Business opportunities using white space spectrum and cognitive radio for mobile broadband services

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***Abstract* —In this paper we consider business feasibility analysis of systems and services using cognitive radio and secondary use of spectrum. The approach is generally applicable to business analysis of services using "new" technology but the analysis is focused on cellular use of TV white space.**

The paper describes what can be learnt from history when mobile technologies have been introduced in the market. New services introduced by new actors are challenging since the market entrant need to invest in infrastructure and marketing and to build up a customer base. Hence the role and position of existing actors and services need to be considered. Promising business cases for mobile broadband services using cognitive radio and secondary spectrum access are presented for both wide area and local area systems. The difference between wide and local area network deployment and business are analyzed providing implications for future local area wireless systems.

***Keywords* – Secondary spectrum access, Mobile broadband, Business feasibility analysis, TV white space, Business scenarios**

I. Introduction

The need to consider business and regulatory aspects for analysis of cognitive radio systems has been addressed in a number of papers [1][2][3][4]. In these papers different scenarios and use cases are described together with models and taxonomies for classification of different scenarios. Other use cases and challenges are described in [5] where also good real life examples of spectrum availability of TV white spaces in the UK are presented.

We fully agree with the authors of [1] that many economic studies "consider CR – and with that, the regulatory and business models for it- as *a monolithic concept"*. CR includes a wide range of technical solutions and application areas; in addition the business parameters diverge for different scenarios. The aim of paper [1] is to propose a taxonomy for CR in general. The scenario dimensions are the complexity of CR technology and its viability as business value generator.

In the EU project Quasar a number of service scenarios are defined [3]: cellular use of white spaces, Wifi-like use of white spaces, secondary wireless backhaul, license exempt use of radar bands, indoor broadband in aeronautical spectrum, and a cognitive machine to machine communication.

The "cellular use of TV WS" includes two types of usage:

1. For mobile operators to enhance its throughput by access to extra spectrum (in addition to exclusive spectrum)
2. For TV-WS-only operators to obtain spectrum as the resource for its normal operation

In [3] also a scenario classification model is presented. The model has four hierarchical levels:*1)*The secondary usage type, *2)* the spectrum sharing type, *3)* the licensing type, *4)* the level of cooperation between primary - secondary systems.

However, despite all the proposed use cases, scenarios and approaches for classification of scenarios there seems to be a lack of approaches for business analysis of systems and services using CR technology. The classification system in [3] is very useful for the analysis of technical performance and system design – but the approach does not include any kinds of business context or end-user service aspects. It is focused on the supply side of the service, i.e. how the networks are deployed and how the spectrum is utilized and managed. In [1] business aspects are considered but the scenarios are not described in such a way that they can be analyzed, they are more examples of a "set of assumptions" that may be promising from a business perspective.

In this paper we will discuss business analysis considering

1. Business scenarios need some business to analyze
2. We can learn from the history of development of and introduction of mobile technology and services.
3. Even if the CR technology will work perfectly and that complexity and price for CR systems will be low – there may still not be a business case.

The paper is outlined as follows: Section II includes theory and methodology background, Section III is about introduction of 1G-4G mobile systems, Section IV contains the analysis section V implications for future research.

II. Theory and Methodology Background

Our starting point is that we can learn from the history of development of mobile services. In doing so we make use of a number of theories and concepts for analyzing and understanding markets and how market players act on these markets. We look into the perceived value for end-users, offering existing or new services to existing or new customers, the difference between wide area and local area wireless services and the implications for actor that want to offer services in local area markets.

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A. BUSINESS MODEL DEFINITION

The business model definition proposed by Chesbrough and Rosenbloom [6] has been used for the analysis of a large number of companies. The paper from 2002 deals with innovation management and look into how technical innovations are developed in-house or in new “spin-off“ companies. The business model definition contains the following elements: i) The value proposition, ii) the market segment, iii) the cost structure and profit potential, iv) the firm organization and value chain, v) the competitive strategy and vi) the position of the firm in the value network.

In the analysis we focus on the following three elements:

- **Value proposition –** The service offer to the end-users that is new and unique compared to what’s available on the market today
- **Market segment –**The types of customers for which the service offer is useful or of special interest
- **Cost structure –** An estimate of the components in the cost structure in terms of investments and running costs related to networks, services, customers and marketing.

B. COMPANY GROWTH STRATEGIES

Igor Ansoff presented a framework for discussion of different growth strategies for a company [7]. The so called Ansoff matrix considers growth in terms of firm's present and potential products and/or present and new customers, hence it provides four different growth strategies:

- **Market Penetration** - the firm seeks to achieve growth with existing products in their current market segments
- **Market Development** - the firm seeks growth by offering its existing products to new market segments
- **Product Development** - the firms develops new products targeted to its existing market segments and customers
- **Diversification** - the firm grows by diversifying into new businesses by developing new products for new markets

If the market grows, maintaining market share will result in growth. The market penetration strategy, i.e. increasing market shares, is the least risky and diversification is the most risky strategy. Diversification requires both product and market development and may be outside the core competencies of the firm. In section III we will use this framework for describing the development of 1G, 2G, 3G and 4G mobile services.

C. PLATFORM LITERATURE

As it relates to the business model of a company the different ways to create value have been researched. Stabell and Fjeldstad [8] discuss different value creation logics, where value creation can be based on e.g. the transformation of inputs into products (e.g. production of network equipment) or solving unique customer problems (e.g. site surveys and planning of a wireless network). In particular they discuss a value creation logic, which is based on linking customers to each other. Typically this relates to one homogeneous group (e.g. the subscribers of a mobile operator), but it is also possible to open the platform for other customers acting as value creators. Microsoft, for example, pursues this kind of a strategy when it links 3rd party software developers of its operating system to the end-users of the operating system.

The platform strategy approach has received much research attention. With a platform strategy, instead of trying to gain control and vertically integrate in the value network, companies try to become platforms for other companies to create value [9][10][11][12].

Mobile operators have thus far mostly pursued vertical integration and it has been argued that also operators should pursue a platform strategy and provide a communications platform for others to innovate on [13]. Ballon [14] indicates that platformization in the mobile industry, is already happening which increases the importance for firms to be in possession of gatekeeper roles, i.e. being in control of the most important “bottleneck” activities.

III. INTRODUCTION OF MOBILE TECHNOLOGIES

In this section we describe the introduction of the first to fourth generations of mobile systems in the Nordic countries. We use generic pictures illustrating end user value and cost structure and the Ansoff matrix representation.

A. *FIRST AND SECOND GENERATION SYSTEMS*

When the first and second generation systems for mobile telephony were introduced the mobility and service coverage represented a very large added value to end-user compared with fixed line telephony. When GSM complemented and later replaced the NMT systems the voice service was more or less the same but the number of user increased substantially. Although market entrants had to make large investments there was still room for new market actors due to a high level of unmet demand for mobile voice services, see Figures 1 and 2.

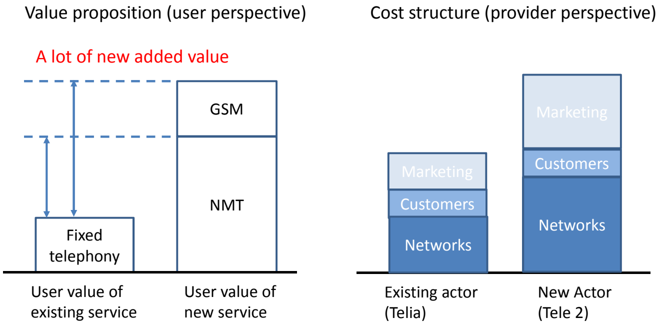

Figure 1. User value for telephony service and comparison of cost structure for existing and new mobile operators

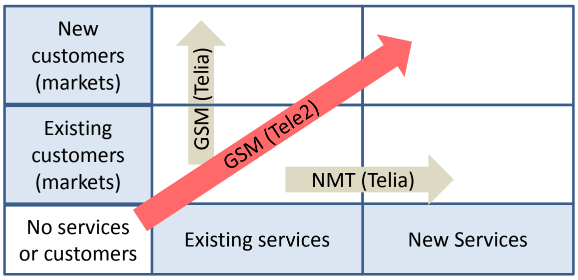

Figure 2. Illustration of introduction of NMT and GSM in Sweden (Telia and Tele 2) using the Ansoff matrix

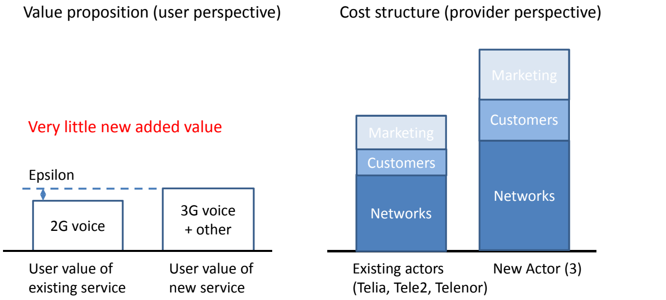

Figure 3. User value for "3G services" and comparison of cost structure for existing and new mobile operators

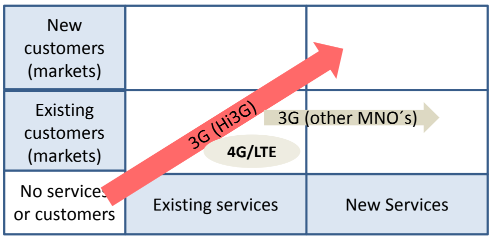

Figure 4. Ansoff matrix representation for introduction of 3G in Sweden

B. *Introduction of Third Generation Systems*

When deployment of 3G systems started in Sweden after year 2000 the situation was different compared to when NMT and GSMA were introduced. There was neither any demand for "3G services" nor any new offered services. Both the existing operators and the market entrant "3" had to make large investments in networks in order to satisfy the promised levels of coverage. Hence, the initial situation was characterized by large network costs for operators but low added value for the end-users, see Figure 3. The situation was challenging for the market entrant "3". The situation was changed when the operator "3" started to focus on cheap voice services instead of video calls and media services. The result was that prices for voice services in Sweden decreased substantially.

C. *Development of 3G and Introduction of 4G*

"3G services" started to take off when mobile broadband was introduced 2006 and 2007. With relatively small investments a high level of added value was offered to the end-users. The base station sites were already there and the costs for upgrading WCDMA to HSPA were reasonable, see Figure 5.
The introduction of 4G networks (LTE) results in substantially improved cost/capacity performance but it is still the same type of service – mobile broadband access, see Figure 4.

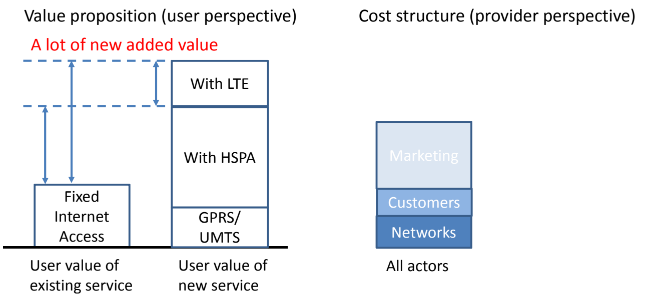

Figure 5 User value for mobile data services and cost structure

IV. Analysis of Cognitive Radio and White Space Usage

In this section we analyse the use cognitive radio technology and usage for mobile broadband services in three ways. First, the end-user value and the operator cost structure are discussed in general terms similar to the description in section III. Next, numerical values are provided for some cost and cost structure examples in order to illustrate the order of magnitude of different cost components. Finally, the differences in network deployment strategies and investments logics of wide area and local area networks are highlighted.

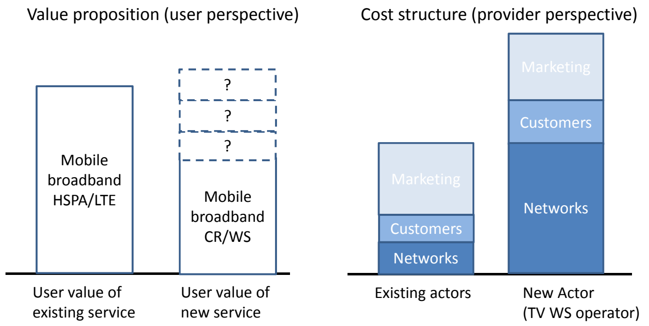

Figure 6. Illustration of generic user value and cost structure for mobile broadband services for an existing operator with licensed spectrum and a new TV white-space-only mobile operator

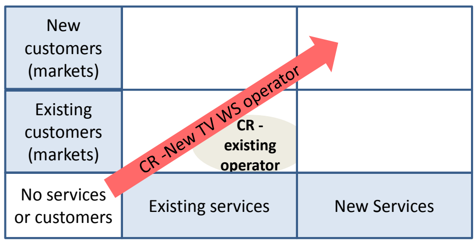

Figure 7. Ansoff matrix representation for the use of cognitive radio by an existing operator and a market entrant using white space only

A. *Overall End-User Value and Operator Cost Structure*

We compare two types of mobile network operators, existing operators with licensed spectrum (using white space spectrum as a complement) and new operators without any licensed spectrum using white space spectrum only (i.e. as the only spectrum resource). In both cases the service is mobile broadband access, the relative end-user value depends on the amount and availability of white space spectrum. In the case of substantially more available white space spectrum than the assumed 10-20 MHz of licensed spectrum then the user experience may be better otherwise not, see the left hand side of Figure 6. When it comes to the cost structure the new actor needs to invest in networks and marketing, see right hand side of Figure 6. This is similar to the 2G and 3G cases shown in the right hand sides of Figures 1 and 3. Using the Ansoff matrix representation we can see the similarities of Figures 2, 4 and 7 illustrating market entry.

B. *Cost Structure for Existing and New Operators*

Here two important aspects should be considered: i) the development and price of radio equipment (transceivers), and ii) the amount of existing base station sites that can be re-used.

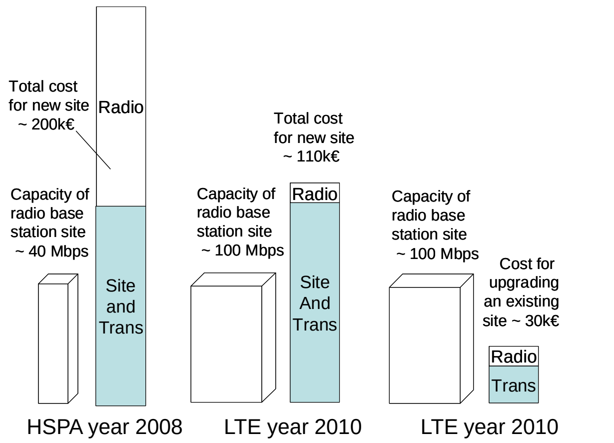

Figure 8. Cost structure for deployment of HSPA and LTE requiring new sites and LTE using already deployed sites, from [15]

The change of cost structure between the introduction of 3G and 4G is clear as indicated in Figure 8. The site costs (masts, towers, power, equipment room, roads, site leases) is the dominating part of the overall networks costs. This has been highlighted the last years since the cost-capacity performance of the radio transceivers has been improved substantially the last few years [15]. Currently the key issue is not the cost of radio equipment, it is if the operator has to build new base station sites or not. An operator with existing base station sites that can be re-used for deployment of additional capacity has a cost advantage compared to an operator that needs to build new sites. A market entrant (no matter if white space is used or not) needs to build a new infrastructure with many new sites. For deployment in capacity limited areas more available spectrum implies less number of base station sites - and the other way around.

We also need to consider the impact of spectrum prices. It is often claimed that one driver for secondary use of spectrum is that the cost of spectrum can be avoided. However, this is only partly true, it depends on the paid spectrum price in relation to other costs like base station sites, transmission, etc. As an example we can consider the prices paid at recent spectrum auctions in different countries. Using the same metric as Mölleryd [16], spectrum price normalized to number of MHz and the population, we can identify large differences between auctions in different countries, see Table 1.

The impact of spectrum prices on operator costs can be illustrated assuming a cost structure with sites that are more costly then the base station sites using recent spectrum auction prices from Sweden and India [17]. When spectrum prices are small compared to sites etc, then the overall network costs decrease the more spectrum an operator has since the base station sites can be re-used. When spectrum prices are "much higher" (like in India) the situation is different, there is a trade off between deployment and spectrum costs.

Case	Bandwidth	€ /MHz/pop	Cost /site
Germany 2.6 GHz	20 MHz	~0,05	~1k€
Sweden 800 MHz	10 MHz	~0,50	~10 k€
India 2.1 GHz	5 MHz	~5	~100 k€

Table 1. Example of spectrum prices, from [16]

C. *VIABILITY OF CR DEPLOYMENTS FOR WIDE AND LOCAL AREA*

As it relates to existing actors, the viability of CR deployments can also be evaluated in terms of the different parts of the mobile and wireless infrastructure. As show in Figure 9, for simplicity we divide mobile and wireless infrastructure roughly into three categories: coverage, capacity and indoor sites. Here, coverage and capacity sites are mostly controlled by mobile operators and indoor sites in turn are mostly controlled by wireless local area operators (LAOs) (i.e. households, enterprises and public venues).

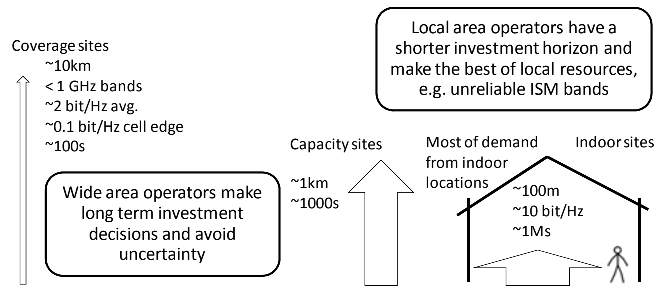

Figure 9. Characteristics of coverage, capacity and indoor sites

For coverage and capacity sites average spectral efficiency is quite low especially in the cell edges (e.g. 2 bit/Hz and 0.1 bit/Hz respectively as discussed by [18]) and the number of sites is typically in the order of thousands. Indoor sites in turn have very high (potential) spectral efficiency (10 bit/Hz as discussed by [18]) and the collective number of access points is in the order of millions in a given market area (e.g. Morgan Stanley estimates that household Wi-Fi penetration in the US will reach 58 % in 2012.

Mobile operators running a wide area infrastructure need to carefully plan and centrally optimize their scarce spectrum resources in a top-down and tight control manner in the acquisition of sites and installation of base stations. Deployments for local area operators on the other hand do not require central planning and can be made in a more uncoordinated and decentralized way to flexibly cater to the demand for wireless connectivity in a bottom-up manner (it has been estimated that most of data traffic demand (~90 %) is generated from indoor locations [19]). The co-existence of the access points is facilitated by decentralized medium access control (e.g. CSMA/CA) and spread spectrum technologies.

If we compare the investment logic of a mobile operator regarding wide area infrastructure to the investment logic of a wireless local area operator differences can be observed. The mobile operator conducts detailed techno-economic modeling of the costs of deploying and operating a wide area network, does corresponding investment calculations and makes long term investment decisions. Since the deployment of wide area infrastructure requires heavy upfront investments, a mobile operator needs very reliable assets (e.g. equipment, sites and spectrum) and avoids uncertainty as much as possible. On the other hand a wireless local area operator (e.g. public venue owner) makes rather small and incremental investments (has a shorter investment horizon) and in general can live with more unreliable assets (ISM bands, non-carrier grade equipment).

Based on these differences in investment logics one can argue that secondary spectrum access has a better fit with the investment logic of a wireless local area operator whereas mobile operators are better off with exclusive licenses that match the long investment periods. In general local area operators have a better ability to mitigate interference with primary systems since the access points work with low power levels and are protected by walls. Furthermore because of the better potential spectral efficiency wireless local area operators could in principle provide broadband speeds with rather small portions of the spectrum band.

In addition to the ISM bands, the local operators would be in a good position to utilize other bands, e.g. white spaces in TV or radar bands and exclusive cellular bands in an unlicensed or licensed manner where secondary access could be facilitated with DSA technologies. Individual wireless local area operators could together establish a large infrastructure in a bottom-up fashion e.g. facilitated with some form of roaming or offloading agreements with mobile operators.

The question of local control of spectrum bands relates closely to the end-to-end principle [20] that has been used in the design of the IP protocol suite and other decentralized systems. It states that communication protocol operations should happen as close as possible to the resource being controlled. Following this logic, it makes sense to manage low frequency bands centrally through a wide area infrastructure since they propagate far, but the same logic does not apply to higher frequency bands that do not propagate far and are in essence a local resource available "here and now".

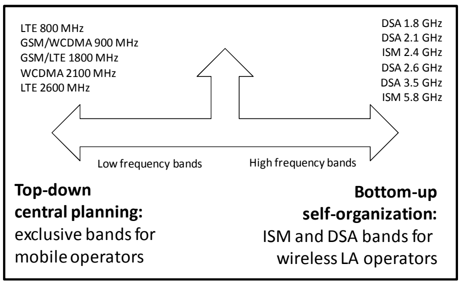

Figure 10. Controlled top-down central planning versus uncoordinated bottom-up self-organization in network deployment (with implications for typical European spectrum bands)

If mobile operators want to leverage higher spectrum bands they need to deploy denser infrastructure. However mobile network costs (e.g. site acquisition, equipment and operations) are proportional to the number of sites and if operators wish to remain profitable they can deploy only a limited number of base stations. Operators can outsource network deployment and operation to venue owners with femtocells, but the uncontrolled nature of the deployments creates coverage holes and cause interference with the wide area infrastructure [15]. It can be argued that the top-down central planning model used by the mobile operators has a better fit with exclusive low frequency bands whereas the bottom-up self-organization model used by wireless local area operators has a better fit with high frequency ISM and DSA bands, see Figure 10.

V. Implications for Operators: Platform Strategies for Wireless Local Area Cognitive Radio

Mobile operators could leverage cognitive radio by combining the strengths of both wide area and local area deployments. Wi-Fi offloading, where a mobile operator offloads traffic from its congested wide area network to wireless local area networks, is an example of mutual benefits. In order to enable such win-win solutions mobile operators could try to pursue a platform strategy where instead of trying to control wireless local area operators, mobile operators could enable new value creation possibilities for them as discussed in platform literature (see Section II).

Here, in a similar manner as e.g. Microsoft treats 3rd party developers as customers of their platform and offers them a wide range of tools for value creation, a mobile operator could offer tools for wireless local area operators to provide local mobile broadband access and create locally relevant services. For many public venue owners (e.g. of a hotel, conference hall or shopping mall) wireless local area access to the Internet is just one value added service in the total bundle of services offered and many of the other services could be enhanced with mobility (e.g. location based services, mobile payments, machine to machine etc.). Therefore, mobile operators could provide authentication, charging and billing and other critical control plane functions for wireless local area cognitive radio deployments and local services.

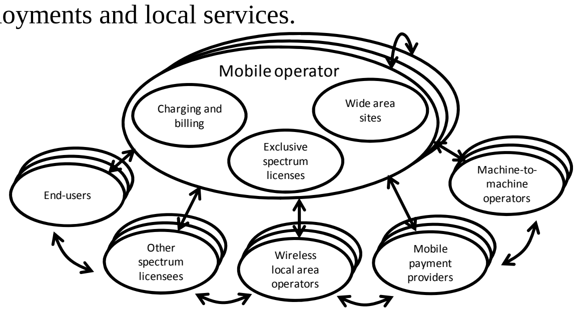

Figure 11. Mobile operator as an enabling platform for other actors

By shifting to a platform strategy mobile operators could attain the position of a platform leader [9][11], while retaining a gatekeeper role [14][9] by controlling wide area infrastructure, and exclusive spectrum licenses (Figure 11). One critical question is if a single mobile operator should try to go for platform dominance alone or create a shared platform with other operators [10]. If there are three separate platforms, e.g. if wireless local area access points do not have multi-operator support or roaming capabilities, the total value of the platform can be significantly lower than in the case where there is one common platform for all operators[21].

VI. Discussion and Conclusions

This paper is about business feasibility analysis of systems and services using cognitive radio and secondary use of spectrum. The problem formulation and analysis approach would be generally applicable to business analysis of services using "new" wireless technology but the analysis is focused on one type of application of cognitive radio – cellular use of TV white space.

There are two main areas of contributions in the paper:

1. We identify a gap in the existing methods for analyzing business feasibility for services using cognitive radio and secondary spectrum access. There is a gap since business and scenario related papers describe methods for classifying business or deployment scenarios, but no analysis of any business can be found.
2. We make a high-level assessment of the business viability of cellular use of white space spectrum for mobile broadband services where we identify promising and less promising business scenarios.

From history we can learn that new actors have been proven to be successful when there is a large demand for a new type of service. For use of CR less promising business scenarios are identified when "new" actors are supposed to offer services to "new" customers that need to be acquired. Even if the CR technology is assumed to work perfectly well and at low cost there may still not be a viable business case since existing competitors with an established market position will have a cost advantage, hence this is a market entry problem. One example of such a less promising business cases using CR technology is wide area mobile broadband services in rural and urban areas where new sites need to be deployed.

Based on the analysis it can also be argued that regulators should, as much as possible, assign low frequency bands exclusively to mobile operators and make high frequency bands available to wireless local area operators, e.g. through unlicensed assignment or secondary spectrum access.

The regulatory condition in the case assumes that licenses and spectrum holdings are two separate issues. This implies that in order to provide mobile broadband services the Greenfield and incumbent operators have acquired spectrum to market prices, in line with recent auctions, while the TV white space operator only needs an operator license in order to be cleared as a provider of electronic communication services. This is a straight forward process as the TV white space is accessible in the presented case. (The wider regulatory issues related to TV white space is out of scope of this paper.)

To conclude, the following *promising business scenarios* to investigate further have been identified.

- Existing mobile operators using TV white space spectrum and re-use of existing sites in order to delay or replace deployment of a more dense network
- Mobile operators using white space spectrum only in countries with very high spectrum prices
- Use of white space spectrum for indoor systems provided by local or mobile operators where mobile operators provide a service platform for businesses. In this case the wireless access service is part of a bundle of offerings.

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REFERENCES

[1] Medeisis,A., Daleare, S:," High-Level Scenarios for the Future of Cognitive Radio Business", 22nd IEEE Int. Symp. on Personal Indoor and Mobile Radio Communications (PIMRC 2011)

[2] Barrie, M., Delaere, S., Ballon, P.; "Classification of business scenarios for spectrum sensing"; 21st IEEE Int. Symp. on Personal Indoor and Mobile Radio Communications (PIMRC 2010), 2010, pp. 2626 – 2631

[3] J. Kronander, M. Nekovee, K. W. Sung, J. Zander, S.-L. Kim, and A. Achtzehn, "QUASAR scenarios for white space assessments and exploitation" URSI EMC conference, Worclaw, September 2010

[4] T. Casey, (2009), "Analysis of radio spectrum market evolution possibilities", Communications and Strategies, No. 75, pp. 109-30.

[5] Fitch, M., et al.; "Wireless Service Provision in TV White Space with Cognitive Radio Technology: a Telecom Operator's Perspective and Experience"; IEEE Communications Magazine, March 2011, pp. 64-73

[6] H. Chesbrough, R.S. Rosenbloom, "The role of business model in capturing value from innovations: Evidence from Xerox Corporation's technology spin-off companies", Industrial and Corporate Change, Vol. 11, no. 3, pp. 529-555, 2002

[7] H.I. Ansoff; "A Model for Diversification", Management Science, Vol. 4, No. 4 (Jul., 1958), pp. 392-414

[8] Stabell, C.B., Fjeldstad, Ø.D., 1998. Configuring value for competitive advantage: On chains, shops, and networks. Strategic Management Journal 19 (5), pp. 413-437.

[9] Iansiti, M., Levien, R., 2004. Strategy as ecology. Harvard Business Review 82 (3), pp. 68-78.

[10] Eisenmann, T., Parker, G., Van Alstyne, M.W., 2006. Strategies for two-sided markets. Harvard Business Review, 84 (10), pp. 92-101.

[11] Gawer, A., Cusumano, M.A., 2008. How companies become platform leaders. MIT Sloan Management Review 49 (2), pp. 28-35.

[12] Jacobides, M.G., Knudsen, T., Augier, M., 2006. Benefiting from innovation: Value creation, value appropriation and the role of industry architectures. Research Policy 35 (8), pp. 1200-1221.

[13] A. Odlyzko, Telecom dogmas and spectrum allocations, Wireless Unleashed blog, 2004.

[14] Ballon, P., 2009. The platformisation of the European mobile industry. Communications & Strategies 75, pp. 15 - 34.

[15] J. Markendahl, "Mobile Network Operators and Cooperation, a Tele-economic study of infrastructure sharing and mobile payment services", PhD thesis, Royal Institute of Technology, Stockholm, 2011

[16] B. G Mölleryd, J Markendahl, "Valuation of spectrum for mobile broadband services- Engineering value versus willingness to pay", 22nd European Regional ITS Conference, Budapest, 18-21 September, 2011

[17] J. Markendahl, P. Gonsalez, B.G. Mölleryd, " Cellular use of TV WS for mobile broadband", COST-TERRA workshop november 2011

[18] J. Markendahl, M. Nilsson; "Business models for deployment and operation of femtocell networks: Are new cooperation strategies needed for mobile operators?", 21st European Regional ITS Conf, Sept. 2010.

[19] B.G. Mölleryd, J. Markendahl, Ö. Mäkitalo; "Analysis of operator options to reduce the impact of the revenue gap caused by flat rate mobile broad bad subscriptions", in Proc. 8th Conference of Telecom, Media and Internet Techno-Economics (CTTE´09), June 2009.

[20] J.H. Saltzer, D.P. Reed, and D.D. Clark, End-to-End Arguments in System Design, ACM Transactions on Computer Systems, Vol. 2, No. 4, November 1984, pp. 277-288.

[21] Markendahl, J., Mäkitalo, Ö., 2007. Analysis of business models and market players for local wireless Internet access. In: Proceedings of the 6th Conference on Telecommunication Techno-Economics, pp. 1 -8.

[22] Weiss, M. B., Delaere, S., and Lehr, W. H. (2010). Sensing as a service: An exploration into practical implementations of DSA, In Proceedings of the IEEE DySPAN 2010, April 2010, pp. 1-8.