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White Paper on Business/Market Research Activities within CRS-cluster Projects

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Author(s): Simon Delaere (iMinds), Vânia Gonçalves (iMinds), Pieter Ballon (iMinds), Dominique Noguet (CEA), Paulo Marques (IT), Hugo Esteves (IT), Filipe Alves (IT)

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Abstract:
In this white paper we aim to bring together the business/market research activities within the CRS-i cluster projects in order to understand what are the market opportunities they envisage, and what are the projects' intentions with regard to certain design choices to be pursued in standardization, with a view of aligning these choices where possible and thereby boosting both the standardization process itself and the commercialisation of products it aims to facilitate.

Keyword list: Project cluster, FP7, Standardization, Cognitive radio, Business Models, Exploitation

Executive Summary

In this report, we look at the available non-technical information coming from CRS-i cluster projects, including use cases and requirements, value networks, business models and exploitation plans, in order to identify complementarities in the business design concepts of these various projects. These complementarities in business design choices may then stimulate more coordinated approaches to the standardization of these objectives. The report shows that there not just significant overlaps in the technical results and objectives of CRS-i cluster projects (which have been described and addressed in various other CRS-i deliverables), but also in the business objectives and scenarios which underpin the technical work and, to a significant extent, determine the design choices made first within the project and, subsequently, in the standardization domain. These synergies mainly relate to carrier aggregation, joint interests in Public Safety scenarios and business scenarios requiring updates to 3GPP standards. Therefore, coordinating the specification of these projects' technical outcomes into standards is not merely beneficial from a technical perspective, but may significantly contribute to realising the exploitation objectives of project partners and the translation of project results into commercially viable solutions.

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List of Abbreviations

ARPU	Average Revenue Per User
CA	Carrier Aggregation
CR	Cognitive Radio
DSA	Dynamic Spectrum Access
FBMC	Filter Bank Multi-Carrier
FCC	Federal Communications Commission
FDD	Frequency Division Duplex
ITU	International Telecommunication Union
LSA	Licenced Shared Access
LTE	Long Term Evolution
MBB	Mobile Broadband
MNO	Mobile Network Operator
MTC	Machine Type Communication
Ofcom	Office of Communications (UK)
OFDM	Orthogonal Frequency Division Multiplex
PMSE	Program Making and Special Events
PMR	Professional Mobile Radio
QoE	Quality of Experience
QoS	Quality of Service
RAT	Radio Access Technology
SDR	Software Defined Radio
TVWS	TV White Spaces
WiFi	Wireless Fidelity
WRC	World Radiocommunication Conference

1 Introduction

The ultimate objective of the standardization process is to create a basis for viable and sustainable commercial deployment of wireless technologies. Already at the R&D stage, but certainly during the standardization process, design choices are made, both conscious and inadvertently, which may have a significant impact on the way in which eventual products are marketed.

In other words, the design choices made during the technical specification of mobile innovations may have –and in many cases have had a profound impact on the later configuration of the market for these technologies. Therefore, when looking at ways to promote the uptake of CRS research results and their transformation into, first, broadly accepted standards and, subsequently, viable new products and services, it is not only crucial to look at the technical research as such and its translation into technical contributions to standards development organisations. Besides this, it is relevant to study the *business considerations* behind the technical activities of the various projects, and to identify potential synergies and obstacles on this level. After all, it can be assumed that these underlying motivations, besides technical compatibility, will ultimately align or antagonize solutions in the standardization domain. A clear picture of the business architecture, the use cases and a first evaluation of the concrete exploitation plans that projects or project partners have, and an analysis of potential synergies and incongruences between these non-technical objectives, may help to coordinate the realisation of these complementary business objectives in the standardization domain.

In this report, we will therefore look at the available non-technical information coming from CRS-i cluster projects, including use cases and requirements, value networks, business models and exploitation plans, in order to identify complementarities in the business design concepts of these various projects. These complementarities in business design choices may then stimulate more coordinated approaches to the standardization of these objectives.

The next section will outline the relationship between research, standards and markets. Subsequently, section 3 evaluates the business objectives of six CRS-i cluster projects, i.e. SOLDER, ADEL, ABSOLUTE, CORASAT 5GNOW and EMPHATIC. For each of these, a short overview of the project objectives is given, as well as a brief overview of standardization requirements. Then, an evaluation is made of the business objectives of the projects. For this, available documentation (deliverables on use cases and requirements, business architectures, business models and exploitation plans) has been consulted, and a dedicated workshop on market perspectives and exploitation was organised by CRS-i in Brussels in March 2015. Where relevant, potential synergies between the business objectives of projects are identified. These synergies are summarized in a concluding section.

2 The link between research, standards and markets in the wireless sector

For a long time, both academic and industrial perspectives on standardization started from the assumption that most standardization occurred late in the product development process when technology was mature and the latter stages of the product cycle were being reached (Vernon 1966[1]; Kindleberger 1983[2], as referenced by Ballon and Hawkins, 2009[3]). Particularly regarding high tech industries, subsequent theories began to situate standardization much earlier in the innovation cycle, demonstrating how standards influence the innovation process by building up positive returns to adoption and creating path dependencies (Arthur 1989[4], Katz & Shapiro 1986[5], David 1985[6], as referenced by Ballon and Hawkins, 2009). This opened the field up to critical exploration of the strategic role that standardization could play, not just in coordinating technologies but also in organising markets (Blind 2004[7], Schmidt & Werle 1998[8], Hawkins 1996[9], as referenced by Ballon and Hawkins, 2009).

Today, it is widely accepted that standards act as platforms that may both enable and hamper innovations. Standards act as a proven mechanism for technology transfer, diffusion and utilisation. In many cases, standards do not constitute innovation in itself, but instead create a modular base platform upon which innovation can be built (Bekkers and Jakobs, 2015)[10]. This is particularly true for mobile ICT systems. As Ballon and Hawkins (2009) put it: *"Mobile information and communication technology (M-ICT) has long ago past the point where technologically it is a form of 'telephone'. Instead, it has become a platform upon which many complementary innovations have been developed. As such, M-ICT could be considered to be a 'general purpose technology' for the wireless distribution of 'data', which in a digital environment includes voice traffic as well. Typically a general-purpose technology opens up new opportunities rather than offering discrete solutions; that is, it realizes most of its value by creating opportunities for complementary innovations to emerge from within a highly heterogeneous group of potential adopters".*

In such a context, maintaining control over the overall architecture, by instituting such control over the interfaces within the system architecture, is crucial, and the success of an innovation is often just as dependent on the technical superiority of the solutions as on the capacity to capture economic value inherent in the design. Therefore, there exists an intimate connection between technical and business model design, as was observed by Gawer in studying the case of Intel Corporation: *"Looking at the transformation of the computer industry through both a technological and an economic lens, we can see that what seemed to be purely a problem of technical design — the allocation of features in functional blocks — has induced a radically different partitioning of the space of economic activity between different firms. Through this transformation, parameters of differentiation between products have been radically altered, and the nature of firms' sources of competitive advantage have changed." (Gawer 2000, p. 77,* as quoted by Ballon and Hawkins, 2009*).*

In short, the design choices made during the technical specification of wireless technologies may have, and in many cases have had, a profound impact on the later configuration of the market for these technologies. Therefore, when looking at ways to promote the uptake of CRS research results and their transformation into, first, broadly accepted standards and, subsequently, viable new products and services, it is not only crucial to look at the technical research as such and its translation into technical contributions to standards development organisations. Besides this, it is relevant to study the *business considerations* behind the technical activities of the various projects, and to identify potential synergies and obstacles on this level. After all, it can be assumed that these underlying motivations, besides technical compatibility, will ultimately align or antagonize solutions in the standardization domain. A clear picture of the business architecture, the use cases and a first evaluation of the concrete exploitation plans that projects or project partners have, and an analysis of potential synergies and

[1] R. Vernon (1966) International investment and international trade in the product cycle, *Quarterly Journal of Economics*, 80 (2), 190-207.

[2] C.P. Kindleberger (1983) Standards as public, collective, and private goods, *Kyklos*, 36 (3), 377-396.

[3] P. Ballon & R. Hawkins. Standardization and Business Models for Platform Competition: The Case of Mobile Television. International Journal of IT Standards & Standardization Research, Vol. 7, N° 1 (Jan-Mar 2009), pp.1-12.

[4] B. Arthur (1989) Competing technologies, increasing returns, and lock-in by historical events, *Economic Journal*, 99, March, 116-131

[5] M.L. Katz & C. Shapiro (1986) Technology adoption in the presence of network externalities, *Journal of Political Economy*, 94, 882-841.

[6] P.A. David(1985) Clio and the economics of QWERTY, *American Economic Review*, 75 (2), 332-337.

[7] K. Blind (2004) *The Economics of Standards - Theory, Evidence, Policy*, Cheltenham: Edward Elgar.

[8] S. Schmidt & R. Werle (1998) *Co-ordinating Technology: Studies in the International Standardization of Telecommunications,* Cambridge MA: MIT Press.

[9] R. Hawkins (1996) Standards for communication technologies: negotiating institutional biases in network design," in Mansell, R. and R. Silverstone (eds.), *Communication by Design: The Politics of Information and Communication Technologies*, Oxford: Oxford University Press, 157-186.

[10] R. Bekkers and K. Jakobs (2015). ICT Research and Standardization – Still uneasy bedfellows? CRS-i RAS Cluster Workshop, Net Futures Conference, Brussels, 25 March 2015

incongruencies between these non-technical objectives, may help to coordinate the realisation of these complementary business objectives in the standardization domain.

In the following sections, we therefore look at the available non-technical information coming from CRS-i cluster projects, including use cases and requirements, value networks, business models and exploitation plans, in order to identify complementarities in the business design concepts of these various projects. These complementarities in business design choices may then stimulate more coordinated approaches to the standardization of these objectives.

3 Standardization involvement, market perspectives and potential synergies for CRS-i cluster projects

3.1 SOLDER: Spectrum Overlay through aggregation of heterogeneous dispersed bands

The goal of SOLDER is to develop a new spectrum overlay technology which will provide the efficient aggregation of non-continuous dispersed spectrum bands licensed to heterogeneous networks (HetNets) and heterogeneous Radio Access Technologies (h-RATs). Importantly, SOLDER also prominently encompasses aggregation of spectrum opportunities and links that have been created by the usage of TV White Spaces, opportunistic spectrum access and spectrum sharing solutions. The combinations of technologies, such as LTE, HSPA, WiFi, TV white space systems, and the variety of spectrum bands that might be used in a contiguous or non-contiguous mode has revealed wide potential of aggregation solutions in future wireless networks and their tremendous effect on the increase of UE’s data rate.

Standardization involvement of SOLDER
SOLDER has identified as particular targets the IEEE 1900 series standards and IEEE Dynamic Spectrum Access Networks Standards Committee (DySPAN-SC) in general, as well as ETSI Reconfigurable Radio Systems (ETSI-RRS) WG2 – Software Defined Radio Architectures.

Business and market perspectives for SOLDER
The SOLDER project distinguishes between two types of use cases for its aggregation solutions: one is aggregation within licensed LTE bands, while the other is the aggregation of heterogeneous Radio Access Technologies and bands.

LTE aggregation
Within the licensed LTE scenarios, the aggregation of LTE carriers using the same duplex mode (e.g. FDD with FDD) is the most basic scenario. The project sees two main business arguments for doing this:

- Firstly, higher aggregated bandwidth can be achieved, especially for operators that did not get awarded 20 MHz of contiguous bandwidth and for operators that use TDD and only have 20 MHz available for both upload and download. With two 20 MHz carriers, these operators could serve category 6 terminals with a 300 Mbps throughput. This use case therefore represents an important, “natural” evolution path for LTE. Such evolution possibly (although not necessarily) leads to higher ARPU and will allow operators to deal with exponentially increasing spectrum demands. It also makes it easier for regulators to reallocate bands to wireless broadband, since these bands become more attractive for operators, which are able to integrate them into their existing spectrum assets.
- Secondly, in fragmented spectrum markets such as in the US, SOLDER spectrum aggregation may serve to unify spectrum operations in a number of bands which, according to the project, should facilitate load balancing and QoS management. Besides increasing service levels (and thus, throughput and customer satisfaction), such integrated spectrum management also possibly decreases operational expenditures. Similar services may also be offered in larger number of markets.

Still within the operators’ domain, a more complex scenario involves the aggregation of TDD and FDD carriers, although the business objective of such aggregation would be similar to what is described above. Another situation however concerns aggregation between bands of different operators, for example in a Primary/Secondary User set-up. In such a scenario a secondary user would opportunistically make use of spectrum licensed to a Primary User, either via pre-determined agreements and signalling methods, or using DSA and CR. The SOLDER project envisages both infrastructure based and non-infastructure based aggregation (e.g. using D2D communications), but focuses on a D2D application scenario. It lists the following three business related objectives for such inter-operator aggregation: 1) increased capacity, 2) increased spectrum efficiency and 3) lower energy consumption. To this can be added that the envisaged inter-operator aggregation schemes may serve as a way to allow new MVNO and MVNE-type entrants to the market, which are able to outsource a significant part of their infrastructure assets and focus on service provision and branding. Besides this, such scenarios could also enable (or even require) the existence of brokers, which negotiate, configure and –through aggregation- implement spectrum access to various sources as a transparent process to their clients. The latter scenarios, although technically more complex than sharing between LTE operators, seems more likely from a strategic perspective, since it involves a relationship between complementary partners in the value network (e.g. operators, brokers and MVNOs) rather than a supposed cooperation between direct competitors which both own spectrum assets.

Heterogeneous aggregation
Under this category, SOLDER identifies four different types of aggregation:

- Licensed spectrum with licensed spectrum aggregation. These are based on LTE but also include macro-pico configurations and co-existence between various RATs (2G/3G/4G), each however functioning in their own bands and managed via Dynamic Spectrum Management Techniques.
- Licensed spectrum with unlicensed spectrum aggregation. One scenario studied by SOLDER is the addition of an unlicensed LTE band to an existing licensed asset on an ad hoc basis, which is being studied by 3GPP under the study item Licensed Assisted Access (LAA). In such cases, the LTE waveform would have to be altered to allow coexistence, and would only be able to function on a best-effort basis. However, with single O&M and the use of a robust LTE technology, the use case could indeed be interesting for operators. The second scenario involves the aggregation of LTE and WiFi in small cell environment with a high number of users and limited licensed spectrum availability. SOLDER focuses on carrier aggregation at the RAN level, realising an aggregation similar to that between LTE carriers in LTE-advanced. From a business perspective, the question then is whether the WiFi Access Points (and underlying backhaul) and LTE nodes will be located in the same business domain (i.e. the same operator) and which level of control the aggregating operator will have on the WiFi sections of the network.
- TVWS with unlicensed spectrum aggregation. The scenario SOLDER looks at in this context is the deployment of eMBMS services in TVWS band for “augmented broadcast”, where the aggregation with WiFi serves to enable additional broadcast layers, large-scale software downloads or the operation of a Cognitive Pilot Channel. It needs to be noted that, although the focus on broadcasting is already a rather specialised application domain of this type of aggregation, the business objectives for each of the sub-scenarios is quite different: while the first (additional layers) is aimed at extended service provisioning towards end users, the latter two (downloads/CPC) are more management oriented, allowing for Software Defined Networking, Reconfigurable Radio Systems and Dynamic Spectrum Access.
- Licensed spectrum with TVWS aggregation. A first scenario in the category is a variant of the LTE/LTE aggregation (with one of the LTE carriers operating in TVWS), although more complex to achieve and probably only allowing for the addition of a supplemental downlink carrier. More generally, TVWS could also be used to provide additional cellular connectivity complementing licensed cellular networks.
- TVWS with TVWS aggregation. In this final scenario, different TVWS bands (as declared available by a Geolocation Database) are aggregated, increasing overall throughput and capacity, and thereby mitigating for the fact that typically a large number of TV channels are available depending on the location, but that in every of these locations there are issues with the use of a number of these channels which, in single TV channel cases, will quickly render the channel useless. This situation is strongly exacerbated in mobile scenarios, as experiments performed in London have shown that TVWS availability and usability can dramatically change over relatively short distances. Therefore, in principle a large number of business scenarios for such aggregation are possible (including cellular provisioning and wireless local area networking). However, the SOLDER project has chosen to focus mainly on point-to-multipoint cellular provisioning and eMBMS broadcast. In mobile scenarios, TVWS aggregation can probably best be used for best-effort traffic such as background downloads.

From the above, it is clear that Carrier Aggregation has a large number of potential business benefits, and can even be considered as a fundamental evolutive requirement to both successful existing (LTE) and upcoming (TVWS) access technologies. It allows for higher throughput and capacity, larger service areas, and unified and simplified management. Besides improving the operational efficiency of existing operators, CA may also serve as a virtualising factor, stimulating the establishment of alternative operators. For the realisation of these more ecosystem-disruptive scenarios, the introduction of Cognitive Radio and Dynamic Spectrum Management Scenarios are indispensable. This requirement becomes even stronger in secondary use and multi-RAT scenarios such as the different TVWS deployments. In such scenarios, a tight interlinking between the different RATs is of very high importance.

3.2 ADEL: Advanced Dynamic Spectrum 5G mobile networks Employing Licensed shared access

The LSA concept foresees the establishment of long-term sharing agreements as a means to make available spectrum bands with low incumbent activity, to users with QoS requirements. The new LSA regulatory concept offers the potential for MNOs to gain access to new spectrum bands under conditions that resemble exclusive licensing while guaranteeing the incumbent spectrum users' rights. The LSA concept can speed up the process of taking harmonized IMT bands into actual use for MNOs by sharing with existing non-MNO incumbent users.

In Europe, the LSA work is currently focused on the 2.3 GHz band as the first application. In this band, the incumbent systems vary in different countries. In some countries, the incumbent is the programme making and special events (PMSE) services including video links. Without LSA, only a minority of countries in Europe would be able to offer access to the 2.3 GHz band. In particular, an ECC harmonization measure could not be implemented without LSA.[11] The resulting market would not be sufficiently big for major operators to deploy the band and for vendors to manufacture European handsets supporting the band.

The key stakeholders in the LSA framework include spectrum regulator, licensee, and incumbent spectrum user. A major benefit envisioned with LSA is that the number of LSA licensees is limited and that these LSA licensees are known to each other. In the special case of LSA applied to mobile broadband, the spectrum regulator is the national regulatory authority (NRA), the licensee is an MNO, and the incumbent spectrum licensee is a non-MNO[12]. The LSA architecture, as specified by ETSI, is shown in Figure 1. Key modules dedicated to the management of the radio access networks are the LSA Repository, which includes information about the spectrum in use by the incumbents, and the LSA controller that assigns to the LSA licensees, on demand, the spectrum not in use by the incumbents.

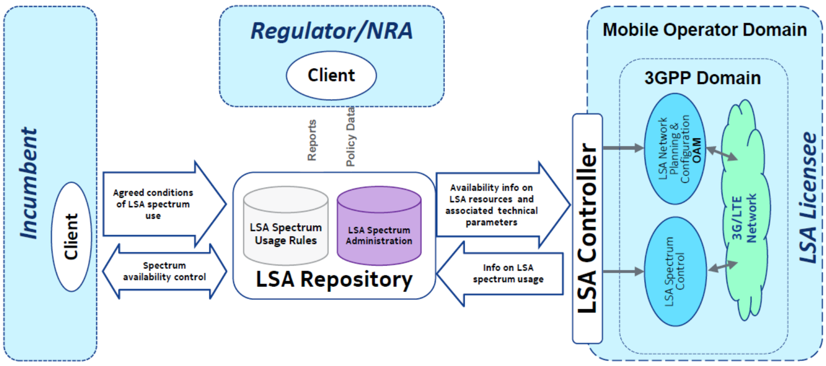

Figure 1 LSA architecture specified in ETSI TS 103 235.

As a research project, ADEL position is to push the LSA original approach towards more dynamic spectrum sharing scenarios, therefore extending the business opportunities. In this section, we will describe the ADEL ideas in what concerns the business opportunities created by ADEL's LSA vision. ADEL proposes the introduction of the LSA approach to more dynamic sharing scenarios, maintaining the requirement that both the incumbent and the LSA licensees benefit from QoS when using the spectrum. In this sense, ADEL proposes the introduction of (possibly) several collaborative spectrum-sensing networks, a spectrum-sensing reasoning module, and details/improves the operation of the LSA controller.

ADEL's proposal of a dynamic LSA approach benefits from spectrum monitoring capabilities introduced by one or more spectrum-sensing network providers, therefore ADEL opens the LSA concept to spectrum sensing networks. Those providers must invest on the creation of the sensing infrastructure. These costs may be alleviated if the sensing network providers has already a network infrastructure in place, as is the case of MNOs.

The more dynamic version of LSA proposed in ADEL, with differentiated LSA licensees, will transform the original LSA value chain, due to the optional, but advisable, introduction of spectrum sensing and reasoning as depicted in Figure 2.[13]

[11] Marja Matinmikko, Hanna Okkonen, Seppo Yrjölä, Petri Ahokangas, Miia Mustonen, Marko Palola, Vânia Gonçalves, Anri Kivimäki, Esko Luttinen, and Jukka Kemppainen. *Business Benefits of Licensed Shared Access (LSA) for Key Stakeholders*. In: Oliver Holland, Hanna Bogucka, Arturas Medeisis (eds.) (2015). Opportunistic Spectrum Sharing and White Space Access: The Practical Reality. Wiley

[12] Ahokangas P, Matinmikko M, Yrjölä S, Okkonen H, Casey T. "Simple rules" for mobile network operators' strategic choices in future spectrum sharing networks. IEEE Wireless Communications 2013;20(2):20–26.

[13] Source: ADEL, D3.1 – Reference scenarios, network architecture, system and user requirements and business models

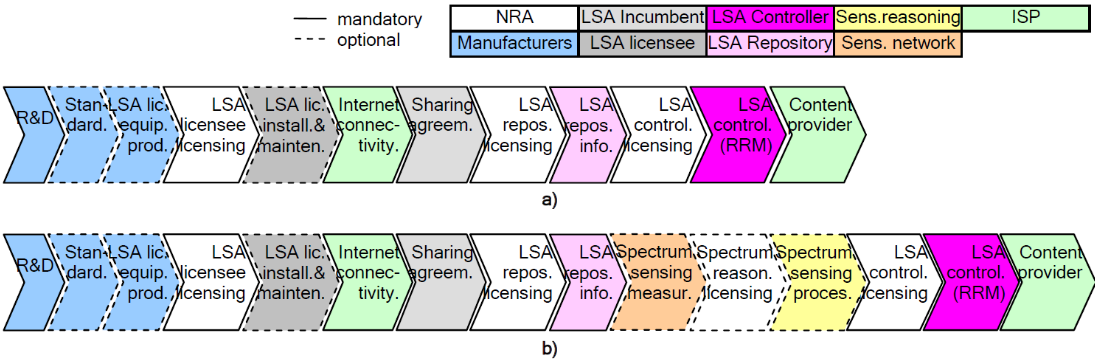

Figure 2 Comparison between a) original LSA value chain, and b) ADEL value chain.

The next figure captures the cash flows between the several players in ADEL's LSA model.

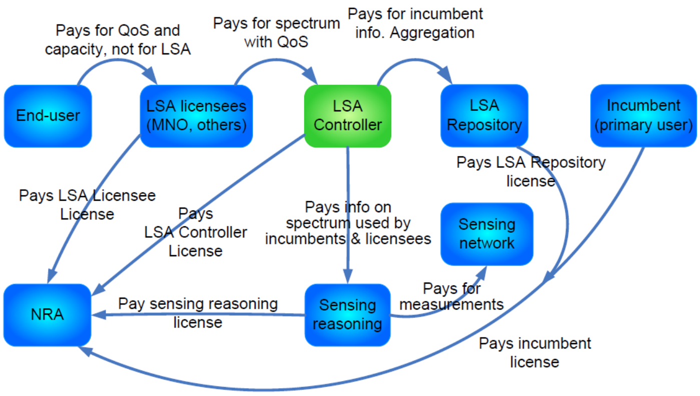

Figure 3 ADEL's business model cash flow [ADEL D3.1].

Standardization involvement of ADEL
Standardization is a key requirement for LSA market success and associated business models. The main reasons for LSA standardization are listed below:

- Support of multi-vendor 3GPP networks;
- Standardized state-of-the-art interfaces, especially between LSA Repository and LSA Controller to limit integration efforts;
- Re-use of existing 3GPP functionalities to meet time to market requirements for new spectrum.

Current standardization work in ETSI considers limited dynamic sharing (based on pre-configurations). ADEL view of LSA follows a more dynamic spectrum sharing approach that includes sensing features, which are currently beyond the scope of the LSA work in ETSI RRS. Thanks to CRS-i consultancy work, ADEL is involved in the ongoing discussions regarding the next phase of the LSA specifications within ETSI RRS WG1 where ADEL research work is expected to be very relevant. The LSA standardization and regulatory roadmap is shown in Figure 4.

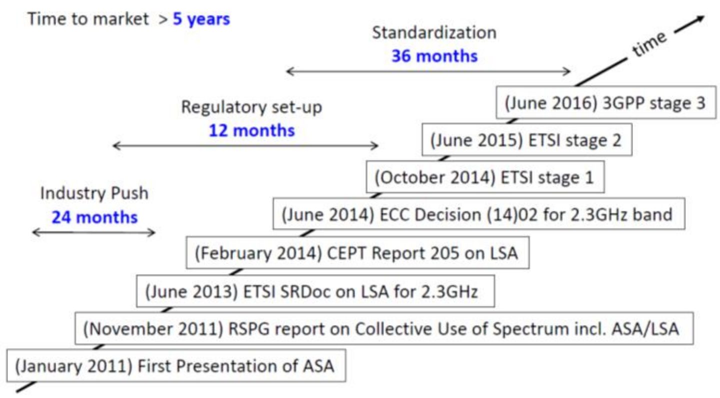

Figure 4 LSA standardization and regulatory roadmap [source: RED Technologies].

Business and market perspectives for ADEL

Business opportunities

As has been demonstrated in Matinmikko et al (2015)[14], Licensed Shared Access has promising business potential for a number of different stakeholders. Firstly, for MNOs, it can help to deal with increasing demand for wireless broadband capacity by going beyond traditional additional exclusive licensing and off-loading in licence exempt bands. Two distinct types of MNOs are identified: for the dominant MNO (with a strong market position and significant spectrum assets) investing LSA could be a cost efficient way of increasing capacity, possibly also without strict coverage obligations. MNOs could use this capacity to offload traffic with guaranteed QoS, as opposed to using WiFi for such purposes, or to serve special areas (such as rural territories). Since such MNOs already have significant capacity in place, they will be less dependent on LSA spectrum and might therefore be willing to such frequencies to their portfolio without great risk to their operations. However, those same existing assets might decrease the need for such MNOs to engage in complex relationships with incumbents and NRAs, and dominant MNOs might even strategically opt against spectrum sharing altogether. For the second type of MNOs, called "challenger MNOs", the potential value of LSA spectrum is much higher, since it may grant these operators access to new markets or new services. Matinmikko et al therefore expect these types of operators to be more likely to engage in longer term relationships with incumbents. Such operators could even lease capacity to dominant incumbents as a way to complement "capacity gaps".

Secondly, for incumbents, LSA offers the opportunity to receive a monetary or other type of compensation[15] for the use of its frequencies. However, these potential benefits are highly dependent on the way in which LSA is regulated in a specific territory and/or for a specific type of incumbent (e.g. the military): in some cases, NRAs will not allow such compensations to flow directly to the incumbent, while the attractiveness of LSA also depends on the possibility given to the incumbent to reclaim the spectrum in case of need. Another, "negative" argument for LSA towards incumbents is that it could prevent some of their frequencies to be straightforwardly reallocated. All of this, however, needs to be traded-off against the risk of interference incurred by the incumbent.

Finally, for NRAs, LSA could imply a new source of income (in case where compensations do not flow towards the incumbents) while the complex procedures of reallocating incumbents' frequencies are avoided. The NRA can also pursue public policy goals of achieving more spectrum efficiency, lowering overall spectrum prices and allowing more competition and new services to be established. This, however, comes at the cost of establishing and implementing a sharing framework, coordination with adjacent bands and bordering nations, and providing enforcement in sometimes complex conflicts concerning contractual arrangements, technical implementation and eventual occurrence of interference (see SCFA, 2012, pp. 158-163 for a detailed account of these additional administrative costs)

Added value

Available studies confirm the business potential of LSA. For example, in 2013 Plum Consulting estimated the net present value of the benefits from deploying LSA in the 2.3–2.4 GHz band over the period 2015–2030 in Europe to be between EUR 6.5 billion and EUR 20 billion.[16] A study by Deloitte for the GSMA in 2014 goes even further, stating that the introduction of LSA in 100 Mhz of spectrum within the 3.5 Ghz band in the USA from 2016, and 50 MHz of spectrum within the 2.3 GHz band in the EU from 2020, could generate up to USD 260 billion of value add in the US over the period 2016-2030, and up to EUR 86 billion in the EU. However, the report clearly emphasizes that exclusions, contractual restrictions, lack of harmonization and excessive dynamism could quickly reduce these economic effects to zero; the maximum figures mentioned would be valid for a scenario in which frequencies are given to MNOs for exclusive use with no geographic or timing restrictions for a period of 20 years.[17] Finally, a study by SCF Associates for the European Commission in 2012 mentions benefits of spectrum sharing (including, but not limited to LSA) over nine years to be between EUR 270 bn in a modest sharing scenario and EUR 776 billion in an advanced scenario, emphasizing that the benefits of sharing would far outweigh the additional costs (for incumbents, MNOs and regulator).

Coordination

Most of the business scenarios outlined above are centred around either a dominant or a challenger MNO acquiring, for a reasonable period of time, usage rights of frequencies that are principally owned by an incumbent. Especially

[14] Marja Matinmikko, Hanna Okkonen, Seppo Yrjölä, Petri Ahokangas, Miia Mustonen, Marko Palola, Vânia Gonçalves, Anri Kivimäki, Esko Luttinen, and Jukka Kemppainen. *Business Benefits of Licensed Shared Access (LSA) for Key Stakeholders*. In: Oliver Holland, Hanna Bogucka, Arturas Medeisis (eds.) (2015). Opportunistic Spectrum Sharing and White Space Access: The Practical Reality. Wiley

[15] Matinmikko et al mention that, as an alternative to monetary compensation, incumbents could also get access to MNO's infrastructure and services.

[16] Lavender T, Marks P,Wongsaroj S, The economic benefits of LSA in 2.3 GHz in Europe.
Plum Consulting, December 2013, p. 51.

[17] Deloitte, GSMA (2014). The impact of Licensed Shared Use of Spectrum.
http://www2.deloitte.com/content/dam/Deloitte/us/Documents/technology-media-telecommunications/us-tmt-gsma-Spectrum-09262014.pdf

in the dominant MNO case, these usage rights are combined with existing spectrum assets, either to provide offloading or to ensure connectivity in remote areas. This implies that LSA and non-LSA frequencies are aggregated. Therefore, ADEL business objectives align with a number of business scenarios outlined by SOLDER, in particular the licensed/licensed scenario.

Inversely, the uptake of aggregation methods is dependent on the existence of credible spectrum sharing use cases. Except straightforward combination of pre-designated LTE bands, LSA currently seems to be the most realistic scenario for spectrum aggregation, since it tends to be pre-negotiated, relatively long-term and –in most scenarios- with QoS guarantees. Moreover, significant regulatory steps have already been taken towards the introduction of LSA. Therefore LSA, and the solutions for it presented by ADEL, are also of importance to the business potential of SOLDER. Coordination between the two projects in designing and promoting a licensed/licensed aggregation method for enabling LSA could therefore be helpful.

3.3 ABSOLUTE: Aerial Base Stations with Opportunistic Links for Unexpected and Temporary Events

ABSOLUTE aims to design and validate an innovative rapidly deployable future network architecture which is resilient and capable of providing Broadband multi-service, secure and dependable connectivity for large coverage areas affected by large scale unexpected events (or disasters) leading to the partial or complete unavailability of the terrestrial communication infrastructure or for temporary events leading to the demand for very high throughput and augmented network capacity. ABSOLUTE heavily incorporates cognitive radio concepts in its solutions.

Standardization involvement of ABSOLUTE
ABSOLUTE investigates the possibility of dynamic use of spectrum resources between commercial and public safety users for disaster relief. In this context ABSOLUTE has identified as particular targets the WG4 for Public Safety in the ETSI Technical Committee (TC) for Reconfigurable Radio Systems (ETSI RRS), as well the direct mode LTE communications and direct messaging services in 3GPP LTE RAN - D2D.

Business and market perspectives for ABSOLUTE
The ABSOLUTE project has outlined two main business cases, each of which have been subdivided into a Public Protection and Disaster Relief (PPDR) communications and a temporary event communication scenario.

The first of these is an acquisition based model involving two main business actors. The first of these is the manufacturer selling the equipment, which (in the project setup) includes an integrated 19 inch cabinet containing an eNB PHY/MAC EPC, SIP server, networking switch and other components, a KA Sat deployable terminal, a Desert Start Helikit with integrated RRH and Helix Antenna (connected to the EPC by fibre) and a PLMU. The second is the client organisation with acquires, deploys and operates the equipment. The second scenario is a lease-based model, in which an intermediary service provider is added to operates the equipment and proposes services or bandwidth for lease. For the moment, the lease-based model is being given focus; work is underway to estimate capital and operating expenditure of the ABSOLUTE system for a service provider, to assess demand and pricing as well as expected operational results. Most of the consortium partners are focusing on the Public Service use case for their exploitation plans, while Orange is also investigating the temporary events use case. Besides this, specific technological components under development in ABSOLUTE may also prove of value in other business scenarios. This is the case for the cognitive mechanisms for resource control, for the Flexible Management Entity (FME) which virtualises and distributes EPC functionality, and for the D2D aspects (a MAC protocol has been defined for this purpose).

Looking at these business cases, there are clear overlaps with the SOLDER project. Even though the application domains targeted by Carrier Aggregation are much broader than just Public Safety and temporary events, a comparison of the exploitation plans of both projects reveals that both have PS scenarios in mind. This is probably related to the presence of Thales in both projects. Moreover, it is clear that the ABSOLUTE system, which intends to assess available frequency bands both through wideband spectrum sensing (between 70 MHz and 6 GHz) and consultation of spectrum databases, could subsequently benefit greatly from the aggregation of available bands and the flexible combination of RATs in these bands.

For these reasons, the business requirements of both projects seem to be very much aligned, as both projects are providing components to the same advanced Public Safety infrastructure. The opportunity for coordination becomes higher in the lease-based business model pursued by ABSOLUTE. In this model, a service provider may lease bandwidth collected from various sources to different clients; for such capacity to be efficiently available, aggregation, either performed by the service provider (acting as spectrum broker and aggregator) or by an actor upstream in the value network, could be required. Moreover, the need for standardization of the solution is higher, as it needs to interact with the systems of several clients as opposed to being a proprietary system purchased and deployed by one specific entity. Finally, alignment also needs to be secured between, for example, the D2D developments in both projects.

3.4 CoRaSat: Cognitive Radio for Satellite Communications

CoRaSat aims at investigating, developing, and demonstrating cognitive radio techniques in satellite communication systems for spectrum sharing. Outcomes of the study will drive the definition of strategic roadmaps to be followed by industry stakeholders, European Institutions, and Governmental actors towards regulatory and standardization groups in order to ensure that the necessary actions are undertaken to open new business perspectives for SatCom through cognitive radio communications in support of the Digital Agenda for Europe.

Standardization involvement of CoRaSat
CoRaSat has established a new work item in ETSI SES SCN (Satellite Earth Stations and Systems - Satellite Communication and Navigation) working group on "Cognitive radio techniques for Satellite Communications". Moreover, CORASAT spectrum database system for sharing the 17.3 to 19.7 GHz bands between FSS/FS/BSS is being taken forward by CEPT FM44 and SE 40 for consideration by the EU regulators.

Business and market perspectives for CoRaSat
CoRaSat addresses the potential business impact of Cognitive Radio (CR) in the context of Satellite Communications. In particular, four markets are analysed:

- Ka-band markets and services: Broadband via satellite is a long-standing requirement by users out of reach to high-speed terrestrial networks. Considering an average number of 1 Million subscribers served per high throughput satellite operating in Ka-band and delivering broadband access, the market represents in Europe a potential for satellites to meet the European Digital Agenda policy objective to ensure that by 2020 all Europeans have access to higher internet data rates of above 30 Mbps. In view of this market potential and considering the increasing bandwidth demand, there is a strong interest to access extra spectrum by including those frequencies that are shared with other services. This justifies the need to explore CR techniques in the satellite communications context, so as to allow the exploitation of these shared frequency bands while guaranteeing the minimum risk of interference. However, access to more spectrum is the current bottleneck.
- Ku-band markets and services: DTH (HD/UHD) and VSAT services are expected to drive capacity demand increase, followed by mobility services and video distribution, underlining the need to have increased access to spectrum and more efficient utilization of the current available spectrum to cater for the demand. Based on the specifics of the Ku-band the typical use cases for Cognitive Radio could be most beneficial for VSAT and mobility services, specifically providing new possibilities in the uplink.
- C-band markets and services: Based on public research information and studies, the C-band demand and supply are increasing mostly due to backhaul and trunking services, contribution and distribution links in the TV sector, and professional services. Due to better propagation conditions, less affected by rain and humidity compared to frequencies in Ku- or even Ka-band, C-band plays an important role to enable continental and intercontinental communications with very high availabilities and very wide coverage. The C-band is heavily used in Africa, Asia, and South America, but less used for consumers in Europe. New services and system concepts are being introduced by the satellite industry to cater for the increasing demand and at the same time leveraging the inherent advantages as the robustness to rain fade. There are already numerous links from Africa and South America to Europe providing contribution links to large hub stations for re-transmission to the original countries via another satellite or other frequency bands. Thus, any disruption or interference would have an impact beyond Europe. In addition, it is difficult to evaluate the number of unregistered C-band Earth stations used as cable head-ends or terminals by consumers, making the implementation of CRs quite complex. Allowing the usage of these frequencies in Europe for terrestrial systems would not only impact users in Europe or North America, but also users in developing countries.
- S-band markets and services: Due to its favourable frequency band, the operation of a Hybrid Network consisting of the Satellite Segment and the Complementary Ground Segment (CGC) in the S-band has advantages to deploy mobile services to a variety of different terminals. The exploited benefits are similar to those common for the existing mobile network operators, such as small antenna and small form factor handsets, good indoor penetration, good atmospheric propagation, good performance at high speed, low power transmission, and low noise floor in relatively interference free spectrum. In this case, CR could provide further performance improvements.

CORASAT has also identified the main business challenges of potential CR developments in satellite communications. These are mostly related with spectrum availability and different regulatory regimes across the globe, and the efficient exploitation of currently underused frequency bands by non-coordinated satellite end user equipment. Specifically, any business case would need to be built around the costs and complexity of the added CR technology, its deployment and its operation compared to the advantages of the improved spectrum utilisation, capacity increase, and potential reduction in service costs. In addition, for some scenarios, the current deployed satellite services are not suitable for CR implementations. Furthermore, from a regulatory perspective, the heterogeneous adoption of terrestrial spectrum directives by national authorities complicates the coexistence of terrestrial deployments with internationally operating satellite systems. In this direction, a holistic techno-regulatory approach is needed in order to set the foundations for engineering and deploying cognitive systems that enable the coexistence of satellite and terrestrial services.

Finally, the market opportunities for CR deployments have to be evaluated where demand for satellite communications is high versus increased efficiency of CR technology and additional costs for CR development. As interference is a major issue for satellite operators as it affects their core business, another important focus and commercial driver in this context are the potentially improved interference mitigation and spectrum aggregation capabilities brought by CR technologies. For this last point, an interface with the SOLDER project could be useful in order to understand to which extent the carrier aggregation solutions developed by SOLDER could be applied or extended to satellite bands. Sharing model based on LSA for terrestrial communications developed by ADEL can be also reused in the context of satellite bands.

3.5 5GNOW – 5th Generation Non-Orthogonal Waveforms for Asynchronous Signalling

There is a consensus on the main challenges 5G technology will have to face: higher capacity, lower latency, embracing IoT and machine type communication (MTC), etc. However, there is no clear choice being made on which technology will be required to fulfil these needs. The gap between 4G (LTE-A) ability and 5G expectations is significant and the design of a new air interface shall be required to enable this evolution. One option is to consider separate specialized air interfaces on dedicated bands to best fit each scenario. The potential shortcoming of this approach is that the spectrum will be inefficiently used (e.g. due to lack of multiplexing gain) and multiple parallel compatibility need to be supported and maintained at network elements and devices. A second option is to aim for a single air interface that would be flexible enough to adapt to each scenarios. 5GNOW has investigated several candidates for such a so-called "golden air interface" that could be used either for broadband services or for MTC. A major statement of 5GNOW is that the underlying design principles –synchronism and orthogonality– of the PHY layer of today's LTE-A radio access network constitutes a major obstacle such a flexible approach. A major asset of the non orthogonal waveforms studied in 5GNOW is the support of asynchronous transmission. This lowers the control traffic required in OFDM based systems to maintain synchronisation and in turn provides lower round trip delays in the network.On top of these waveforms, 5GNOW has proposed a Unified Frame Structure concept which supports an integrated 5G air interface, capable of dealing both with broadband data services and small packet services within the same band.

Standardization involvement of 5GNOW

LTE and its evolution LTE-A are standardized via the 3rd generation partnership project (3GPP). The foreseen diversification of the service and device-class mix of future telecommunications and the related expansion of the requirement space require a revolutionary step. This step from 4G to 5G, anticipated in the 5GNOW project goals, implies change in air interfaces. New waveforms and the usage of the Unified Frame Structure with a mixture of synchronous and asynchronous traffic are a major building block for supporting those goals. The 5GNOW project assesses the advantages gained when using the new 5GNOW technologies and thus generated technical findings which guide the decisions on this generation change. The wireless industry as a whole has to build up consensus on the technology candidates for 5G standardization. For this purpose, 5GNOW was in close contact to the European METIS research project, in order to spread 5GNOW outcomes on a broad basis into the industry and research community. The encouraging results 5GNOW and METIS have achieved so far, lay the ground for the arising 5G infrastructure PPP projects. Those projects, based on generated 5GNOW know-how, guided by METIS system concepts, will then be able to directly work towards pre-standardization. 3GPP release 14, starting in 2016 could be a first platform for creating a study item focused on a new air interface. In parallel, 5GNOW also investigated how the project could impact IEEE P1900.7 working group on PHY and MAC for white spaces, with a focus on TVWS. This impact on IEEE P1900.7 stems from the collaboration with CRS-i through the CRS-i consultancy service. The contributions to IEEE P1900.7 have focussed on the FBMC air interface, which was a candidate for the PHY of the IEEE P1900.7 group. 5GNOW provided additional technical insights to assess the performance of FBMC in the context of white spaces.

Business and market perspectives for 5GNOW

With traditional voice and data revenues decreasing over the last couple of years, many operators are developing an MTC offering as the next growth market. Paradigms such as the Internet of Things (IoT) and Smart Cities envisage a world of connected entities, ranging from vehicles, household appliances and assembly lines, over lamp posts, streets and trees, to human beings. Every connected device collects transmits data with varying size, frequency and complexity, which needs to be transmitted for processing, resulting in an innumerable amount of (relatively small and often stochastic) data sources. Therefore, what MTC lacks in Average Revenues Per User (ARPU), it makes up with its ubiquity and its presence across networked environment.

Globally, Machina Research expects global aggregated revenue from MTC operations to increase up to €714bn (US$948bn) by 2020. This estimate includes hardware and connectivity, which in turn is an eight-fold increase from €91bn (US$121bn) in 2010. More conservatively, a US-based market research firm, ABI Research, predicts annual revenue in 2016 of US$35bn (€26bn), with automotive accounting for the biggest single sector. Another US-based market research group, Yankee Group, even more carefully predicts the connectivity revenue doubling between 2011 and 2015, but to just US$6.7bn (€5.1bn). Such a high volatility in growth forecast can be explained on the basis of measurement metrics such as MTC application types (broadband vs. Pure Machine based communications) and the number of sectors taken in account –for example many studies underestimate the contribution of sectors such as agriculture to the growth of MTC.

Mobile Network Operators (MNOs) are the first market players to capitalize on the MTC opportunity. Several MNOs have started to tailor sector-specific MTC services and have successfully generated extra revenue per connection. Such services may be based on a diverse set of Radio Access Technologies, including LTE. However, as the above has shown, the current design of the standard, as developed in 3GPP, presents significant obstacles to the successful use of LTE for MTC. Therefore, it is important for 5GNOW to have its solutions pushed through to 3GPP via the industrial partners of the consortium (e.g. Alcatel-Lucent) and to integrate them in the "Golden Air Interface" concept proposed by successor project Fantastic-5G, which comprises a much larger set of industrial actors, among which Alcatel-Lucent, Huawei, Intel, Nokia, Samsung and Telecom Italia.

3.6 EMPhAtiC: Enhanced Multicarrier Techniques for Professional Ad-Hoc and Cell-Based Communications

The goal of EMPhAtiC is to develop, evaluate and demonstrate the capability of enhanced multicarrier techniques to make better use of the existing radio frequency bands in providing broadband data services in coexistence with narrowband legacy services. The project addresses the Professional Mobile Radio (PMR) application, and in particular the evolution of the Public Protection & Disaster Relief (PPDR) service currently using TETRA or other legacy systems for voice and low-speed data services. Both cell-based and ad-hoc networking solutions are needed for PPDR and are expected to be developed. EMPhAtiC main emphasis is on filterbank based multicarrier (FB-MC) and single-carrier (FB-SC) waveforms for utilizing effectively the available fragmented spectrum in such heterogeneous environments. The core idea is to develop a multi-mode radio platform, based on variable filter-bank processing, which is able to perform modulation/detection functions simultaneously for different signal formats with adjustable centre frequencies, bandwidths and subchannel spacings. The project also targets the development of MIMO and MAC-layer techniques, as well as compatible relay networking solutions with the goal of maximizing the benefits of the waveform level solutions.

As such, EMPhAtiC contributed to identify possible future evolutions of PMR systems for providing broadband communications for Public Safety by deploying their PMR broadband systems in bands where other systems are already present. This is the case for the 400 MHz band, which is considered as one of the best fitted for deployment of new Broadband PMR systems for Public Safety. Overall EMPhAtiC states that the objective was to add "to the narrowband capacity a broadband capacity corresponding to approximately 2/3 of a full broadband capability".

On the other hand, the FB-MC (or a similar technologies) has also gathered the potential to be a key technology for 5G Broadband systems, specifically in what respects the physical layer. At the radio resource management (RRM) level, the use of FBMC in both ad-hoc and cell-based networks has been studied and compared with the alternative CP-OFDM technology. It has been shown that the FB-MC physical layer can greatly contribute to improving the scheduling process.

Standardization involvement of EMPhAtiC
Particular targets include the IEEE 1900 series, more specifically the IEEE 1900.7 - *IEEE Draft Radio Interface for White Space Dynamic Spectrum Access Radio Systems Supporting Fixed and Mobile Operation*, as well as ETSI Reconfigurable Radio Systems (ETSI-RRS) WG4 – *Civil Security and Inter-Domain Synergies*. The FB-MC as proposed by EMPhAtiC is currently part of the draft ETSI Technical Report 103 207 - *Feasibility study on inter-domain synergies; Synergies between PPDR/civil PMR, military and commercial domains* (currently in a frozen state waiting for the decisions to be taken after the ITU World Radio Communication Conference 2015).

One possible immediate requirement that could bring momentum to FB-MC standardization and applicability (in the PMR/PPDR market) is a decision to reframe frequencies in the 400 MHz so a significant part of the spectrum could be free for a better usage, followed by a reframing of (PMR) narrowband systems that would maximize LTE capacity (deployment of LTE using 1.4, 3 or 5 MHz bandwidth). This would benefit from the usage of a well frequency-contained Broadband waveform, such as the one provided by FB-MC.

Business and market perspectives for EMPhAtiC

The two main industrial partners in EMPhAtiC, Thales and Airbus Defence and Space (formerly Cassidian) both have indicated that they will use the project results to migrate their PMR product line to a next generation.

For Airbus, the objective is to deploy high bandwidth PMR systems based on LTE in both the 400 MHz (low density areas) and 700 MHz (high density areas) bands. In order to protect the existing narrowband systems (TETRA, TETRAPOL) while increasing broadband capacity particularly in the 400 MHz band[18], the EMPHATIC FB-MC solution would be introduced.

Thales currently has a PMR product line up based on TETRA, WiMax and LTE standards. Seen the potential of FB-MC for specific future 5G deployments, and the investments competitors such as Airbus are making into the technology, Thales is investigating whether it can use EMPHATIC results to evolve its Nexium LTE based PMR products, as well as apply the concept in other systems with spectral constraints. Thales also indicates that they want to continue research into adapting the 3GPP-LTE Advanced standard for use with high data rate security specific services such as PMR.[19]

For these two companies, synchronisation with the ABSOLUTE and SOLDER projects could be beneficial –and will to a certain extent naturally take place, seen the presence of THALES in all three projects. Looking at concrete products and services derived from these projects, the rapid deployment kit developed by ABSOLUTE, which will use spectrum sensing and the consultation of databases to operate between 70MHz and 6GHz and which intends to use both LTE-A and satellite communications, could benefit from (or even be dependent on) co-existence mechanisms with present narrowband systems offered by EMPHaTiC, insofar as these systems are available in the emergency scenarios outlined by ABSOLUTE. Inversely, the versatility of the PMR products developed in EMPHaTiC would be improved if they were compatible with the temporary networks envisaged by ABSOLUTE.

Another business scenario pursued by EMPHATIC partner Bitgear, is the upgrading of wireless audio and video devices coexisting with professional audio systems in the UHF band. This would be done by replacing the Digital FM modulation of existing professional audio devices by FB-MC. This scenario is interesting because PMSE systems in the UHF band are currently under pressure, due to successive waves of UHF bandwidth reallocation towards IMT systems in many regions of the world (the so-called first and second digital dividend) as well as the introduction of TVWS devices in these bands. Here, synchronisation with the TVWS aggregation scenarios of SOLDER could be useful: these currently focus on aggregating spectrum for offering cellular and eMBMS services in the same bands. Finally, CTTC is using FB-MC technology to design and implement a transceiver for High Voltage Power Lines, which will be commercialised by a local company.

[18] More particularly in the 380-385/390-395 MHz sections of the band

[19] Sources: EMPHATIC Deliverable 10.1.1: Plan for the use and dissemination of foreground, issue 1. Xavier Mestre (2015). EMPHATIC project main achievements and exploitation plan. Presentation given at CRS-i workshop, Net Futures, Brussels, 25 March 2015.

4 Conclusions

In this document, we have evaluated the available non-technical information coming from six CRS-i cluster projects (i.e. SOLDER, ADEL, ABSOLUTE, CORASAT 5GNOW and EMPHaTiC) including use cases and requirements, value networks, business models and exploitation plans. In addition to this, a dedicated workshop on market perspectives and exploitation was organised by CRS-i in March 2015, in order to gather additional information. The objective of the evaluation has been to identify complementarities in the business design concepts of these various projects. These complementarities in business design choices may then stimulate more coordinated approaches to the standardization of these objectives.

From the analysis, a number of congruencies have clearly surfaced which would warrant coordination between the projects involved. These can be summarized as follows:

Carrier aggregation
From the above, it is clear that Carrier Aggregation as developed by the SOLDER project has a large number of potential business benefits, and can even be considered as a fundamental evolutive requirement to both successful existing (LTE) and upcoming (TVWS) access technologies. It allows for higher throughput and capacity, larger service areas, and unified and simplified management. Besides improving the operational efficiency of existing operators, CA may also serve as a virtualising factor, stimulating the establishment of alternative operators. In such scenarios, and specifically in those involving multiple RATs, strong coordination is desirable.

When looking at the business objectives of some of the other cluster projects, the applicability of SOLDER mechanisms becomes apparent:

- For ADEL, especially within the dominant MNO business case where LSA and non-LSA spectrum assets are combined, there is a clear alignment with a number of business scenarios outlined by SOLDER, in particular the licensed/licensed scenario. Inversely, SOLDER may benefit from mature and credible use cases for spectrum sharing. Except straightforward combination of pre-designated LTE bands, LSA currently seems to be the most realistic scenario for spectrum aggregation, for which significant regulatory steps have already been taken. Therefore LSA, and the solutions for it presented by ADEL, are also of importance to the realisation of SOLDER's business potential.
- For ABSOLUTE, the multi-band system (making use of frequencies between 70 MHz and 6 GHz) as proposed by the project could benefit greatly from the aggregation of available bands and the flexible combination of RATs in these bands. This is especially the case in the lease-based business model currently preferred by the project partners, in which a service provider (acting as spectrum broker and aggregator) or an actor upstream in the value network, would probably aggregate frequency bands from various domains.
- Within EMPHaTiC, there could be synergies between SOLDER and the business scenario pursued by project partner Bitgear, which focuses is the upgrading of wireless audio and video devices coexisting with professional audio systems in the UHF band. Here, synchronisation with the TVWS aggregation scenarios of SOLDER could be useful: these currently focus on aggregating spectrum for offering cellular and eMBMS services in the same bands.
- Finally, the business objectives of CORASAT requires aggregation of heterogeneous spectrum bands, although SOLDER does not consider satellite use cases. Moreover, CORASAT exploit cognitive radio concepts developed by terrestrial communications in the satellite context (e.g. spectrum geo-location database and spectrum sensing), therefore synergies with the spectrum database model developed by ADEL are also possible.

Public Safety
A number of projects focus strongly on Public Protection and Disaster Relief scenarios. This is either the case for the project in general (e.g. ABSOLUTE and EMPHaTiC), or for the exploitation objectives of individual project partners (e.g. Thales within SOLDER)[20]. Concretely, the rapid deployment kit developed by ABSOLUTE, which will operate between 70MHz and 6GHz using both LTE-A and satellite communications, could benefit from (or even be dependent on) co-existence mechanisms with present narrowband systems offered by EMPHaTiC. Inversely, the versatility of the PMR products developed in EMPHaTiC would be improved if they were compatible with the temporary networks envisaged by ABSOLUTE. As Thales is a project partner in the three projects mentioned, it can be assumed that a degree of coordination will take place in any case.

[20] Especially the latter case does not become apparent when looking at the general and technical project deliverables and presentations, since the official project objectives are not specifically geared towards Public Safety.

Common approaches towards 3GPP

Finally, the business objectives and exploitation plans of a number of projects require extensions to 3GPP standards:

- The non-infrastructure based aggregation scenarios in SOLDER and the device-to-device communications envisaged by ABSOLUTE could warrant joint inputs to 3GPP LTE RAN - D2D
- For operators to fully exploit their LTE deployments for broadband as well as for the exponentially growing market of MTC, the "golden interface" concept of 5GNOW and its follow-up project Fantastic-5G would need to be incorporated into 3GPP standards
- For EMPhAtiC, one of the longer-term objectives is to adapt the 3GPP-LTE Advanced standard for use with high data rate security specific services such as PMR.

3GPP standardization can only take place through the 3GPP members of the project consortia. For SOLDER, this is THALES and SEQUANS, for 5GNOW Alcatel-Lucent and National Instruments are member, while EMPhAtiC has THALES and Airbus as 3GPP members. Fantastic-5G (a new 5G PPP project) comprises a much larger set of industrial actors, among which Alcatel-Lucent, Huawei, Intel, Nokia, Samsung and Telecom Italia.

As this report has shown, there are not just significant overlaps in the technical results and objectives of CRS-i cluster projects (which have been described and addressed in various other CRS-i deliverables), but also in the business objectives and scenarios which underpin the technical work and, to a significant extent, determine the design choices made first within the project and, subsequently, in the standardization domain. Therefore, coordinating the specification of these projects' technical outcomes into standards is not merely beneficial from a technical perspective, but may significantly contribute to realising the exploitation objectives of project partners and the translation of project results into commercially viable solutions.