COGEU

FP7 ICT-2009.1.1

COgnitive radio systems for efficient sharing of TV white spaces in EUropean context

D8.2
Dissemination and Exploitation – Final Report

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Abstract:
Summary of 2nd and 3rd year's dissemination activities and description of the partners exploitation plans after project lifetime.

Keyword list: Dissemination, Exploitation, Intellectual Property Rights

Executive Summary

This deliverable reports on the dissemination activities in the second and third year of COGEU project and presents the partners exploitation plans after project lifetime. In total in the reporting period COGEU were presented in 60 events and has contributed to the following activities :

- 3 CEPT SE43 meetings with 3 technical contributions;
- 3 responses to public consultations on CR technologies;
- 5 ETSI RRS meetings with 4 technical contributions ;
- 1 IEEE DySPAN standard published with COGEU contributions;
- 1 presentation at DVB-T standardization meeting;
- 1 patent published;
- 11 meetings with other international research activities;
- 30 papers in international conferences;
- 10 Journal papers published and 3 book chapters;
- 3 publications for a broader audience;
- 6 Tutorials and summer schools;
- 5 COGEU project exhibitions with live demonstrations;
- 2 COGEU dedicated workshops;
- 1 video promoting the trials in Munich;

As landmarks in the COGEU dissemination process we highlight:

- COGEU was invited to give a presentation at the public hearing on Radio Spectrum Policy Program in the European Parliament on 1st March 2011;
- The European Commission Communication on "Promoting the shared use of radio spectrum resources in the EU" published in September 2012 includes a reference to the COGEU trails in Germany and Slovakia;
- The European Commission Mandate to CEN-CENELEC-ETSI on Reconfigurable Radio Systems (M/512) published in November 2012 includes the statement: “COGEU has created a very good database” in its section on R&D environment;
- COGEU was invited to be presented at two Cambridge White Spaces events (industrial consortium lead by Microsoft) as an outstanding example of a TVWS project beyond UK and US efforts.

The number of events and the attention COGEU experienced from various sides evidence that COGEU went into the right direction and beyond what was is in the grant agreement contract. Especially the concept of secondary spectrum trading offers interesting aspects for spectrum holders as well as possible licensees. COGEU embeds this concept into a comprehensive environment consisting of technical, economical and regulatory views on the matter of TVWS utilization by secondary devices, operated on a non-interfering and non-protected basis.

With its work and its results COGEU made an important contribution to the introduction of White Space usage in Europe. For the benefit of the public the results of COGEU were widely disseminated and the knowledge and practical experience gained by the project serve as an excellent basis to put the results into real products and services.

The plans on how the outcomes of the project will be used by the different partners after the project lifetime are summarized below.

- IT will extend COGEU contribution to CR standardization through the FP7 Coordination Action CRS-I (www.ict-crsi.eu) where IT has the leading role. Moreover, IT is prepared to commercialize geo-location database software solutions for spectrum management;

- TCD started the White Spaces Ireland initiative (www.whitespaces.ie). TCD is currently engaging with interested Irish and international entities to establish the details of further trials in Ireland;
- PTIN is planning to test WiFi over TVWS pre-commercial solutions in Portugal;
- PUT is currently engaging with the polish electricity suppliers providing consultancy on technical and business scenarios for machine to machine communication in TVWS (M2M), especially for electricity smart metering.
- SIGINT's contributions to the project are expected to assist in the development of new products such as "White Spaces Interference Emulator";
- THALES is currently including COGEU Routing / Transport protocols for Cognitive Radio Ad-Hocs Networks in its PMR market portfolio;
- AEGEAN will further exploit, for academic purposes, all software tools developed for the optimum allocation of TVWS;
- R&S is planning to publish an application note that describes the set-up and operation of a testbed for WSDs, and market the related test set-up as a self-contained, comprehensive solution for WSD certification. Moreover, the inclusion of the COGEU sensing tools of DVB-T signals is currently under test for a new generation of R&S professional test receivers.
- IRT as the R&D institute of the public broadcasters in Germany, Austria and Switzerland will exploit COGEU results to increase spectrum efficiency of broadcast networks and to further investigate the use of TVWS as feedback channel for TV interactive services.
- TOWERCOM as the main broadcasting infrastructure provider in Slovakia will consider the development of the new utilization of TVWS for M2M communications networks.

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1 Introduction

The main objective of the COGEU project is to design, implement and demonstrate enabling technologies to allow an efficient use of TV White Spaces (TVWS) for radio communications based on two spectrum sharing business models: spectrum commons and real-time secondary spectrum markets. COGEU also defines new methodologies for TVWS equipment certification while addressing coexistence with the DVB-T European standard. As a consequence the project should aid the European decision makers to move the TV spectrum management paradigm towards a more liberal and efficient method, by providing sufficient evidence on the technology and economic viability and its deployment.

The eventual move from the classical “command and control” to a more liberal approach of spectrum sharing (secondary spectrum trading) in the context of the digital switchover represents an immense paradigm shift. Hence the proof of evidence for the technological feasibility and socio-economic benefits are crucial to encourage decision makers to take such a step. COGEU has the potential to make a large impact in encouraging this decision to take place and showing the way not just in terms of implementation but also in terms of economic gains.

The main objective of WP8 is to promote the widespread utilisation and exploitation of the project results. To achieve the above impact the project follows a dissemination plan subdivided into:

- Contributions to regulatory groups;
- Contributions to standardisation;
- Scientific publications;
- Cooperation with international research projects;
- Other means to disseminate COGEU plans and results;

This deliverable reports the dissemination activities in the second and third year of COGEU project (2011-2012) and presents the plans for the exploitation of the results. Note that the first year dissemination activities (20120) were reported in D8.1 [1]. Chapters 1 to 8 describe the means used to disseminate and promote COGEU solutions, Chapter 9 is dedicated to the partners exploitation plans after the project ends.

2 Contributions to spectrum regulation

COGEU aims to inform EU policy in relation to the enabling of efficient spectrum sharing and usage over TVWS at European level. During the second and third years of the project COGEU consortium has disseminated results in national and European regulatory bodies as detailed in the following sections.

Regulatory body/event	Date	COGEU contribution
Call for public input on the draft RSPG Opinion on Cognitive Technologies (RSPG10-348)	January 2011	COGEU response to the call for public input on the draft RSPG Opinion on Cognitive Technologies (RSPG10-348)
10th CEPT SE43 meeting, Bologna	5-7 July 2011	CEPT SE43, contribution SE43(10)28: IRT, Study on maximum transmit power for TVWS devices and available amount of TVWS in Bavaria/Germany, June 2011.
11th CEPT SE43 meeting, Lisbon	19 – 21 September 2011	Rogerio Dionísio (IT) presented the results of SEAMCAT simulations of interference potential from LTE-type WSD into incumbent services/systems, considering COGEU scenarios (Document SE43(11)Info12).
Spectrum impact questionnaire for research projects funded under FP7, organized by SCF Associates Ltd as part of a study to support the preparation of an impact assessment to accompany a planned EC Communication on shared uses of spectrum (SMART 2011/0017).	September 2011	COGEU consortium answered the questionnaire based on the regulatory scenarios developed by the project.
Questionnaire related to the regulatory consideration of the protection of PMSE in the UHF band in a context of WSD, organized by the ECO:	Sep. 2011	COGEU consortium answered the questionnaire based on the regulatory scenarios developed by the project.
Invitation from the European Communication Office (ECO) for a Web conference with the Director of the ECO.	12 Oct. 2011	Description of COGEU model and exchange of opinions regarding issues related to the COGEU approach for TVWS usage in Europe. COGEU is placed on the CEPT portal at: http://www.cept.org/ecc/topics/research-activity
European Commission Workshop on Flexible and Shared Use of Spectrum, European Commission	13 Feb. 2012	COGEU's contribution, "Shared Use of TV Spectrum in Europe: Why is needed a political decision ?"
CEPT Workshop cognitive radio and software defined radio: policy and regulations	2 May 2012	COGEU's contribution: "Policies to enable secondary spectrum trading of White Spaces"
CEPT SE43	June 2012	SE43(12)Info09: "New protection ratio measurements for LTE interferes to DVB-T".

2.1 Contact to national regulators

ComReg, Ireland

CTVR-Trinity College Dublin regularly communicates with the Irish communications regulator, Comreg. While Comreg and CTVR have no formal relationship, meetings are held from time to time at which CTVR brief the regulators on activities in the TV white space area. CTVR also regularly seeks the opinion or advice of Comreg on new policy or technology concepts.

OFCOM UK

Prof. Linda Doyle of CTVR-Trinity College Dublin is a member of Ofcom UK's Spectrum Advisory Board (OSAB). OSAB provides independent advice to Ofcom on strategic spectrum management issues. Provision of independent strategic advice helps Ofcom to carry out its remit in securing optimal use of the radio spectrum, taking account of the different needs and interests of all users. Involvement in this organisation provides CTVR, Trinity College with a broader, deeper and more long-term understanding of telecommunications developments and trends. It also allows CTVR, Trinity College to feed out experience, of which COGEU is part, into this group.

BNetzA, Germany

On 2nd and 3rd May 2012 BNetzA Mainz hosted a workshop on "Cognitive Radio and Software Defined Radio", organized by ECC in cooperation with 'COST-TERRA'. More than 130 delegates attended the workshop.

The workshop was arranged in five sessions. The first session on the first day was dedicated to the European and national CR/SDR regulation efforts. The following two sessions were dealt with a review of the state-of-the-art in European research and CR/SDR testing as well as practical implementation projects. Second day was arranged in the following way: the first session was coordinated by ETSI and dedicated to standardisation and industry specification issues. The second part of the day was dedicated to the considerations of regulatory efforts regarding CR/SDR outside [2]

The workshop offered a good opportunity to discuss Cognitive Radio matters with the attendees. The discussions consolidate the view that for several of the European regulators there seems to be the tendency to wait and see. They contribute to the regulation activities in case Cognitive Radio should come but they do not actively push introduction of Cognitive Radio Systems.

2.2 COGEU and the Radio Spectrum policy Programme debate

COGEU was invited to be presented at the Hearings on the Radio Spectrum Policy Program (RSPP) organized by the European Parliament S&D Group, 1 March 2011. The target audience included European Parliament Members involved on the Radio Spectrum Program. Paulo Marques, as scientific coordinator of COGEU informed the audience about the challenges and possible solutions for an efficient use of TV white spaces in Europe.

Figure 1 The agenda of the Public Hearing on Radio Spectrum Policy Programme with COGEU participation.

Figure 2 The COGEU model was presented to approx. 100 attendants from stakeholders and Members of the European Parliament (MEP).

Main conclusions from the hearings in relation with COGEU objectives:

- S&D vice-president Marita Ulvskog said: "*There is an urgent need to be more efficient and optimise management of frequencies already available*."

- Euro MP Catherine Trautmann, S&D shadow rapporteur of parliament's legislative report, said: "*Having an inventory is a pre-condition for developing a European economic approach to the broader value of the spectrum. This exhaustive study of potential synergies will help us address the needs of our citizens*."
- S&D vice-president Maria Badia said: "*Our priority is to find the balance between present and future, between traditional media such as terrestrial television and more competitive services provided through the internet*."

2.3 COGEU and the EC communication on the shared use of radio spectrum

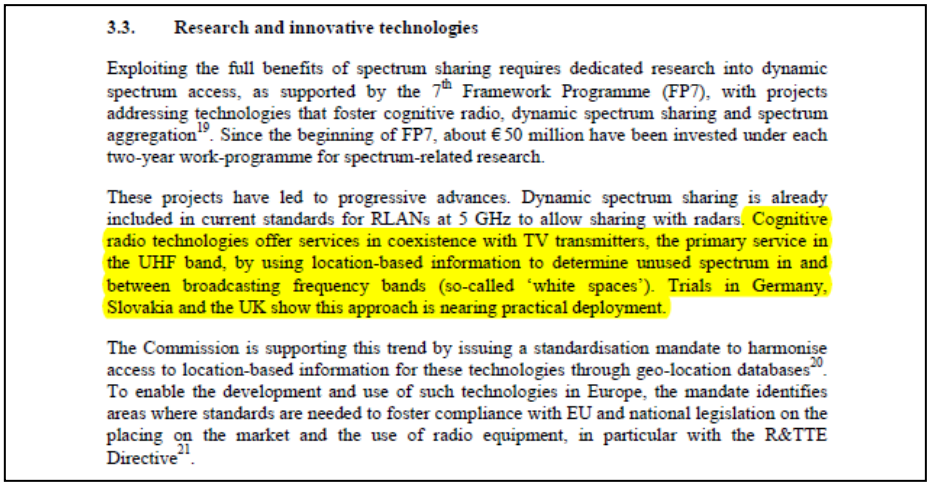
In line with the Radio Spectrum Policy Programme (RSPP), the European Commission has published a Communication on "Promoting the shared use of radio spectrum resources in the EU" in September 2012 [3]. It highlights the importance of technologies that can share radio frequencies as well as the need to create incentives and legal certainty for innovators in the internal market. In the Section dedicated to Research and innovative technologies there is a clear reference to the COGEU trails carried out in Germany and Slovakia as showed below.

EUROPEAN COMMISSION

Brussels, 3.9.2012
COM(2012) 478 final

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

Promoting the shared use of radio spectrum resources in the internal market



3.3. Research and innovative technologies

Exploiting the full benefits of spectrum sharing requires dedicated research into dynamic spectrum access, as supported by the 7th Framework Programme (FP7), with projects addressing technologies that foster cognitive radio, dynamic spectrum sharing and spectrum aggregation[19]. Since the beginning of FP7, about € 50 million have been invested under each two-year work-programme for spectrum-related research.

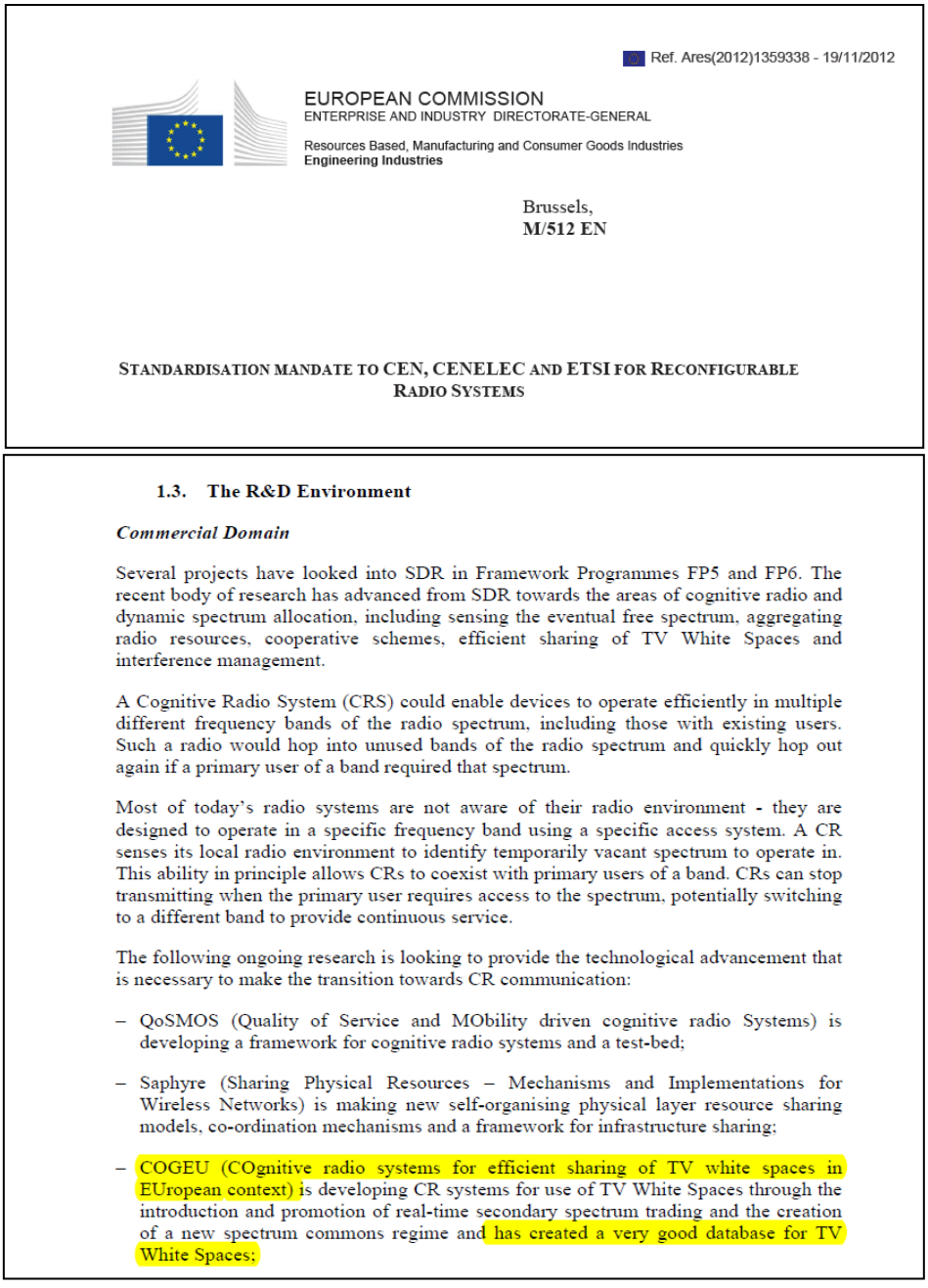
These projects have led to progressive advances. Dynamic spectrum sharing is already included in current standards for RLANs at 5 GHz to allow sharing with radars. Cognitive radio technologies offer services in coexistence with TV transmitters, the primary service in the UHF band, by using location-based information to determine unused spectrum in and between broadcasting frequency bands (so-called 'white spaces'). Trials in Germany, Slovakia and the UK show this approach is nearing practical deployment.

The Commission is supporting this trend by issuing a standardisation mandate to harmonise access to location-based information for these technologies through geo-location databases[20]. To enable the development and use of such technologies in Europe, the mandate identifies areas where standards are needed to foster compliance with EU and national legislation on the placing on the market and the use of radio equipment, in particular with the R&TTE Directive[21].

Figure 3 Excerpt from the EC Communication on the shared use of spectrum with reference to the COGEU trials in Germany and Slovakia.

2.4 COGEU and the EC standardisation mandate for reconfigurable radio systems

In November 2012, the EC issued a standardisation Mandate to CEN-CENELEC-ETSI on Reconfigurable Radio Systems (M/512) [4], which, among other tasks, requests the development of European SDR architecture (and related interfaces with spectrum geo-location databases) for the civil and security markets. In the section related to the R&D Environment that support this Mandate there is a statement on the COGEU geo-location database.



Ref. Ares(2012)1359338 - 19/11/2012

EUROPEAN COMMISSION
ENTERPRISE AND INDUSTRY DIRECTORATE-GENERAL

Resources Based, Manufacturing and Consumer Goods Industries
Engineering Industries

Brussels,
M/512 EN

STANDARDISATION MANDATE TO CEN, CENELEC AND ETSI FOR RECONFIGURABLE RADIO SYSTEMS

1.3. The R&D Environment

Commercial Domain

Several projects have looked into SDR in Framework Programmes FP5 and FP6. The recent body of research has advanced from SDR towards the areas of cognitive radio and dynamic spectrum allocation, including sensing the eventual free spectrum, aggregating radio resources, cooperative schemes, efficient sharing of TV White Spaces and interference management.

A Cognitive Radio System (CRS) could enable devices to operate efficiently in multiple different frequency bands of the radio spectrum, including those with existing users. Such a radio would hop into unused bands of the radio spectrum and quickly hop out again if a primary user of a band required that spectrum.

Most of today's radio systems are not aware of their radio environment - they are designed to operate in a specific frequency band using a specific access system. A CR senses its local radio environment to identify temporarily vacant spectrum to operate in. This ability in principle allows CRs to coexist with primary users of a band. CRs can stop transmitting when the primary user requires access to the spectrum, potentially switching to a different band to provide continuous service.

The following ongoing research is looking to provide the technological advancement that is necessary to make the transition towards CR communication:

– QoSMOS (Quality of Service and MObility driven cognitive radio Systems) is developing a framework for cognitive radio systems and a test-bed;

– Saphyre (Sharing Physical Resources – Mechanisms and Implementations for Wireless Networks) is making new self-organising physical layer resource sharing models, co-ordination mechanisms and a framework for infrastructure sharing;

– COGEU (COgnitive radio systems for efficient sharing of TV white spaces in EUropean context) is developing CR systems for use of TV White Spaces through the introduction and promotion of real-time secondary spectrum trading and the creation of a new spectrum commons regime and has created a very good database for TV White Spaces;

Figure 4 Excerpt from the EC Mandate to CEN-CENELEC-ETSI on Reconfigurable Radio Systems.

3 Standardization

3.1 ETSI RRS

COGEU project has been following and participating in ETSI RRS standardization activities. The following content from COGEU have been presented to ETSI RRS WG1/WG3:

The novel geo-location database concept developed by COGEU has been introduced to ETSI RRS. The COGEU geo-location database allows separation of bands for sharing, i.e. commons usage, and for secondary trading. The commons bands are shared; thus there is no guarantee of the quality of service. The traded bands are exclusively used; hence there is guarantee of the quality of service.

COGEU has introduced the concept of Broker based secondary spectrum trading to ETSI RRS. The COGEU Broker model for usage of TV white spaces with temporary exclusive rights as well as related message flow chart with respective information flow description for the proposed broker model has been included in the ETSI RRS TR 102 907 document.

In the ETSI RRS WG1 technical meeting, COGEU is engaged in the development of the "Use Cases for Dynamic Declaration of Conformity" work item (TR 102 967) where COGEU is leveraging its accumulated work in the TV white spaces to contribute on approaches for the dynamic declaration of conformity for cognitive radio devices.

Standardization body\event	**Date**	**Venue**	**Contribution**
ETSI RRS #13 meeting	9-10 Feb. 2011	Paris, France	Contribution to ETSI RRS WG1 document RRSWG1(11)0053 – Discussion on Usage of TVWS with Temporary Exclusive Rights that was included in TR 102 907 – Reconfigurable Radio Systems (RRS); Use cases for Operation in White Space Frequency Bands.
ETSI RRS #15 meeting	8-9 Sep. 2011	Sophia Antipolis, France	Contribution to the WG1 technical meeting, on the "Use Cases for Dynamic Declaration of Conformity" work item (TR 102 967) with contribution number RRSWG1(11)0143 entitled: "Use Case for Multi-Stage Digital and Dynamic Declaration of Conformity"
ETSI RRS #16 meeting	24-25 Nov. 2011	Ispra, Italy	Contributions were made in the context of the ETSI TR 102 967 "Use Cases for Dynamic Declaration of Conformity". The use case is related with COGEU project Task 4.4.
ETSI RRS #17 meeting	27th of Feb.– 2nd of March, 2012	Paris, France	During the ETSI RRS WG1 Meeting, COGEU main contribution was in TR 102 967 "Use Cases for Dynamic Declaration of Conformity". The TR is a joint work between IT representing COGEU, RIM (COGEU project EAB Member) and Intel (ETSI RRS Chair). The TR focuses on adapting the certification procedure to the anticipated changes in the R&TTE directive regarding reconfigurable radio devices. Based on the feedback of previous meetings, the authors combined their contributions while addressing the comments received. The respective contribution for the meeting was: RRS01(12)018003r1.

ETSI RRS #20 meeting	13th of Dec.–, 2012	Sophia Antipolis, France	During the ETSI RRS plenary meeting Paulo Marques gave an overview of the COGEU project main achievements and discussed the plans for further contributions to standardization in ETSI RRS after the project life time.

3.2 IEEE DySPAN Standards Committee (DySPAN-SC)

On March 22, 2007, the IEEE Standards Board approved the reorganization of the IEEE 1900 effort as Standards Coordinating Committee 41 (SCC41) on Dynamic Spectrum Access Networks (DySPAN). The IEEE Communications Society and Electromagnetic Compatibility Society are sponsoring societies for this effort, as they were for the IEEE 1900 effort.

The IEEE 1900.6 working group was launched in September, 2008 to address the development of spectrum sensing interfaces and data structures for the exchange of sensing related information to increase interoperability between sensors and their clients provided by different manufacturers. Such capabilities will assist devices and associated radio equipment in identifying locally/temporally available spectrum that can be accessed without affecting the incumbent users of that spectrum. The standard provides a formal definition of data structures and interfaces for exchange of spectrum sensing related information, IEEE P1900.6 scope is illustrated in Figure 5.

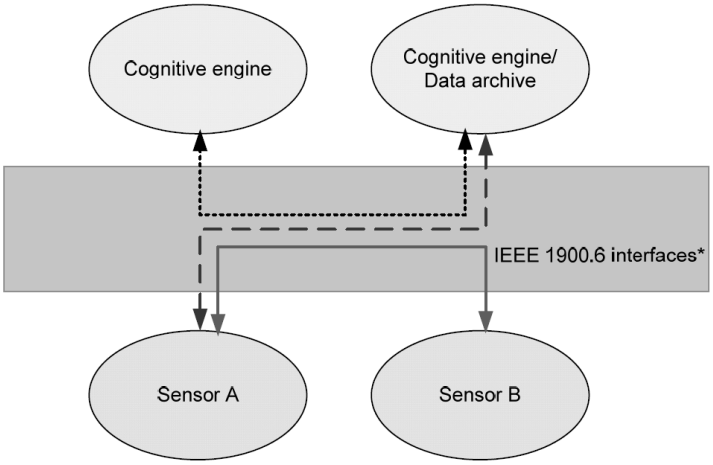


Figure 5 Scope of IEEE P1900.6 standard.

The IEEE P1900.6 standard was published in April 2011 under the title “Spectrum Sensing Interfaces and Data Structures for Dynamic Spectrum Access and other Advanced Radio Communication Systems”. Paulo Marques (IT) is co-author of the standard and contributed to the specification of the interface between Spectrum Sensors and the Data Archive of IEEE 1900.6 system model in order to meet COGEU spectrum sensing and database requirements.

3.3 DVB project

The results from the COGEU Project were presented to the DVB Technical Module on 20th September 2012 by R&S. The audience included 50+ experts from different parts of the industry, broadcasters, chip manufacturers, consumer electronics suppliers, regulators and software companies. After the introduction of the project’s objectives and methods, which were given to the same body in June 2011, this presentation was well received and led to an interesting discussion, partly on technical aspects which had been shown by COGEU but mainly on the feasibility of the broker as an institution in a new regulatory environment that needs created soon in Europe.

4 Intellectual property rights and patents

The work performed by THALES under the frame of COGEU Work-Package WP6 of COGEU resulted in a patent application related to OSI Layer 4 transport protocols. Thales Communications & Security patented a process for optimized end-to-end transport in Wireless multi-hop networks with a focus on cognitive radio characteristics possibly available on those networks.

Patent title (in French):

“Procédé pour le transport optimisé de bout-en-bout dans les réseaux radios ad hoc”

Authors:

Jérémie Leguay (TCS), Hicham Khalife (TCS), Damien Lavaux (TCS)

Submitted to:

The French Institute of Intellectual Property (INPI) in March 2012.

Abstract:

The patented process addresses the end-to-end transport of data in radio networks with a specific focus on cognitive radio networks. The invention relates to a method for conveying data flows in a wireless multi-hop network, said network comprising several nodes in a configuration at a given instant, a source node, a destination, and several intermediate nodes characterized in that at each of said nodes a processing of packets using the following modules occurs: interception module, management module, cognitive module, reception module and transmitting module. The interception module intercepts IP packets entering the network and registers data flows to the management module. Packets belonging to already registered flows are sent to the reception module. The management module keeps status about active flows currently transiting inside the considered node. For each new flow, a treatment is achieved resulting in the instantiation of a transmitting module and a reception module. Updates of flow status are then managed while the cognitive module can trigger events related to environmental stimuli. The cognitive module has access to environmental data that can be external to the considered system (sensing information, spectrum availability, resource allocations strategies). It is also responsible for sending back pressure notifications triggering congestion control in intermediate nodes. Claims of the considered invention includes : a mechanism for reliability management including acknowledgments (and retransmission strategies), a congestion control mechanism with the ability to regulate node sending rate on a hop-by-hop basis and based on external inputs retrieved by the cognitive module.

5 Scientific publications

5.1 Conference papers

In the following table all conference papers published by COGEU partners in the second and third year of COGEU are listed:

Date	Title	Event	Lead Partner
Feb. 2011	G. Mastorakis, A. Bourdena, G. Kormentzas, E. Pallis, V. Zacharopoulos, "TV White Spaces exploitation utilizing a Cognitive Radio system based on DVB-H"	International Symposium on Computer Networks and Distributed Systems (IEEE CNDS 2011), February 23-24 2011, Tehran, Iran.	AEGEAN
May 2011	J. Mwangoka, P. Marques and J. Rodriguez "Exploiting TV White Spaces in Europe: The COGEU Approach"	Fifth IEEE International Symposium on New Frontiers in Dynamic Spectrum Access Networks 2011, DySPAN 2011, Aachen, Germany	IT
May 2011	M. Parzy, H. Bogucka "Non-identical objects auction for spectrum sharing in TV white spaces - the perspective of service providers as secondary users"	Fifth IEEE International Symposium on New Frontiers in Dynamic Spectrum Access Networks 2011, DySPAN 2011, Aachen, Germany	PUT
June 2011	J. Mwangoka, P. Marques and J. Rodriguez , "Broker Based Secondary Spectrum Trading"	7th International ICST Conference on Cognitive Radio Oriented Wireless Networks and Communications, CrownCom 2011, Osaka, Japan	IT
June 2011	P. Kryszkiewicz, "Spectrum Shaping in OFDM-based Cognitive Radio" (in Polish)	National Conference on Mobile Radio Communications and Broadcasting KKRRIT'2011, Poznan, 8-10 June, 2011	PUT
June 2011	C. Silva, A. Gomes "Extension of LTE Operational Mode over TV White Spaces"	Future Networks and Mobile Summit, in Warsaw, Poland	PTIN
June 2011	M. Parzy, H. Bogucka, "Auction model for TVWS spectrum sharing between mobile radio communication systems" (in Polish)	National Conference on Mobile Radio Communications and Broadcasting KKRRIT'2011, Poznan, Poland, 8-10 June, 2011	PUT
June 2011	R. Dionísio, P. Marques and J. Rodriguez "TV White Spaces Maps Computation through Interference Analysis"	Future Networks and Mobile Summit, in Warsaw, Poland	IT
June 2011	Damien Lavaux, , Herve.Aiache, "COGEU architecture and applicability to Public Safety networks."	Wireless Innovation Forum's European conference, Brussels, 27-29 June 2011.	THALES

Sep. 2011	C. Dosch, J. Kubasik and C. Silva, "*TVWS policies to enable efficient spectrum sharing*".	22nd European Regional ITS Conference, Budapest, 18-21 September 2011	PUT
Sep. 2011	J. Kubasik, „*TV White Spaces Frequency Trading*" (in Polish)	National Symposium on Telecommunications and Teleinformatics, KSTiT, Lodz, Poland, 14-16 September 2011)	PUT
Dec. 2011	Bourdena, E. Pallis, G. Kormentzas, G. Mastorakis, "Real-Time TVWS trading based on a centralized CR network architecture"	IEEE GlobeCom 2011, International Workshop on Recent Advances in Cognitive Communications and Networking, Houston, USA, 5 - 9 December 2011	AEGEAN
Apr. 2012	P. Kryszkiewicz, H. Bogucka, Flexible quasi-systematic precoding for the out-of-band energy reduction in NC-OFDM	Wireless Communications and Networking Conference (WCNC) 2012, 1-4 April, 2012, Paris, France	PUT
Apr. 2012	P. Kryszkiewicz, H. Bogucka, Signal Shaping for PMSE Protection	18th European Wireless Conference, Poznan (POLAND), 18-20 April 2012	PUT
May 2012	P. Kryszkiewicz, H. Bogucka, Dynamic spectrum mask and throughput calculation for cognitive radio system (in Polish)	National Conference on Mobile Radio Communications and Broadcasting KKRRIT'2012, Gdansk (Poland), 14-16 May, 2012	PUT
May 2012	M. Parzy, H. Bogucka, Application of combinatorial auction for spectrum sharing in cognitive radio (in Polish)	National Conference on Mobile Radio Communications and Broadcasting KKRRIT'2012, Gdansk (Poland), 14-16 May, 2012	PUT
June 2012	Bourdena, E. Pallis, G. Kormentzas, G. Mastorakis, , A centralised broker-based CR network architecture for TVWS exploitation under the RTSSM policy	2nd IEEE Workshop on Convergence among Heterogeneous Wireless Systems in Future Internet (CONWIRE 2012), IEEE ICC2012, Ottawa, Canada, 10-15 June, 2012	AEGEAN
June 2012	R. Dionisio, P. Marques, J. Rodriguez, Interference Study between Wireless Microphone Systems and TV White Space Devices	IEEE International Conference on Communications (ICC) 2012, 10-15 June, Ottawa, Canada	IT
July 2012	Bourdena, E. Pallis, G. Kormentzas, G. Mastorakis, Spectrum aware routing in ad-hoc cognitive radio networks	Future Network & Mobile Summit 2012 (FUNEMS2012), Berlin, Germany, 04-06 July, 2012	AEGEAN

July 2012	Bourdena, E. Pallis, G. Kormentzas, G. Mastorakis, A Spectrum Aware Routing Protocol for Public Safety Applications over Cognitive Radio Networks	International Conference on Telecommunication & Multimedia, TEMU 2012, Heraklion, Crete, Greece, 30th July – 1st August, 2012.	AEGEAN
July 2012	Bourdena, E. Pallis, G. Kormentzas, G. Mastorakis, A radio resource management framework for TVWS exploitation under the RTSSM policy	International Conference on Telecommunication & Multimedia, TEMU 2012, Heraklion, Crete, Greece, 30th July – 1st August, 2012.	AEGEAN
July 2012	R. Dionisio, J. Ribeiro, P. Marques, J. Rodriguez, Cross-platform Demonstrator Combining Spectrum Sensing and a Geo-location Database	FUNEMS 2012 Proceedings	IT
July 2012	M. Parzy, H. Bogucka, Environment aware spectrum shaping for cognitive radio systems	Future Network & Mobile Summit, FuNeMS 2012,Berlin (Germany) 4-6 July 2012	PUT
July 2012	J. Lauterjung, Testbed for Coexistence Evaluation in TV White Spaces	FUNEMS 2012 Proceedings	R&S
Aug. 2012	M. Parzy, H. Bogucka, Policies and technology constraints for auctions in TV White Spaces - a practical approach for LTE-A	9th International Symposium on Wireless Communication Systems (ISWCS 2012), Paris (France), 28-31 August 2012	PUT
Sep 2012	Bourdena, E. Pallis, G. Kormentzas, G. Mastorakis, A Spectrum Aware Routing Protocol for Ad-Hoc Cognitive Radio Networks	23rd International Conference on Personal, Indoor and Mobile Radio Communication, PIMRC 2012, Sydney, Australia, 9-12 September 2012.	AEGEAN
Sep 2012	Bourdena, E. Pallis, G. Kormentzas, G. Mastorakis, A Dynamic Spectrum Management Framework for Efficient TVWS Exploitation	17th IEEE International Workshop on Computer-Aided Modeling Analysis and Design of Communication Links and Networks, IEEE CAMAD 2012, Barcelona, Spain, 17-19 September 2012.	AEGEAN
Sep. 2012	Tim Forde, Linda Doyle, Managing Spectrum into Abundance	Proceeding of the Workshop on Telecom Economics, Engineering and Policy	TCD

Oct 2012	Bourdena, E. Pallis, G. Kormentzas, G. Mastorakis, A radio resource management framework for TVWS exploitation under an auction-based approach	8th International Conference on Network and Service Management, CNSM 2012, The Mirage, Las Vegas, USA, 22-26 October 2012.	AEGEAN
Oct 2012	Bourdena, E. Pallis, G. Kormentzas, G. Mastorakis, A Radio Resource Management Framework for Opportunistic TVWS Access	1st ACM Workshop on High Performance Mobile Opportunistic Systems, HP-MOSys 2012, Paphos, Cyprus, October 21-25 2012.	AEGEAN
Dec 2012	Bourdena, E. Pallis, G. Kormentzas, G. Mastorakis, QoS provisioning and policy management in a broker-based CR network architecture	IEEE Globecom2012, IEEE International Workshop on Recent Advances in Cognitive Communications and Networking, Anaheim, San Francisco, USA, 3-7 December, 2012.	AEGEAN
June 2013	Bourdena, E. Pallis, G. Kormentzas, G. Mastorakis, Radio Resource Management Algorithms for Efficient QoS Provisioning over Cognitive Radio Networks	IEEE ICC2013, Budapest, Hungary, 9-13 June, 2013	AEGEAN

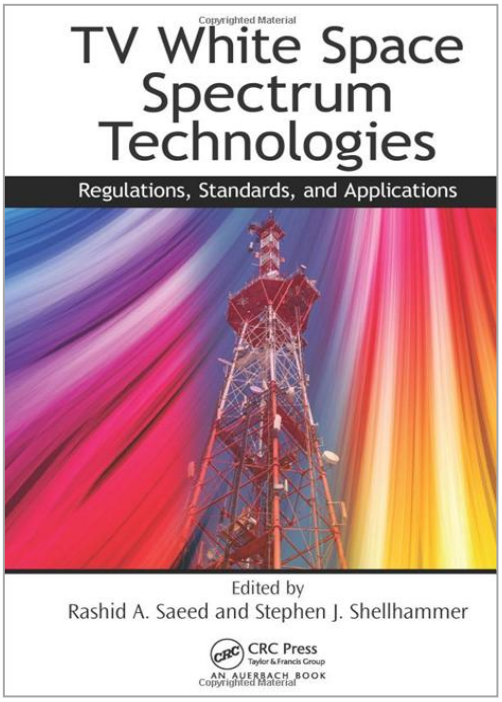
5.2 Journal papers

In the following table all journal papers published by COGEU partners in the second and third year of COGEU are listed:

Title	Journal	Lead Partner
Maurizio Murroni, Venkatesha Prasad, Dominique Noguet, Klaus Mossner, Paulo Marques, Hiroshi Harada "*IEEE 1900.6 Spectrum Sensing Interfaces and Data Structures for Dynamic Spectrum Access and other Advanced Radio Communication Systems Standard: Technical Aspects and Future Outlook*"	IEEE Communications Magazine, Dec 2011.	IT in collaboration with a team from FP7 QoSMOS project
Pawel Kryszkiewicz, Hanna Bogucka and Alexander Wyglinski, "*Protection of Primary Users in Dynamically Varying Radio Environment: Practical Solutions and Challenges*"	EURASIP Journal on Wireless Communications and Networking Jan. 2012.	PUT
Irene Macaluso, Tim Forde, Luiz DaSilva and Linda Doyle, "*Recognition and Informed Exploitation of Grey Spectrum Opportunities*"	IEEE VTC special issue magazine on 'Applications of Cognitive Radio Networks' June 2012.	TCD

Justin Tallon, Tim Forde and Linda Doyle, "*Independent coalition formation for dynamic spectrum access networks*"	IEEE VTC special issue magazine on 'Applications of Cognitive Radio Networks' June 2012.	TCD
A. Bourdena, E. Pallis, G. Kormentzas, G. Mastorakis, "*A prototype cognitive radio architecture for TVWS exploitation under the real time secondary spectrum market policy*"	Physical Communications, Special Issue of Physical Communication on "Cognitive Radio for LTE Advanced & Beyond", Elsevier.	AEGEAN
José Ribeiro, Rogério Dionísio, Paulo Marques and Jonathan Rodriguez, "*Testbed for Combination of Local Sensing with Geo-location Database in Real Environments*"	Radio Networks: A Practical Perspective, IEEE Wireless Communications Magazine, August 2012.	IT
Marcin Parzy, Hanna Bogucka, "*On-line spectrum auctions in TV white spaces for supporting mobile services - a practical manual*"	Telecommunications Policy, Elsevier, October 2012.	PUT
Joseph W. Mwangoka, Paulo Marques, Jonathan Rodriguez, "*TV white spaces exploitation through a bicameral geo-location database*"	Telecommunications Policy, Elsevier, October 2012.	IT
Tim Forde and Linda Doyle, "*A TV Whitespace Ecosystem for Licensed Cognitive Radio"*	Telecommunications Policy, Elsevier, October 2012.	TCD
Hanna Bogucka, Marcin Parzy, Paulo Marques, Joseph W. Mwangoka, Tim Forde, "*Secondary Spectrum Trading in TV White Spaces*"	IEEE Communications Magazine, Nov. 2012.	PUT

5.3 Book Chapters



- J. Mwangoka, P. Marques, J. Rodriguez, "*Elements of Efficient TV White Space Allocation: Part I*: *Acquisition Principles*", in book: TV White Space Spectrum Technologies: Regulations, Standards and Applications, edited by Rashid A. Saeed and Stephen J. Shellhammer, chapter accepted, December 2011. [ISBN-13: 978-1439848791]
- J. Mwangoka, P. Marques, J. Rodriguez, "*Elements of Efficient TV White Space Allocation: Part II: Business Models*", in book: TV White Space Spectrum Technologies: Regulations, Standards and Applications, edited by Rashid A. Saeed and Stephen J. Shellhammer, December 2011. [ISBN-13: 978-1439848791]
- A. Bourdena, P. Makris, D. N. Skoutas, C. Skianis, G. Kormentzas, E. Pallis, G. Mastorakis , "Joint Radio Resource Management in cognitive Networks: TV White Spaces Exploitation Paradigm", in book Evolution of Cognitive Networks and Self-Adaptive Communications Systems, IGI Global [To appear]

5.4 Invited Presentations

Besides the scientific papers there are invited presentations listed in the subsequent table.

Date	Event	Audience	Partners involved	Nature
1st March 2011	European Parliament , Public Hearing on Radio Spectrum Policy Programme, Paulo Marques, "Common management of radio-spectrum is an opportunity for *EU growth and competitiveness*"	European Parliament Members and invited stakeholders	IT	Panel 1 – Spectrum in the EU: towards a smarter management of a scarce public resource
23 June 2011	Wireless Innovation Forum, Brussels, Paulo Marques, "*Secondary trading of TV white spaces: the low-cost 4G spectrum*"	Mainly Software Defined Radio industry	IT	Presentation

5 Oct. 2011	IC0902 COST action: (5th Management Committee Meeting and IC0902 2nd Year Workshop)	Mainly IC0902 COST action members	PUT	Presentation
29 Nov. 2011	FP7 QoSMOS workshop at SDR'11-WInnComm in Washington D.C.	Mainly SDR community	TCD	Presentation
13 Dec. 2011	Cambridge White Spaces Policymaker Event, Microsoft Research, Paulo Marques, "*Overview of FP7 COGEU work on Bavarian white spaces and spectrum database demonstrator*"	Policymakers and regulatory authorities	IT	Presentation and COGEU databse demonstration
25 April 2012	5th meeting of COST-TERRA, 25-27 April 2012, Vilnius (Lithuania)	Public / H. Bogucka TV White Spaces Spectrum Broker.	PUT	Presentation, best presentation award
Sep. 2012	COGEU database presentation, White Spaces Workshop, Dublin, Ireland	Audience of 80+: Irish and international audience; telecoms companies, regulators	TCD, IT	organised and presented at the workshop which aims to broaden knowledge of the TVWS opportunity within Ireland; demonstrated TVWS radios
28 Nov.. 2012	Key note speech on COGEU final results, 6th meeting of COST Action IC0905 TERRA, Brussels	CR research community	IT	Key note speech

5.5 Training, education and tutorials

The COGEU project was presented in tutorials, summer schools and invited lectures dedicated to the selected areas in wireless communications. Moreover, the results obtained within COGEU project has been exploited to advance the work of five PhD students directly involved in COGEU research activities.

Date	Event	Audience / Title	Partners involved	Nature
July 2011	Cognitive Radio Summer School, Vilnius, Lithuania	Postgraduate students from Lithuania	TCD	lectures at summer school
June 2012	Game Theoretic Modeling of Resource Management in Cognitive Radio Networks	WiFiUS Summer School, Oulu, Finland,	TCD	Invited lecture
May 2012	Theory and Practice of Cognitive Radio, Ph.D. course, Aalborg University, Denmark	PhD students	TCD	Invited lecture
July 2012	CR/SDR summer school , July 2012, Dublin	40 students from 13 countries	TCD	Summer school

July 2012	COST Action IC0902 2nd Intl. Summer School on Cognitive Wireless Communications: Highlight on Game Theory, Paris, France	Introduction to Dynamic Games	TCD	Tutorial
Aug. 2012	PERSEUS - Erasmus Intensive Programme	Cognitive Radio technologies - Students from France, Turkey, Greece, Portugal	AEGEAN	Lectures at summer school

5.1 Other publications

COGEU has produced other technical publications targeting a broader audience as listed below.

Date	Publication	Title
March 2012	Tech-i, EBU Technical, page 8-9 (in cooperation with Microsoft)	In the zone: Broadcast trial White Spaces in Europe
July 2012	National Instruments Labview case study publication	"*LabVIEW and NI USRP Hardware Accelerate Cognitive Radio Research*" , a worldwide case study for cognitive radio practical implementation
Sep. 2012	Net-tech future, European Commission, page 28-29	Building a Wireless Web for all on TV White Space

in focus

In the Zone

Broadcasters trial 'White Spaces' in Europe

With the growing demand for spectrum, Jim Beveridge of Microsoft reports on how some broadcasters are assessing the potential use of White Spaces in the UHF Band to ease the scarcity.

The year 2012 will be a landmark for TV White Spaces (TVWS) in Europe. The hi-tech cities of Cambridge and Munich are exploring the potential afforded by the use of White Spaces in the UHF Band. Both cities are covered by White Spaces transmission hotspots as part of the trials, with detailed measurements being undertaken by trial members. This information will be used in ongoing UHF band planning.

EBU Members are actively supporting both trials. In Munich the TVWS trial is supported by IRT as members of the EU funded COGEU consortium[1]. In Cambridge the BBC actively supports the trial as a member of the Cambridge White Spaces Consortium[2].

White Spaces - Using Technology to Avoid Interference

The first recorded regulatory acknowledgement of White Spaces took place in the 1950s. Early UHF tuner designs suffered from poor image frequency and adjacent-channel rejection, resulting in the FCC being forced to mandate that transmitters operating in the same immediate area in Oregon (KPTV, Portland, Oregon) keep a minimum of six channels apart to avoid interference. The term 'White Space' was coined by the FCC to refer to frequencies allocated to a broadcasting service but not used locally.

These results made it clear to network planners, particularly in Europe, that they needed to plan for a considerable distance between transmitters operating on the same frequency, so that only a subset of the available frequencies was used at each site.

By the time UHF transmission started in Europe, advances in technology, championed by the broadcast community, had solved many of the initial interference problems.

Fast forward 60 years, with the growing number of new applications and uses for the same spectrum, White Spaces are no longer viewed merely as a buffer zone for the TV but a real economic and social opportunity. This time around, advances in silicon and software through cognitive and geolocation database technologies, available today, are being deployed to compliment the broadcasters' traditional array of tools to avoid interference. Smart databases controlling smart devices make for greater spectrum utilisation.

White Spaces - Multiple Platforms, Growing Demand

Demand for wireless connectivity is growing at an exponential pace. Society is more connected than ever, with laptops, smartphones and tablets. Perhaps most important is that expectations have changed. Consumers expect to be connected and now want multi-megabyte pictures and multi-gigabyte video on these devices. In Europe a good proportion of IP video content will be generated by broadcasters.

Phil Kesby from Arqiva at work at the Cambridge Trial (photo courtesy of Arqiva)

IRT testing vehicle used in the Munich Trial (photo courtesy of IRT)

Jim Beveridge
Senior Director, International Technology Policy, Microsoft

Jim Beveridge is responsible for driving Microsoft's Technology Policy Initiatives in EMEA, LATAM and Asia Pacific. Prior to joining Microsoft, Jim worked for Pace Micro Technology as General Manager of their Digital Division. He is a member of the DVB Steering Board, and member and Chairman of the Digital Interoperability Forum. For recreation Jim enjoys sailing the sunny Western Isles of Scotland.

Even fixed, connected TVs raise the requirement for wireless connectivity, as broadband access stretches out to the more sparsely populated rural areas. Within the home too, there are opportunities for wireless networks to allow consumers to reach the content they want from whichever smart glass device is most convenient. Smarter use of the White Spaces can help satisfy these demands to the benefit of the consumers and the broadcaster community alike.

White Spaces – Sharing Spectrum Solutions

Globally, there is a growing understanding that the way spectrum has been allocated is creating scarcity. That is because allocations are based on historic limitations of legacy radio technologies in which wide swathes of spectrum are allocated for a particular use, but not necessarily actually used. These allocations were made with no knowledge of the types of uses of spectrum that we have today or any understanding of the technology and techniques that can be applied to manage the spectrum.

This fixed physical asset coupled with increased demand means we have to start sharing, and to get used to using smart technology to allow sharing of the spectrum between different users and applications. Inherent in this is the idea that the smart devices are licensed on the condition that they report where they are and operate under control from a database. Smarter databases and devices will lead to greater spectral efficiencies and lay the foundation for enhanced consumer services and an

BUILDING A WIRELESS WEB FOR ALL ON TV 'WHITE SPACE'

As the internet goes increasingly mobile and wireless, the gaps between frequencies used for television, known as 'white space', can help all citizens gain access to broadband through the airwaves.

To a writer or artist, 'white space' sounds like the portions of a page unoccupied by words or images, and leaving enough of these empty areas is crucial to the art of making text or graphics visually attractive and to avoiding unnecessary 'noise' and interference.

A similar principle used to apply to the broadcast media. Analogue TV once required large swathes of white space between channels to preserve their quality of broadcast, enable antennae to pick them up and avoid interference between adjacent channels.

However, as technology has progressed, much of this white space has become redundant. Moreover, the switchover from analogue to digital TV, which is set to be completed in the EU by the end of this year, has freed up additional space on the spectrum (mostly, between 470 and 790 MHz).

Yet despite all this unutilised white space, there exists the paradoxical situation of an apparent shortage of spectrum. "Spectrum is a scarce resource and there are conflicting spectrum requirements across the telecommunication industry," explains Dr Paulo Marques, senior research engineer at Portugal's Instituto de Telecomunicações. "As with any other limited resource, proper management of the frequency spectrum is important in maximising its value to society."

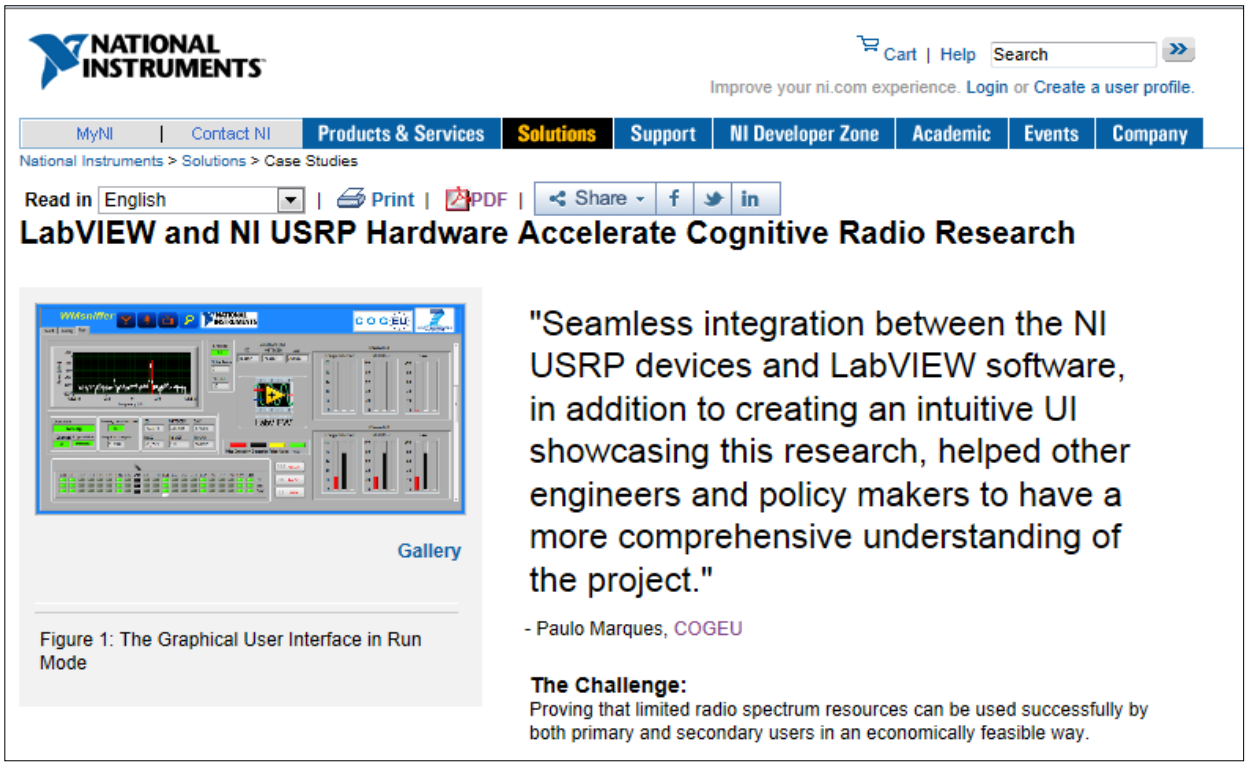


Figure 6 Other COGEU publications for a broader audience.

6 COGEU workshops

In the reporting period of 2011 and 2012 COGEU organized two workshops, one held in Munich in November 2011 and the second one held in Bratislava in October 2012.

6.1 COGEU Munich workshop

On the 10th of November 2011, being the project's second year, the COGEU project consortium organized a Workshop on the Efficient Use of the TV White Spaces in European Context. The theme of the Workshop was: "Can Europe make use of the TV White Spaces?" The one day event was hosted by IRT in Munich, Germany. The main objective of the workshop was to stimulate discussions and exchange of ideas between the COGEU team, invited speakers and the audience to validate COGEU's views and approaches about an efficient use of TV white spaces in European context.

The number of participants exceeded 130, representing the spectrum of the TV white space stakeholders in the European context. The list of attendants included regulators, broadcasters, spectrum users, PMSE companies, academia, operators, researchers from other FP7 projects on cognitive radio technologies, standardization bodies, as well as EU officers, i.e., project funding authority, among others.

The workshop was split into five main sessions namely: introductory session; presentation on COGEU's intermediate results: scenarios, business models, technology options and preliminary trial results of the COGEU demonstrator; reports on ongoing activities in the field, mainly presentations of complementary research aspects to COGEU from sibling FP7 projects; regulatory, standardization and business viewpoints; and a panel discussion. In parallel to the main auditorium event, COGEU demonstrated some of its achievements in TV white space detection, sensing methods, spectrum shaping and PMSE booking through a database.

Figure 7 The final panel at COGEU workshop (Presentations and photos available: http://www.ict-cogeu.eu/diss_workshops.html)

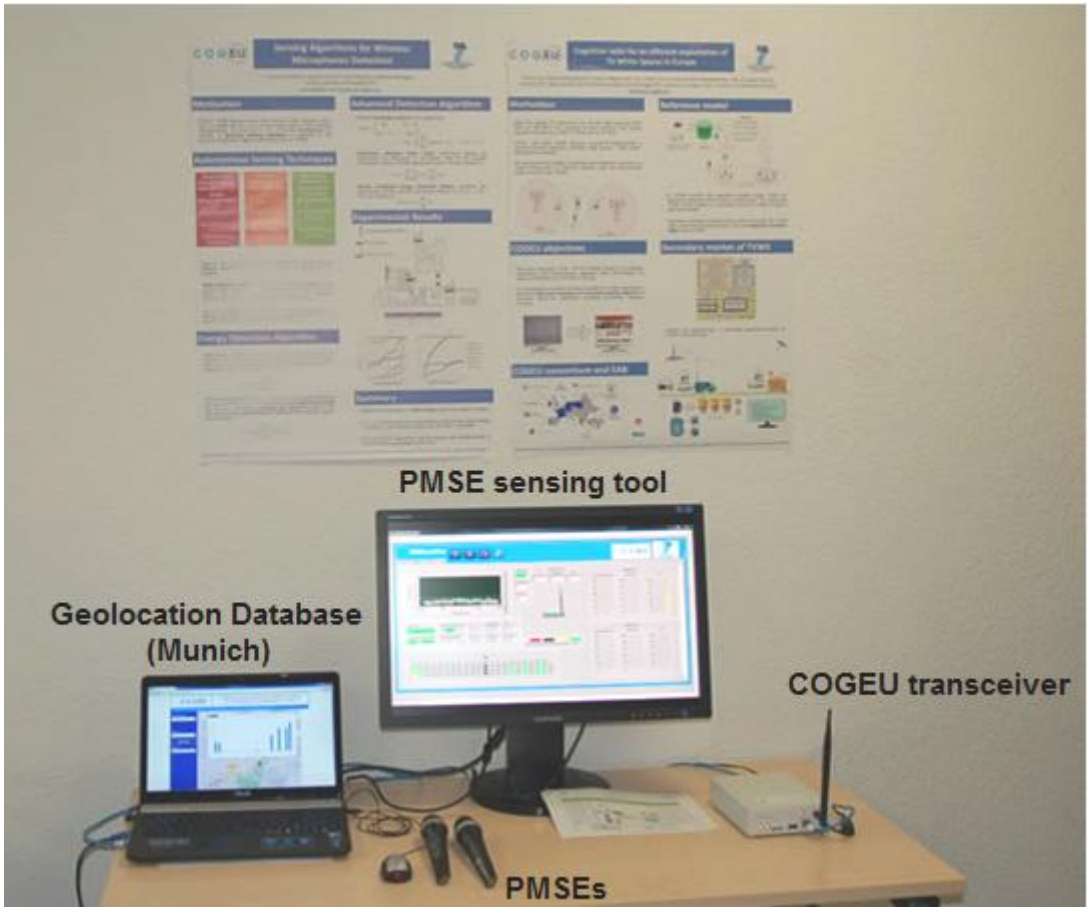


Figure 8 Demonstration of combination of geo-location database access with local PMSE sensing (COGEU workshop in IRT-Munich, November 2011).

Through this workshop, the COGEU consortium was able to present its intermediate results on the usage of the TV white spaces in the European context and received feedback from workshop participants. The number and variety of the participants are clear indications of the importance of the project's research activities. The COGEU project research work, through a combination of actual measurements campaigns, development of regulatory tools, architectural designs and demonstrations showcased the possibility of using the TV white spaces to enable broadband Internet access, even in rural areas, hence support the achievement of the EU Parliament goal for the equal treatment of all regions. Moreover, the feedback obtained from participants, including sibling projects, invited presentation from regulators, standardization body and the operator as well as the panel discussions indicated that the path taken by the project has the potential to lead to successful exploitation of the TV white spaces and the user of cognitive radio technologies.

During the workshop a representative of Microsoft contacted the COGEU Project Manager. Microsoft is strongly interested in White Space use and has been a big player in the Cambridge trials conducted in the UK in 2011/2012. After the workshop COGEU became the opportunity to be presented at the Cambridge White Spaces Policymaker Events in December 2011 and April 2012 in Cambridge (UK).

6.2 COGEU Bratislava workshop

As part of the dissemination activities within the central European area, COGEU decided to organize the second workshop in Bratislava during the second half of the project's last year. The aim was to openly discuss COGEU approach to secondary spectrum utilization within the TV White Spaces with the audience. For this workshop COGEU consortium took the opportunity to organize COGEU workshop as special event of Central European Radiocommunication Days, an international conference annually organized in Bratislava. Detailed information about the event is available here [5].

The main goal of this workshop was focused on showing and demonstrating real outcomes of research within the COGEU project in the field of cognitive radio techniques in the White Spaces of TV spectrum and compare publicly results of two different on-the-air tests in Munich and Bratislava and Banská Bystrica. Invited were representatives of national regulatory authorities, policy makers, mobile operators, broadcasters and related industry representatives.

Main contributions from COGEU consortium members where aimed to present results and differences from on-the-air test in Munich held in July 2012 and very preliminary results measured and recorded in recent days before workshop held on 19-th October 2012. In addition to the measurement results and some technical details the focus was put on economical models and spectrum policies in COGEU.

Other contributions were given by representatives of FP7 QoSMOS project and Microsoft Coroporation (from the Cambridge White Spaces Consortium) who supplemented information on business model for white spaces.

During the breaks live video streaming service within counted and measured TVWS spectrum channels without any harmful interference to the primary DVB-T broadcasting service (Figure 119) was demonstrated.

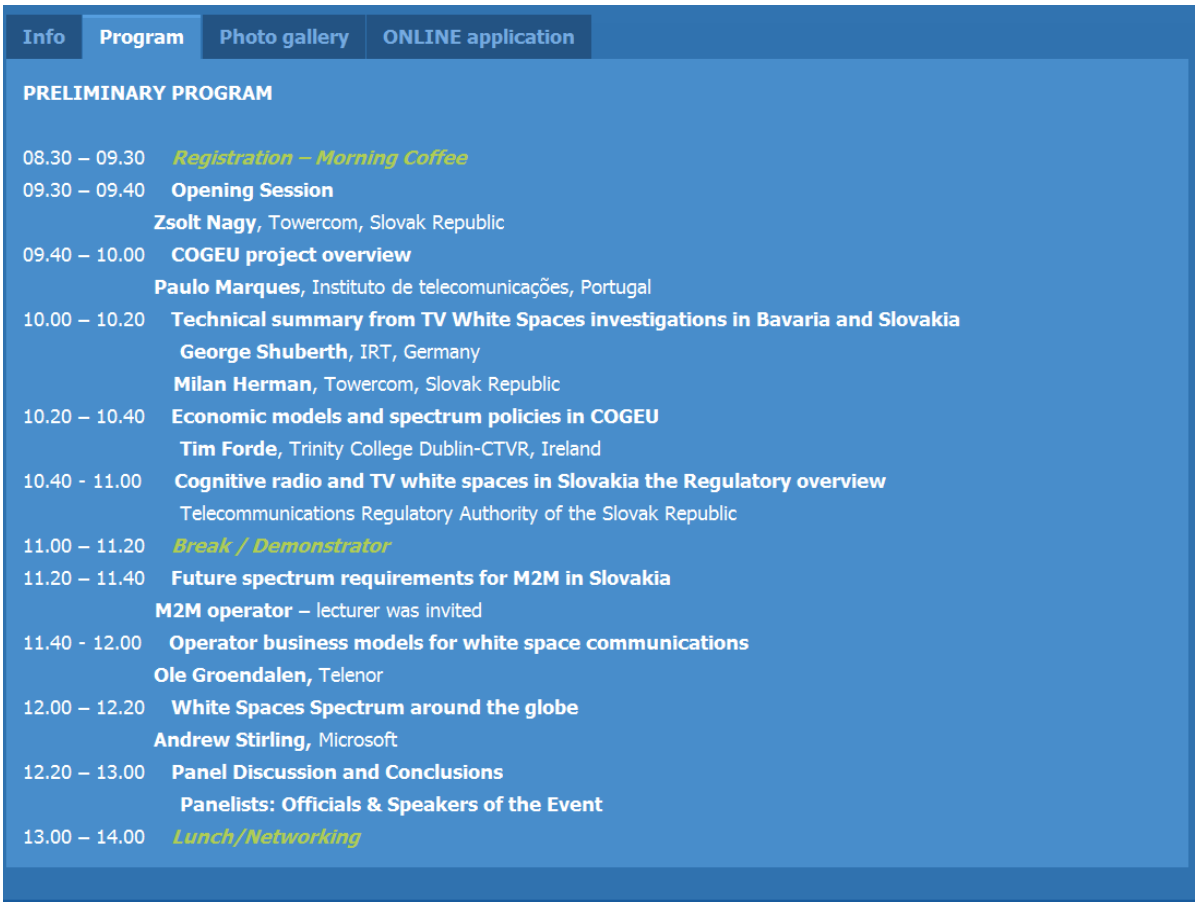


Figure 9 COGEU Bratislava workshop programme (19th October 2012) [5].

Figure 10 The audience at the Bratislava workshop included Slovak broadcasters and officials from the national regulator.

Figure 11 Demonstration set-up in the Bratislava workshop: video surveillance service over TVWS without harmful interference to DVB indoor reception.

The panel round at the end of the workshop was held as an open discussion. Some of the outcomes of the discussion will be considered in other deliverables of COGEU project. Some delegates pointed out that there is a lack of information on TVWS spectrum utilization and concluded that this workshop brought valuable information to regulatory and industry representatives.

Recently the 800 MHz and 2.6 GHz spectrum auction in Slovakia was postponed to 2013 and due to this open situation, it is difficult to get a regulatory overview for TVWS future in

Slovakia. Representative of commercial broadcasters simply express its opinion to protect TV spectrum primary for TV broadcasting services.

The Bratislava workshop showed the importance of sharing information of research projects within concerned parties to support innovative approaches. The delegated welcomed this opportunity and appreciated this by lively discussions during the coffee breaks and also at the final panel discussion.

6.3 COGEU exhibitions

During the reporting period COGEU has organized five exhibitions. The COGEU exhibitions were attended by many researchers, spectrum regulators and industry representatives.

Date and venue	Demonstrators
June 2011 FUNEMS 2011 Warsaw, Poland	Demo I – Wireless microphone sensing. Demo II – Highly efficient TVWS signal shaping. Demo III – Advanced TVWS Rendezous using Spectrum Watermarking.
November 2011 COGEU Workshop Munich (IRT), Germany	Demo I – High sensitivity DVB detector. Demo II – PMSE spectrum booking platform. Demo II - Highly efficient TVWS signal shaping.
July 2012 FUNEMS 2012 Berlin, Germany	Demo I - Show TV White Spaces tools Munich area and Slovakia – online public available. Demo II - PMSE online booking tool. Demo III - Combination of PMSE sensing with TVWS database access. Demo IV - Online TV White Spaces auction tool for Munich area. Demo V - DVB-T high sensitivity detector. Demo VI - COGEU transceiver with Advanced spectrum shaping Demo VII - TVWS repository. Demo VIII - Protocol to Access White Space database COGEU-PAWS draft implementation.
Sep. 2012 Filling the White Spaces workshop Dublin, Ireland	Live demonstration of the COGEU geo-location database framework (Munich, Bratislava and Banska Bystrica). Audience of 80+: Irish and international audience; telecoms companies and regulators
October 2012 COGEU workshop Bratislava, Slovakia	Demonstration of a video surveillance radio link over a TVWS channel using the COGEU transceiver connected to the Bratislava database, coexistence with DVB-T indoor reception.

Figure 12 COGEU project presented its progress with a demonstration stand at the Future Network and Mobile Summit 2011, in Warsaw, Poland.

Figure 13 COGEU project presented mature demonstrators at the Future Network and Mobile Summit 2012, in Berlin.

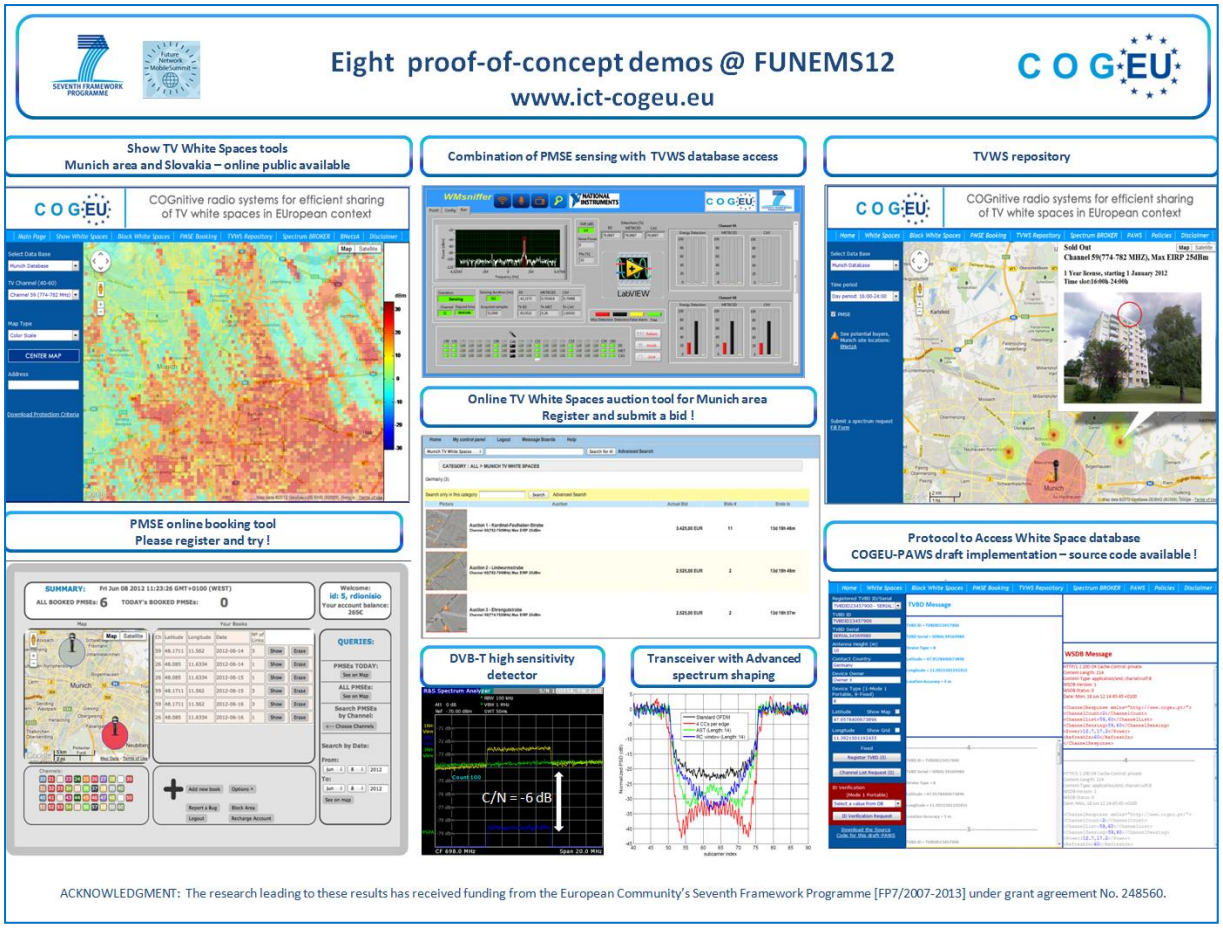


Figure 14 COGEU flyer distributed to advertise the eight COGEU tools available for demonstration at FUNEMS2012 exhibition.

7 Cooperation with other international research activities

The COGEU consortium interacts with international research projects and activities in the specific area to closely follow the coming evolutions and technological achievements as well as to communicate COGEU ideas and results to a broad audience of experts.

7.1 COGEU and the Cambridge White Spaces consortium

On the 13 December 2011, high-level European Union policymakers were in Cambridge to witness results from TV white spaces trials. Intermediate results from the Cambridge TV White Spaces Consortium (comprising companies such as - Arqiva, BBC, BSkyB, BT, Microsoft, Neul, Nokia, Samsung and Virgin Media) were presented. COGEU was invited to be presented at this workshop as an outstanding example of a European project beyond UK efforts. Paulo Marques presented to the policy makers audience the COGEU model and the COGEU geo-location database tools.

On the 25th April 2012, the final Cambridge TVWS event marked the closing event in the Cambridge White Space trial, an event led by Microsoft and including nearly twenty key players. Over 150 people attended including very senior figures from industry and regulation from the UK, US, Singapore, Malaysia, South Africa and elsewhere. The event was even reported on by BBC prime-time news. The agenda included a COGEU presentation on "Future of white spaces: Germany". COGEU was regarded as the most relevant research effort targeting TVWS experimentation in continental Europe.

Cambridge TV White Spaces Trial Summit

April 25th, 2012

Supported by Cambridge Wireless

Venue

The AirSpace Conference Centre at Imperial War Museum, Duxford, Cambridge CB22 4QR, UK

Agenda

Schedule	Topics	Presenters
MORNING – OFF-THE RECORD TECHNICAL SESSION (NO PRESS)		
09:30 – 10:00	Arrival and registrations	
10:00 – 10:05	How the regulatory requirements are met: overview of Trial	BSkyB
10:05 – 10:30	Path loss, coverage, protection requirements for DTT, Performance	Arqiva
10:30 – 10:55	DTT Receiver protection & Database calculations	BBC
10:55 – 11:10	Database facilitated co-existence for White Spaces Devices	Spectrum Bridge
11:10 – 11:30	PMSE protection	CSR
11:30 – 11:40	Rural links	TTP
11:40 – 11:50	Observing the White Spaces in Cambridge	CRFS
11:50 – 12:30	Panel and Q&A	
AFTERNOON – OPEN SESSION		
12:30 – 13:30	Arrival, registrations, TV White Spaces demonstrations and lunch	
13:30 – 14:00	Keynote speech	DCMS
14:00 – 14:10	Economic value of flexible access to spectrum	Microsoft
14:10 – 14:20	Broadband Rural: business applications looking forward	BT
14:20 – 14:30	Ad-hoc flexibility: emergency services	UK Cabinet Office
14:30 – 14:40	Machine-to-machine applications	ARM
14:40 – 14:50	Future of services: devices and databases	Nokia
14:50 – 15:05	TV White Spaces: the regulatory opportunities	Ofcom (Hyacinth Nwana, partner)
15:05 – 15:20	The European regulatory landscape	European Commission (Pearse O'Donohue)
15:20 – 15:30	Future of White Spaces: Germany	COGEU
15:30 – 15:40	Future of White Spaces: Singapore	IDA
15:40 – 15:50	Future of White Spaces: USA	FCC
15:50 – 16:30	Panel and Q&A session	

Figure 15 Agenda of the Cambridge White Spaces event on 25th April 2012.

7.2 COST TERRA-ICT Action IC0905

COST IC0905 TERRA is one of the European networking activities within the framework of COST - European Cooperation in Science and Technology. One of the key objectives of COST-TERRA is to establish a multi-disciplinary European forum focused on coordinating techno-economic studies for the development of a harmonized European regulatory framework to facilitate the advancement and broad commercial deployment of cognitive radio/software defined radio (CR/SDR) systems.

Launched in May 2012, COST-TERRA now has members from 22 countries. Research findings are disseminated at regular COST-TERRA meetings and workshops through a series of invited presentations and joint publications.

Dr. Keith Nolan of CTVR, Trinity College Dublin is a member of the COST-TERRA management committee representing Ireland. He is chairman of a working group focusing on the economic aspects of CR/SDR regulation, which works on evaluating the economic aspects of CR/SDR regulations and new regulatory paradigms based on economic policies. These studies help assess critical factors impacting economic benefits and viability of CR/SDR technologies. Dr. Nolan is also vice-chair of a special interest group within COST-TERRA developing a new regulatory approach called pluralistic licensing. Recent outputs from this collaborative process include a paper published in Proceedings of IEEE DySPAN 2012 on pluralistic licensing, and an article regarding the use of cognitive radio for medical body area networks using ultra wideband in IEEE Wireless Communications Magazine.

7.3 NewCOM ++

NEWCOM++ is the acronym of the Network of Excellence in Wireless COMmunications, funded by the VII Framework Program under the Objective ICT-2007.1.1: The Network of the Future, mainly in its target direction “Ubiquitous network infrastructure and architectures”. NEWCOM++ promotes solutions to problems and challenges of future wireless networks by creating a trans-European virtual research centre linking a proper number of leading European research groups in a highly integrated, carefully harmonized, cooperative fashion.

The overall NEWCOM++ organization comprises 11 core research work packages spanning physical layer communications (PHY), networking (NET) and cross-layer interactions (X-LAYER). From a purely academic perspective this number and types of work packages will lead to cross-fertilization and exchange of ideas, mathematical tools and design methodologies stemming from the different scientific communities comprising the consortium.

Prof. Hanna Bogucka from PUT, active in COGEU and the member of the COGEU Project Coordinating Committee (PCC) was also the member of the Executive Board of NEWCOM++, providing a link between these two 7th FP EU projects.

7.4 COGEU and the RAS cluster projects

COGEU belongs to the FP7 "Radio Access & Spectrum" cluster, where the coordinators and delegated responsible persons from these projects have the opportunity to interact and exchange ideas in the area of future wireless networks, which are in common interest. The EC project cluster "Radio Access & Spectrum" (RAS) aims to provide a platform for exchanges and concertation between FP7 projects. The main objectives are:

- To create a technical platform where all projects can harmoniously exchange/disseminate information;
- To identify synergies and future technical challenges/requirements in the field of radio networks;
- To Assist European Commission (EC) on future research directions;
- To develop a recommendation to standardization and regulation bodies.

The RAS cluster allow the consortium to share the results of the project with other FP7 projects. IT, as COGEU project coordinator, has participated in all the RAS cluster meetings as detailed below.

Table 1 –COGEU participation in the FP7 RAS cluster meetings.

RAS cluster meeting	**COGEU contribution**
14th June 2011	The main objective of the meeting was to collect feedback from projects regarding potential questions to the regulator panel at FUNEMS. COGEU, as a project with significant regulatory implications, contributed with several ideas for the interaction with the regulators.
6th October 2011	IT presented the COGEU methodology to compute TV white spaces and demonstrate a draft version of the geo-location database for the Munich area.
13th February 2012	IT gave a talk on SEAMCAT, the open source professional interference analysis tool developed by CEPT-ECO. The aim was to motivate other RAS cluster projects to exploit and contribute to the development of this software tool, which also facilitates the comparison of simulation results between projects.
10th October 2012	IT presented the pre-final results of the COGEU trials in Munich including the COGEU promotional video. In this meeting Paulo Marques was appointed as a co-chair of the RAS cluster.

Regarding peer-to-peer interaction with other RAS cluster projects COGEU has developed links with SACRA and QoSMOS projects.

The SACRA project (Spectrum and Energy Efficiency through multi band cognitive radio) was presented at the COGEU Munich workshop where the following common research issues were identified and discussed:

1- Common scenario: LTE over fragmented spectrum (such as TVWS)
2- Spectrum aggregation techniques (spectrum shaping algorithms)
3- Sensing of incumbent systems

The COGEU geo-location database prototype was presented at the SACRA workshop on 23 Feb. 2012 in Sophia-Antipolis.

COGEU participated in QoSMOS (Quality of service and Mobility driven cognitive radio systems) workshop at SDR'11-WInnComm in Washington D.C. on 29th November 2011. Paul Sutton (TCD), presented "Cognitive radio systems for efficient sharing of TV white spaces in European context".

The QoSMOS project was present at the COGEU Bratislava workshop with a contribution on “Operator business models for white space communications” given by Telenor.

7.5 Wireless Innovation Forum

Established in 1996, the Wireless Innovation Forum (WInnF) is an non-profit “mutual benefit corporation” dedicated driving technology innovation in commercial, civil, and defense communications around the world. Forum members bring a broad base of experience in Software Defined Radio (SDR), Cognitive Radio(CR) and Dynamic Spectrum Access (DSA) technologies in diverse markets and at all levels of the wireless value chain to address emerging wireless communications requirements through enhanced value, reduced total life cost of ownership, and accelerated deployment of standardized families of products, technologies, and services. The Forum acts as the premier venue for its members to

collaborate to achieve these objectives, providing opportunities to network with customers, partners and competitors, educate decision makers, develop and expand markets and advance relevant technologies.

Paul Sutton of CTVR, Trinity College Dublin is a director of the WInnF and Keith Nolan of CTVR, Trinity College Dublin is vice-chair of WInnF's regulatory committee representing ITU Region 1.

COGEU interacted with the WInnF through conferences, workshops and teleconferences, e.g., Linda Doyle gave a keynote speech at the Wireless Innovation Forum European Conference on Communications Technologies and Software Defined Radio in Brussels in June, 2011.

COGEU was presented in the “programs track” of the Wireless Innovation Forum Conference on Communications Technologies and Software Defined Radio (SDR’11 – WInnCOMM – Europe) held in Brussels from 22nd to 24th of June, 2011.

8 COGEU External Advisory Board

After contacts from external entities seeking to join COGEU project, the COGEU PCC (Project Coordinator Committee) decided to establish an External Advisory Board. The EAB includes representatives from industry who can advise on the research topics. These experts can be suggested by any partner and will be agreed by the PCC (Project Coordinator Committee).

The COGEU EAB members are:

- Dr David Steer (PhD)
  Principal Member of Technical Staff
  Research In Motion (RIM)

- Dr Egon Schulz (PhD)
  Director of Wireless Innovation Centre
  Huawei Technologies Duesseldorf GmbH

The cooperation with the EAB members was enriching to all parties because the advisors brought in the overview of mobile industry and the insight to the developments and their view to the markets.

Moreover in the 3rd EAB meeting (15th June 2011) Ben Smith from **Agentschap**, the Netherland's regulator was invited to the EAB meeting which offered the opportunity to exchange information and viewpoints with a regulator. In the 4th EAB meeting (4th July 2012) Max Riegel from **Nokia-Siemens-Networks** was invited which offered the opportunity to exchange information and viewpoints with a network manufacture.

The COGEU consortium consider cooperation with global industrial players such as RIM and HUAWEI beneficial for COGEU impact and visibility, contributing to the success of the project. The EAB members have a strong involvement on standardization activities, RIM is chairing the IEEE 802.11af standard on WiFi over TVWS and Huawei participates in ETSI RRS working groups with special interest on the LTE over TVWS scenario. COGEU benefits with the up-to-date vision of the standardization effort brought by the EAB.

The process of the flow of information between COGEU partners and the EAB follows a NDA (Non Disclosure Agreement).

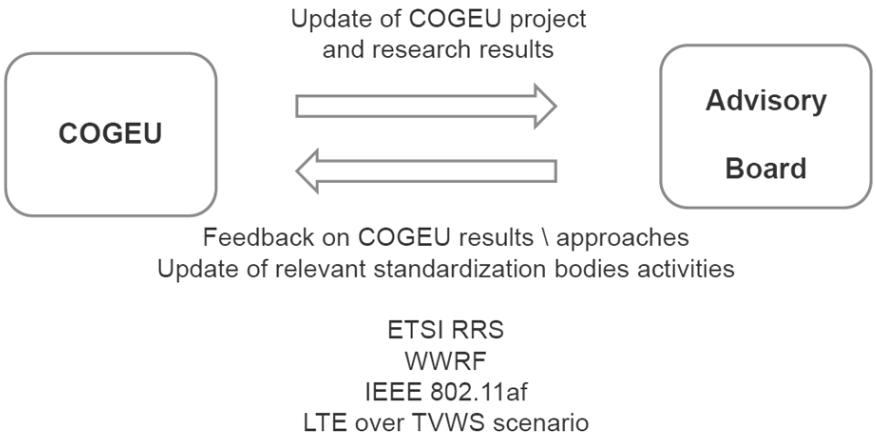


Figure 16 Information flow between COGEU and the EAB.

During the second and third years of the project life two EAB meetings took place with the following agendas.

- **3rd EAB meeting**
  15th July, Warsaw, Poland collocated with the conference FUNEMS 2011
  Meeting agenda:

Item	Time	Topic	Responsible
Wednesday, 15.06.2011			
1	9:00-9:15	Agenda approval	ALL
2	9:15-9:30	The current status of COGEU project	IT
3	9:30 – 10:00	Overview of COGEU test cases and final demonstrator	SIGINT
4	10:00-10:30	Feedback on COGEU test cases and final demonstrator	EAB
	10:30-10:45	Break	
5	10:45-11:15	COGEU spectrum market model: Alternatives for the COGEU auction design	PUT
6	11:15-11:45	Feedback on COGEU spectrum market model	EAB
7	11:45-12:00	Status of COGEU participation in ETSI RRS and future plans	IT,PTIN
8	12:00-12:15	Feedback on COGEU standardization in ETSI RRS and way forward	EAB
9	12:15-12:30	Action Points \ Wrap up	IT

- **4th EAB meeting**
  4th July 2012, Berlin, Germany, collocated with the conference FUNEMS 2012:
  Meeting agenda:

Item	Time	Topic	Responsible
Wednesday, 4.07.2012			
1	9:30-9:45	Welcome and agenda approval	Paulo Marques (IT)
2	9:45-10:15	COGEU progress overview and presentation of the geo-location database tools	Paulo Marques (IT)
3	10:15-10:30	EAB's feedback	ALL
	10:30-10:45	Coffee Break	
4	10:45-11:00	Progress on the COGEU TV White Space transceiver	Tim Forde (TCD)
5	11:00-11:30	Technical summary from the TV White Spaces trial in Munich	George Schuberth (IRT)
6	11:30-11:45	EAB's feedback	ALL
7	11:45-12:15	News from ETSI RRS and IEEE cognitive radio standardization – opportunities for COGEU	EAB
8	12:15 12:30	Wrap up and conclusive remarks	Paulo Marques (IT)
	12:30	Meeting closes	

9 COGEU web site and promotional video

The official website for the COGEU project has been maintained at the IT web servers with the address: www.ict-cogeu.eu . The web site is regularly updated and acts as the first dissemination tool of the project. IT also set up a collaborative tool used as a means to share and manage project files from the Consortium members.

During the reporting period the COGEU website was improved with RRS feed and a new section dedicated to demonstrators where short videos with COGEU system building blocks are shown. The demos page of COGEU website is shown in Figure 17Figure 17Figure 13. It includes a link to the COGEU geo-location database where multiple functionalities are available for online testing (Figure 18). The COGEU geo-location database is a powerful tool for COGEU dissemination.

Figure 17 Demos page of COGEU web site (http://www.ict-cogeu.eu/demos.html).

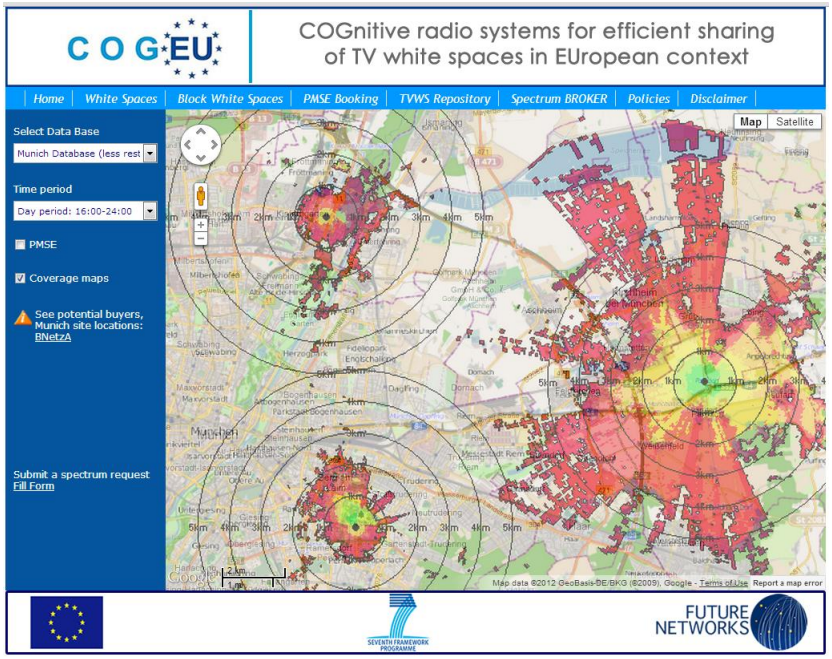


Figure 18 The COGEU geo-location database is online available for testing.
(http://projectos.est.ipcb.pt/cogeu2/index.php)

The website has a tracker tool installed that monitors COGEU website visits, geo-location of the visitors, among other important statistics. Examples of usage statistics for the period from January to December 2011 are given below. From Figure 19 we can see the impact of four important dissemination activities (presentations at the European Parliament, DYSPAN conference, exhibition at FUNEMS, COGEU workshop ant the participation in the Cambridge whitespace policy event) on the number of visits.

The total number of visits in 2011 were 4,375 more than double the 1,671 visits reported in 2010. The total number of visits in 2012 were 3,655.

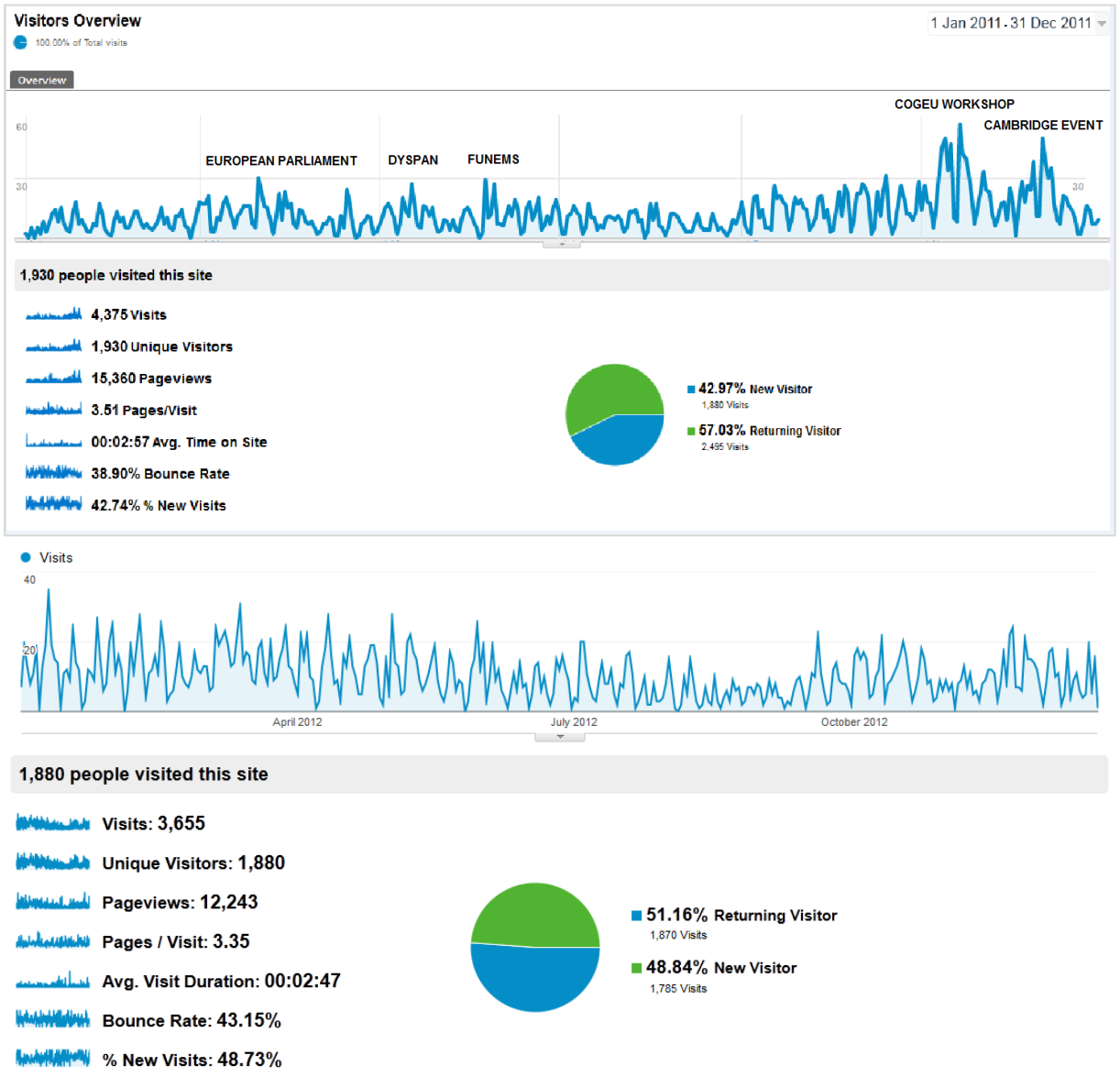


Figure 19 Summary Period: January 2011 – December 2011 , Total Visits (4,375 visits) and January 2012 –December 2012 , Total visits (3,655). Some key dissemination events are highlighted to see the impact on web site visits.

To support a wide dissemination of the project trials, a professional video team from PTIN has produced a 5 minutes video showing the measurement scenarios, test equipment and summarizing the main conclusions of the COGEU trials in Munich. The video is available in the COGEU website and in the YouTube, it has been used to promote COGEU in several events.

Figure 20 The 5 minutes COGEU promotional video is available here 0.

10 Exploitation activities

This section presents the plans on how the outcomes of the project will be used by the different partners after the project lifetime.

10.1 Universities and Research institutes

10.1.1 IT

In the context of COGEU project, IT has been participating in ETSI RRS standardization activities. Building on the project results, COGEU has a potential for further standardization activities. This includes currently ongoing activities, which might not be finalized during the lifetime of the project with emphasis to the following aspects:

- European standardized data format and protocols for geo-location database access is especially indispensable for cross-border operation.
- Standardized formats that support the flexibility necessary to accommodate automatic spectrum economics transactions between spectrum owners and spectrum seekers (secondary spectrum trading beyond current license exempt TVWS regime).
- Spectrum mobility (spectrum handover) mechanism is an important area of TV white space usage to ensure continued service in case of unavailability of spectrum resources. Therefore there is potential for standardization in defining the requirements and methods related to spectrum handover for cognitive radio wireless systems and devices operating on UHF white space frequency bands based on geo-location or broker based spectrum management.

Since Nov 2012, IT is leading a new FP7 Coordination Action called CRS-i: "*Cognitive Radio Standardization-initiative: from FP7 research to global standards*", which the main objective is to facilitate the exploitation of results from Cognitive Radio and Dynamic Spectrum Access projects by strengthening their impact on standardization (www.ict-crsi.eu). In the context of CRS-i framework, IT plans to extend COGEU standardization activities beyond the project life time and contribute to met the objectives of the EC mandate on Reconfigurable Radio Systems (M/512) [4],

At national level, IT plans to establish a consortium with PTIN and a WSD provider to carry out a TV White Spaces trial in Portugal. With the knowhow gained in COGEU project IT is prepared to develop commercial solutions for White Spaces databases and associated protocols.

10.1.2 AEGEAN

AEGEAN will exploit its participation in COGEU by exposing a large number of under-graduate and graduate engineers/researchers to high-level scientific work, mainly in the area of cognitive radio network architectures, based on both regulation models proposed by the project. AEGEAN will consider the exploitation of COGEU mechanisms and Radio Resource Management (RRM) algorithms in a real DVB-H networking test-bed. Pertinent knowledge will be further widely disseminated through publications in peer reviewed scientific journals.

AEGEAN will further exploit, for academic purposes, all software tools developed for the optimum allocation of TVWS. By this way, AEGEAN will empower its own research position and reputation among European universities and academia giving the chance to other researchers/students to make use of its own software tools and experimental facilities for academic and research purposes. AEGEAN will exploit its findings in any way that will help to expand new knowledge base and enable to bring the forefront of technological development in the field of Cognitive Radio networks into academic syllabuses educating future engineers and computer scientists.

Participation and contribution to a successful COGEU project will also help stimulate spin-off projects with industry partners. As an academic institution, it is essential for AEGEAN to attract newly graduated students to pursue postgraduate research on the relevant subjects of COGEU for the coming years. All developed technology within COGEU, including software tools produced for RRM mechanisms will be considered for protection by patenting. Finally, AEGEAN software solutions will be presented in trade shows and summer schools, in order to strengthen research activities and attract new research projects portfolio.

10.1.3 PUT

The team from PUT will continue to publish papers in leading conferences and peer reviewed journals further exploiting the advances made in the COGEU project. Moreover the results obtained within COGEU project will be included and published in two PhD theses which refer to the main research areas investigated within WP2, WP5 and WP6 of the COGEU project. COGEU results will be also presented to students attending the lectures dedicated to cognitive radio and to PhD students.

Using experience gathered in COGEU project, PUT is interested in realization of first cognitive radio transmission in TVWS in Poland. To realize this task, PUT will get involved in the national consortium with National Institute of Telecommunications and Emitel Ltd. National Institute of Communications is a leading scientific and research institute in the area of telecommunications and information technologies, involved in the electromagnetic compatibility tests and in the DVB-T coverage maps and TV White Spaces definition. Emitel is the leading terrestrial radio and TV broadcast infrastructure operator in Poland. Emitel provides radio, TV and communications services. With the potential of three institutions the consortium will prepare the TVWS maps for selected cities in Poland according to protection criteria for major wireless standards, and it will aim at the set up of the TVWS geo-location databases in Poland.

The consortium also plans the design of innovative transmission methods which allow for efficient use of TVWS in Poland. The whole system will be validated by computer simulations, laboratory tests and field tests. Finally, based on the results, recommendations to the regulatory and standardization bodies will be presented.

Furthermore, PUT has been contacted by Emitel Ltd. and the electricity supplier Energa Co. to consult technical and business scenarios for machine to machine communication in TVWS (M2M), especially for electricity smart metering. Emitel and Energa are considering and planning the implementation of the European Commission directive (2009/72/WE) for one of the major energy suppliers in Poland. This directive tells that 80% of energy end users should have installed intelligent energy meters until 2020. Customers could control their energy consumption. Energy suppliers will have the possibility to better plan their energy production which can be better tailored to the market needs. The end-users will benefit from the information acquired from the suppliers to lower the energy consumption and to manage it in a more efficient manner within the household. Conformance with the above mentioned Directive requires two-way transmission link between the energy-supplier centre and every household.

PUT team involved in COGEU has gained an experience in exploration and exploitation of TVWS for transmission of secondary users. Therefore PUT plans to prepare the proposal for the national regulator UKE on the M2M technology choice for smart metering. In the proposed approach an energy meter will have the cognitive radio transceiver chip which will communicate with the data fusion station (e.g. the base station) using TVWS. The cognitive base station will have fixed Internet connection or use Emitel-licensed TV frequency channel. Cognitive transceiver will require low power levels to operate with a small battery for a long lime (e.g. 20 years). Additionally, low power and burst-mode transmission should guarantee primary users protection. This data transmission should not be sensitive to moderate delays. Required throughputs are also small and are of the order of 64kbps.

PUT team will most probably be involved in the choice of proper wireless technology for this M2M communication, and its application in real-world scenario.

10.1.4 CTVR, Trinity College Dublin (TCD)

TCD has already begun to explore exploitation plans beyond the lifetime of the COGEU project. In September of 2012 CTVR, Trinity College hosted a one-day workshop on TV whitespaces. The workshop, "Filling The White Spaces" was attended by over 100 Irish and international delegates. It featured presentations from a number of commercial entities who are active in the field, namely; Adaptrum, Microsoft, Spectrum Bridge, BskyB, FairSpectrum. The Irish regulator, the Irish Department of Communications, the national DTT network operator and the public service TV provider (RTÉ) were also in attendance.

Following on from this event CTVR established White Spaces Ireland (www.whitespaces.ie) on October 24th, 2012, the date of the analogue TV switch-off in Ireland. White Spaces Ireland aims:

- To disseminate information about the latest advances in spectrum access techniques;
- To foster white space trials within Ireland that will support innovation, identify commercial opportunities and assimilate evidence for policy development and legislation;
- To promote Ireland as a Spectrum Playground;
- To support the goal of providing all citizens, businesses, and institutions within Ireland with access to high-quality broadband so that Ireland can reach its full economic potential.

TCD is currently engaging with interested Irish and international entities to establish the details of further trials in Ireland. As a first step we have populated a TVWS database for Ireland facilitated by Spectrum Bridge.

TCD will continue to publish papers in leading conferences and journals further exploiting the advances made in the COGEU project.

Linda Doyle continues to be a member of the U.K's Ofcom Strategic Advisory Board (OSAB). OSAB provides independent advice to Ofcom on strategic spectrum management issues. Provision of independent strategic advice helps Ofcom to carry out its remit in securing optimal use of the radio spectrum, taking account of the different needs and interests of all users. Involvement in this organisation provides CTVR, Trinity College with a broader, deeper and more long-term understanding of telecommunications developments and trends. It also allows CTVR, Trinity College to feed out experience, of which COGEU is part, into this group.

A key component of the CTVR, Trinity College's remit is to engage in outreach programmes. Outreach involves engaging the interest of students (at all stages of their education) in engineering and computer science and providing them with educational-level-appropriate information, i.e. workshops, tutorials, seminars. CTVR Trinity College have, and will continue, to promote outreach through these channels.

The IRIS-based SDR platform is currently being open-sourced by a company being spun-out of CTVR, Trinity College Dublin. This open-sourcing will allow other entities to build on the IRIS architecture if they wish to pursue this route of SDR development.

10.2 Broadcasters

10.2.1 IRT

IRT is the R&D institute of the public broadcasters in Germany, Austria and Switzerland. At the beginning of COGEU project the prevailing position of the broadcasters towards new usage concepts within the broadcast bands was between reluctance and rejection. Much has changed in the time since then and broadcasters now have become interested in increasing spectrum efficiency in the broadcast bands provided that, at the same time, the protection of their broadcast signals (and PMSE use, of course) is guaranteed.

Broadcasters also became aware that in order to keep their users and, even more, to acquire new users, especially among the younger people, interactivity with the users becomes more and more important. The usage of TVWS may provide a possibility to send retrieved content (on demand) to the requesting users.

IRT will disseminate COGEU results to its parent companies and endorse activities to use TVWS as a means to create different levels of interactivity:

- Broadcast program related information in parallel to the linear program;
- Point to multipoint transmission, to distribute content on request (e.g. non-linear program concept)
- Point to point transmission for interactivity (e.g. for games)

Depending on the reaction of its parent companies to follow this way of TVWS use, IRT would promote to work in this direction and so endeavouring to make public broadcast even more valuable to the user.

10.2.2 TWC

Towercom as the broadcasting infrastructure provider aims its research activities on this project mainly to investigate appropriate protection of the existing digital terrestrial TV broadcasting services hand in hand with possible development of the new utilization of TVWS for new and emerging services (e.g. M2M communications networks).

Towercom will disseminate COGEU results to National regulatory body and its customers to secure:

- better understanding of TVWS usage;
- innovative approach to protect the existing digital terrestrial TV broadcasting services;
- more effective usage of TV spectrum;
- development new commercial services and networks;

10.3 Mobile Network Operator

10.3.1 PTIN

PTIN research activities in the project were particularly focus in the LTE extension over TVWS. The very positive results achieved shown clearly the benefits of using the TVWS and how to do it. This knowledge is the paramount importance to PTIN on two aspects: to motivate the other players mainly spectrum regulatory entities and manufacturers to adopt the COGEU innovative proposals and to provide consultation and training services to the PT group of companies in Portugal and abroad.

In the short term and taking advantage of the existing pre commercial equipment's for the TVWS and in line with PT decision of increase the national WiFi network coverage PTIN intends to evaluate the TVWS in the WiFi, "Super Wifi ", formally IEEE 802.11af. The

consortium formation to carry out the trial is presently underway (equipment manufacturer, DB provider, academia and PT).

10.4 Industry and SME

10.4.1 R&S

R&S is planning to publish an application note that describes the set-up and operation of a testbed for WSDs, and market the related test set-up as a self-contained, comprehensive solution for WSD certification. The measurement procedures are based on D4.5 'Guidelines for TVWS equipment certification and compliance'. The software/ firmware tools for automatic set-up of the selected certification procedure is planned as part of a package.

The software tools for sensing of DVB-T signals that were developed in COGEU form the basis for further investigation in the direction of sensing of DVB-T2 signals and other signals of OFDM based broadcast standards. The inclusion of this application in currently under test for a new generation of R&S professional test receivers.

10.4.2 THALES

The context for the exploitation of the COGEU project results by Thales Communications & Security (TCS) falls in the area of public safety radio networks and deployable radio networks. In 2010, at the start of the COGEU project, the PMR (Professional Mobile Radio) product portfolio of TCS consisted in providing turnkey PMR networks based on the PMR world leading standard TETRA (Terrestrial Trunked Radio). The PMR market covers public safety organisations (blue lights, including police, fire and ambulance, or border surveillance) and a variety of private mobile radio systems, mostly but not exclusively for the transportation markets (railways or motorways for example).

TCS activities in the COGEU project were targeting the study and exploitation of Cognitive Radio Networks deployment and use for public safety applications, with a special focus on investigating end-to-end QoS communications in a mesh multi-hop setting.

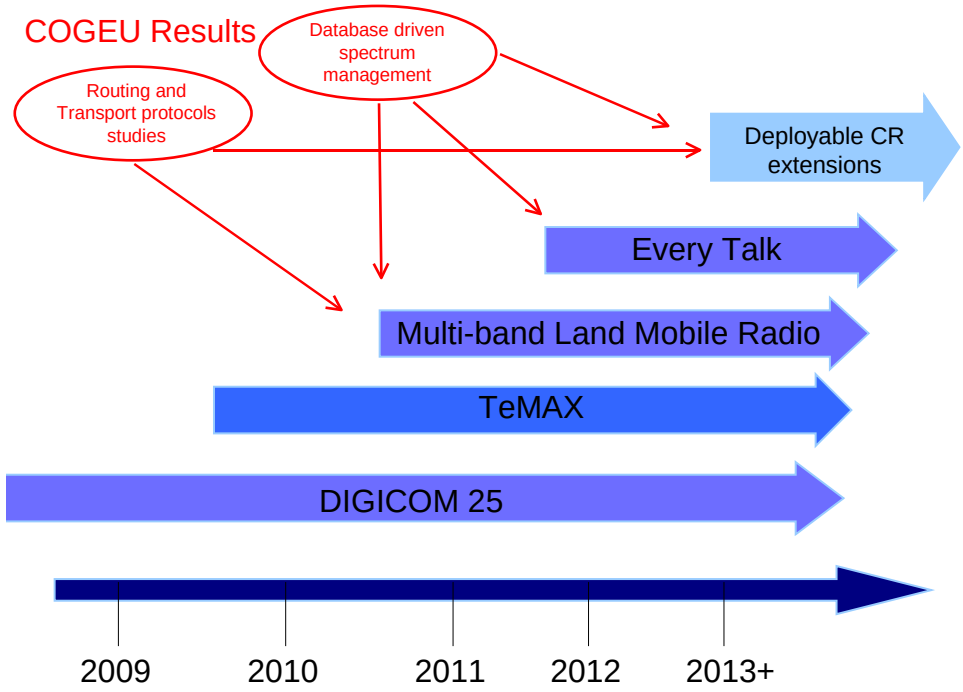


Figure 21 Thales PMR roadmap and COGEU results.

During the Tetra World Congress 2011 in Budapest, Thales announces the launch of *Every Talk*, the first ruggedized Push-to-Talk Terminal to add broadband capabilities to existing Professional Mobile Radio networks used by many user groups, such as public safety, transportation and utilities. The future of Professional Mobile Radio (PMR) involves not only voice communication and text messaging but also multimedia services such as data, images, video, live feeds, face recognition and database queries. With the Thales Every Talk smartphone, all these services are available in a single pocket-size device. Every Talk rounds out the Thales range of TeMax solutions launched in 2010. It is an innovative communication system acting as an “application booster” over standard TETRA network. This Broadband connectivity enables the integration of multimedia applications and the exchange of large volumes of data. TeMax is considered to PMR networks what 4G is to consumer GSM networks. Short-term evolution of this newly available device includes LTE and Wi-Fi-Direct. Use-cases, targeted during COGEU project, were defined with the capabilities of this device to partially use White-Spaces for LTE-over-WS and Wi-Fi-over-WS.

The Multi-band Liberty LMR (Land Mobile Radio) is a software-defined, portable LMR that enables emergency responders to communicate with partner agencies, regardless of radio frequency band. It operates across US available public safety bands (136-174 MHz, 380-520 MHz, 700 MHz, and 800 MHz) and in Project 25 (P25) conventional, P25 trunked, and legacy analog modes. Liberty LMR includes the features that Wildland Firefighters need:

- Multiband:
  - VHF: 136 - 174 MHz
  - UHF: 380 - 520 MHz
  - 700 MHz
  - 800 MHz
- Multi-Mode
  - Project 25 Conventional and Trunking
  - AES/OFB-DES with OTAR
  - Legacy Analog 25/12.5 kHz channel spacing
  - CTCSS/CDCSS/DTMF/MDC 1200
- Front panel programming (conventional channels only) Enables rapid programming without needing a PC or AC power
- Tone picklist – CTCSS, CDCSS, and P25 NAC. A single channel can access up to 32 repeaters
- Single zone cloning: Rapid deployment deployment at incidents while keeping home radio intact
- Scan and priority scan: Monitor all incident traffic
- Supports any standard P25 or analog FM radio system
- Maximizes standardized interoperability

Figure 22 Thales multiband Land Mobile Radio(Liberty radio)

Being SDR, Liberty Radio can operate on multi-band multi-mode. Nevertheless there exist huge needs in Spectrum management strategies. In order to fill this functionality gap, TCS is continuously seeking new ways to further extend its PMR market portfolio, in order to provide cutting edge technology and solutions to its customers, as a key differentiator with respect to the competition. In this sense, results from COGEU are enablers for efficient spectrum management and better QoS for the previously mentioned products.

Main COGEU exploitable results includes Database Driven Spectrum management and Routing / Transport protocols for Cognitive Radio Ad-Hocs Networks.

Database Driven Spectrum management

Protocols and system proposals for contacting centralised database, populating it and managing the Spectrum allocation are expected to be investigated for future studies and products. Moreover, while COGEU especially focuses on TVWS, the innovations brought in this context by the project are suitable for other spectrum bands. More precisely, Database Driven Spectrum Management is foreseen to be used for next generation cognitive radio

equipment provided by Thales Communications & Security. As an example of possibility, Liberty Radio®, already provides re-configurability and spectrum management but everything is pre-planned before the beginning of the mission, and wired connection to a PC is required. Dynamic spectrum management can be achieved efficiently using a central geo-location Spectrum Database and using the network architecture defined in COGEU WP3.

Routing & Transport protocols for Cognitive Radio Ad-Hocs Networks
TCS carried out its research activities in the field of routing protocols for multi-hop wireless networks. Within the framework of COGEU project, TAI investigated different approaches to improve the network capacity and ensure End-To-End QoS in a Cognitive Radio Ad-hoc network. TCS first benefits from a new routing strategy in order to efficiently distribute critical information (for example: sensing information in the case of cooperative sensing) in a Cognitive Radio Network; the network was modelled using a graph-based model and it was shown that this techniques are reliably routing traffic even when spectrum availability is dynamic or limited. A considerable improvement for TCS simulator was possible thanks to the effort coming from the beginning of WP6. The simulator improvements are also a huge advancement for Thales Communications Security in order to better assess cognitive radio network. Then, transport protocols research for Cognitive Radio Networks is of particular interest for Thales Communications.

While radio devices and spectrum management strategies are reaching maturity this is still not the case for efficient end-to-end transport of information in Cognitive Radio Networks. Indeed, it is still very challenging to provide a guaranteed QoS while the radio resources are not predictable. As a system provider, TCS is dedicated to not only provide, radio equipment exploiting the benefits of SDR and Cognitive Radio, but also to make sure added value services are performing well from an end user perspective. In this sense, TCS submitted a patent for performance enhancement of the whole end-to-end session. The patent is described in more detail in Chapter 4.

10.4.3 SIGINT

Sigint Solution's exploitation plan regarding the outcomes of the COGEU project, mainly embroils the creation of innovative products and services to complement the current line of products and services offered by the company.

SIGINT Solutions is a SME heavily involved with the definition and development of the geo-location database, the interference emulator, the broker architecture and the development of simulation driving models for its own radio planning tool, 3DTruEM.

SIGINT's contributions to the project are expected to assist in the development of the following products and services:

- A White Spaces Interference Emulator;
- Simulator add-on modules to drive the White Spaces Interference Emulator;
- A Broker system, consisting of a geo-location database that can be used to manage spectrum and more specifically white spaces frequency spectrum;
- An online service that utilizes the simulator add-on modules to remotely drive Interference simulator.

Possible recipients of the above products and services include telecommunication companies, operators, regulators, universities and research centres etc.

11 Conclusions

The number of events and the attention COGEU experienced from various sides evidence that COGEU went into the right direction. Especially the concept of secondary spectrum trading offers interesting aspects for spectrum holders as well as possible licensees. COGEU embeds this concept into a comprehensive environment consisting of technical, economical and regulatory views on the matter of TVWS utilization by secondary devices, operated on a non-interfering and non-protected basis.

With its work and its results COGEU made an important contribution to the introduction of White Space usage in Europe (beyond UK efforts). For the benefit of the public the results of COGEU were widely disseminated and the knowledge and experience gained by the project serve as an excellent basis to put the results into real products and services.

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List of Abbreviations

CEPT	Conference of European Postal & Telecommunications
COST	European Corporation is Science and Technology
COST-TERRA	COST Techno Economic Regulatory Framework for Radio Spectrum Access for Cognitive Radio/Software Defined Radio
CR	Cognitive Radio
DVB-T	Digital Video Broadcasting – Terrestrial
EBU	European Broadcast Union
ECC	CEPT Electronic Communications Committee
EC	European Comission
ECO	European Communication Office
ETSI	European Telecommunication Standards Institute
EU	European Union
FCC	Federal Communications Commission
ICT	Information and Communications Technologies
IEEE	The Institute of Electrical and Electronics Engineers
IPR	Intellectual Property Rights
ITU	International Telecommunication Union
LTE	Long Term Evolution
OFCOM	Office of Communications
PMSE	Programme Making and Special Events
QoS	Quality of Service
RSPG	Radio Spectrum Policy Group
SDR	Software Defined Radio
SEAMCAT	Spectrum Engineering Advanced Monte Carlo Analysis Tool
TETRA	Terrestrial Trunked Radio
TV	Television
TVWS	TV White Spaces
UHF	Ultra High Frequency
UE	User Equipment
US	Unites States of America
WGSE	CEPT Working Group Spectrum Engineering
WIF	Wireless Innovation Forum
WiFi	IEEE 802.11
WiMAX	Worldwide Interoperability for Microwave Access
WinCOMM	Wireless Innovation Forum Conference on Communications Technologies and Software Defined Radio
WLAN	Wireless Local Area Network
WSD	White Space Device
WWRF	World Wireless Research Forum