Quality Of Service and MObility driven cognitive radio Systems

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QoSMOS

D8.6

Standardization and Dissemination activity report v2

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Abstract:

This report documents the contributions to a number of related standardisation bodies made by the QoSMOS project and summarizes the various dissemination activities since the beginning of the project. It further provides an update to the exploitation plans of individual partners.

Keyword list:

Cognitive Radio, TV White Spaces, Spectrum Allocation, Dissemination, Exploitation, Standardization, Education

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Abbreviations

ACROPOLIS	Advanced coexistence technologies for radio optimisation in licensed and unlicensed spectrum
BSCW	Basic Support for Cooperative Work
CEPT	European Conference of Postal and Telecommunications Administrations
DS&E	Dissemination, Standardisation and Exploitation
DySPAN-SC	Dynamic Spectrum Access Networks – Standards Committee (formerly SCC41)
EAB	External Advisory Board
ETSI	European Telecommunications Standards Institute
FCC	Federal Communications Commission
HW	Hardware
IEEE	Institute of Electrical and Electronics Engineers
ITU-R	International Telecommunication Union - Radio Communication Sector
OneFIT	Opportunistic networks and Cognitive Management Systems for Efficient Application Provision in the Future Internet
PTCRB	PTCRB is a global organization created by Mobile Network Operators to provide an independent evaluation process where GSM / UMTS Type Certification can take place.
R&TTE Directive	Radio and Telecommunications Terminal Equipment Directive
RRS	Reconfigurable Radio Systems
SCC41	Standards Coordination Committee 41 (Dynamic Spectrum Access)
SDR	Software Defined Radio
TC	Technical Committee
TCAM	Telecommunications Conformity Assessment and Market Surveillance Committee
TGaf	Task Group af (Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications – Amendment 5: TV White Spaces Operation)
TVWS	Television White Spaces
WG	Working Group
WInnF	Wireless Innovation Forum

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Executive Summary

QoSMOS (Quality Of Service and MObility driven cognitive radio Systems) is an EU-funded Framework Programme 7 (FP7) integrated project (IP) that started in January 2010. The project is focusing on the exploitation of white spaces in the frequency spectrum by adapting cognitive radio (CR) technology, with strong emphasis on the Quality of Service (QoS) and mobility aspects.

This deliverable provides a snapshot on the current status and how much of the original dissemination, standardization and exploitation (DS&E) plans are realized since the beginning of the project. The main areas of the QoSMOS DS&E plan concentrated on and achievements were made:

- *Publication of outstanding technical achievements in acknowledged international journals and magazines*. QoSMOS has managed to achieve significant results.
- *Participation and contribution to relevant, high-profile international conferences, symposia and summits, serving as panelists at panel sessions*. QoSMOS representatives have already served as panelists at two important ev*ents, and have published and presented around 50 papers.*
- *Contribution to relevant standards, influence regulatory work and trigger new activities in these bodies.* To date QoSMOS has made a high number of contributions to standardization work, and has been involved in shaping the definition of new standardization projects and working groups (in ETSI RRS as well as in DySPAN-SC).
- *Organization or co-organization of workshops.* A workshop was held in Washington DC on Quality of Service and Mobility over Cognitive Communications radio systems (QMCC11), in conjunction with the WinnComm conference.
- *Offering tutorial sessions in conjunction with important international conferences. Publishing technical white papers, co-authored by project partners, is also expected.*. Two white papers were authored and published on the web site, two further white papers are planned before the end of the project. A tutorial on "Application and Deployment of Cognitive Radio Networks - High Potential Scenario Examples" was given at the IECE General Conference in Tokyo. One training session on architectural issues of CRS was held at the University of Surrey. QOSMOS is also taking overall ownership of a jointly written white paper on spectrum sharing, which is an output from the cluster planned in time for FuNeMS in July 2012.
- *QoSMOS will develop various prototypes during the project lifetime. To show these achievements, demonstration events will be arranged.* This work is ongoing. Project demonstrations have been given at the FUNEMS conferences 2011 & 2012. At the end of the project, on December 12th, it is planned to have a seminar at BT Centre in London where the QoSMOS project will be demonstrated.
- *Project-related information will be published by circulating the QoSMOS flyer and by issuing press releases. The QoSMOS flyer has been* published and project members have distributed it at various conferences.
- *Project results are regularly presented at the meetings of the external advisory board (EAB), and feedback from EAB members is collected and addressed in the project. Four meetings with the advisory bo*ard have taken place, the discussions and feedback to the project has been reported in four deliverables, the feedback is being taken into account.
- *The project will aim at building connections to relevant industry forums. Project members also intend to promote ideas and disseminate results through special interest groups.* First approaches towards the Digital Communications Knowledge Transfer Network (DCKTN) as well as "Cambridge Wireless" have been made.

1 Introduction and overview

QoSMOS deliverable D8.2 [1] outlined the dissemination, standardization and exploitation activities the FP7 project QoSMOS aims to undertake during project lifetime as well as in the immediate aftermath of the project. This current deliverable D8.6 presents a snapshot of where the project stands in terms of the dissemination, standardization and exploitation activities since the beginning of the project. The deliverable provides an overview of what has been achieved and which activities remains before the end of the project. It also underlines where further efforts will be required to ensure that the project meets the original dissemination, standardization and exploitation targets, where necessary it provides reasons and alternatives where plans had to be amended due to external developments.

To date 2 submissions to relevant journals have been made, some 50 conference papers have been presented and QoSMOS members have participated in several Panels at leading conferences (ICC Cape Town,PIMRC 2010 and FuNeMS 2011), as well as at an IEICE event.

QoSMOS has contributed to different standard organisations, QoSMOS partners were present in the discussions to formulate new work items and new working directions in both IEEE DySPAN-SC (formerly IEEE SCC41) as well as ETSI RRS.

A proposal for an international QoSMOS workshop at CrownCom 2011 [2] was submitted, but the plans were upset by the disaster in Japan. A workshop was held in Washington DC on Quality of Service and Mobility over Cognitive Communications radio systems (QMCC11), in conjunction with the WinnComm conference. It is planned to hold another, probably called QMCC12, in conjunction with the IEICE event on 'wireless distributed network, general topics', which is scheduled for October 17 – 19th in Fukuoka Japan.

A half-day tutorial on dynamic spectrum access systems was held in November 2011 at the FUSECO FORUM. Approx. 20 representatives of equipment manufactures and operators attended this tutorial.

One training session was held at the University of Surrey, where a QoSMOS member presented and discussed work on architectural issues of the project. The session was attended by some 30 doctoral and MSc students.

Several External Advisory Board (EAB) meetings were held. Representatives from the project did present research findings and reported on various activities such as standardization and planning of the measurement campaigns. The members of the EAB engaged in discussions and provided comprehensive feedback on the regulatory and commercial viability of the approaches taken. The feedback is being taken into account by the project.

The overall dissemination strategy of QoSMOS remains unaltered; the approaches outlined in D8.2 remain valid and will continue to be applied till end of the project.

The remainder of this deliverable describes the different contributions and advances in more detail.

2 Dissemination activities

2.1 Publications

The main aim for QoSMOS, in terms of dissemination, is of course to publish in journals and magazines with high impact factors. The plans for this are outlined in D8.2, however, considering the early stages of the work and the fact that journal publications do have a rather long submission-acceptance period, this leads to a concentration of conference publications and alike, during the first year.

The publication and dissemination plans of QoSMOS, as outlined in deliverable D8.2, remain valid, there are no concrete updates to these plans after the second year of the project has been almost completed. The main aim, to disseminate QoSMOS project outcomes as widely as possible and sensible was followed and, despite the project work in the first year was mainly towards defining and establishing common frameworks and common solution approaches, there was already quite some significant dissemination.

Table 1 QoSMOS Dissemination Months 1-29

Type of publication	Authors	Title	Conference	Place	Status
Pres	Michael Fitch	QOSMOS RAS Presentation	RAS Workshop "Cognitive Radio - Technology and Regulation"	Brussels	Published
Pres	Dominique Noguet	QoSMOS EU Project	ERRT 2010	Mainz	Published
Paper	Masayuki Ariyoshi, Hiroto Sugahara, Yasunori Futatsugi, Kazushi, Muraoka, Pierre Marchand, Vincent Merat	A Cognitive Radio Mobile Network Utilising White Space Spectrum (1) – System Overview and Functional Architecture –	IEICE Society Conference 2010	Osaka, Japan	Published
Paper	Hiroto Sugahara, Ken-ichiro Yamazaki, Kazushi Muraoka, Masayuki Ariyoshi	A Cognitive Radio Mobile Network Utilising White Space Spectrum (2) – Inter-System Interference Analysis –	IEICE Society Conference 2010	Osaka, Japan	Published
Paper	Kazushi Muraoka, Hiroto Sugahara, Masayuki Ariyoshi	A Cognitive Radio Mobile Network Utilising White Space Spectrum (3) – Interference Monitoring for Advanced Spectrum Management –	IEICE Society Conference 2010	Osaka, Japan	Published
Paper	Yasunori Futatsugi, Masayuki Ariyoshi	A Cognitive Radio Mobile Network Utilising White Space Spectrum (4) – A Transmission Technique for Interference Avoidance –	IEICE Society Conference 2010	Osaka, Japan	Published
Paper	Olasunkanmi Durowoju, Kamran Arshad and Klaus Moessner	Distributed Power Control for Cognitive Radios with Primary Protection via Spectrum Sensing	IEEE VTC 2010 Fall	Ottawa, Canada	Published
Paper	Xiaobo Yu, Pirabakaran Navaratnam, Klaus Moessner	Distributed Resource Reservation Mechanism for IEEE 802.11e-Based Networks	IEEE VTC 2010 Fall	Ottawa, Canada	Published
Paper	Kamran Arshad and Klaus Moessner	Fusion strategies for collaborative spectrum sensing	ERRT 2010	Mainz, Germany	Published
Paper	Uvaraj Rajeskaran,	Joint Rate and Power	SDR 2010	Washingt	Accepted

	Kamran Arshad, Klaus Moessner	Optimisation using Distributed Power Control Algorithms in Cognitive Radio Networks		on, USA	
Paper	M. Fitch, D. Noguet, B. Bochow	Towards Quality of Service and Mobility in Cognitive Radio Systems	FUNEMS 2010	Firenze, Italy	Published
Paper	M. Gautier, M. Laugeois, D. Noguet	Teager-Kaiser energy detector for narrowband wireless microphone spectrum sensing	CROWNCOM 2010	Cannes, France	Published
Article	Zs. Kollár, P. Horváth	Modulation Schemes for Cognitive Radio in White Spaces	Radioengineering, Vol. 19, No. 4, Part I, pp. 511-517		Published
Conference	Richard MacKenzie, Per-Hjalmar Lehne, Ulrico Celentano, Masayuki Ariyoshi	Identifying Scenarios with High Potential for Future Cognitive Radio Networks	FUNEMS 2011	Warszaw, Poland, 15-17 Jun 2011	Published
Conference	Zs. Kollár, G. Péceli, P. Horváth	Adaptive Decision Feedback Equalization for FBMC Systems	COCORA 2011	Budapest, Hungary	Published
Conference	Geneviève Mange, Christophe Rosik, Stéphanie Leveil,Ulrico Celentano, Durowoju Olasunkanmi, Arshad Kamran	Cognitive Resource Management for QoS Support in Mobile Opportunistic Communications	FuNeMS 2011	Warszaw, Poland, 15-17 Jun 2011	Published
Conference	Masayuki Ariyoshi, Hiroto Sugahara, Vincent Merat, Christophe Rosik	[Panel Discussion] Cross Layer Technologies for Cognitive Radio Systems in QoSMOS Project	IEICE Technical Meeting on Software Radio, Jan 2011	Fukuoka, Japan 27.01.2011	Published
Conference	Yasunori Futatsugi, Masayuki Ariyoshi	Transmission Performance of Interference Avoidance Transmission by Partitioned Frequency- and Time-domain Processing for DSA	IEICE Technical Meeting on Radio Communication Systems, Mar 2011	Yokosuka, Japan 02.03.2011	Published
Conference	Masayuki Ariyoshi, Richard MacKenzie, Per-Hjalmar Lehne, Ulrico Celentano	[Tutorial] Application and Deployment of Cognitive Radio Networks: High Potential Scenario Examples	IEICE General Conference 2011	Tokyo, Japan 14.03.2011	Published

Conference	Yasunori Futatsugi, Masayuki Ariyoshi	PAPR Performance of Interference Avoidance Transmission by Partitioned Frequency- and Time-domain Processing for DSA	IEICE General Conference 2011	Tokyo, Japan 14.03.2011	Published
Conference	Kazushi Muraoka, Hiroto Sugahara, Masayuki Ariyoshi	MMSE-Based Cooperative Interference Monitoring for Cognitive Mobile Networks	IEICE General Conference 2011	Tokyo, Japan	Published
Conference	Kazushi Muraoka, Hiroto Sugahara, Masayuki Ariyoshi	Monitoring-Based Interference Management for Expanding Opportunities of White Space Utilization	IEEE DySPAN	Aachen, Germany 03.05.2011	Published
Conference	David Depierre François Delaveau François Sirven	Oriented processing of Communication signals for Sensing and disseminated spectrum monitoring	SDR '11 - WInnComm - Europe	Brussels, 22-24 June 2011	Published
Conference	Zs. Kollár, P. Horváth	Physical Layer Considerations For Cognitive Radio: Modulation Techniques	IEEE VTC 2011 Spring	Budapest, Hungary	Published
Conference	Zs. Kollár, P. Horváth	Physical Layer Considerations For Cognitive Radio: Synchronization Point of View	IEEE VTC 2011 Spring	Budapest, Hungary	Published
Conference	Kamran Arshad and Klaus Moessner	Mobility and Spectrum Sensing for Cognitive Radios	UKIWCS 2010	Delhi, India	Published
Conference	Kamran Arshad and Klaus Moessner	Efficient Spectrum Management among Spectrum Sharing UMTS Operators	IEEE VTC 2011-Spring	Budapest, Hungary	Published

Conference	Olasunkanmi Durowoju, Kamran Arshad and Klaus Moessner	Distributed Power Control for Cognitive Radios based on Incumbent Outage Information	ICC 2011	Kyoto, Japan	Published
Conference	Olasunkanmi Durowoju, Kamran Arshad and Klaus Moessner	Autonomous Time Variant Power Control for Cognitive Radio Networks	IEEE VTC 2011-Spring	Budapest, Hungary	Published
Conference	Dominique Noguet, Rohit Datta, Per Hjalmar Lehne, Matthieu Gautier, and Gerhard Fettweis	TVWS regulation and QoSMOS requirements	Wireless VITAE 2011	Chennai, India	Published
Conference	Markus Mueck, Dominique Noguet	TV White Space Standardization and Regulation in Europe	Wireless VITAE 2011	Chennai, India	Published
Conference	Per Hjalmar Lehne Dominique Noguet Rohit Datta Ulrico Celentano Vincent Merat Philippe Delahaye Gerhard Fettweis	Requirements for a CR-system – Challenges compared to conventional wireless technology	SDR '11 - WInnComm - Europe	Brussels, 22-24 June 2011	Published
Conference	Rohit Datta Matthieu Gautier Vincent Berg Yasunori Futatsugi Masayuki Ariyoshi Mario Schühler Zsolt Kollar Peter Horvath Dominique Noguet	Flexible Multicarrier PHY design for Cognitive Radio in White Space	CROWNCOM 2011	Osaka, Japan 31.05.11 - 03.06.2011	Published
Conference	Talha Zahir, Kamran Arshad, Youngwook Ko and Klaus Moessner	A Downlink Power Control Scheme for Interference Avoidance in Femtocells	7th International Wireless Communications and Mobile Computing Conference (IWCMC 2011)	Istanbul, Turkey, 5-8 July 2011	Published

Conference	Ulrico Celentano, Bernd Bochow, Jesús Herrero, Bruno Cendón, Christian Lange, Ferenc Noack, Ole Grøndalen, Vincent Mérat, Christophe Rosik	Flexible Architecture for Spectrum and Resource Management in the Whitespace	International Symposium on Wireless Personal Multimedia Communications (WPMC)	Brest, France, 3-7 October 2011	Published
Conference	Dorin Panaitopol, Abdoulaye Bagayoko, Philippe Delahaye, Lanto Rakotoharison	Fast and Reliable Sensing Using a Background Process for Noise Estimation	CROWNCOM 2011	Osaka, Japan, 1-3 June 2011	Published
Article	Zs. Kollár, P. Horváth	Equalization of Multicarrier Cognitive Radio Transmissions over Multipath Channels with Large Delay Spread.	INFOCOMMUNICATIONS JOURNAL 3:(2) pp. 42-47. (2011)	Budapest, Hungary	Published
Article	Olasunkanmi Durowoju, Kamran Arshad and Klaus Moessner	Distributed Power Control Algorithm for Cognitive Radios with Primary protection via Spectrum Sensing under User Mobility	Elsevier Journal of AdHoc Networks, Special Issue: CRAHNs		Published
Conference	Talha Zahir, Kamran Arshad, Youngwook Ko and Klaus Moessner	A Downlink Power Control Scheme for Interference Avoidance in Femtocells	7th International Wireless Communications and Mobile Computing Conference (IWCMC 2011)	Istanbul, Turkey, 5-8 July 2011	Published
Conference	Ghassan Alnwaimi, Kamran Arshad and Klaus Moessner	Dynamic Spectrum Allocation Algorithm with Interference Management in Displaced Networks	7th International Wireless Communications and Mobile Computing Conference (IWCMC 2011)	Istanbul, Turkey, 5-8 July 2011	Published
Conference	Kamran Arshad and Klaus Moessner	Robust Collaborative Spectrum Sensing based on Beta Reputation System	FuNeMS 2011	Warszaw, Poland, 15-17 Jun 2011	Published

Conference	Kamran Arshad and Klaus Moessner	Statistical Models of Spectrum Opportunities for Cognitive Radio	PIMRC 2011	Toronto, Canada, 11-14 September 2011	Published
Conference	Xiobo Yu, Pirabakan Navaratnam, Klaus Moessner	'Distributed Resource Reservation for Real Time Sessions in Multi-Hop Wireless Networks	7th International Wireless Communications and Mobile Computing Conference (IWCMC 2011)	Istanbul, Turkey, 5-8 July 2011	Published
Conference	Janne Lehtomäki, Johanna Vartiainen, Risto Vuohtoniemi, Harri Saarnisaari	Adaptive FCME-Based Threshold Setting for Energy Detectors	COGART 2011	Barcelona, Spain, 26-29 October 2011	Published
Article	Ghassan Alnwaimi, Kamran Arshad and Klaus Moessner	Dynamic Spectrum Allocation between two UMTS Operators with Interference Handling	IEEE Communication Letters	IEEE	Accepted
Conference	Atsushi Nakata, Kamran Arshad and Klaus Moessner	Interference Tolerable Threshold Analysis in Cognitive Femtocells	Wireless Innovation Forum Conference on Communications Technologies and Software Defined Radio	Washington, USA, 29/11/2011 - 02/12/2011	Published
Conference	László Csurgai-Horváth, János Bitó	Primary and secondary user activity models for cognitive wireless network	ConTEL 2011	Graz, Austria, 15/Jun/2011- 17/Jun/2011	Published
Conference	Kamran Arshad, Keith Briggs and Klaus Moessner	Robust Spectrum Sensing for Cognitive Radio based on Statistical Tests	CogART 2011	Barcelona, Spain	Published
Conference	Rohit Datta, Gerhard Fettweis, Zsolt Kollar and Peter Horvath	FBMC and GFDM Interference Cancellation Schemes for Flexible Digital Radio PHY Design	DSD'11	Oulu, Finland, 31/08/2011 - 02/09/2011	Published

Article	Talha Zahir, Kamran Arshad, Youngwook Ko and Klaus Moessner	Interference Management in Cognitive Femtocells	IEEE Surveys and Tutorials	IEEE	Accepted
Article	D. Tandur, J. Duplicy, K. Arshad, K. Moessner, D. Depierre, J. Lehtomäki, K. Briggs, L. Gonçalves , A. Gameiro	MME approach for cognitive radio systems evaluation: Measurement, Modeling and Emulation	IEEE Vehicular Technology Magazine	IEEE	Accepted
Article	D. Noguet, M. Gautier, V. Berg	Advances in opportunistic radio technologies for TVWS	EURASIP Journal on Wireless Communications and Networking special issue on "Ten years of cognitive radio: state of the art and perspectives"		Published
WorkShop	D. Noguet	Physical Layer techniques for TV White Spaces	FUNEMS 2011 QOSMOS workshop	Warszaw , Poland, 15-17 Jun 2011	Published
Conference	M. Gautier, V. Berg, D. Noguet	Wideband frequency domain detection using Teager-Kaiser energy operator	WCNC 2011	Paris	Submitted
Conference	D. Noguet, M. Fitch, W.Koenig	QoSMOS: Towards managed QoS and Mobility over Share Spectrum,	WINNCOM 2011	Brussels	Published
Conference	G. Mange	Cognitive Radio in Wireless Networks	Canada-EU Future Internet	Waterloo (CA) 23-25/03/2011	Published

Conference	Masayuki Ariyoshi, Richard MacKenzie, Per-Hjalmar Lehne, Ulrico Celentano	[Tutorial Lecture] Application and Deployment of Cognitive Radio Networks - High Potential Scenario Examples -	IEICE Technical Meeting on Software Radio, Oct 2011	Tokyo, Japan	Published
Journal Paper	Janne Lehtomäki, Risto Vuohtoniemi, Kenta Umebayashi, Juha-Pekka Mäkelä	Energy detection based estimation of channel occupancy rate with adaptive noise estimation.	IEICE Transactions on Communications E95-B: 04. April 2012	IEICE	Published
Article	Kamran Arshad Richard MacKenzie Ulrico Celentano Arpad Drozdy Stéphanie Leveil Geneviève Mange Juan Rico Arturo Medela Christophe Rosik	Resource Management for QoS support in Cognitive Radio Network	IEEE Communications Magazine		Submitted
Conference	Dorin Panaitopol, Rohit Datta, Gerhard Fettweis	Cyclostationary Detection of Cognitive Radio Systems using GFDM Modulation	WCNC 2012	Paris	Accepted
Conference	Ramiro Samano, Atilio Gameiro	Multi-Objective and Portfolio Optimization in Cognitive Radio Systems	W-PIN 2012: The first Workshop on Pricing and Incentive in Networks	Paris	Accepted
Conference	Ramiro Samano, Atilio Gameiro	Resource allocation and beamforming based on Multi-Objective and Portfolio Optimization in Cognitive Radio Systems	ICCN13	San Diego	Submitted
Conference	Eduardo Castañeda, Ramiro Samano, Atilio Gameiro	Frequency-Reuse Planning of the Down-Link of Cognitive Distributed Antenna Systems	Latincom 2011	Belem	Published

Article	Eduardo Castañeda, Ramiro Samano, Atilio Gameiro	Frequency-Reuse Planning of the Down-Link of Cognitive Distributed Antenna Systems	IEEE Latin America Transactions	IEEE	Selected from Latincom to be published
Article	Diogo Cunha, Luis Gonçalves, A. Gameiro	to Determine the Delay between Measurements in two or more Spectrum Analyzers	Electronics letters	IET	Submitted
Conference	Tao Guo, Klaus Moessner	Optimal Strategy for QoS Provision under Spectrum Mobility in Cognitive Radio Networks	VTC2012	Quebec, Canada	Submitted
Book	M. Schuehler, A. Jaschke, A. Popugaev	Reconfigurable RF Receiver Front-end for Cognitive Radio	Festschrift for Prof. Dr.-Ing. Heinz Gerhäuser	Springer	Accepted
Conference	A. Jaschke, M. Schuehler, R. Wansch	Digital Tunable LC Bandpass Filter	German Microwave Conference, GeMiC 2012	Ilmenau, Germany	Submitted
Conference	Johanna Vartiainen, Janne Lehtomäki, Risto Vuohtoniemi	Performance of the LAD Methods Under Channel Impairments	COGART 2011	Barcelona, Spain, 26-29 October 2011	Published
WorkShop Presentation	Bernd Bochow	Dynamic Spectrum Access Standardization in IEEE	QoSMOS Workshop at FUNEMS 2011	Warszaw, Poland, 15-17 Jun 2011	Published
WorkShop Keynote	Marc Emmelmann, Bernd Bochow	Challenges of enabling high mobility in future flexible spectrum scenarios	IEEE LCN ON-MOVE 2011, 5th Workshop On User MObility and VEhicular Networks	Bonn, Germany, 4-7 October 2011	Published

Article	Maurizio Murroni, R. Venkatesha Prasad, Paulo, J. Marques, Bernd Bochow, Dominique Noguet, Chen Sun, Klaus Moessner, and 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	Published
Conference	David Depierre François Pipon	Multi-Antenna Cyclostationarity Feature Detection for Parallel Sensing in Cognitive Radio	FUNEMS 2012	Berlin, 4-6 July 2012	Accepted
Conference	Stéphanie Leveil, Christophe J. Le Martret, Hicham Anouar, Kamran Arshad, Talha Zahir, János Bitó, Ulrico Celentano, Geneviève Mange, Juan Rico Fernández and Arturo Medela Ceballos	Resource Management of Centrally Controlled Cognitive Radio Networks	FUNEMS 2012	Berlin, 4-6 July 2012	Accepted
Conference	Pål Grønsund Richard MacKenzie Per Hjalmar Lehne Keith Briggs Ole Grøndalen Paal Engelstad	Towards Spectrum micro-trading	FUNEMS 2012	Berlin, 4-6 July 2012	Accepted
Conference	Xiaobo Yu, Pirabakaran Navaratnam, Klaus Moessner	Distributed MAC Scheduling Mechanism Based on Resource Reservation for IEEE 802.11e-Based Multi-Hop Wireless Networks	IEEE VTC 2012 Fall	Quebec Canada, Sept. 2012	Accepted
Conference	Yasunori Futatsugi, Masayuki Ariyoshi	Interference Avoidance Transmission by Partitioned Frequency- and Time-domain Processing	IEEE VTC 2012 Spring	Yokohama, Japan, 6-9 May 2012	Accepted
Conference	Rohit Datta, Gerhard Fettweis, Yasunori Futatsugi, Masayuki Ariyoshi	Comparative Analysis on Interference Suppressive Transmission Schemes for White Space Radio Access	IEEE VTC 2012 Spring	Yokohama, Japan, 6-9 May 2012	Accepted

Conference	Toshifumi Nakamura, Hiroto Sugahara, Kazushi Muraoka, Masayuki Ariyoshi	Propagation Estimation Error Correlation Characteristics at Rooftops Based on Field Measurement	IEICE General Conference 2012	Okayama, Japan, 20-23 March 2012	Accepted
Conference	Bernd Bochow, Marc Emmelmann	Dynamic spectrum access, cognitive radio networks, and spectrum management as key enablers for upcoming mobile communications	Tutorial, Fraunhofer FUSECO FORUM, Nov. 17-18, Berlin, Germany	Berlin, DE, Nov. 17-18, 2011	Published
Patent	Bernd Bochow, Marc Emmelmann	A method for operating a geolocation database and a geolocation database system	Patent application		Accepted
Conference	Per H. Lehne, Richard MacKenzie, Dominique Noguet, Vincent Berg, Ole Grøndalen	Mapping Cognitive Radio System Scenarios into the TVWS Context	SDR'12-WInnComm-Europe	Brussels, 25-28 June 2012	Accepted
Conference	Richard MacKenzie, Keith Briggs	Comparison of contention-based protocols for secondary access in TV whitespaces	SDR'12-WInnComm-Europe	Brussels, 25-28 June 2012	Submitted
Conference	Lajos Varga, Zsolt Kollár, Péter Horváth	Recursive discrete fourier transform based SMT receivers for cognitive radio applications	IWSSIP 2012	Wien, Austria	Accepted
Article	Zsolt Kollár, Lajos Varga, Péter Horváth	Modern többvivős rendszerek kognitív rádiós alkalmazásokban.	HÍRADÁSTECHNIKA 2011/3: pp. 18-22. (2011)	Budapest, Hungary	Published
Conference	Janne Lehtomäki, Risto Vuohtoniemi, Kenta Umebayashi	Duty Cycle and Channel Occupancy Rate Estimation with MED-FCME LAD ACC	CROWNCOM 2012	Stockholm, June 2012	Accepted
Conference	Johanna Vartiainen, Janne Lehtomäki, Risto Vuohtoniemi	The LAD methods in WLAN indoor multipath channels	CROWNCOM 2012	Stockholm, June 2012	Accepted
Conference	Johanna Vartiainen	Always One/Zero Malicious User Detection in Cooperative Sensing Using the FCME Method	CROWNCOM 2012	Stockholm, June 2012	Accepted

2.2 Standards and regulatory bodies

QoSMOS consortium members have actively participated in various standardization organizations. The following table lists the contributions made and the subsequent sections list some of the standardization bodies that play an important role in areas covered by QoSMOS. Results stemming from the QoSMOS project might be exploited primarily in these organizations.

Table 2 QoSMOS Standardisation Contributions Months 1-29

Contributor	Title of contribution	Standardisation group	Place	Status
Joint contribution of Alcatel-Lucent, NTUK, BT (all 3 are QoSMOS members), Nokia and Huawei (Not members of QoSMOS)	RRS(10)0005r2_WI_Proposal_on_Operation_in_White_Space_Frequency_Bands_-_WG1.doc	ETSI RRS	Madrid	Published
Alcatel-Lucent (Jens Gebert)	RRSWG1(10)0014 Use Cases for Operation in White Space Frequency Bands	ETSI RRS WG1	Sophia Antipolis	Published
Joint contribution of Alcatel-Lucent and Nokia (Not a QoSMOS member)	RRSWG1(10)0021 Use Cases for Operation in White Space Frequency Bands (Merged contribution)	ETSI RRS WG1	Sophia Antipolis	Published
Alcatel-Lucent	RRS(10)0041_QoSMOS_Project_Overview.ppt	ETSI RRS	Athens	Published
B. Bochow, D. Noguet	SCC41 P1900.6 Procedures and Protocols - merged proposal for a new WG activity	IEEE P1900.6	Presented @ P1900.6 phc	Published
Dominique Noguet	QoSMOS Project	SCC41/P1900.6 meeting	San Diego	Published
Dominique Noguet	Tentative answers to the Notice of Inquiry of the FCC (FCC 10-198)	IEEE P1900.6	Presented @ P1900.6 phc	Published
Bernd BOCHOW, Dorota WITASZEK	SCC41 P1900.6 candidate protocols: IPFIX	IEEE P1900.6	Presented @ P1900.6 phc	Published
Philippe Delahaye	QoSMOS Project Overview	ETSI RRS#14	Aachen, 11/12 May 2011	Accepted
D. Noguet	IEEE 1900.6 extension suggestion	P1900.6	Delft 05/07/2010	Accepted
V. Berg, D. Noguet	Regulatory and propagation conditions in the TVWS	P1900.7	Berlin 29/09/2011	Accepted

Kazushi Muraoka, Hiroto Sugahara, Masayuki Ariyoshi	RRSWG1(11)0173 Combined Interference Monitoring and Geo-location Database Design	ETSI RRS WG1	Ispra Italy	Published
Bernd Bochow (Fraunhofer)	DySPAN for Vehicular Ad Hoc - Proposal for a New Study Group	IEEE DySPAN-SC	Brussels, BE, Jun. 20-22, 2011	Published
Bernd Bochow (Fraunhofer)	DSA-VE Progress Report	IEEE DySPAN-SC - DSA for Vehicular Ad Hoc	Scottsdale, USA, Dec. 12-14, 2011	Published
Bernd Bochow (Fraunhofer)	Draft DySPAN-SC individual WG P&Ps	IEEE DySPAN-SC	Scottsdale, USA, Dec. 12-14, 2011	Published
Bernd Bochow (Fraunhofer)	Open Issues on the draft DySPAN-SC individual WG P&Ps	IEEE DySPAN-SC	Scottsdale, USA, Dec. 12-14, 2011	Published
Bernd Bochow (Fraunhofer)	Proposal to enhance A-SAP primitives	IEEE DySPAN-SC - 1900.6	Scottsdale, USA, Dec. 12-14, 2011	Published
Bernd Bochow (Fraunhofer)	Draft 1900.6a 5C	IEEE DySPAN-SC - 1900.6	Singapore, Mar. 21-23, 2011	Published
Bernd Bochow (Fraunhofer)	Draft 1900.6a PAR	IEEE DySPAN-SC - 1900.6	Singapore, Mar. 21-23, 2011	Published
Bernd Bochow (Fraunhofer)	Request for information to support 1900.1	IEEE DySPAN-SC - 1900.6	Scottsdale, USA, Dec. 12-14, 2011	Published
Bernd Bochow (Fraunhofer)	Proposal to adopt legacy sensing hardware with 1900.6 compliant Sensors	IEEE DySPAN-SC - 1900.6	Berlin, DE, Sep. 26-30, 2011	Published
Bernd Bochow (Fraunhofer FOKUS), Dominique Noguet (CEA LETI), Xue Jiantao (BUPT), Darcy Swain (MITRE), Klaus Moessner (UNIS)	6-11-0005-02-0000-6-11-0005-00-dyspan-wg6-response-to-fcc-noi-draft_DS edits	IEEE DySPAN-SC - 1900.6		Published
Bernd Bochow (Fraunhofer)	1900.1 Progress Report	IEEE DySPAN-SC - 1900.1	Scottsdale, USA, Dec. 12-14, 2011	Published

Bernd Bochow (Fraunhofer)	2nd-Request for information to support 1900.1	IEEE DySPAN-SC - 1900.1		Published
Bernd Bochow (Fraunhofer)	Proposal for a definition of the term 'Reasoner'	IEEE DySPAN-SC - 1900.1		Published
Bernd Bochow (Fraunhofer)	P1900.1a Workflow and Procedures	IEEE DySPAN-SC - 1900.1		Published
Bernd Bochow (Fraunhofer)	IEEE DYSPAN SC 1900.1 List of Terms	IEEE DySPAN-SC - 1900.1		Published
Bernd Bochow (Fraunhofer)	Draft Policies and Procedures for IEEE P1900.1	IEEE DySPAN-SC - 1900.1		Published
Bernd Bochow (Fraunhofer)	DYSPAN SC P1900.1 Submission List	IEEE DySPAN-SC - 1900.1		Published
Philippe Delahaye (NTUK)	Term definitions for system requirements TS 102 946	ETSI RRS WG1	Ispra Italy	Accepted
Pål Grønsund (TEL)	Spectrum Micro-trading as a use case for spectrum sharing in TR 102 970	ETSI RRS WG4	Manchester, UK April 19, 2012	Accepted
Bernd Bochow (Fraunhofer)	Submission to P1900.5.1: Draft Standard Policy Language for Dynamic Spectrum Access Systems - Use Case: Machine Type Communications in White Space	IEEE P1900.5.1	Osaka, JP, March 26, 2012	Accepted
Dominique Noguet Vincent Berg (CEA)	Preliminary scenario and requirement analysis	IEEE P1900.7	Osaka, JP, March 27, 2012	Accepted

2.2.1 ETSI RRS

The main focus of the QoSMOS contributions towards ETSI RRS is related to the works items related to TV White Space Frequency bands.

QoSMOS partners (Alcatel-Lucent, NTUK, BT) initiated the Work Item "Uses Cases for operation in White Space Frequency bands " during the RRS#9 meeting in Madrid in February 2010. It got support from two other ETSI members and was approved during the RRS#9 meeting.

The scope of this work item was to provide the Technical Report TR 102 907 describing on how radio networks can operate, on a secondary basis, in frequency bands assigned/licensed to one (or several) primary users(s). In particular, the work item covers the following topics:

- Operation of Cognitive Radio Systems in UHF White Space Frequency bands
- Methods for protecting the primary/incumbent users
- System Requirements and Use Cases (including but not limited to the situation in Europe)

QoSMOS partners contributed to the use cases, mainly on mid-/long range wireless access as well as on short range wireless access. The technical report was approved by WG1 in the teleconference, June 22. It was also approved during the ETSI RRS#15 plenary meeting in September 2011, and finally describes the following use cases:

- Mid-/long range wireless access over white space frequency bands
- Short range wireless access over white space frequency bands
- Ad-hoc networking over white space frequency bands
- Combined Ad-hoc networking and wireless access over white space frequency bands
- Sporadic use of TV white space frequency bands
- Backhaul link using TV white space frequency bands
- Multimedia Broadcast Multicast Service (MBMS) operating in TV white space frequency bands

QoSMOS partners are also interested by the WI proposal on Feasibility study on Radio Frequency (RF) performances for secondary systems operating in UHF TV band White Spaces. The scope of WI proposal is the RF performance analysis for systems operating in TV WS. The three main aspects of this WI are to study:

- Advanced sensing techniques for incumbent protection (for instance multi-node sensing solutions have not been considered yet by CEPT).
- Sensing techniques that could be specific to the technology used in an area outside of Europe. ETSI addresses a global standard, thus it is relevant to investigate solutions for Asia, China and America, which have different incumbent wireless technology.
- RF Solutions for coexistence between secondary systems.

QoSMOS partners are considering advanced sensing techniques taking advantage of cooperation between several sensing nodes. These studies put QoSMOS partners in a position to contribute to this RRS Work item, disseminating the most promising cooperative sensing for incumbent protection. Several contributions have been discussed since the creation of the work item, such as combined sensing and geo-location, coexistence, spectrum broking, WSD parameters. The committee also discussed on whether TC RRS is allowed to work on coexistence studies concerning CRS to incumbent interference since it is the CEPT responsibility to study that. Anyway, these issues were not intended to be covered according TR scope. QoSMOS partner contributed to this technical report describing Interference Monitoring as an advanced incumbent protection technique. This technique can be categorized in the combination of the spectrum sensing and geo-location database, but the purpose of the Interference Monitoring is different from that of ordinary spectrum sensing. The spectrum sensing is basically for detecting incumbent signals to determine if incumbent transmitters are operating around the opportunistic transmitter. On the other hand, the Interference Monitoring determines how much interference is actually caused to incumbent receiver. For this purpose, the interference signals are measured at spectrum sensors located near the incumbent receiver and are effectively used for the estimation of CIR at the incumbent receiver.

The Work Item on "System Requirements for Operation in White Space Frequency Bands" (TS 102 946) is one of the major technical specifications relevant for QoSMOS project. The scope of this technical specification is to define the system requirements for operation of secondary Reconfigurable Radio Systems within UHF TV band white spaces. The requirements are based from the use cases described in TR 102 907 "Use cases for Operation in White Space Frequency Bands". A draft is available with requirements related to coexistence, carrier aggregation, radio access, spectrum management and advanced geo-location. The document has been also pointed as draft deliverable to CEPT SE43 (see section 2.2.11) for information by RRS, as information of the progress was requested by SE43. Currently, advanced geo-location requirements are foreseen as a way to facilitate the management of Terrestrial Broadcasting Service protection and coexistence function requirements areforeseen to facilitate the coexistence among TV White Space CRSs in UHF TV band white spaces. QoSMOS partner contributed to the TS102946 with the clarification of the terminologies to be used in the specification. Due to the Rapporteur position of QoSMOS partner NEC Technologies, there have been several submissions to this TS but only few technical submissions. QoSMOS is expected to contribute to this TS based on the requirements defined in the technical WPs.

One QoSMOS partner has also contributed to ETSI RRS WG4 TR 102 970 on "Use Cases for spectrum and network usage among Public Safety, Commercial or Military". The contribution is on spectrum micro-trading as a use case for spectrum sharing. Spectrum trading is an important tool that enables spectrum sharing, increases overall spectrum utilization and opens up opportunities for organizations such as telecom operators and public safety to get access to desired spectrum. A model for spectrum micro-trading referred to as the "Micro-trading Pixelation Model" is described, which addresses three dimensions on the micro scale; spatial, temporal and frequency. The contribution is a result from technical work on spectrum micro-trading in WP1 Task 1.3 on Spectrum Micro-trading. A paragraph describing QoSMOS together with a relation to this contribution has also been included in TR 102 970 in a section on relevant projects.

As a next step, after having progressed with the work on use cases and requirements definition, ETSI RRS plans to create new work items on the definition of the architecture and protocols for Cognitive radio systems operating in TWS band and associated Cognitive Management and Control mechanism definition. It will bring new opportunities for QoSMOS partners to contribute based on technical WPs outcomes.

At the same time, the European Commission (EC) is investigating a common standardization mandate, including SDR and CR requests, collectively named Reconfigurable Radio System (RRS), for civil security/military and commercial applications. There is a specific request in the commercial area, addressing at least use of TV White Spaces or opportunistic spectrum access.

The scope of the mandate will be:

- To allow CR Devices to comply with EU and national legislation on the placing on the market and the use of radio equipment
- To ensure that implementation of RRS technologies does not create barriers to the Single Market
- To ensure that standardization of RRS happens timely in Europe in order to lead or keep pace with global developments

The objective is to develop a harmonized standard in order to enable the deployment and use of cognitive radio devices (CRDs) dependent upon information obtained from geo-location databases (GLDB), covering at least use by CRDs of TV White Spaces. The standard should include:

- The parameters and other information to be exchanged between a CRD and a GLDB
- The procedures for such information exchange, including security and reliability aspects

- Discovery and access to GLDBs

QoSMOS has good opportunities to also contribute towards several ETSI RRS work items, especially towards the task force which is envisaged to manage the development of harmonized standards.

2.2.2 IEEE 1900.1

The DySPAN-SC working group 1 (WG1) was reestablished at the Osaka meeting in March 2011. QoSMOS participant Fraunhofer is chairing this working group. Nokia Siemens Networks is supporting this WG by sponsoring the WG's Secretary, Michael Gundlach. Elected Vice-Chair and technical editor of the draft standard P1900.1a Oliver Holland of King's College, London. The WG1 started its work on P1900.1a, which will amend the IEEE Std 1900.1-2008 by new terms and definitions. P1900.1a aims to provide an up-to-date standard terminology for upcoming dynamic spectrum access systems.

> **Title:** IEEE Standard Definitions and Concepts for Dynamic Spectrum Access: Terminology Relating to Emerging Wireless Networks, System Functionality, and Spectrum Management Amendment: Addition of New Terms and Associated Definitions.
>
> **Scope:** This amendment adds new terms and associated definitions to IEEE 1900.1
>
> **Purpose:** Due to the rapidly evolving field of dynamic spectrum access (DSA) and related technologies, IEEE 1900.1 does not cover all terms in use as of today. This amendment provides definitions for those missing terms only.

The WG1 list of terms to consider consists of more than 52 new terms. Given that there always is "a story behind" each of these terms, the 1900.1 is becoming more and more a reference document in the field. This is emphasized by the fact that the "Digital Policy Initiative" of the U.S. DoD seems to be strongly supporting an initiative to develop a "DSA taxonomy" foreseen for being addressed by a later revision of the 1900.1 standard.

The WG1 synchronized with other DySPAN-SC working groups to verify the relevance of terms considered for inclusion into the 1900.1a draft standard and to formulate suitable definitions. A final review process has been started to get approval from the WG in December 2011 and the draft 1900.a has been forwarded to mandatory editorial check and sponsor's ballot in May 2012. Publication of the 1900.1a standard in 2012 is within reach.

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2.2.3 IEEE 1900.4 WG

The IEEE 1900.4 WG under the sponsorship of IEEE DySPAN-SC has been developing standards on architectural building blocks enabling network-device distributed decision making for optimised radio resource usage in heterogeneous wireless access networks, focusing cognitive radios. QoSMOS partners, NEC and NTUK, have been actively participated in developing standards within the WG, where M Ariyoshi, NEC has been chairing the WG since November 2010.

The IEEE Standard 1900.4™ had been published in February 2009, as a base of the 1900.4 standard series.

> **IEEE Standard 1900.4™-2009**
>
> **Title:** IEEE Standard for Architectural Building Blocks Enabling Network-Device Distributed Decision Making for Optimized Radio Resource Usage in Heterogeneous Wireless Access Networks
>
> **Scope:** The standard defines the building blocks comprising (i) network resource managers, (ii) device resource managers, and (iii) the information to be exchanged between the building

blocks, for enabling coordinated network-device distributed decision making that will aid in the optimization of radio resource usage, including spectrum access control, in heterogeneous wireless access networks. The standard is limited to the architectural and functional definitions at a first stage. The corresponding protocols definition related to the information exchange will be addressed at a later stage.

Purpose: The purpose is to improve overall composite capacity and quality of service of wireless systems in a multiple Radio Access Technologies (RATs) environment, by defining an appropriate system architecture and protocols that will facilitate the optimization of radio resource usage, in particular, by exploiting information exchanged between network and mobile Terminals, whether or not they support multiple simultaneous links and dynamic spectrum access.

QoSMOS partners continued to participate in two successive projects: P1900.4a and P1900.4.1. P1900.4a amends the IEEE 1900.4 for supporting operations in white spaces, whereas P1900.4.1 defines interfaces and protocols for the IEEE 1900.4. The former has been completed its work and accordingly the IEEE Standard 1900.4a™ was published in September 2011. The details of the IEEE 1900.4a are as follows.

IEEE Standard 1900.4a™ -2011

Title: IEEE Standard for Architectural Building Blocks Enabling Network-Device Distributed Decision Making for Optimized Radio Resource Usage in Heterogeneous Wireless Access Networks, Amendment 1: Architecture and Interfaces for Dynamic Spectrum Access Networks in White Space Frequency Bands

Scope: In addition to the scope stated in the IEEE 1900.4-2009, this amendment of the standard enables mobile access service in white space frequency bands without any limitation on used radio interface (physical and media access control layers, carrier frequency, etc.) by defining additional components of the IEEE 1900.4a system.

Purpose: In addition to the IEEE 1900.4-2009, this amendment of the standard facilitates cost-effective and multi-vendor production of wireless access system, including cognitive base stations and terminals, capable of operation in white space frequency bands without any limitation on used radio interface, as well as, accelerates commercialization of this system to improve spectrum usage.

In this standard IEEE 1900.4a, contributions linked to QoSMOS proposing use case "Cellular extension" had been presented and accepted. These contributions proposed:

- New system and functional requirements (collection of context information, reconfiguration requests, policy management)
- Modification of the system architecture to introduce a new interface between IEEE 1900.4-2009 decision entity and the new entities introduced in P1900.4a
- Modification of the functional architecture according to the new system architecture

Currently, there is one ongoing project P1900.4.1.

IEEE P1900.4.1

Title: IEEE Standard for Interfaces and Protocols Enabling Distributed Decision Making for Optimized Radio Resource Usage in Heterogeneous Wireless Networks

Scope: This standard uses the IEEE 1900.4 standard as a baseline standard. It provides detailed description of interfaces and service access points defined in the IEEE 1900.4 standard enabling distributed decision making in heterogeneous wireless networks and obtaining context information for this decision making.

Purpose: This standard facilitates innovative, cost-effective, and multi-vendor production of network side and terminal side components of IEEE 1900.4 system and accelerates commercialization of this system to improve capacity and quality of service in heterogeneous wireless networks.

QoSMOS see opportunities to impact this project as some of the protocols being defined in P1900.4.1 will be reused by the IEEE 1900.4a system in white spaces, which could be mapped onto the QoSMOS reference system model.

2.2.4 IEEE P1900.5

On Dec. 7th 2011 the IEEE-SA approved the IEEE Std 1900.5-2011 – IEEE Standard Policy Language Requirements and System Architectures for Dynamic Spectrum Access Systems, and published the standard end of January 2012. The WG5 now has kicked off the P1900.5.1 – Standard Policy Language for Dynamic Spectrum Access Systems. The WG5 is currently asking for submissions addressing special scenarios in policy-based mechanisms. QoSMOS participant Fraunhofer has joined this activity because of the increasing relevance of policy radio.

A submission has been made by QoSMOS partner Fraunhofer reflecting QoSMOS position regarding the "required expressiveness of a suitable policy language applicable to machine type communications use cases". The presentation of this submission was accepted by P1900.5.1 and further detailing was requested. It is also foreseen to forward accompanying use case descriptions to the MLM group of the WInnForum.

2.2.5 IEEE P1900.6

The Std IEEE 1900.6™-2011 was published in April 2011. Since 2010 significant input to this standard was provided by the ICT-ORACLE, ICT-E3 and ICT- QoSMOS projects, driven by project participants of all three projects. Submissions to the standard have been made by individual QoSMOS participants as well as by the projects in whole.

Considering current TV white space activities, the corresponding FCC decision of September 2010 and its expected impact on European regulations and market regarding the development of a geolocation database infrastructure, spectrum sensing has lost some of its immediate relevance for mobile terminal development but remains an important research topic. In consequence spectrum sensing has developed two distinct industrial perspectives for the near and mid-term (i.e., during the lifetime of the QoSMOS project and closely beyond, respectively):

1. In the near term, spectrum sensing will become relevant for validating calculated data (e.g., calculated from transmitter location characteristic and a terrain and propagation models) from a geo-location data base.
2. In the mid-term, spectrum sensing will evolve into existing wireless communication systems enabling these to utilize allotted spectrum more efficiently, applying to managed systems, for example, under an operator's regime.

The former topic is addressed by a proposed new activity of the P1900.6 targeting to add specifications for the exchange of sensing related and other relevant data and related interfaces between the data archive and other data sources to IEEE Std 1900.6™-2011. This activity in particular plans to enhance protocol capabilities and interfaces used in communication with a 1900.6 logical entity "Data Archive" to interoperate with white space and geo-location data bases.

The latter topic is addressed by a proposed new activity of the P1900.6 targeting to add procedure, protocol and message format specifications for the exchange of sensing related data, control data and configuration data between spectrum sensors and their clients to IEEE Std 1900.6™-2011. This activity is expected to attract device manufacturers and system operators or providers to add sensing capabilities to existing wireless systems. Support of existing protocols for sensing data exchange and

distributed sensing system management will significantly lower the threshold for 1900.6 based sensing into the market. Both initiatives originated from submissions of QoSMOS participants to the IEEE.

The WG6 is now continuing its work scheduled to develop initial system engineering documents that form the basis of the upcoming P1900.6a.

> **Title:** IEEE Standard for Spectrum Sensing Interfaces and Data Structures for Dynamic Spectrum Access and other Advanced Radio – Amendment: Procedures, Protocols and Data Archive Enhanced Interfaces.
>
> **Scope:** This amendment to the IEEE Std 1900.6™ adds procedures, protocols and message format specifications for the exchange of sensing related data, control data and configuration data between spectrum sensors and their clients. In addition, it adds specifications for the exchange of sensing related and other relevant data and specifies related interfaces between the data archive and other data sources.
>
> **Purpose:** This amendment provides specifications to allow integrating 1900.6 based distributed sensing systems into existing and future dynamic spectrum access radio communication systems. It enables existing legacy systems to benefit so as to widen the potential adoption of the IEEE 1900.6 interface as an add-on to these systems and to claim standard conformance for an implementation of the interface. In addition it facilitates sharing of spectrum sensing data and other relevant data among 1900.6 based entities and external data archives.

QoSMOS partner Fraunhofer contributed so far contributed several submissions to 1900.6a and will continue its participation until end of 2012.

In [D3.4] we identified protocol stack messages based upon P1900.6-2011 and we extended them by additional fields identified by QoSMOS' requirements, especially in respect of quality of service parameters. To cope with the main requirements for LTE and 802.11 we were able to introduce a minimum set of additional messages as most of the messages were already incorporated in P1900.6. As outcome we are planning to contribute the following two messages to the new standard's version P1900.6a:

- target probability of a false alarm (PFA),
- delivery latency of the sensing results.

2.2.6 IEEE P1900.7

In 2012 the Standardisation Committee SCC41 opened an Ad hoc committee on White Space Radios. The aim was to prepare a Project Authorization Request (PAR) on this topic. QoSMOS members have participated in discussions and telephone-conferences leading to the submission of this PAR entitled "Radio Interface for White Space Dynamic Spectrum Access Radio Systems Supporting Fixed and Mobile Operation". The PAR was accepted on June 16th, 2011 and the Working Group (WG) 7 was setup to work on this project. The WG's kick off took place on Sept. 29th, 2009.

The scope of this WG is defined as follows: "This standard specifies a radio interface including medium access control (MAC) sublayer(s) and physical (PHY) layer(s) of white space dynamic spectrum access radio systems supporting fixed and mobile operation in white space frequency bands, while avoiding causing harmful interference to incumbent users in these frequency bands. The standard provides means to support P1900.4a for white space management and P1900.6 to obtain and exchange sensing related information (spectrum sensing and geolocation information)."

The QoSMOS partners contributed to the definition of the PAR and thus have ensured that relevant results and project outcomes from QoSMOS can be brought into the development of the standard. It is

expected that P1900.7 will be a relevant body to push WP4 activities related to physical layer design for white spaces.

Since it has started, the WG mainly worked on the definition of relevant scenarios and specifications. WP1 and WP2 activities were therefore also relevant during these steps. So, far the contributions have been as follows:

There have been 2 presentations from QoSMOS:

- "Regulatory and propagation conditions in the TVWS" (based on WP2 inputs), Vincent Berg, Dominique Noguet (CEA)
- "Potential Use Cases For TVWS" (based on WP1 inputs), Richard MacKenzie, Michael Fitch (BT).
- "ACLR issues with OFDM for TVWS operation" (based on WP4 inputs), Vincent Berg, Dominique Noguet (CEA).
- "Preliminary scenario and requirement analysis", Dominique Noguet, Vincent Berg (CEA).

Currently, the WG works in order to finalize the list of requirements on which future contributions on technology solutions will be based.

2.2.7 IEEE 802.11 TGaf

The IEEE 802.11 TGaf currently is preparing its first draft of the proposed standard for a sponsor's ballot planned for December 2010. Working group participants, namely Cisco, RIM, Broadcom and Intel as well as the WiFi Alliance had a significant impact on the current FCC decision, and the working group is now incorporating changes due to the FCC decision into the draft standard.

The current position of the TGaf is split between incorporating changes to the draft caused by the FCC decision (e.g., removing all references to sensing from the draft) and awaiting further changes to the FCC decision that may require further alignment with regulations, for example, relaxing adjacent channel emission limitations. IEEE 802.11, 802.18 and the WiFi Alliance are planning to approach the FCC within due timeframe, preparing a "petition to reconsider" for these issues. The concerns regarding these issues are seen as crucial and will be understood as a prohibition of market, which in turn may cause reconsidering the purpose of the TGaf activity, potentially no longer addressing the U.S. market but aiming for regulatory allowance in Asia or Europe only.

In 2010 QoSMOS participants have been following the regular telephone conferences of the TGaf almost continuously but did not participate actively due to a lack of travel budget required to attain voting membership. In consequence participation and voluntary contributions (e.g., the review of a draft version D0.02 earlier this year) were not considered nor recorded in the meeting minutes. The situation changed recently due to changes in personnel, enabling active participation. Nevertheless, this was too late to influence to development of the standard, but it may become relevant for future activities in the scope of potential follow-up activities in the 802.11.

During the January 2011 session, the task group approved Draft 1.0, which was subject to working group letter ballot in January 2011. The task group received approximately 1300 comments and is still resolving comments considering changing regulations and the recently published IEEE Std 802.11-2012. Currently the TGaf Draft 1.07 is under preparation.

The current draft is clearly focused on requirements coming from FCC regulation; hence it is expected that upcoming revisions will likely include additional aspects required to meet European (in particular OFCOM) regulations

2.2.8 IEEE 802.19

No contribution to IEEE 802.19 has been made by QoSMOS so far. The project is following the developments and is engaged in the wider discussions with some of the 802.19 group members. QoSMOS will continue monitoring the developments within IEEE802.19 and will provide input if and when opportunity arises.

2.2.9 IEEE 802.22

No contribution to IEEE 802.22 has been made by QoSMOS so far. The project is following the developments and is engaged in the wider discussions with some of the 802.22 group members. QoSMOS will continue monitoring the developments within IEEE802.22 and will provide input if and when opportunity arises.

2.2.10 IETF PAWS

The IETF Working Group 'Protocol for Accessing TV WhiteSpace) has a mandate to produce two documents that will specify the protocol that operates between a TVWS system and a database. The first document contains use-cases and requirements and was originally due for ratification in April 2012 but is running late, version 4 of the draft was made available in May 2012 and is in a fairly mature state. QoSMOS contributed to this document, ensuring that the six use-cases that were found most relevant as part of WP1 activities were included.

The second document is the standard itself which was originally due for publication in December 2012 but is likely to be delayed until mid-2013 since work will start on this in a serious manner only when the requirements document is ratified.

Another significant contribution from QoSMOS was to the scope of the PAWS charter. Originally, the group had no intention of including any mechanisms for fairness, but they were persuaded to include the provision of a feedback path from the TVWS base-station to the database. This informs the database which channels the base-station is using, plus optional information such as power and antenna patterns adopted. This breakthrough required some intensive lobbying, and in the end Ofcom in the UK backed the proposal, not from a motivation to enable fairness, but from the motivation to be able to calculate aggregate interference. This change in the charter is still being debated in the PAWS group, with some members opposing it, on the basis that in the US this is not included. The members opposing it are US Companies who have business models that would suffer by having the database able to take advantage of feedback. It is not known how this will resolve, but if the PAWS group do not adopt feedback in their scope, it reduces the ability of QoSMOS to contribute and we will reduce effort accordingly.

2.2.11 CEPT

CEPT, the European Conference of Postal and Telecommunications Administrations, is one of the key organisations when it comes to efforts of harmonising telecommunications regulation in Europe. The Electronic Communications Committee (ECC), within the CEPT, has formed a working group for Spectrum Engineering (i.e. the so called "SE43") which deals with CR Systems and SDR.

QoSMOS has not directly contributed to CEPT, but some of the External Advisory Board members are linked to the CEPT and the project has received feedback on the latest advances and developments in the CEPT. QoSMOS will continue monitoring the developments within CEPT and will provide information material on topics that may be of interest to the different groups in the CEPT.

The CEPT ECC Project Team SE 43 "Cognitive Radio Systems – White Spaces" is part of the wider Working Group on Spectrum Engineering (WG SE); SE 43 focuses on CR Systems and White Spaces and it was started in May 2009 during the 53rd WGSE meeting. The group has focussed on the

definition of requirements for the operation of CR devices in the 470-790 MHz band, exploiting the potential availability of White Spaces in this frequency range. The work in SE 43 led to the release of the ECC report 159 [5], in January 2011. The report discusses the technical and operational requirements for the operation of White Space Devices in the 470-790 MHz band. The document also defines a set of criteria that need to be met in the operation of WSDs with the aim to ensure protection of incumbent/primary services, such as broadcasting, Program Making and Special Event (PMSE) systems, radio astronomy, aeronautical radio-navigation and other services operating in bands neighbouring the 470-790 MHz band.

SE43 define a number of deployment scenarios that describe the use as well as the requirements that must be imposed on white space devices. The requirements are mainly in terms of spectrum awareness with the aim to ensure incumbent protection. The options for obtaining relevant spectrum use information were outlined in the report as:

- Sensing;
- Geo-location databases;
- Beacon transmissions by the incumbent.

A combination of sensing and geo-location databases was considered as an additional option, however, that only applies to selected application cases.

ECC Report 159 identifies a wide set of areas that still require further study, this includes

- white space device characteristics
- technical requirements on protection of incumbents and incumbent services
- requirements for the geo-location database and the certification of such data bases
- assessment of potential spectrum for use by white space devices

These issues are under investigation within SE 43 (Work item SE 43_02), the results will be summarised in a report that will complement, or extend ECC report 159. The work is planned to be completed and the new reports are supposed to be approved by September 2012.

As aforementioned, the most appropriate way to contribute to CEPT and SE43 in particular, would be via information releases, especially to those EAB members that are members of CEPT.

2.2.12 ITU-R

No contribution to ITU-R has been made during the second year of QoSMOS. The project is following the developments and has received feedback on the latest advances through the members of the External Advisory Board. QoSMOS will continue monitoring the developments within ITU-R and will provide input if and when opportunity arises.

2.3 Workshops and seminars

At the end of November 2011, a workshop was held in Washington DC on Quality of Service and Mobility over Cognitive Communications radio systems (QMCC11), in conjunction with the WinnComm conference that is organised by the Wireless Innovation Forum. Our workshop attracted more than 20 people from the US. The feedback from this event was excellent, with some saying it was the best event at the conference. The project had originally planned to hold this workshop in conjunction with CROWNCOM in Japan, but the plans were upset by the disaster in Japan.

It is planned to hold another, probably called QMCC12, in conjunction with the IEICE event on 'wireless distributed network, general topics', which is scheduled for October 17 – 19th in Fukuoka Japan.

QoSMOS was invited to present material for a spectrum sharing seminar organized by the EC on 13th February in Brussels.

QoSMOS continues to participate significantly in the RAS cluster meetings and the project manager has been chairing the meetings and presenting the outputs into the concertation plenaries. The last meeting that will be chaired by QoSMOS will be October 2012, as QoSMOS finishes in December 2012. The operation of the RAS cluster has been streamlined significantly during the time that QoSMOS has been leading it. The member projects have been clarified and the mailing list refined and maintained when projects start and finish and this was not a simple task.

At the end of the project, on December 12th, it is planned to have a seminar at BT Centre in London where the QoSMOS project will be demonstrated and presented to a wide range of stake-holders and policy-makers. We will also invite selected press.

2.4 Website and other web resources

The QoSMOS website (http://ict-QoSMOS.eu/) is two fold, it contains a public part that is accessible to all Internet users and provides current information on the progress of the project to external community, and a private part dedicated to the QOSMOS consortium partners and only accessible using specific credentials.

The QoSMOS website is on-line since December 2009, and continuously updated and enhanced, both externally and internally. The QoSMOS consortium is always proactively taking additional measures to raise awareness and promote the adoption of the technical concepts developed though the development of the public website.

2.4.1 Public Website

The QoSMOS public website front page (see Figure 2-1) is providing access to the following information:

- Project Overview (Motivation, Approach, Technical Highlights, Schedule, Workpackages (WP1-WP9),
- Partners, External Advisory Board (Objectives, Members, Meetings),
- Standardization and Regulation,
- Dissemination (Deliverables, White Papers, Publications, Journals or Book Chapters, Conferences, Standardization and Regulation, Workshops),
- QoSMOS Workshops,
- RAS Cluster,
- News,
- Future and Past Events.

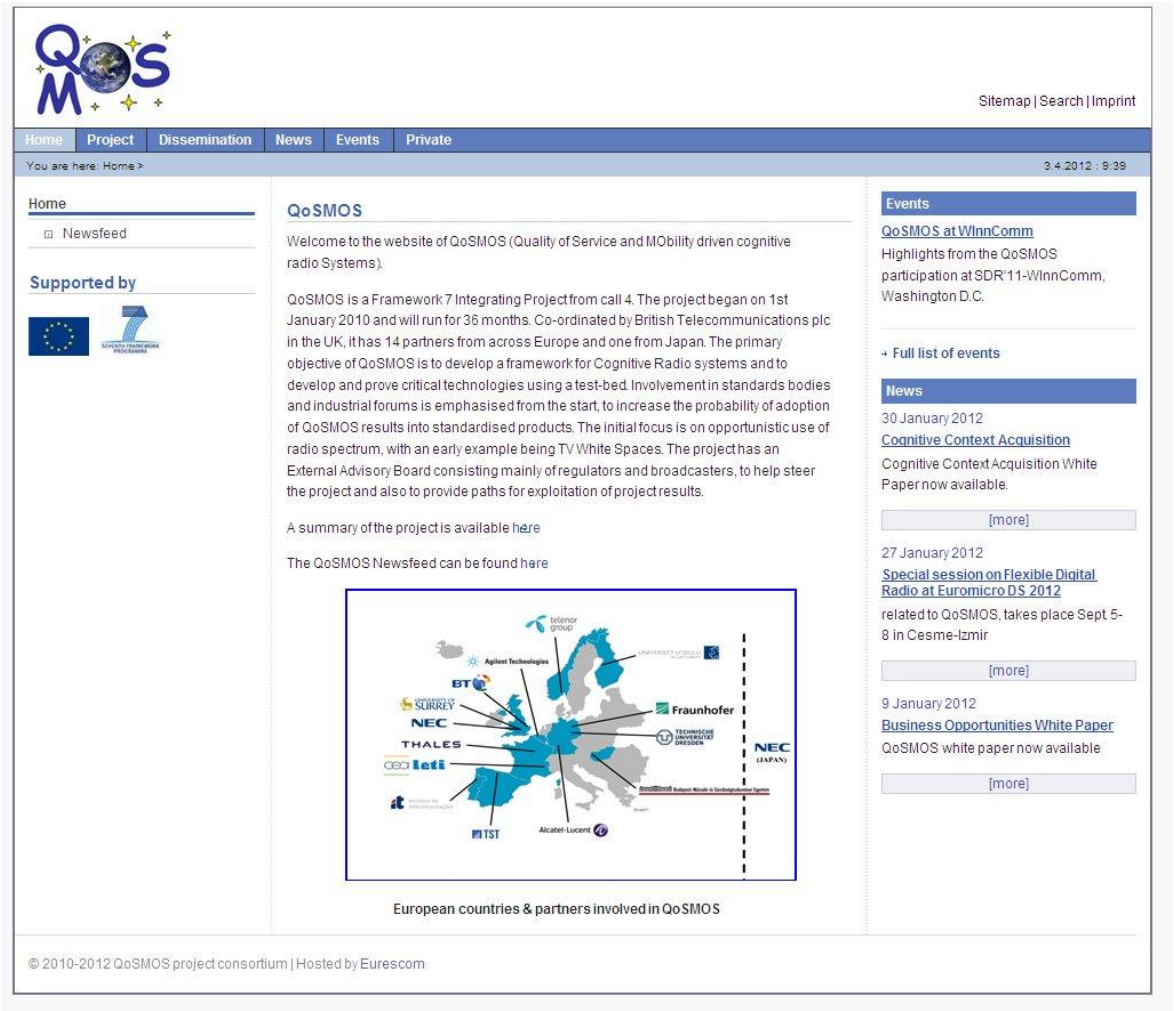


Figure 2-1: QoSMOS Public Website – Home Page

The structure of the Website is depicted in Figure 2-2.

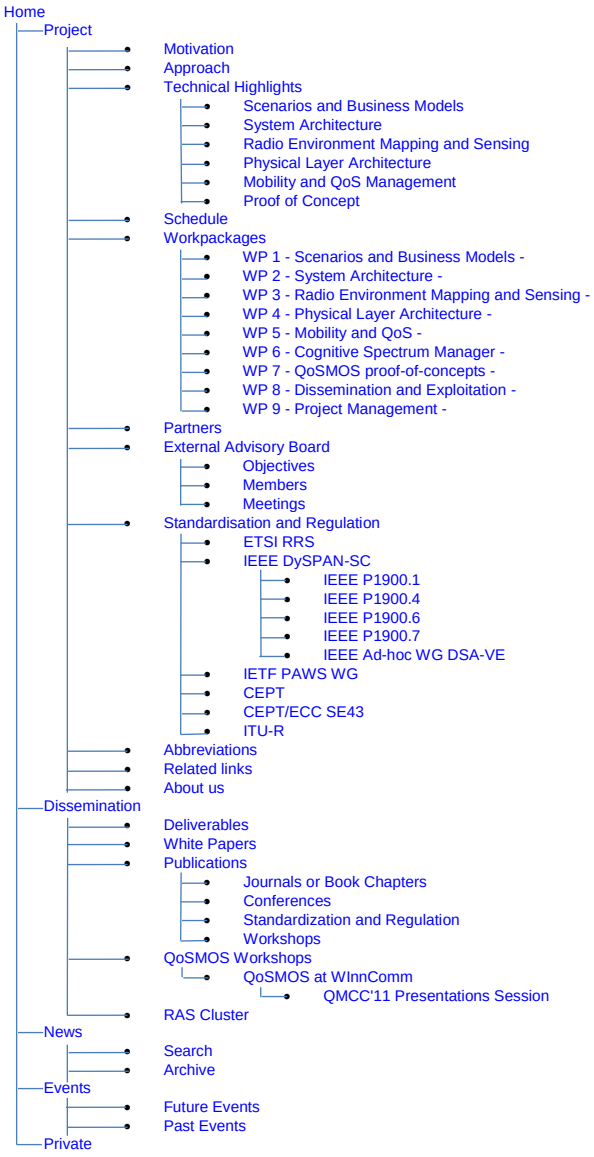


Figure 2-2: QoSMOS Public Website – Structure

Beside general project information on the QoSMOS project Technical Highlights are also presented in the QoSMOS public website. Major results of the project are listed and described. Currently following highlights are given:

- Scenarios and Business Models
- System Architecture
- Radio Environment Mapping and Sensing
- Physical Layer Architecture
- Mobility and QoS Management
- Proof of Concept

As the other parts of the website this section will be extended as further major outcomes become available.

The EAB section provides information about objectives, members and meetings of the External Advisory Board. The EAB has proven as an excellent vehicle for a lively dialog with regulators and other stakeholders in the White Space domain.

In the standardization and regulation section of the website status of relevant standardization bodies with QoSMOS engagement is described. Figure 2-3 depicts the entry page of the standardization and regulation section.

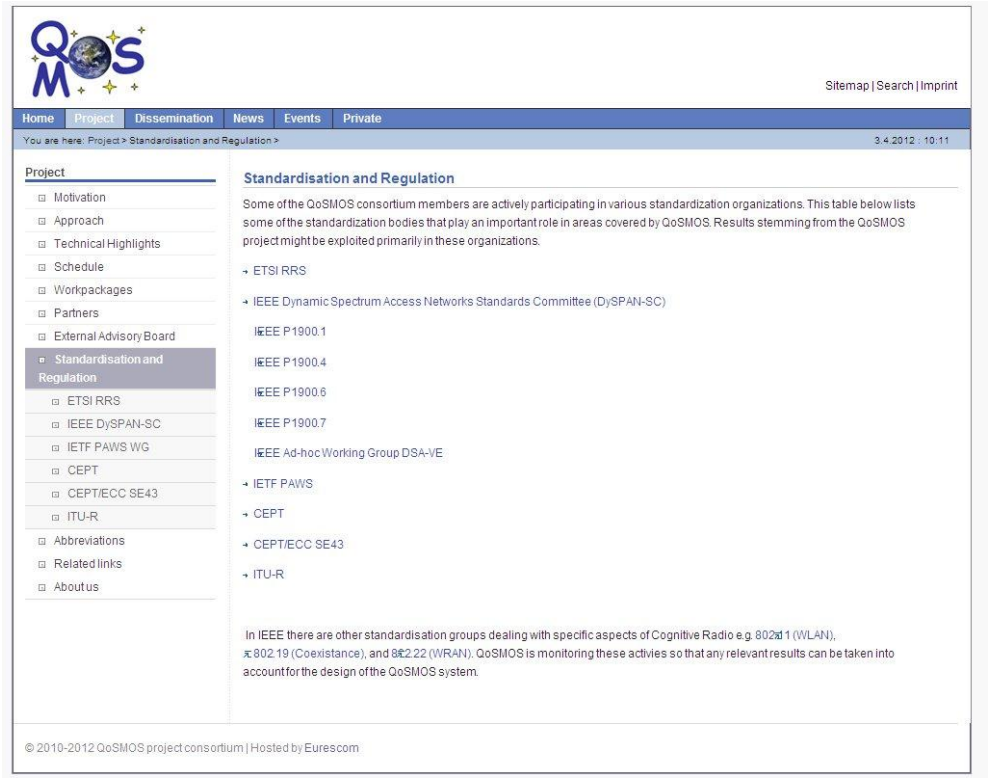


Figure 2-3: QoSMOS Public Website – Standardization and Regulation

All public dissemination material from QoSMOS can be directly retrieved from the website of the project (see http://www.ict-QoSMOS.eu/), allowing in this way external community to follow the project progress and be up-to-date on the latest developments.

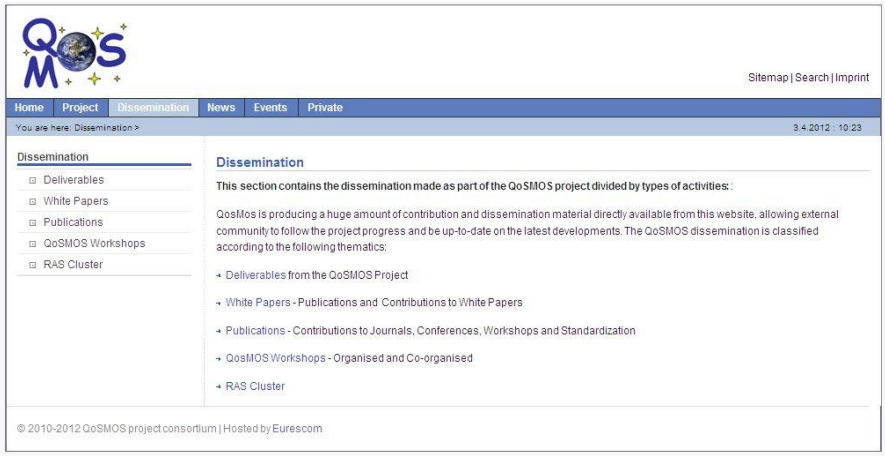
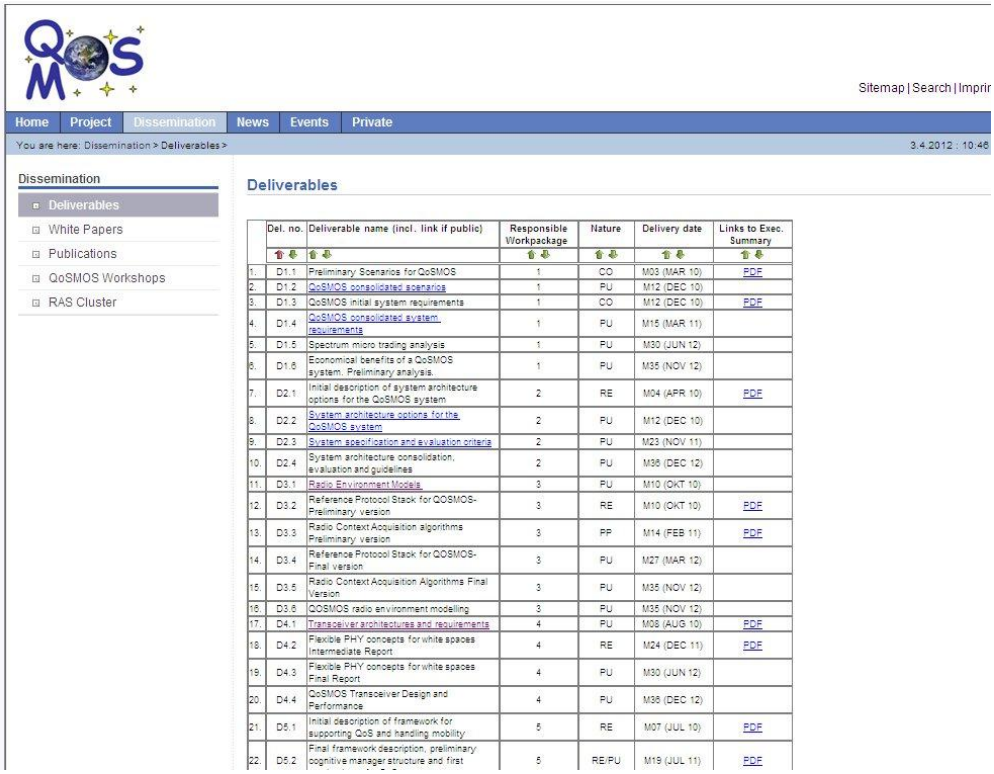


Figure 2-4: QoSMOS Public Website – Dissemination

Beside an up to date list of all project publications this includes available white papers, information on project workshops as well as QoSMOS contractual deliverables executive summaries or full versions (for public deliverables only) as depicted in Figure 2-5. In this way, external communities are always up-to-date with the progress of the different workpackages.



	Del. no.	Deliverable name (incl. link if public)	Responsible Workpackage	Nature	Delivery date	Links to Exec. Summary
1.	D1.1	Preliminary Scenarios for QoSMOS	1	CO	M03 (MAR 10)	PDF
2.	D1.2	QoSMOS consolidated scenarios	1	PU	M12 (DEC 10)	
3.	D1.3	QoSMOS initial system requirements	1	CO	M12 (DEC 10)	PDF
4.	D1.4	QoSMOS consolidated system requirements	1	PU	M15 (MAR 11)	
5.	D1.5	Spectrum micro trading analysis	1	PU	M30 (JUN 12)	
6.	D1.6	Economical benefits of a QoSMOS system. Preliminary analysis.	1	PU	M35 (NOV 12)	
7.	D2.1	Initial description of system architecture options for the QoSMOS system	2	RE	M04 (APR 10)	PDF
8.	D2.2	System architecture options for the QoSMOS system	2	PU	M12 (DEC 10)	
9.	D2.3	System specification and evaluation criteria	2	PU	M23 (NOV 11)	
10.	D2.4	System architecture consolidation, evaluation and guidelines	2	PU	M36 (DEC 12)	
11.	D3.1	Radio Environment Models	3	PU	M10 (OKT 10)	
12.	D3.2	Reference Protocol Stack for QOSMOS-Preliminary version	3	RE	M10 (OKT 10)	PDF
13.	D3.3	Radio Context Acquisition algorithms Preliminary version	3	PP	M14 (FEB 11)	PDF
14.	D3.4	Reference Protocol Stack for QOSMOS-Final version	3	PU	M27 (MAR 12)	
15.	D3.5	Radio Context Acquisition Algorithms Final Version	3	PU	M35 (NOV 12)	
16.	D3.6	QOSMOS radio environment modelling	3	PU	M35 (NOV 12)	
17.	D4.1	Transceiver architectures and requirements	4	PU	M08 (AUG 10)	PDF
18.	D4.2	Flexible PHY concepts for white spaces Intermediate Report	4	RE	M24 (DEC 11)	PDF
19.	D4.3	Flexible PHY concepts for white spaces Final Report	4	PU	M30 (JUN 12)	
20.	D4.4	QoSMOS Transceiver Design and Performance	4	PU	M36 (DEC 12)	
21.	D5.1	Initial description of framework for supporting QoS and handling mobility	5	RE	M07 (JUL 10)	PDF
22.	D5.2	Final framework description, preliminary cognitive manager structure and first	5	RE/PU	M19 (JUL 11)	PDF

Figure 2-5: QoSMOS Public Website – Dissemination: Deliverables

The main menu item “News” provides actual relevant news about the project, e.g. on project workshops that were organized. An archive webpage contains the older news and a search-functionality allows to find specific news about the project.

The main menu item “Events” is divided in two submenus “Future Events” and “Past Events”. At the event webpage it is possible to find information about all past and planned meetings and other QoSMOS activities.

The last main menu item is direct link to the QoSMOS BSCW server webpage, access is password protected.

2.4.2 QoSMOS Internal Collaboration Website

The internal collaboration platform is based on a BSCW server, Figure 2-1 depicts a actual screenshot of the main page. As displayed in this figure, the QoSMOS Home Page provides access to a series of 19 folders each containing data relating to the overall project management, documentation and operation. The BSCW server is used as the basic tool for exchange of information and documents in

the project as well as joint edition of deliverables and other joint papers or presentations. The calendar feature is a tool used in QOSMOS to provide an overall view of the events and meetings taking place during the life of the project. Thanks to the shared calendar, each QoSMOS user can have visibility on the project activity and include relevant events. A specific folder is accessible for EC officers and evaluators containing all information relevant and required for the project audits.

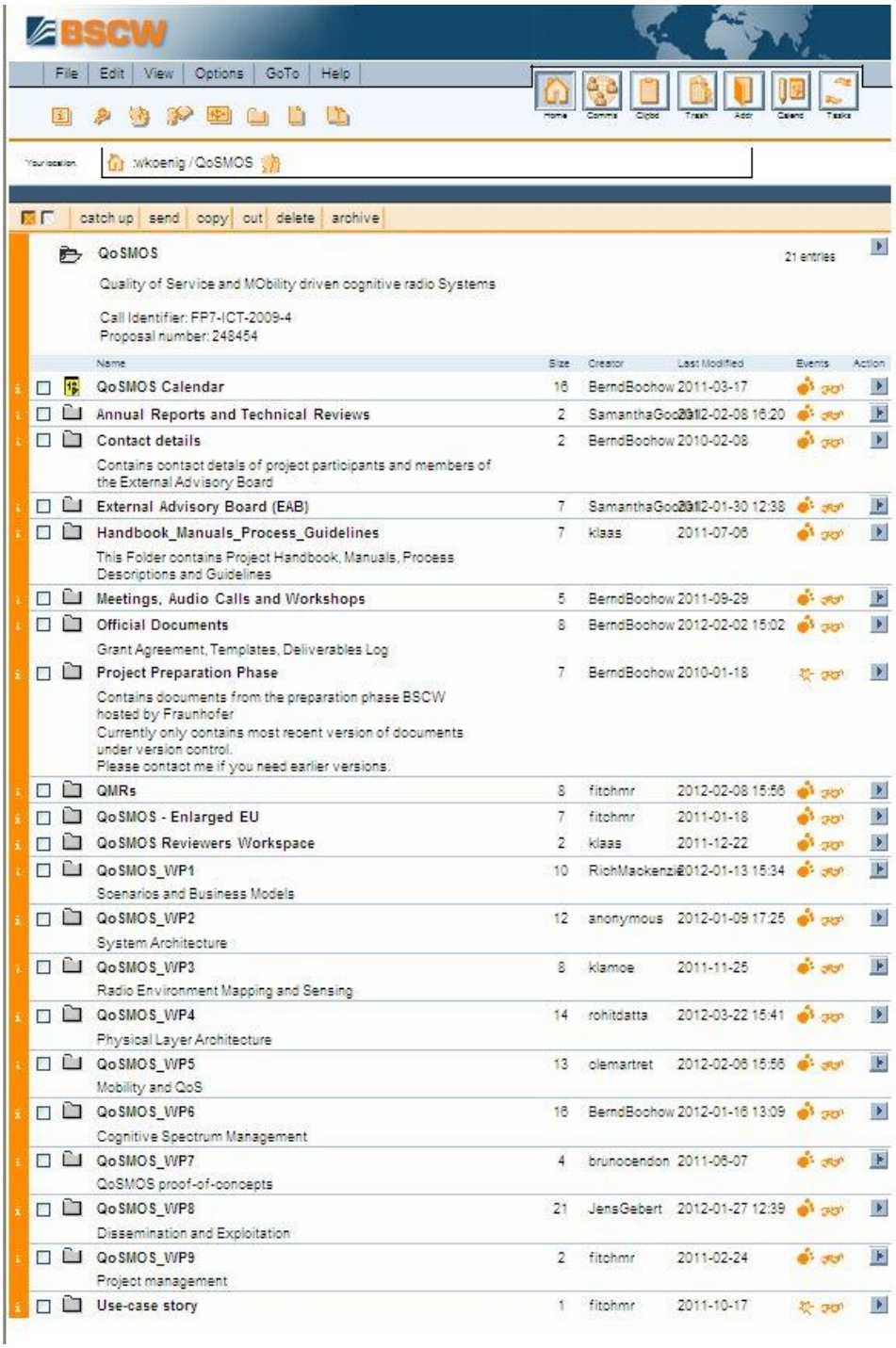


Figure 2-1: QoSMOS Internal Collaboration Website

WP8 folders, as depicted in Figure 2-2, also include a living list and docs of all publications, contributions to standardizationas well as reports from standardization meetings attended. This information is accessible by all partners ensuring project internal dissemination of results.

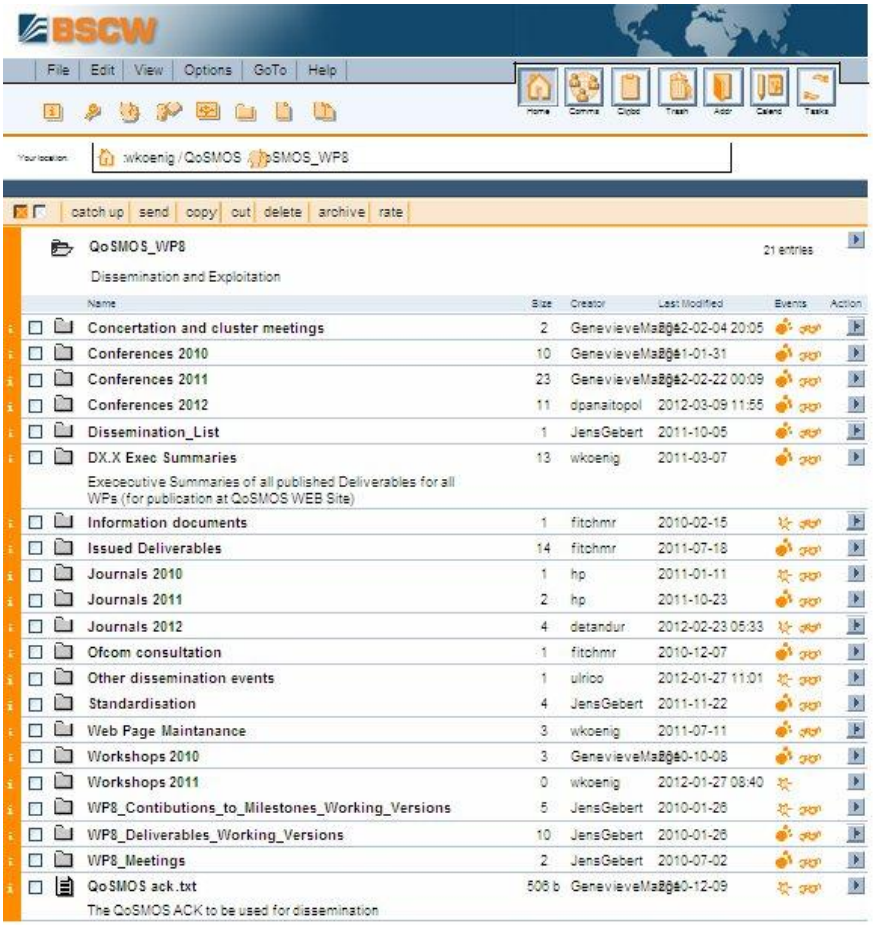


Figure 2-2: QoSMOS Internal Collaboration Website for WP8

2.5 Cooperation with other projects and organizations

QoSMOS has engaged with other relevant active EU funded projects in the Cognitive Radio and Spectrum Allocation area. The interactions to date have been mainly through cluster workshops and cluster events, in order to share project findings and best practice. The RAS cluster is preparing a white paper on Spectrum Sharing, with the aim of finishing it for FuNeMS in July. The contributing projects are OneFit, Acropolis, CoGEU and Quasar, with QoSMOS and Where2 being the main editors.

A joint workshop is planned between CogEU, Quasar and QoSMOS on TV Whitespace protection margins, for late June 2012. The rationale for this is, that these three projects have run measurement campaigns of interference into TV sets and radio microphones. The output from this workshop will be tendered to SE43 and ETSI RRS, with the aim of moderating the high protection margins that are being proposed by the BBC and other broadcasters that, in our view, are too conservative.

The main targeted projects are as listed in D8.2, there are a number of additional projects that have started since D8.2 was published, and we do aim to interact and collaborate with them as well. They include:

- ICT-ACROPOLIS (NOE) - http://www.ict-acropolis.eu/. The purpose of ACROPOLIS (Advanced coexistence technologies for radio optimisation in licensed and unlicensed spectrum) is to link experts and projects from around Europe working on coexistence technologies such as spectrum sharing and cognitive radio, to obtain a rounded complement of European research and to investigate areas that are missing from the current European research repertoire. Such coexistence technologies within ACROPOLIS are aimed towards the optimisation of radio spectrum usage.
- ICT-OneFIT (STREP) - http://www.ict-onefit.eu/. OneFIT (Opportunistic networks and Cognitive Management Systems for Efficient Application Provision in the Future Internet) will develop and validate the vision of opportunistic networks that are managed, and coordinated with the infrastructure, using cognitive systems. OneFIT addresses several technical challenges (such as network and access heterogeneity and scalability), and evolves, bundles and exploits different types of approaches, ranging from dynamic spectrum management and infrastructure-less networks to social networks.
- A joint workshop was held with the CARMEN project (www.ict-carmen.eu) in September 2010. CARMEN is a STREP that is focussing upon mesh networks, and it has a self-configuration element and functions that can repair the mesh by selecting one of several wireless technologies. The CARMEN project is finishing in December 2010 and, while it does not focus upon Cognitive Radio, it was felt that some of the functionality is similar. BT is a partner of both projects and initiated this workshop in order to learn lessons from the CARMEN project that would provide QoSMOS with a step forward. Two aspects of interest were a cost metric that is used for choosing least-cost routes through the mesh – which could possibly be adopted by QoSMOS in working out rules for fair spectrum trading – and the discovery that processing speed can limit the rate that new wireless links can be set up. Both aspects have been reported to QoSMOS WP5 for consideration.
- There is some overlap of interest with other projects in the RAS cluster. One example is FARAMIR, which is looking at the framework necessary to extend network management processes onto the wireless access network; this is interesting to QoSMOS because of the vision to provide managed QoS and mobility. Other examples are CoGEU that is focussing specifically on technology for TV Whitespace and QUASAR that has the objective to evaluate how much TV Whitespace will be available. A joint white paper is being written on the subject of Spectrum Sharing, with contributions from OneFit, FARAMIR, CoGEU and QUASAR, the editing is the responsibility of Where2 and QoSMOS.

Presentations have been made at two meetings of the DC-KTN (Digital Communications Knowledge Transfer Network) Wireless Technology and Spectrum Working Group in the UK.

Members of QoSMOS have attended and presented work at meetings of the Wireless World Research Forum, and they are engaged in the provision of material for future editions of the book of visions.

3 Equipment Certification

The purpose of this part is to set the scene for cognitive radio equipments certification. First, we provide an overview on the certification bodies applicable to mobile devices and secondly, we review the classical certification tests and then list the new challenges associated with the cognitive aspects. Finally, we study the certification of sensing capable devices.

3.1 Mobile device certification

The main objectives of this section are to provide an overview on certification bodies applicable to mobile devices and explain the main differences between certification bodies:

- Global Certification forum (GCF),
- PTCRB Certification group which is a global organization created by Mobile Network Operators to provide an independent evaluation process where GSM / UMTS Type Certification can take place.

To improve global interoperability of defined wireless technologies and more recently, harmonise the global operators requirements on manufacturers, industry certification schemes have been created and evolved over the last two decades. These certification bodies were initially regional/operator &/or technologies focussed. The globalization/unification of wireless technologies and the adoption of these device certifications by more and more operators changed the certification schemes from regional to globally focussed. LTE can be considered as the first global wireless technology, being an evolution path for UMTS FDD & TDD, CDMA 2000 and even WiMax. As a result, several operators who were using “non 3GPP based” technology have joined the GCF (China Mobile, Verizon, Yota & more).

The 3GPP / 3GPP2 core specifications are necessary to design the mobile user equipment, and the 3GPP / 3GPP2 conformance tests provide a method to measure compliance of a design against the core specifications. There are two main certification schemes:

3.1.1.1 Global Certification Forum Certification

The GCF scheme was founded in 1999 and is managed by operator and mobile device manufacturer members with equal voting rights. Test equipment vendors, test labs etc. are observer members. The GCF provides a harmonised way of demonstrating the interoperability of a mobile device utilising industry validated methods to test all aspects of a GSM. WDCMA, LTE product RF, protocol, SIM, USIM and applications. On completion of testing the manufacturer self certifies the product via the GCF web site. Main operators influencing the scheme are Vodafone, Orange, Verizon Wireless, and NTT Docomo.

GCF is an industry certification scheme for handsets, wireless modules (since 2010) and devices incorporating a certified wireless module, which include 3GPP functionalities. It’s mainly a partnership between Network operators, handset Manufacturers and test equipment providers. The test cases are selected by consensus and the focus is on the interoperability of mobile devices and networks.

There are some pre-requisites for certification. A manufacturer needs to be GCF manufacturer member which mandates that the manufacturer is using a quality assurance programme meeting the requirements of ISO9001 or equivalent. The manufactuer places 3GPP capable devices on the market under his own brand name. The independent laboratory (most manufacturers have their own labs) testing the device needs to be ISO17025 accredited. The labs do not need to be GCF member as the responsibility for the declaration is on the manufacturer.

3.1.1.2 PTCRB Certification

Founded in the US in 1997 for Personal Communications System (PCS) radios, the scheme was subsequently extended to include GSM850/1900 and now includes WDCMA and LTE technologies.

Whilst the test cases are similar to those in GCF, the scheme is run by, and focused towards the requirements of the North American Operators. A key difference from GCF being that a PTCRB Certified (PVG) Test Lab must manage the testing and send results to the PTCRB for review / approval.

Certification groups became more important in the global market and have the biggest number of operator and manufacturer members. Benefits for the manufacturers to perform certification are therefore expected to be bigger and facilitate delivery for the same product to a larger number of operators. The recommendation is therefore to extend the certification for WSD on these schemes and participate in these schemes to influence the direction of them for the future of WSDs.

3.2 Certification for cognitive radio devices

The emergence of cognitive radio devices raises new challenges in terms of testing and certification. Sensing and spectrum agility are the key drivers there. The topic is largely unexplored and would require rapid R&D effort to accompany the deployment of these networks.

We first list classical certification tests that a CR device should pass. Then, we list the novel tests foreseen because of the cognitive aspects. Some of these items will be studied in a to-come deliverable.

Note that a prerequisite for these tests is for the certification body to have access to a dedicated test mode on the device under test (DUT).

"Classical certification"

- **Transmit power**: to minimize interference (and at the same time battery drain and health hazard), it is necessary to verify that the DUT's transmit power does not exceed a certain threshold. Values will depend on various criterions, notably mobility capabilities of the DUT;
- **Antenna gain**: obviously, antenna gain should be limited or compensated by a lower threshold for the transmit power. This needs to be tested;
- **Out-of-band leakage**: the spectral leakage should be below a given mask.

"New certification needs"

Obviously, these needs will depend on the considered CR system, e.g. database / sensing. In principle, we will assume that any waveform (e.g. OFDM) can be used by CR devices. This choice would be left to manufacturers.

- **Sensing**: accuracy, latency;
- **Database**: proper access to a database. Note that this DB should also follow a process of certification;
- **Integrity of the primary user**: First two items should be such to preserve the integrity of the primary user;
- **Sustainability**: can we guarantee that in case of a new (primary) system being approved in the considered bands, the sensing / database schemes would also detect it;
- **SDR technology:** Most likely CR devices will be SDR based. This leads to other challenges. For example, how to guarantee that the SW updates will also fulfill the certification requirements;

Furthermore, we emphasize that these tests should be as close as possible to reality. As example, the test stimulus sent to sensing device should at best replicate encountered over-the-air scenarios. Channel fading and the hidden node problem should not be overlooked. These real-world aspects have been at the basis of the MME approach developed in WP3 framework.

At last, it is worth mentioning, that in the framework of the US TVWhite spaces operations, the FCC has worked out the certification test procedures for WSD. The details can be found in ["Proposed Certification Test Procedures for TV Band (White Space) Devices Authorized Under Subpart H of the Part 15 Rules ; FCC]. The key tests are:

- Verification that the DUT cannot operate on unauthorized TV channels ;
- Power limits for fixed and mobile operations;
- Emission limits in adjacent channels.

3.3 Certification of Sensing

It is appropriate that the equipment be certified in terms of demonstrating its ability to perform correct sensing under both normal and extreme conditions for which it is specified to operate.

In this regards a number of scenarios are considered appropriate.

- To sense correctly under nominal operating conditions;
- To sense correctly at the upper end of the sensed signal level range in the presence of high level adjacent channel signals;
- To sense correctly at the lower end of the sensed signal level range in the presence of high level adjacent channel signals,

For equipment specified in an ETSI document such as a Technical Standard (TS) or European Norm (EN) document it is common practice to include clauses containing the technical requirements specifications along with clauses covering related conformance requirements. Added to these is material relating to the specific test methodology in a section on 'Testing for compliance with technical requirements' and 'performance profiles'

These are typically formatted as below:-

Technical requirements specifications

- Environmental profile
- Conformance requirements

Format (repeated for each specific parameter)

- Specific parameter to be tested e.g. Transmitter maximum output power
    - Definition
    - Limits
    - Conformance

Testing for compliance with technical requirements

- Environmental conditions for testing
- Interpretation of the measurement results

Typically the tests are separated into an 'Essential Radio Test Suite' and/or 'Other Test Suite'.

Essential radio test suite

Format (repeated for each specific parameter)

- Specific parameter to be tested e.g. Transmitter maximum output power
- Method of test

- Initial conditions
- Procedure
- Test requirements

'Other Test Suite' tests are handled in a similar manner but are in general not normative.

Annexes may be used to emphasise some specifics such as the example below.

Annex A: Harmonised Standard Requirements and conformance Test specifications Table,

Annex B: Environmental profile.

If the ETSI approach is adopted for Certification of Sensing then several issues are to be addressed.

The first is the establishment of a Standard (TS or EN). This should contain a full description of the equipment and itemise the Technical requirements specification in terms of specific parameters and characterise what the equipment should comply to.

For example, to be able to sense an existing signal (and identify its signature) in the spectrum under consideration over a specific power range (say +10 dBm to -100 dBm). Also, to be able to sense the bandwidth of the spectrum gap within a set accuracy. The equipment should be able to perform this sensing accurately (accuracy to be specified) in the presence of adjacent channel signals operating at a specified level.

The second issue to be addressed is the validation tests to identify id the equipment meets these specifications. This detailed it the Testing for compliance with technical requirements clauses. These clauses describe the test method and any special equipment used. They may contain block diagrams and equipment details.

The initial conditions for setting the test at the correct operating point are detailed along with the operating procedure to conduct the tests. Finally the results are compared to the test requirements in order to assess compliance.

It is anticipated that such tests would require three signal sources that can be varied in level and frequency, one representing the in-band signal that is to be sensed and the other two representing adjacent channel signals. Each should be capable of representing the range of modulated signals and characteristics of carriers normally operating in the band being sensed. The equipment under test should receive all three signals via a suitable coupler and a range of tests conducted to provide validation of the equipment compliance. This may require that the equipment has suitable tests modes built in with appropriate indicators.

It is possible that type approval or batch testing could be adopted for such equipment given the large number of devices envisaged, with simpler compliance testing done in factory on each individual unit.

The development of a suitable ETSI TS or EN is only possible when the full technical aspects of the equipment are determined to a level where the design can be frozen.

4 Exploitation Plans

Agilent Technologies, through QoSMOS, has developed a great knowledge about the new tests required by cognitive radio technology. Beyond learning, the company has developed / is developing the technology needed for these tests; both for the signal generation and signal analysis sides. This is being / will be included in different commercial products. Moreover, thanks to QoSMOS, Agilent has filed a patent. All of this is contributing to position the company as leader is this important future test and measurement market.

ALUD: Increasing demand for mobile data communication will lead to shortages of spectrum available for wireless communication. New concepts enabling spectrum sharing among different

applications respectively networks entities such as (TV-) White Space usage, Licensed Shared Spectrum Use and Dynamic Spectrum Access are promising candidates for more efficient use of the existing spectrum. For Alcatel-Lucent a more flexible and more efficient use of spectrum is a key enabler for future mobile networks capable to deal with the exploding wireless data traffic. Joint elaboration of use cases, scenarios and related business models together with major European operators and equipment vendors is of high importance for the company and respective outcomes are used as an input for ALU internal discussions on strategy and product portfolio roadmaps in this domain. Standardization and Regulation as supported by QoSMOS are considered to be of high importance as enabler for future products in this domain. Furthermore QoSMOS results will be taken up in further collaboration with industrial partners to test and demonstrate the concepts developed by QoSMOS and to evaluate expected benefits.

The novel self organizing network (SON) concept for the QoSMOS spectrum manager as presented in [D6.4] and [D6.5] is a generic solution which is capable to configure and optimize a multitude of coupled and interacting parameters in cellular networks. In addition to the plan to employ it in future Alcatel-Lucent's cognitive radio functionalities and products, this SON solution is also offered to Alcatel-Lucent's business divisions, especially to contribute to several SON use cases in LTE-A.

BME: The QoSMOS outcomes are relevant for both national frequency authority and mobile operators. This fact already led to several consultations between BME and those parties dealing with spectrum management issues and strengthens BME's position as an expert in QoSMOS relevant fields. As higher education institution having PhD program BME also plans to continue its strong contribution activities to national and international conferences and journals involving research students.

BT has been exploiting the project results in several ways. The scenarios of interest to BT are Rural Broadband, Indoor Networking and Machine to Machine, which are subsets of the Cellular Extension, Cognitive Femtocell and Ad-hoc networks scenarios respectively.

In the case of Rural Broadband, this provides BT with a useful infill technology, for reaching premises that are positioned too far from telephone exchanges to be able to connect on broadband (in this case 2Mbit/s). It fills a gap in the broadband availability, between about 3km and 5km distance from the exchange, which enables a significant increase in the premises that can be reached. BT is very interested in this fixed point to multi-point topology, and has taken the QoSMOS results to be trialled in Scotland. In this trial, which is on the Scottish island of Bute, ten triallists are receiving rural broadband connectivity using TV Whitespace, with WiMAX TDD air interface, but using QoSMOS designed spectrum management to avoid interference to local TV services. This is achieved by a prototype QoSMOS database, which is managing the spectrum that the radio system on Bute is using. BT plans further trials and, if this is successful, may increase the exploitation to commercial deployment nationally.

In the case of Indoor Networking, we have briefed the BTY business units on the QoSMOS project and one of them has asked us to build a demonstrator for indoor networking, because is potentially solves a problem they have related to network resilience. The idea is, that a small transmitter in one building will cover the inside of that building for broadband connection, but also the adjacent building will be covered, thereby providing network resilience to the adjacent building. We intend to build this demonstrator before March 2013. Whereas this could be achieved with WiFi systems, the coverage at 2.4GHz is not considered adequate and at 5.8GHz is certainly not adequate. Also, the WiFi spectrum is becoming very crowded, which will become even worse with VDSL or fibre is made available to more premises. QoSMOS provides the spectrum management capability to allow TV Whitespace and other spectrum sharing to increase the capacity for this use-case.

In the case of Machine to Machine, we are using the QoSMOS CM-RM distributed manager principles as a potential solution to the problem of spectrum management to high numbers of low power M2M devices. This is being done in co-operation with another team that is developing Smart Cities. We are

also working with other players in the M2M field, such as Neul, where we are using QoSMOS results to comment on and steer the Weightless protocol.

CEA-LETI: Cognitive Radio is a major research focus at CEA-LETI, and CEA-LETI has been involved in European Cognitive Radio research from its first stage by coordinating the pioneering FP6 IST-ORACLE project. QoSMOS is expected to give more momentum to this research by enabling CEA to extend and exploit its technology know-how. More specifically, a major contribution of CEA is on low adjacent channel air interface specification and design for white spaces. In WP4, this was introduce through the FBMC air interface, which was selected by WP4 as the most promising air interface in terms of performance / implementation complexity tradeoff. CEA also researches new algorithms for signal detection, with a major focus on PMSE detection. CEA expect that QoSMOS will bring significant innovations that will enable CEA to extend its patent portfolio (2 patents have been filed since the start of the project) in this area. By working closely with the silicon industry, CEA intends to use its active patent policy to get royalties on these patents when the Cognitive Radio will be more mature. Also, CEA is involved in WP7 where an electronic board was designed in order to prove PHY layer technology. This will put CEA's technology closer to industrial transfer. The budget is then reallocated to other forefront research programmes with virtuous cycle perspective. This maturity will also come from standardisation that is one task CEA intends to contribute to and have impact on. CEA is a voting member of IEEE P1900.6 and P1900.7 which are the key standardization targets for CEA's technology. Finally, as a research institute, CEA also contributes to the scientific dissemination of QoSMOS results through papers in journals and conferences.

Fraunhofer IIS benefits in several ways from the work carried out in QoSMOS. One aspect regards the RF hardware developments that extend the capability and functionality of Fraunhofer's software-defined radio platform. The QoSMOS objectives and the requirements associated therewith demand a new frequency-agile, flexible RF hardware transceiver, whose design and development strengthen the competitiveness in the area of wireless communications. As wireless communication increasingly asks for reconfigurable and flexible hardware components to cover multiple communication standards, Fraunhofer IIS can reuse and exploit the outcomes generated in QoSMOS or parts therefrom in further projects in the framework of industrial contracts as well as on European, national and bi-lateral level. To date, dissemination activities have included participation in a workshop on cognitive radio, contributions to conferences and a contribution to a book, whereas further contributions based on the RF hardware prototype are planned. In addition, a patent application on flexible RF front-ends has been requested that mainly addresses the flexible pre-selection part. Among RF hardware developments, an extension of the IEEE P1900.6 standard has been initiated. As abovementioned in Sec. 2.2.4, in D3.4 two additional messages were defined with respect to quality-of-service aspects that are supposed to flow into IEEE 1900.6a, an amendment to IEEE P1900.6-2011.

Fraunhofer FOKUS benefits from its work in QoSMOS in various ways.

Its standardization activities in the area of dynamic spectrum access systems in the IEEE Dynamic Spectrum Access Networks Standardization Committee (DySPAN-SC) within the IEEE Communication Society Standards Development (COMSOC) are recognized world-wide and so far resulted in the publication of one Standard (IEEE Std 1900.6-2011). Two draft standards (P1900.1a and P1900.6a) are nearing completion and will be published in 2012 or 2013. Leading positions have been earned through these activities (1900.1 working group chair, 1900.6 technical editor and chair positions for several ad hoc groups). It is planned to keep this involvement.

Through journal publications, conference publications, workshop presentations and tutorials FOKUS disseminated its involvement in the area of dynamic spectrum access and cognitive spectrum management. A half-day tutorial given at the FUSECO Forum 2011 to industry and academia was recognized and established unexpected contacts with stakeholders in the area of white space

communications. Towards the end of 2012 a second tutorial will be given and it is intended to complement this one with demonstrations for industry and operators.

The need for having practical demonstrations to be recognized by industry and operators initiated work on a software framework aiming to enable cognitive methods for dynamic spectrum management, which then was modified to the needs of the QoSMOS project and its unique architectural model. It is assumed that cognitive spectrum management in QoSMOS can be at least partly demonstrated utilizing this framework. The software framework has been labeled 'openCTK'. It is currently in a pre-product stage and will be integrated with the Fraunhofer FOKUS' implementation of a 3GPP Evolved Packet Core. It is foreseen to offer cognitive functions as an optional feature of this already marketed product.

A patent claim has been issued from that work mainly addressing cognitive extensions to geolocation databases for enabling efficiency enhancements to spectrum sharing in upcoming white space communications.

IT mission is to create and disseminate scientific knowledge in the field of telecommunications. As a research institution, IT has no commercial objectives, and its main interests are to capitalize on the acquired know how, to further advance in the field. The general goals in terms of formation and training are: transfer the know-how to the industry; advance with training actions through implementations of post graduate and industry oriented courses. At the research level, continue with investigations in the field, namely through the implementation of algorithms in software radio.

According to the results obtained up to now in the QoSMOS project, the short term IT exploitation plans, are the following:

- Develop a course on cognitive communications for the PhD of the University of Aveiro in Telecommunications.
- Develop a short course on cognitive communications and standardization activities aimed at industry and operators.
- Promote the selective reporting algorithms to the industry for its development.
- Implement a gerneral bench test for sensing algorithms and promote it to the industry. Namely it is intended to develop a sensing platform to be installed in public transports on behalf of operators

NEC Corporation and **NEC Technologies UK (NTUK)** is leading the research in the field of cognitive radio for future mobile and network technologies to expand the global telecom market. As a global vendor of mobile network and devices, NEC is focussing on the scenario of deployment of LTE cellular networks in TV white spaces. NEC will use the valuable business & technical framework produced by QoSMOS to promote the exploitation of white spaces in Europe, to complement and catch up with what has already started in the US and in UK for the use of TV white space for Broadband or M2M. NEC intends to use the technologies they developed for QoSMOS, such as interference monitoring and spectrum management, signal classification and separation, interference suppressive transmission (IA-PFT), and QoS and mobility management (eviction control) to feed the industrial roadmap when the Cognitive Radio concepts will be recognized as part of the operational cellular systems. Towards this recognition, NEC contributes to relevant Standardization bodies, namely DySPAN and RRS, to enable the adoption of its technologies and the development of new business opportunities for their future product roadmap of mobile devices and network equipments for European and Global market. Finally, NEC intends to pursue the definition of system architecture and promote it to the adequate standardization bodies after the lifetime of the project, thanks to the CRS-i coordination action accepted by the EC during FP7 call8.

Telenor is a global wireless operator exploiting standardized wireless technologies. This also means that for Telenor to exploit QoSMOS technologies explicitly, they have to become part of future standards. Consequently, Telenor will evaluate different standards for future exploitation. Telenor is exploring the opportunities of new spectrum management methods and regulations in both mature and

growing markets to make wireless operations more efficient. Telenor has regular dialogs with vendors and it will be natural to include the topic on future cognitive functionalities in network products and solutions in these discussions. Telenor will do performance studies and pursue the QoSMOS scenario definitions to develop the business cases and investigate possible business models for CR. Telenor will use the insight into the actual possibilities of cognitive radio for wider access, higher capacity mobile services and evaluate how it can still ensure the QoS that is expected from an operator. Findings will be used as input to Telenor's strategy development.

TST will take advantage of its role as system integrator to apply the novelties implied by the implementation and validations of the Adaptation Layer it is developing within QoSMOS project. Namely, its RAT agnostic consideration, since it will made the AL a proper fit in TST's own boards, which works with several different technologies

UOULU has been disseminating project results in spectrum sensing and cognitive spectrum and resource management, thus contributing to strengthen its position in such a strategic theme. The University of Oulu plans to continue disseminating in relevant international journals and conferences.

5 References

[1] Horvath P, et al "QoSMOS Dissemination Plan", Project Deliverable, June 2010

[2] CrownCom 2011, http://www.crowncom.org/2011 /

[3] QoSMOS, http://www.ict-QoSMOS.eu/

[4] FCC certification test procedures for WSD, https://apps.fcc.gov/eas/comments/GetPublishedDocument.html?id=223&tn=194631

[5] ECC Report 159 http://www.erodocdb.dk/docs/doc98/official/Pdf/ECCRep159.pdf