CRS-i

FP7 – 318563
Coordination Action

Cognitive Radio Standardization-initiative: from FP7 research to global standards

D4.4
Report of the third workshop on CR standardization

Contractual Date of Delivery to the CEC: October 2015

Actual Date of Delivery to the CEC: August 2015

Author(s): Simon Delaere, Paulo Marques

Work Package: WP4

Est. Person Months: 2

Security: PU

Nature: Report

Version: 1.0

Total number of pages: 44

Abstract:
This deliverable provides an account of two workshops, organised at Net Futures in Brussels and EUCNC in Paris respectively, as well as of a panel session at IEEE DySpan 2015 including key figures from the main SDOs active in the domain of CR and SDR. The events discussed in this deliverable may be considered a success by the project. They featured Interesting keynotes from both IAB and non-IAB members, focusing on the relationship between research and standards, between standards and markets and on global regulatory and market evolutions; Specific overviews of exploitation plans by six RAS cluster projects, including standardization activities, which were used as inputs by the CRS-i Market Task Force to identify potential synergies between the projects; seven project updates also coming from the RAS cluster; and a panel with IEEE, Wireless Innovation Forum, ETSI and industry representatives discussing current activities and next steps in CR and DSA standardization, and analysing opportunities and bottlenecks for closer cooperation between research and standards on the one hand, and between standardization organisations on the other hand. Overall, attendees got a complete overview of global standardization activities in this domain, high level academic contributions from keynote speakers, and ample indications for inter-project cooperation both in the domains of research, standardization and exploitation. The interactions on these three subjects also clearly demonstrated the intrinsic links between them.

Keyword list: Project cluster, FP7, Standardization, Cognitive radio, International Advisory Board, RAS Cluster, FI Concertation

Executive Summary

Besides the set-up of a website and specific peer-to-peer dialogues with specific projects and other stakeholders, as well as establishment of an International Advisory Board and the involvement into the Future Internet Concertation Process (see below), the organisation of workshops is one of the ways in which his CR standardization forum is given shape. Concretely, CRS-i is to organize at least three workshops during the lifetime of the project. The workshops intend to bring together all stakeholders involved in the research/standards interfacing process, and feature well-known speakers from both the research and the CR standards communities, as well as representatives from the USA, Japan and Europe. In this sense, the workshops also function as the primary points of interaction with the International Advisory Board, of which Members are invited as keynote speakers.

Like the previous report in this series, this deliverable provides an overview not just of one CRS-i workshop, but of a series of events organised by the project. This different approach was chosen partly because it was deemed better to be present at various events gathering the EU and, in the case of DySPAN, even global CR/DSA community, and partly because CRS-i assumed chairmanship of the RAS Cluster within the EU FP7 concertation process. Therefore, it provides an account of two workshops, organised at Net Futures in Brussels and EUCNC in Paris respectively, as well as of a panel session at IEEE DySpan 2015 including key figures from the main Standards Development Organisations active in the domain of CR and SDR (IEEE, WinnF and ETSI).

Each of the workshops has taken a distinct approach. The Net Futures event, in line with the main theme of the overall conference set by the European Commission, focused on market prospects and exploitation plans of RAS cluster projects, while also providing an IAB keynote address on the relationship between research and standards. The results of this workshop directly fed the activities of the Market Task Force within CRS-i. The EUCNC workshop focused on providing a broader status update on RAS Cluster activities as well as an IAB overview on current issues in the US, while the DySPAN panel –originally also set up as a workshop- focused on global CR and DSA standardization and opportunities for cooperation between SDOs. Taken together, the events offered a well-timed set of interaction points with the community.

This report is structured as follows. Section 2 describes the context and objectives of the workshops as well as their partial integration with Net-Tec Future Coordination activities as well as the CRS-i International Advisory Board. Sections 3, 4 and 5 provide an overview of the main conclusions of most of the interactions. The IAB members' interactions, individually as well as in the panels, are captured in detail in Deliverable 4.5 ("Report on the standardization/regulatory debate between CRS-i and the USA and Japan 's "cognitive radio stakeholders" – final. Section 6 concludes this deliverable.

The two Workshops and the panel discussed in this deliverable may be considered a success by the project. They featured:

- Interesting keynotes from both IAB and non-IAB members, focusing on the relationship between research and standards, between standards and markets and on global regulatory and market evolutions;

- Specific overviews of exploitation plans by six RAS cluster projects, including standardization activities, which were used as inputs by the CRS-i Market Task Force to identify potential synergies between the projects;
- Seven project updates also coming from the RAS cluster;
- A panel with IEEE, Wireless Innovation Forum, ETSI and industry representatives discussing current activities and next steps in CR and DSA standardization, and analysing opportunities and bottlenecks for closer cooperation between research and standards on the one hand, and between standardization organisations on the other hand.

All the events organised by the project had a good attendance and very good levels of interaction. The choice to transform the DySPAN workshop into a plenary panel certainly contributed to this success. Overall, attendees got a complete overview of global standardization activities in this domain, high level academic contributions from keynote speakers, and ample indications for inter-project cooperation both in the domains of research, standardization and exploitation. The interactions on these three subjects also clearly demonstrated the intrinsic links between them.

Table of Contents

1 Introduction

Besides the set-up of a website and specific peer-to-peer dialogues with specific projects and other stakeholders, as well as establishment of an International Advisory Board and the involvement into the Future Internet Concertation Process (see below), the organisation of workshops is one of the ways in which his CR standardization forum is given shape. Concretely, CRS-i is to organize at least three workshops during the lifetime of the project. The workshops intend to bring together all stakeholders involved in the research/standards interfacing process, and feature well-known speakers from both the research and the CR standards communities, as well as representatives from the USA, Japan and Europe. In this sense, the workshops also function as the primary points of interaction with the International Advisory Board, of which Members are invited as keynote speakers.

Like the previous report in this series, this deliverable provides an overview not just of one CRS-i workshop, but of a series of events organised by the project. This different approach was chosen partly because it was deemed better to be present at various events gathering the EU and, in the case of DySPAN, even global CR/DSA community, and partly because CRS-i assumed chairmanship of the RAS Cluster within the EU FP7 concertation process. Therefore, it provides an account of two workshops, organised at Net Futures in Brussels and EUCNC in Paris respectively, as well as of a panel session at IEEE DySpan 2015 including key figures from the main Standards Development Organisations active in the domain of CR and SDR (IEEE, WinnF and ETSI).

Each of the workshops has taken a distinct approach. The Net Futures event, in line with the main theme of the overall conference set by the European Commission, focused on market prospects and exploitation plans of RAS cluster projects, while also providing an IAB keynote address on the relationship between research and standards. The results of this workshop directly fed the activities of the Market Task Force within CRS-i. The EUCNC workshop focused on providing a broader status update on RAS Cluster activities as well as an IAB overview on current issues in the US, while the DySPAN panel –originally also set up as a workshop- focused on global CR and DSA standardization and opportunities for cooperation between SDOs. Taken together, the events offered a well-timed set of interaction points with the community.

This report is structured as follows. Section 2 describes the context and objectives of the workshops as well as their partial integration with Net-Tec Future Coordination activities as well as the CRS-i International Advisory Board. Sections 3, 4 and 5 provide an overview of the main conclusions of most of the interactions. The IAB members' interactions, individually as well as in the panels, are captured in detail in Deliverable 4.5 ("Report on the standardization/regulatory debate between CRS-i and the USA and Japan 's "cognitive radio stakeholders" – final). Section 6 concludes this deliverable.

2 Workshops as part of CRS-i activities

2.1 Context and objectives

The CRS-i project aims create a forum for the discussion of trends in the research, regulation and standardization of Cognitive Radio and Dynamic Spectrum Access. There are several reasons for creating such a forum: firstly, it allows RAS Cluster projects to present research results and standardization activities which may be of interest to other projects, industry and regulators. Secondly, it informs these projects on relevant evolutions in these domains. Thirdly, it specifically helps to bridge the gap between trends in other parts of the world (notably the USA, Japan and China) in the field of Cognitive Radio, and what is happening within Europe. Fourthly and finally, it serves as an input to the standardization coordination activities planned by the CRS-i project.

Besides the set-up of a website and specific peer-to-peer dialogues with specific projects and other stakeholders, as well as establishment of an International Advisory Board and the involvement into the Future Internet Concertation Process (see below), the organisation of workshops is one of the ways in which his CR standardization forum is given shape. Concretely, CRS-i will organize three workshops during the lifetime of the project. The workshops intend to bring together all stakeholders involved in the research/standards interfacing process, and will feature well-known speakers from both the research and the CR standards communities, as well as representatives from the USA, Japan and Europe. The main objectives are:

- The exchange and dissemination of good practices on standardization in the CR area;
- The fostering of debate on the results of existing standardization work and on opportunities for future collaboration;
- The validation and adjustment of CRS-i strategy to influence global CR standards.

The workshops will identify the elements of collaboration between relevant partners, in particular, FP7 projects, standardization bodies and regulatory authorities. Moreover the workshops will stimulate discussions and exchange of ideas between the CRS-i team, invited speakers and the audience. Through interactions with the participants the consortium wants to validate its views and approaches.

Areas to be addressed include:

- What are the major challenges FP7 projects face when cooperating with standards organizations, and how these challenges should be addressed;
- What are the main areas in CR standardization ecosystem where future closer cooperation with research projects in FP7 will be required;
- How can contributing to standards-making be made more attractive to research projects, and how this will contribute to Europe achieving its overall goal of furthering its position in the CR systems development;
- What is the role of regulation in the CR standardization process;
- How can CRS-i support improving cooperation between projects and standards organizations in the CR area, and which results can be shown in this area;

- What needs to be standardized to allow a success cognitive radio in Europe, and how are current standardization efforts evaluated.

In practice, the CRS-i workshops are organised by iMinds as the natural continuation of the series of International iMinds-MIT Joint International Workshop on Cognitive Radio Standards and Markets (CRSM), of which five editions had taken place and which itself emanated from the Cognitive Radio Business Model Workshops organised under the E^2R^2 and E^3 projects between 2006 and 2009.

2.2 Integration into the Net-Tech Future Coordination Process

The European Commission investment in Future Networks research is undertaken through collaborative projects, selected in highly competitive calls for proposals. The work is based on a cost-sharing agreement between the European Commission and the consortia of EU leading industry, academia and research centres. Projects are grouped into a set of clusters of common interest, to develop synergies and critical mass.

Within European collaborative research, the purpose of "concertation" is to bring together ongoing FP7 projects in a given area to facilitate exchange of results and achievements, and to build consensus on specific issues. Currently, four clusters are active:

- Future Internet Technologies (FI Cluster);
- Radio Access and Spectrum (RAS Cluster);
- Converged and Optical Networks (CaON Cluster) and
- The Internet of Things European Research Cluster (IERC).

More specifically, the concertation process aims to:

- Support the ongoing FP7 projects in sharing their latest research achievements;
- Enhancing project cooperation activities, sharing of best practices and opportunities for (pre-) standardisation;
- Set up future activities and topics of common interest;
- Facilitate networking and discussion among the participants;

In addition, input from the concertation process should help the European Commission to shape future work programmes and to develop appropriate metrics to assess the wider impact of research work. As a requirement for funding, projects must plan sufficient resources in their budget to finance the costs of their participation in the concertation activities.

In this context, the RAS (Radio Access and Spectrum) is a cluster activity comprising a portfolio of more than 20 research projects participating in the 7th Framework Program (Objective 1.1 - Networks) and investigating Radio Access and Spectrum aspects of future wireless networks. In 2014, the concertation instrument was reformed to be more in line with Horizon2020 objectives, and was renamed "Net-Tech Futures Coordination".

CRS-i assumed responsibility of the RAS cluster in 2013. Since its coordination activities, including the organisation of workshops in collaboration with the European Commission and other regulators, run very much parallel with the concertation

objectives of the RAS cluster (the main difference being that the scope of targeted projects is larger than just Cognitive Radio oriented ones, in conjunction with the European Commission it was decided to organise at least part of CRS-i's dissemination activities in the context of the RAS cluster. Indeed, the targeted audience (Commission, projects, regulators) and the themes to be discussed are of high relevance to the RAS cluster, while the International Advisory Board Members and other external experts invited by CRS-i could provide valuable contributions to the Net Tech Coordination on the whole –on the condition that topics would be picked such that they have general relevance to RAS cluster members and, at the same time, specific importance to the CR and DSA related projects.

2.3 Integration with IAB activities

One of the tasks of the CRS-i project is to identify strategic relationships with international relevant stakeholder organizations involved in CR standardization, notably with the USA, China and Japan. In order to forge these relationships, an International Advisory Board has been set up by the CRS-i project. The objectives of this Board include:

- Reinforce the collaboration of FP7 projects with USA and Japan ‘s “cognitive radio stakeholders” and ensure that Europe will be able to turn the research outcomes into standard compliant product;
- Facilitation of a continuous, global high-level debate on the results of CRS-i standardization activities, the relationship between regulation and standardization, and the relationship and potential for coordination between standardization bodies and their contributing members.
- Wireless research and future trends analysis: keeping abreast of the innovations on the horizon and the likely implications for CR/DSA technology and acceptance. This will require engagement of academics from leading research institutions;

The IAB is a key target group in spreading and disseminating excellence and knowledge and reciprocally building up excellence and knowledge in the CRS-i. At least one face-to-face meeting with the IAB is foreseen. As 1) quite a few of the members come from academia or research institutions, 2) allocated budgets only allow to cover travel expenses for one or two IAB members per year, and 3) IAB discussions should not only serve the project internally but take place to the advantage of the wider community, it was deemed important to collocate IAB interactions with the workshops, and or with scientific missions. For this reason, the main interactions with IAB members have taken place during public workshops organised by CRS-i (notably FIA Athens in March, and the RAS cluster meeting in October), with three IAB members providing a keynote address.

3 RAS Cluster Workshop on Project Main Achievements and Plans for Exploitation

3.1 Theme and organisation

On 25 March 2015, CRS-i organized a half day RAS cluster workshop in Brussels in the context of the NET FUTURES conference. NET FUTURES is one of the main ICT events organized by the European Commission's DG CONNECT –and in fact the successor of the Future Internet Assembly where CRS-i was already present. As was the case previously, this concerned a workshop aimed at the wide RAS cluster community.

In line with the NET FUTURES thematic priorities of Market Validation, Business Development, Entrepreneurship and Enterprise Strategy, the RAS cluster workshop chose the theme of "Project Main Achievements and Plans for Exploitation". The idea was for mature RAS cluster projects to demonstrate their most tangible results and explain how these tie in to existing market demand and concrete business development plans for their consortium partners. A panel would then discuss the relationship between research, standards and markets, and the successful transition of wireless research into commercial products.

Besides fitting with some of the key priorities put forward by the European Commission, the theme of the workshop was also chosen deliberately so that it could provide input to CRS-i's Market Task Force and the report (D3.4, "White Paper on Business/Market Research Activities within CRS-cluster Projects") it was preparing. Using the results from the workshop and other sources, this report was completed in July 2015.

The workshop featured two keynote presentations. The first one was given by two European Members of CRS-i's International Advisory Board, Kai Jakobs from RWTH/Aachen University and Rudi Bekkers from Eindhoven University of Technology, who discussed the relationship between ICT research and standardization. This keynote will be described in more detail in D4.5 ("Report on the standardization/regulatory debate between CRS-i and the USA and Japan's "cognitive radio stakeholders"). The second keynote was delivered by Pierre-Jean Muller, CEO of RED technologies, one of the few companies commercially active in the Dynamic Spectrum Access field (notably in LSA). Combined, the two keynotes provided both a critical academic view, and a hands-on business perspective on DSA market success and the role of research and standards in that success.

Following the keynotes, six RAS cluster projects gave insights in their progress and, specifically, into the exploitation aspects. Also, the European Commission took the floor to provide very recent updates to on the 5G-PPP call, for which results were being released at the time of the event. A final panel concluded the workshop.

Figure 1 - Audience at the Net Futures workshop

3.2 Programme

9.00-11.00

- Welcome and introduction, Paulo Marques, Instituto de Telecomunicações [CRS-i project]
- Rémy Bayou, European Commission: Overview of the ICT-14 call: “Advanced 5G Network Infrastructure for the Future Internet”
- CRS-i keynotes [chair: Simon Delaere, iMINDS]
    - Kai Jakobs, RWTH: “The link between research and standardization and what should be done to improve it”
    - Pierre-Jean Muller, RED Technologies: “Moving from the LSA research topic to a business opportunity”
- Olav Queseth, Ericsson: “METIS - Mobile and wireless communications enablers for 2020 information society: Project main achievement and exploitation plan”

11.00 – 11.30 Coffee Break

11.30 – 12.40
Chair: Dominique Noguet, CEA-LETI

- Isabelle Bucaille, Thales Communications & Security: “ABSOLUTE - Aerial Base Stations with Opportunistic Links For Unexpected e Temporary Events: Project main achievement and exploitation plan”

- Xavier Mestre, CTTC: “EMPHATIC - Enhanced Multicarrier Techniques for Professional Ad-Hoc and Cell-Based Communications: Project main achievement and exploitation plan”

- Kari Rikkinen, University of Oulu: “DUPLO - Full-Duplex Radios for Local Access : Project main achievement and exploitation plan”

- Peter Rost, NEC Europe: “iJOIN - Interworking and joint design of an open access and backhaul network architecture for small cells : Project main achievement and exploitation plan”

- Gerhard Wunder, HHI, “5GNOW - 5th Generation Non-Orthogonal Waveforms for Asynchronous Signaling : Project main achievement and exploitation plan”

12.40 – 13.00 Panel - **Factors for a successful transition of wireless research into commercial products**

3.3 Results

3.3.1 Introductory remarks and European Commission intervention

Paulo Marques starts by introducing the workshop. He then passes the floor to Rémy Bayou from the European Commission, in order to share results on the ICT-14 call of Horizon 2020 on 5G networks. The call had closed in November 2014, and results had been available since March 2015. In total 18 proposals out of 82 were selected. The topic of wireless technologies at large took up a large part of the budget due to the high quality. Bayou specifies that proposals were welcome from the so-called 5G-PPP pre-structuring model, but also from outside, and that the repartition between the two was about fifty-fifty. There is a good spread of topics, except for MTC communications and security. Importantly for the RAS cluster, it is still unclear how concertation will happen under the 5G-PPP and how projects will be encouraged to collaborate under this programme. Following the call, a second phase will be launched in two years (probably focusing in November 2016), focusing on 5G hardcore technologies, as well as a “Beyond 5G” call with less industrial and more academic, longer term focus. Bayou outlines the projected focus of the two calls. A number of questions are raised, for example relating to the foreseen starting date of projects, and the way in which to involve SMEs into the projects.

3.3.2 Keynote addresses

As mentioned, the first keynote was given by CRS-i’s International Advisory Board Member **Kai Jakobs** from RWTH/Aachen University, while his co-author **Rudi Bekkers** from Eindhoven University of Technology was in the audience and answered

questions after the talk. The main theme of the keynote was the relationship between ICT research and standardization. A detailed overview of this talk is provided in D4.5 (Report on the standardization/regulatory debate between CRS-i and the USA and Japan's "cognitive radio stakeholders" – final)**.** The speaker summarizes the issues with the following overview of the state-of-the-art:

Barriers	**Stakeholder(s) in Charge**	**Implemented Remedies**
General lack of awareness	SSOs, R&D orgs, academia, firms, funding entities	Limited – websites, publications
Lack of relevant (tertiary) education	Academia (also SSOs, funding entities)	Limited – several curricula developed by SSOs, isolated activities at unis
Expenses not covered	Funding entities, SSOs	Very limited – Horizon 2020; (special rates at ITU-T)
Inflexible and slow process	SSOs, (policy makers)	Improving – CWAs, ISs, (Regulation (EU) No 1025/ 2012)
No positive impact on research evaluation	Rating/funding entities, academia	Nothing (to the best of my knowledge)
Research expertise not relevant	(SSOs, R&D orgs, academia, firms)	Not correct -> Awareness

Finally, the key lessons of the talk can be summarized as follows:

- Speed-up mechanisms have been implemented.
- Selective, ad-hoc activities could be – and have in part been – initiated (participation in R&D projects, co-operation with professional associations, promotional activities, etc.).
- Long-term activities (e.g. monitoring/alerting) will require discussions with funding entities.
- Structural/procedural changes (TC/WG structure, etc.) may be hard to implement.
- Educational activities will be most crucial in the medium/long run.

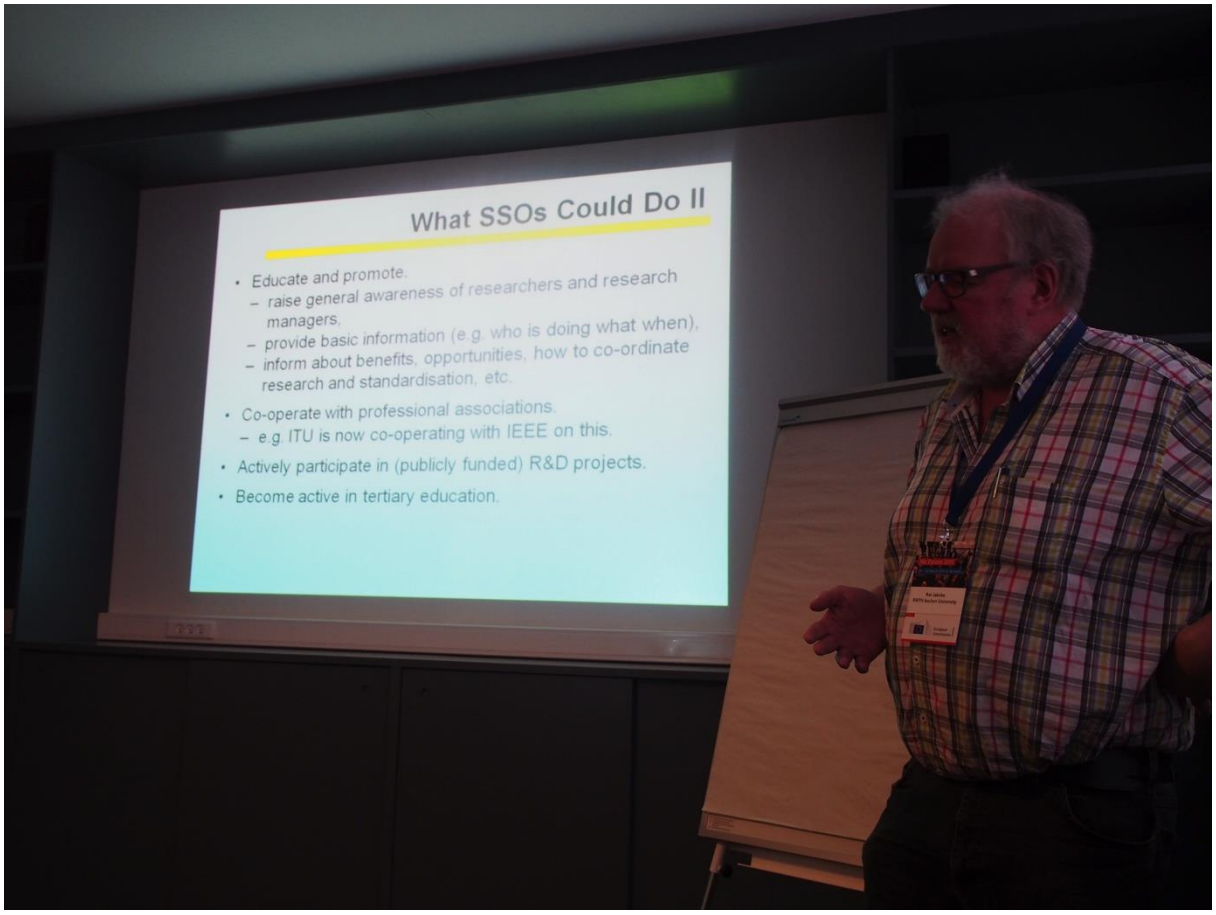
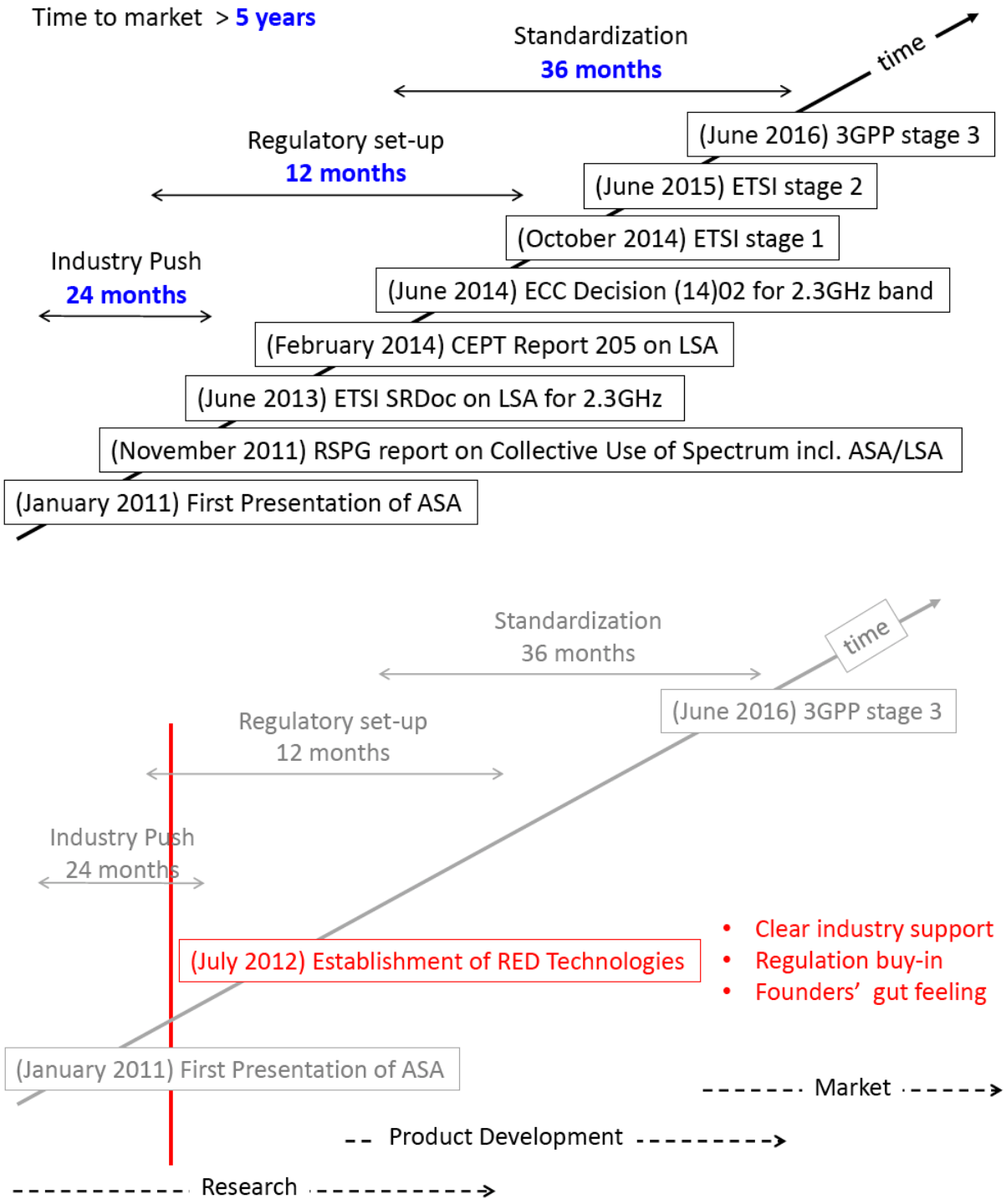


Figure 2 - Kai Jakobs keynote address

The second keynote is provided by **Pierre-Jean Muller, CEO of RED technologies**. He starts by saying that according to him, there is a time for research, and researchers are often very far from commercial solutions, while for him, standards imply markets, when research is mature.

He then introduces Licensed Shared Access, as a technology made for regulators and by regulators. To enable such regulatory system, a complex technological platform is required. RED provides IT platforms for DSA applying a specific technical framework, i.e. the Radio Environment Maps. The speaker argues that for the telecom sector, perhaps even more so than in IT, going through standardization is key for commercial success. For this reason, standardization is a somewhat closed activity.

The speaker illustrates this point with the LSA example. Work on this started around 2011, and as regulators were showing interest, commitment from industry was required. So, after a year of preparations, work on a System Reference document was initiated within ETSI. In 2014, a first report from CEPT was released and a decision was taken at ECC level for using LSA in specific bands, standardization was continued in ETSI, and then introduction in 3GPP was pursued. The timeline was summarized by Muller as follows:



In other words, time to market is 5 years, but several years of research need to be added to this. Muller claims that this input mainly came from industry, and that RED technologies was based on three evolutions: clear industry support (large corporations pushing for LSA), regulatory buy-in and the founder's gut feeling. The speaker therefore stresses that he did not launch the company based on research results. However, he then illustrates the "start-flat" syndrome typical for start-ups in telecom (where they remain small and unprofitable for a long period) and applicable very much to the LSA case:

- Research was mature
- The foreseen B2B business model was complex. As a platform between large

telecom corporations and the military, it is difficult to foresee how one would sell the product
- The product depends on regulation. Luckily, in the case of LSA this was in place, but when RED started it was not yet ready
- Standardization is required and takes significant time (several years between stage 1, requirments, and stage 3, where you can make standardized products) because it requires consensus
- A governmental user is involved, which makes business more complex
- The time-to-market cycle is not compatible with the start-up life cycle (5 years)
- Venture Capital does not fund this type of activities, since regulation is involved. Therefore other financing must be found.

The speaker concludes by providing several lessons learned with regard to the marketing and exploitation of DSA technologies:

- When you start on a technology in an early stage you cannot know whether the timing is right.

- It requires serious **cash**

- It requires **time**

- It requires serious **expertise**

- The **life cycle** is often not compatible with the “start-up” life cycle –time to market can easily be over 5 years

- The **big names** will ultimately catch-up. Either you are very early and the market is very complex, or you are bought by a bigger company

- Being the first on the market is one goal but selling your technology when the market becomes a reality should be another one

- Do not start business based on a research idea, but on a business opportunity. Going from one to the other, it can take five years but it is possible.

Figure 3 - Pierre-Jean Muller keynote address (RED Technologies)

3.3.3 Project presentations

In the following session, several RAS cluster projects provide insight into their project achivements and exploitation plans. As said, they were specifically asked to do so to contribute to the objectives of both the NET FUTURES conference and the CRS-i Market Task Force. First, **Olav Queseth from Ericsson** talked about the METIS project. He outlined the METIS concept for 5G consisting of Dynamic RAN, a lean System Control Plane, a Spectrum Toolbox, Localised traffic and 5G services, resulting in more than 140 technology components being worked on within the project. This has had the following results:

- Larger bandwidths (at higher frequencies) necessary to meet 5G demands
- Massive MIMO can increase the spectral efficiency by a factor of 20.
- Indoor UDN capacity scales $\propto N_{AP}$ when interference coordination is used
- D2D can increase system capacity and reduces latency to $\approx$TTI length
- New waveforms and multiple-access technologies can reduce access time
- Traffic concentration reduces battery consumption, and improves coverage and throughput.

In terms of exploitation, the speaker pointed out that METIS is in the very early stage of technology development, preceding, regulatory and standardization phases and, of course, market diffusion. The first 3GPP releases of 5G are expected from 2016 onwards, while commercial deployment is only expected after 2020. Nevertheless, METIS has been providing training ground for researchers and engineers, with tutorials and lectures being generated and personal networks formed. This work is now

continuing within METIS II under the 5G PPP umbrella.

Figure 4 - Olav Queseth (Ericsson)

Next, **Isabelle Bucaille from Thales Communications & Security** talked about **ABSOLUTE** (Aerial Base Stations with Opportunistic Links For Unexpected and Temporary Events). She first outlined the scope of the project: In the aftermath of an emergency, disaster or any related tremendous unexpected events, communications infrastructure play an essential role. By using rapidly deployable flexible aerial platforms with embedded 4G eNodeB, ABSOLUTE project provides maximum system availability, communications reliability and robustness; it allows also to increase network capacity during specific events (Olympic Games,..)**.** The speaker then outlined the architecture and the overview of the integration of aerial platform components, as well as a terrestrial eNodeB, and then outlines the business model analysis being performed in ABSOLUTE, with the aims to evaluate existing business environments related to PPDR communications and to temporary event communication scenarios, as well as to study public safety stakeholders and their current roles, and identify potential evolution in the value chain. She then defined two business models under study (an acquisition based model and a lease based model), each subdivided in a public safety and a temporary services sub case. Emphasis within the project is on the lease-based model, for which a user acceptance testing process is defined. Finally, the speaker went over the various exploitation plans of project partners, and over the exploitation potential of various ABSOLUTE components in general (i.e. Cognitive Mechanisms for resource usage control, the Flexible Management Entity and D2D communications).

Following this, **Xavier Mestre of CTTC** talked about achievements and plans within **EMPHATIC** (Enhanced Multicarrier Techniques for Professional Ad-Hoc and Cell-Based Communications). The speaker started by outlining the objective of EMPHATIC, which is to develop a PHY-MAC technological solution for broadband services in Professional Mobile Radio systems. He explained that, in the domain of PMR currently dominated by narrowband systems, there is a current need for higher data throughput services (video streaming, HD pictures, rapid access to remote data bases, etc.). In Europe, the choice of 3GPP LTE standard for public protection and disaster relief appears as the most viable candidate (economy of scale, widely accepted technology). However, a new system based on 3GPP LTE requires additional spectrum, which is very scarce. Therefore, the EMPhAtiC project proposes to introduce broadband services within the current frequency allocation, in spectral coexistence with current narrowband systems. The speaker then introduces the technical solution for this, i.e. Filter bank multi carrier modulation, using a flexible filterbank structure, based on fast convolution, which can process and synthesize multiple modulations while adapting the transmission to the scenario at hand. He then highlights the main intermediate results of the project after two years:

- Coexistence in a highly fragmented scenario has been demonstrated via Flexible, multimode, variable filter bank solution based on Fast Convolution;
- The solution has been adapted to PMR scenario conditions;
- Novel schemes for improved spectral efficiency with multi-antenna (MIMO) processing have been derived;
- Specific RRM methodologies have been developed for FB-MC under cell-based and ad-hoc TX;
- The feasibility and performance of FB-MC techniques have been evaluated in cooperative and relaying schemes

Finally, the speaker goes into the exploitation plans of various consortium partners (Airbus, Thales, Magister, Bitgear, Sintef and CTTC). These are described in more detail in D3.4 (“White Paper on Business/Market Research Activities within CRS-

cluster Projects").

Figure 5 - Xavier Mestre (CTTC)

The next speaker is **Kari Rikkinen from the University of Oulu**, representing the **DUPLO** (Full Duplex Radios for Local Access) project. The objectives of the project, which ended in May 2015, were to develop In-band full-duplex (FD) technology for wireless communications transceivers (RF, antenna and digital baseband solutions enabling efficient self-interference cancellation in wireless transceivers)as well as system solutions for in-band full-duplex transmission, with a focus on small area radio communication solutions. For reaching these objectives, three novel RF/antenna design solutions (all operating at 2.45 GHz) for compact form factor full-duplex radios were developed, fabricated and validated. Besides this, DUPLO developed digital baseband algorithms for self-interference cancellation (SIC) in the presence of transceiver non-linearity and with multiple antennas. In terms of project results exploitation in general, the speaker mentions DUPLO presence at international workshops and conferences, and the identification of two potential standardization tracks (3GPP release 14 and IEEE 802.11ax), however adding that no concrete actions are planned in standardization. He specifically mentions exploitation plans of TTI and of Thales, which (like in other RAS cluster projects) wishes to implement results into FD TETRA PMR technology, but also to 3GPP for what concerns D2D for public safety.

Following this, **Peter Rost from NEC Europe** talked about project progress and

exploitation plans for **iJOIN** (Interworking and joint design of an open access and backhaul network architecture for small cells). He started by explaining the key concepts behind iJOIN, which are flexible centralization through the use of RANaaS (Radio Access Networks as a Service) and joint design and optimization of RAN and backhaul. He explained the expected benefits of these concepts. These can be measured by a number of quantitative indicators, such as Improved area throughput (cooperation / coordination), improved energy-efficiency, lower CAPEX and OPEX and higher utilization (due to temporal and spatial traffic fluctuations). He also mentions a number of soft KPIs such as higher flexibility, better upgradability and re-programmability and improved maintenance.

Figure 6 - Peter Rost (NEC)

Then Mr. Rost detailed the exploitation activities of iJOIN. First, he outlined the impact of the project on standardization, with contributions to ITU-R, NGMIN, the Small Cell Forum, IETF, ONF and 3GPP. He added that the impact is higher on groups that support SDOs than on normative SDOS such as 3GPP, and commented that one has to be realistic about the impact a project can make during its lifetime. Besides standardization, iJOIN organized various industry workshops with strong industry presence, project partners filed around 10 patent application, and pre-product demos were developed in the project, which industry partners then further commercialized (with ALU and Intel, Nokia and ARM recently presenting products at Mobile World

Congress). Also, several partners continued their activity within the 5G-PPP. Finally, the speakers mentioned the iJOIN testbeds which can be used by industry.

Finally, **Gerhard Wunder from HHI** provided an update on **5GNOW** main achievements and exploitation plans. He first explained the vision of the project (which ended in March 2015) as representing the physical layer evolution of mobile communication network technology such as LTE-Advanced towards emerging application challenges, using non-orthogonal waveforms. According to 5GNOW, future air interface requirements such as flexibility, scalability, robustness, efficiency, latency and reliability cannot be guaranteed by OFDM. Although the speaker admits this is not an uncontroversial proposition, 5GNOW proposed an alternative unified frame concept requiring new (multiple) waveforms, new multiple access as well as common control channels. The speaker skipped the technical details (that can be found in the presentation) and goes directly to the impact the project has had. He mentioned the publication track (with seven joinyt papers, with a ComMag publication having more than 50 citations), a 400 member LinkedIn group, a successful Twitter account. He also mentioned that 5GNOW had successfully contributed to pre-standardization activities (for example 4G-AMERICA which cites the deliverables of the project). Interestingly, the speaker stated that the main exploitation activity of the project is to have a follow-up project, i.e. FANTASTIC5G, which will explore the possibility of a so-called “golden interface”. The speaker concludes by highlighting the presence of 5GNOW at VTC, Globecom and the Mobile World Congress.

3.3.4 Panel

The workshop is concluded with a panel on factors for a successful transition of wireless research into commercial products, as a complement to the different views given by the speakers in the previous slots.

A first topic relates to the difference between the computer science and the wireless domains, which requires a remarkably large investment and therefore does not attract the research domain in the way that the IT sector does. Mr. Muller replies that research always influences standards, although not always directly. Mr. Bekker adds that there is a pool of knowledge not valorised in an optimal way, even though this does not mean scientists have to be present in any standardization organisation. He sees this right now in work that is being done with ETSI and IEEE, who want to reach out to academia in new ways but don’t really know how yet. For this is about the scientific world in the broader sense.

Figure 7 - Panel at Net Futures

The question is then raised whether 3GPP is different from any other SDO, and whether this is the cause for the complete lack of academic involvement in 3GPP, unlike IEEE, ITU, ISO and others. According to Colin Wilcock of NSN, 3GPP is indeed unique in the way it is set up, in the rules and processes and in its global scale. According to him, these differences –and the lack of academic involvement- stem from the revenue involved in telecommunications: people offer compare WiFi and 3GPP, but the latter generates a multifold of revenues. This does not mean that research has no role in 3GPP, but usually comes after the research has been done (referring to the funnel model presented in the METIS presentation). It is in the pre-standardization consultation building process that academic input is vital. It is only in the last phase, when these ideas need to be presented in standardization and tested for commercial value, that industry takes the forefront. For Mr. Muller, also in ETSI standardization is driven by perceived markets and the need for multi-vendor solutions.

One speaker complains that, while academics are (and need to be) approached by industry in an early stage, most European industries have their own researchers and do not seek solutions in academia, while non-European companies seem to do this more. Rather than standardization, the speaker argues, the discussion should be much more in innovation. Mr. Muller agrees with this, but states that when you look at FP6, FP7 and H2020, this is the place where industry and academia meet. Mr. Delaere however points out that an important group like ETSI RRS is a direct consequence of the E2R and E3 research projects.

A question is raised by the audience on security issues related to the radio aspects of the mobile networks, and whether these do not conflict with economic (and standardization priorities). Mr. Wilcock replies that security is handled by 3GPP SA3, while Mr. Muller argues that there is a business behind security, with specific firms specialising in the topic. The original speaker specifies that a lack of security might break the economic value of certain solutions. Mr Bekkers agrees, and says that in hindsight, technology could have benefited a lot from interaction with academics when it comes to security.

3.4 Feedback to the workshop

Once more, CRS-i distributed a questionnaire during a workshop to gather feedback from participants. The workshop attendants were asked to evaluate the workshop using a scale from 1 to 5, where 5 is “Strongly Agree” and 1 is “Strongly Disagree” The areas considered, as well as the average evaluation provided by the attendants is as follows:

The workshop content was consistent with the description in the agenda.	**4.25/5**
I can use the information I learned right away.	**3.56/5**
Overall, the speakers of the workshop were knowledgeable.	**4.38/5**
Overall, the speakers of the workshop were engaging.	**3.88/5**
The workshop met or exceeded my expectation.	**3.50/5**
The topics covered were relevant, interesting and timely.	**3.88/5**
The conclusions were relevant for my project.	**3.56/5**

As it can be seen, the feedback regarding the quality, timeliness and overall interest of the workshop was again quite positive. Especially encouraging was the degree of appreciation for the (keynote speakers).

Moreover, the attendants were requested to state how dependent the exploitation plans of their projects are dependent on standardization and/or regulation. 62% of the responding audience members answered that they were “quite”, “very”, “a lot” or “extremely” dependent on standardization, and one project stated that standardization was the main outcome of the project, while only two respondents thought such dependency was low, and a few project stated that standardization was important but not necessarily within the project time frame.

A second question related to the most important factor for a successful transition from wireless research into commercial products. A number of answers were given (in order of prevalence):

- Interaction/mediation between industry, regulatory and research organisations
- The right timing between research output and market need, and between research and standardization
- Influence of end-users on R&D

- Creating awareness
- Know-how to go from research prototype to successful product

4 Radio Access and Spectrum cluster Workshop at EUCNC 2015

4.1 Theme and organisation

The second workshop organized by CRS-i in 2015 was a general RAS Cluster workshop at the European Conference on Networks and Communications Conference held in Paris, France, on 29 June. The main objective of this workshop was to exchange and disseminate EU project's innovations in the Radio Access and Spectrum area, and to foster debate on opportunities for collaboration between research projects. In this sense, the workshop went beyond the core domain of Cognitive Radio and Dynamic Spectrum Access and, next to the specific thematic events during Net Futures and DySPAN, offered a general update on innovative research within the RAS cluster. Besides this, however, CRS-i also invited a prominent member of the International Advisory Board in order to provide useful regulatory and research updates from the USA.

After the keynote address, the workshop was structured in two Sessions in order to facilitate exchanges on topics of common interest: "Innovations on the PHY layer" and "Innovations on the Network Architecture". These two areas combined will contribute to the capacity improvement required by the next generation of wireless networks. The workshop concluded with a panel addressing the role of regulation on wireless innovation and future plans for the RAS cluster.

Figure 8 - The EuCNC CRS-i workshop (Paris)

4.2 Programme

14:00 Welcome address

Paulo Marques, Instituto de Telecomunicações, Portugal, CRS-i project
Bernard Barani, European Commission

14:10 CRS-i keynote speaker
"Trends on wireless technology and radio spectrum management in the US"
Jon Peha, Full Professor at Carnegie Mellon University and former FCC Chief Technologist, US

14:30 Session 1: RAS cluster innovations on the PHY layer [15' each project]

- *SOLDER "Spectrum overlay through aggregation of heterogeneous dispersed bands", Fotis Foukalas, I.S.I, Greece*
- *MiWAVES and E3NETWORK: "Millimeter-Wave Small Cell Access and Backhauling", Laurent Dussop CEA-LETI, France and Igone Vélez, CEIT, Spain*
- *MAMMOET: "Massive MIMO for efficient transmission", Liesbet Vander Perre, IMEC, Belgium*
- *PHYLAWS: "Physical layer wireless security", François Delaveau, Thales, France*

15:30 – 16:00 Coffee Break

16:00 Session 2: RAS cluster innovations on the Network architecture [15' each project]

- *DIWINE: "Dense Cooperative Wireless Cloud Network", Stojan Denic, Toshiba Research Europe Ltd, UK*
- *RESCUE: "Links-on-the-fly technology for robust, efficient and smart communication in unpredictable environments", Hicham Khalife, Thales, France*
- *SEMAFOUR: "Self-Management for Unified Heterogeneous Radio Access Networks", Colin Willcock, NOKIA, Germany*

17:00 – 17:30 Panel

- The role of regulatory policies on wireless innovation
- Open discussion on how to boost research projects collaboration in H2020

4.3 Results

4.3.1 Welcome address

CRS-i coordinator and RAS chairman Paulo Marques starts by outlining the structure of the RAS cluster and the evolution of its project membership, as only Call 11 projects will remain from January 2016 onwards. He highlights the need for a transition from the FP7 cluster model to 5G PPP in H2020, and in particular a need to reconcile the 5GPPP model for project collaboration with the FP7 concertation system.

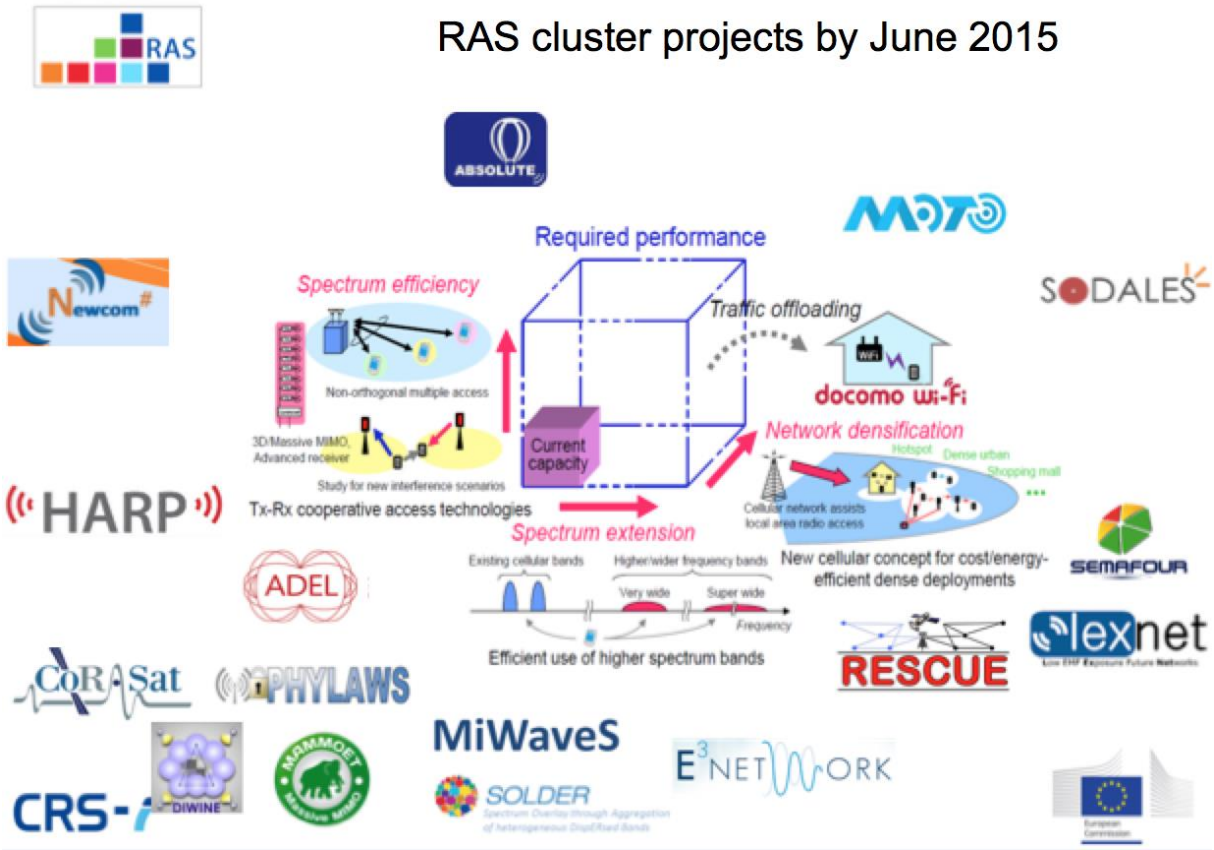


Figure 9 - RAS cluster in June 2015

After this, Bernard Barani from the European Commission gives an update of the 5GPPP. He explains the different working groups in the 5GPPP and how they will cooperate with the projects. To achieve this, the projects will be made aware of the existence of working groups. Then, collaboration agreements will be signed between projects in order to give visibility to each others' work (including foreground and background knowledge). They will then work together under the leadership of Association working groups. If FP7 projects have meaningful results and wish to collaborate with the Association, they can do so if they sign an agreement. What this implies for the clusters is not clear, but as there will be other projects working together in a less constrained mode, they will likely continue to exist.

4.3.2 Keynote address Jon Peha: new trends in wireless technology and spectrum management in the US

Jon Peha started by explaining that there is currently a big wireless and spectrum agenda in the United States. Of the many current issues, Jon picked three topics on which a lot has happened in the last six months and a lot is about to happen: three tier spectrum sharing models, net neutrality and its impact on wireless and high frequency

spectrum. Other interesting issues include incentive auctions to reallocate TV spectrum, vehicular networks and public safety communications. Again, as Jon Peha is a member of CRS-i's International Advisory Board, a detailed discussion of the interactions with him is provided in D4.5 (Report on the standardization/regulatory debate between CRS-i and the USA and Japan's "cognitive radio stakeholders" – final)**.** Jon concludes that spectrum policy in the US is in a period of rapid change, including:

- Great progress on three-tiered sharing at 3.5 GHz, which, if successful, could be the model for other bands
- New network neutrality rules, that could significantly affect wireless technology, although further action is coming at the FCC, in the courts, and maybe in Congress
- Using spectrum at 24+ GHz for mobile
- Incentive auctions coming soon. Novel approach to spectrum reallocation, the most complex spectrum auction ever attempted

4.3.3 Project updates

In the following workshop contributions, seven projects presented updates to the RAS cluster community. Since these are general in nature (i.e. not relating to cognitive radio and DSA, nor to standardization or exploitation, which are the core topics of CRS-i), we only provide a brief overview of the contributions here. Like with all CRS-i events, slidesets are available from the CRS-i website.

The first project to be presented is **SOLDER** (Spectrum Overlay through Aggregation of Heterogeneous Dispersed Bands), by **Fotis Foukalas from ISI Greece**. Fotis first outlines eight application scenarios and use cases targeted by the project. He gives an overview of the h-RAT/HetBand aggregation supporting architecture as well as the system level overlay management architecture for LTE-only aggregation. Then, he presents some results for six of the use cases, as well as five POC components. Fotis concludes by outlining next steps for the second half of the project, including the development of solutions for carrier aggregations in HetNets and h-RATs, and the implementation of new building blocks introduced in the LTE-A system and beyond.

Scenario name	Spectrum to be aggregated	Radio access technologies to be aggregated
LTE Carrier Aggregation	Licensed + Licensed	LTE FDD+FDD LTE FDD+TDD
LTE in Unlicensed Bands	Licensed + Unlicensed	LTE + Unlicensed
LTE Supplement at DL Carrier in TVWS	Licensed + TVWS	LTE + LTE
TVWS aggregation	TVWS + TVWS	LTE + LTE
LTE + WiFi aggregation	Licensed + Unlicensed	LTE + WiFi
Augmented Broadcast	TVWS + Unlicensed	LTE + WiFi
5G Waveform	Licensed + Licensed	5G+5G
Multi-RAT Aggregation	Licensed + Licensed	3G+4G+5G

Figure 10 - SOLDER use cases and scenarios

Next, **Laurent Dussopt (CEA-LETI) and Igone Velez (CEIT)** provide updates from the **MiWAVES and E3NETWORK** projects on milimetre-wave small-cell access and backhauling for 5G. After defining the concepts of heterogeneous networks and mm-wave small cells (60, 71-86 GHz bands, multi-Gbps data rates, no interference with macro cell), they outline the challenges in terms of networking functions, smart mm-wave radios, beem-steering algorithms and high-gain active antennas. They then elaborate on the backhaul and fronthaul aspects of C-RAN, listing mm-wave backhaul link requirements and challenges and outlining their design for a final front-end TX consisting of an IQ modulator and an mmW transmitter chip, again showing challenges and measurement results.

The following update is from the **MAMMOET** (Massive MiMO for Efficient Transmission) project, given by **Claude Desset from IMEC**. He first outlines the vision of the project, which is to enable mobile and ubiquitous access to gigabytes of information with significantly improved energy efficiency and reduced emitted RF-power by progressing Massive MIMO technology. After having outlined the workpackage structure and consortium composition, Claude gives a short overview of the status regarding MAMMOET KPIs in terms of functional validation, overall energy efficiency validation, standardization and dissemination. He then explains how MAMMOET used METIS project results as a basis, selecting five tough, representative scenarios (outdoor & indoor) where MaMi could offer a breakthrough. The idea is that MaMi can contribute to the promise brought by 5G for these scenarios, both by providing a consistent end-to-end user experience throughout the cell and by maintaining a good quality even in crowded situations. Claude then elaborates on the frond-end/power efficient transmitter and the DSP solutions the project is working on, as well as the validation activities of the project.

Following MAMMOET, **François Deleveau from Thales** speaks about **PHYLAWS**, which deals with physical layer security. He starts by stating the main goals of the project, which are to improve the security of wireless links, to search for key-free solutions based on physical layer security, to experiment these solutions in real-world settings, and to search for practical implementations in existing and future public RATs. In doing this, the project wishes to merge academic and industrial skills on radio propagation, radio-communications and security, considering any kind of threat at the physical layer (passive + various active types), and concentrating on signaling and access phases of RATs, and not only on established data links. The speaker states that usual assumptions of security are no more valid in wireless public networks, whatever the RAT is: faults within SS7 and international roaming protocols are exploited (as was the case with the German Chancellor Angela Merkel) and SIM card providers are hacked to obtain Ki Keys. These recent events have shown that subscriber authentication, identification and roaming remain weak in 2G/3G/4G and other RATs. To counter this, PHYLAWS exploits the multipath randomness of a wireless radio channel, i.e. the fact that the waveforms between two legitimate parties are altered through reflection, diffraction, scattering and shadowing, and these alterations are different towards illegitimate (“eavesdropping”) parties, resulting in the possibility to create keys only known to legitimate parties. The speaker elaborates on the theory behind the concept as well as the real-world measurements and test bed set up by the project, and gives an overview of the remaining gaps for practical implementation of Physical Layer Security schemes. Finally, he goes over various dissemination activities, started standardization activities (ETSI, 3GPP, EDA) and other relevant projects.

Next, **Alister Burr of the University of York** provides an update on the **DIWINE** (Dense Cooperative Wireless Cloud Networks) project. He first explains how DIWINE addresses rapidly-increasing density of wireless networks (especially for machine-type or "Internet of Things" applications) by offering a new paradigm for wireless networks, in which many functions traditionally performed at higher layers are delegated to the distributed, self-organised, network-aware physical layer. This avoids dividing resources between separate, orthogonal channels, which leads to inefficiency, and exploits wireless physical-layer network coding (WPNC) to route mixtures of source data through the "cloud". He elaborates on the latter concept of WPNC, in which relays decode signals from two or more sources simultaneously, and on the distributed learning algorithm for coordination between multiple relays, using game theory based bargaining between relays. Alister then presents two use cases of the project, a smart meter network and critical industrial monitoring and control, as well as three simulators (SMN, CIMC and SLS) developed within the project.

Following this, **Yi Ma of the University of Surrey** presents the technical approach, progress and future plans of the **RESCUE** project. RESCUE aims to provide links-on-the-fly technology for robust, efficient and smart communications in unpredictable environments. The project starts from the assumptions that the physical layer of today's communications systems is not optimized for multi-hop communications in dense network, that accurate link-budget allocation is needed for lossless data communications (resulting in low spectral and energy efficiencies and large end-to-end latency) and that links-on-the-fly technology allows for the existence of broken links in such multi-hop communications. Such links-on-the-fly can be understood, on the PHY level, as a distributed source and channel coding/decoding technique, facilitating reaching the destination or some intermediate nodes with a strong link error correction; this is combined with a new routing protocol on the MAC level. After clarifying the project structure, Yi summarizes current progress regarding 1) use cases, building blocks and fundamental limits, 2) Distributed coding/decoding, lossy-link adaptation and PLNC, 3) lossy message transfer and SDR test bed and field
trials, especially in a vehicle-to-vehicle scenario (public safety being a second focus for the project).

Finally, **Colin Wilcock of Nokia** presents an update on the **SEMAFOUR** project. He first presents the key challenges the project wants to confront: market pressure (explosion of data, decline in revenues, increasing use of smartphones for all kinds of services with related strain on battery life) and the management of future network complexity (with multiple RATs, macro/micro/femto coexistence, and the introduction of dynamic on/off mechanisms and active antennas for higher efficiency and energy saving). In order to address these challenges, SEMAFOUR aims to develop a Unified self-management system, efficiently operating a heterogeneous mobile network comprising a multitude of radio access technologies and layers. Such a system addresses a number of domains: automated traffic steering across multiple RATs and layers, Dynamic Spectrum and Interference, Active/Reconfigurable antenna systems, and integrated SON management. Colin then goes over the various achievements of the project in terms of vision development, the elaboration of use cases and requirements, the development and deployment of a complex Hannover simulation model, the development of a demonstrator, the development and validation of various new SON algorithms, the creation of an integrated SON management system and dissemination (including standardization via 3GPP).

4.3.4 Panel: the role of regulatory policies on wireless innovation

As a conclusion to the workshop, a panel is organized which, complementary to earlier CRS-i workshops on standardization and exploitation, now wants to focus on the links between research and regulation, making use of the presence of Jon Peha (who has been active in both academia, industry and regulatory contexts).

A first question posed to Jon is how he sees this link between research and policy in reality. Jon responds that, when you are in academia, you have innovative (yet illegal) technology that regulators stand in the way of, and when you are a regulator, you do not get the right information to go forward. Some of these disconnects become apparent in the discussions today: when people want factory automation system with type control and interference protection from the outside world, this probably means I need QoS guarantees in a small area, which is a regulatory system that doesn't yet exist. Or the SON-based solutions that were presented just now, making sense in a license based world where all spectrum is controlled, but very complicated in a shared spectrum context. On the question how research and policy interact in the US in practice, Jon argues that every major decision is preceded by a Notice and Inquiry, where written comments are solicited. Jon used to think these comments did not matter much, but has seen that the FCC takes academic comments seriously and follows up on them, even inviting academics over to further explain their viewpoints based on written comments. The best way however is to have one-on-one meetings, which researchers do not engage in as much as they could.

The representative for E3NETWORKS mentions that one of the consortium partners is member of ETSI and ITU, so that they have all information on which solutions can be standardized where. What should be clear for researchers is that we have to have a concrete product first before we can standardize it. The SEMAFOUR representative adds to this that for technical issues, standardization is indeed the way forward (and takes 6 months to two years easily), however the situation for spectrum is more complex, as situations are different in various parts of the world. Global solutions are found via ITU, which works via country memberships and is somewhat limited. Usually there are organisations behind the countries, which steer the positions, but typically this is big industry rather than academics. Jon adds that there are certainly overlaps between standards and regulations, but there are also differences. And since most decisions are not made at the ITU level, but at the regional or national level, getting influence at this point is probably most important. A representative from ETSI adds that, for a link between research and regulation to happen, it cannot be pure research performed by groups without industry (and business) interest. Within ETSI, national regulators are part of many technical groups, so this is a good venue to show such results; by the way, in famous projects such as E2R, the regulators were also on board inside the project.

The moderator then turns the question around, and asks the audience what position regulators should take on a number of current issues, such as millimeter waves, LTE in unlicensed bands, LSA and others. As for LTE-U, Colin Wilcock believes that the market should decide. It would be unwise that LTE-U would destroy the WIFI market; on the other hand, WIFI vendors are making unrealistic claims (saying that only WIFI can operate in these bands). In reality, a lot can be done on LTE transmission to allow

it to coexist with WIFI even better than between WIFI transmitters themselves. Jon adds that this is a perfect example of handling things in the wrong way too late. When we regulated unlicensed bands (before even knowing what WIFI was), we were discussing on whether to introduce etiquette rules. That didn't happen, the WIFI community did not want it; and when Bluetooth came up, suddenly the WIFI community was experiencing interference and became in favour of protection. All of this is because we should not define standards and then work out how they have to function together. Now WIFI and LTE are on a collision course, but Jon points out that there are other bands where we have not made a decision on how technologies should interact.

On the question how millimeter waves should be regulated, Jon argues that, even though lawyers like to remain technology agnostic, we have to decide to an extent on how the technology works so that we can make these decisions. How wide will we make the bands? Should these be unlicensed? What are the use cases? Jon does not think the answers are known by anyone, but different regimes can be used in different bands, hedging the risk somewhat. We just have to be careful not to regulate too fast.

Regarding the regulation of receiver thresholds, Jon explains US current plans, which should define some minimal requirements within the next 18 months. However it is not easy to implement, especially retroactively. According to Jon, such rules will probably only be possible in cleared bands.

An audience member refers to the tiered access system and the comparison with TVWS. In TVWS, incentive auctions are actually shrinking the available spectrum and the importance of licensed access is increasing. Therefore the speaker is interested in knowing whether Jon considers shared access a temporary feature of certain bands. According to Jon, sharing is a system that is absolutely necessary to meet spectrum needs, and will only become more important. Also, while current thinking seems to focus on sharing in a three year time frame, it will have to become a minute time frame. TVWS is a particular case, partly because it is happening in the midst of trying to reduce TV spectrum in general, and because it is a 50 year old technology actually only used by a small percentage of the population. Added to this are new technologies such as Single Frequency Networks which can also change a lot of things in these bands, so this makes for a very unrepresentative case. Finally, Jon argues that there is a political problem with spectrum sharing in the US: a recent auction of spectrum in the US raised USD 45 billion, which puts enormous political pressure on legislators. This makes it very hard to move to models that do not bring in revenue, and any arguments that such systems might increase productivity by one percent and that revenue from that would dwarf any auction income, are very difficult to make. However, sharing does not have to be unlicensed: in the three tier system there are auctions and revenue is coming in, so one does not the exclude the other.

5 DySPAN 2015 panel on Global standardization of DSA and the link between research and standards

5.1 Theme and organisation

The last third and last dissemination activity of the CRS-i project in 2015 was the organisation and moderation of an expert panel on standardization held at IEEE DysPAN 2015. After editions in Dublin (2007) and Aachen (2011), the well-known IEEE Conference on Dynamic Spectrum Access Networks (DySPAN), started ten years ago in 2005, came back to Europe in 2015. This edition (held in Stockholm, Sweden, from 29 September to 2 October 2015) was backed by a pan-European initiative, involving most of the key players in the spectrum domain in Europe, including key industry players, regulators, leading universities and the European Commission itself. The conference has a long tradition of organising dedicated technical and policy tracks, while at the same time trying to combine the two in joint plenary sessions, making this the ideal venue to discuss issues of global CR and DSA standardization and regulation.

For this reason, two CRS-i members were part of the DySPAN Steering Committee, and a proposal was initially submitted for a half day workshop. Such a workshop was to provide an update of global CR/DSA standardization effort and discuss synergies among SDOs, coming from leading experts currently having responsibilities within the main standardization bodies concerned. The workshop would be a good opportunity to discuss particular issues within the Work Items currently under discussion, launch calls for contributions to standards and present standardization opportunities to the DySPAN research community. The proposal was that no papers would be solicited for this workshop, but leading experts would be invited by CRS-i.

The DySPAN organising committee accepted the workshop proposal. However, as details of the programme emerged, it appeared that the workshops were programmed on the day before the actual conference, and that only two of these workshops were withheld. Because of this, and also the fact that an additional registration fee needed to be paid to attend the workshops, CRS-i feared that attendance for the standardization workshop would be low. Therefore, a request was filed to transform the workshop into a plenary panel session and include it in the regular programme. In the end, this was accepted. In order to cover a wide number of relevant Standards Development Organisations and regions, CRS-i invited the following experts to the panel:

- Lee Pucker (Canada) – CEO, Wireless Innovation Forum
- Oliver Holland (UK) – Kings College London / Acting Secretary of IEEE DYSPAN-SC, Chair of IEEE P1900.1 and P1900.6
- Michael Gundlach (DE) – NOKIA / involved in 3GPP and ETSI (on LSA)
- Andrea Lorelli (IT) – Senior Research Officer ETSI, former Technical Officer of ETSI RRS

Figure 11 - The DySPAN panel organized by CRS-i.

Each of the panellists started by giving a short presentation on the concerned SDOs activities and plans, taking into account where possible the following points:

- How to foster coordination and harmonization between different standardization organizations?
- How to foster contributions from research organizations to global standards activities?
- What is the relationship between standards and patents?
- What has been the uptake of approved DSA standards by industry?
- What are the next standardization priorities for DSA?

After this, a conversation between the panellists and the audience was moderated based on the same questions.

Figure 12 - DySPAN panel session

5.2 Results

The first panellist to speak was **Lee Pucker, CEO of the Wireless Innovation Forum**. Lee starts by introducing the Forum, which is structured around three Committees: one looks at new technologies, while the other two are so-called commercialisation committees, focusing on standardization activities. Of these, one is the Coordinating Committee on SCA standards, focusing on defence related standards and SDR platforms, while the other (more relevant for today's discussion) is the Spectrum Sharing Committee, which was formed this year to specifically support the needs of the community in the context of the FCC's new 3.5GHz Citizen Broadband Radio Service. Currently, about 142 people from more than 40 organisations are participating in this committee, with representatives from big industry taking up positions in the steering group. The Committee also has a number of observing members, such as the DoD, WiMAX forum etc. The structure of the Committee, and the related planned deliverables are as follows:

- **WG1 (Operational and Function Requirements, Chairs: Andy Clegg, Google and Al Jette, Nokia Networks)**
  - This group defines the requirements that the other groups base their work on. Some 41 "Scenarios" have been identified
  - Requirements for Commercial Operation in the U.S. 3550-3700 MHz CBRS Band: February 2016
- **WG2 (Security Requirements, Chair: Charles Clancy, Federated Wireless)**
  - Operational Security Requirements: February 2016 (running in parallel with WG1)
  - Communication Security Requirements: February 2016
- **WG3 (Protocols, Chair Jesse Caulfield, Keybridge Global)**

    - Interim Technical Report balloted in August, in comment resolution
    - SAS to CBSD Protocol (Chair: Prakash Moorut, Nokia Networks): February 2016
    - SAS to SAS Protocol (Chair: James Ni, Federated Wireless): March 2016
- **WG4 (Test and Certification, Chair: Kurt Shaubach, Federated Wireless)**. Results of this group depend on the other groups
    - High level certification flow balloted in August, in comment resolution
    - Test and Certification Objectives: February 2016
    - Test and Certification Requirements Specification: May 2016

The WINNF has formal partnerships with many other organisations, such as an MoU with IEEE P1900.5, sessions with 1900.1 and 1900.6, an MoU with ETSI RRS, and more recently exchanging information with 3GPP. The WINNF approach is to collaborate with SDOs, and to develop standards itself when they are not being developed. In terms of the relationship with research, the Forum yearly publishes a top ten list of most wanted innovations which, if realized, would address various shortcomings in existing wireless communications from the point of view of the different stakeholders in the wireless industry value-chain. A lot of the innovations on the current list are particularly relevant to the DySPAN community. The list is used to engage with research and policy makers globally and to help drive the agenda for research on these issues. The current (fifth) list is as follows:

- Innovation #1: Techniques for Efficient Porting of Waveform Applications Between Embedded Heterogeneous Platforms
- Innovation #2: Network Management of Mobile Ad-hoc Radios
- Innovation #3: Receiver Performance Interference Thresholds
- Innovation #4: Low Cost Wide Spectral Range RF Front-End (Multi-octave Contiguous)(Tx,Rx)
- Innovation #5: Efficient Techniques to Minimize Power Amplifier Spectral Regrowth in Non-contiguous Spectral Environment
- Innovation #6: Increase Communications Time on Battery Charge by an Order of Magnitude
- Innovation #7: Context Aware Cognitive Radio
- Innovation #8: Interference Mitigation Techniques
- Innovation #9: Standardized Computer Interpretable Policy Language for Cognitive Radio
- Innovation #10: Flexible Regulatory Framework for Temporary, Cooperative and Opportunistic Access

Figure 13 - Lee Pucker (WINNF)

The next speaker is **Oliver Holland, speaking on IEEE 1900**. He starts by introducing DYSPAN-SC, which sponsors IEEE 1900 working groups, on Dynamic Spectrum Access Networks and related technologies. It standardizes overarching solutions based on particular problems, needs or technologies. Examples of these are management architecture in DSA context, policy formation for DSA, sensing and spectrum database interactions, interference management in DSA context, radio interfaces for DSA. The Committee operates under the IEEE Communications Society, as opposed to, for example, IEEE 802, which operates under IEEE Computer Society. This also implies that 802 standards are related to quite particular technologies, whereas 1900 standards are much more generic.

Oliver then provides an overview of active groups and ongoing work within them:

- IEEE 1900.1-2008: “Terminology Relating to Emerging Wireless Networks, System Functionality, and Spectrum Management”. Inherent to this is the

interaction between various concepts, such as “cognitive” aspects are inherited into cognitive radio, and how cognitive radio is inherited into Cognitive Radio systems
  - IEEE 1900.1a-2012: “Addition of New Terms and Associated Definitions”
  - Currently working on root/branch revision of 1900.1-2008 (will incorporate 1900.1a-2012, as well as other changes to terms/definitions and annexes)
- IEEE 1900.2-2008: “Recommended Practice for the Analysis of In-Band and Adjacent Band Interference and Coexistence Between Radio Systems” (WG in hibernation)
- IEEE 1900.4-2009: “Architectural Building Blocks Enabling Network-Device Distributed Decision Making for Optimized Radio Resource Usage in Heterogeneous Wireless Access Networks” (WG in hibernation)
  - IEEE 1900.4a-2011: “Architecture and Interfaces for Dynamic Spectrum Access Networks in White Space Frequency Bands”. This is a baseline definition which is very much operator-centric, used to distribute decisions.
  - IEEE 1900.4.1-2013: “IEEE Standard for Interfaces and Protocols Enabling Distributed Decision Making for Optimized Radio Resource Usage in Heterogeneous Wireless Networks”, an amendment which makes the architecture applicable to TVWS
- IEEE 1900.5-2011: “Policy Language Requirements and System Architectures for Dynamic Spectrum Access Systems”
  - IEEE 1900.5.1: “Policy Language for Dynamic Spectrum Access Systems” (ongoing work)
  - IEEE 1900.5.2: “Standard Method for Modeling Spectrum Consumption” (complete version that has entered the Ballot for approval of standard)
- IEEE 1900.6-2011: “Spectrum Sensing Interfaces and Data Structures for DSA and other Advanced Radio Communication Systems”, particularly for distributed sensing for use of Cognitive Engines based on this.
  - IEEE 1900.6a-2014: “Procedures, Protocols, and Data Archive Enhanced Interfaces”
  - IEEE 1900.6b: “Spectrum Database Interfaces Amendment” (ongoing very active work—to continue very active standard development for at least the next year (perhaps longer))
- IEEE 1900.7: “Radio Interface for White Space Dynamic Spectrum Access Radio Systems Supporting Fixed and Mobile Operation” (completed – approved by voting process on the final standard; to undergo final approval by IEEE for publication)

Oliver provides some examples of the current work within 1900.4 and 1900.6. He invites everyone to join the standardization in DySPAN-SC, and then goes into the potential synergies between SDOs working on DSA. He argues that such synergies are particularly difficult, due to the diverging market interests, groups and companies behind the different bodies. However such synergies are possible and already present in some places. Firstly, this may happen where standards “need” each other, for example when higher OSI layers are standardized by one group (e.g., PAWS) and lower layers by another (e.g., 802.11af/1900.7). In this particular case, IETF does not standardize lower layers, while IEEE is not active in the higher layers. Another example of this is standards for hardware (e.g., mobile phone sensors, detectors) needed for

the overall system (e.g., communications), as wells as the synergies between ETSI 301598 and TVWS radio interfaces.

Secondly, synergies are also possible when standards are under a similar group (e.g., IEEE 802 standards, or even IEEE standards in general), hence being coordinated in some way (in some cases that coordination being forced by a top level—e.g., the IEEE Standards Association directives). However, due to standards being skewed by market and competition interests, Olivers's general feeling is that synergies will have to be "forced" by a higher level. An obvious choice for this is the ITU, forcing synergies with the ground-up input of governments (national administrations) which ultimately have to be the driving force. This could be beneficial for example in the context of TV white spaces, where there is wide range of standards already out there, and proprietary systems, that will undoubtedly cause big interference to each other.

Finally, on the question of how to link research and standards, Oliver argues that this ultimately comes down to the need of a better understanding of market potential and market direction in doing research. This implies a cross-disciplinary understanding (e.g., also business models, market interests and perspectives, detailed analysis of potential up-takers of the research to standards, real-world situations understanding, etc.). Either research has to prepare a compelling standard that will be taken up by the market (there are very rare, if any, examples of research alone doing this), or research has to sell itself to industry or other stakeholders that will take the ideas to standards. In general, research has to be more short-term, aiming for big money-making interests in the next 5-10 years. Oliver argues that initiatives to help push subsets of research in such directions could be developed, for example by EC or other central policy and funding organisations.

Figure 14 - Oliver Holland (KCL)

The next expert is Michael Gundlach from NOKIA, talking about LSA standardization in various standardization bodies. He starts by outlining the different phases in the standardization process of LSA within ETSI. This process started with a system reference document in 2013, followed by system requirements. Subsequently, just a few weeks before the conference (on 11 September 2015), the second phase was completed with the system architecture and high level procedures Technical Specification. This is an important baseline document containing the main LSA principles in a level of detail also of important to other groups (this was also sent to 3GPP and WINNF). At present, work on the stage 3 document has just started, which will describe the information elements to be sent between the main architectural components. Work on this document is expected to continue for another year. He then briefly outlines the architecture reference model and the mapping of high level functions and function groups to logical elements in the system envisaged by ETSI RRS. The main components in the architecture are the LSA Repository and the LSA Controller, the latter being the MNO domain (and to be further specified by 3GPP).

One thing not included here are the interfaces with the incumbents and the regulatory domain, since these are not used often so should not be standardized. The interfaces that are studies, focus on general LSA information exchange, as well as on security support, robustness and reliability and fault management.

Michael then looks at the activities of 3GPP (as mentioned, for what concerns the MNO domain). This SDO just started a Study Item on the interface between the LSA Controller (LC) and Operation, Administration and Maintenance (OAM), clearly complementing the work done within ETSI RRS. After that, he comes back to the activities within the Wireless Innovation Forum already introduced by Lee Pucker. These activities are related to the so-called US-based SAS system, which has some similarities with LSA but also some differences, among which the band used and the use of a three-tiered model as opposed to a two-tier system in ETSI. He argues that it would be good to exchange information between the two organisations.

Figure 15 - Michael Gundlach (NOKIA)

Regarding the cooperation between the three groups mentioned, Michael repeats that there already exist formal liaisons between them and that they try to avoid competition. Some more cooperation would be nice, but currently the SDOs are looking at different aspects of spectrum sharing, so that competition is limited. One thing that need to be mentioned, however, is that the work within ETSI RRS is mainly driven by manufacturers. There are some operators in the group (notably Telecom Italia and Orange) but they are slowing down the activities rather than supporting them. However, this can sometimes be a positive thing, as it is sometimes good not to be too fast and to have too many features. The LSA system now standardized is fairly simple but effective, and trials started this week in Finland in Italy (with the Italian Ministry of Economic Development, the Joint Research Centre (JRC) of the European Commission, Qualcomm, RED, Poste Mobile and others), so commercialization is coming closer. He concludes the talk by saying that Nokia is very interested in LSA, sees it coming to market quite soon, and is also looking at further phases for its standardization, for example also looking at sensing and other technologies coming from research.

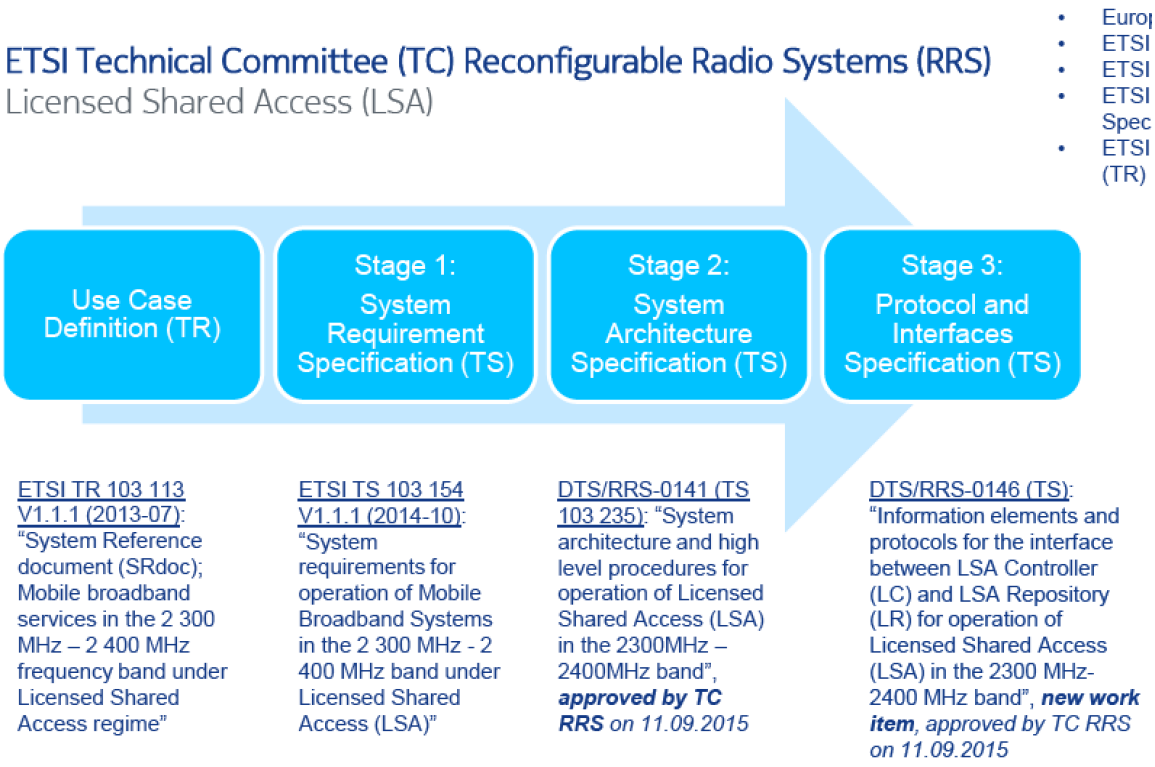


Figure 16 - LSA standardization in ETSI

The last speaker of the panel is Andrea Lorelli of ETSI. He starts by introducing ETSI, an organization with more than 800 members and more than 30,000 publications. He then shows the global collaboration for the standards that ETSI produces, such as an MoU with the Wireless Innovation Forum, with IEEE and a number of other SDOs, for a total of more than 100 partnerships. DSA-related work within ETSI focuses on LSA, White Space devices, Reconfigurable Radio as a DSA enabler as well as some activities in satellite communications, PMSE and RFID.

On LSA, the overview was already given by the previous speaker. In TVWS, standardization is already in the phase of European Norms, with a Harmonised

Standard published, and thus nearing completion. Both LSA and TVWS work are being carried out under a European Commission mandate. On the topic of Reconfigurable Radio, there has been significant progress recently, with requirements and architecture already published as European norms, interfaces definition underway, and activities on security and dynamic certification started.

Coming back to the panel question of inter-SDO coordination, it is Andrea's opinion that there is no real overlap. Delegates participate in a number of SDOs (for example IETF and WINNF) and make sure there is alignment between the activities. An important argument to keep into account is that, while global solutions are often desirable, they are not always possible. Particularly when talking about frequencies, often a regional or national solution is required, with regulators such as FCC and CEPT defining diverging parameters. However, whenever possible, joint meetings can be held and can be very useful.

Andrea finally provides a number of examples of successful coordination between research and standards. The first one is E3 (End-to-End Efficiency), a FP7 project that ended in 2009, which triggered the creation of ETSI RRS in 2008. The other example is ONEFIT, a project that ended in 2012 and that was the driver behind a specific working item on control channels within ETSI RRS. From these projects, we can learn that research projects should be research driven and contain pre-standardization activities, which makes the presence of industrial partners required. The output of these projects should then be fed into standardization.

Figure 17 - Andrea Lorelli (ETSI)

The moderator then moves to a Q&A session. He starts by asking Lee Pucker how the link between research and standardization is perceived by WinnF. Lee responds that a number of paths are pursued for this, similar to the strategies used in Europe. The first one is the National Science Foundation which has a programme called EARS (Enhancing Access to Radio Spectrum) which is equivalent to FP7 research, focusing on research supporting spectrum access. Results are periodicly presented to industry, and WinnF is trying to work together with NSF to include a principal investigators' workshop at its conference in March 2016. The second track is corporate funded R&D. For example in the 3.5GHz discussion there was the question how close an LTE system can operate in the presence of a Navy radar (the incumbent). To facilitate, Google partnered up with Virginia Tech and the Navy to do experiments on this topic. This had a direct business impact, results were filed with the FCC. So there was corporate funding in cooperation with the government to solve a specific business need.

The moderator then asks about the research priorities for the SDOs involved. Lee Pucker refers to the top ten list that WinnF publishes every year. Oliver Holland agrees that academia is primarily concerned with long term research aimed at pioneering breakthroughs, and not so much what is the best solution at a particular time and how this impacts the market. As he highlighted in his presentation, we need a much better analysis regarding the market and societal potential of standards that are already there. He applauds that there are efforts being done, for example by the European Commission, but this should be extended and also come from academia (and be taken into account when assessing the research community). Andrea states that in ETSI, there are about 100 members from research institutes and universities. They do this for example in cases where research is sponsored by industry or governments.

The moderator subsequently refers to the lack of commercial applications based on the Cognitive Radio standards developed in the various SDOs mentions, and asks the panelists what they think the commercial outcome is of more than ten years of Cognitive Radio standardization. Lee Pucker starts by stating that there are a lot of standards developed for the sake of developing them, which implies very low chances of adoption. If you need a standard, this is because you need to interoperate with someone else who is also using that standard, and you need to invest in certification (to show that you are compliant with the standard). If one of these aspect is absent, there will be no adoption of the standard. This has been the case in TVWS, because US Congress initiated the Incentive Auction programme which froze the market at least until after the auction takes place next year. In the UK you do see adoption of the standard through the involvement of Ofcom. Andrea Lorelli agrees with the points made: when there is no business case, the standard is useless, and this is unfortunately often the case, especially for standards that were primarily developed from the research side. When you look at standards like DECT, these are still being worked on and improved, because the actors involve believe that these standards will be taken up and have significance.

Finally, the moderator asks about the relationship between standards and patents. Lee Pucker responds that some standards are specifically designed not to have IP associated with them, however most standards do have patented IPR included. The general rule is that such IPR should be made available under fair, reasonable and non-discriminatory terms to implementing parties. Andrea Lorelli agrees with this, and clarifies that pending patents within ETSI have to declared, and may subsequently be

included in the standard, as a potential source of income. However, if the declaration is not made, this can really damage the standard.

A member of the audience asks the panelists whether they see any fundamental differences of opinion arising between the different SDOs, with the discussion between LTE and WIFI as an example. Lee Pucker answers that WinnF will dedicate a session to this particular topic at its European Conference next week. The WinnF itself has taken no position on the topic. It works on standards that support multiple technology implementations. Oliver Holland confirms that the sharing between LTE and WIFI is indeed an obvious example. He expects that some sort of top-down coordination and mediation will be required, for example via the ITU. Lee add that the World Radiocommunications Conference is happening right now, and since this only happens every for years, any answer from ITU will only come in 2021. Therefore he expects that the issue will be resolved in some way before that time (and outside of ITU).

6 Conclusion

The two Workshops and the panel discussed in this deliverable may be considered a success by the project. They featured:

- Interesting keynotes from both IAB and non-IAB members, focusing on the relationship between research and standards, between standards and markets and on global regulatory and market evolutions;
- Specific overviews of exploitation plans by six RAS cluster projects, including standardization activities, which were used as inputs by the CRS-i Market Task Force to identify potential synergies between the projects;
- Seven project updates also coming from the RAS cluster;
- A panel with IEEE, Wireless Innovation Forum, ETSI and industry representatives discussing current activities and next steps in CR and DSA standardization, and analysing opportunities and bottlenecks for closer cooperation between research and standards on the one hand, and between standardization organisations on the other hand.

All the events organised by the project had a good attendance and very good levels of interaction. The choice to transform the DySPAN workshop into a plenary panel certainly contributed to this success. Overall, attendees got a complete overview of global standardization activities in this domain, high level academic contributions from keynote speakers, and ample indications for inter-project cooperation both in the domains of research, standardization and exploitation. The interactions on these three subjects also clearly demonstrated the intrinsic links between them.