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DISSEMINATION LEVEL		
<b>PU</b>	Public	<b>X</b>
<b>PCA</b>	Public with confidential annex	
<b>CO</b>	Confidential, only for members of the consortium (including Commission Services)	

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## EXECUTIVE SUMMARY

The work of SACRA moves towards several directions, ranging from basic research into new approaches and technologies for future communication systems, to application of technologies and techniques in existing architectures and systems. This also includes investigations into the business cases for these new technologies and approaches, as well as studies on the potential impact of the considered technologies and whether working on them actually does make sense from a business perspective.

There is, however, a range of issues that all this work has in common:

- the work needs to be disseminated to get a wider consensus about the applicability of the findings
- the techniques investigated need to find their way either directly into products, or into standards, to make sure that the communication systems that will use these techniques will be able to interoperate
- as SACRA addresses regulated communication systems, it needs to be made sure that the technologies researched, once they enter the market, may actually be used
- there is an economical incentive to pursue this research and in one way or another, the results obtained will need to be exploited to justify the work.

The SACRA project is following an integrated approach to these issues. In this direction, the present document provides an overview into the activities and plans for regulation, standardization, dissemination and exploitation that have already been achieved and are further expected to be accomplished once the project has finalized its activities.

More specifically, a detailed and multifaceted dissemination and exploitation process has taken place aiming to utilize various different tools in order to facilitate wide dissemination of the SACRA outcomes. The considered approach combined the publication of already emerged technical outcomes to appropriate international conferences, workshops and journals as well as to scheduled organization of SACRA workshops and training events. Interactions with other EU projects working on similar technical areas have also been pursued through the participation in European Commission concentration and cluster meetings. Furthermore, a strong on-line presence is maintained in order to guarantee the availability of up to date information about the main technical directions and key outcomes of the consortium. All the partners are exploiting and will further exploit the project outcomes for industrial and research purposes. Finally, industrial level exploitation of the project outcomes has taken place through the submission of contributions in related standardization bodies.

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# 1 INTRODUCTION

One of the main goals of the SACRA project is to provide a rather holistic approach that surpasses the strict research bounds and further strives to place its outcomes in the wider, industry relevant community. To this direction, Work Package WP7 of the SACRA project focuses on the identification of opportunities for the promotion of SACRA outcomes to different interest groups and on the implementation of the resulting dissemination plan. The scientific community, the industry, various standardization groups and regulation authorities are identified as target groups.

Under this prism, the following issues have to be taken into account during the SACRA lifetime:

- the work needs to be disseminated to get a wider consensus about the applicability of the findings
- the techniques investigated need to find their way either directly into products, or into standards, to make sure that the communication systems that will use these techniques will be able to interoperate
- as SACRA deals with regulated communication systems, it needs to be made sure that the technologies researched, once they enter the market, may actually be used
- there is an economical incentive to pursue this research and in one way or another, the results obtained will need to be exploited to justify the work

Dissemination objectives of SACRA project include participation in international workshops and conferences, organization of workshops, scientific publications in international journals and various training activities. Another important goal of the consortium is to promote relevant SACRA outcomes into standardization bodies. Main standardization targets constitute the 3GPP Release 11+, the IEEE SCC41, and the ETSI RRS. All actions taken during the dissemination process aim to create strong awareness of scientific solutions proposed by SACRA and to facilitate their adoption by both society and industry. Furthermore, SACRA findings shall be exploited so as to benefit from the outcomes and the experimentation of the project partners. Such exploitation includes the use of the foreground in publications, and its combination to PhD and master activities. The partners' intention is to exploit the project outcomes by incorporating the produced solutions in novel schemes currently under development.

The SACRA project has developed an integrated approach to these issues in accordance to the Technical Annex; this document provides an overview of the activities related to standardization, dissemination and exploitation during all three years of the project's duration, as well as plans of using SACRA's foreground in the future. More specifically, Deliverable 7.1 volume 3 provides an extensive presentation of the related achievements, and further elaborates on the dissemination and exploitation plans, which include participation in upcoming conferences and workshops, publications of SACRA outcomes to peer reviewed magazines and journals with high Impact Factors, project online presence through its website (<http://ict-sacra.eu>) and other dissemination related actions. Deliverable 7.1 volume 3 incorporates the content of D7.1 and D7.2 by including both the dissemination plan and the publications (D7.1) as well as the use and the dissemination of the foreground (D7.2). More precisely, the structure of this deliverable is the following:

Section 2 provides a detailed description of the proposed dissemination plan, the identified dissemination opportunities and the way the consortium plans to further orchestrate and implement the specific actions. Moreover, open source activities are addressed.

Section 3 summarizes the dissemination outcomes achieved in SACRA project. Additionally, it presents metrics used to assess the impact of each dissemination opportunity such as the impact factor that determines the quality of a journal or the acceptance rate and the h-index that constitute criteria of the quality of a conference. In SACRA dissemination these metrics are used as

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indicators to target more impacting publications. Using these guidelines, the SACRA project has published or submitted papers in events with high impact factors over the project's lifetime.

Section 4 outlines standardization and exploitation activities such as dissemination of project results to standardization bodies, regulation meetings and organization of training activities, as well as project liaisons.

Section 5 provides a detailed list of the type of foreground as well as the use of the foreground by SACRA partners. More specifically, a detailed table has been included in this document so as to highlight the partners' intentions regarding the projects' foreground.

Section 6 provides a detailed view of exploitation plans. More specifically, it presents various foreground types that consortium has achieved and the plans for future use.

Section 7 presents patents that have been filed under the SACRA Project.

Section 8 concludes the document with a brief summary.

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## 2 DISSEMINATION PLAN

As described in SACRA Annex I (“Description of Work”, 15.10.09), dissemination is considered as a key activity and, therefore, it is an essential element of the SACRA strategy to disseminate widely and with the maximal impact the project outcomes.

Towards this goal the consortium aimed at designing, coordinating, implementing, and articulating dissemination and exploitations plans for creating a strong awareness of SACRA at European level. The scope of this activity was twofold: to coordinate the output of results and technological solutions in European society and facilitate the adoption of SACRA outcomes by a large community of related business users, increasing its strategic importance.

### 2.1 DISSEMINATION PROCESS

The wide availability of results to a broader audience was pursued by targeting a number of different dissemination activities. High quality work items were presented in highly ranked international conferences such as IEEE events (e.g., INFOCOM, ICC, VTC, and PIMRC). In addition, the publication of SACRA solutions to peer reviewed journals and magazines and special issues in the research areas of the project was performed, increasing awareness for the project work. Especially journals that are characterized by high Impact Factors improve the visibility of the consortium, resulting also in increased number of citations, which are a major factor for determining the quality and impact of scientific work.

As previously referred, the dissemination of the exported SACRA results to the research as well as the standardization community was one of the key goals of the consortium. To achieve this, SACRA partners followed a dissemination strategy which encompassed a number of different means, to achieve the highest possible impact. The strategy aims, once any relevant IPR is secured, at promoting the project results and ensuring project awareness within the European ICT and the global research community. The SACRA consortium will exploit various dissemination channels for the work items researched and technology solutions investigated.

#### 2.1.1 Identification of dissemination opportunities

More specifically, the dissemination efforts will identify and include the following opportunities and activities:

- **SACRA online presence:** SACRA, since the beginning of the project, provides a web portal (<http://ict-sacra.eu>) for public dissemination of project information and results. This includes information about the project structure, scope, vision, challenges and objectives as well as all dissemination material of the project. Moreover, public project documents have been published on this home page for dissemination purpose. Additionally, SACRA project results include the design of software. The software that is not restricted to project participants only, will also be placed on the project web site. Thus, people who are working in the same domain will be able to exploit these results. The homepage also includes a restricted section, which is available only for the project partners and another restricted section for Commission services and reviewers.
- **Publications of high quality project results in International peer reviewed Journals, Magazines and book chapters:** Submission and publication of the technological concepts and results achieved by SACRA, in selected internationally acknowledged Journals and Magazines as well as special issues related to the end-to-end efficiency research areas. The editorship of book chapters related to the project research items will be also exploited as a means to externalise SACRA work and to document the advances w.r.t the state of the art SACRA achievements. The results also have been included in Thesis pursued by the Ph.D. students working in SACRA.

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- **Contributions and participation at international conferences, workshops and summits:** This dissemination activity concerns the coordinated preparation, submission and presentation of papers in selected highly recognised international conferences and workshops (including IEEE events such as ICC, Globecom, and VTC). In addition, the participation to special sessions in large international mobile communications conferences and workshops has been pursued, fostering the promotion of project work and investigating the positioning of the project achievements in relation to new business opportunities and technological trends.
- **Organisation of SACRA workshops:** Facilitate targeted dissemination of project results and ensure high visibility of the SACRA work within the 7<sup>th</sup> Framework. This concerns both the potential organisation of SACRA public workshops, joined workshops. Such common workshops provide venues for interactive exchange of ideas. This has been supported with special brainstorming sessions tailored to specific research problems which will help shaping consensual concept development.
- **Open source software:** An additional means of dissemination will be to post selected software code resulting from the project as freely available on the web-page. Indeed, the different WPs include development of different software for cognitive radio applications. The software, which is not defined as restricted in this plan, will be placed on the web. Thus, others working in the same field will be able to use these results. This has the potential to significantly advance knowledge in this sector.
- **Participation and Contributions to European Commission concertation and cluster Meetings:** SACRA partners have actively participated and contributed to concertation and cluster meetings, fostering the aggregation of the project work in the unified framework of related European projects.
- **Training Course:** One of the last targeted dissemination is the inclusion of the SACRA Know-how as part of future graduate and postgraduate courses. Partner Universities had enriched their courses.

### 2.1.2 Cascaded top-down and bottom-up dissemination orchestration

The dissemination of the SACRA outcomes to both the research and the standardisation community was one of the major goals of the consortium. Towards this goal the SACRA consortium aims at designing, orchestrating and implementing dissemination plans to create a strong awareness of the SACRA project at European level. Specifically, the SACRA consortium applied a cascaded top-down and bottom-up dissemination strategy which encompasses a number of different means so as to achieve the highest possible impact of the project outcomes within the European ICT and the global research community.

The considered approach involved the identification of appropriate dissemination opportunities, using a combination of quality criteria (described in following Sections of this document) as a guideline in this process. Every partner also provided feedback regarding other potential dissemination opportunities that could be included to the list. Following this process, discussions took place in order to investigate the possibility for joined publications between partners that work in the same or similar technical areas. The selected dissemination procedure targeted both the wide dissemination of the project's outcomes in various conferences and workshops with a broad audience, as well as the selective publication of key outcomes in high quality journals, flagship IEEE conferences and book chapters.



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### 3 DISSEMINATION IMPACT ASSESSMENT

In this section the dissemination impact assessment is presented. This includes the dissemination outcomes produced during the so far lifetime of the SACRA Project as well the description of impact assessment metrics. As described in the Technical Annex, publications in international peer-reviewed conferences are very important for the dissemination of the project results. The list of accepted and submitted papers includes some well known IEEE conferences with high impact factors (e.g. VTC and MELECON), as well as conferences that are crucial for achieving wide awareness of the project outcomes in the area of Cognitive Radio in particular, such as SDRF, Future Network & Mobile Summit, and Crowncom.

#### 3.1 IMPACT ASSESSMENT METRICS

##### 3.1.1 Impact factor

As previously referred, one of the main goals of the SACRA project was to target Journals which are characterized by high Impact Factors (IF) in order to improve the visibility of the consortium, thus, resulting in increased number of citations, which are a major factor for determining the quality and impact of scientific work. The SACRA dissemination plan that was updated periodically with relevant dissemination opportunities includes information on such metrics or links to the related databases, so as to help the partners select the most appropriate journals and conferences.

The Impact factor [1] was devised by Eugene Garfield, the founder of the Institute for Scientific Information, now part of Thomson, a large worldwide US-based publisher. Impact factors are calculated each year by Thomson Scientific for those journals which it indexes, and the factors and indices are published in Journal Citation Reports.

The impact factor for a journal is calculated based on a three-year period. It can be viewed as an approximation of the average number of citations in a year, given to those papers in a journal that were published during the two preceding years. For example, the 2003 impact factor for a journal would be calculated as follows:

A = the number of times articles published in 2006-7 were cited in indexed journals during 2008

B = the number of "citable items" (usually articles, reviews, proceedings or notes; not editorials and letters-to-the-Editor) published in 2006-7

2008 impact factor =  $A/B$

(Note that the 2008 impact factor was actually published in 2009, because it could not be calculated until all of the 2008 publications had been received.) A convenient way of thinking about it is that a journal that is cited once, on average, for each article published has an IF of 1 in the expression above.

The journal cited half-life: the median age of the articles that were cited in Journal Citation Reports each year. For example, if a journal's half-life in 2008 is 5, that means the citations from 2001-2008 are 50% of all the citations from that journal in 2008.

Immediacy index is a measure of how topical and urgent work published in a scientific journal is. Along with the better known impact factor measure, it is a calculated each year by the Institute for Scientific Information for those journals which it indexes; both impact factors and immediacy indices are published annually in the Journal Citation Reports.

The immediacy index is calculated based on the papers published in a journal in a single calendar year. For example, the 2009 immediacy index for a journal would be calculated as follows:

A = the number of times articles published in 2009 were cited in indexed journals during 2009

B = the number of articles, reviews, proceedings or notes published in 2009

2009 immediacy index =  $A/B$

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### 3.1.2 H-index

Conferences are also important dissemination targets, since they often attract a broad audience and have usually a short time interval between submission and publication, constituting them preferable choices for fast dissemination of project outcomes.

Common quality criteria for conferences include the acceptance rate (a low acceptance rate indicates strict selection between the submitted research works), as well as metrics related to the citations of the conference (h-index, g-index, etc). The h-index [2] of a conference is the largest number  $x$  of articles that have appeared in that conference and have been cited at least  $x$  times. It is a standard measure of the impact of research of individuals and equally valid for journals and conferences [3]. Like all metrics that are based on citations (g-index, etc), h-index favors established events that have published a significant number of high-quality papers (thus increasing the likelihood of papers that have gathered a significant number of citations). However, it might not be fair to evaluate events that have been established very recently (i.e. less than five years) using such a metric, since the papers appearing in such events did not have appropriate time to collect a significant number of citations. (For an event that takes place for the first time, all citation-based metrics are by definition zero). Finally, the accuracy of all metrics based on citation count is depending on the completeness and robustness of the corresponding databases, therefore a combination of metrics should be used whenever possible [4].

A list of upcoming conferences that have been identified as indicative potential targets of the SACRA consortium is presented below:

Conference Name	Loc.	Date	H-index	References & Citers
IEEE Radio and Wireless Symposium (RWS 2012)  <a href="http://rawcon.org/index.html">http://rawcon.org/index.html</a>  Paper Summary Due: 8 July, 2011 Final Manuscript Due : 30 October, 2011	Santa Clara, USA	15-19.01.2012	15	
International Conference on Cognitive Radio Oriented Wireless Networks and Communications (CrownCom 2012)  <a href="http://www.crowncom.org/">http://www.crowncom.org/</a>  Full paper submission deadline: 16.01.12  Acceptance Notification: Feb. 27th, 2012 Camera-ready Submission Due: March 23th, 2012	Stockholm, Sweden	18-20.06.12	4	
19th International Conference on Telecommunications (ICT 2012)  <a href="http://www.ict2012.org/">http://www.ict2012.org/</a>  Paper submission deadline: December 5, 2011 Notification of acceptance: January 31, 2012	Jounieh, Lebanon	23-25.04.12	12	

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<p>IEEE VTC Spring 2012</p> <p><a href="http://www.ieeevtc.org/vtc2012spring/">http://www.ieeevtc.org/vtc2012spring/</a></p> <p>Submit papers for review by: 30 September 2011 Final paper due: 6 February 2012</p> <p>Acceptance notice sent: 4 January 2012</p>	Yokohama, Japan	6-9.05.12	88	
<p>Table 1 : IEEE INFOCOM 2012</p> <p><a href="http://www.ieee-infocom.org/">http://www.ieee-infocom.org/</a></p> <p>Abstract due: Friday, July 22, 2011 Full paper due: Friday, July 29, 2011 Notification of acceptance: Monday, November 21, 2011</p>	Orlando, USA	25-30.03.12	213	
<p>The fourteenth International Mobility Conference (IMC14)</p> <p><a href="http://www.imc14.com/page.php?1">http://www.imc14.com/page.php?1</a></p> <p>Call for Abstracts: 1 February 2011 Close of Abstracts: 30 April 2011 Early Bird Registration Cut Off: 31 October 2011 Standard Registration Fee Applies: 1 November 2011</p>	Palmerston North, New Zealand	13-17.02.12	3	
<p>The Second International Conference on Advances in Cognitive Radio</p> <p>Table 2 : (COCORA 2012)</p> <p><a href="http://www.iaria.org/conferences2012/COCORA12.html">http://www.iaria.org/conferences2012/COCORA12.html</a></p> <p>Submission (full paper): December 5, 2011 Notification: January 23, 2012 Registration: February 7, 2012 Camera ready: February 7, 2012</p>	Chamonix / Mont Blanc, France	29.04.2012-04.05.2012	14	
<p>The Eighth Advanced International Conference on Telecommunications (AICT 2012)</p> <p><a href="http://www.iaria.org/conferences2012/AICT12.html">http://www.iaria.org/conferences2012/AICT12.html</a></p> <p>Submission (full paper): January 5, 2012 Notification: February 23, 2012 Registration: March 7, 2012 Camera ready: March 7, 2012</p>	Stuttgart, Germany	27.05.2012-01.06.2012	16	

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### 3.1.3 Acceptance rate

Acceptance rates are one of the key ways of measuring the quality of conferences [9]. More specifically, acceptance rate of a conference is the number of accepted papers divided by the number of the total submitted papers. It is clear that this metric does not rely on the number of citations as previous metrics did, but is calculated based on the percentage of the accepted works. Obviously, a low acceptance rate indicates that the conference accepts only a strict, small portion of submitted research works, which in turn, translates into higher quality papers. Therefore, SACRA will target conferences with a low acceptance in order to present the high quality of the conducted scientific work and, consequently, lead to a higher number of citations.

### 3.1.4 Holistic impact assessment

Successful accomplishment of the SACRA project results and well-targeted active exploitation and broad dissemination of the outcomes, evaluation of potential implications, and corresponding recommendations are required to prepare ground for the adoption of the SACRA vision. The process for the quantification of SACRA impact will be built upon the monitoring of different metrics: impact factor, h-index, acceptance rate and the availability of information about the progress of SACRA scientific research. SACRA will quantify and develop its impact with respect to these metrics:

Impact factor: SACRA partners aim at publishing their scientific work in journals with high impact factors, in order to promote its awareness. However, 2011 impact factors cannot be calculated until the end of the year, this is why we have to evaluate the importance of a journal with respect to 2010 impact factors. Especially Journals that are characterized by high Impact Factors will improve the visibility of the consortium, resulting also in increased number of citations.

H-index: H-index is a standard measure of the impact of research of individuals and equally valid for journals and conferences. This metric evaluates conferences and journals with respect to their citations. Considering this, SACRA partners target at publishing SACRA results in journals and conferences characterized by high h-index.

Acceptance rate: This metric shows whether the selection of papers published in a journal or conference is strict or not. A low acceptance rate indicates string selection among submitted research works and as a result accepted papers of high quality. Considering this, one of the main goals of dissemination plan is to publish and present SACRA scientific work to conferences and journals characterized by low acceptance rates.

The combination of these three metrics will help us choose conferences, journals and magazines that will facilitate the promotion and presentation of SACRA project results to a broader audience. Already during the first two year of the project, the SACRA publications take such criteria into consideration. Specifically, papers have been accepted or are under review in well known conferences with high impact factors (e.g. VTC and MELECON) as well as events that are of particular interest in the area of Cognitive Radios (e.g. SDRF and Crowncom). A few other parameters should also be considered:

Consultation and access to the SACRA website: The SACRA website will offer enhanced features in guest mode, relevant to SACRA objectives, technical approach, results and software that is not restricted to project participants only. Thus, people who are working in the same domain will be able to exploit these results.

Search for citations: A search for citations will be conducted, in parallel to search engines analysis. This process involves an analysis that shall be conducted systematically, in cooperation with numerous local documentation centers, which provide information on citations. Specifically, dissemination material coming from SACRA that will be used in this process includes publications in journals, conferences and books.

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## 3.2 DISSEMINATION OUTCOMES

### 3.2.1 International Conferences:

Authors	Title	Conference Name	Status	Loc.	Date
A. Merentitis, A. Kaloylos, M. Stamatelatos, N. Alonistioti	Optimal Periodic Radio Sensing and Low Energy Reasoning for Cognitive Devices	Mediterranean Electrotechnical Conference (MELECON)	Published	Valetta, Malta	25-28.04.10
R. Pacalet, J. Gonzalez	Full-reconfigurable interleaver Architecture for High-performance SDR applications	Wireless Innovation Conference and Exposition (SDR'10)	Published	Washington , DC, USA	30 Nov. - 3 Dec. 2010
B. Zayen, W. Guibene, A.Hayar	Performance comparison for low complexity blind sensing techniques in cognitive radio systems	CIP'10, 2nd International Workshop on Cognitive Information Processing	Published	Elba Island, Tuscany, Italy	June 14-16, 2010,
W. Guibene, A. Hayar, M. Turki	Distribution discontinuities detection using algebraic technique for spectrum sensing in cognitive radio networks	CrownCom 2010, 5th International Conference on Cognitive Radio Oriented Wireless Networks and Communications	Published	Cannes, France	9-11 Juin 2010,
H. Moussavinik, W. Guibene, A., Hayar	Centralized Collaborative Compressed Sensing of Wideband Spectrum for Cognitive Radios	ICUMT 2010, International Congress on Ultra Modern Telecommunications (Telecommunications)	Published	Moscow, Russia	18-20 October 2010
W. Guibene, A. Hayar	Joint Time-Frequency Spectrum Sensing for Cognitive Radio	COGART 2010 3rd International Workshop on Cognitive Radio and Advanced Spectrum Management	Published	Rome, Italy	November 08-10, 2010
I. Harjula, A. Hekkala, M. Matinmikko, M. Mustonen	Performance Evaluation of Spectrum Sensing Using Welch Periodogram for OFDM Signals	VTC Spring 2011	Published	Budapest, Hungary	B-18 ay 2011
B. Zayen A. Hayar G. Noubir	Utility/Pricing-based Resource Allocation for Cognitive Radio Systems	The 2nd International Conference on Multimedia Computing and Systems	Published	Ouarzazate Morocco	07-09 April 2011
A. Hekkala, I. Harjula, D. Panaitopol, T. Rautio, R Pacalet	Cooperative Spectrum Sensing Study Using Welch Periodogram	11 <sup>th</sup> International Conference on Telecommunications (ConTEL)	Published	Graz, Austria	15-17 June 2011
U. Salim and	Mixed CSIT DL Channel: Gains with	VTC Spring 2011	Published	Budapest, Hungary	15-18 May 2011

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I. Ghauri	an Additional Receive Antenna				
R. Ghaffar, U. Salim, I. Ghauri and R. Knopp	Mixed CSIT DL Channel: Gains with Interference Aware Receivers	European Wireless 2011	Published	Vienna, Austria	27-29 April 2011
U. Salim	Achievable Rate Regions for Cognitive Radio Gaussian Fading Channels with Partial CSIT	IEEE SPAWC 2011	Published	San Francisco, USA	26-29 June 2011
I. Harjula, A. Hekkala	Spectrum Sensing in Cognitive Femto Base Stations Using Welch Periodogram	the ICT-ACROPOLIS Network of Excellence Workshop on "Cognitive Radio and Networking: Challenges and Solutions Ahead", being held at IEEE PIMRC 2011	Published	Toronto, Canada	11-14 September 2011
B. Zayen A. Hayar	A Performance Study of Kullback-Leibler Distance-based Spectrum Sensing Algorithm	ICUMT'11, 3rd IEEE International Conference on Ultra Modern Telecommunications.	Published	Budapest, Hungary	05-07 October, 2011
B. Zayen A. Hayar	On the Performance of Dimension Estimation-based Spectrum Sensing for Cognitive Radio	IEEE PIMRC'11, 22nd IEEE Symposium on Personal, Indoor, Mobile and Radio Communications,	Published	Toronto, Canada	11-14 September, 2011
R. R. Thomas B. Zayen R. Knopp B.T.J. Maharaj	Multiband Time-of-Arrival Positioning Technique for Cognitive Radio Systems	IEEE PIMRC'11, 22nd IEEE Symposium on Personal, Indoor, Mobile and Radio Communications,	Published	Toronto, Canada.	11-14 September, 2011
N. Milosevic, D. Panaitopol, A. Bagayoko	Wide-Band Cooperative Spectrum Sensing Method	CogART 2011	Published	Barcelona, Spain	26-29 October, 2011
D. Panaitopol, A. Bagayoko, N. Milosevic	Cooperative Spectrum Sensing Optimization under Different System Constraints	WCNC 2012	Rejected	Paris, France	1-4 April, 2012
A. Bagayoko, D. Panaitopol, P. Delahaye, C. Mouton	Spectrum Sensing Configuration Based on Detector Selection under Regulatory Constraints	WCNC 2012	Rejected	Paris, France	1-4 April, 2012
A. Jaschke, M. Schühler, R. Wansch	Digital Tunable LC Bandpass Filter	GeMIC 2012	Rejected	Illmenau, Germany	13-14 <sup>th</sup> March, 2012
A. Jaschke(SACRA), M. Tessema (QoS MOS), M. Schühler (QoS MOS), R. Wansch (SACRA)	Digitally Tunable Bandpass Filter for Cognitive Radio Application	17 <sup>th</sup> IEEE CAMAD 2012	Published	Barcelona, Catalonia, Spain	17 – 19 <sup>th</sup> September 2012
G., Wael, D. Slock	Spectrum sensing for cognitive radio exploiting spectral masks	CogART 2011, International Conference on Cognitive Radio and Advanced Spectrum Management	Published	Barcelona, Catalonia, Spain	October 26-29 October, 2011

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W. Guibene, H. Moussavinik, A. Hayar	Combined compressive sampling and distribution discontinuities detection approach to wideband spectrum sensing for cognitive radios	ICUMT 2011, International Conference on Ultra Modern Telecommunications,	Published	Budapest, Hungary	October 5-7, 2011
K. Chatzikokolakis, R. Arapoglou, A. Merentitis, N. Alonistioti	Fair Power Control in Cooperative Systems Based on Evolutionary Techniques	WCNC 2012	Rejected	Paris, France	1-4 April, 2012
B. Zayen, A. Hekkala	Design and Implementation of Spectrum Sensing Techniques using OpenAirInterface Platform	Future Network and Mobile Summit 2012	Rejected	Berlin, Germany	4 - 6 July 2012
V. T. Nguyen, F. Villain and Y. Le Guillou,	Cognitive Radio Systems: Overview and Challenges	Invited paper at 3rd International Conference on Awareness Science and Technology	Published	Dalian, China	Sep. 27-30, 2011
C. Jabbour, H. Fakhoury, V.-T. Nguyen and P. Loumeau	A Novel Design Methodology for Multiplierless filters	IEEE International Conference on Electronics, Circuits, and Systems	Published	Beirut, Lebanon	Dec. 11-14, 2011
C. Jabbour, H. A. Khushk, V.-T. Nguyen and P. Loumeau	High-Pass or Low-Pass $\Delta\Sigma$ Modulators?	IEEE International Conference on Electronics, Circuits, and Systems	Published	Beirut, Lebanon	Dec. 11-14, 2011
V.-T. Nguyen, H. A. Khushk, C. Jabbour and P. Loumeau	High Pass Filter Implementation Comparison in Unity STF High Pass $\Delta\Sigma$ Modulator	IEEE International Conference on Electronics, Circuits, and Systems	Published	Beirut, Lebanon	Dec. 11-14, 2011
C. Ouffoue, V.-T. Nguyen, C. Jabbour, H. Fakhoury, P. Loumeau	A Low Power RC Time Constant Auto-tuning circuit for RC-integrators in High Linearity Continuous-Time $\Sigma\Delta$ modulators	IEEE International NEW Circuits and Systems Conference	Published	Montréal, Canada	17-18 June 2012
L. Mouffok, AC. Lepage, J. Sarrazin, X. Begaud	A compact dual-band dual-port diversity antenna for LTE (700 MHz/2.5GHz)	Advanced Electromagnetics Symposium	Published	Paris, France	16-19 April 2012
F. Negro, U. Salim, I. Ghauri, D. Slock	The Noisy MIMO Interference Channel with Distributed CSI Acquisition and Filter Computation	Asilomar 2011, 45th Conference on Signals, Systems, and Computers	Published	CA, USA	November 6-9, 2011
R. Ghaffar, P.-H. Ho, U. Salim, B. Wu	Femtocell Networks: Breaking the Complexity of Centralized Processing with Novel Dual-Stage Receivers	WCNC 2012 Workshop on Broadband Femtocell Technologies - Broadband femtocell technologies	Published	Paris, France	1-4 April 2012
R. Ghaffar, U. Salim,	Near ML treatment of n Interferers with Linear Complexity	SPAWC 2012	Published	Cesme, Turkey	17-20 June 2012

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P.-H. Ho,					
N. Mahmood, G. Oien, L. Iundheim, U. Salim	A Relative Rate Utility based Distributed Power Allocation Algorithm for Cognitive Radio Networks	2012 International WDN Workshop on Cooperative and Heterogeneous Cellular Networks	Published	Sydney, Australia	9-12 September 2012
M. Cardone, D. Tuninetti, R. Knopp, U. Salim	On the Interference Channel with Causal Cognition	ICC 2013	Submitted	Budapest, Hungary	9-13 June 2013
M. Cardone, D. Tuninetti, R. Knopp, U. Salim	Gaussian Half-Duplex Relay Channels: Generalized Degrees of Freedom and Constant Gap Results	ICC 2013	Submitted	Budapest, Hungary	9-13 June 2013
M. Cardone, D. Tuninetti, R. Knopp, U. Salim	The capacity of the Gaussian Half-Duplex Multiple-Relay Network to within a Constant Gap	ICC 2013	Submitted	Budapest, Hungary	9-13 June 2013
B. Kouassi, B. Zayen, I. Ghauri, L. Deneire	Reciprocity calibration techniques, implementation on the OpenAirInterface platform	CogART'11, 4th International Conference on Cognitive Radio and Advanced Spectrum Management	Published	Barcelona, Spain	26-29 October 2011
B. Kouassi, I. Ghauri, B. Zayen, L. Deneire	On the Performance of Calibration Techniques for cognitive radio systems	WPMC'11, 14th International Symposium on Wireless Personal Multimedia Communications	Published	Brest, France	3-7 October 2011
C. Bonnet, D. Camara, R. Ghaddab, L. Iacobelli, F. Kaltenberger, R. Knopp, B. Mercier, N. Nikaein, D. Nussbaum, E. Yilmaz, B. Zayen	Sensor network aided agile spectrum access through low-latency multi-band communications	DCOSS'11, 7th IEEE International Conference on Distributed Computing in Sensor Systems	Published	Barcelona, Spain	27-29 June 2011
C. Bonnet, D. Camara, R. Ghaddab, A. Hayar, L. Iacobelli, F. Kaltenberger, R. Knopp, B. Mercier, N. Nikaein, D. Nussbaum, E. Yilmaz, B. Zayen	OpenAirInterface and Agile Spectrum Access	Dyspan 2011, 7th IEEE Symposium on Dynamic Spectrum Access Networks	Published	Aachen, Germany	03-06 May 2011
Bassem Zayen, Aawatif Hayar	Dimension Estimation based Detector for Multiple-Antenna Cognitive Radio Networks	ICT2012, 19th International Conference on Telecommunications	Published	Jounieh, Lebanon	23-25 April 2012
Negro, Francesco; Ghauri, Irfan; Slock, Dirk T M	Spatial interweave for a MIMO secondary interference channel with multiple primary users	CogART 2011, International Conference on Cognitive Radio and Advanced Spectrum Management,	Published	Barcelona, Spain	October 26-29 October, 2011,



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Gallo, Laurent; Negro, Francesco; Ghauri, Irfan; Slock, Dirk T M	Weighted sum rate maximization in the underlay cognitive MISO interference channel	PIMRC 2011, 22nd Annual IEEE International Symposium on Personal, Indoor and Mobile Radio Communications,	Published	Toronto, Canada	September 11-14, 2011
- Negro, Francesco; Ghauri, Irfan; Slock, Dirk T M	Deterministic annealing design and analysis of the noisy MIMO interference channel	ITA 2011, IEEE Information Theory and Applications Workshop, February 6-11, 2011, San Diego, CA, USA , pp 1-10	Published	San Diego, CA, USA	February 6-11, 2011
A. Bagayoko, D. Panaitopol, P. Delahaye, C. Mouton	A novel architectural framework and configuration scheme for spectrum sensing	CROWNCOM 2012, 7th IEEE International Conference on Cognitive Radio Oriented Wireless Networks	Published	Stockholm, Sweden	June 18-20, 2012
A. Marzouki, X. Jin	Precoder Design for Orthogonal Space-Time Block Coding based Cognitive Radio with Polarized Antennas	International Symposium on Wireless Communication Systems 2012 (ISWCS 2012)	Published	Paris, France	August 28-31, 2012
D. Panaitopol, A. Bagayoko, N. Milosevic	Cooperative Spectrum Sensing Optimization under Different System Constraints	International Symposium on Wireless Communication Systems 2012 (ISWCS 2012)	Published	Paris, France	August 28-31, 2012
D. Panaitopol, A. Bagayoko, C. Mouton, P. Delahaye, G. Abril	Primary User Identification when Secondary User is Transmitting without using Quiet Period	12th International Symposium on Communications and Information Technologies (ISCIT 2012)	Published	Australia	October 2-5, 2012
Guibene, Wael; Hayar, Aawatif; Turki, Monia; Slock, Dirk T M	A complete framework for spectrum sensing based on spectrum change points detection for wideband signals	VTC 2012-Spring, IEEE 75th Vehicular Technology Conference	Published	Yokohama, Japan	May 6-9, 2012
Ben Jemaa, Amira; Turki, Monia; Guibene, Wael	Enhanced energy detector via algebraic approach for spectrum sensing in cognitive radio networks	CROWNCOM 2012, 7th IEEE International Conference on Cognitive Radio Oriented Wireless Networks	Published	Stockholm, Sweden	June 18-20, 2012
Guibene, Wael; Slock, Dirk TM	Signal separation and classification algorithm for cognitive radio networks	ISWCS 2012, 9th International Symposium on Wireless Communication Systems	Published	Paris, France	August 28-31, 2012
Guibene, Wael; Slock, Dirk TM	A compressive sampling approach for spectrum sensing and terminals localization in cognitive radio networks	CAMAD 2012, IEEE 17th International Workshop on Computer Aided Modeling and Design of Communication Links and Networks	Published	Barcelona, Spain	September 17-19, 2012
Guibene, Wael; Slock, Dirk TM	A combined spectrum sensing and terminals localization technique for cognitive radio networks	WIMOB 2012, 8th IEEE International Conference on Wireless and Mobile Computing, Networking and Communications	Published	Barcelona, Spain	October 8-10, 2012
K. Chatzikokolakis, R. Arapoglou, A. Merentitis,	Fair Power Control in Cooperative Systems	UBICOMM 2012, 6th International Conference on Mobile Ubiquitous Computing, Systems, Services and	Published	Barcelona, Spain	September 23-28, 2012

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N.Alonistioti	Based on Evolutionary Techniques	Technologies			
J. Gonzalez-Pina, R. Ameur-Boulifa, R. Pacalet	DiplodocusDF, a domain-specific modelling language for software defined radio applications	SEAA'2012, 38th Euromicro Conference on Software Engineering and Advanced Applications	Published	Cesme, Izmir, Turkey	September 5-8, 2012
Y. Lejosne and D.T.M. Slock and Y. Yuan-Wu	On Greedy Stream Selection in MIMO BC	EEE WCNC Workshop on 4G Mobile Radio Access Networks	Published	Paris, France	2012
Amara, Mustapha; Slock, Dirk T M; Yuan-Wu, Yi	Recursive stream selection for CF MU-MIMO BC precoders design	ISIT 2011, IEEE International Symposium on Information Theory	Published	Saint-Petersburg	July 31-August 5, 2011
Negro, Francesco; Ghauri, Irfan; Slock, Dirk T M	Sum rate maximization in the noisy MIMO interfering broadcast channel with partial CSIT via the expected weighted MSE	ISWCS 2012, 9th International Symposium on Wireless Communication Systems	Published	Paris, France	August 28-31, 2012
Zayen, Bassem; Kouassi, Boris; Knopp, Raymond; Kaltenberger, Florian; Slock, Dirk; Ghauri, Irfan; Deneire, Luc	Software implementation of spatial interweave cognitive radio communication using OpenAirInterface platform	ISWCS 2012, 9th International Symposium on Wireless Communication Systems	Published	Paris, France	August 28-31, 2012
Lejosne, Yohan; Slock, Dirk T M	Degrees of freedom in the MISO BC with delayed-CSIT and finite coherence time: a simple optimal scheme	ICSPCC 2012, IEEE International Conference on Signal Processing, Communications and Control	Published	Hong Kong	August 12-15, 2012
Slock, Dirk T M	Location aided wireless communications	ISCCSP 2012, 5th International Symposium on Communications Control and Signal Processing	Published	Rome, Italy	May 2-4, 2012
Negro, Francesco; Slock, Dirk T M ; Ghauri, Irfan	On the noisy MIMO interference channel with CSI through analog feedback	ISCCSP 2012, 5th International Symposium on Communications Control and Signal Processing	Published	Rome, Italy	May 2-4, 2012

### 3.2.2 Fora and Concertation Meetings

Authors	Title	Fora and Concertation Meetings	Loc.	Date
D. Merel	SACRA - Spectrum and Energy Efficiency through multi-band Cognitive Radio	Future Networks 5th FP7 Concertation Meeting	Brussels	Jan 27 <sup>th</sup> , 2010
D. Merel	SACRA - Spectrum and Energy Efficiency through multi-band Cognitive Radio	RAS Workshop on Cognitive Radio	Brussels	Jan 28 <sup>th</sup> , 2010
P. Spapis, S. Leveil, Ph. Delahaye	SACRA - Spectrum and Energy Efficiency	ICT 2010 – Regulatory and Technological Requirements for	Brussels	Sept. 28 <sup>th</sup> , 2010

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	through multi-band Cognitive Radio	Cognitive Radio		
S. Leveil	SACRA – Use Cases and Requirements	Future Networks 6th FP7 Concertation Meeting - RAS cluster meeting	Brussels	Oct 20 <sup>th</sup> , 2010
W. Guibène		GDR ISIS workshop - <i>10 ans de Radio Intelligente : bilan et perspectives</i>	Paris	May 9th, 2011
P. Loumeau	<i>Etat de l'art des architectures des récepteurs, évolution vers plus de flexibilité</i>	GDR SoC-SiP workshop - <i>Les évolutions du Front-End RF pour la Radio Cognitive et la Radio opportuniste</i>	Paris	May 10th, 2011
V.Rekkas	ICT SACRA Green Radio and Energy Efficiency	Invited paper at the workshop on Green Radio at Wireless Innovation Forum European Conference	Brussels	June 22 <sup>nd</sup> – 24 <sup>th</sup> , 2011
S. Leveil	SACRA - Spectrum and Energy Efficiency through multi-band Cognitive Radio - Cognitive spectrum aggregation	Future Networks 8th FP7 Concertation Meeting - RAS cluster meeting	Brussels	Oct 6 <sup>th</sup> , 2011
A.Jaschke	SACRA - Spectrum and Energy Efficiency through multi-band Cognitive Radio - Cognitive spectrum aggregation	COGEU Workshop - Can Europe make use of TV White Spaces?	Munich	Nov10 <sup>th</sup> , 2011

### 3.2.3 Scientific Journals

Authors	Title	Journal Name	Status
A. Hekkala, A. Kotelba, M. Lasanen, P. Järvensivu, A. Mämmelä	Novel Digital Compensation Approaches for Envelope Tracking Amplifiers	Wireless Personal Communications	Published online: 29 May 2010. In print: Volume 62 (2012), Number 1, pp. 55-77, DOI: 10.1007/s11277-010-0038-0.
B. Zayen A. Hayar G. Noubir	Game Theory-based Resource Management Strategy for Cognitive Radio Networks	Journal of Multimedia Tools and Applications	Published online: 08 September 2012 DOI: <a href="http://dx.doi.org/10.1007/s11042-012-1211-0">http://dx.doi.org/10.1007/s11042-012-1211-0</a>
B. Zayen A. Hayar	Dimension Estimation-based Spectrum Sensing for Cognitive Radio	EURASIP Journal on Wireless Communications and Networking	Published online: 24 February 2012 DOI:10.1186/1687-1499-2012-64
W. Guibene M. Turki B. Zayen A. Hayar	Spectrum Sensing for Cognitive Radio Exploiting Spectrum Discontinuities Detection	EURASIP Journal on Wireless Communications and Networking	Published online: 09 January 2012 DOI:10.1186/1687-1499-2012-4

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BassemZayen AawatifHayar	Primary Outage- based Resource Allocation Strategies	Chapter book in "Cognitive Radio Systems", InTech, Ed. Samuel Cheng, ISBN 978- 953-308-70-9	Published Available online: <a href="http://www.intechopen.com/books/foundation-of-cognitive-radio-systems/primary-outage-based-resource-allocation-strategies">http://www.intechopen.com/books/foundation-of-cognitive-radio-systems/primary-outage-based-resource-allocation-strategies</a> DOI: 10.5772/31063.
UmerSalim, Dirk Slock	Average minimum transmit power to achieve SINR targets: performance comparison of various user selection algorithms	EURASIP Journal on Wireless Communications and Networking 2011, 2011:127	Published
Umer Salim, David Gesbert, Dirk Slock	Combining Training and Quantized Feedback in Multi- Antenna Reciprocal Channels	IEEE Transactions on Signal Processing	Published March 2012. Volume 60, Issue 3, pp. 1383 - 1396 DOI:10.1109/TSP.2011.2178841
Rizwan Ghaffar, Umer Salim, Pin-Han Ho, Hong Wen	On Managing Interferences under Heterogeneous Broadcast Channel for Multi- User Transmission	IEEE Transactions on Wireless Communications	Accepted on October 2012
L. Mouffok, A. C. Lepage, J. Sarrazin, X.Begaud	A compact dual- band dual-port diversity antenna for LTE	Advanced Electromagnetics (AEM)	Published <a href="http://aemjournal.org/index.php/AEM/article/view/42">http://aemjournal.org/index.php/AEM/article/view/42</a>
L. Mouffok, A. C. Lepage, J. Sarrazin, X.Begaud	Compact dual- band dual- polarized antenna for MIMO LTE applications	International Journal of Antennas and Propagation Special issue "Advances in Antenna Technology for Wireless Handheld Devices"	Published <a href="http://downloads.hindawi.com/journals/ijap/2012/398423.pdf">http://downloads.hindawi.com/journals/ijap/2012/398423.pdf</a>
C. Jabbour, H. Khushk, Van Tam Nguyen, P. Loumeau	A comparison between high-pass and low-pass Delta Sigma modulators	International Journal of Analog Integrated Circuits and Signal Processing	PublishedSubmitted last July 2012 <a href="http://link.springer.com/content/pdf/10.1007%2Fs10470-012-9920-x">http://link.springer.com/content/pdf/10.1007%2Fs10470-012-9920-x</a>
K.Chatzikokolakis, P.Spapis, M.Stamatelatos, G.Katsikas, R.Arapoglou, A. Kaloxylos, N.Alonistioti	Spectrum Aggregation in Cognitive Radio Access Networks: business and power control aspects	Chapter book in "Evolution of Cognitive Networks and Self-Adaptive Communication Systems", IGI Global	Accepted on December 2012

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### 3.2.4 Open source software and related activities

Software defined and cognitive radio systems rely on flexible RF front ends and digital baseband processors. The typical baseband processor for such applications is a complex mixture of hardware accelerators and micro-processors. The target baseband processor of the SACRA project comprises the ExpressMIMO platform developed by IT and EURE. Designing the software layers for this kind of platform is very challenging. WP5 activities aimed at providing a software design framework for the specification, modelling, design and validation of the baseband software.

A software library named EMBB (ExpressMimoBaseBand) has been designed by IT. EMBB is the basic building block on top of which SACRA baseband applications have been developed. The library is available in two different flavors, one synchronous and the other asynchronous. In the synchronous version, operations are sequential only and the high level of parallelism of the target hardware is underused. Apart this performance aspect, the function is accurately represented. This mode is mainly used for validation of the processing chain. In asynchronous mode operations can be parallelized and the programmer uses several extra time-related primitives to synchronize them. The primitives are exported by an underlying tiny operating system named MutekH (<http://www.mutekh.org/>) distributed under the GNU GPL license, version 2. The asynchronous mode is used for the final version of the application. EMBB is also available with two targets, a regular desktop PC (emulation) and the ExpressMIMO platform (actual final target). The same application runs unmodified on both. An asynchronous application will behave differently because the true parallelization on a desktop PC depends on the number of cores / processors while on ExpressMIMO it is directly related to the available processing units. All these features will ease the debugging and speedup the whole software design cycle. EMBB is distributed under the CeCILL license (<http://www.cecill.info/index.en.html>), a French equivalent of the GNU GPL.

Along EMBB, IT has developed a UML-based design framework in order to further improve and secure the software design tasks. This framework is based on TTool (<http://labsoc.comelec.enst.fr/turtle/ttool.html>), another open source tool developed and maintained by IT and also distributed under the CeCILL license. A companion formal UML profile allows designers to represent their baseband applications and the related performance requirements as UML diagrams. The main benefit is a higher level of abstraction (more low-level details will be hidden, like memory management and scheduling). IT has investigated ways to conduct formal static analysis, ultra-fast simulations and code generation of the embedded software, again based on the EMBB library. All these developments and the UML-based design framework will be released under the same CeCILL license.

Thanks to the chosen licenses the visibility of these outcomes of SACRA shall increase. It is also expected that contributors, even not members of the SACRA consortium, will help improving the library and the toolkit. Porting them on different baseband processors could, for instance, is a very interesting extension.

### 3.2.5 Courses and Lectures

As indicated in the technical annex of the project, the intention has been to enhance the curricula offered at the partner universities using the SACRA project outcomes. SACRA results and know-how have and will be included as part of graduate and postgraduate courses.

Institut Telecom has opened a training session (continuous education, in-service training) on "opportunistic and cognitive radio: challenges, constraints and perspectives" from September 28th to September 29th 2010. This session has attracted trainees from various players in the telecom industry.

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#### Abstract of the session:

*“The demand for seamless connectivity and the proliferation of standards, and the need for optimal management of the spectrum leads to the concept of cognitive radio where reconfiguration decisions are made based on the optimum conditions of connectivity and spectrum availability. The ultimate evolution of opportunistic radio is when the decision and intelligence are decentralized at the terminal. However, the deployment of these systems still raises many technical challenges. This course covers the deployment of the opportunistic radio terminals at: innovative approaches to managing the flexibility of the spectrum, the optimized design of front-end components, both in reception and transmission, and development of an embedded and powerful platform.”*

The session covered first the landscape of cognitive radio systems, spectrum access schemes classification; policy defined cognitive radio and standardization of cognitive radios. Then spectrum management models, dynamic spectrum allocation and usage scenarios were studied. Following the course is to study the antenna, in particular the design and choice of antenna and Smart Antenna. And then radio frequency transceivers for cognitive radio terminals are presented including CR requirements and bottlenecks and future directions. Strategies, algorithms for spectrum sensing in cognitive radio are also presented before the elements of modern Software Defined Radio Architectures - RF, Baseband DSP and Embedded Software.

The content of this course through SACRA project and others projects related to cognitive radio systems is going to be periodically enriched and will be open once every year.

In June 2011, an engineer – system architect from IMC (formerly Infineon Technologies France) came to give a two lectures on System in Package and System on Chip architecture for an UMTS WCDMA receiver at Telecom ParisTech / Institut Telecom. Another two lectures on RF transceiver architecture, design and challenges for cellular systems has been given by a former engineer – system architect from DMCE (formerly DICE). These lectures have been given to Ph.D students and Ms.C students from Telecom ParisTech / Institut Telecom.

In June 2011, three professors from Telecom ParisTech / Institut Telecom gave a tutorial on cognitive and opportunistic radio at The 9th IEEE International NEWCAS Conference. This tutorial has three parts. In the first part, an overview of cognitive radio systems is presented, some big challenges are pointed out, especially how to split the intelligence between cognitive terminals and cognitive networks; how to distribute cognitions between layers; the difference between opportunistic spectrum use, dynamic spectrum access and smart, context aware radio. The regulation and standardization status of cognitive radio systems, promising applications are also highlighted. The research challenges including implementation challenges in cognitive radio systems are finally presented.

The second part is focused on the flexible RF receiver. The goal has been to present the state of the art of the receiver architecture and evolution from RF sampling to Sigma Delta Receiver. There are a lot of solutions and this talk tried to classify them in terms of frequency plan, filtering techniques, continuous time or discrete time processing. The main topics are the agility and the power consumption.

The third part presented the new challenges in converter design due to cognitive radio requirements. Primarily, the challenges are caused by very large spectrum bandwidth (10 MHz up to 10 GHz) and no prior knowledge of interfering frequency bands. Therefore, wideband and high resolution converters are searched out with possibilities of reconfiguration to deal with the inherent trade-off between these two achievements. We will give an overview of the most promising ADC

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architectures for this goal: Pipeline, Parallel ADC, Sigma\_Delta and the required high performance ADC.

University of Athens (UoA) has been offering a couple of courses on cognitive radio issues both in theoretical basis and in implementation/simulation perspective. More specifically, the undergraduate course "Software Development in Telecommunication systems" consists of an extensive implementation of network functions, protocols and applications. This approach aims to familiarize the planning phase at different network levels. More specifically, it includes planning for fixed and mobile networks and future Internet applications, mobile and wireless systems. Applications and implementation also concern cognitive and reconfigurable environments and mobile and wireless communications (e.g. J2ME, Android). Finally, the development will be extended by using Web programming techniques to manage mobile devices (in a pre-simulation environment).

In October 2011, an assignment was given for the implementation and extension of a simplified Cognitive Pilot Channel, for the efficient communication among network devices with the existing radio access network technologies. More specifically, the scenario, students were urged to implement, is the efficient communication of heterogeneous terminal devices with existing communication infrastructure. For this reason, a simplified CPC channel must be developed and used so as terminals get informed for the existing network state.

A master thesis entitled "Energy efficient policies for power control in cognitive radio networks" has been concluded in terms of SACRA. The main outcome of this thesis was to quantify the benefits from the incorporation of policies in the Cooperative Power Control algorithm developed within SACRA. Furthermore, a bachelor thesis aiming at quantifying the cost of the incorporation of the genetic algorithms in terms of processing and memory cost, building on the top of the SACRA outcomes related to the SESC simulator has been assigned to an undergraduate student.

Furthermore, the postgraduate course "Advanced topics in wireless communication networks" has been offering a series of lectures in cognitive radio networks, since October 2010. Professor Nancy Alonistioti had given a series of introductory lectures in order to present cognitive radio issues. In addition, students are invited to search for topics and state of the art in order to make their own presentations. Indicatively, a series of topics covered are "Spectrum management framework in cognitive radios", "Infrastructure for cognitive networks", "4G LTE analysis and challenges", "Reconfigurable hardware systems" and "Cloud RAN".

### 3.2.6 Exhibitions

Authors	Title	Fora and Concertation Meetings	Loc.	Date
S. Leveil, D. Nussbaum, B. Zayen	SACRA - Spectrum and Energy Efficiency through multi-band Cognitive Radio	Demonstration stand in the Exhibition at Future Network and Mobile Summit 2011	Warsaw, Poland	June 15 <sup>th</sup> -17 <sup>th</sup> , 2011
C. Bonnet D. Camara R. Ghaddab L. Iacobelli F. KALTENBERGER R. KNOPP	Sensor Network aided Agile Spectrum Access through Low-Latency Multi-Band Communications	demonstration at IEEE DCOSS 2011	Barcelona, Spain	June 27th-29th, 2011

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B. MERCIER N. NIKAEIN D. NUSSBAUM E. YILMAZ B. ZAYEN				
W. Guibene, D. Slock	Spatial Interweave Demo	ETSI Workshop on RRS	Cannes, France	December 12, 2012

### 3.2.7 Workshops

Workshops enable better understanding of views, ideas, and outcomes. Towards this direction SACRA project, in order to enable and trigger further development of algorithms and hardware technologies has successfully organized the first Workshop on “Experimental platforms for 4G and beyond wireless systems”. In this workshop the project achievements and key features have been presented and its results and aims at providing a landscape of the most advanced Hardware and Software platforms for the experimentation of post 4G systems, in numerous fields such as Cognitive Radio, Green Radio, Software Defined Radio, new networks topologies have been demonstrated. The workshop is also seen as a forum for both developers and users of the platforms to share their research results, and discuss problems and new developments. The technical focus of the workshop was the End-to-End wireless communication, from antenna design up to high layers in the protocol stacks. Several platforms have been demonstrated and real-time communications have been performed during the demonstration part of the Workshop.

The workshop took place on the 23rd of February, 2012, in the “Centre International de Communication Avancée”, 2229 Route des Crêtes, 06560, Valbonne, Provence-Alpes-Côte d'Azur, France. The Program is presented below in Figure 1.



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Workshop Agenda		
Experimental platforms for 4G and beyond wireless systems		
09:30 - 10:00	Registration	
10:00 - 11:50	Presentations: session #1	
10:00 - 10:10	Welcome to the SACRA workshop 2012	Stéphanie Leveil (Thales Communications & Security)
10:10 - 10:30	SACRA modem presentation	Andreas Mayer (Danube Mobile Communications Engineering)
10:30 - 10:50	EMBB: a hardware/software architecture for Software Defined Radio baseband	Renaud Pacalet (Télécom ParisTech)
10:50 - 11:10	Presentation on SDR4all	Sylvain Azarian (Supélec)
11:10 - 11:30	CEA presentation (Magali/ARTIST 4G)	Fabien Clermidy (CEA-LETI)
11:30 - 11:50	FARAMIR presentation	Janne Riihijärvi (RWTH Aachen University)
12:00 - 13:30	Lunch at Oasis Restaurant of Mediagarden hotel ( <a href="http://www.mediathel.com">http://www.mediathel.com</a> )	
13:40 - 15:20	Presentations: session #2	
13:40 - 14:00	COGEU: the low fares spectrum for 4G	Paulo Marques (Instituto de Telecomunicações)
14:00 - 14:20	HDCRAM Management for Cognitive Radio Real-Time Demos with USRP	Amor Nafkha (Supélec)
14:20 - 14:40	The CROWN FET project: Spatial Cognitive Radio	Dirk Slock (EURECOM)
14:40 - 15:00	C2POWER: Cooperative Algorithms towards Energy Savings: Evaluation and Business Models	Ayman Radwan (Instituto de Telecomunicações)
15:00 - 15:20	CONNECT presentation	Raymond Knopp (EURECOM)
15:30 - 17:30	DEMONSTRATION SESSION and Networking	
	SACRA RF modem building blocks	SACRA
	SYMPA main prototyping results	SYMPA
	HDCRAM Management for Cognitive Radio Real-Time Demos with USRP	SUPELEC
	The COGEU TV white spaces database and spectrum broker	COGEU
		CROWN
		CEA-LETI
		SDR4ALL

Figure 1: Workshop Agenda

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## 4 STANDARDIZATION

### 4.1 IDENTIFICATION OF RELATED STANDARDIZATION BODIES

SACRA consortium has currently selected ETSI RRS as initial target for the standardization of the project's outcomes, while monitoring the progress and roadmaps of other potential targets, namely IEEE P1900.4 and 3GPP. Hereafter, the following sections are describing the scope of these main standardization bodies and give a view on how SACRA project has contributed.

#### 4.1.1 Scope of IEEE SCC41 and potential SACRA contributions

IEEE Standards Coordinating Committee 41 (SCC41) is seeking proposals for standards projects in the areas of dynamic spectrum access, cognitive radio, interference management, coordination of wireless systems, advanced spectrum management, and policy languages for next generation radio systems. SCC41 is particularly interested in ideas that could be implemented in commercial products in the near to medium term.

IEEE 1900.4 WG was previously sponsored by SCC41 of IEEE Standards Association Standards Board (SASB). In December 2010, SCC41 was re-organised and renamed as DySPAN Standards Committee (DySPAN-SC) which is sponsored by the Communication Society (ComSoc) of IEEE and under the regulation of the IEEE SASB. However, this structure change doesn't affect actual activities of 1900.4 WG.

DySPAN WG4 is a working group aiming at defining "Architectural Building Blocks Enabling Network-Device Distributed Decision Making for Optimized Radio Resource Usage in Heterogeneous Wireless Access Networks". A standard, IEEE 1900.4-2009, has been published in February 2009. This standard defines the architectural building blocks, the interfaces, the information model and the procedures for optimized radio resource usage in heterogeneous wireless access networks. From April 2009, 1900.4 Working Group works on two projects:

- 1900.4a: Standard for Architectural Building Blocks Enabling Network-Device Distributed Decision Making for Optimized Radio Resource Usage in Heterogeneous Wireless Access Networks - Amendment: Architecture and Interfaces for Dynamic Spectrum Access Networks in White Space Frequency Bands. This standard amends the IEEE 1900.4 standard to enable mobile wireless access service in white space frequency bands without any limitation on used radio interface (physical and media access control layers, carrier frequency, etc) by defining additional components of the IEEE 1900.4 system. The P1900.4a system aims at enabling the coexistence of secondary systems operating in white spaces by providing the Base Stations (Cognitive Base Stations – CBSs – in the P1900.4a terminology) and the terminals with the following capabilities: spectrum sensing control, silent period management, white space classification and access to white space database.
- 1900.4.1: Standard for Interfaces and Protocols Enabling Distributed Decision Making for Optimized Radio Resource Usage in Heterogeneous Wireless Networks. This project aims at defining the protocols and the Service Access Points (SAPs) associated with the interfaces standardized in IEEE 1900.4-2009. Some of these protocols and SAPs are likely to be reused in the P1900.4a system.

The specification IEEE Std 1900.4a-2011 related 1900.4a project was published on 16th September. In terms of P1900.4.1 project, the work is continuing with the specification of I/F and

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protocols for optimized resource usage in heterogeneous networks. The consortium did not see any complementary effort for standardization in this remaining project because the subject is not addressed by SACRA project. The consortium may consider a follow-up of P1900.4a project to define the interface and protocols for the mobile wireless access use case in white space frequency bands. But in the other hand, although P1900.4a is a well advanced standard for WS operation, it does not seem to have raised enough interest in the industry and its market and future is unclear. P1900.4.1 work is still in progress but there was no contribution and there are no clear intentions from the floor. Finally, the partners involved in this group will review the situation later on in order to complement the effort of standardization if the viability of the group is recognized.

#### **4.1.2 Scope of 3GPP Release 11+ and potential SACRA contributions**

The 3rd Generation Partnership Project (3GPP) is a collaboration agreement that was established in December 1998. The collaboration agreement brings together a number of telecommunications standards bodies which are known as 'Organizational Partners'. The current Organizational Partners are ARIB, CCSA, ETSI, ATIS, TTA, and TTC.

The current scope of 3GPP is to produce globally applicable Technical Specifications and Technical Reports for a 4rd Generation Mobile System based on 3G core networks and the radio access technologies that they support. Concerning the current release 11, the work items can be found in the current work plan[7]. The status of Features being developed under the current work plan can be found in the summary presentation to the most recent TSG SA meeting and the overview of the 3GPP Release 11 is available on-line [8].

Related to the SACRA scenario, two work items related to carrier aggregation are recognized of interest by the SACRA consortium. The consortium reviewed the possible opportunities in 3GPP release 11, whose requirement phase (stage 1) has started in November 2010 and this release is due to be "frozen" (essentially complete) in November 2012. Carrier Aggregation (CA) in LTE is a feature supported from Rel-10. In Carrier Aggregation (CA), two or more component carriers (CCs) are aggregated in order to support wider transmission bandwidths (up to 100MHz). CA is supported for both contiguous and non-contiguous CCs. In Release 11, the objectives of the first WI are to identify required performance measurements and KPIs to support CA management, specify required configurations for CA management, identify the use cases and requirements for SON functionality Self-establishment of eNodeB, and Self-healing in CA, identify the use cases and requirements for Energy Saving in CA and provide solution extensions. The objectives of second WI related to CA enhancement are to specify the support of the use of multiple timing advances in case of LTE uplink carrier aggregation and identify details for the enhancements methods in the related signalling for the use of LTE carrier aggregation to be specified through tradeoff analyses.

In terms of Release 12, there is no item related to carrier aggregation. In this current context, release 11 and 12 are frozen and didn't contain any item related to the extension of CA concept with opportunist carrier component in the TV White space band. SACRA consortium didn't see any forward to contribute to 3GPP for the lifetime of the project. Based on the review of ETSI RRS, ETSI RRS is an appropriate vehicle for the definition of CA enhancement in TVWS Band before any SI or WI will be created in the next release.

#### **4.1.3 Scope of ETSI RRS and potential SACRA contributions**

The European Telecommunications Standards Institute (ETSI) [5] produces globally-applicable standards for Information and Communications Technologies (ICT), including fixed, mobile, radio, converged, broadcast and internet technologies. ETSI is officially recognized by the European

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Union as a European Standards Organization. ETSI is a not-for-profit organization with more than 700 ETSI member organizations drawn from 62 countries across 5 continents world-wide.

ETSI RRS (Reconfigurable Radio Systems) is an ETSI Technical Committee (TC) working on standardizing Software Defined Radio and Cognitive Radio. TC RRS is responsible for standardization activities related to Reconfigurable Radio Systems encompassing both Software Defined Radio (SDR) and Cognitive Radio (CR). In this context, TC RRS is taking into account all the related requirements from relevant stakeholders, as well as the work done in other fora on the same subject in order to avoid overlapping activities in the overall standardization process in Software Defined Radio and Cognitive Radio.

ETSI RRS TC is composed of the following four Working Groups (WGs) [6], in which the technical discussions are organized and reports are produced (see Figure 2 below):

- **WG1** focuses on “**System Aspects**” and develops proposals from a system aspects point of view for a common framework in TC RRS with the aims to guarantee coherence among the different TC RRS WGs and to avoid overlapping and gaps between related activities.
- **WG2** focuses on SDR technology with a particular interest in “**Radio Equipment Architecture**” and proposes common reference architectures for SDR/CR radio equipments (mobile handset devices, radio base stations, etc.), related interfaces, etc.
- **WG3** focuses on “**Cognitive Management and Control**”; the group collects and defines the system functionalities for Reconfigurable Radio Systems which are related to the Spectrum Management and Joint Radio Resource Management across heterogeneous access technologies. Furthermore, the group has developed a Functional Architecture for the Management and Control for Reconfigurable Radio Systems as well as a report on the Cognitive Pilot Channel as an enabler to support the management of the RRS.
- **WG4** focuses on “**Public Safety**” and collects and defines the related RRS requirements from relevant stakeholders in the Public Safety and Defense domain. The group defines the system aspects for the applications of RRS in Public Safety and Defense.

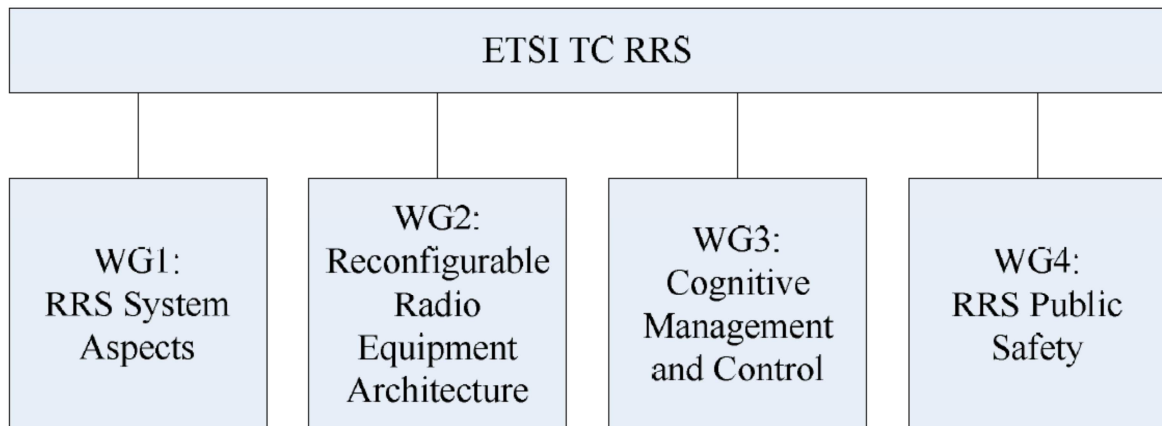


Figure 2: ETSI RRS structure.

Corresponding working items are active in the mentioned working groups, working on respective Technical Reports (TRs) and Technical Specifications (TS). In 2011, the following TRs are available as published deliverables of ETSI TC RRS:

- TR 102 839 “Multiradio Interface for SDR MD Architecture and Services”
- TR 103 064 “Business and cost considerations for RRS in Public Safety”

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- TR 103 062 “Definition of refined Scenarios and Use Cases for Software Defined Radio (SDR) Reference Architecture for Mobile Device”
- TR 102 907 “Use Cases for Operation in White Space Frequency Bands”
- TR 103 063 “Use Cases for Reconfigurable Radio Systems operating in IMT bands and GSM bands for intra-operator scenarios”

ETSI RRS considers the introduction of Cognitive Radio Systems (CRS) as a whole based on a top-down approach. Recently, ETSI RRS has achieved major progress in the areas of TVWS usage, in particular with a focus on the adaptation of existing and/or evolving Radio Standards, such as 3GPP Long Term Evolution (3GPP LTE), to a possible operation in UHF White Space bands.

For the time being, ETSI RRS are working on several work items which are of interest for SACRA and in which SACRA consortium contributed:

- WI “Operation in White Space Frequency Bands”, producing TR102.907. The scope of the present document is to describe Use Cases for the operation of Reconfigurable Radio Systems within White Spaces in the UHF 470-790 MHz frequency band and gives an overview on methods for protecting the primary/incumbent users like TV broadcasts and wireless microphones.

SACRA partner already contributed to this technical specification. Various use cases have been included in the TR 102 907 “Operation in White Space Frequency Bands” classified in distance (e.g., short range, middle range and long range) and in applications (e.g., ad-hoc). As foreseen for SACRA system, carrier aggregation, known as the main feature of 4G systems which is being standardized in 3GPP as part of Release 10, could be extended to include the aggregation of the opportunistic UHF TV WS band to provide maximum flexibility in utilizing the scarce radio spectrum.

This report is finalized and approved by WG1 in the teleconference, June 22. It is also approved during the ETSI RRS#15 plenary meeting in September 2011.

- WI proposal on Feasibility study on Radio Frequency (RF) performances for secondary systems operating in UHF TV band White Spaces. The scope of WI proposal is the RF performance analysis for systems operating in TV WS. The three main aspects of this WI are to study:
  - Advanced sensing techniques for incumbent protection (for instance multi-node sensing solutions have not been considered yet by CEPT).
  - Sensing techniques that could be specific to the technology used in an area outside of Europe. ETSI addresses a global standard, thus it is relevant to investigate solutions for Asia, China and America which have different incumbent wireless technology.
  - RF Solutions for coexistence between secondary systems.

In WP2 SACRA partners have considered advanced sensing techniques taking advantage of cooperation between several sensing nodes. These studies put SACRA partners in a position to contribute to this RRS Work item, disseminating the most promising cooperative sensing techniques and signal classification techniques for incumbent protection.

- WI on TS 102 946 “System Requirements for Operation in White Space Frequency Bands”

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The scope of this technical specification is to define the system requirements for operation of secondary Reconfigurable Radio Systems within UHF TV band white spaces. The requirements are based from the use cases described in Technical Report 102 907 "Use cases for Operation in White Space Frequency Bands". SACRA partner contributed to the definition of functional requirements for carrier aggregation in TVWS which fall into the Spectrum Management Requirements section of TS 102 946. In addition, requirements for LTE operation in TVWS are presented for the Radio Access Requirements Section.

As a next step, after having progressed with the work on use cases and requirements definition, ETSI RRS plans to create new work items on the definition of the architecture and protocols for Cognitive radio systems operating in TVWS band and associated Cognitive Management and Control mechanism definition. It will bring new opportunities for SACRA partners to contribute based on WP1 and WP3 outcomes. This work is intending to be continued within the Coordination and Support Action (CRS-i) funded during the FP7 call 8 call for tender.

## 4.2 PARTICIPATION TO STANDARDIZATION AND REGULATION MEETINGS

Authors	Title	Standardization Meetings	Loc.	Date
D. Nussbaum, S. Leveil	Presentation of "SACRA - Spectrum and Energy Efficiency through multi-band Cognitive Radio"	ETSI RRS#11	Sophia-Antipolis	Sept 7 <sup>th</sup> -9 <sup>th</sup> 2010
Philippe Delahaye	Contribution on Opportunistic Carrier Aggregation into TR 102.907: Carrier aggregation between Component Carriers from IMT and TV WS bands	ETSI RRS#12	Munich	Nov 22nd-25th 2010
Christian Mouton	SACRA Spectrum and Energy Efficiency through Multi-Band Cognitive Radio IEEE DYSPAN standards Committee – Working Group 6	kick-off meeting of new project (DySPAN P1900.6a)	Brussels	21 June 2011
Philippe Delahaye	Joint Contribution on definition of functional requirements for carrier aggregation in TVWS and requirements for LTE operation in TVWS for TS 102 946.	RRS1-RRS3-Conf call	Audio-conference	22 June 2011

Authors	Title	Regulator	Loc.	Date
Stéphanie Leveil	SACRA use cases and requirements	Agence Nationale des Fréquences (ANFR) - French Radio Spectrum Assignment Authorities	Maison-Alfort	November 2nd, 2010

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## 5 LIST OF EXPLOITABLE PROJECT RESULTS AND THEIR USE

### 5.1 MAIN TYPE OF FOREGROUND

This chapter identifies the different types of foreground produced during the project implementation phases. It highlights the achievements that are of interest for a future use or reuse by the consortium members.

#### 5.1.1 RRM techniques

##### Description of the CRRM

The overall CRRM system is composed of a hierarchy of algorithms, each contributing a key aspect in the complete cognitive radio resource management framework. The proposed CRRM algorithms cover a number of the SACRA target objectives.

A detailed description of these algorithms is provided in WP3, deliverable D3.2. A summarized list is given below:

- Sensing configuration
- Distributed primary users and secondary users spectrum access control and power setting based on a probability of outage criterion in terminals
- Secondary users cooperative power control in shared bands to optimize secondary users utility subject to primary user interference constraint
- Higher level application and flow partitioning algorithm that aims at partitioning flows across combined or aggregated bands located in the SACRA CRRM hierarchy.

##### Cooperative power control algorithms

The main research activities UoA concentrates on is the study, simulation and implementation of cooperative power control algorithm. The main idea of the cooperative power control algorithm is to fine tune power control levels for opportunistic users that have been granted access already. It relies on shared and exchanged experience instantaneous utility among these users to derive the best power settings. As the data gets shared and exchanged and delays as well as uncertainties in received data qualities are experienced, the cooperative power control algorithm introduced fuzzy logic features to handle these doubts and become robust to the unreliable utility reporting.

Furthermore, UoA has examined the integration of the algorithm to SACRA based use cases and scenarios. More specifically, simulation tests have taken place and network policies have been discovered and enforced to the cooperative power control algorithm. The performance of the algorithm was examined and interesting results and trade-offs were extracted.

#### 5.1.2 Sensing and classification techniques

The main research activities are divided between sensing algorithms and classification algorithms. Sensing and classification is important in order to meet regulation requirements for WS operation and SU system constraints. In a fast changing environment, parameters such as fading, noise uncertainty, far away interferers, wrong noise estimation may result in a wrong detection result. SACRA has studied the sensing and classification techniques, defined the modules responsible for sensing control and studied their integration. Standardization experience also helped to extract useful parameters from DVBT, PMSE and LTE (3GPP) standards as well recommendation based

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on CEPT, Ofcom, 802.22 and FCC reports. With respect to these reports, SACRA developed algorithms that meet all these requirements.

In a matter of meeting SACRA's requirements for signal classification, two techniques were presented in D2.2.

The first proposed approach is operating in three steps. As a first step, the algorithm should locate the used sub-bands by locating their frequency edges. Then, the algorithm separates the different signals by some blind signal separation technique. Finally, the different signals are classified step using DVB-T signals cyclostationary properties.

The second proposed approach presents a less an LTE signal classification technique without quiet period. The objective of this study is to classify PUs detect while receiving and decoding LTE, but in this case the choice of the classification time will not affect the Quality of Service. These two techniques were then compared in order to help choosing the final algorithm to be implemented for final SACRA's demo.

Following SACRA target scenario, different spectrum sensing algorithms are developed, compared, and will be demonstrated through field trials performed in WP6. The studied algorithms have been or will be presented in WP2 deliverables. Recommendations about suitable sensing algorithms for different spectrum sensing tasks in SACRA are given.

### 5.1.3 Hardware technologies

One of the outcomes of WP4 is the design of dual band dual polarized antennas. Two directions are studied: the first one focuses on reducing the overall size whereas the second one offers better performances at the expense of the compactness. In any case, the challenge is to gather in a single element the dual band and dual polarization constraints. Moreover, the two considered bands (700-862 MHz) and (2.5-2.69 GHz) are widely spaced which makes difficult the design of the antenna. On the other hand, as the SACRA antennas are used in a MIMO context, a study of their diversity performances has also been performed. Thus, the studies conducted in the framework of SACRA will lead to innovative antennas which can be reused for other wideband applications.

Another outcome of WP4 is the design of a flexible antenna switch enabling, together with a dual uplink cellular transmitter, various TX MIMO investigations and demonstrations. TX MIMO and dual uplink investigations are not only important for the SACRA project, they are key features of upcoming cellular standards like LTE-A. Upcoming standards are targeting the capabilities of dual TX and all the advantages of MIMO systems to improve uplink performance for applications like cloud computing. WP4 is addressing these topics and results of the related demonstrator will lead to innovative future products, power and area efficient transmitter architectures

The baseband digital signal processor and its associated software libraries, operating system and software development kit are a major outcome of WP5 activities. The whole processor and its software environment are distributed under free software licences

## 5.2 USE OF FOREGROUND

The SACRA project has produced various types of foreground, among which reusable foreground for future activities in the wireless communications domain, and especially towards the development of future wireless devices. This chapter provides the detailed plans for the use of foreground by technology.



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The following table provides a list of main technical project results. It describes the achievement, points to the contributing partner(s) and outlines how this result shall be exploited by the partner(s)

No	Self-descriptive title of the result	Partner(s) owning the result(s) (referring in particular to specific patents, copyrights, etc.) & Explanation of how the foreground has been or is going to be used, in either further research or commercial exploitation activities,
1	WP2: Sensing algorithms design	<p><b>VTT:</b> VTT has developed knowledge of spectrum sensing for cognitive radio environments. VTT exploits this knowledge to support the industry which aims at developing future wireless communication networks. The developed techniques and knowledge are transferred to the industry by establishing joint projects to accomplish specific short or long term goals. The studied algorithms have been and will be used in different kind of cognitive radio demonstrations in VTT. Several publications have been made using SACRA foreground.</p> <p><b>NTUK:</b> NTUK developed optimization of cooperative sensing techniques and novel SNR prediction method. NTUK also develop a method allowing to divide the wide operating frequency band into narrow bands and evaluated the method for a narrow band system. The evaluation results showed that the measurement techniques are exploitable. As a result, these inventions are offered to be incorporated into our future base station and mobile terminal products</p> <p><b>IT:</b> IT will use these results in research activities as application examples for the EMBB processor and its companion software design kits.</p> <p><b>EURE :</b> EURECOM has developed several sensing detection techniques, especially for multiband sensing that could be used for future demonstrations</p>
2	WP2 : Mixed-signals separation	<p><b>EURE :</b> EURECOM has developed a mixed signal separation and classification algorithms that can be exploited for heterogeneous cognitive networks</p> <p><b>INF/IMC:</b> IMC developed expertise for mixed signal separations in the sense of identifying and cancelling the undesired signals at the users. This would be useful not only in upcoming research projects but for future mobile receiver design as well.</p> <p><b>IT:</b> IT will make use of the mixed-signal separation results as a state of the art in future projects</p>
3	WP2: Signal classification	<p><b>NTUK:</b> NTUK studied classification method without quiet period. NTUK performed simulation and analyzed the performance with respect to regulatory requirements and compared the method with mixed signal separation. NTUK also provided a method based on exclusion of unreliable nodes. Furthermore, NTUK studied another classification method based on higher order cumulants for non-OFDM signals. As a result, these inventions are offered to be incorporated into our future base station and mobile terminal products.</p> <p><b>EURE:</b> Eurecom worked on signal classification and developed a robust classifier for cognitive radio systems that can be used as a start point material for future projects on heterogeneous cognitive networks.</p>

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4	WP2 : MIMO algorithms	<p><b>IT :</b> IT will use the developed MIMO algorithms as a state of the art for future projects and possibly experiment them in advanced 4G prototypes</p> <p><b>VTT :</b> VTT has developed knowledge of channel estimation using superimposed pilots in polarised MIMO system. VTT exploits this knowledge to support the industry which aims at developing future wireless communication networks. The developed techniques and knowledge are transferred to the industry by establishing joint projects to accomplish specific short or long term goals.</p> <p><b>INF/IMC:</b> Cognitive MIMO algorithms were developed while conducting research at IMC in the framework for SACRA. This know-how would be directly useful for future EU research projects and also for receiver design for upcoming mobile standards which is the core activity of IMC.</p>
5	WP2 : Time Frequency Polarization codes	<p><b>IT :</b> IT has developed time frequency polarization coding techniques that can be used in a cognitive radio environment. The developed techniques will be used as a start point for future international projects.</p>
6	WP2 : MIMO multiplexing techniques	<p><b>IT :</b> IT will make use of the MIMO multiplexing techniques as a state of the art in future projects</p> <p><b>INF/IMC:</b> IMC proposed novel cognitive MIMO multiplexing techniques working under the SACRA framework. Such techniques are especially interesting for future network architectures with research community getting to know the spectrum scarcity. Although this expertise does not directly concern the product design of IMC but would be helpful in future EU research projects.</p>
7	WP3: high level cognitive part of the SACRA system by specifying and implementing the rules, policies and the models that will drive (govern and pilot) the overall management of radio resources and spectrum within and across systems.	<p><b>IT:</b> The foreground from WP3 will be integrated in the graduate education program at Télécom SudParis, a branch of Institut Mines-Télécom. In parallel IT is working on combining the results of the proposed algorithms (traffic partitioning with inputs from access control, cooperative power and sensing configuration results) for valorization assessments. Since IT is also involved in WP2, other sensing algorithms will be considered. In addition, we are training our graduate and doctoral students on the proposed algorithms to pursue the research and propose enhancements with our current and future doctoral students.</p> <p><b>NTUK:</b> NTUK has proposed the concept of spectrum sensing algorithm selection in a single node radio. Rules and policies have been defined to configure the selection process taking into account the type of environment, the type of primary signal, the false alarm probability, the detection probability and the sensing duration and periodicity. NTUK intends to use the outcomes of these studies to design an algorithm selection process that should allows dynamically selecting the adequate sensing algorithm in a single node radio.</p> <p><b>EURE:</b> EURECOM has contributed by a binary power control algorithm in WP3. This algorithm will be extended and will be used for upcoming EU projects.</p> <p><b>UoA:</b> UoA has used the developed solutions in terms of research activities related to master theses and PhDs. The SACRA foreground has been used for several publications; a book chapter has also been produced. UoA intends to develop the proposed solution for Android smartphones for</p>

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		experimental purposes. Also, future work considerations include the extension of a similar solution to BS.
8	WP3: design of the networking system needed for cognitive radio resource management and coordination of the SACRA system.	<p><b>IT:</b> IT explored how to exchange information via the existing control channels in the involved systems and the possibility to exchange information using the X2 interface so base stations can also share knowledge on sensed carrier components. This acquired understanding is being shared with our graduate students in our training programs. We will pursue or work and investigations after the project lifetime to consolidate our preliminary results. The methodology developed in this activity will be used for future projects.</p> <p><b>NTUK:</b> NTUK has proposed a novel architecture and configuration scheme for single-node spectrum sensing. It is assumed that the sensing node may use more than one sensing algorithms. The proposed sensing architecture allows a dynamic algorithm selection that depends on the sensing configuration parameters, and it includes a regulatory conformance checking. As a result, local sensing is enhanced by dynamic selection of the most reliable sensing algorithm, while a regulatory conformance indicator shows whether the current sensing result should be assumed reliable or not. Such information could be used further by a cooperative sensing system for efficient data fusion and decision making. NTUK intends to use the outcomes of these studies in its future cognitive radio devices in order to efficiently find and use the opportunistic free parts of the spectrum.</p>
9	WP4: compact multiband dual polarized multiple antennas,	<p><b>IT:</b> The antennas and the studies performed on diversity have contributed to develop the research and teaching activities in this field at IT. A PhD position has been opened in the framework of this project and several publications are been produced. The methodology to conceive compact dual band dual polarized antennas that has been proposed in this project is general and applicable to other research projects. Moreover, as diversity will be more and more present in future wireless systems, the developed tools are also reusable. Regarding the teaching, these results will contribute to update the courses at Master's degree and continuing education.</p> <p><b>Fraunhofer IIS:</b> The developed antennas are going to be used for further research projects in conjunction with reconfigurable radio systems.</p>
10	WP4: multiport RF Front end and Base Band motherboard	<p><b>Eurecom:</b> The developed RF Front End is very ambitious in term of flexibility, since it can address 10 different bands, from TVWS at 400 MHz up to 5.9 GHz..It can also support Frequency division duplex(FDD) and Time division duplex (TDD).</p> <p>Concerning the Base Band motherboard (so-called "ExpressMIMO2" in the Wp4 deliverables), it comprises a FPGA (Spartan 6 from Xilinx) and 4 LMS6002D transceivers (<a href="http://www.limemicro.com/">http://www.limemicro.com/</a>). This board can it can be used for low power MIMO terminals or base stations, from 300 MHz to 3.8 GHz, both in FDD and TDD. The base band processing will be done mainly in a host PC, and the FPGA is mainly used for the samples transfer.</p> <p>The 2 developed boards (flexible RF front end and Base Band motherboard) will be used by Eurecom and potentially others partners in new research activities in various areas such as Cognitive Radio, relying, small cells deployments, beyond 4G studies. Concretely, the boards will be used in new French and European projects for the validation of new concepts in the areas mentioned above.</p>

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		<p>It is planned to produced 20 Base Band motherboards and 15 RF front end part by April 2013.</p> <p><b>Fraunhofer IIS:</b></p> <p>The designed and implemented digitally tuneable bandpass filter applicable in TVWS and LTE-800 for image rejection and suppression of higher-order harmonics is going to be used in reconfigurable radio systems. Demonstrations at exhibitions are planned in order to form further project with industry partners.</p> <p>A frequency agile analog RF front-end was designed and validated suitable for the cognitive radios. The front-end architecture is considered a basis for further flexible front-ends implementations not exclusively in the field of cognitive radio. The front-end are going to be reused in conjunction with other ultra flexible reconfigurable radio systems.</p>
11	WP4: versatile ADC	<p><b>IT:</b> We have designed an Analog to Digital Converter (ADC) in a 65nm CMOS process that can convert a full 40MHz signal bandwidth with 12-bit resolution while consuming less than 100mW. The outstanding performances of this circuit are a combination of an innovative architecture and its implementation in an advanced CMOS process. Furthermore, the proposed architecture has a built-in anti-alias filter which reduces the bill of material (BOM) when it is embedded on a PCB. This prototype is a key component for the design of future cognitive radio systems. Furthermore, this architecture will be reused for the implementation of a new prototype in more advanced CMOS process (40nm or 28nm).</p>
12	WP4: flexible RF transmitter front-end from DAC to PA	<p><b>DICE:</b>DICE is no longer developing cellular products. DMCE is the spin of continuing cellular business.</p> <p><b>DMCE:</b> The developed multi-mode multi-standard RF transmitter architecture supporting LTE carrier aggregation of TVWS and LTE high bands is going to be improved and used in upcoming reconfigurable products. Further demonstrations are planned and the design will be tweaked to fulfil upcoming market requirements. The configurable antenna switch, part of the AFE, will also be used for the evaluation of novel Front-End setups, especially for PhD and master thesis's.</p>
13	WP4: predistortion	<p><b>TCS:</b> TCS has developed a precise knowledge of Power Amplifier digital predistortion. The front-end RF impairments limit the capacity and the development of the digital predistortion for commercial use and TCS has developed solutions to cope with these impairments.</p> <p>As result, the developed algorithms will most probably be included in the design of our future products.</p>
14	WP5: EMBB baseband processor	<p><b>IT:</b> IT will continue the design of the EMBB processor and will use it in research and higher education activities. IT will release EMBB under an open source license and use it as a dissemination and self-promotion vehicle. Industrial transfer is also a mid-term goal.</p>
15	WP5: libembb emulation library	<p><b>IT:</b> IT will continue to maintain the library and will release it under an open source license. It will be used in research and higher education activities and as a building block of the complete software design flow for EMBB.</p>
16	WP5: EMBB software drivers, operating system	<p><b>IT:</b> IT will continue to maintain the embedded software stack and will release it under an open source license. It will be used in research and</p>

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	and convenience library	higher education activities and as a building block of the complete software design flow for EMBB.
17	WP5: UML based software design entry tool, including software generators	<b>IT:</b> IT will continue research activities on this topic in order to completely free software designers from handling the memory management and the low level scheduling. The UML framework will be released under an open source license. It will be used to promote the EMBB processor by making it much more user friendly and easy to program. It will be an essential part for wide acceptance and industrial transfer.
18	WP5/6: Sensing algorithms implementation	<b>VTT:</b> VTT has developed knowledge about modelling and software implementation of spectrum sensing algorithms for the SDR platform (EMBB). This knowledge will be exploited in developing equipment for different cognitive radio demonstrations in VTT.

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## 6 PARTNER INDIVIDUAL EXPLOITATION

This chapter provides an overview of the plans for the use of foreground by each SACRA consortium member.

### 6.1 INDUSTRIAL MEMBERS

#### 6.1.1 THALES COMMUNICATIONS& SECURITY SA

SACRA foreground will be used by TCS for several purposes.

First the project foreground allows TCS to progress in its research activities in the field of cognitive radio, in particular from the specification of system requirements to the elaboration of a reference system architecture and to the definition of a cognitive radio terminal. Such terminals could be proposed in the future in the domain of Professional Mobile Radio (PMR). In this PMR market, TCS already proposes a product range of TETRA networks, called Digicom 25. TETRA is the European standard for PMR narrowband and wideband digital radio for professional usages (from public safety to railway networks). TCS is also promoting a broadband solution to complement Digicom 25, that is labelled TEMAX and is currently based on Wimax technology, but should also include LTE technology in the near future.

Second, the study of digital pre-distortion techniques that is conducted in the scope of WP4 and WP5 shows the benefits of the proposed algorithms in terms of power consumption. The reduction of the non-linearities can also lead to a better frequency reuse, especially when introducing broadband solutions, and then contribute to a more efficient use of the resources in cognitive radio networks for PMR market.

This study of pre-distortion techniques was motivated by the need to evaluate the gains in terms of power consumption for two types of products: mobile terminals and high power equipments (such as base stations). The results of the study showed that the pre-distortion algorithms developed in SACRA provide significant gains for high power equipments, but the implementation of these techniques on mobile terminals could not be justified due to the complexity of the algorithms. These conclusions are considered in the development of narrowband/broadband products.

#### 6.1.2 NEC TECHNOLOGIES (UK) LIMITED

The main use case of interest for NTUK is LTE communication in TVWS. In order to deal with this situation where classical sensing techniques cannot be used in all cases due to LTE constraints, NTUK studied classification algorithms which are necessary to discriminate between the primary user transmissions and (own) secondary user transmissions. SACRA further provided classification algorithms exemplified for LTE FDD DL. SACRA also showed that the performance of these algorithms copes with the FCC requirements, without employing more expensive Quiet Period techniques. So, project foreground in this area will allow NTUK to propose future LTE mobile equipment with sensing and classification techniques for operation in WS. More globally, the SACRA conclusion of the studies related to WS allows checking and revising the future specification of the mobile equipments which will have the capability to operate in White Spaces.

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### **6.1.3 INTEL Mobile Communications, FRANCE**

The main area of interest for IMC in SACRA is the investigation of novel receive algorithms which are required to make primary and secondary (cognitive) communications successful simultaneously. As the development of the sophisticated modems is the core business for IMC, this study will provide the know-how about the future sophisticated MIMO mobile receivers which have additional capabilities to cancel/strip the interference.

### **6.1.4 DMCE Danube Mobile Communications Engineering GmbH & Co KG**

SACRA foreground related to modem architectures; cognitive radio and the exploitation of unlicensed frequency bands will found the basis for important, future RF cellular platform decisions. The efficient use of the highly expensive and limited frequency resource is a major task of all upcoming cellular standards and products and DMCE will have to cover all upcoming requirements. The SACRA project targets several efficiency topics from software, hardware to top level perspectives and many novel aspects investigated or developed within the SACRA project are directly related to modem features and software assisted hardware algorithms. Therefore any foreground developed might be important for upcoming cellular standards and products of DMCE. The significant mobile terminal performance gain possible due to the introduced digital pre distortion algorithm will be of interest for future product developments and architectures.

## **6.2 ACADEMIC MEMBERS**

### **6.2.1 VALTION TEKNILLINEN TUTKIMUSKESKUS (VTT)**

VTT is mainly participating to research activities and software development of studied algorithms. In algorithm point of view, VTT has studied single node and cooperative spectrum sensing methods for cognitive radios. In addition, software development and implementation considerations on the studied algorithms have been carried out. Several publications have been published in different international conferences.

### **6.2.2 Institut Telecom**

On antenna design, IT has offered a PhD position in the framework of SACRA. This will contribute to the reinforcement of the research activities of the antenna design group. In this thesis, some designs methodologies for dual band dual polarized antenna will be proposed and could be reused for other applications. Publications are expected in international conferences as well as international journals.

The baseband digital signal processor and its companion software is actively used by IT as a way to promote and demonstrate the benefits of this type of flexible software / hardware combination for software defined and cognitive radio applications. It is used in lectures and tutorials. Scientific papers are based on it and on results obtained from implementation experiments on the processor. Finally, it is also a very valuable use case and design example for other research activities at IT, like, for instance, high level modelling and validation of complex embedded systems. IT will continue to maintain and enhance the processor and will use it in every future project dealing with wireless digital communications.

Other results obtained concerning sensing algorithms (WP2), network layer (WP3) and ADC design (WP4) are also used in lectures and tutorials. Several publications have been published, some others will come in the future. The methodology developed in this project will be used for other applications or future projects.

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### **6.2.3 FRAUNHOFER-GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V (IIS)**

The main research objectives for the Fraunhofer IIS can be found in the antenna design and tunable band pass filter in WP4. Publications have been submitted in different conferences. Regarding to the digitally tunable band pass filter a patent is submitted at the German patent office. Demonstrations at exhibitions in 2012 have been presented. Future work will profit from these researching results in further projects in the framework of industrial contracts as well as on European, national and bi-lateral level.

### **6.2.4 EURECOM**

EURECOM is participating to research activities: spectrum sensing and classification techniques related to WP2, and resource management techniques related to WP3. EURECOM is participating also in implementation procedures related to WP5 and WP6 by designing and developing the final demonstration using EURECOM's OpenAirInterface platform. Several publications have been published in different selective conferences, books and journals.

### **6.2.5 NATIONAL AND KAPODISTRIAN UNIVERSITY OF ATHENS**

The main purpose of UoA is the participation to research activities. Investigation of cognitive wireless communications and especially techniques for power control allocation for green communications are among the key points that characterize the role of UoA. For these reasons, concentrated investigation of power allocation policies has led to a series of publications in a number of international conferences.



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## 7 PATENTS AND IPR

As captured by the project objectives SACRA aims at providing innovative concepts that could be published (see section 3) and patented. Towards this direction, SACRA partners have been working in the detailed description of solutions as regards the antenna, the RF and base band design as well as cognitive actuation techniques for dual-band resources management of the SACRA terminal.

During the development for the new SACRA terminal, described in Deliverable D4.2, the IIS could make a patent application with the title “KognitivesFunksystem und VerfahrenfürinkognitivesFunksystem” (“Cognitive Radio and Procedure for a cognitive radio system”). Examples of the patent claims are given:

A cognitive radio with a characteristic of:

- Filtering an incoming and/or outgoing signal with a tunable band pass filter.
- The center frequency of the incoming and/or outgoing signal can be adjusted digitally.

The patent has been written and has been submitted at the German patent office since 21October2011.

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## 8 CONCLUSIONS

This deliverable has presented the overall regulation, standardization, dissemination and exploitation efforts within the SACRA project. Furthermore, the deliverable provides a detailed description of the dissemination strategy the SACRA consortium plans to follow in the remaining 12 months of the project, in order to achieve even wider promotion of SACRA outcomes and to convince the society and the industry to adopt the already introduced scientific solutions. The purpose of this dissemination plan is to make the high quality work items of SACRA available to a wider audience through many different dissemination activities.

It is worth mentioning, that during the project's lifetime, considerable outcomes have been achieved by SACRA, including both conference papers and journal publications. In terms of regulation, SACRA has presented its work and participated in working groups within the ETSI Reconfigurable Radio Systems (RRS). Additionally, significant open source software has been developed and is expected to be further evolved. Furthermore, in order to maximise dissemination and impact of the project, SACRA project has organized a first Workshop on "Experimental platforms for 4G and beyond wireless systems" in February 2012. Last but not least, a patent was written and submitted at the German patent office, during the second year of the SACRA project.

The dissemination strategy adopted by SACRA, in compliance with the Technical Annex descriptions, facilitates the dissemination of SACRA work through its own website where users can find news about the evolution of project work and all the relative information. Such information include the submission and publication of the technological concepts and results achieved by the project in selected journals, magazines and international conferences, workshops, etc. Additionally, the consortium targets also the industry level dissemination, the interaction with worldwide forums and institutes and the promotion of project solutions to the identified standardization bodies and significant steps in this direction have already been achieved.

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