COGNITIVE RADIO SYSTEMS:
MARKET ASSESSMENT OF SELECTED VALUE PROPOSITIONS

Pierre Carbonne (IDATE, Montpellier, BP 4167 France, p.carbonne@idate.org); Other IDATE's contributors: Thomas Hain, Soichi Nakajima, Michael Nique, Sophie Pernet, Julien Salanave; Pierre Marchand (NEC Technologies, Paris, France, pierre.marchand@nectech.fr) Simon Delaere (VUB IBBT, Brussels, Belgium, simon.delaere@vub.ac.be), Gary Clemo (OFCOM, London, the United Kingdoms, gary.clemo@ofcom.org.uk).

ABSTRACT

The work presented within this paper was performed within the Work Package 1 (WP1) of the End-to-End Efficiency (E3) project [1]. It aims at assessing the value propositions offered by Cognitive Radio Systems, defined in the context of E3. The paper is organized in two main sections:

- The first section of the document presents an analysis of the consolidated feedbacks given by mobile industry stakeholders to a questionnaire on Cognitive Pilot Channels and specific autonomous functionalities.
- The second section explores the quantitative gains that could be expected from specific Cognitive Radio Systems. Sensitivity analysis to given parameters are undertaken thanks to a generic cost model.

1. PERCEPTION OF THE INDUSTRY

E3 project gathered mobile network operators' and equipment vendors' feedbacks on cognitive pilot channel, and self planning / self optimization of network elements.

1.1. Cognitive Pilot Channel: the key enabler

The Cognitive Pilot Channel (CPC), sub-element that enables operations in heterogeneous environment, appears to be an important element in the implementation of cognitive radio solutions.

For operators and equipment vendors, the CPC allows a terminal to select a network in an environment where several technologies are available. Key gain compared to a terminal centric approach is energy saving at the terminal level. Some operators and equipment vendors recommended that this potential energy savings are evaluated.

CPC is perceived as a key enabler for future dynamic spectrum access context: network management should be easier and cheaper with dynamic spectrum access.

CPC is also expected to provide updated connectivity information. Real time information should enable service innovation, especially by the mean of location based services, and should also improve network management.

Main remarks regarding feasibility revolve around the need for technology maturity, standardization and reduced additional costs to drive implementation of CPC.

Operators and equipment suppliers also say that this technology is in competition with several others like discovery by terminal sensing, control by the network, based on capabilities sent by UE, with a centralized RRM. CPC has to improve significantly Network Management and Spectrum Efficiency compared to current techniques if it is to be considered by network operators.

Both vendors and operators consider that CPC could impact negatively economics in CapEx and impact positively Quality of Service.

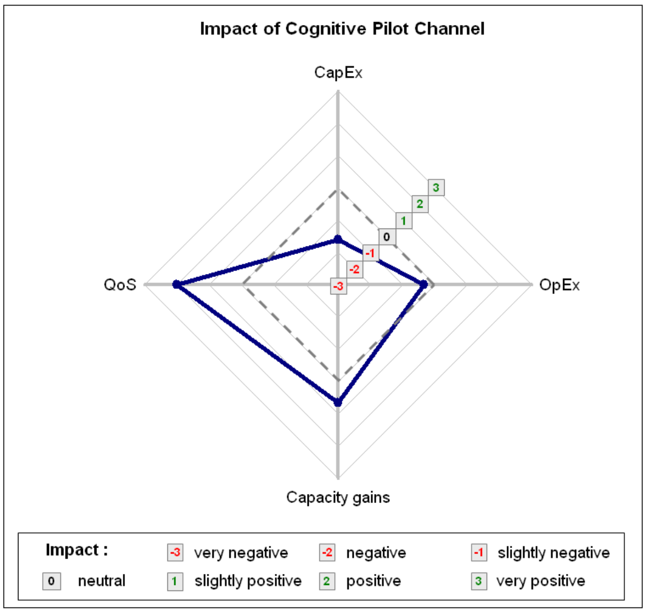

Figure 1: CPC Economic Impact

Both operators and equipment providers indicated that 3GPP might be the appropriate standardization body for this technique. Contribution to bodies like CEPT or ITU-R could also be relevant in order to mitigate potential regulatory bottlenecks.

1.2. Self Optimization and Self Planning: operational economy can be achieved

As regards autonomous Network Management techniques, potential gains for operators are viewed to be the highest in Self Optimization. Potential OpEx and CapEx gains could be achieved in particular for Self Optimization and Self Planning functionalities.
Regarding self-x functionalities, OpEx gains are expected to be higher than CapEx gains. Capital Expenditure gains are generally not expected by interviewees. If they materialize, they would mainly originate from Self Optimization and Self Planning Functionalities. Some even expect that integration of self-x functionalities in future standards would lead to higher equipment costs and higher CapEx.
Potential OpEx gains could be achieved in all Self-x Functionalities, especially from Self Optimization Functionality.
According to a vendor, on a cost versus revenues basis, benefits of self-X functionalities seem limited for today's networks as most planning and optimization operations have already been carried out. Human operations can hardly be avoided and replaced. Next generation technology might benefit more from these functionalities. Gains are more likely to materialize through functionalities integrated from scratch in the standard. Some interviewees mention that self-planning and self-optimization functionalities will be integrated in LTE standards.

Some respondents (mainly operators) also highlight that interfaces between network elements should be standardized and vendor independent.
According to a vendor, potential gains from self network management also include "Energy saving, through shutdown at off-peak hours and reconfiguration".

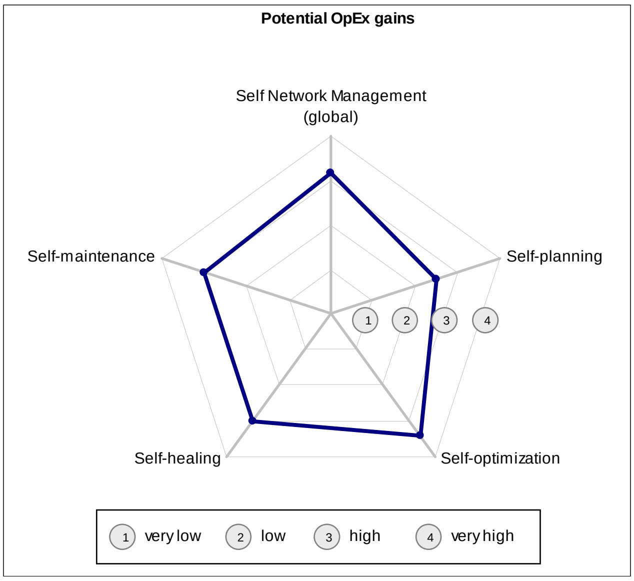

Figure 2: Evaluation of OpEx gains for autonomous Functionalities (selected MNO and equipment vendors' feedbacks)

Feasibility for full self-healing and self-maintenance is generally perceived as low on the short term. They will require further investigation to develop stable solutions that can be adopted by the industry. However self-planning and self-optimization are perceived as more achievable in the short term.

1.3. Development and adoption roadmaps

As regards roadmaps of Cognitive Radio Systems and / or elements, there are significant differences between the two propositions that were investigated. Vendors stated that CPC technique might take time to implement from standardization starting at best in 2011 to commercial deployments not before 2016. The roadmap for this technique is subject to the interest recognized by the industry.
Self Network Management might be deployed faster as standardization may be finalized by 2010 with commercial deployments from 2011. This technique will be part of LTE Rel. 8 and further releases [2].

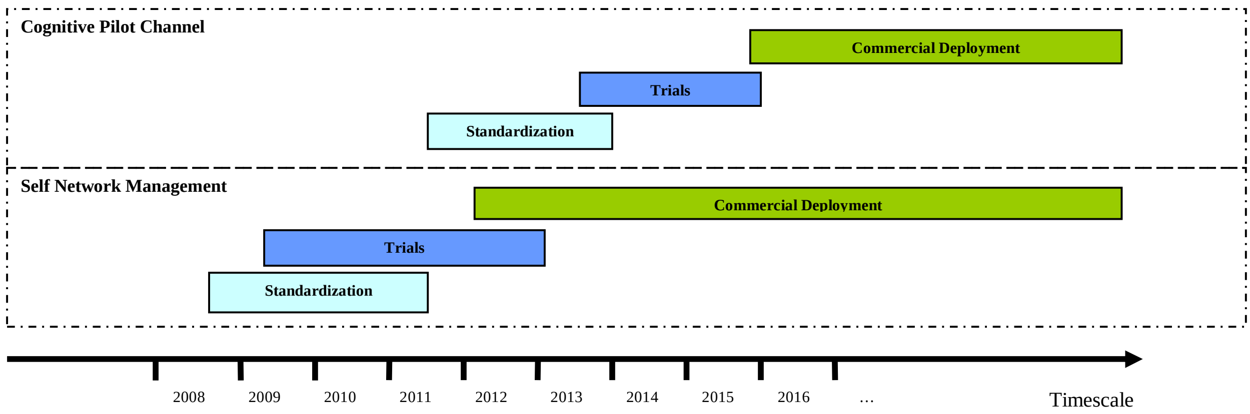

Figure 3: Roadmap forecast for Cognitive Radio Systems

2. QUANTITATIVE ASSESSMENT OF CPC AND SELF PLANNING / SELF OPTIMIZATION OF NETWORK ELEMENTS

Different quantitative simulations of CPC and Self-X adoption scenarios bring precisions to the stakeholders' feedbacks regarding possible costs impact.

2.1 CPC simulation

2.1.1. OpEx gains

The CPC scenario that has been simulated in the model presents the following characteristics:

- Inband / downlink only
- CPC operated in the operator's domain
- Reuse of existing GSM infrastructure; no specific hardware needed (200 kHz GSM channel)
- 200 kHz needed (With spectrum efficiency of 1 bit/Hz/s)
- Existing data base with networks information (Coverage of different RATs: GSM, UMTS, LTE, WiFi WLAN and PAN network provided by femtocells).

Main costs considered are the CPC software and equipment cost per Radio Site in particular costs related to software updates in GSM base stations; the cost of GSM spectrum used; the cost of building and operating RAT database.

The results of the simulation show that a 10% churn reduction is sufficient to cover all the additional cost related to CPC implementation which are:

- 100 EUR of annual costs per radio site
- 10% increase of SAC per subscriber acquisition related to higher CPC enabled device cost.

2.1.2. Traffic offloads: a clear gain for integrated operators

Another impact of CPC is the possibility to offload part of the traffic to available networks (wireless or fixed) with reduced cost of transport.

Applications requiring low bandwidth usage such as voice can be offloaded to lower spectral efficiency RAT such as GSM leaving capacity in UMTS/HSPA or LTE networks for more bandwidth consuming applications. The overall capacity optimization translates into more QoS and usages for subscribers.

Part of mobile network traffic can also be offloaded to alternative network such as WAN (WiFi).

Traffic offloading to fixed network might be interesting in terms of cost savings and revenue growth for 3 factors:

- Indoor Coverage.
- Capacity Increase
- Equipment, Power and Backhaul related costs reduction: The cost per transported Gigabyte on WiFi network is lower than on any other mobile network.

In the case of an inband CPC operated in the operator's domain, traffic offloading to fixed network is particularly interesting for integrated operators that leverage their presence in the fixed business to lower mobile network OpEx and CapEx. Therefore the business case, or business cases, for CPC can be neatly divided into technical and marketing-based propositions.

From a technical perspective, the case for CPC is based primarily on cost savings and reflects the fact that the technology addresses the two single biggest mobile operator costs: backhaul and power. In a CPC scenario, the backhaul is provided by the subscriber's fixed

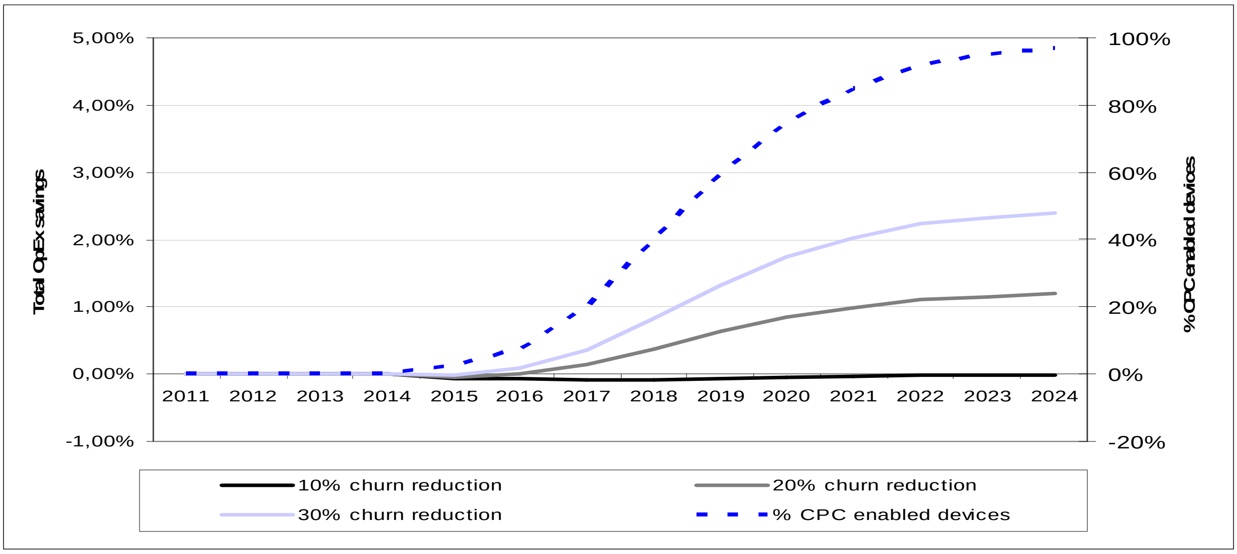

Figure 4: Total OpEx savings with different hypothesis of churn reduction among CPC users _ CPC additional OpEx of 100 EUR per radio site

connection while at home, while the power is paid for by the user. In addition, with the offloading of data to the public internet, the mobile operator's core network benefits from lower capacity levels.

For operators wishing to expand their mobile coverage there will be a choice between deploying additional macro base stations and encouraging subscribers to use the CPC feature. The relative cost levels seen with macro equipment and Wifi equipment are massively different, both in terms of CapEx and OpEx. It is also stressed that CPC could be even more beneficial at exactly those areas where coverage and capacity need to be improved. In the case of the macro option, good quality indoor mobile broadband coverage necessitates high levels of additional expenditure, with an increase in the number of outdoor cells (depending on the levels of capacity applicable to the operator) required to provide the same level of service as Wifi access would provide thanks to the CPC feature.

2.2 Self-planning and self-optimisation

2.2.1. Base case scenario

The self-planning and self-optimisation scenario that has been simulated in the model presents the following characteristics:

The scenario is based on self planning and self optimization functionalities developed within E³ project

- Adoption of self planning and self optimization functionalities for future standard (functionalities are not deployed in GSM and UMTS networks)
- Functionalities integrated in the standard from scratch
- Vendor independent standardized interfaces

It is based on the definition of self-planning and self-optimisation as described in E3 white paper titled "Self-x in Radio Access Networks" [3]:

Self-planning might be considered as a particular case of the self-configuration situation. It comprises the processes were radio planning parameters are assigned to a newly deployed network node. Parameters in scope of self-planning [4]:

- Neighbour cell relations
- Max TX power values of UE and eNodeB.
- Handover parameters, Hysteresis, trigger levels, etc

Self-optimisation process is defined as the process where user equipment (UE) and base station measurements and performance measurements are used to auto-tune the network. The tuning actions could mean changing parameters, thresholds, neighbourhood relationships, etc. The main benefits of self-optimisation will be:

- Operational effort minimisation
- Quality and performance increase
- Planning effort and failure reduction

This process is accomplished in the operational state. The operational state is defined as the state where the RF interface is commercially active.

Increased CapEx are expected because of the Self-X functionalities related software and equipment cost per radio site.

Taking as a reference the different use cases of E3 Deliverable D2.1 "System Scenarios, Use Cases, Assessment" [5] and the various interviews of operators and equipment manufacturers previously undertaken, we centred our sensitivity analysis on possible variations of CapEx and OpEx gains for specific costs items related to LTE network roll-out and maintenance:

- 20 to 40% gains in LTE network planning related costs (CapEx) which are achieved through faster site selection and faster insertion/configuration of new network elements while deploying.
- 20 to 40% gains in LTE network optimisation related costs(OpEx) notably thanks to reduced manual operations of network technicians (both in quantity and average duration)

We then compared CapEx and OpEx levels of the self-X scenario with the scenario "Business as usual" in which self-X functionalities would not have been activated.

2.2.2. Results and sensitivity analysis

One observes that results from the modelling exercise show a greater impact on CapEx than OpEx for self-planning and self-optimisation functionalities adoption.

The results are to be considered in a situation where self-planning and self-optimisation functionalities have independent standardized interfaces. Generally, mobile operators have multi-vendor equipment within their networks. Standardized interfaces for self-X would allow them to get the full benefit of such functionalities in terms of OpEx and CapEx savings.

The results in terms of CapEx savings are presented in the following figure.

As it presented in the figure below, relative CapEx savings range from 3.3% to 6.6 % depending on the hypothesis of RAN planning and optimisation costs reduction (20% to 40%). These values are observed for the period 2013 – 2015 when LTE network is deployed at high pace.

Putting results into perspective, savings levels are significant since the CapEx perimeter also include backhaul, core network and IT investments as well as GSM and UMTS RAN equipment replacements.

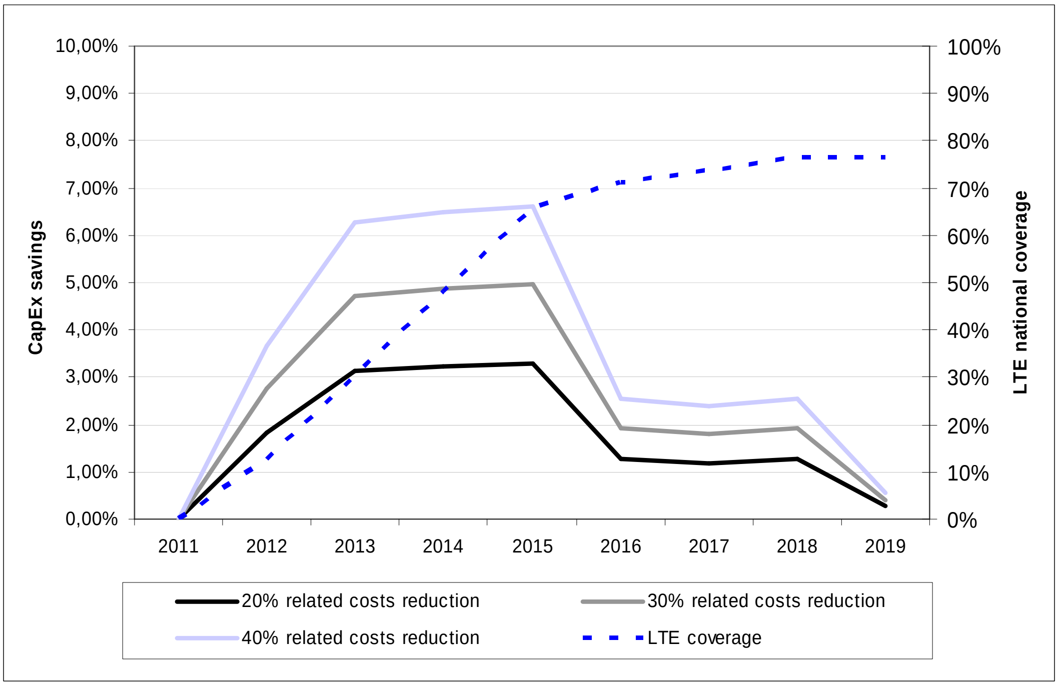

Figure 5: Total CapEx savings with different hypothesis of RAN planning and optimisation costs reduction induced by self-planning and self-optimisation functionalities adoption.

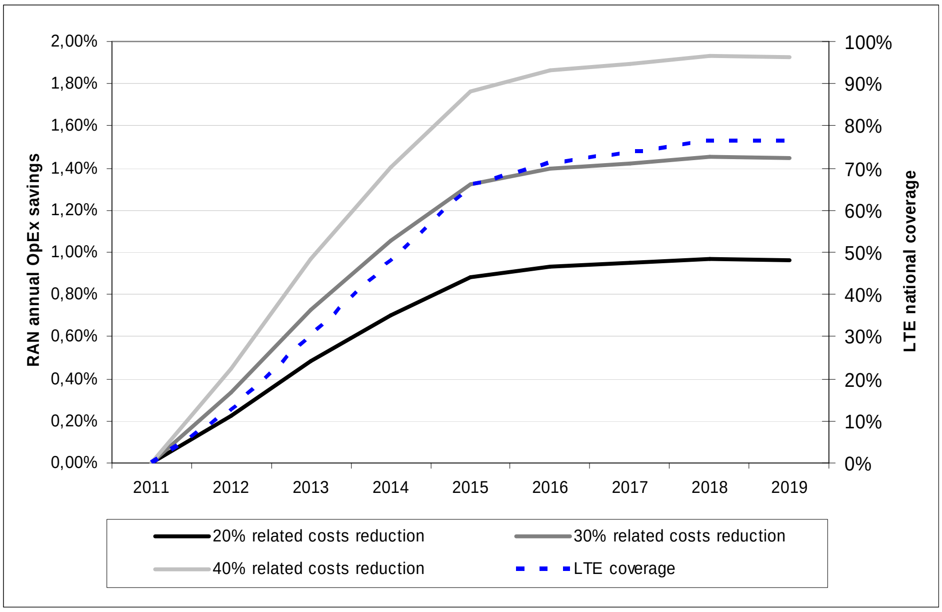

Figure 5: RAN annual OpEx savings with different hypothesis of RAN maintenance & optimisation costs reduction induced by self-planning and self-optimisation functionalities adoption.

In the same manner, the results in terms of OpEx savings are presented in the figure above.

Self-planning and self-optimisation impact on RAN OpEx seem lower but it is important to underline the following facts:

- RAN OpEx also include GSM and UMTS networks for which no gains are achieved
- A great portion of RAN OpEx is composed of cell site location rental, cell site power supply and mast maintenance cost.
- OpEx savings are repeated every year unlike CapEx. Their accumulations over the entire equipment life-span represent a substantial gain for the operator.

3. REFERENCES

[1] ICT-2007-216248 E3 Project, http://www.ict-e3.eu/.
[2] LTE Rel-9 and LTE-Advanced in 3GPP presentation, 3GPP TSG-RAN chairman
[3] ICT-2007-216248 E3 Project, Self-x in Radio Access Networks
[4] NGMN Project 12, Use Cases related to Self Organising Network.
[5] ICT-2007-216248 E3 Project, Deliverable D2.1 "System Scenarios, Use Cases, Assessment"