TECHNOLOGY • RESEARCH HIGHLIGHTS • VISIONS • SCIENCE

55

Future scenarios, ecosystems and business models for cognitive radio systems

Petri Ahokangas | Marja Matinmikko | Jenni Myllykoski | Hanna Okkonen

VTT

VTT TECHNOLOGY 55

Future scenarios, ecosystems and business models for cognitive radio systems

Petri Ahokangas
University of Oulu

Marja Matinmikko
VTT Technical Research Centre of Finland

Jenni Myllykoski
University of Oulu

Hanna Okkonen
University of Oulu

ISBN 978-951-38-7883-2 (soft back ed.)
ISSN 2242-1211 (soft back ed.)

ISBN 978-951-38-7884-9 (URL: http://www.vtt.fi/publications/index.jsp)
ISSN 2242-122X (URL: http://www.vtt.fi/publications/index.jsp)

JULKAISIJA – UTGIVARE – PUBLISHER

VTT
PL 1000 (Tekniikantie 4 A, Espoo)
02044 VTT
Puh. 020 722 111, faksi 020 722 7001

VTT
PB 1000 (Teknikvägen 4 A, Esbo)
FI-2044 VTT
Tfn +358 20 722 111, telefax +358 20 722 7001

VTT Technical Research Centre of Finland
P.O. Box 1000 (Tekniikantie 4 A, Espoo)
FI-02044 VTT, Finland
Tel. +358 20 722 111, fax +358 20 722 7001

Kopijyvä Oy, Kuopio 2012

Future scenarios, ecosystems and business models for cognitive radio systems

Tulevaisuuden skenaarioita, ekosysteemejä ja liiketoimintamalleja kognitiivisille radiojärjestelmille. **Petri Ahokangas, Marja Matinmikko, Jenni Myllykoski & Hanna Okkonen.** Espoo 2012. VTT Technology 55. 54 p.

Abstract

The introduction of cognitive radio techniques into wireless mobile communications systems has potential to change their operations in a number of ways, most notably in terms of the way they access the radio spectrum. In fact, the whole business ecosystem could be affected by the advent of cognitive radio systems (CRS). Recent developments in the mobile communication systems and spectrum regulatory frameworks are paving the way to shared use of the spectrum in an attempt to fulfil the growing future traffic demand. Spectrum sharing using CRS can become an alternative way to provide access to new the spectrum in addition to the costly and time-consuming “re-farming” of spectrum bands where a band is cleared of its previous usage.

This publication focuses on the business aspects of those systems and aims to understand the potential effects of their emergence from a business perspective. Key findings from the literature in terms of the technological and business context of cognitive radio systems are summarized. Furthermore, the theoretical framework of business scenarios, business models, and business ecosystems is explained. Specific scenarios, business models and business ecosystems suggested for cognitive radio systems following four workshops are presented. First the key actors within the cognitive radio systems business/value chain were identified along with their needs and the benefits of cognitive technology. Scenarios were then created for the future cognitive business environment together with an analysis of the drivers, limitations and challenges of the different scenarios. Initial attempts to develop business models for selected actors in selected scenarios are also presented.

Keywords Business model, business ecosystem, cognitive radio system, scenario

Tulevaisuuden skenaarioita, ekosysteemejä ja liiketoimintamalleja kognitiivisille radiojärjestelmille

Future scenarios, ecosystems and business models for cognitive radio systems. **Petri Ahokangas, Marja Matinmikko, Jenni Myllykoski & Hanna Okkonen.** Espoo 2012. VTT Technology 55. 54 s.

Tiivistelmä

Kognitiivisten radiotekniikoiden tulo langattomiin matkaviestintäjärjestelmiin voi muuttaa järjestelmien toimintaa usealla eri tavalla. Erityisesti taajuuksien käyttötapa voi muuttua. Itse asiassa kognitiivisten radiojärjestelmien tulo voi vaikuttaa koko liiketoimintaympäristöön. Matkaviestintäjärjestelmien ja taajuusregulaation viimeaikainen kehitys on mahdollistamassa taajuuksien yhteiskäytön vastauksena tulevaisuuden kasvavaan tiedonsiirtotarpeeseen. Taajuuksien yhteiskäytöstä kognitiivisten radiotekniikoiden avulla voi tulla vaihtoehto kalliille ja aikaa vievälle taajuuksien uudelleen jakamiselle, jossa taajuuskaista tyhjennetään alkuperäisestä käytöstä.

Tämä julkaisu keskittyy kognitiivisten radiojärjestelmien liiketoimintanäkökulmiin. Tavoitteena on ymmärtää näiden järjestelmien mahdollisesti aiheuttamat vaikutukset liiketoimintanäkökulmasta. Julkaisu esittää yhteenvedon kirjallisuudesta kerätystä tiedosta kognitiivisten radiojärjestelmien teknisiin ja liiketoimintanäkökulmiin liittyen. Julkaisu esittää teoreettisen viitekehyksen liiketoimintaskenaarioille, liiketoimintamalleille sekä liiketoimintaekosysteemeille. Tämän lisäksi julkaisu esittää neljän työpajan pohjalta kehitetyt skenaariot, liiketoimintamallit ja liiketoimintaekosysteemit kognitiivisille radiojärjestelmille. Ensimmäiseksi on tunnistettu kognitiivisten radiojärjestelmien liiketoimintaympäristön päätoimijat sekä toimijoiden tarpeet ja hyödyt kognitiivisiin tekniikoihin liittyen. Tämän jälkeen on kehitetty skenaarioita kognitiivisten radiotekniikoiden mukaantulolle liiketoimintaympäristöön sisältäen analyysia eri skenaarioiden ajureista, rajoituksista ja haasteista. Lisäksi julkaisu esittää alustavia liiketoimintamalleja valituille toimijoille valituissa skenaarioissa.

Avainsanat Business model, business ecosystem, cognitive radio system, scenario

Preface

This publication summarizes those business environment studies related to cognitive radio systems from the Cognitive Radio Trial Environment (CORE) project 2011–2012. The project is a part of the Tekes Trial programme. This work is based on four workshops arranged at VTT in Oulu and at the University of Oulu in May and September 2011, and in February and May 2012. Special thanks to the workshop participants: Seppo Salonen from Elektrobit, Jukka Kemppainen and Rainer Timonen from EXFO NetHawk, Heikki Rantanen from the Finnish Defence Forces, Kari Horneman, Jari Hulkkonen and Seppo Yrjölä from Nokia Siemens Networks, Jari Roininen, Jani Manninen, and Heikki Salmela from PPO, Ville Kukonlehto, Kai Molander and Pekka Päivärinta from Pehutec, Timo Koskela from Renesas Mobile Europe, Harri Posti from Business Oulu, Kari Heiska from Digita, Heikki Kokkinen from Fairspectrum, Marko Höyhtyä, Jukka Kiviniemi, Miia Mustonen, Aarne Mämmelä, Marko Palola, Tapio Rautio, Kyösti Rautiola, and Miika Lahti from VTT, Timo Bräysy, Janne Lehtomäki and Harri Saarnisaari from CWC, Janne Känsäkoski from CENTRIA, Thomas Casey and Arturo Basaure from Aalto University, Alexey Shveykovskiy from Oulu Business School, and Esko Luttinen.

Petri Ahokangas, Marja Matinmikko, Jenni Myllykoski and Hanna Okkonen

Contents

Abstract **3**

Tiivistelmä **4**

Preface **5**

List of abbreviations **7**

1. Introduction **9**
- 1.1 Objectives of the publication 10
- 1.2 Methodology applied in the publication 11
- 1.3 Structure of the publication 12

2. The context of a CRS **13**
- 2.1 Technical context of a CRS 13
- 2.2 The business context of the CRS 15

3. Business models and business ecosystems **20**
- 3.1 Business models as the unit of analysis 20
- 3.2 Business ecosystems 23

4. Developing business ecosystems, business scenarios and business models relating to a CRS **26**
- 4.1 Workshop process 26
- 4.2 Step 1: Recognizing the Key actors in the Business ecosystem 27
- 4.3 Step 2: Creating Scenarios for the identified ecosystem 29
  - 4.3.1 Identification of dimensions for scenarios 30
  - 4.3.2 Drivers, limitations and challenges of the scenarios 33
  - 4.3.3 Created business scenarios 36
- 4.4 Step 3: Creating business models 37
  - 4.4.1 Towards business models 37
  - 4.4.2 The business models created for selected actors in selected scenarios 40
  - 4.4.3 Summarizing the business models 47

5. Conclusions and recommendations **49**

References **52**

List of abbreviations

3G	Third Generation
ARPU	Average Revenue per User
CAPEX	Capital Expenditure
CRS	Cognitive Radio System
CWC	Centre for Wireless Communications, University of Oulu
EDGE	Enhanced Data Rates for GSM Evolution
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communication
HSPA	High Speed Packet Access
HW	Hardware
ITU-R	International Telecommunication Union Radiocommunication sector
LAN	Local Area Network
LTE	Long-Term Evolution
M-to-M	Machine-to-Machine
NMT	Nordic Mobile Telephony
OEM	Original Equipment Manufacturer
OPEX	Operational Expenditure
RAT	Radio Access Technique
RRM	Radio Resource Management
SDR	Software Defined Radio
SMS	Short Message Service
SON	Self-organizing Network
SW	Software
WAN	Wide Area Network
WCDMA	Wideband Code Division Multiple Access
WLAN	Wireless Local Area Network

1. Introduction

Chester I. Barnard stated in his famous management book “The Functions Of The Executive” that the most difficult bottleneck in the development of communications technologies is the length of women’s arms (Barnard 1968). This important notion came from observing how telephone centres were staffed by mainly female operators manually connecting calls in front of large switchboards. As the number of telephone lines increased, there was, however, a limit to how large the switchboards could be made.

Since Chester I. Barnard’s day communication technologies have evolved considerably and become mobile. Europe has seen the rapid development of mobile communications and the convergence with internet technologies. First generation Nordic Mobile Telephony (NMT) evolved into the second generation Global System for Mobile Communications (GSM) and its subsequent iterations the General Packet Radio Service (GPRS) and Enhanced Data Rates for GSM Evolution (EDGE) to the third generation Wideband Code Division Multiple Access (WCDMA) and its iteration the High Speed Packet Access (HSPA) to the Long-Term Evolution (LTE) – and similar developments have occurred worldwide. A significant factor in the success of the evolution of mobile communication systems was the fact that sufficient spectrum was made available for these systems in good time. A major challenge in the future development of mobile communication systems will be the availability of a spectrum able to satisfy the growing user requirements in terms of data rates for example.

Currently, the sphere of the cognitive radio system (CRS) represents one of the areas of development where future telecommunications are expected to advance significantly. CRS represent a wireless telecommunications system where the system itself obtains information to adjust its operations to provide services and improve its performance by applying learning techniques. Regarding spectrum use, future wireless systems equipped with CRS capabilities could dynamically access new frequency bands and at the same time protect higher priority users on the same bands from harmful interference.

Forecasts of future global mobile data traffic predict that the traffic in the year 2015 will be much higher than currently and that the growth will continue to be strong between 2015 and 2020 (Report ITU-R M.2243). To carry the predicted traffic in 2020, the future mobile communication systems are likely to require more spectrum than is currently available. Making new spectrum available is traditionally handled by re-farming a spectrum band where the current usage on the band is removed to allow new usage. This process is typically time-consuming and costly as the current usage will need to be moved to another band or its termination needs to be compensated. For future mobile communication systems, cognitive radio techniques present a promising opportunity offering cost-efficient access to spectrum bands to meet growing user demand by enabling shared spectrum use where multiple systems could use the same frequency band taking advantage of the new CRS technology for interference control. In fact, recent regulatory developments, (e.g. European Commission 2012) are moving towards the shared use of the spectrum. Moreover, the recent technology developments in the mobile communication systems are paving the way towards the shared use of the spectrum as many features such as the self-organizing network (SON) and carrier aggregation are enablers of this evolution. CRS technology in an intra-operator scenario allows an operator who is the exclusive owner of the spectrum to use CRS technology to better manage its heterogeneous radio access networks (ITU-R Report M.2242).

The Tekes Trial Environment for Cognitive Radio and Network programme is one of the efforts to research what cognitive really stands for in both technical development as well as for business. In this publication on future business models and ecosystems for a CRS, we focus primarily on the business side of cognitive radio systems. We start by defining what a CRS might include and continue with a review of the (albeit rather scarce) previous research on cognitive business. The main body of the publication consists of discussion related to business models and of the results of the scenario and business modelling workshops organized as a part of the CORE project work.

1.1 Objectives of the publication

The objectives of the publication stem directly from the objectives of the CORE project, especially its business research related parts. The research questions were put forward in a rather exploratory manner: to explore and identify:

1. the preliminary value propositions of future wireless cognitive technologies / networks / services / devices
2. the evolving business contexts for future wireless cognitive technologies / networks / services / devices
3. alternative business models to be employed within future wireless cognitive technologies / networks / services / devices
4. the emerging business ecosystems around future wireless cognitive technologies / networks / services / devices.

To be able to answer to these questions it is necessary first to review previous business research in the field of the CRS, second to have an understanding of how value propositions, business context, business models, and business ecosystems are conceptually and theoretically interconnected, third to find and build a research methodology that enables us to collect, generate, and analyse future-oriented data, and fourth to draw conclusions from the research.

1.2 Methodology applied in the publication

Companies share one universal challenge: how to prepare for an unknown future. This paradoxical challenge is growing all the time, as the speed of change is increasing and the business environment is becoming more and more complex and networked, turbulent and uncertain; making forecasting the future even more difficult. At the same time, companies have to be able to rapidly adapt to the changing environment (Kagerman et al. 2010) and to business ecosystems generally. In practice this means that today's companies are also changing in terms of what they deliver, how much they charge for their products and services and how they organize delivery of their value proposition (Kagerman et al. 2010).

The scenario technique is one approach available to research the future. Building on the exploratory research questions of the CORE project, this publication applies the scenario approach to researching the anticipated future of the CRS. As a result we can describe this research as qualitative and processual. From a business perspective it may well be said that it is impossible to predict the future, but this does not mean that the more distant and uncertain future should be completely ignored in strategic and business model development processes. To a certain extent, companies can influence their own future. Reshaping the environment is possible for example through the development of new technologies and other innovations (Kagerman et.al. 2010). It is important to understand the issues likely to change in the future, what is the nature of those changes and what kind of implications do they have for future business. Therefore, playing with different future scenarios can be a useful approach to change.

The basic idea of the scenario approach is that it considers multiple alternative futures (Van Der Hejden 2007). The purpose is to ensure that all plausible futures are considered, not just the one the management expects (Bishop et al. 2007). Creating scenarios enables identification of critical change elements and experimentation with alternatives for future change. The scenario process is useful both at an industry and single firm level. For example, at the industry level it is possible to increase understanding of the implications of technological development, the world economy, or the dynamics of the industry ecosystem. For example in the context of this project, the scenarios can help understand the implications of cognitive radio systems for the entire business ecosystem. At the firm level, creating scenarios can identify both the risks and opportunities related to the firm's future, so that strategy and a business model may be built on more solid ground. The purpose of creating scenarios is to identify those change elements that have a great impact on the industry or on one company's future, but whose consequences are hard to predict. Usually scenarios are prepared for a matrix, where the different outcomes are significantly spread out and differ from each other (Van Der Hejden 2007, 247).

Scenario techniques have already been widely utilized in developing strategy, and there are dozens of different versions documented (Bishop et al. 2007). Van Der Hejden (2007, Xviii) argues that for management the “scenarios are the best possible language for the strategic conversation, as is allows both differentiation in views, but also brings people together towards a shared understanding of the situation, making decision making possible when the time has arrived to take action”. Scenarios are useful when facing uncertainty about the future, as in such situations, intuition is as important as strategic reasoning. (Van Der Hejden 2007, xv) The challenge for scenario-based planning is how to engage the key people fully and creatively, especially when trying to encourage radically different thinking and adopt a wider perspective on future business (Mason & Herman 2003). The scenario techniques used within the research conducted under the CORE project are described in detail in Section 4.

As this research also concerns change processes at multiple levels of analysis, a processual approach is also needed in researching the CRS context. In this research we mainly refer to Van de Ven and Poole (2005), who have proposed four approaches to conducting processual organization related research: (1) variance-based research where static independent variables explain change as a dependent variable, (2) variance-based research where time-dependent dynamic and complex systems of organizational processes are modelled, (3) process research where path-dependent phases of an organization along its development are described and (4) process research where the social construction of emergence and continuous re-emergence of an organization is reported. In this scenario-based research, we apply mainly the second, third, and fourth categories of Van de Ven and Poole’s framework.

In order to ensure reliability, validity and the overall quality of the research work, a triangulation approach is used in this research. The strategies and business models within the research setting are both firm-specific and time dependent so the results of this research are not expected to be directly generalizable in the positivist sense. In fact, generalization was not among the aims of the research. However, it is argued that the theoretical frameworks constructed and chosen for this research are transferable to the study of other firms in other contexts and with other research methods. Our approach is based on triangulation of the data source (respondents, times, places), the research method (scenario processes, earlier research), the data type (qualitative and reported), different theories or theoretical perspectives, and the researchers’ knowledge.

1.3 Structure of the publication

The publication is organized as follows. Section 2 describes the CRS context in terms of both technical and business aspects including key findings from the literature. The theoretical framework of business scenarios, business models, and business ecosystems is explained in Section 3. The developed CRS-related business ecosystems, business scenarios, and business models are presented in Section 4. Finally, conclusions are drawn in Section 5.

2. The context of a CRS

From a technical perspective a CRS cannot be regarded as a specific simple system but is more a set of capabilities that could be applied in a variety of wireless systems. However, in order to acquire a preliminary understanding of the business drivers leading to the development and emergence of cognitive systems or the business potential offered by this development, it is necessary to adopt a generalized view of the CRS. From a technical perspective it can be stated that each element of a CRS

- Knows what and where it is
- Knows what services and resources are available or accessible
- Knows what services interest the user, and knows how to find them
- Knows the current degree of needs and future likelihood of needs of its user
- Learns and recognizes from the environment and its own operations as it does from usage patterns.

These features present both opportunities and threats for incumbent and prospective firms interested in CRS business. As a CRS is a result of technical evolution, preceding technologies offer elements of functionality that can, at least to some extent, be described as cognitive.

2.1 Technical context of a CRS

A CRS is defined by the International Telecommunication Union Radiocommunication Sector (ITU-R) as “A radio system employing technology that allows the system to obtain knowledge of its operational and geographical environment, established policies and its internal state; to dynamically and autonomously adjust its operational parameters and protocols according to its obtained knowledge in order to achieve predefined objectives; and to learn from the results obtained” (Report ITU-R SM.2152).

The CRS field has attracted significant research efforts globally (see e.g. Ohmori 2011; Matinmikko & Bräysy 2011 and the references therein). From a technical point of view, a CRS is expected to offer several benefits including improved efficiency of the use of various resources and particularly spectrum use, new approaches to interference management, additional flexibility, potential for new applications, increased reliability, and improved energy efficiency (Report ITU-R M.2225). The main benefit of CRS technology is that it can facilitate shared spectrum use where multiple systems could use the same frequency band. This is particularly beneficial for future mobile communication systems as they are expected to run out of spectrum in their attempt to accommodate the future global mobile data traffic forecast (Report ITU-R M.2243). To carry the mobile traffic predicted in 2020, future mobile communication systems are likely to require more of the spectrum than is currently available. As mentioned above, the traditional way of making spectrum available for mobile communications requires the costly and time-consuming re-farming process which means that the current usage in the band is removed to allow mobile access. The new CRS technology offers an alternative way to access new spectrum resources, and future mobile communication systems could obtain cost-efficient access to spectrum bands by sharing bandwidth with current users without causing harmful interference.

In fact, as mentioned above (see p.15) recent technology and regulatory developments are pointing in the direction of shared use of the spectrum. For example, the European Commission promotes shared use in (European Commission 2012). The recent technology developments in mobile communication systems are also paving the way towards the shared use of spectrum as many features such as SON, carrier aggregation, dynamic use of spectrum resources via radio resource management (RRM) functionality, and measurements of the radio environment are enablers for this evolution. Already today in an intra-operator scenario, the CRS technology allows an operator who is the exclusive owner of the spectrum to better manage its heterogeneous radio access networks, see e.g. (ITU-R Report M.2242). In the intra-operator scenario, the operator can adapt to traffic variations and jointly manage its deployed resources in its assigned spectrum bands to maximize the overall network capacity.

Heterogeneous wireless communication networks with multiple radio access techniques (RAT) have become an appealing application area for CRSs. Cognitive radio techniques can be used to select the most suitable access technique and related parameters in the multi-RAT and multi-frequency situation resulting in improved efficiency of resource use and better service for users.

Several technical advances are currently ongoing and are driving the development of CRS including for example (see Matinmikko & Bräysy 2011):

- Spectrum occupancy measurement studies indicating the temporal and spatial variations in the current spectrum use on different bands offering potential spectrum opportunities for CRS operations
- Awareness of the availability and status of different resources in the network including radio resources, built-in resources, user interface resources, connectivity resources, and social resources
- Advanced techniques to provide knowledge of the current state of spectrum use including spectrum sensing techniques, cognitive control channels, and access to databases

- Dynamic channel access techniques to share the spectrum among multiple CRS users and other, potentially higher priority, users
- Advanced coexistence mechanisms with interference management techniques to control interference inside the system and among multiple wireless systems
- Decision-making techniques to optimize resource use inside a network and across multiple air interfaces
- Cooperation among multiple CRS entities
- Learning techniques to improve the performance of CRS by using stored information to aid decision making
- New licensing schemes that protect higher priority systems from harmful interference but at the same time guarantee some QoS for the secondary system.

2.2 The business context of the CRS

From the business perspective, the promise of the CRS is not yet clear. This despite existing mobile radio systems, such as LTE, already including the first elements of cognitive systems. As a minimum, the following benefits of CRS have been recognized; more efficient spectrum utilization, better accessibility and enhanced ease of use, better adaptability, better connectivity, increased scalability and improved reliability, smaller size, lower energy consumption, increased efficiency and lower prices. As can be seen, this rather disorganized list does not differentiate between different roles in the business system. Casey (2010, COST-TERRA workshop meeting) added PEST-analysis into the consideration of CRS business and noted several forces shaping the CRS landscape. These include: political (liberalization of spectrum regulation, threat of losing control of the spectrum market, allocation of unlicensed bands); economic (operators using the spectrum more efficiently, incumbent operators' fear of losing market control, increased number of local operators, vertical/horizontal integration); social (demand for additional spectrum, growth of connected devices, high bandwidth consuming applications, diffusion of flat rate pricing, substitution of wired with wireless, fear of radio emissions); and technological (cognitive and reconfigurable devices, locality of spectrum markets, decentralization of intelligence in wireless networks, interference issues, bottlenecks in backhaul). These drivers should facilitate the emergence of business opportunities around CRS.

In terms of business opportunities themselves, their size and growth rates and, especially, where they can be found are still less clearly specified in current research. The challenge of defining the business context for CRS is twofold. First, we need to have an understanding of how technical development may change the nature, scope, and size of business opportunities around CRS for start-ups and incumbents active within existing business segments. Second, we need to look for perspectives from which completely new business opportunities could be identified and the emergence of cognitive solutions might be captured. Moreover, it appears evident that different countries exhibit different needs and development patterns regarding CRS opportunities and utilization. For example, national variations can be seen in the spectrum available or allocated to operators, in the multitude of services, in customer demand and purchasing power of the customers, and in that operators have differing capacity requirements and therefore also varying cost structures.

As a new and emerging area of business opportunity, the CRS context so far lacks coherent and holistic market research and market estimates. As a minimum, the following business drivers have been identified behind CRSs:

- Increased use of mobile communications
- The need for more capacity and speed
- New areas of application for mobile communications
- Substitution of wired by wireless
- Indoors versus outdoors coverage
- New services and applications
- New user interfaces
- Need for better cost efficiency (CAPEX, OPEX)
  - cheaper implementation and technology updates
- Need for “greener” technologies (energy, radio emissions)
- Inefficient spectrum usage, need for increased spectrum usage
  - distribution of spectrum for mobile communications
  - need for regulation or incentives for spectrum allocation
  - dynamic spectrum access
- Convergence and co-evolution of various wireless and fixed access technologies
  - WAN and LAN technologies and their generations
  - development of new devices for CRS
- Price competition
  - pressure to decrease roaming prices
  - subsidized handsets.

To provide a systematic approach to understanding the CRS business environment, we can first look at three co-evolutionary domains identified within it: the domains of market, technology and policy (Fomin et al. 2010). In the market domain, the drivers identified include 1) consumer demand for lower-priced broadband wireless services, 2) consumer demand for licence-exempt home devices, and 3) operator demand for broader supply and diversity of radio access technologies whereas the barriers included i) incumbent operators’ strong position in wireless services, ii) uncertainties regarding the business model for CRS services and iii) interference concerns. These market domain related drivers and barriers were identified as leading to a decrease in software prices and increases in the variation and adaptability needs of cognitive technologies. Also the regulation related to CRS was found to require, as well as to promote, experimentation.

In the technology domain, the drivers found by Fomin, Vitkuté-Adzgauskiené & Magnus (2010) included 1) a shift from HW to SW and 2) opportunistic spectrum access. Barriers identified in the same domain included i) the resistance of operators to disruptive technology changes and ii) interference and approval concerns, resulting in demand for new access technologies and formation of new role positions in the market (such as data base operators and location-based services) related to CRS services.

In the policy domain, the aforementioned technology drivers and barriers were seen to imply "natural" growth due to a new spectrum and regulation – the purpose of which was to reassure incumbents of the benefits of CRS. The drivers identified in the policy domain, included 1) a shift from administrative to market based frequency allocation, 2) the need for flexible ad hoc emergency frequencies and 3) making use of rarely-used spectrum bands. The barriers identified in the policy domain included i) concerns related to the as yet unproven spectrum assignment processes, ii) concerns related to control of emergency services and iii) the reluctance of government spectrum owners to relinquish control of the spectrum. These drivers and barriers were seen in the context of the market domain to imply an increased need for new and diverse access technologies, cost savings in the form of off-the-shelf equipment, and increased turnover. In the technology domain, the policy domain drivers and barriers were noted as implying new innovative solutions and reconfigurable technologies.

Second, many research papers and presentations have focused on spectrum usage. Barrie, Delaere and Ballon (2011) identified four parameters affecting spectrum sensing-related business scenarios: spectrum ownership, exclusivity of spectrum, tradability of the accessible spectrum, and technology neutrality of licensed spectrum bands. The same analysis identified five business scenarios: 1) the unlicensed business scenario, 2) the single radio access technology pool scenario, 3) the multi-radio access market scenario, 4) the single radio access market scenario, and 5) the flexible operator. In addition, the study claimed that the static spectrum scenario and multi-radio access technology pool scenarios were not applicable from a CRS sensing perspective.

In the unlicensed scenario (being a device-centric business) Barrie, Delaere and Ballon (2011) judge interference related problems would lead to an increased role for regulators in forcing users and vendors to comply with regulation intended to decrease interference. In the single radio access technology pool scenario (being an operator-centric scenario) the aforementioned study notes that all spectrum licensees would have to collaborate as they share the spectrum, and that therefore sensing would play an important role in this scenario. However, competition would be the major problem in this scenario. In the multi-radio access technology market scenario, licences would be issued, spectrum bands assigned exclusively, and tradability allowed. This would also lead to the appearance of secondary users in the system. Emergency and public services could, in this scenario, be borrowed by secondary customers in the same way as TV white spaces could be used for mobile communications. For it to become a workable solution would, however, require finding a suitable compensation system applicable over the spectrum (Barrie et al. 2011).

In the single radio access technology market scenario, the most interesting element is the role of secondary users, as in this case the question is not about a spectrum pool but about exclusive frequency bands that could be accessed by secondary users meeting certain conditions. This scenario assumes tradability of the spectrum in its various forms. It must be noted that this does not mean roaming, as sensing is the key to accessing the frequencies in question. The motivation of the primary user for trading the spectrum could be earning from an underutilized spectrum, and the secondary users might be motivated by a desire to off-load. The flexible operator scenario builds on the idea of using femtocells – that use the internet for backhaul – as an addition to the normal mobile system. In this scenario, sensing is required for managing handovers, but the key driver would be the advantageous CAPEX and OPEX of femtocells (Barrie et al. 2011).

Third, Casey, Smura and Sorri (2011) analysed the value network configurations in wireless local area access and identified seven different configurations of value networks. It can be argued that these value networks have several consequences for CRS. The first of the identified value configurations was the venue-owner-driven value network. In this model, the venue owner has a monopoly over fixed access, but also over power supply, and therefore may be in the position to ask for compensation if for example, femtocells were installed at the venue. The second configuration, that of the mobile operator-driven value network, could be seen as the basic model in mobile communications. But, if venue owners or internet broadband operators controlling access points start asking for compensation for use of their resources, this mobile operator driven value network may change. The broadband-access-operator-driven value network configuration may emerge when there are only a limited number of actors in possession of a fixed access network, these actors may be in a position to extend to the wireless side. Fixed-mobile operators provide service on both WAN and LAN levels, and therefore do not have the problem of sharing revenue with venue owners or other operators. It is also possible that access aggregators, in the specific circumstances of fragmented LAN access, obtain a key role arising from the platforms they have. There are also cases where service providers (such as Google) have extended their position toward the wireless side. In this kind of value configuration, the content of the service is directly related to access. The last of the value network configurations discussed by Casey, Smura and Sorri (2011) is the device-driven value network, where the venue owner and local area access provider are bypassed by a device and/or service that can be used in an ad hoc manner to connect to a wireless network. This device-centric value network may offer unexplored business opportunities. As a summary of their analysis, Casey and Smura (2010) and Casey, Smura and Sorri (2011) conclude that there are two dimensions, an industry structure (horizontal and vertical) and access (integrated or fragmented) that can be used to create future scenarios regarding the value network configurations.

In conclusion, it can be stated that as a consequence of the CRS as a technology still being in its infancy, the business- or opportunity-related CRS research available today is at a similar stage of development. From the business perspective, we might ask the following questions:

- Who are the actors in the CRS business?
- What benefits could CRS offer to different actors?
- What will the future cognitive business environment look like?
- What kind of business scenarios could emerge with the advent of CRS?
- What are the roles of the different actors in the scenarios?
- What kind of factors are related to value creation and capture with CRS businesses?
- What kind of business models are needed for value creation and value capture within a value chain or business ecosystem of CRS?

The following chapters address these questions.

3. Business models and business ecosystems

Based on the discussion and review presented in the previous chapter, the purpose of this chapter is to combine a framework for understanding business models, value networks (ecosystems) and scenarios on the application of a CRS.

3.1 Business models as the unit of analysis

Right from its establishment, every business employs a specific business model (Teece 2010), which illustrates how the firm operates (Casadeus-Masanell & Ricart 2010; Osterwalder et al. 2005). Usually the business model addresses the fundamental questions on how the firm will find its competitive advantage and profits by creating and capturing value (see e.g. Teece 2010; Zott & Amit 2010), that is, how it will provide benefits to customers that they value (value creation) and in exchange derive profit for the company itself (value capture). Following this view, for example Shafer et al. (2005) define a business model as “a representation of a firm’s underlying core logic and strategic choices for creating and capturing value within a value network.”

For practical purposes, it is useful to deconstruct the business model concept into simple elements that are familiar from real business. With this purpose in mind, Osterwalder and Pigneur (2010) have proposed nine elements that make up a business model: customer segments, customer relationships, channels, revenue streams, value propositions, key activities, key resources, key partners and cost structure. The basic idea is that the business model is created by designing and organizing these elements. Together these elements reveal the core logic of business.

The business model elements describe and identify the following issues:

- **Value propositions**: Describes the bundle of products / services offered to customers and the value created through the offering. The value can be either quantitative (e.g. price, time) or qualitative (e.g. customer experience).
- **Customer segments**: Defines the target customer groups for the product/service, based on the distinct channels used to reach them or any cus-

tomization the product requires to appeal to different user groups or the nature of the relationship they each require, for example.

- **Channels**: Describes the channel for customer communication and for reaching the customer segments to deliver the value proposition.
- **Customer relationships**: Identifies the types of relationships created with the different customer segments.
- **Revenue streams**: Defines how the company earns money through its operations – the earning logic and pricing model.
- **Key resources**: Describes the assets the business model depends on to make it work.
- **Key activities**: Identifies the most important activities the company must perform in order to operate successfully.
- **Key partnerships**: Describes the key partners needed to create and deliver the value proposition. The key partnerships are connected with the key resources and activities, as they can be acquired and utilized both internally and externally.
- **Cost structure**: Describes the costs and their implications for the business model.

The business model concept has attracted increasing attention both from practitioners and academics. The usefulness of the business model concept lies in its simplicity and practicality. It makes it possible to capture the essence of the business. Furthermore, it bridges the gap between strategy and the practical process level, thus enabling transformation of strategies into implemented profitable business (Osterwalder & Pigneur 2002). Furthermore, the business model "..involves simultaneous consideration of the content and process of 'doing business' " thus, answering both what and how questions (Zott et al. 2011, 19). The business model can be considered as a new unit of analysis combining the firm and network levels of analysis (Zott et al. 2011).

Despite the increasing recognition of the importance of creating a business model, it has so far been a rather neglected process. Whereas many organizations invest heavily in exploring and developing new technologies and related competences, they may at the same time lack the ability to formulate their business model (Chesbrough 2010). However, it is important to understand that no technological innovation alone can guarantee business success (Teece 2010). Similar ideas or technologies commercialized through two different business models will result in two different economic outcomes (Chesbrough 2010). This is clearly visible especially in the discussions about e-business, where both the success and failure of firms' have been explained by the business model adopted (Chen 2003). The normative conclusion is that technological development should be coupled with innovative business model creation.

Naturally there is no obvious single business model for the company just waiting to be discovered, but the challenge is to find an optimal combination and fit between the different business model elements. Success requires the consideration of two important issues that should be added to the original business model development framework comprising the nine elements mentioned above. The first issue is the underlying logic of the business model already stated in its definition: The dynamic process of value creation and capture. This value-centric logic is the common thread between the business model elements, because the elements should be organized in a way that maximizes value creation and capture. This simple value logic means that the success of the business depends on the firms' ability to maximize customer satisfaction (value creation) and accrue profits in return (value capture). The important notion in value creation is that the customer value is not created when the product or service is delivered to the customer, but only when the product or service is consumed. Products and services can be viewed as resources enhancing the customer's ability to create value for itself (Grönroos 2008). For customers, products and services are just enablers (Bouwman et al. 2008). The other side of the coin, value capture, takes place when the customer is willing to pay for the value received from the product or service. Maximizing the value capture is possible through application of an innovative business model and maximized customer value. The value logic determines the entire business model creation. What kind of offering is built from resources and technologies, what is the best sales channel, what kind of customer relationships are required, what is the pricing model for the offering – these should all be based on the value creation and capture logic.

The second important issue is the impact of the firm's external environment, in other words the ecosystem encapsulating the development of the business model. A business model is not just a firm's internal issue, involving plotting transferring resources into products with some customer value and specific earning logic, but must also consider the advantages of cooperation and threats of competition. The firm's value proposition is evaluated against competing value propositions. Furthermore, customers often create value by combining several complementary products and services, or even single value propositions containing input from several companies. This means that customer value creation is not merely dependent on one company, but is also influenced by other companies. Therefore, today cooperation is one efficient and very common way to enhance customer value.

In the current dynamic business environment, competition and cooperation are no longer just separate issues, but are taking place in parallel. Hearn and Pace (2006) use the term coopetition in order to reflect the increased complexity of the business environment. The term is based on the notion of duality, as value creation can be seen as a cooperative and value capture as a competitive process. Through cooperation, companies create a bigger "pie" and through competition they divide it between themselves (Brandenburger & Nalebuff 1996). Similarly, the impact of the external environment can be illustrated in the concepts of value creation and capture by renaming them value co-creation and co-capture. The extended business model development framework, where business model elements are complemented by the concepts of value co-creation, co-capture and coopetition is presented in Figure 1 (Myllykoski & Ahokangas 2012).

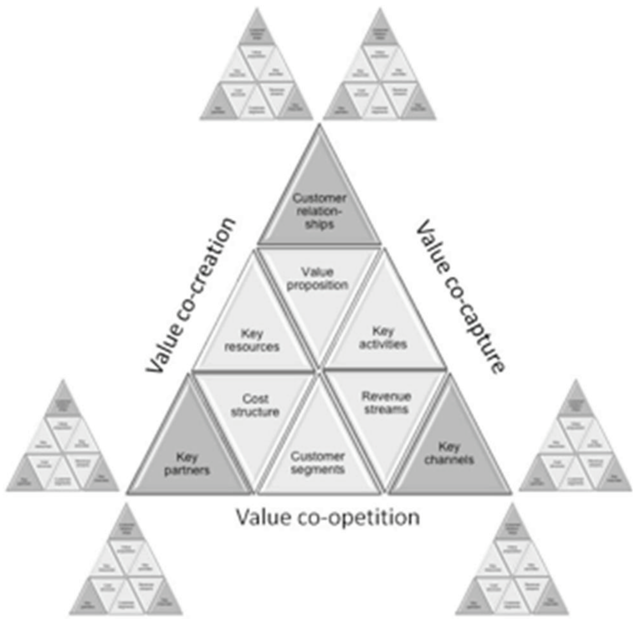

Figure 1. Extended business model development framework.

3.2 Business ecosystems

“No business is an island”, states a well-known article by Håkanson and Snehota (1989), highlighting the importance and impact of the external environment on the firm. Today, many industries can be described as massively interconnected networks, where companies can no longer concentrate merely on the management of their internal resources, but must be aware of resources that are beyond their direct ownership and control (Iansiti & Levien 2004a). Sharing this view, the metaphor of the ecosystem, borrowed from biology, is used to describe the environment and network of actors the firms are embedded in. The reason for drawing an analogy between biology and the business system is to illustrate how companies share some fundamental properties with natural ecosystems, those being interconnectedness, complexity, adaptation and co-evolution (Peltoniemi 2006). As a result, treating business networks as ecosystems supports better understanding of their development and dynamics. Companies resemble biological organisms in several ways as they “live in an environment that is defined by (the action of) other organisms that evolve themselves” (Pagie 1999, 2). As a consequence, the success of individual firms is determined by the health of the ecosystem it is a part of. As in the biological ecosystem, “each member of a business ecosystem ultimately shares the fate of the network as a whole, regardless of that member’s apparent strength” (Iansiti & Levien 2004b). Similarly, for an ecosystem to function effectively, all critical domains in the product or service delivery should be healthy, as they affect the performance of the whole ecosystem (Hearn & Pace 2006, Iansiti & Levien 2004). The importance of the ecosystem seems to be growing; actually so much so that competition is said to increasingly be occurring between the ecosystems rather that between individual firms (Hearn & Pace 2006).

Moore (1998) describes business ecosystems as synergistic "communities of customers, suppliers, lead producers, and other stakeholders - interacting with one another to produce goods and services". In addition to the main stakeholders, the ecosystems consist of other actors, for example financiers, trade associations, standards bodies, labour unions, governmental and quasi-governmental institutions, and other interested parties (ibid). Drawing absolute boundaries for an ecosystem is not possible, as they do not typically equate with the traditional industry boundaries, but instead may span several industries. A prime example of this is computing, as its impact is not limited to the traditional computing industry of software and hardware developers. One way to define ecosystem boundaries is for example from the viewpoint of one specific firm (Iansiti & Levien 2004a).

It is possible to understand the dynamics of the business ecosystem by looking at the roles, (i.e. the operating strategies) that different companies have in their ecosystem. Iansiti and Levien (2004a) discuss three typical roles in an ecosystem: keystones, niche players and dominators. Keystones are companies that act as important enablers or hubs in the ecosystem and hence have a great impact on the health of the entire ecosystem. Keystones are important companies, but such companies constitute only a small fraction of the total volume of companies within the ecosystem. Niche players in turn individually have very little impact on the ecosystem, but collectively form the bulk of the business ecosystem. Dominators to some extent contrast with the keystones and are easy to detect by their size, for example. Unlike keystones, they have a tendency to take over the functions of other companies, and so eliminate them from the ecosystem. The threat of a dominated ecosystem is the limited ability to adjust to sudden changes in the environment owing to its uniformity (ibid.). These roles are interesting, because they can help to understand the actions of individual firms.

The unique feature of business ecosystems compared to biological ones is the conscious decision-making ability and innovativeness of the ecosystem members. Moore (1998) suggests that especially in the processes of transformation and improvement, single firms should actively relate with and pay attention to the other actors within their respective ecosystem. In practice, this means for example allying with other actors to ensure the availability of complementary contributions (ibid.). However, individual organizations (especially niche players) still have a very limited ability to shape the ecosystem. This is due to complexity and emergence, which are the predominant characteristics of an ecosystem. Emergence means that the system is so complex that the "links between individual agent actions and the long-term systemic outcome are unpredictable" (Smith & Stacey 1997). In other words, there is no telling what effects an individual company action has on the ecosystem. The other side of the coin is that there is no single actor that alone can determine or control the development of the ecosystem. The decision making in ecosystems is decentralized and the system is self-organizing.

Hence, the ecosystem members evolve together, which is called co-evolution. Peltoniemi (2006) defines this co-evolution as "..two-way interaction where both entities have an effect on each other's success potential, which may induce change in some direction".

Pagie (1999) and Peltoniemi (2006) discuss three different types of ecosystem co-evolution: the competitive, the mutualistic, and the exploitative. Competitive co-evolution means that different companies compete with the same pool of resources, and are evolving towards more efficient utilization or acquisition of those resources. Mutualistic co-evolution it is based on parallel change or actors moving towards better compatibility, as they both benefit from tighter integration. This is usual in complementary offerings, for example in the evolution of software and hardware. Exploitative co-evolution on the other hand does not benefit all parties to the interaction, but the more powerful organization pushes the evolution in a certain direction (ibid.). Following the notion of co-evolution, the ecosystem's success level is determined by how robust it is against environment changes. Even if individual firms within the ecosystem fail, a robust ecosystem is able to recover and continue. This adaptability and flexibility is required from the ecosystem especially in a complex and turbulent environment (Hearn & Pace 2006).

The ecosystem is held together by the cooperative and competitive interactions between different companies. When trying the capture these connections between different firms within the ecosystem, the business model can again be a useful concept. This kind of approach suggests that companies are connected with each other through their business models. Therefore the business ecosystem can be defined as a coopetitive, synergistically value-creating and capturing an aggregate of interdependent business models (Ahokangas & Myllykoski 2011), see Figure 2. The evolution of the ecosystem occurs when companies synergistically adjust their business models towards an optimal fit.

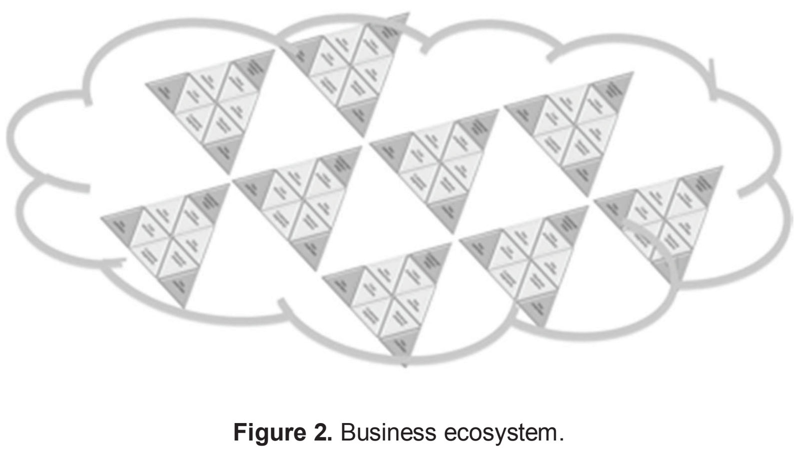

Figure 2. Business ecosystem.

4. Developing business ecosystems, business scenarios and business models relating to a CRS

Based on the description of the CRS context and the theoretical framework for business models, ecosystems and scenarios from the previous chapters, the purpose of this chapter is to suggest specific business ecosystems, business scenarios, and business models pertaining to a CRS.

4.1 Workshop process

In May and September 2011, a group of industry representatives and researchers met in two workshops to discuss future business scenarios and ecosystems for pertaining to a CRS. The workshops were organized by VTT as a part of the CORE research project. The purpose of the first two workshops was to combine different perspectives on the CRS, identify the key actors in the CRS business ecosystem and create future business scenarios pertaining to a CRS. The workshops continued in 2012, where the industry representatives and CRS researchers were to elaborate further on the scenarios and to suggest new business models enabled by the development of the cognitive radio technologies. The workshops brought together approximately 20–25 participants.

The workshop structure had four parts: it began by identifying all the key actors within the CRS business/value chain. It is recognized that the emergence of cognitive radio technologies will cause substantial change to the entire business ecosystem and therefore it is important to look at all the key actors simultaneously. Furthermore, the core needs of each actor as well as the benefits of cognitive technology were identified. Analysing these needs and benefits enhances the understanding of the real value of cognitive technology rather than merely its technical features. The workshop went on to create potential scenarios for the future cognitive business environment (step 2), and also analysed the drivers, limitations and challenges of the different scenarios. The final step of the workshop process (step 3) was to create preliminary business models for different actors within the cognitive ecosystem. These business models derived from the results of steps 1–3 above.

4.2 Step 1: Recognizing the Key actors in the Business ecosystem

For this first phase, the participants of the workshop held in May 2011, were divided into three groups and given the following Actors-Needs-Benefits framework to work with, which also served to present the findings of the groups. The idea of the framework was to make the workgroup think about the kind of roles a CRS demands and the needs and benefits of each of the players within the CRS. Each of the groups applied the framework differently, hence the variation in the format of the results. Tables 1–3 present the results of this first step of the workshops.

Table 1. Actors, needs and benefits of Group 1.

Value chain partner	Need	Benefit
Operator → Service operator → Network operator Data, TV, Speech, SMS, Radio, Video, Advertisements, Location data	Business: current + new Network sharing – balancing the capacity	Service operator: more extensive, faster, more reliable Network operator: cooperation, saving energy
Authorities	Developing and maintaining own systems	Authorities/Military reliability, band, flexibility
Original equipment manufacturers (OEM) → Base stations, Devices, Testing, Infrastructure i.e. factories, materials	Business status	OEM. Energy saving, new business
Research and development (R&D)	Research assignments (meets the needs) Basic research	Increased degree of freedom in the research
Contractual work	Inefficiency of the network, Business	
Regulators	Trouble free, reliability, creating regulations, fees	Regulation, standardization
Standardization	Compatibility	
Content creation	Business, informing the society, education, communities	More information about the network and users

Customer	**Need & Benefit** (combined here)
→ Military, authorities	Reliability, security, need for bandwidth
→ Government, municipalities	Cost savings
→ Companies	Affordable, data transfer, video conference management, marketing, logistics
→ Consumer	Affordable services, sufficient services, *effortless*
M2M (for example. meter information)	Affordable, sufficiently reliable connection

Table 2. Actors, needs and benefits of Group 2.

Value chain partner	**Need**	**Cognitive solutions**	**Benefit**
Research	Money, scientific breakthrough		Continuation of research activities
Regulator	Guidance on resource use	Handling interference harmonization	Enough resources for all
Manufacturer	One step ahead		Competitive edge
Service provider			Services quality, capacity, QoS, increased number of customers, more efficient use of spectrum, increased coverage
Operator		Opportunistic capacity allocation	Satisfied customer, Full benefit from operator's network
Organization (customers), **Public sector** (customers)	Harmonization, more capacity, fast deployment		
Consumer	Mobility support	Intelligent RAT selection	Generic end equipment, enhanced services, increased coverage

To sum up the first step of the analysis, the three workgroups identified different actors in the value chain but the same baseline actors were recognized including the five different CRS business ecosystem players: Regulator, Content Provider, Equipment Vendor, Infrastructure Vendor and Communication Service Provider. The key actors in the CRS business ecosystem are depicted in Figure 3.

The challenge was that the groups sometimes had difficulty in identifying differences between needs of and benefits to the CRS actors, and did not at this point of the analysis identify any new actors that would emerge owing to the advance of CRSs. However, all the consequences identified by the groups were positive.

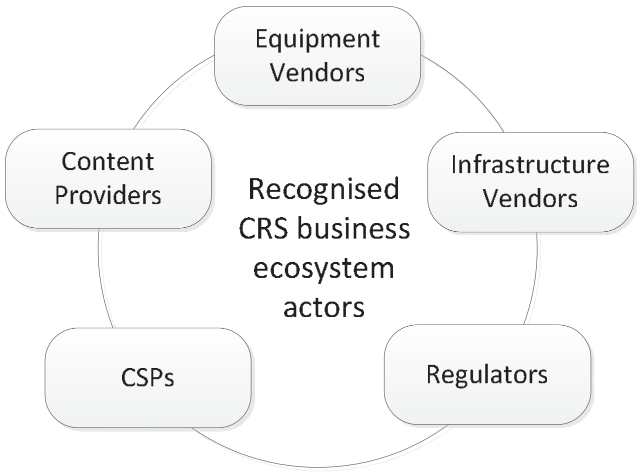

Figure 3. The Key actors in the CRS business ecosystem.

4.3 Step 2: Creating Scenarios for the identified ecosystem

The second workshop step was to create different scenarios about the future business environment. The purpose of the scenario exercise was to create a better understanding of the change related to the emergence of CRSs, as well as to create different visions about the future cognitive business environment. Scenarios describe how the identified business ecosystem is restructured when the defined variables change in the business environment. The workshop was held in September 2012 and this time the participants were divided into two groups that followed the scenario process described below:

1. List the changing context variables on sticky notes
2. Place them on the classification canvas
3. Pick the critical variables
4. Group them by theme
5. Identify extremes
6. Select the two most important

7. Draw the scenario matrix
8. Describe the scenarios
9. Identify drivers / limitations / challenges of each scenario.

4.3.1 Identification of dimensions for scenarios

The first step of the process was to identify issues within the cognitive business environment that seemed liable to change (called change variables). The groups were able to identify over 100 change variables. As a second step, they were positioned on a canvas depending on the magnitude of their impact (small – great) and the predictability of their consequences (low – high), as jointly evaluated by the workgroup participants. The purpose was to find such change variables that might have a great impact but with consequences that were hard to predict (Step 3). It is not possible to present the entire canvases here due to limitations of space, but examples of the variables are listed below:

- Maximized utilization of resources: WLAN, 3G, GSM sharing the resource within an operator
- Energy-saving solutions: considering what is needed
- Smart spaces
- The device functions in all networks: the cheapest or fastest regardless of operator
- Cloud services
- Intelligence from the user to the device
- Who leads and controls the industry development?
- Competition between traditional operators and broadcasters increases
- Where and how the revenue is generated and by whom?

The most critical variables were picked for further analysis and grouped into dimensions. After that, the extreme outcomes (End 1 and End 2) of the dimensions were created, see Table 3.

Table 3. Key dimensions of Group 1.

End 1	Dimension	End 2
Fossil fuels dominate	**Energy**	Energy saving dominates (“20–20-20” targets from EU)
Steady growth (linear)	**Data explosion**	100x wireless traffic (exponential)
Device centric	**Cloud**	Cloud centric
Data exhibitionists “Good enough”	**Trust, privacy & security**	“Stubborn” Critical infrastructures
Smart devices (smart phones)	**Intelligent heterogeneous devices**	Smart spaces (M2M,…)

The two dimensions identified as the most important were then selected as axes of a future scenario matrix. The criterion for selecting the dimensions was that they had to be independent of each other, in that a change in one dimension would not automatically change the other dimension in a predictable way. As an outcome, each group formed four different scenarios. The scenarios were then described, as in Figure 4 and Figure 5.

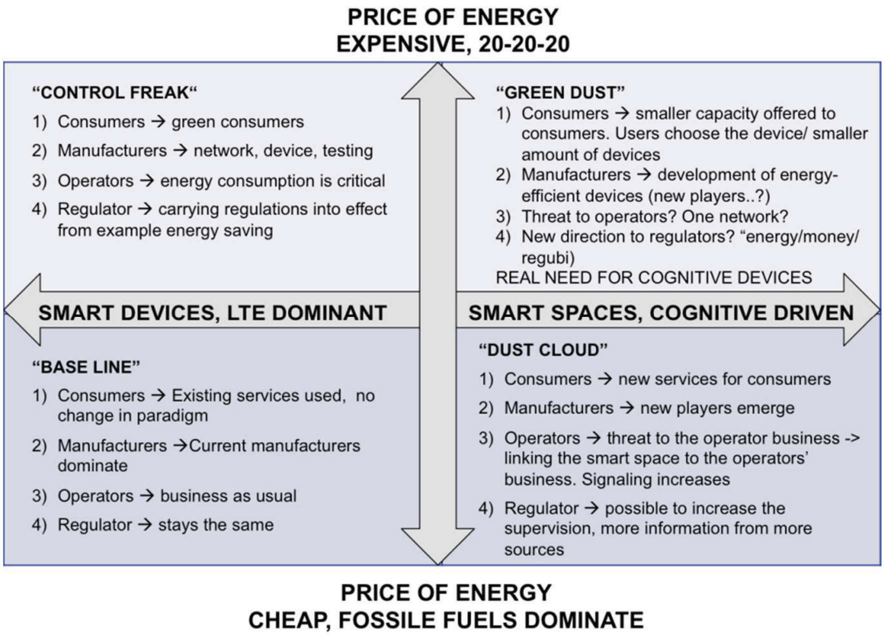

Figure 4. Future scenario matrix of Group 1.

For Group 1, the scenarios were based on the price of energy (cheap / expensive) and devices versus spaces (smart devices / smart spaces). Without going into great detail on the scenarios, the left side scenarios "Control freak" and "Base line" represent the continuation of the current business scenarios within the communications industry, whereas the right side and the "green dust" and "dust cloud" represent changes triggered by the advances in cloud computing. For the first time, the potential negative consequences for the business environment were also identified. The group further discussed whether the price of energy as one dimension of the scenario could be replaced with the role of the cloud (Cloud / No cloud). Unfortunately, due to time limitations within the workshops, this alternative scenario matrix was not created.

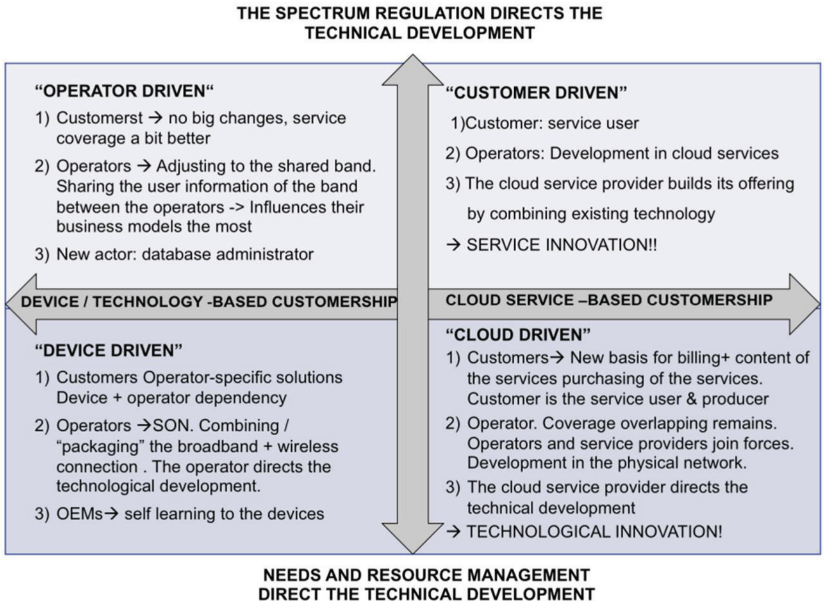

Figure 5. Future scenario matrix of Group 2.

For Group 2, the scenarios were defined by "customership" (devices / cloud service) and technical development from two different perspectives (spectrum regulation / resource management). "Customership" was selected as the sole scenario dimension because it significantly defines how the future cognitive ecosystem will look by asking the question of whether the end customers purchase the devices they need and then complement the devices with available services, or if they select the most valuable (cloud based) service offering and then get the devices best suited to consuming that service, regardless of the device brand. In these two extremes, different actors dominate the entire ecosystem. The two extremes related to the technical development dimension indicate two alternative strategies for technology developers: Reactive (spectrum regulation directs the development) or proactive (customer needs and resource management direct the development).

Eventually each of the scenarios was seen to be driven by a different actor, either the customer, operator, cloud, or device. The discussion led to further development of ideas, and the group also presented a different matrix, as presented in Figure 6. In this new scenario the discussion was around the weakening of the role of operators due to CRS.

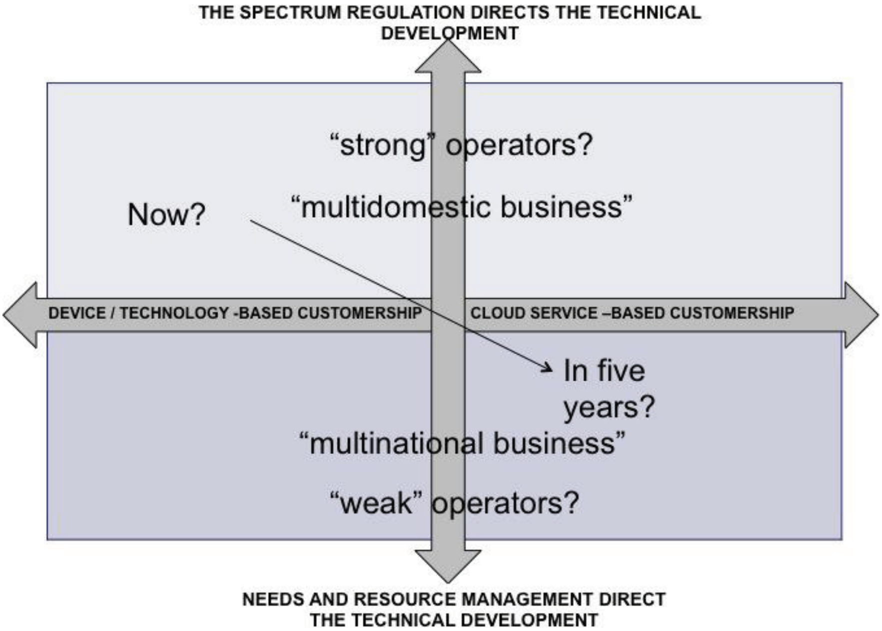

Figure 6. Further scenario ideas from Group 2.

4.3.2 Drivers, limitations and challenges of the scenarios

The next step of the scenario exercise was to analyse the drivers, limitations and challenges of each scenario, (see Table 4 and Table 5). The purpose of this step was to better understand which issues might lead to the different scenarios and which issues might prevent the scenarios from happening. Furthermore, the challenges that each scenario would present to the actors were analysed.

Table 4. Drivers, limitations and challenges for Group 1.

	DRIVERS	LIMITATIONS	CHALLENGES
CONTROL FREAK	1) Rising price of energy. 2) Controlled use of frequencies.	Rising energy price is big expense for operators.	Not enough allocated frequencies in the long run. → Operators are not interested in a CRS, since there are no guarantees for the frequency use periods or usability.
BASE LINE	**DRIVERS** 1) Financial recession → no new investments. 2) Frequency regulation.	**LIMITATIONS** 1) No space for new players. 2) The business of different actors gets into a rut.	**CHALLENGES** No frequency allocations for long enough periods.
GREEN DUST	**DRIVERS** 1) Rising energy price 2) The freer (white space) usage of frequencies.	**LIMITATIONS** Complexity of devices.	**CHALLENGES** 1) The end user does not see the value of the new services. 2) Data security.
DUST CLOUD	**DRIVERS** 1) New innovative services. 2) Intelligent devices.	**LIMITATIONS** Malfunctions, uncertain quality of service.	**CHALLENGES** Data security.

Table 5. Drivers, limitations and challenges for Group 2.

OPERATOR DRIVEN	**DRIVERS** Operators already have a strong customer base, profitable business, long licences, strong device base (network infrastructure) and business model → Strong position that enables control of the market.	**LIMITATIONS** Free WLAN. Operators have not succeeded in getting involved with the "Indoor" business. Consumers object to the operator lock-in. Hard to create innovative new services. Loosening regulation changes the position of Operators. The impact of the internet!!	**CHALLENGES** The emerging ecosystems affect the roles of operators.
CUSTOMER-DRIVEN	**DRIVERS** Easy for the customers. Small amount of services, but they can be marketed to the masses. Guarantees a good quality service, because just one actor takes care of the network.	**LIMITATIONS** Serving only the mass market, hard to commercialize smaller innovative services. The impact of the internet!!	**CHALLENGES** Renewing the services is slow and inflexible.
DEVICE DRIVEN	**DRIVERS** Device manufacturers launch enough new innovative devices. The service is bundled to the device, smart spaces – linkage. Technology driven and individual solutions.	**LIMITATIONS** Consumers do not want a large number of devices. Market limited for single solutions. Differentiating/standing out from the crowd.	**CHALLENGES** How the new devices are brought to market?

	DRIVERS	LIMITATIONS	CHALLENGES
CLOUD DRIVEN	Devices have more support for different access types → Competitive advantage for device manufacturers. Free network infrastructure broadens. Freeing the competition to boost innovations.	No earning model for the released network usage and services. National roaming forbidden. The trust of users.	Data security & responsibilities.

To sum up the discussion of drivers, limitations and challenges – it can be clearly noted that each scenario created by the groups has different characteristics, and different business drivers affect them differently. In addition, the business challenges created for the different CRS players vary across the scenarios.

4.3.3 Created business scenarios

The scenario workshops formed the groundwork for the final CRS business scenarios. By combining the key change variables found within the business environment, the identified business ecosystem, and the workshop scenario matrix dimensions, two scenario dimensions were developed. First, value creation within the ecosystem was seen to emerge through customer attraction and lock-in enabled by either the devices used by the customers or the service enjoyed by the customers. Second, value capture with the ecosystem was seen to be related to competition between various heterogeneous access services in either a licensed or unlicensed spectrum.

The following four scenarios were developed from the scenario matrix dimensions presented above:

1. Gyro Gearloose: a scenario where there is an abundance of new innovative gadgets and devices with non-standard and informal service in the background. The key players in this scenario ecosystem would include content providers and equipment vendors.
2. Snow White: a scenario where operators fear that someone is feeding them poisoned fruit (e.g., apples) and taking over the business by reducing the operators to a bit pipe. The key players in this scenario would include equipment vendors and infrastructure vendors.
3. Cruella de Vil: a scenario where regulators have provided incumbent operators with the "right" to exploit other ecosystem players, the spectrum being the scarce resource. The key players in this scenario would include regulators and communications service providers.

4. The Cheshire Cat: a scenario where Google or similar content providers lure consumers with philosophical answers to their questions and thereby control the consumers and how profits are distributed within the ecosystem. The key players in this scenario would include communications service providers and content providers.

The four scenarios are depicted in Figure 7 below.

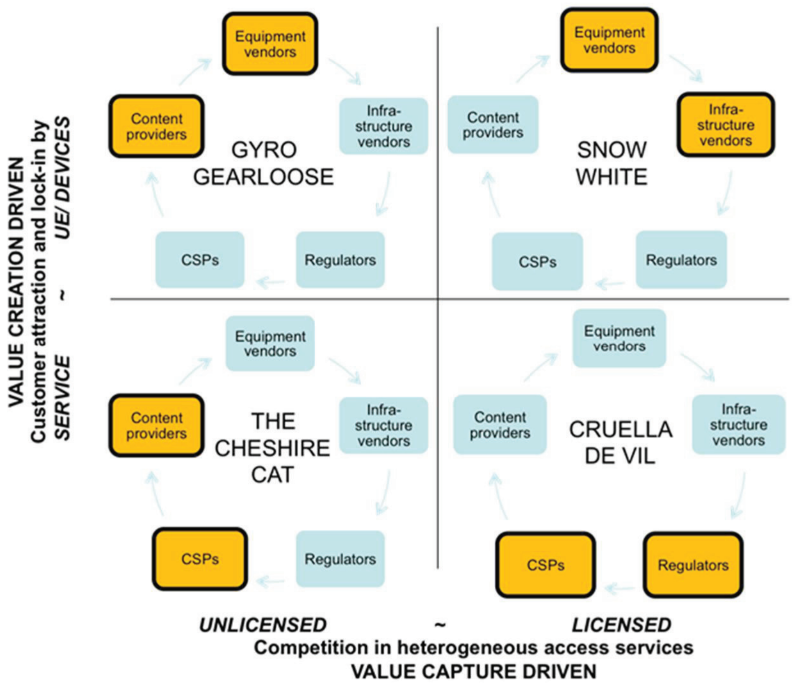

Figure 7. CRS business scenarios.

4.4 Step 3: Creating business models

4.4.1 Towards business models

The final workshop exercise invited participants to select one of the scenarios created and develop business models for the actors identified in the first workshop exercise. This business model development exercise utilized the business model canvas by Osterwalder and Pigneur (2010). The canvas distinguishes nine business model elements and the business model is developed by describing and organizing these elements. The elements are: customer segments, customer relationship, channels, value proposition, key activities, key resources, key partners, revenues and cost structure.

The difficult challenge encountered in this last workshop phase was to look beyond the existing business models of the actors, and envisage business models radically different from what is currently observable. To meet this challenge we organized a second business model workshop, where we changed the exercise from developing a business model for each player in each previously identified scenario to developing only one business model for one player in a chosen scenario. Also the starting point for the workshop was changed to meet a specific time: since the CRS is still not in use and only on the horizon, the starting point for the business model development was set to 2015, when the following issues were anticipated:

1. Incumbent operators start to run out of spectrum
2. Smaller or challenger operators cannot compete in the mobile broadband sector
3. The auction prices of the spectrum will increase
4. More than half of internet traffic is will be wireless
5. Traffic will be at least four times greater than at present
6. Traditional spectrum assignment is too slow to meet the demand.

The future assumptions for 2015 meant the business models for different actors were created in parallel, because the different business models had to be compatible. This approach is based on the view that companies within an ecosystem are connected to each other through their business models. The key actors identified in the first workshop exercise were used as a starting point, but due to the assumptions regarding the workshop task, the key actors were complemented by dividing the CSPs into “incumbent operator” and “challenger operator” groups, so increasing the key CRS ecosystem actors from the original five to six. The new segmentation accounted for CSPs potentially having different roles by 2015. The six key actors for the workshop are depicted in Figure 8.

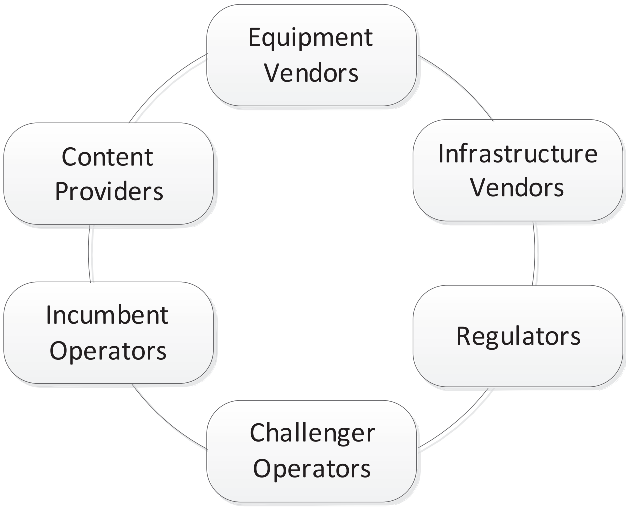

Figure 8. The modified key actors.

The workshop participants were divided into five different groups, and each group assigned one of the ecosystem players identified earlier. For this player the group then had to choose the most interesting scenario and develop the business model for that given player in the chosen scenario. In order to bring anchor the business models at a practical level, the groups were told to place the player in a specific business and determine its business model in the chosen scenario in 2015. "Regulator" was excluded from the exercise as its business model would not change significantly under different scenarios, only the Regulator's decisions on the cognitive radio system environment would change, and such changes were already envisaged in the scenarios described earlier. The key actors were:

1. Incumbent CSP
2. Challenger CSP
3. Content/cloud provider
4. Equipment vendor
5. Infrastructure vendor.

Table 6. The table of networked business models.

Actor	El-ement1	E 2	E3	E 4	E 5	E6	E7	E8	E9
Actor 1									
Actor 2									
Actor 3									

Individual business model of a company

Table 6 illustrates how an individual business model can be connected to the business models of the other actors within its respective value network or ecosystem. Reading one row from the table reveals the individual business model of a company and reading the columns reveals how the business model elements of different companies are connected to each other.

The next step in the second cognitive radio system business model workshop was to create and tabulate the business models. The business models have been created using the business model canvas from Osterwalder and Pigneur (2010).

4.4.2 The business models created for selected actors in selected scenarios

Group one: The incumbent CSP business model

Group 1 (one) were assigned the Incumbent CSP as their CRS ecosystem player. The group chose the scenario Snow White where the spectrum is licensed and the value creation is device driven. The reason for this decision was that, from the predominant operator's perspective, the licensed scenario is more advantageous than the unlicensed scenario. In addition, Group 1 saw the cognitivity as being in the devices through equipment vendors and infrastructure vendors, and not in the services.

The group concluded that equipment vendors would develop the technology and bring it to the operators. The equipment vendors would not necessarily gain huge monetary advantage in this scenario, but they would manage the CRS technology. This scenario was seen to be the closest to the current situation, where the operators are strong and the equipment vendors are weaker. In this scenario the incumbent operators would try to defend their strong position while the challengers tried to reduce the incumbent operator to a bit pipe. The challengers might for example be MVNOs and equipment vendors. The infrastructure vendor's role is determined by how it responds to the actions of challengers: will the infrastructure vendor support their current customer, the incumbent operator, or also support the challengers by offering them the network to operate in competition with the incumbent operators.

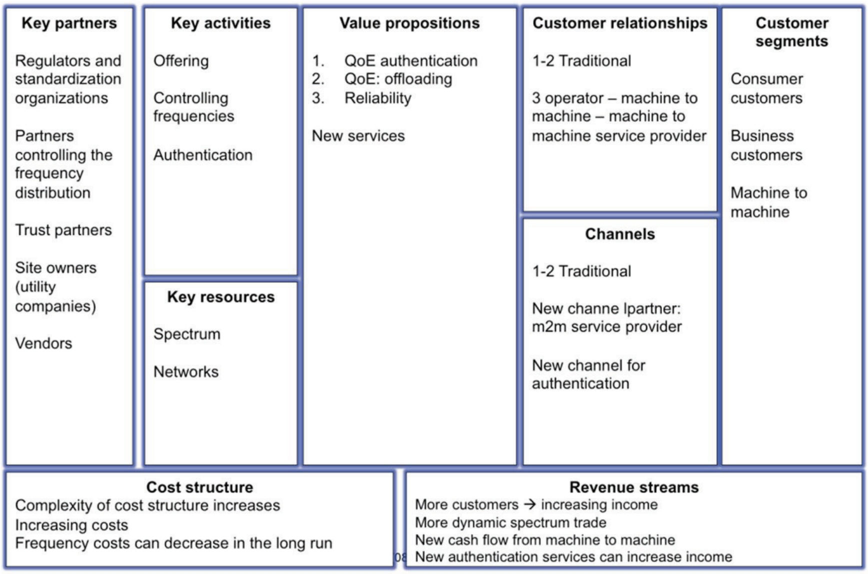

Figure 9. Group one's incumbent operator's business model in the White Snow scenario based on the business model canvas from Osterwalder and Pigneur (2010).

The developed business model is presented in Figure 9. In the incumbent operator's business model the customers are the consumer and business customer and machine-to-machine (m-to-m) business actors. The first two are managed in traditional ways, and the m-to-m customers are managed through a new CRS ecosystem player: an m-to-m service provider. In addition, the incumbent operator could require a new channel for the new authentication services.

The value proposition for the incumbent operator's customers is quality of experience in offloading and the quality of experience in authentication. Reliability is also an important value for the customers, especially for the m-to-m customers.

The key resources for the incumbent operators are naturally the spectrum and the networks. The regulators and standardization organizations play a huge role in the incumbent operator's business, since they decide whether the spectrum stays licensed or becomes unlicensed. The incumbent operators' goal in this chosen scenario is to maintain their strong position and influence the decision makers, in this case the regulator and standardization organizations, to keep the spectrum licensed. Other key partners are the actors controlling the spectrum distribution, since the incumbent operator wants to own as much spectrum as possible. In addition the site owners and different vendors, such as infrastructure vendors, can be seen as the incumbent operator's key partners.

The key activities are related to the value proposition and owning the spectrum: controlling the frequencies and offering authentication and capacity. In order to prosecute its key activities the incumbent operator requires spectrum and network resources, among other things.

The cost associated with the spectrum is eventually going to increase, adding cost for the incumbent operator. Furthermore, the new business services, like m-to-m services, will make the cost structure more complex, but bring more revenue.

Group two: The Challenger CSP

Group 2 (two) representing the challenger CSP player opted to view the scenario from the point of view of a mobile operator. The group selected the Cheshire Cat scenario, because it offered more options for the challenger competing against the incumbent operators and the scenario envisaged the challenger luring away the incumbent operator's customers by offering tailored, high quality services for city areas. The developed business model is presented in Figure 10.

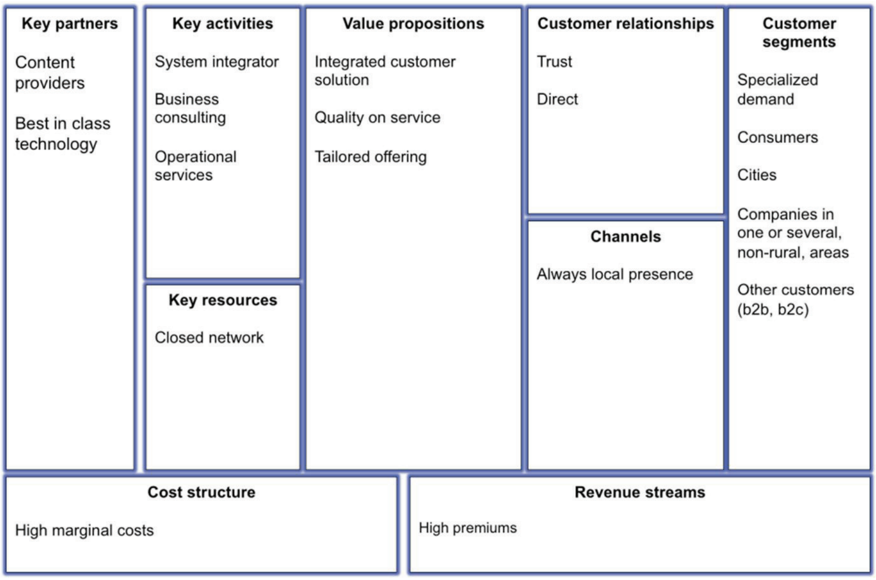

Figure 10. Group two's challenger mobile operator business model in the Cheshire Cat scenario based on the business model canvas from Osterwalder and Pigneur (2010).

The challenger's key customers would be those with special needs in local areas, such as consumers, cities, and business customers. The customers would require more than basic services, and would be more demanding or have specialized needs. Lack of infrastructure, or its high cost, would deter the challengers from operating in rural areas, which consequently would be left to the incumbent operators. Being smaller than the incumbent operators, the challenger could adapt more quickly to changing situations and offer their customers more tailored services. The value proposition for the customers would be made up of the integrated customer solution, quality of service and the tailored offering. The value proposition would not mean that the customer relationship would demand more time of the operator, but the customer relationships would be based on trust and the service provider would always have a local presence.

In order to offer these tailored services the challenger would need to have good relationships with content providers and best-in-class technology providers, who would be the challenger's key partners. In addition to the technology, the challenger would need to have a closed network to maintain the business. Key activities are the system integrator operations, but also business consulting and operational services.

The business would have high marginal costs because of the tailored nature of the offering, but the revenue stream would bring high premiums.

Group three: content/cloud provider

Group three selected a player with similarities to Google to represent their content/cloud provider. They chose the Cheshire Cat scenario because it offered the most interesting opportunities for their player to challenge the other players. In that scenario, the revenue would not be generated by access but from the service. The network could be moved into a cloud, allowing the service providers to act as virtual operators, much as Google and Microsoft do. The developed business model is presented in Figure 11.

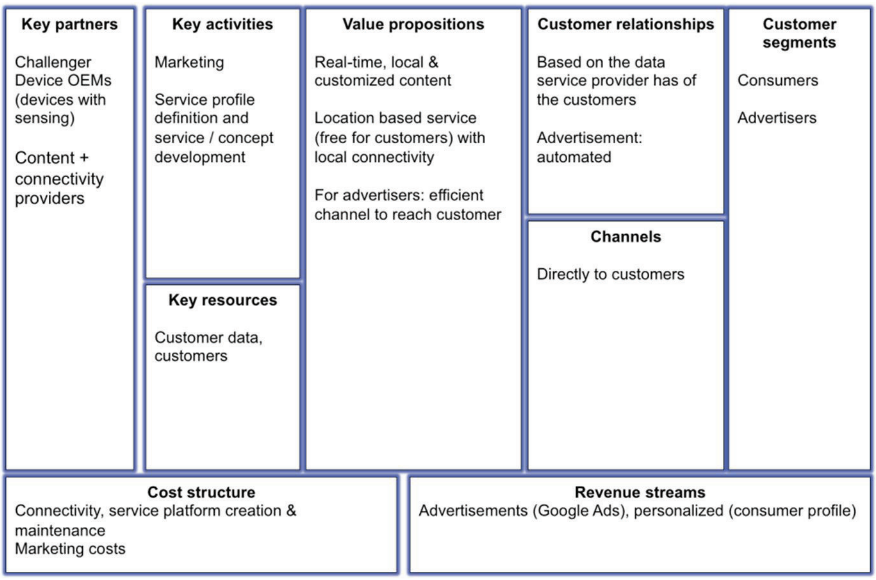

Figure 11. Group three's cloud service provider's (Google) business model in the Cheshire Cat scenario based on the business model canvas from Osterwalder and Pigneur (2010).

Such a player's key customers would be the consumer and its advertisers, the former being the service or content user and the latter using the service or content as a channel to reach the consumer. The value proposition for the customers would be real-time, local and customized content. Other key drivers would involve being location-based, offering free services with local connectivity and customized content for the consumer. For the advertisers the value would lie in having an efficient channel to reach consumers.

The consumer relationships would be based on the consumers' recorded user data and the relationship with the advertisers being automated. The channels to the customers would be direct.

A content provider wishing to offer customers location-specific free services with local connectivity would have to cooperate with manufacturers of devices with a sensing feature challenging the market leaders. The content and connectivity partners would also be important, since the content of the service would be a key value for the consumers.

Key activities noted were marketing and service profile definition and concept development, where the key resource would be consumer data. The major costs would relate to connectivity and the creation and maintenance of the service platform, but marketing costs would also be high. The marketing costs would decrease once a wide consumer user base was in place, and concurrently revenue streams from general and personalized advertisements would increase.

Group four: the infrastructure vendor

Group four chose to investigate the business model of an infrastructure vendor operating in the Snow White scenario. As discussed above on the incumbent operator's business model of Group one, the infrastructure vendor's role would depend on how it reacted to the challengers, such as equipment vendors and challenger CSPs. In this case, the group saw that in addition to acquiring the incumbent operators as customers, the infrastructure vendor should also include the challengers as their customers and support their ambitions to reduce the bigger operators to a bit pipe. The Snow White scenario offers the infrastructure vendor the opportunity to serve its existing customers but also to offer an infrastructure for intelligent devices and for challenger CSPs, thus increasing its customer base. The developed business model is presented in Figure 12.

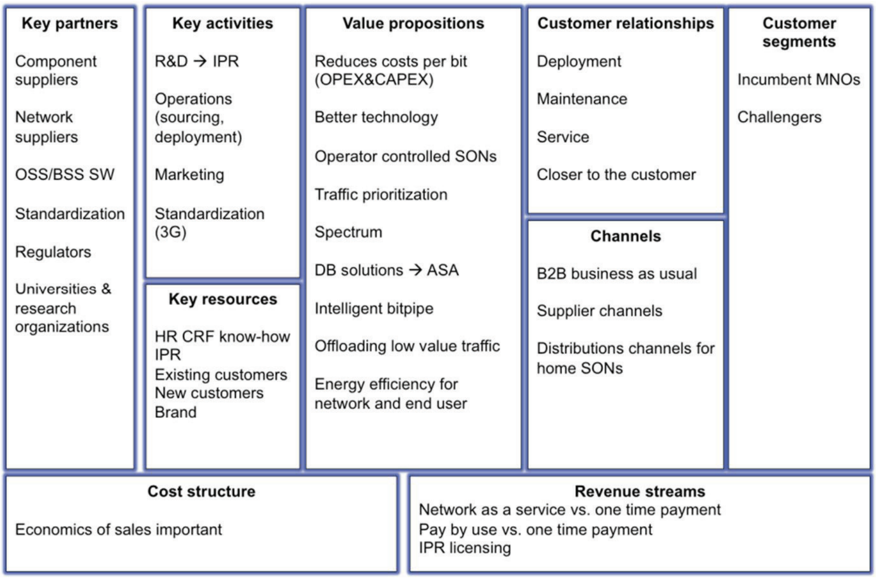

Figure 12. Group four's infrastructure vendor in the Snow White scenario based on the business model canvas from Osterwalder and Pigneur (2010).

The value that the infrastructure vendor could offer its customer in the future CRS business scenario would be reduced costs, more efficient and better-managed services with better technology and intelligent features, such as SONs. The customer relationships would be created through deployment and maintenance work and through various services requiring a local presence. Business-to-business customers would be managed in a traditional way, but there could be supplier channels and distribution channels for home SONs. Customer value would accrue through deployment and maintenance services delivered in direct cooperation with the customer or through distribution and supplier channels.

Key partners would include various partners developing and maintaining an intelligent infrastructure, such as open source software and base station subsystem software developers, but also standardization and regulation organizations, since they will decide the future role of the challengers. The regulators will also decide if the existing infrastructure should be shared and, if so, how.

The infrastructure vendor's key activities would consist of turning research and development work into useful intellectual property rights, working toward 3G standardization, sourcing and deployment operations and marketing activities. Marketing would become important especially when developing new services and targeting new customer segments. New business areas not only increase costs, but also make the billing structure more complex and the infrastructure vendor would have to pay attention to its billing models. Would the customer be charged by use or through a single user payment? In addition the economies of sales would influence the billing models, and the advent of new services should lead to traditional models being challenged.

Group five: the Equipment vendor

Group five chose to extrapolate a business model for an equipment vendor similar to Amazon in the Snow White scenario. The group reasoned that the equipment and operating system (OS) vendors together with the infrastructure vendors will push new technologies, including CRS. This would come to generate the majority of the income of the equipment and OS vendors. The goal for the equipment vendor would be to move from the current Snow White situation toward the Cheshire Cat scenario, where the revenue would accrue from the service. The developed business model is presented in Figure 13.

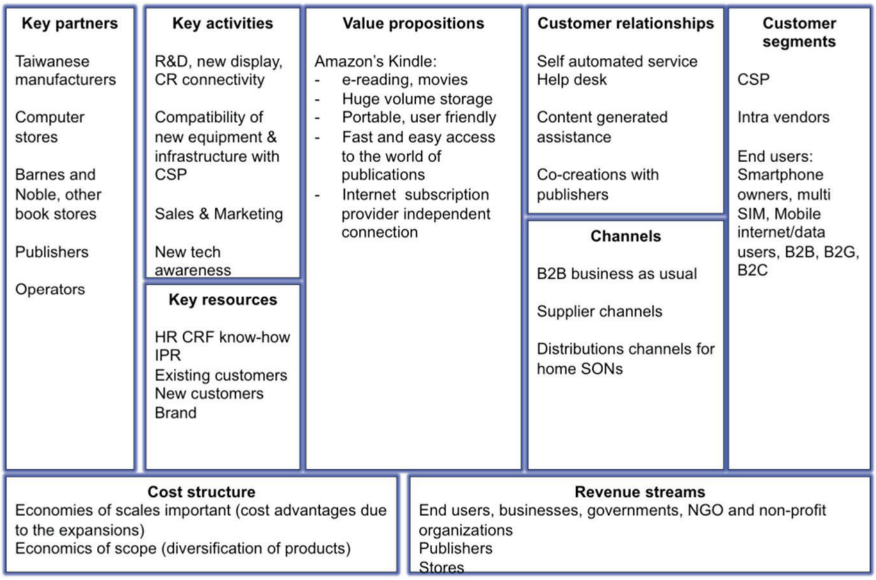

Figure 13. Group five's equipment vendor's business model in the White Snow scenario based on the business model canvas from Osterwalder and Pigneur (2010).

The key customer segments for a future player like Amazon would be CSPs, infrastructure vendors, and various end user segments, such as users using various smart devices with sensing and mobile internet capability and data users. The value for the customer would be in the service and in the smart device: irrespective of the content, as the content is always reachable either with a free connection or with the fastest connection. The devices would be equipped with a sensing function and permanently accessible services the customer wants, be it an eBook, their own data (photos, videos etc.), a TV-series or movies. The business model anticipates cooperation not only with the different manufacturers and content providers, but also with cloud service providers, that could ensure the user's content is always accessible from the user's personal cloud.

Key activities would include important R&D functions, developing new display technologies for the devices and developing new intelligent features. Establishing the compatibility between new equipment and infrastructure would also be important, as would the role of the sales and marketing function in raising awareness of new devices and services among end users. The scenario relies on strong cooperation with different channels, such as Amazon.com, entertainment and media channels and equipment resellers. For the equipment vendor, considering cost economies will always be vital. Considerations would have to include noting the advantages arising from expansion, and the benefits of making several different devices. Examples of two different business cases that could offer information are the single iPhone versus the multitude of different Nokia smart phones.

Revenue streams would flow from the different customer segments and from different distribution channels like books stores, movie rental businesses and device resellers.

4.4.3 Summarizing the business models

As a result of the CRS business model workshop we were able to develop at least one business model for each player in a chosen scenario. Unfortunately, due to time limitations within the workshops, it was not possible to create a business model for each player in every business scenario. The key actors and the scenarios for which the business models were developed are summarized in Figure 14.

Regardless of the time limitations, the workshops have provided insights into the likely future changes in the CRS business environment and their impact on the recognized key actors in the ecosystem. The Snow White scenario is the most interesting scenario from the strong players' point of view since it offers an opportunity to maintain their strong position within the ecosystem. In this scenario these key actors were connected to each other by their business model and by capturing the value in the ecosystem they would improve their business and protect their position. In the Cheshire Cat scenario where the current positions are threatened, the content provider and the challenger operator would have mutual goals. By cooperating in this scenario they would generate new business opportunities and create value, strengthen their positions, and shift the balance of power within the CRS business ecosystem.

Constructing different scenarios and roleplaying them from different actors' points of view alerted us to the opportunities and threats that might face each of the players identified. Being proactive in a fast changing environment would not only make it possible for the actors to influence the future business environment but also enable them to recognize and build new cooperative value relationships and networks. Proactivity could also generate new business, such as a database operator offering information about spectrum availability.

In addition to the formal results presented in this chapter, the workshops raised some interesting new ideas and concepts, which are discussed in the following section.

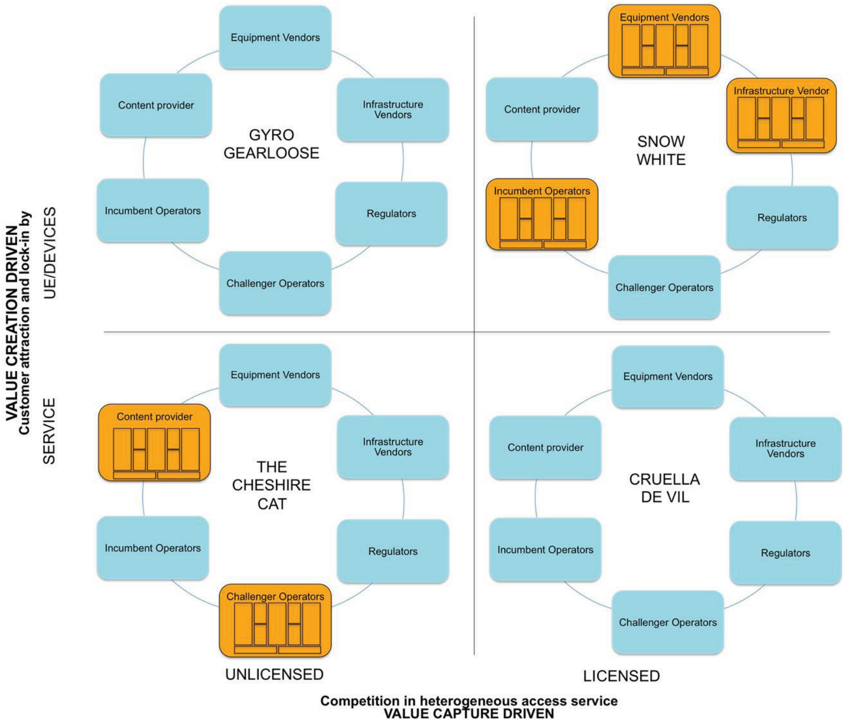

Figure 14. The CRS business scenarios and created business models within it.

5. Conclusions and recommendations

The four CORE workshops with their three consecutive steps were one of the first attempts to understand the changes related to the emergence of CRS from a business perspective. There is a diverse set of ICT companies and industry experts involved in the CORE project and the Tekes Trial programme, making it a fruitful setting for scenario-based and future-oriented studies. The four workshops created a good basis for further analysis and innovative brainstorming around CRS-related business. In the following paragraphs we draw some preliminary conclusions concerning the future of CRS business based on the workshops and earlier research.

The CRS technology is a key enabler for the shared use of the radio spectrum that can drastically change access to the spectrum and correspondingly the whole business ecosystem. Shared use of the spectrum can offer an alternative way to gain access to new areas of the spectrum and overcome the challenges of the traditional costly and time-consuming re-farming approach. Shared use of the spectrum can be particularly appealing for mobile communication systems to complement their current spectrum assignments as their demand for a greater share of the spectrum is expected to increase in the next decade in response to the predicted growth of mobile data traffic. Currently, mobile communication systems technology is evolving towards shared use of the spectrum.

The first implication for companies working within CRS businesses may be that the whole communications industry is facing change resulting from its maturation as it moves from a technology push towards more customer-centric thinking. From a business perspective, the industry seems to be entering an era of value innovation – the simultaneous increase in value added and decrease in costs. From a technical perspective, the emergence of services based on cloud computing, heterogeneous access networks, smart devices with network sensing features, and user generated content/services is only the tip of the iceberg of the ongoing convergence of different wireless, mobile and fixed communications technologies.

Second, the key ecosystem roles this research reveals as likely to be affected by the advent of the CRS include communication service providers, user equipment (device) vendors, network infrastructure vendors, content and service providers, and regulators. If we are to understand the development of the whole industry, we need to identify the change drivers and scenarios related to CRS and to analyse the potential effects of those ecosystem roles. On the one hand, value-added-driven customer attraction and lock-in is sought by the ecosystem players either by focusing on service or on devices. For operators the services delivered to customers can be a source of competitive advantage, and there are attempts to enhance this advantage either through increased data rates or by offering subsidized devices – mobile or internet content per se being available to customers does not seem to be so noteworthy in this respect. For device manufacturers, the continuing launch of new generations of devices seems to resemble haute couture as the design and user experience of the devices seem more important to the customers than their technical platform. This service versus device duality may indeed become one of the key characteristics of the future CRS business, affecting all players in the CRS ecosystem.

On the other hand, the parallel value-capture-driven competition for the provision of heterogeneous access services (be it licensed or unlicensed) will affect CRS business as strongly as the search for customer attraction and lock-in. The volume of traffic in all networks is expected to increase, and as m-to-m networks really start to take off as a market, the growth of traffic will become even more pronounced. Therefore, the cost per transferred byte needs to reduce as wireline and wireless access compete and because part of the wireless services is already “free” to customers. Technological convergence and the limited spectrum available for wireless systems can be said to be the key background drivers of this competition. In addition, the role of the internet service and content providers may well become more central in the future owing to the emergence of CRS.

Indeed, as the spectrum available for wireless systems is a limited resource and one competed over, there seem to be two extreme views in the governance over the ways to access a spectrum using cognitive radio techniques: licensed or unlicensed access. Under a licensed access system, entrants would be required to follow rules such as authorized shared access between the operators. In the unlicensed access variant, the coexistence of the various devices on the same spectrum band would be left to be handled by the devices themselves without strict rules. It may well be that the regulatory bodies that hold the key to defining the future of CRS business, by determining such issues as what access rules will be created for the better utilization of free space on different spectrum bands.

The two aforementioned drivers, customer attraction and lock-in (service vs. devices) and competition over service provision (licensed vs. unlicensed) might be used as a basis for creating different scenarios for CRS businesses, whether CSPs (operators of different kinds), content and service providers, device manufacturers, infrastructure manufacturers, or regulators. The inaugural workshops have contributed interesting ideas and perspectives on cognitivity. Some new terms emerged including for example “Spectrum brokerage - Kaistapörssi”. A CRS could reduce the price of the spectrum, as a shared spectrum can be cheaper than a dedicated spectrum. The emergence of new roles is possible including that of “Cognitive operator – Kognitiivioperaattori”. It is possible that there could be new pricing schemes with CRS – “Night bits/Day bits and urban bits/rural bits. An interesting aspect is how customers will be tied into cognitive services compared to the traditional approach through Device – Contents – Access. The concept of a “personal cloud” may well emerge as CRS develops further into the cloud context, too.

The preliminary workshop results cannot be said to have generated full business models for any of the key actors within CRS, but they certainly provide food for thought for those developing the business models and respective business ecosystems. From the ecosystem perspective, the role of the traditional, incumbent communications service providers seems to be threatened by the opportunities exposed by SDR and the CRS, but to what degree this will really occur is an interesting question. A further question to be considered is what kinds of new ecosystem roles might emerge. The preliminary conceptions of “cognitive operators” or “spectrum brokers” discussed in the workshops open up interesting avenues to explore, but it may well be the regulatory bodies that determine the future of CRS more than the operators do; or perhaps the incumbent operators will assume the role and tasks of “cognitive operators” so efficiently that there are no real business opportunities available for new entrants.

At least one new role has already emerged: the database operator that provides information about spectrum availability and the rules for use in a given location. This is due to the fact that spectrum regulators have decided that consulting a database should be the method used for the unlicensed TV white space devices to access TV bands in the USA, and other countries (e.g. the UK) are following the approach.

Based on the scenario framework described above, the positive continuation of the work around this stream of research is likely to involve detailed planning of alternative business models for different key players within CRS, namely, the user equipment (device) vendors, network infrastructure vendors, content and service providers, and regulators.

References

Barnard, C., (1968). The functions of the executive. USA: Harvard University Press. Original 1938.

Barrie, M., Delaere, S. & Ballon, P. (2011). Classification of business scenarios for spectrum sensing. Unpublished COST-TERRA paper.

Bishop, P. Hines, A. & Collins, T. (2007). The current state of scenario development: an overview of techniques. Foresight, 9 (1), 5–25.

Bouwman, H., De Vos, H. & Haaker, T. (2008). Mobile service innovation and business models. Springer-Verlag, Berling Heidelberg.

Brandenburger, A. M. & Nalebuff, B.J. (1996). Co-opetition. Doubleday, New York.

Casadeus-Masanell, R. & Ricart, J.E. (2010). Competitiveness: A business model reconfiguration for innovation and internationalization. Management Research, 8 (2), 123–149.

Casey, T., Smura, T. & Sorri, A. (2011). Value network configuration in wireless local area access. Unpublished COST-TERRA paper.

Chen, S. (2003). The real value of "e-business models". Business Horizons, 46 (6), 27–33.

Chesbrough, H. (2010). Business Model Innovation: Opportunities and Barriers. Long Range Planning, 43 (2/3), 354–363.

European Commission COM(2012)478. (2012). Promoting the shared use of radio spectrum resources in the internal market.

Fomin, V. Vitkuté-Adzgauskiené, D. & Vytautas, M. (2010). Co-evolutionary development of cognitive radio systems.

Grönroos, C. (2008). Service logic revisited: who creates value? And who co-creates? European Business Review, 20 (4), 298–314.

Hearn, G. & Pace, C. (2006). Value-creating ecologies: understanding next generation business systems. Foresight, 8 (1), 55–65.

Håkanson, H. & Snehota, I. (1989). No business is an island: The network concept of business strategy. Scandinavian Journal of Management, 5 (3), 187–200.

Iansiti, M. & Levien, R. (2004a). Strategy as ecology. Harvard Business Review, 82 (3), 68–78.

Iansiti, M. & Levien, R. (2004b). The Keystone advantage. Harward Business School Press, Massachusets.

ITU-R Report SM.2152. (2009). Definitions of software-defined radio (SDR) and cognitive radio system (CRS).

ITU-R Report M.2225. (2011). Introduction to cognitive radio systems in the land mobile service.

ITU-R Report M.2242. (2011). Cognitive radio systems specific for International Mobile Telecommunications systems.

ITU-R Report M.2243. (2011). Assessment of the global mobile broadband deployments and forecasts for International Mobile Telecommunications.

Kagermann, H., Osterle, H. & Jordan, J.M. (2010). It-driven business models. Global case studies in transformation. John Wiley & Sons, New Jersey.

Mason, D. & Herman, J. (2003). Scenarios and strategies: making the scenario about the business. Strategy & Leadership, 31 (1), 23–31.

Matinmikko, M. & Bräysy, T. (2011). Towards cognitive radio systems. Main Findings from COGNAC project. VTT Research Notes 2575.

Myllykoski, J. & Ahokangas, P. (2012). Transformation toward a cloud business model. Communications of Cloud Software.

Moore, J.F. (1998). The rise of a new corporate form. The Washington Quarterly, 21 (1), 167–181.

Ohmori, S. Report on Japan study in cognitive radio and networks.

Osterwalder, A. & Pigneur, Y. (2002). An e-Business Model Ontology for Modeling e-Business. Paper presenter at the 15th Bled Electronic Commerce Conference.

Osterwalder, A. & Pigneur, Y. (2010). Business Model Generation. John Wiley & Sons, New Jersey.

Osterwalder, A., Pigneur, T. & Tucci, C.L. (2005). Clarifying business models: present, and future of the concept. Communications of the Association for Information Systems, 15. http://www.scribd.com/doc/1038389/The-theory-of-Business-Models. Cited July 1st, 2011.

Pagie, L.W.P. (1999). Information integration in evolutionary processes. Dissertation thesis, Universiteit Utrecht.

Peltoniemi, M. (2006). Preliminary theoretical framework for the study of business ecosystems E:CO, Vol. 8, No. 1, pp. 10–19

Shafer, S.M., Smith, H.J. & Linder, J.C. (2005). The power of business models. Business Horizons, 48 (3), 199–205.

Smith, M.Y. & Stacey, R. (1997). Governance and cooperative networks: Ad adaptative systems perspective. Technological Forecasting and Social Change, 54 (1), 79–94.

Teece, D. (2010). Business models, business strategy and innovation. Long Range Planning, 43 (2/3), 172–194.

Van de Ven, A. & Poole, M. (2005). Alternative approaches for studying organizational change. Organization Studies, September 2005, Vol. 26, No. 9, pp. 1377–1404

Van Der Hejden, K. (2007). Scenarios – The art of strategic conversation. John Wiley & Sons, England. 2nd ed.

Zott, C. & Amit, R. (2010). Business mode design: An activity system perspective. Long Range Planning, 43, 216–226.

Zott, C., Amit, R. & Massa, L. (2011). The business model: Recent developments and future research. Journal of Management, 37 (4), 1019–1042.

Series title and number
VTT Technology 55

Title	**Future scenarios, ecosystems and business models for cognitive radio systems**
Author(s)	Petri Ahokangas, Marja Matinmikko, Jenni Myllykoski & Hanna Okkonen
Abstract	The introduction of cognitive radio techniques into wireless mobile communications systems has potential to change their operations in a number of ways, most notably in terms of the way they access the radio spectrum. In fact, the whole business ecosystem could be affected by the advent of cognitive radio systems (CRS). Recent developments in the mobile communication systems and spectrum regulatory frameworks are paving the way to shared use of the spectrum in an attempt to fulfil the growing future traffic demand. Spectrum sharing using CRS can become an alternative way to provide access to new the spectrum in addition to the costly and time-consuming “re-farming” of spectrum bands where a band is cleared of its previous usage. This publication focuses on the business aspects of those systems and aims to understand the potential effects of their emergence from a business perspective. Key findings from the literature in terms of the technological and business context of cognitive radio systems are summarized. Furthermore, the theoretical framework of business scenarios, business models, and business ecosystems is explained. Specific scenarios, business models and business ecosystems suggested for cognitive radio systems following four workshops are presented. First the key actors within the cognitive radio systems business/value chain were identified along with their needs and the benefits of cognitive technology. Scenarios were then created for the future cognitive business environment together with an analysis of the drivers, limitations and challenges of the different scenarios. Initial attempts to develop business models for selected actors in selected scenarios are also presented.
ISBN, ISSN	ISBN 978-951-38-7883-2 (soft back ed.) ISSN 2242-1211 (soft back ed.) ISBN 978-951-38-7884-9 (URL: http://www.vtt.fi/publications/index.jsp) ISSN 2242-122X (URL: http://www.vtt.fi/publications/index.jsp)
Date	November 2012
Language	English, Finnish abstract
Pages	54 p.
Keywords	Business model, business ecosystem, cognitive radio system, scenario
Publisher	VTT Technical Research Centre of Finland P.O. Box 1000, FI-02044 VTT, Finland, Tel. 020 722 111

Julkaisun sarja ja numero
VTT Technology 55

Nimeke	**Tulevaisuuden skenaarioita, ekosysteemejä ja liiketoimintamalleja kognitiivisille radiojärjestelmille**
Tekijä(t)	Petri Ahokangas, Marja Matinmikko, Jenni Myllykoski & Hanna Okkonen
Tiivistelmä	Kognitiivisten radiotekniikoiden tulo langattomiin matkaviestintäjärjestelmiin voi muuttaa järjestelmien toimintaa usealla eri tavalla. Erityisesti taajuuksien käyttötapa voi muuttua. Itse asiassa kognitiivisten radiojärjestelmien tulo voi vaikuttaa koko liiketoimintaympäristöön. Matkaviestintäjärjestelmien ja taajuusregulaation viimeaikainen kehitys on mahdollistamassa taajuuksien yhteiskäytön vastauksena tulevaisuuden kasvavaan tiedonsiirtotarpeeseen. Taajuuksien yhteiskäytöstä kognitiivisten radiotekniikoiden avulla voi tulla vaihtoehto kalliille ja aikaa vievälle taajuuksien uudelleen jakamiselle, jossa taajuuskaista tyhjennetään alkuperäisestä käytöstä. Tämä julkaisu keskittyy kognitiivisten radiojärjestelmien liiketoimintanäkökulmiin. Tavoitteena on ymmärtää näiden järjestelmien mahdollisesti aiheuttamat vaikutukset liiketoimintanäkökulmasta. Julkaisu esittää yhteenvedon kirjallisuudesta kerätystä tiedosta kognitiivisten radiojärjestelmien teknisiin ja liiketoimintanäkökulmiin liittyen. Julkaisu esittää teoreettisen viitekehyksen liiketoimintaskenaarioille, liiketoimintamalleille sekä liiketoimintaekosysteemeille. Tämän lisäksi julkaisu esittää neljän työpajan pohjalta kehitetyt skenaariot, liiketoimintamallit ja liiketoimintaekosysteemit kognitiivisille radiojärjestelmille. Ensimmäiseksi on tunnistettu kogniitivisten radiojärjestelmien liiketoimintaympäristön päätoimijat sekä toimijoiden tarpeet ja hyödyt kognitiivisiin tekniikoihin liittyen. Tämän jälkeen on kehitetty skenaarioita kognitiivisten radiotekniikoiden mukaantulolle liiketoimintaympäristöön sisältäen analyysia eri skenaarioiden ajureista, rajoituksista ja haasteista. Lisäksi julkaisu esittää alustavia liiketoimintamalleja valituille toimijoille valituissa skenaarioissa.
ISBN, ISSN	ISBN 978-951-38-7883-2 (nid.) ISSN 2242-1211 (nid.) ISBN 978-951-38-7884-9 (URL: http://www.vtt.fi/publications/index.jsp) ISSN 2242-122X (URL: http://www.vtt.fi/publications/index.jsp)
Julkaisuaika	Marraskuu 2012
Kieli	Englanti, suomenkielinen tiivistelmä
Sivumäärä	54 s.
Avainsanat	Business model, business ecosystem, cognitive radio system, scenario
Julkaisija	VTT PL 1000, 02044 VTT, Puh. 020 722 111

VTT Technical Research Centre of Finland is a globally networked multitechnological contract research organization. VTT provides high-end technology solutions, research and innovation services. We enhance our customers' competitiveness, thereby creating prerequisites for society's sustainable development, employment, and wellbeing.

Turnover: EUR 300 million
Personnel: 3,200

VTT publications

VTT employees publish their research results in Finnish and foreign scientific journals, trade periodicals and publication series, in books, in conference papers, in patents and in VTT's own publication series. The VTT publication series are VTT Visions, VTT Science, VTT Technology and VTT Research Highlights. About 100 high-quality scientific and professional publications are released in these series each year. All the publications are released in electronic format and most of them also in print.

VTT Visions
This series contains future visions and foresights on technological, societal and business topics that VTT considers important. It is aimed primarily at decision-makers and experts in companies and in public administration.

VTT Science
This series showcases VTT's scientific expertise and features doctoral dissertations and other peer-reviewed publications. It is aimed primarily at researchers and the scientific community.

VTT Technology
This series features the outcomes of public research projects, technology and market reviews, literature reviews, manuals and papers from conferences organised by VTT. It is aimed at professionals, developers and practical users.

VTT Research Highlights
This series presents summaries of recent research results, solutions and impacts in selected VTT research areas. Its target group consists of customers, decision-makers and collaborators.

Future scenarios, ecosystems and business models for cognitive radio systems

The introduction of cognitive radio techniques into wireless mobile communications systems has potential to change their operations in a number of ways, most notably in terms of the way they access the radio spectrum. In fact, the whole business ecosystem could be affected by the advent of cognitive radio systems (CRS). Recent developments in the mobile communication systems and spectrum regulatory frameworks are paving the way to shared use of the spectrum in an attempt to fulfil the growing future traffic demand. Spectrum sharing using CRS can become an alternative way to provide access to new the spectrum in addition to the costly and time-consuming “re-farming” of spectrum bands where a band is cleared of its previous usage.

This publication focuses on the business aspects of those systems and aims to understand the potential effects of their emergence from a business perspective. Key findings from the literature in terms of the technological and business context of cognitive radio systems are summarized. Furthermore, the theoretical framework of business scenarios, business models, and business ecosystems is explained. Specific scenarios, business models and business ecosystems suggested for cognitive radio systems following four workshops are presented. First the key actors within the cognitive radio systems business/value chain were identified along with their needs and the benefits of cognitive technology. Scenarios were then created for the future cognitive business environment together with an analysis of the drivers, limitations and challenges of the different scenarios. Initial attempts to develop business models for selected actors in selected scenarios are also presented.

ISBN 978-951-38-7883-2 (soft back ed.)
ISBN 978-951-38-7884-9 (URL: http://www.vtt.fi/publications/index.jsp)
ISSN 2242-1211 (soft back ed.)
ISSN 2242-122X (URL: http://www.vtt.fi/publications/index.jsp)