment of CR technologies, we have researched five episodes of successful introduction of new wireless technologies:

1. 1890-1910 Radio at see (Europe),
2. 1970-1980 Analogue cellular (USA and Europe),
3. 1980-1990 Digital cellular (Europe and USA),

4. 1985-2000 CDMA (USA),
5. 1985-2000 Wi-Fi (USA and Europe).

Our findings are reported in the proceedings of the 2010 Conference on Competition and Regulation in Network Industries, in November in Brussels (Lemstra, Anker and Hayes, 2010) and can be summarized as follows:

> **Episode #1: 1890-1910 Radio at see** (Europe): The need for interoperability and interconnection, triggered by Marconism and the Titanic disaster, has led governments to assume a coordinating role in the use of the radio frequency spectrum, and as a consequence governments have become a determining factor in the development of the industry structure. The government involvement has led to a complex institutional arrangement operating at global, regional and national level.
>
> **Episode #2: 1970-1980 Analogue cellular** (USA and Europe) provides an illustration of entrepreneurial coordination emerging as a result of a very lengthy and ill conceived license award process by the US government.
>
> This Episode also shows that a single firm in a large homogeneous market can be highly successful, as the diffusion of AMPS within the Bell System illustrates. The coordination effort by the Nordic incumbent operators shows that coordination around a single specification with agreed upon functionality can also lead to market success (NMT). The adoption outside the Nordic area is primarily being driven by the Nordic manufacturers operating in 'export' markets.
>
> **Episode #3 1980-1990 Digital cellular** (Europe and USA) shows that a very fragmented market in Europe, as a result of incompatibility and lack of interconnection of 1st Generation analogue cellular systems, can stimulate regional coordination in establishing a pan-European standard for a 2nd Generation of digital cellular technology (GSM) and such efforts can result in a very successful world-wide deployment. The break-up of the Bell System suggests an almost reverse process has taken place in the USA.
>
> From the diffusion patterns of the 1st and 2nd Generation cellular systems we may conclude that a standards approach leads to higher adoption rates (through a larger overall market size) and is therefore an approach to be recommended to innovators-entrepreneurs to be pursued.
>
> Whether such a standards effort can be pursued successfully alone, as done by Qualcomm in establishing the CDMA standard, see **Episode #4: 1985-2000 CDMA** (USA), or is better done in cooperation with other industry players, as shown in Episode #3 for GSM and in **Episode #5: 1985-2000 Wi-Fi** (USA and Europe) for Wi-Fi, is highly dependent on the resource base of the firm and the centrality of the new technology as well as the perceived market opportunities in relation to the overall business of the firm. Compare in this respect for instance the business systems of Qualcomm and NCR.
>
> The example of spread spectrum ruling by the FCC, **Episode #5 1985-2000 Wi-Fi** (USA and Europe), shows that radio spectrum regulation can also be pro-active and lead to innovation, whit a highly successful use of the radio spectrum.

Reflecting on the five Episodes one can conclude that successful application of new radio technologies requires a large degree of coordination, by entrepreneurs and by governments, underlining our hypothesis on the need of coordination to create industry success. One can argue that if governments (governments directly or their agencies) apply a high degree of specificity in the allocation and assignment of radio spectrum usage rights they have already reduced the degrees of freedom in the implementation,

hence, less coordination is required from the entrepreneurs (public or private firms), reflected by the trade-off line in Figure 1. Episode #2 and #3 analogue and digital cellular nicely illustrate this situation. In Europe, during Episode #2, where coordination remains lrgely restricted to the nation level it leads to national solutions and hence a patch work of national markets. While the coordinated approach in Episode #3 leads to a highly successful regional, even worldwide market for GSM. On the same token the single AMPS standard in Episode #2 leads to a relative successful uptake compared to Europe, while during Episode #3 the reverse image emerges.

In all periods it are the operators, either as public or private entities, that assume most of the coordination efforts required. Coordination that is bounded by the conditions set by government agencies through frequency band allocations and license conditions. In Episode #2 it are the private firms that apply additional coordination efforts to remedy the chaos as a result of an ill conceived license award process. In Episodes 2 through 5, in creating business success industry players have taken on the coordination of their activities through standardization efforts and the establishment of industry alliances.

Episode #5 describing the Wi-Fi developments, has most likely the largest degree of freedom left to the industry as no service profile was defined, only the type of technology prescribed was driving the industry in a certain direction. This Episode shows that the industry has taken on the coordinating role. However, this was not evident at the outset.

The dilemma that governments are now facing is that prevailing policy suggest a technology neutral assignment of radio spectrum to improve dynamic efficiency, while enabling the deployment of a specific technology, i.e. cognitive radio technology, is of public interest to achieve higher utilization efficiency of the radio frequency spectrum.

Whereby enabling the deployment of CR is in itself contributing to innovation in radio spectrum use and can potentially increase dynamic efficiency depending on the ultimate success of this new technology.

It appears that in this light allowing deployment of a specific type of technologies in parts of the radio spectrum that would otherwise be under utilized or not used at all is justified.

This approach is much alike the 1985 FCC decision to allow spread spectrum technologies to be deployed for data communication in the ISM bands.

The question than remaining is to what degree governments should provide coordination in the implementation of the CR technologies.

In this respect it is of interest to observe the developments in the USA whereby the FCC is aiming to improve broadband access in rural areas using CR technologies in so-called white spaces within the TV-bands. In the initial Report and Order of 2008 (FCC, 2008) the FCC opted for a sensing-based solution. The FCC in the second Memorandum Opinion and Order issued November 2010 (FCC, 2010) changed its preference and opted for a database driven solution, possibly driven by industry feedback on the state-of-the-art of sensing. The provision of the database service is left to the industry, as is the standardization of the protocol to access the database.

To assess whether government coordination is required to assure a timely 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. Moreover, an assessment can be made to what degree government coordination is desired or required.

3 Use Cases

Considering the lead provided by the FCC on broadband access in rural areas, the first question to be asked is why no service is being provided at the moment. This is not because of lack of radio spectrum. We understand the main reason to be the costs to provide the service are too high compared to the revenues that can be obtained. The cost being determined by the demand of the users, the number of users within a base station serving area, and the size of the serving area, which is determined by the frequency assignment.

For the rural business case to become attractive the deployment of CR technologies should have a positive effect on these cost parameters.

Through the assignment of TV White spaces a lower frequency range is made available, which extends the coverage area of a base station. However, the business case will only become viable if the cost reduction is larger than the additional costs associated with the deployment of cognitive technology in comparison with 3G/4G alternatives.

Existing mobile networks operate at frequencies that are just above the television band. This means that the gains of using a lower frequency (a difference of 100 MHz or less) are not very high. Therefore the business case for rural wide area networking based on white spot access is questionable. More likely is that white spot access will be used to provide local access to the internet at specific conurbations. This is a business case that is comparable to Wi-Fi hot spot access, albeit with a much larger coverage area.

Other product-market combinations have been assessed in Use Case Workshops held under the auspices of the 'Cognitive Radio platform The Netherlands' (www.crplaform.nl).[6] The Use Cases that have been discussed reflect situations of high user demand, typically exceeding the currently available spectrum, where CR technologies may provide for relief. Communication areas that have been investigated so far include: container terminal in a major harbour; R/TV major event capture; police and emergency services at incidents. Interaction with product providers revealed that hybrid solutions of existing access technologies are considered a stepping stone towards the deployment of CR technologies in the future.

The Use cases discussed suggest that the CR functionality adds most value in situations that are typically niche application or are a small segment of the overall market for wireless technologies. Although each of the Use Cases reflects specific requirements, they have many characteristics in common such that they might be served by a generalized 'CR platform', thus providing for some economies of scale.

Nonetheless, the Use Cases show that a viable business case for CR will require economies of scale that will need coordination at 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.

Moreover, true global success will require either an extremely compelling product offering, such as GSM, or a very strong IP position, such as Qualcomm, or coordination between the industry and governments across the regions, as the case of Wi-Fi has shown.

When governments assume a leading role in coordinating the deployment of CR, the subsequent challenge they will be facing is the choice among some of the more fundamental features of CR, such as sensing and/or the use of database and/or the use of a cognitive pilot channel. Their choices will need to be well informed as they will steer the industry in a certain direction. As in this early stage of developing a new technology the future is uncertain, government and industry actors are well advised to share their insights to arrive at outcomes that are considered optimal under circumstances of uncertainty.

The main purpose of coordination between governments and the industry is finding and enabling the 'sweet spot' for CR deployment.

From an EU internal market perspective harmonization across Member States may be advisable to avoid divergence that could result in new barriers emerging.

4 Point by point response to the RSPG recommendations

Based on the terms of reference developed in Section 1 through 3 our response to the RSPG request for public opinion on the recommendations provided in document RSPG10-348 on Cognitive Technologies is as follows:

Ad 1: We recommended that measures to introduce CR technologies in some bands are **coordinated** between Member States to achieve economies of scale and a timely introduction of CR.

Ad 2: We recommend to add representatives of the service and equipment industry to coordinate research activities in a direction that is economically viable.

Ad 3: We recommend that additionally Administrations coordinate the deployment of databases (if at all) as to avoid creating (new) barriers to the internal market.

Ad 4: We recommend that additionally ETSI considers the need for sufficient economies of scale and hence will liaise with similar institutions across the world to achieve its objectives.

Ad 5: We recommend that additionally the industry is invited to submit information to ETSI.

Ad 6: We recommend that additionally ETSI considers the need for sufficient economies of scale and hence will liaise with similar institutions across the world to achieve its standardization objectives.

Ad 7: Agreed.

Ad 8: Agreed

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Notes

[1] As a proxy for the development of CR the scope of contributions to the IEEE DySPAN conferences can be used, which are dedicated to flexible spectrum access, software defined and cognitive radios: 2007 theoretical and technical paper contributions only; 2008 papers and demonstrations (Microsoft, Philips, Shared Spectrum, Vanu); 2010 papers, reports on test bed results, and two policy contributions.

[2] As examples: (1) The concept of cellular systems dates back to 1947, the required technology only emerged at an affordable level in the 1970s, spectrum assignments and network construction required another 10 years. Mass market take-off of cellular can be linked to the (next) generation of digital technologies. The GSM project started in 1982 and by 1992 13 operators in 7 countries introduced GSM-based services. (2) The principle technology of Wi-Fi, spread spectrum, goes back to the 1940s and was first deployed in the military domain, to be released for commercial use by the FCC in 1985. The market break-through occurred in 2000. (3) Qualcomm filed a first patent on CDMA in 1986. The US Telecom Industry Association adopted the IS95 (CDMA) standard in 1993. The break-through follows in 1997 with the deployment of CDMA under the PCS licenses.

[3] While this approximation is considered to be valid given the state-of-the-art of the technologies under consideration at a certain point in time, for more versatile or general purpose technologies there are more degrees of freedom and hence the trade-off line is shifting to the right hand top corner.

[4] In this characterization we do not consider public private partnerships as a possible mode of coordination.

[5] Note that the transposition of historical findings into forward looking statements should be done with care as the context may have changed or the position and/or the role of the actors. In our case, as a result of liberalization and privatization as well as consolidation in the aftermath of the internet/telecom bubble, R&D activities related to infrastructure developments by operators has diminished significantly. As a result, the emphasis in the standardisation process has shifted from the operators to the manufacturers. The dependency of the industry of a single firm in terms of IPR has also diminished with the introduction of Orthogonal Frequency Division Multiplexing (OFDM) replacing CDMA in 4G systems, such as Wi-MAX.

[6] A Community of Practice (CoP) related to CR has been established in the Netherlands (www.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, responsible for radio spectrum management, and the industry organized in the so-called “Nationaal Frequentie Overleg” meetings. The objectives of the Community of Practice are: (1) Sharing information regarding research, development and deployment of CR; (2) identifying the uncertainties surrounding the deployment of CR; (3) discussing ways and means of addressing and reducing these uncertainties; (4) advising regulators regarding the needs of CR devices; (5) to contribute to the successful deployment of CR-based products and services.