Quality Of Service and MObility driven cognitive radio Systems

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D8.9

Standardization and Dissemination

Activity Report v3

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Abstract:

This report, covering the overall duration of the project, 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.

Keyword list:

Cognitive Radio, TV Whitespaces, Spectrum Allocation, Dissemination, Exploitation, Standardization, Education

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Abbreviations

ACROPOLIS	Advanced coexistence technologies for radio optimisation in licensed and unlicensed spectrum
BLER	BLock Error Rate
BSCW	Basic Support for Cooperative Work
CEPT	European Conference of Postal and Telecommunications Administrations
CRS	Cognitive Radio System
DS&E	Dissemination, Standardisation and Exploitation
DUT	Device Under Test
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
MME	Measure, Modelling and Emulation
OneFIT	Opportunistic networks and Cognitive Management Systems for Efficient Application Provision in the Future Internet
PSD	Power Spectral Density
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
RF	Radio Frequency
RRS	Reconfigurable Radio Systems
SCC41	Standards Coordination Committee 41 (Dynamic Spectrum Access)
SDR	Software Defined Radio
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 WhiteSpace
WG	Working Group
WInnF	Wireless Innovation Forum
WSD	White Space Device

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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 whitespaces in the radio frequency spectrum by adapting cognitive radio (CR) technology, with strong emphasis on the Quality of Service (QoS) and mobility aspects.

This deliverable provides the final status on dissemination, standardization and exploitation (DS&E) that have been realized during the QoSMOS project. Below, the main areas of the QoSMOS DS&E plan and related achievements made are given.

- *Publication of outstanding technical achievements in acknowledged international journals and magazines*. QoSMOS has managed to achieve significant results with more than 100 papers and article.
- *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 important events, and have published and presented around 120 papers.
- *Contribution to relevant standards, influence regulatory work and trigger new activities in these bodies.* 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 IEEE 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 (QMCC'11), in conjunction with the WInnComm conference. Another one was held in Fukuoka during IEICE (Technical Committee in Software Radio) in October 2012 (QMCC'12).
- *Offering tutorial sessions in conjunction with important international conferences. Publishing technical white papers, co-authored by project partners, is also expected.*. Five white papers were authored and published on the web site. 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 will develop various prototypes during the project lifetime. To show these achievements, demonstration events will be arranged.* Project demonstrations have been given at the FUNEMS conferences in both 2011 and 2012. At the end of the project, on December 12th, 2012, a seminar at BT Centre in London was held where the different proofs of concept of the QoSMOS project were 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 will be regularly presented at the meetings of the external advisory board (EAB), and feedback from EAB members will be collected and addressed in the project.* Six meetings with the advisory board have taken place, the discussions and feedback to the project has been reported in 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 to "Cambridge Wireless" have been made.

1 Introduction and Overview

This current deliverable presents a complete description of QoSMOS achievements in terms of the dissemination, standardization, regulation activities and equipment certification during the whole duration of the project.

To date 11 submissions to relevant journals have been made, some 90 conference papers have been presented and QoSMOS members have participated in several panels at leading conferences (ICC Cape Town, PIMRC 2010 and FUNEMS 2011 and 2012), as well as at two IEICE events.

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

A proposal for an international QoSMOS workshop at CROWNCOM 2011 [1] 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 (QMCC'11), in conjunction with the WInnComm conference. Another workshop, in conjunction with the IEICE event on "Technical Committee in Software Radio", was held in October 2012 in Fukuoka Japan (QMCC'12).

A tutorial lecture was given at IEICE TCSR in October 2011. Moreover, 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.

Six External Advisory Board (EAB) meetings were held. Representatives from the project presented 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 remained unaltered; the approaches outlined in D8.2 remained valid until the end of the project.

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.

The publication and dissemination plans of QoSMOS, as outlined in deliverable D8.2, remain valid, so there are no concrete updates to these plans. The main aim, to disseminate QoSMOS project outcomes as widely as possible and sensible was followed. The presentations at conferences and workshops as well as panel sessions are listed in Table 1 while the publications in journals and books are listed in Table 2. Two QoSMOS papers received the best paper award at FUNEMS 2011 and WInnComm Europe 2012.

Table 1: QoSMOS dissemination on conferences and workshops Months 1-36

Type of publication	Authors	Title	Conference	Location	Status
Presentation	M. Fitch	QoSMOS RAS Presentation	RAS Workshop "Cognitive Radio - Technology and Regulation"	Brussels, Belgium	Published
Presentation	D. Noguet	QoSMOS EU Project	ERRT 2010	Mainz, Germany	Published
Conference	K. Arshad, K.Moessner	Fusion strategies for collaborative spectrum sensing	ERRT 2010	Mainz, Germany	Published
Conference	M. Ariyoshi, H. Sugahara, Y Futatsugi, K. Muraoka, P. Marchand, V. Merat	A Cognitive Radio Mobile Network Utilising White Space Spectrum (1) – System Overview and Functional Architecture –	IEICE Society Conference 2010	Osaka, Japan	Published
Conference	H. Sugahara, K. Yamazaki, K. Muraoka, M. Ariyoshi	A Cognitive Radio Mobile Network Utilising White Space Spectrum (2) – Inter-System Interference Analysis –	IEICE Society Conference 2010	Osaka, Japan	Published
Conference	K. Muraoka, H. Sugahara, M. Ariyoshi	A Cognitive Radio Mobile Network Utilising White Space Spectrum (3) – Interference Monitoring for Advanced Spectrum Management –	IEICE Society Conference 2010	Osaka, Japan	Published
Conference	Y. Futatsugi, M. Ariyoshi	A Cognitive Radio Mobile Network Utilising White Space Spectrum (4) – A Transmission Technique for Interference Avoidance –	IEICE Society Conference 2010	Osaka, Japan	Published
Conference	T. Nakamura, H. Sugahara, K. Muraoka, M. Ariyoshi	Site Specific Interference Estimation for Advanced Spectrum Management in Cognitive Radio Systems over White Space Spectrum	IEICE Technical Meeting on Software Radio, 2010	Osaka, Japan	Published

Type of publication	Authors	Title	Conference	Location	Status
Conference	O. Durowoju, K. Arshad, K. Moessner	Distributed Power Control for Cognitive Radios with Primary Protection via Spectrum Sensing	IEEE VTC 2010 Fall	Ottawa, Canada	Published
Conference	X. Yu, P. Navaratnam, K. Moessner	Distributed Resource Reservation Mechanism for IEEE 802.11e-Based Networks	IEEE VTC 2010 Fall	Ottawa, Canada	Published
Conference	U. Rajeskaran, K. Arshad, K. Moessner	Joint Rate and Power Optimisation using Distributed Power Control Algorithms in Cognitive Radio Networks	SDR'10	Washington, USA	Published
Conference	M. Fitch, D. Noguet, B. Bochow	Towards Quality of Service and Mobility in Cognitive Radio Systems	FUNEMS 2010	Firenze, Italy	Published
Conference	K. Arshad, K. Moessner	Mobility driven energy detection based Spectrum Sensing framework of a Cognitive Radio	UKIWCS 2010	Delhi, India	Published
Conference	M. Gautier, M. Laugeois, D. Noguet	Teager-Kaiser energy detector for narrowband wireless microphone spectrum sensing	CROWNCOM 2010	Cannes, France	Published
Conference	R. MacKenzie, P. Lehne, U. Celentano, M. Ariyoshi	Identifying Scenarios with High Potential for Future Cognitive Radio Networks	FUNEMS 2011	Warszaw, Poland	Published
Conference	G. Mange, C. Rosik, S. Leveil, U. Celentano, O. Olasunkanmi, K. Arshad	Cognitive Resource Management for QoS Support in Mobile Opportunistic Communications	FUNEMS 2011	Warszaw, Poland	Published
Conference	K. Arshad, K. Moessner	Robust Collaborative Spectrum Sensing based on Beta Reputation System	FUNEMS 2011	Warszaw, Poland	Published
Workshop	R. MacKenzie	MAC Layer Modelling using Markov Chains	FUNEMS 2011 QOSMOS workshop	Warszaw, Poland	Published
Workshop	D. Noguet	Physical Layer techniques for TV White Spaces	FUNEMS 2011 QOSMOS workshop	Warszaw, Poland	Published
Workshop	R. Datta	Flexible PHY design for Cogntive Radio	FUNEMS 2011 QOSMOS workshop	Warszaw, Poland	Published
Workshop	B. Bochow	Dynamic Spectrum Access Standardization in IEEE	FUNEMS 2011 QOSMOS workshop	Warszaw, Poland	Published
Workshop	M. Fitch	[Panel discussion] Regulation & Cogntive Radio	FUNEMS 2011 QOSMOS workshop	Warszaw, Poland	Took place

Type of publication	Authors	Title	Conference	Location	Status
Workshop	P. Lehne, R. MacKenzie, D. Noguet, C. Le Martret	[Panel discussion] Use Cases for Cogntive Radio	FUNEMS 2011 QOSMOS workshop	Warszaw, Poland	Took place
Conference	Z. Kollár, G. Péceli, P. Horváth	Adaptive Decision Feedback Equalization for FBMC Systems	COCORA 2011	Budapest, Hungary	Published
Conference	M. Ariyoshi, H. Sugahara, V. Merat, C. Rosik	[Panel Discussion] Cross Layer Technologies for Cognitive Radio Systems in QoSMOS Project	IEICE Technical Meeting on Software Radio, 2011	Fukuoka, Japan	Took place
Conference	Y. Futatsugi, M. Ariyoshi	Transmission Performance of Interference Avoidance Transmission by Partitioned Frequency- and Time-domain Processing for DSA	IEICE Technical Meeting on Radio Communication Systems, 2011	Yokosuka, Japan	Published
Conference	M. Ariyoshi, R. MacKenzie, P. Lehne, U. Celentano	[Tutorial] Application and Deployment of Cognitive Radio Networks: High Potential Scenario Examples	IEICE General Conference 2011	Tokyo, Japan	Published
Conference	Y. Futatsugi, M. Ariyoshi	PAPR Performance of Interference Avoidance Transmission by Partitioned Frequency- and Time-domain Processing for DSA	IEICE General Conference 2011	Tokyo, Japan	Published
Conference	K. Muraoka, H. Sugahara, M. Ariyoshi	MMSE-Based Cooperative Interference Monitoring for Cognitive Mobile Networks	IEICE General Conference 2011	Tokyo, Japan	Published
Conference	M. Ariyoshi, R. MacKenzie, P. Lehne, U. Celentano	[Tutorial Lecture] Application and Deployment of Cognitive Radio Networks - High Potential Scenario Examples	IEICE Technical Meeting on Software Radio, 2011	Tokyo, Japan	Published
Conference	K. Muraoka, H. Sugahara, M. Ariyoshi	Monitoring-Based Interference Management for Expanding Opportunities of White Space Utilization	IEEE DySPAN 2011	Aachen, Germany	Published
Conference	D. Depierre, F. Delaveau, F. Sirven	Oriented processing of Communication signals for Sensing and disseminated spectrum monitoring	SDR '11 - WInnComm - Europe	Brussels, Belgium	Published
Conference	P. Lehne, D. Noguet, R. Datta, U. Celentano, V. Merat, P. Delahaye, G. Fettweis	Requirements for a CR-system – Challenges compared to conventional wireless technology	SDR '11 - WInnComm - Europe	Brussels, Belgium	Published
Conference	D. Noguet, M. Fitch, W. Koenig	QoSMOS: Towards managed QoS and Mobility over Share Spectrum,	SDR '11 - WInnComm - Europe	Brussels, Belgium	Published
Conference	Z. Kollár, P. Horváth	Physical Layer Considerations For Cognitive Radio: Modulation Techniques	IEEE VTC 2011 Spring	Budapest, Hungary	Published

Type of publication	Authors	Title	Conference	Location	Status
Conference	Z. Kollár, P. Horváth	Physical Layer Considerations For Cognitive Radio: Synchronization Point of View	IEEE VTC 2011 Spring	Budapest, Hungary	Published
Conference	O. Durowoju, K. Arshad, K. Moessner	Cognitive time variant power control in slow fading mobile channels	IEEE VTC 2011 Spring	Budapest, Hungary	Published
Conference	K. Arshad, K. Moessner	Efficient Spectrum Management among Spectrum Sharing UMTS Operators	IEEE VTC 2011 Spring	Budapest, Hungary	Published
Conference	O. Durowoju, K. Arshad, K. Moessner	Autonomous Time Variant Power Control for Cognitive Radio Networks	IEEE VTC 2011 Spring	Budapest, Hungary	Published
Conference	O. Durowoju, K. Arshad, K. Moessner	Distributed Power Control for Cognitive Radios based on Incumbent Outage Information	ICC 2011	Kyoto, Japan	Published
Conference	D. Noguet, R. Datta, P. Lehne, M. Gautier, G. Fettweis	TVWS regulation and QoSMOS requirements	Wireless VITAE 2011	Chennai, India	Published
Conference	M. Mueck, D. Noguet	TV White Space Standardization and Regulation in Europe	Wireless VITAE 2011	Chennai, India	Published
Conference	R. Datta, M. Gautier, V. Berg, Y. Futatsugi, M. Ariyoshi, M. Schühler, Z. Kollar, P. Horvath, D. Noguet	Flexible Multicarrier PHY design for Cognitive Radio in White Space	CROWNCOM 2011	Osaka, Japan	Published
Conference	D. Panaitopol, A. Bagayoko, P. Delahaye, L. Rakotoharison	Fast and Reliable Sensing Using a Background Process for Noise Estimation	CROWNCOM 2011	Osaka, Japan	Published
Conference	T. Zahir, K. Arshad, Y. Ko, K. Moessner	A Downlink Power Control Scheme for Interference Avoidance in Femtocells	IWCMC 2011	Istanbul, Turkey	Published
Conference	G. Alnwaimi, K. Arshad, K. Moessner	Dynamic Spectrum Allocation Algorithm with Interference Management in Displaced Networks	IWCMC 2011	Istanbul, Turkey	Published
Conference	X. Yu, P. Navaratnam, K. Moessner	Distributed Resource Reservation for Real Time Sessions in Multi-Hop Wireless Networks	IWCMC 2011	Istanbul, Turkey	Published
Conference	U. Celentano, B. Bochow, J. Herrero, B. Cendón, C. Lange, F. Noack, O. Grøndalen, V. Mérat, C. Rosik	Flexible Architecture for Spectrum and Resource Management in the Whitespace	WPMC 2011	Brest, France	Published
Conference	K. Arshad, K. Moessner	Statistical Models of Spectrum Opportunities for Cognitive Radio	PIMRC 2011	Toronto, Canada	Published

Type of publication	Authors	Title	Conference	Location	Status
Conference	J. Lehtomäki, J. Vartiainen, R. Vuohtoniemi, H. Saarnisaari	Adaptive FCME-Based Threshold Setting for Energy Detectors	CogART 2011	Barcelona, Spain	Published
Conference	K. Arshad, K. Briggs, K. Moessner	Robust Spectrum Sensing for Cognitive Radio based on Statistical Tests	CogART 2011	Barcelona, Spain	Published
Conference	J. Vartiainen, J. Lehtomäki, R. Vuohtoniemi	Performance of the LAD Methods Under Channel Impairments	CogART 2011	Barcelona, Spain	Published
Conference	A. Nakata, K. Arshad, K. Moessner	Interference Tolerable Threshold Analysis in Cognitive Femtocells	SDR '11 - WInnComm	Washington, USA	Published
Workshop	K. Moessner	Functional architecture overview for the cognitive management of opportunistic networks in the context of future Internet	(QMCC'11) at SDR '11 - WInnComm	Washington, USA	Uploaded on web site
Workshop	D. Noguet	Dependable Indoor-to-Outdoor Wireless Technology in the TVWS for First Responders' assistance	(QMCC'11) at SDR '11 - WInnComm	Washington, USA	Uploaded on web site
Workshop	R. MacKenzie	MAC Layers for White Space Radio Systems	(QMCC'11) at SDR '11 - WInnComm	Washington, USA	Uploaded on web site
Conference	M. Fitch	[Panel discussion] Extending White Space Beyond TV Bands	SDR '11 - WInnComm	Washington, USA	Took place
Conference	L. Csurgai-Horváth, J. Bitó	Primary and secondary user activity models for cognitive wireless network	ConTEL 2011	Graz, Austria	Published
Conference	R. Datta, G. Fettweis, Z. Kollar, P. Horvath	FBMC and GFDM Interference Cancellation Schemes for Flexible Digital Radio PHY Design	DSD'11	Oulu, Finland	Published
Conference	E. Castañeda, R. Samano, A. Gameiro	Frequency-Reuse Planning of the Down-Link of Cognitive Distributed Antenna Systems	Latincom 2011	Belem, Brazil	Published
Conference	B. Bochow, M. Emmelmann	[Tutorial] Dynamic spectrum access, cognitive radio networks, and spectrum management as key enablers for upcoming mobile communications	Fraunhofer FUSECO FORUM, 2011	Berlin, Germany	Published
Conference	G. Mange	Cognitive Radio in Wireless Networks	Canada-EU Future Internet	Waterloo, Canada	Published
WorkShop	M. Emmelmann, B. Bochow	Challenges of enabling high mobility in future flexible spectrum scenarios	IEEE LCN ON-MOVE 2011	Bonn, Germany	Published

Type of publication	Authors	Title	Conference	Location	Status
Poster	D. Panaitopol, R. Datta, G. Fettweis	Cyclostationary Detection of Cognitive Radio Systems using GFDM Modulation	WCNC 2012	Paris, France	Published
Conference	D.M. Godarzi, K. Arshad, Y. Ko, K. Moessner	Selecting users in energy-efficient collaborative spectrum sensing	WCNC 2012	Paris, France	Published
Poster	U. Celentano	Flexible spectrum and resource management for cognitive radio networks	Wireless Communications Research Seminar 2012	Oulu, Finland	Published
Conference	R. Samano, A. Gameiro	Multi-Objective and Portfolio Optimization in Cognitive Radio Systems	W-PIN 2012	Paris, France	Published
Conference	D. Depierre, F. Pipon, D. Noguet	Multi-Antenna Cyclostationarity Feature Detection for Parallel Sensing in Cognitive Radio	FUNEMS 2012	Berlin, Germany	Published
Conference	S. Leveil, C. Le Martret, H. Anouar, K. Arshad, T. Zahir, J. Bitó, U. Celentano, G. Mange, J. R. Fernández, A. M. Ceballos	Resource Management of Centrally Controlled Cognitive Radio Networks	FUNEMS 2012	Berlin, Germany	Published
Conference	P. Grønsund, R. MacKenzie, P. Lehne, K. Briggs, O. Grøndalen, P. Engelstad	Towards Spectrum micro-trading	FUNEMS 2012	Berlin, Germany	Published
Conference	V. Berg, Z. Kollar, R. Datta, P. Horvath, D. Noguet, G. Fettweis	Low ACLR communication systems for TVWS operation	FUNEMS 2012	Berlin, Germany	Published
Conference	Y. Futatsugi, M. Ariyoshi	Interference Avoidance Transmission by Partitioned Frequency- and Time-domain Processing	IEEE VTC 2012 Spring	Yokohama, Japan	Published
Conference	R. Datta, G. Fettweis, Y. Futatsugi, M. Ariyoshi	Comparative Analysis on Interference Suppressive Transmission Schemes for White Space Radio Access	IEEE VTC 2012 Spring	Yokohama, Japan	Published
Conference	X. Yu, P. Navaratnam, K. Moessner	Distributed MAC Scheduling Mechanism Based on Resource Reservation for IEEE 802.11e-Based Multi-Hop Wireless Networks	IEEE VTC 2012 Fall	Quebec Canada,	Published
Conference	R. Datta, N. Michailow, M. Lentmaier, G. Fettweis	GFDM Interference Cancellation for Flexible Cognitive Radio PHY Design	IEEE VTC 2012 Fall	Quebec Canada,	Published

Type of publication	Authors	Title	Conference	Location	Status
Conference	T. Guo, K. Moessner	Optimal Strategy for QoS Provision under Spectrum Mobility in Cognitive Radio Networks	IEEE VTC 2012 Fall	Quebec, Canada	Published
Conference	T. Nakamura, H. Sugahara, K. Muraoka, M. Ariyoshi	Propagation Estimation Error Correlation Characteristics at Rooftops Based on Field Measurement	IEICE General Conference 2012	Okayama, Japan	Published
Conference	P. Lehne, R. MacKenzie, D. Noguet, V. Berg, O. Grøndalen	Mapping Cognitive Radio System Scenarios into the TVWS Context	SDR '12 - WInnComm - Europe	Brussels, Belgium	Published
Conference	R. MacKenzie, K. Briggs	Comparison of contention-based protocols for secondary access in TV whitespaces	SDR '12 - WInnComm - Europe	Brussels, Belgium	Published
Conference	L. Varga, Z. Kollár, P. Horváth	Recursive discrete Fourier transform based SMT receivers for cognitive radio applications	IWSSIP 2012	Wien, Austria	Published
Conference	J. Lehtomäki, R. Vuohtoniemi, K. Umebayashi	Duty Cycle and Channel Occupancy Rate Estimation with MED-FCME LAD ACC	CROWNCOM 2012	Stockholm, Sweden	Published
Conference	J. Vartiainen, J. Lehtomäki, R. Vuohtoniemi	The LAD methods in WLAN indoor multipath channels	CROWNCOM 2012	Stockholm, Sweden	Published
Conference	J. Vartiainen	Always One/Zero Malicious User Detection in Cooperative Sensing Using the FCME Method	CROWNCOM 2012	Stockholm, Sweden	Published
Conference	M. Gautier, V. Berg, D. Noguet	Wideband frequency domain detection using Teager-Kaiser energy operator	CROWNCOM 2012	Stockholm, Sweden	Published
Conference	Z. Kollár, J. Gazda, P. Horváth, D. Kocur, L. Varga	Iterative compensation of baseband clipping in SMT transceivers	Radioelektronika 2012	Brno, Czech Republic	Published
Workshop	M. Schuehler, R. Wansch	RF Receiver Front-End Architectures for Cognitive-Radio Systems	GeMic 2012	Ilmenau, Germany	Published
Conference	R. Datta, K. Arshad, G. Fettweis	Analysis of Spectrum Sensing Characteristics for Cognitive Radio GFDM Signal	IWCMC 2012	Limassol, Cyprus	Published
Conference	Z. Kollár, L. Varga, K. Czimer	Clipping-Based Iterative PAPR-Reduction Techniques for FBMC	InOWo'12	Essen-Kettwig, Germany	Published
Conference	V. Berg, D. Noguet, X. Popon	A Flexible Hardware Platform for Mobile Cognitive Radio Applications	Euromicro DSD 2012	Izmir, Turkey	Published

Type of publication	Authors	Title	Conference	Location	Status
Conference	K. Zsolt, B. János, B. Péter, C. H. László, H. Péter	QoSMOS FP7 ICT projekt - kognitív rádió rendszerek analóg TV sávokban	HTE Infokom 2012	Matrahaza, Hungary	Published
Conference	I. Karla	Resolving SON Interactions via Self-Learning Prediction in Cellular Wireless Networks	WICOM 2012	Shanghai, China	Published
Workshop	N Sato, R Sawai, C Sun, K Muraoka, M Ariyoshi, P Delahaye, J Xiao, Y Zhang, M Freda	TV White Spaces as Part of the Future Spectrum Landscape for Wireless Communications	ETSI Workshop on Reconfigurable Radio Systems	Cannes, France	Published
Workshop	Z. Kollár, J. Bitó, L. Varga, P. Horváth	Novel Multicarrier Modulation for Cognitive Radio Systems	(QMCC'12) at IEICE 2012, Technical committee on Software Radio	Fukuoka, Japan	Published
Workshop	M. Fitch, R. MacKenzie, P. Lehne	QoSMOS Overview and Scenarios	(QMCC'12) at IEICE 2012, Technical committee on Software Radio	Fukuoka, Japan	Published
Workshop	L. Csurgai-Horváth, J. Bitó	Novel Multicarrier Modulation for Cognitive Radio Systems	(QMCC'12) at IEICE 2012, Technical committee on Software Radio	Fukuoka, Japan	Published
Workshop	D. Noguet, V. Berg, X. Popon, M. Schuehler, M. Tessema	T-Flex: A mobile SDR platform for TVWS flexible operation	(QMCC'12) at IEICE 2012, Technical committee on Software Radio	Fukuoka, Japan	Published
Workshop	U. Celentano	QoSMOS system architecture and reference model	(QMCC'12) at IEICE 2012, Technical committee on Software Radio	Fukuoka, Japan	Published
Workshop	R. Datta, G. Fettweis	Improved CR Spectrum Sensing Performance with Lower ACLR GFDM Signals	(QMCC'12) at IEICE 2012, Technical committee on Software Radio	Fukuoka, Japan	Published
Conference	R. Datta, N. Michailow, S. Krone, M. Lentmaier, G. Fettweis	Generalized Frequency Division Multiplexing in Cognitive Radio	EUSIPCO 2012	Bucharest, Romania	Published
Conference	E. Castaneda, R. Samana, A. Gameiro,	Cooperative Scheduling for Distributed Antenna Systems	EUSIPCO 2012	Bucharest, Romania	Published
Conference	A. Jaschke, M. Tessema, M. Schühler, R. Wansch	Digitally Tunable Bandpass Filter for Cognitive Radio Applications	IEEE CAMAD 2012	Barcelona, Spain	Published

Type of publication	Authors	Title	Conference	Location	Status
Conference	R. Datta, D. Panaitopol, G. Fettweis	Analysis of Cyclostationary GFDM Signal Properties in Flexible Cognitive Radio	ISCIT 2012	Gold Coast, Australia	Published
Workshop	O. Grøndalen	Operator business models for white space communications	CogEU - Cognitive radio for TV white spaces workshop,	Bratislava, Slovakia	Published
Conference	B. Horváth, Z. Kollár, P. Bakki, P. Horváth, J. Bitó, B. Eged	Evaluation and comparison of novel PAPR reduction techniques for FBMC	IEEE ICC 2013	Budapest, Hungary	Submitted
Conference	O. Durowoju, K. Arshad, K. Moessner	Distributed Power Control and User Selection Algorithm for Cognitive Radios	IEEE ICC 2013	Budapest, Hungary	Submitted
Conference	R. Samano, A. Gameiro	Joint Spectrum Selection and Radio Resource Management for Distributed Antenna Systems with Cognitive Radio and Space Division Multiplexing	WSA 2013	Stuttgart, Germany	Submitted

Table 2: QoSMOS Journal and book publications Months 1-36

Type of publication	Authors	Title	Journal	Status
Article	O. Durowoju, K. Arshad, K. 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
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
Article	Z. Kollár, L. Varga, P. Horváth	Modern többvivős rendszerek kognitív rádiós alkalmazásokban.	HÍRADÁSTECHNIKA 2011/3: pp. 18-22. (2011)	Published
Article	G. Alnwaimi, K. Arshad, K. Moessner	Dynamic Spectrum Allocation between two UMTS Operators with Interference Handling	IEEE Communication Letters	Published
Article	S. Rostami, K. Arshad, K. Moessner	Order-Statistc based Spectrum Sensing for Cognitive Radio	IEEE Communications Letters	Published

Type of publication	Authors	Title	Journal	Status
Article	M. Murroni, R. V. Prasad, P. J. Marques, B. Bochow, D. Noguet, C. Sun, K. Moessner, H. 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, December 2011	Published
Article	E. Castañeda, R. Samano, A. Gameiro	Frequency-Reuse Planning of the Down-Link of Cognitive Distributed Antenna Systems	IEEE Latin America Transactions	Published
Article	T. Zahir, K. Arshad, Y. Ko, K. Moessner	Interference Management in Cognitive Femtocells	IEEE Surveys and Tutorials	Published
Article	Y. Ko, Klaus Moessner	Maximum outage capacity in dense indoor femtocell networks with joint energy and spectrum utilization	IEEE Trans. Wireless Communication	Published
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, Modelling and Emulation	IEEE Vehicular Technology Magazine	Published
Article	J. Lehtomäki, R. Vuohtoniemi, K. Umebayashi, J. P. Mäkelä	Energy detection based estimation of channel occupancy rate with adaptive noise estimation.	IEICE Transactions on Communications E95-B: 04. April 2012	Published
Article	K. Arshad, K. Moessner	Robust collaborative spectrum sensing in the presence of deleterious users	IET Communications	Published
Article	Z. Kollár, P. Horváth	Equalization of Multicarrier Cognitive Radio Transmissions over Multipath Channels with Large Delay Spread.	Infocommunications journal 3:(2) pp. 42-47. (2011)	Published
Article	Z. Kollár, P. Horváth	PAPR Reduction of FBMC by Clipping and its Iterative Compensation	Journal of computer networks and communication, 2012	Published
Article	Z. Kollár, P. Horváth	Modulation Schemes for Cognitive Radio in White Spaces	Radioengineering, Vol. 19, No. 4, Part I, pp. 511-517	Published
Article	R. MacKenzie, P. Lehne, U. Celentano, M. Ariyoshi	Rádio cognitivo	RTI: Redes, Telecom e Instalações (ISSN: 1808-3544)	Published
Book	M. Schuehler, A. Jaschke, A. Popugaev	Reconfigurable RF Receiver Front-end for Cognitive Radio	Festschrift for Prof. Dr.-Ing. Heinz Gerhäuser, Springer	Published

Type of publication	Authors	Title	Journal	Status
Article	J. Lehtomäki, R. Vuohtoniemi, K. Umebayashi	On the Measurement of Duty Cycle and Channel Occupancy Rate	IEEE Journal on Selected Areas in Communications	Accepted
Article	R. Samano, A. Gameiro	Throughput and Return-Risk Trade-off Regions of Cognitive Radio with Random Transmission Control	IEEE Journal on Select. Areas on Communications	Accepted
Article	K. Muraoka, H. Sugahara, M. Ariyoshi	Interference Monitoring-Based Spectrum Management to Maximize White Space Utilization for Cognitive Radios	IEICE Trans. On Communications	Accepted
Article	K. Arshad, R. MacKenzie, U. Celentano, A. Drozdy, S. Leveil, G. Mange, J. Rico, A. Medela, C. Rosik	Resource Management for QoS support in, Cognitive Radio Network	IEEE Communications Magazine	Submitted
Article	M. López-Benítez, K. Moessner	On the estimation of channel activity statistics in cognitive radio based on periodic channel observations	IEEE Journal on Selected Areas in Communications - Cognitive Radio series	Submitted
Article	D. Castanheira, A. Gameiro	Novel Windowing Scheme for Cognitive OFDM Systems	IEEE Wireless Com. Letters	Submitted
Article	R. Mackenzie, K. Briggs, P. Grønsund, P.H. Lehne	Spectrum micro-trading for mobile operators	IEEE Wireless Communications Magazine, Special Issue: Next Generation Cognitive Cellular Networks: Spectrum Sharing and Trading	Submitted
Article	K. Arshad, K. Moessner	Robust spectrum sensing in Rician channels based on statistical tests	IET Communications	Submitted
Article	P. H. Lehne, O. Grøndalen, R. MacKenzie, D Noguet, V. Berg	Mapping Cognitive Radio System Scenarios into the TVWS Context	Springer Journal of Signal Processing Systems, Special issue: Wireless Innovation Forum	Submitted
Article	I. M. Suliman, J. Lehtomäki, K. Umebayashi, M. Katz	Analysis of Cognitive Radio Networks with Imperfect Sensing	IEICE Trans. Communications	Submitted

2.2 Conference Booth

The QoSMOS project was presented in booths during several conferences:

- In June 2011, in Warsaw, Poland during FUNEMS where a poster was proposed as well as a demonstration of the QoSMOS database.
- In June 2012, in Berlin, Germany during FUNEMS where a demonstration of the QoSMOS prototype was made.
- In October 2012, in Bellevue, USA during DySPAN where a demonstration about "TVWS Context Acquisition and Low Interference Communication System" was made.

2.3 Workshops and Seminars

A workshop, "Cognitive Radio – Technology and Regulation Workshop", was held in June 2011 at the FUNEMS conference in Warsaw, Poland. This workshop was co-organised with QoSMOS, the RAS cluster and Orange Labs. This workshop included six technical presentations (four from QoSMOS partners, one from Qualcomm and another from Huawei) and a keynote speech from Orange Group Spectrum Office. The workshop also included two panels. The first panel, "Regulation & Cognitive Radio", was chaired by QoSMOS manager Michael Fitch and included regulators, broadcasters and other industry bodies. Several members of the panel are on the QoSMOS EAB. The second panel session, "Use Cases for Cognitive Radio" was chaired by Per-Hjalmar Lehne (Telenor). The panel included three other members of QoSMOS and a member of France Telecom Orange Group. All sessions were well attended with 20-40 attendees for most presentations. The panel sessions received even higher attendance; the first panel session in particular, which attracted approximately 100 people.

At the end of November 2011, a workshop was held in Washington DC on Quality of Service and Mobility over Cognitive Communications radio systems (QMCC'11), 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. Two panel sessions were also arranged at WInnComm, that involved QoSMOS. The first was jointly arranged between QoSMOS and the regulatory workshop. This panel, "The Global QoS Perspective", had two QoSMOS EAB members. The second panel, "Extending White Space Beyond TV Bands" included QoSMOS manager Michael Fitch.

The project had originally planned to hold the QMCC'11 workshop in conjunction with CROWNCOM in Japan, but the plans were upset by the disaster in Japan. In October 2012, another workshop was held in Fukuoka, Japan, as part of the IEICE technical committee workshop on "Software Radio". This workshop (QMCC'12) included eight technical presentations. The attendance was again high with approximately 40 people in attendance.

QoSMOS was invited to present material for a spectrum sharing seminar organized by Ruprecht Neopold from the EC Spectrum Policy Office on 13th February in Brussels. This contributed to the EC statement on spectrum sharing that was issued later in the year.

QoSMOS had a session at a COGEU workshop in October to discuss economic models for whitespace databases. This work was instigated from the QoSMOS business cases.

QoSMOS continues to participate significantly in the RAS cluster meetings and the project manager was chairing the meetings and presenting the outputs into the concertation plenaries. The last meeting that was be chaired by QoSMOS was in 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, a seminar at BT Centre in London was held where the QoSMOS proofs of concept were demonstrated and presented to a wide range of stake-holders and

policy-makers. In total there were approximately 80 attendees. A flyer including a full list of attendees for the day and an overview of the demonstrations can be found on the QoSMOS website.

2.4 Website and Other Web Resources

The QoSMOS website (http://ict-QoSMOS.eu/) is twofold, 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), Demos, …)
- 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.

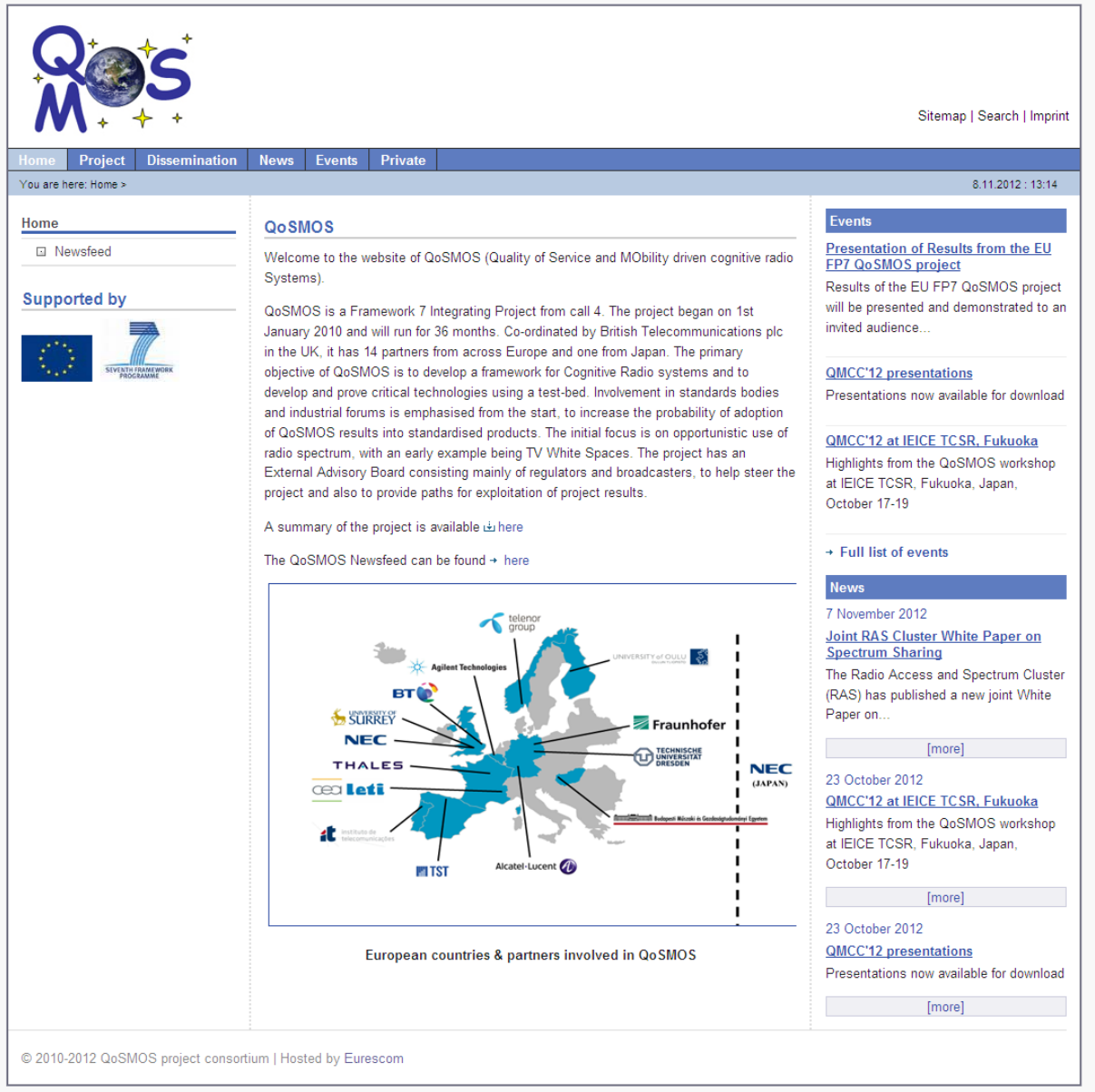


Figure 2-1: QoSMOS Public Website – Home Page

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

- Home
  - Newsfeed
- Project
  - Motivation
  - Approach
  - Technical Highlights
    - Scenarios and Business Models
    - System Architecture
    - Radio Environment Mapping and Sensing
    - Physical Layer Architecture
    - Mobility and QoS Management
    - Proof of Concept
  - Schedule
  - Workpackages
    - WP 1 - Scenarios and Business Models -
    - WP 2 - System Architecture -
    - WP 3 - Radio Environment Mapping and Sensing -
    - WP 4 - Physical Layer Architecture -
    - WP 5 - Mobility and QoS -
    - WP 6 - Cognitive Spectrum Manager -
    - WP 7 - QoSMOS proof-of-concepts -
    - WP 8 - Dissemination and Exploitation -
    - WP 9 - Project Management -
  - Demos
  - Partners
  - External Advisory Board
    - Objectives
    - Members
    - Meetings
  - Standardisation and Regulation
    - ETSI RRS
    - IEEE DySPAN-SC
      - IEEE P1900.1
      - IEEE P1900.4
      - IEEE P1900.6
      - IEEE P1900.7
      - IEEE Ad-hoc WG DSA-VE
    - IETF PAWS WG
    - CEPT
    - CEPT/ECC SE43
    - ITU-R
  - Abbreviations
  - Related links
  - About us
- Dissemination
  - Deliverables
  - White Papers
  - Publications
    - Journals or Book Chapters
    - Conferences
    - Standardization and Regulation
    - Workshops
  - QoSMOS Workshops
    - QoSMOS at WInnComm 2011
      - QMCC'11 Presentations Session
    - QoSMOS at IEICE 2012
      - QMCC'12 Presentations
    - QoSMOS at IEICE TCSR 2012
    - QoSMOS Industry Briefing Dec. 2012
  - RAS Cluster
- News
  - Search
  - Archive
- Events
  - Future Events
  - Past Events
- Private

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, highlights from following areas are given in particular:

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

In 2012 a new page "Demos' was introduced that provides information about the demos available from QoSMOS. Figure 2-3 depicts the web access to the TV Whitespace database prototype that has been setup in the scope of QoSMOS by a project partner.

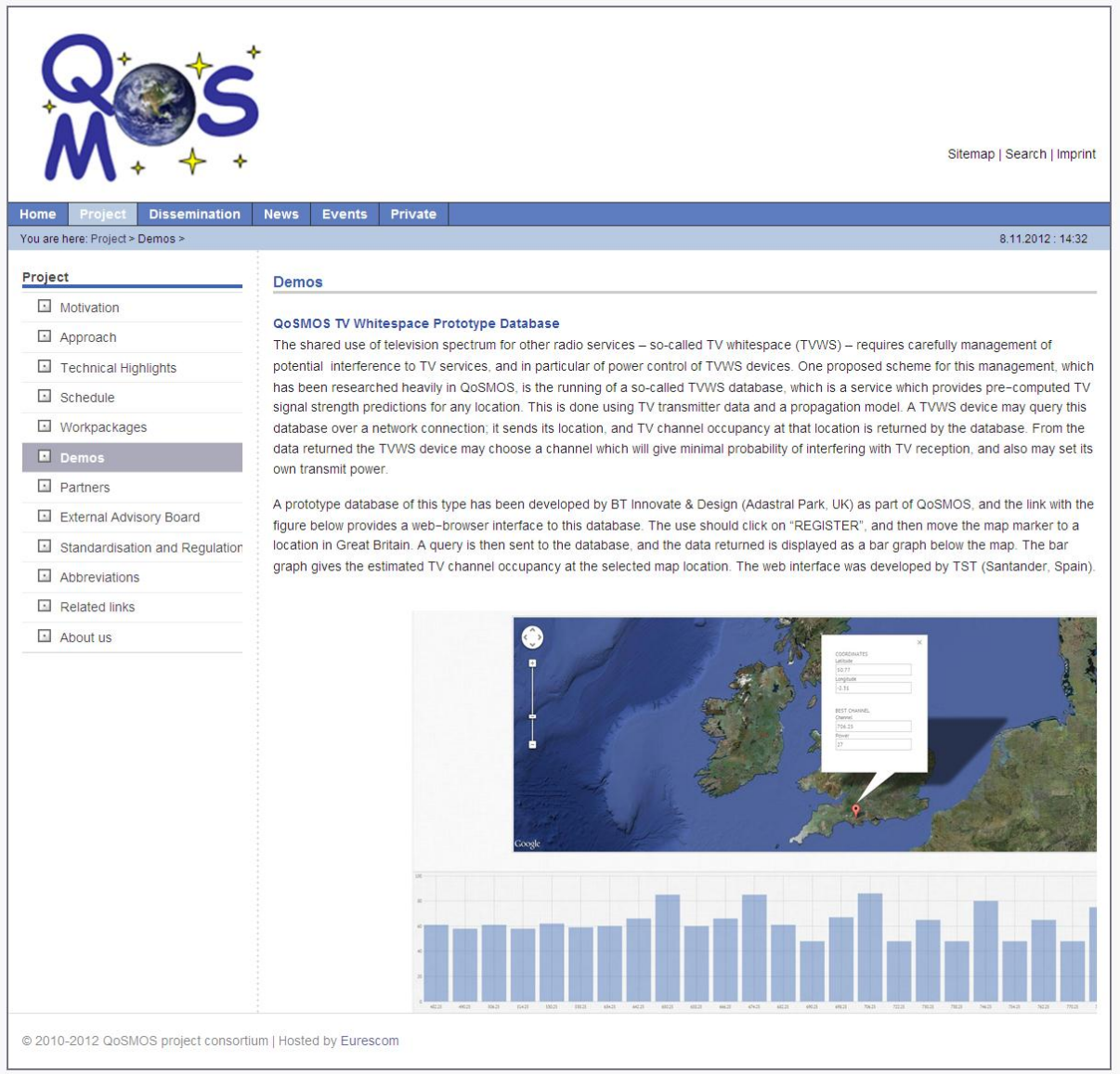


Figure 2-3: QoSMOS TV Whitespace Prototype Database

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 whitespace domain.

In the standardisation and regulation section of the website, status of relevant standardization bodies with QoSMOS engagement is described. Figure 2-4 depicts the entry page of the standardization and regulation section.

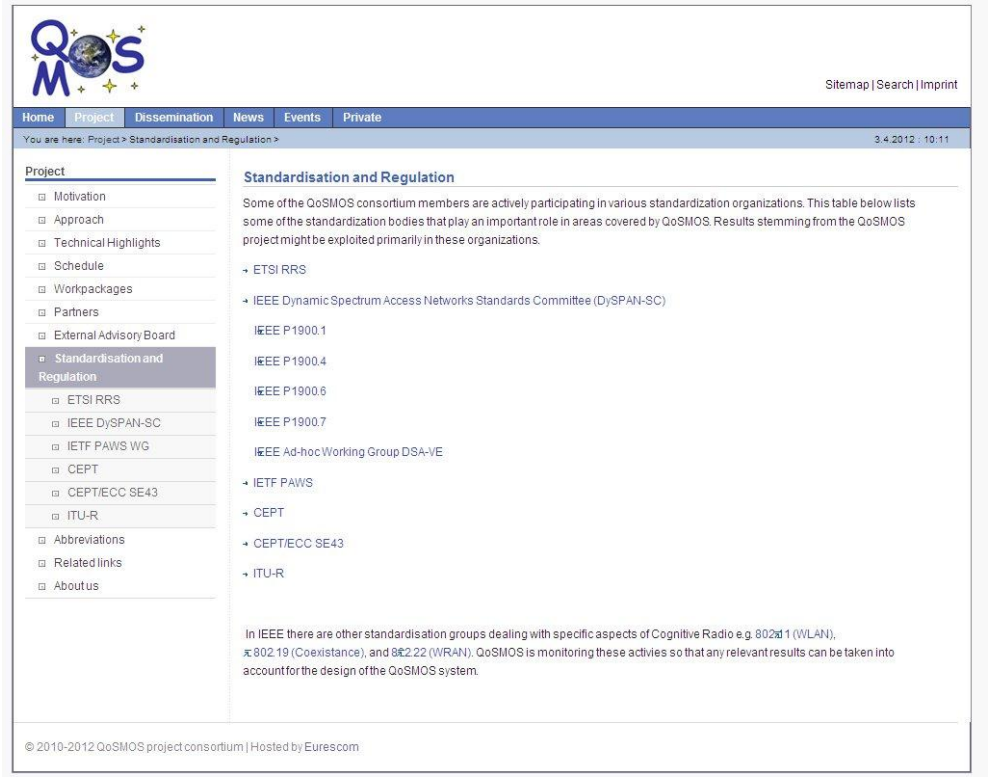


Figure 2-4: QoSMOS Public Website – Standardization and Regulation

All public dissemination material from QoSMOS can be directly retrieved from the website of the project (see Figure 2-5), allowing the external community to follow the project progress and be up-to-date on the latest developments.

Five dedicated white papers are published on the website:

- Quality of Service in Cognitive Radio Systems: System architecture options and detailed functions
- Business Opportunities and Scenarios for Cognitive Radio Systems
- Cognitive Context Acquisition
- Flexible Multicarrier PHY Design for Opportunistic Spectrum Access
- Cognitive Radio Resource Management

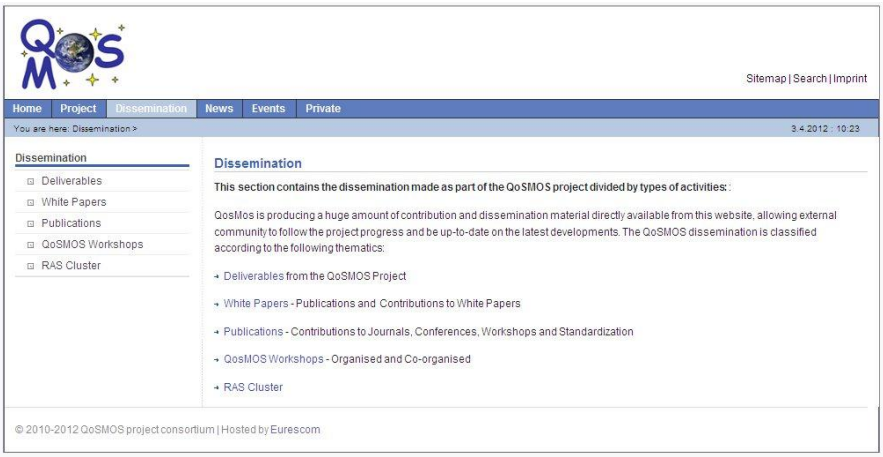
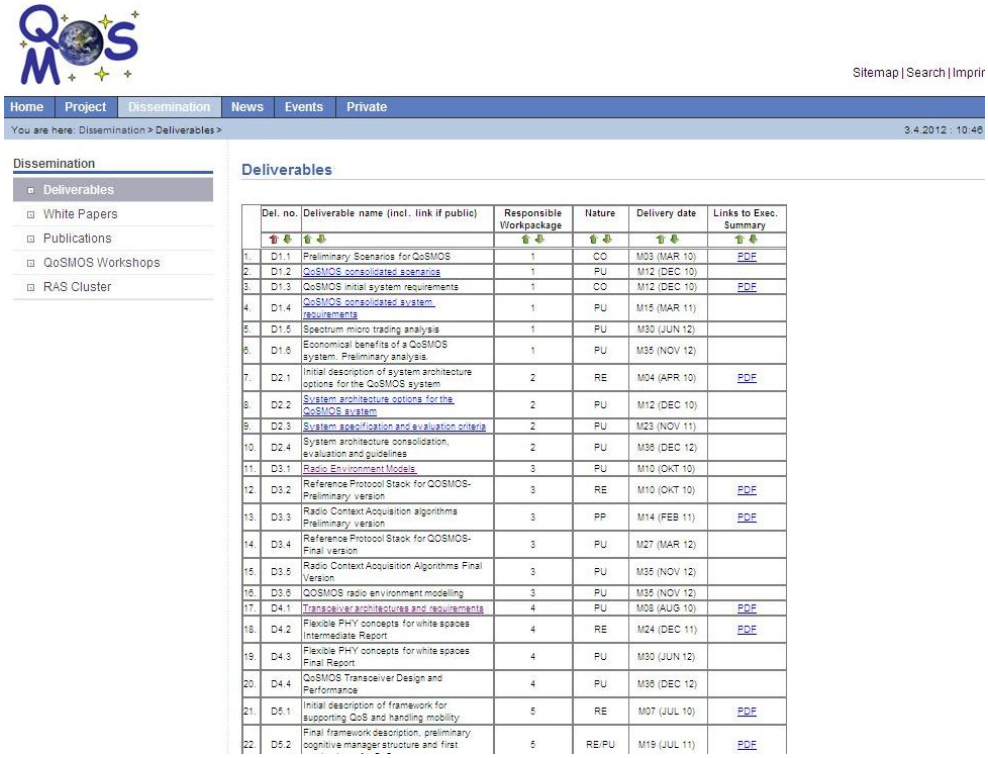


Figure 2-5: QoSMOS Public Website – Dissemination

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 2-6. In this way, external communities are always up-to-date with the progress of the different work-packages.



	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 2-6: 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 finding 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 a direct link to the QoSMOS BSCW server webpage, where access is password protected.

2.4.2 QoSMOS Internal Collaboration Website

The internal collaboration platform is based on a BSCW server. Figure 2-7 depicts an 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.

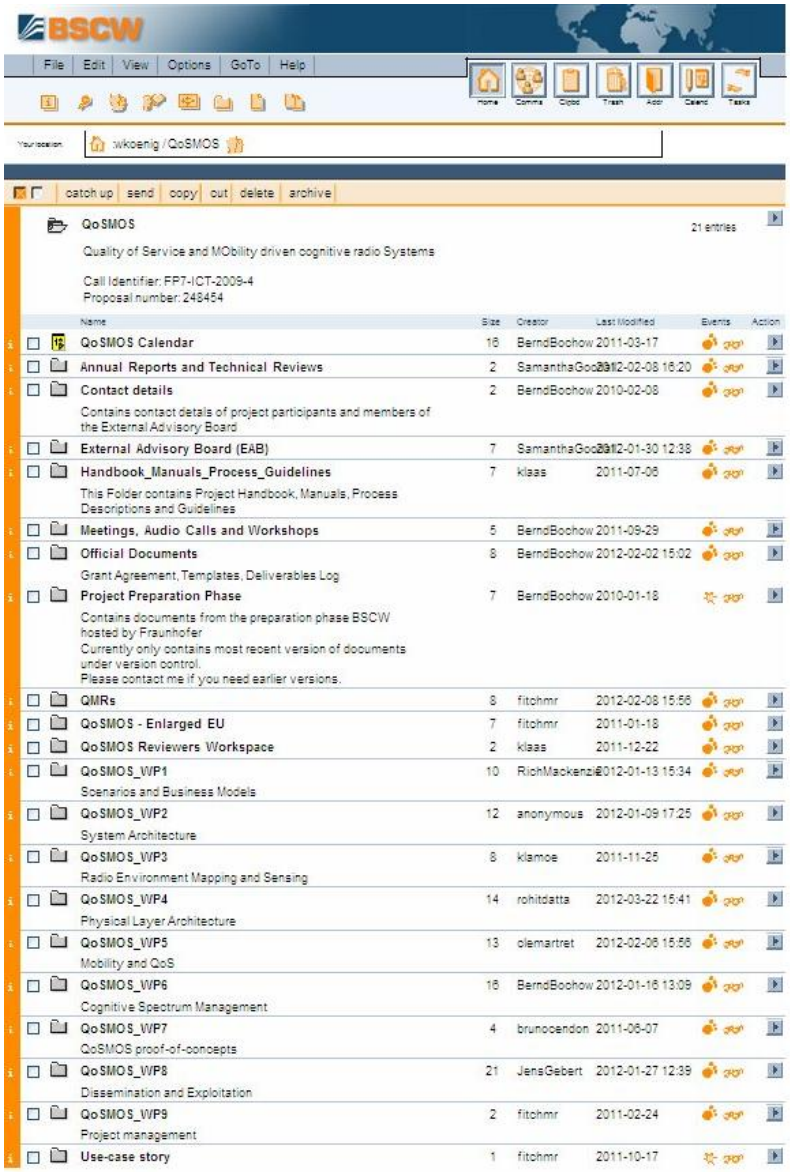


Figure 2-7: QoSMOS Internal Collaboration Website

WP8 folders, as depicted in Figure 2-8: QoSMOS Internal Collaboration Website for WP8, also include a living list and documents of all publications, contributions to standardization as well as reports from standardization meetings attended. This information is accessible by all partners ensuring project internal dissemination of results.

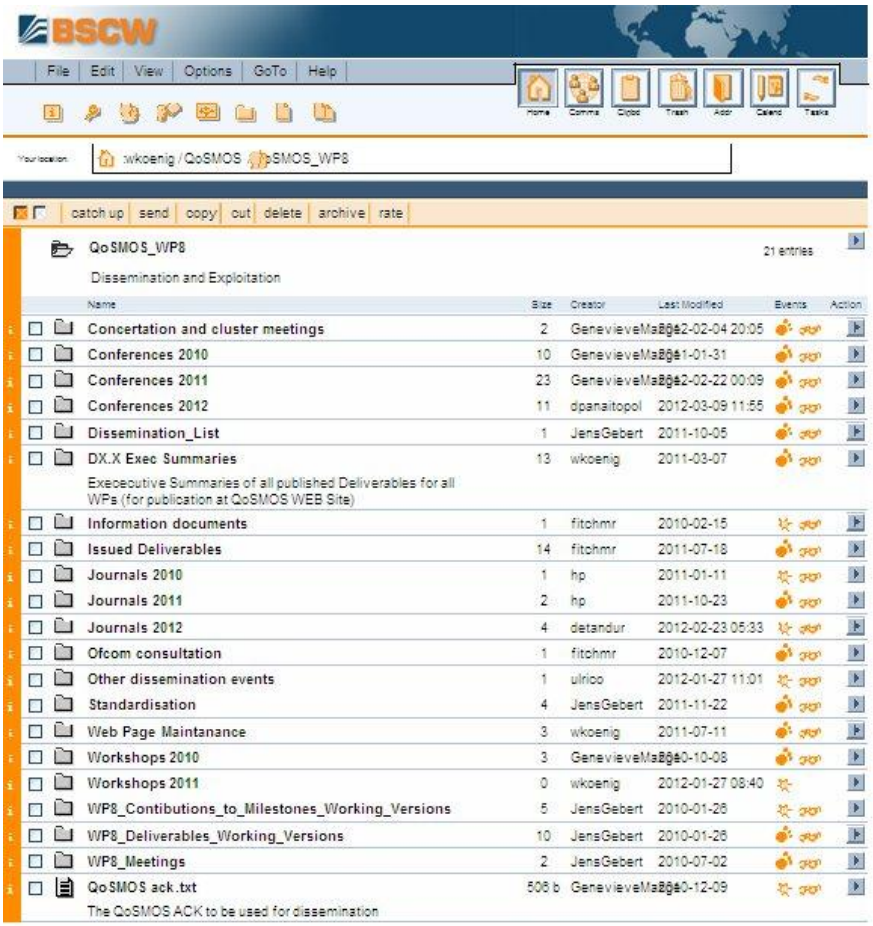


Figure 2-8: QoSMOS Internal Collaboration Website for WP8

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 has prepared a white paper on Spectrum Sharing, which was finished in October 2012. The contributing projects are OneFit, Acropolis, CoGEU and Quasar, with QoSMOS and Where2 being the main editors.

Results from the QoSMOS business case studies were presented at the Central European Radiocommunication Days – Special workshop on Cognitive Radio for TV White Spaces in Bratislava in October 2012. The event was organized by the CoGEU-project [http://www.ict-cogeu.eu/ - http://www.intenziva.sk/?intenziva=3&akcia=60&lang=en].

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 was written on the subject of Spectrum Sharing, with contributions from OneFit, FARAMIR, CoGEU and QUASAR, the editing was 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 Standardization and Regulation Activities

3.1 Global Strategy of the Project

Considering that standardization is a continuous process usually extending beyond the lifecycle of a single project, the QoSMOS project standardization strategy was targeting standardization as a dissemination opportunity creating short-term impact during project lifetime and as an activity creating exploitation opportunities beyond the project lifetime. Three main target activities have been identified for these purposes:

- Observation of standardization activities and technology evolution driving that activity, keeping project participants aware of the relevant market, technology and regulatory developments;
- Preparing submissions to existing standardization activities, disseminating project results and raising awareness for further topics relevant for later standardization to pave the way for upcoming project or past-project partner activities;
- Initiating new standardization activities or liaisons whenever the project or individual project partners have been in a position to forward concrete achievements into standardization.

The three targeted standardization activities "observation", "submitting" and "chairing" each demanded for a different level of involvement, but all of these required active participation to a specific degree. In contrast to "observation" and "submitting", initiating new standardization activities has a rather uncertain impact since preparing a standardization project description, getting approval of this proposal, forming a group, up-taking with the current state of technology and preparing a draft standard document is a process that takes several years until its (market-) relevance becomes obvious.

In consequence, the project chose to address a broad variety of standardization bodies and their relevant working groups by categorizing and planning its activities along an initial expectation for achievable impact along the three target activities outlined above.

3.2 List of Contributions

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 3: QoSMOS Standardisation Contributions Months 1-36

Contributor	Title of contribution	Standardisation group	Location	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, Spain	Published
J. Gebert (Alcatel-Lucent)	RRSWG1(10)0014 Use Cases for Operation in White Space Frequency Bands	ETSI RRS WG1	Sophia Antipolis, France	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, France	Published

Contributor	Title of contribution	Standardisation group	Location	Status
J. Gebert Alcatel-Lucent	RRS(10)0041_QoSMOS_Project_Overview.ppt	ETSI RRS	Athens, Greece	Published
B. Bochow (Fraunhofer), D. Noguet (CEA)	SCC41 P1900.6 Procedures and Protocols - merged proposal for a new WG activity	IEEE P1900.6	P1900.6 phone call	Published
D. Noguet (CEA)	QoSMOS Project	SCC41/P1900.6 meeting	San Diego, USA	Published
D. Noguet (CEA)	Tentative answers to the Notice of Inquiry of the FCC (FCC 10-198)	IEEE P1900.6	P1900.6 phone call	Published
B. Bochow, D. Witaszek (Fraunhofer)	SCC41 P1900.6 candidate protocols: IPFIX	IEEE P1900.6	P1900.6 phone call	Published
P. Delahaye (NTUK)	QoSMOS Project Overview	ETSI RRS#14	Aachen, Germany	Published
D. Noguet (CEA)	IEEE 1900.6 extension suggestion	P1900.6	Delft, netherlands	Published
V. Berg, D. Noguet (CEA)	Regulatory and propagation conditions in the TVWS	P1900.7	Berlin, Germany	Published
R. MacKenzie, M. Fitch (BT)	Potential Use Cases for TVWS	P1900.7	Berlin, Germany	Published
K. Muraoka, H. Sugahara, M. Ariyoshi (NEC)	RRSWG1(11)0173 Combined Interference Monitoring and Geo-location Database Design	ETSI RRS WG1	Ispra, Italy	Published
P. Delahaye (NTUK)	Term definitions for system requirements TS 102 946	ETSI RRS WG1	Ispra, Italy	Published
B. Bochow (Fraunhofer)	DySPAN for Vehicular Ad Hoc - Proposal for a New Study Group	IEEE DySPAN-SC	Brussels, Belgium	Published
B. Bochow (Fraunhofer)	DSA-VE Progress Report	IEEE DySPAN-SC - DSA for Vehicular Ad Hoc	Scottsdale, USA,	Published
B. Bochow (Fraunhofer)	Draft DySPAN-SC individual WG P&Ps	IEEE DySPAN-SC	Scottsdale, USA	Published
B. Bochow (Fraunhofer)	Open Issues on the draft DySPAN-SC individual WG P&Ps	IEEE DySPAN-SC	Scottsdale, USA	Published
B. Bochow (Fraunhofer)	Proposal to enhance A-SAP primitives	IEEE DySPAN-SC - 1900.6	Scottsdale, USA	Published
B. Bochow (Fraunhofer)	Request for information to support 1900.1	IEEE DySPAN-SC - 1900.6	Scottsdale, USA	Published
B. Bochow (Fraunhofer)	1900.1 Progress Report	IEEE DySPAN-SC - 1900.1	Scottsdale, USA	Published
B. Bochow (Fraunhofer)	Draft 1900.6a 5C	IEEE DySPAN-SC - 1900.6	Singapore, Singapore	Published
B. Bochow (Fraunhofer)	Draft 1900.6a PAR	IEEE DySPAN-SC - 1900.6	Singapore, Singapore	Published

Contributor	Title of contribution	Standardisation group	Location	Status
B. Bochow (Fraunhofer)	Proposal to adopt legacy sensing hardware with 1900.6 compliant Sensors	IEEE DySPAN-SC - 1900.6	Berlin, Germany	Published
B. Bochow (Fraunhofer), D. Noguet (CEA), X. Jiantao (BUPT), D. Swain (MITRE), K. 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
B. Bochow (Fraunhofer)	2nd-Request for information to support 1900.1	IEEE DySPAN-SC - 1900.1		Published
B. Bochow (Fraunhofer)	Proposal for a definition of the term 'Reasoner'	IEEE DySPAN-SC - 1900.1		Published
B. Bochow (Fraunhofer)	P1900.1a Workflow and Procedures	IEEE DySPAN-SC - 1900.1		Published
B. Bochow (Fraunhofer)	IEEE DYSPAN SC 1900.1 List of Terms	IEEE DySPAN-SC - 1900.1		Published
B. Bochow (Fraunhofer)	Draft Policies and Procedures for IEEE P1900.1	IEEE DySPAN-SC - 1900.1		Published
B. Bochow (Fraunhofer)	DYSPAN SC P1900.1 Submission List	IEEE DySPAN-SC - 1900.1		Published
P. Grønsund (TEL)	Spectrum Micro-trading as a use case for spectrum sharing in TR 102 970	ETSI RRS WG4	Manchester, UK	Published
B. 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, Japan	Published
D. Noguet, V. Berg (CEA)	Preliminary scenario and requirement analysis	IEEE P1900.7	Osaka, Japan	Published
D. Noguet, V. Berg (CEA)	Low ACLR and flexibility with FBMC	IEEE P1900.7	Osaka, Japan	Published
D. Noguet, V. Berg (CEA)	FBMC spectral efficiency	IEEE P1900.7	Osaka, Japan	Published
D. Noguet, V. Berg (CEA)	FBMC in fragmented spectrum	IEEE P1900.7	Osaka, Japan	Published
J. Wang, H. Vinh-Dien, H. Harada (NICT), R. MacKenzie (BT)	Merged Use Cases	IEEE P1900.7	Osaka, Japan	Published
H.Vinh-Dien, X. Zhang, Z. Ming-Tuo, H. Harada (NICT), R. MacKenzie (BT), P. Kryszkiewicz, A. Kliks, H. Bogucka (PUT), O. Holland (KCL), F. Bader (CTTC)	Consolidated Use Cases	IEEE P1900.7		Published

Contributor	Title of contribution	Standardisation group	Location	Status
K. Muraoka, M. Ariyoshi (NEC), P. Delahaye (NTUK)	Additional Requirements for Terrestrial Broadcasting Service Protection	ETSI RRS WG1	Chengdu, China	Published
K. Muraoka, M. Ariyoshi (NEC), P. Delahaye (NTUK)	RRSWG1(12)100080r4: Requirements for Advanced Geo-location Function	ETSI RRS WG1	St Petersburg, Russia	Published
Kazushi Muraoka, Masayuki Ariyoshi (NEC), Philippe Delahaye (NTUK)	RRSWG1(12)100121: Requirements for Multiple Advanced Geo-location Function	ETSI RRS WG1	Sophia Antipolis, France	Published

3.3 ETSI RRS

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

QoSMOS partners (Alcatel-Lucent, NTUK, BT) initiated the Work Item (WI). "Uses Cases for operation in whitespace 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 whitespace 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 2011. 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 whitespace frequency bands
- Short range wireless access over whitespace frequency bands
- Ad-hoc networking over whitespace frequency bands
- Combined Ad-hoc networking and wireless access over whitespace frequency bands
- Sporadic use of TV whitespace frequency bands
- Backhaul link using TV whitespace frequency bands
- Multimedia Broadcast Multicast Service (MBMS) operating in TV whitespace frequency bands

QoSMOS partners are also interested by the WI proposal on the Feasibility study on Radio Frequency (RF) performances for secondary systems operating in UHF TV band whitespaces. The scope of the

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. A 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 whitespace Frequency Bands" (TS 102 946) is one of the major technical specifications relevant for the 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 whitespaces. The requirements are based on the use cases described in TR 102 907 "Use cases for Operation in whitespace 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 3.10) 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 are foreseen to facilitate the coexistence among TV whitespace CRSs in UHF TV band whitespaces. A QoSMOS partner contributed to TS 102.946 with the clarification of the terminologies to be used in the specification. Due to the rapporteur position of the QoSMOS partner NEC Technologies, there have been several submissions to this TS but only a few technical submissions. QoSMOS is expected to contribute to this TS based on the requirements defined in the technical WPs. QoSMOS partners focused on the definition of additional requirements for a geo-location database in TS 102 946. QoSMOS partners proposed to add requirements so that the advanced geo-location function shall support interference estimation and relevant information exchange to control spectrum sensors. These are fundamental functions to support spectrum management integrated with radiowave monitoring defined in the WP6 technical Work Package. As a result of discussion, this contribution was agreed as optional requirements. Furthermore, in order to improve spectrum efficiency in whitespace, QoSMOS partners defined additional requirements for advanced geo-location functions which will have to accurately know parameters of active WSDs. This knowledge enables the current level of interference from the active WSDs to be calculated, and accordingly enables a maximum power level for a new

WSD to be calculated. In addition, operating transmit power levels of the active WSDs have to be controlled to accommodate the new WSD when the current interference level is approaching a limit.

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 TV WS band and associated Cognitive Management and Control mechanism definition. It will bring new opportunities for QoSMOS partners to contribute based on technical WPs outcomes.

3.4 IEEE 1900.1

The DySPAN-SC working group 1 (WG1) was re-established 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 is Oliver Holland of King's College, London. The WG1 started its work on P1900.1a, that amends 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 as 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. The finalization of the 1900.1a draft standard has been initiated in December 2011 with a working group internal ballot process. The draft then has been submitted to the DySPAN-SC committee for a readiness review and finally has been forwarded to sponsor ballot in May 2012. Sponsor ballot was concluded in September 2012 including comment resolution and a recirculation vote. The ballot group consisted of 108 people. After recirculation 82 affirmative votes have been achieved and 2 negative votes with comments remained.

In consequence, the resulting draft 2.0 was submitted to IEEE RevCom for approval and has been approved on Dec. 5th, 2012. The IEEE Std 1900.1a-2012 will be published early 2013.

3.5 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 on cognitive radios. QoSMOS partners, NEC and NTUK, have been actively participating in the development of standards within the WG, where M Ariyoshi (NEC) has been Chair of 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 whitespaces, whereas P1900.4.1 defines interfaces and protocols for the IEEE 1900.4. The former has 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 whitespace 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 whitespace 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 the 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. This project is getting into the final stage: the sponsor ballot on the draft standard P1900.4.1 D2 has been initiated. It is anticipated that the project would be completed around March 2013.

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 a potential new project opened in 1900.4 WG, which would cover interface and protocols for IEEE 1900.4a (Dynamic Spectrum Access Networks in white space frequency band). Although the new project might start in 2013 at the earliest, some of the architectural concepts, interfaces, and protocols output from QoSMOS are supposed to be applied to this potential standard.

3.6 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 at the 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 the 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. Unfortunately company policies did not allow to progress further on this issue.

The 1900.5 is currently reviewing its PAR (Project Authorization Request) again since it has been recognized that there is no clear separation between ontology and policy language for policy-based systems. Both depend on each other in a way that the group does not expect a solution for its initial objective to design a generic ontology that can support major policy languages within a reasonable time frame. The WG is now reconsidering its approach and will focus on the ontology while reviewing major policy languages for their suitability to rely upon a future 1900.5 ontology. The problems experienced so far in that WG may be caused by the complexity of the task and the pressure for providing solutions with commercial relevance in a very short time frame dictated by upcoming products.

3.7 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 whitespace activities, the corresponding FCC decision of September 2010 and its expected impact on European regulations and market regarding the development of a geo-location 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):

- 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 database.
- 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 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 whitespace and geo-location databases.

The latter topic is addressed by a proposed new activity of 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 has so far contributed several submissions to 1900.6a and will continue its participation until end of 2012.

In QoSMOS deliverable D3.4 we identified protocol stack messages based upon IEEE Std 1900.6-2011 and we extended them by additional fields identified by QoSMOS' requirements, especially in respect to 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 an 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.

The 1900.6 WG has developed a first draft from available contributions and expects to conduct a WG ballot on this draft in early 2013. A number of topics introduced by QoSMOS participants could not be concluded and will require further elaboration on the level of technical details. During the October joint meeting of 1900.6 and 1900.7, it was proposed to continue with 1900.6 next addressing a best-practice standard.

3.8 IEEE P1900.7

In 2010the Standardisation Committee SCC41 opened an Ad hoc committee on whitespace 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, 2011

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 whitespace dynamic spectrum access radio systems supporting fixed and mobile operation in whitespace frequency bands, while avoiding causing harmful interference to incumbent users in these frequency bands. The standard provides means to support P1900.4a for whitespace management and P1900.6 to obtain and exchange sensing related information (spectrum sensing and geo-location 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 whitespaces.

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 7 presentations from QoSMOS:

- "Regulatory and propagation conditions in the TVWS" (based on WP2 inputs), Vincent Berg, Dominique Noguet (CEA), Sept.2009.
- "Potential Use Cases For TVWS" (based on WP1 inputs), Richard MacKenzie, Michael Fitch (BT), Sept. 2009.
- "ACLR issues with OFDM for TVWS operation" (based on WP4 inputs), Vincent Berg, Dominique Noguet (CEA), Dec. 2011.
- "Merged Use Cases" (based on WP1 inputs), Junyi Wang, Hoang Vinh-Dien, Hiroshi Harada (NICT), Richard MacKenzie (BT), Feb 2012, March 2012.

- "Preliminary scenario and requirement analysis", Dominique Noguet, Vincent Berg (CEA), March 2012. "Low ACLR and flexibility with FBMC" Dominique Noguet, Vincent Berg (CEA), March 2012, June 2012.
- "FBMC spectrum efficiency" Dominique Noguet, Vincent Berg (CEA), March 2012, June 2012.
- "Consolidated Use Cases" (based on WP1 inputs), Hoang Vinh-Dien, Xin Zhang, Zhou Ming-Tuo, Hiroshi Harada (NICT), Richard MacKenzie (BT), Pawel Kryszkiewicz, Adrian Kliks, Hanna Bogucka (PUT), Oliver Holland (KCL), Faouzi Bader (CTTC), April 2012, June 2012."FBMC vs OFDM in fragmented spectrum" Dominique Noguet, Vincent Berg (CEA), June 2012.

BT and CEA also contributed to the requirement document of P1900.7, which provides the baseline for the WG developments.

In October 2012, the WG opened a call for technical contributions on PHY and MAC layers.

3.9 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.

3.10 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 "SE 43") 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 CEPT and the project has received feedback on the latest advances and developments in CEPT. QoSMOS will continue monitoring the developments within CEPT and provide information material on topics of interest to the different groups in 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 whitespaces

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 whitespaces in this frequency range. The work in SE 43 led to the release of the ECC report 159 [2], in January 2011. The report discusses the technical and operational requirements for the operation of whitespace 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.

SE.43 defines 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 were 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

- whitespace device characteristics
- technical requirements on protection of incumbents and incumbent services
- requirements for the geo-location database and the certification of such databases
- assessment of potential spectrum for use by whitespace 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 on this was completed and the new reports, which are complementary to ECC Report 159, have been issued for public consultation. The work is covered in two reports, where ECC Report 185 directly complements Report 159, and Report 186 covers topics on geo-location. The reports are expected to be approved by the start of February 2013.

3.11 ITU-R

The QoSMOS project followed the developments and received feedback on the latest advances through the members of the External Advisory Board. The resolution 58 of ITU-R, issued on January 23rd 2012, is highly relevant to the outcomes and the use of the outcomes of QoSMOS. The resolution covers “Studies on the implementation and use of cognitive radio systems” and it considers the need for ITU-R studies to give guidance for the evolution of cognitive radio systems (CRS), re-iterates the validity of the definition of Cognitive Radio Systems (provided in Report ITU-R SM.2152) and that CRSs are expected to provide flexibility and improved efficiency to the overall spectrum use. The considerations and definitions are provided in detail in the resolution text (ITU-R 56, see [3]).

3.12 IEEE 802

The IEEE project 802 and its working groups form a standardization area having a clear focus on MAC and PHY topics, in particular regarding product evolution. In general, the 802 projects only consider enhancement or evolution of existing 802 standards having market relevance and being

driven by product evolution. New topics are introduced to the 802 in general through dedicated task groups such as the 802.11 Wireless Next Generation Standing Committee (WNG SC). In consequence, the QoSMOS project considered specific activities within the IEEE 802.11, 802.15, 802.16, 802.19, and 802.22 mainly for observation regarding distinct technical solutions, on the evolving market for coexistence scenarios and on regulatory developments in the U.S. No active participation or submissions have been considered due to their very limited potential impact.

3.12.1 802.11 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.

In 2011 the position of the TGaf was split between incorporating changes to the draft caused by recent FCC decisions (e.g., removing all references to sensing from the draft) and awaiting further changes to FCC decisions that may require further alignment with regulations, for example, relaxing adjacent channel emission limitations. IEEE 802.11, 802.18 and the WiFi Alliance approached the FCC by preparing a "petition to reconsider" for these issues but failed in the approach. The concerns regarding these issues are seen as crucial and are 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 to 2012 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 in 2010) were not considered nor recorded in the meeting minutes, making clear that potential contributions from non-active participants are not recognized. 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 a 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.

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. Regarding that, the TGaf is now closely monitoring the new FCC communication regarding spectrum sharing and incentive auctioning as well as the situation in U.K. and the contributions to ETSI BRAN.

End of 2012 the TGaf is still in its comment resolution phase. 998 comments have been received for draft 2.0 from its letter ballot in August 2012. Approx. 500 comments have been resolved so far. In consequence, draft 2.1 is currently prepared for entering the next letter ballot.

The delay (if such) in TGaf has a number of reasons among those on-going changes in the regulatory situation and the progress of other 802.11 task groups (e.g. TGae, TGaa, TGad, TGac must be considered for the comment resolution) had the most significant impact on the TGaf time plan. Although the TGaf already matched the 75% approval rate requirements, it can be expected that 90% or above will be targeted before asking for approval to enter sponsor ballot. That might require another several hundreds of technical submission addressing comments from the WG letter ballots.

3.12.2 802.19

The IEEE 802.19 Coexistence Technical Advisory Group (TAG) is targeting coexistence issues with a clear focus on systems standardized within the various working groups of the IEEE 802 project. Objectives of 802.19 are similar to those addressed by the IEEE DySPAN-SC 1900.2 working group, while the latter has a much wider scope. In consequence, the QoSMOS project was observing 802.19 with special consideration of 802.19.1, developing coexistence architectures. No contribution was made to 802.19 since this working group would likely not recognize contributions that do not originate from active 802 participants or that do not address topics from focus areas of other 802 groups. This is due to the fact that active and well-received participation in any of the 802 working groups requires very detailed knowledge and experience with 802.x standards, technical concepts and implementation details. Achieving noticeable impact even would have required hiring consultancy services.

3.12.3 802.22 Wireless Regional Area Networks - WRAN

No contribution to IEEE 802.22 has been made by QoSMOS. The project has used the 802.22 specification as a framework for simulating CM-SM performance (spectrum analyser, SAN, and spectrum selector, SSE, performance). The 802.22 specifications are finalized and the timing of the QoSMOS work has not been aligned with the evolution of the 802.22 standard. Therefore QoSMOS has not prioritized direct contributions to this WG.

4 Equipment Certification

The purpose of this part is to set the scene for cognitive radio equipment certification. First, we provide an overview on the certification bodies applicable to mobile devices. Second, we propose a testing plan for cognitive radio conformance testing including RF and protocol aspects. Finally, we further develop the sensing part, which is one of the main differences between cognitive radio and classical RF devices.

4.1 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 the 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 and/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 regionally to global focus. 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 the two main certification schemes:

4.1.1.1 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's 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 its 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.

4.1.1.2 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.

4.2 Conformance Testing for Cognitive Radio Devices

Conformance testing or **type testing** is testing to determine whether a product or system meets some specified standard that has been developed for efficiency or interoperability. The QoSMOS project has however, on purpose, not been tied to a given standard but was rather meant to deliver advances applicable to potentially any standard. Defining a complete conformance test scheme is therefore meaningless and anyway out-of-scope for the little quantity of man-months allocated to the task. Instead, we hereby briefly describe a (non-exhaustive) series of test cases that would typically be required for standards involving cognitive radio aspects. We use a classical 'divide and conquer approach', meaning testing one part assuming all others function correctly.

4.2.1 **RF Testing**

- **Transmitter:**
  - Power control & antenna gain: The Device Under Test's (DUT) transmit power should not exceed a given threshold (which is defined based on multiple criteria).
  - Spectral mask: The transmitter's emissions should be kept within a mask defined in the Power Spectral Density (PSD) domain.
- **Receiver:**
  - Sensitivity: How "low" the receiver can operate?
  - Maximum input level: Inverse of above.
  - BLER test: Block error rate
    - Without interference.
    - With in-band interference.
    - With out-of-band interference.
    - With co-channel interference.

  = Ability to receive
  - Performance test: Typically BLER tests under various channel and noise profiles.
- **Sensing (single or multi-node):**
  Thanks to a signal generator (or a 'scene emulator') and a channel emulator.
  - Accuracy: How accurately the RF sensing is performed? Time / Frequency axis; Probabilities of false alarm / misdetection.
  - Latency: How much time it takes for detection?

4.2.2 **Protocol Testing Under Normal Conditions**

Key assumption: the RF has passed the above conformance tests:

- **Changes in the primary scene (sensing and database cases):**

- Some (one or more) primary channels are turned OFF: What is the impact on the (secondary) transmission?
- Some primary channels are turned ON: What is the impact on the transmission?

- **Changes in the secondary scene:**
  - Some (one or more) secondary users turn OFF: What is the impact on the transmission?
  - Some (one or more) secondary users turn ON: What is the impact on the transmission?
  - Changes in the quality of some secondary channels: What is the impact on the transmission?
- **Lack of capacity:**
  - The number of available primary channels is forced so that the available capacity is below the secondary needs: How does the DUT react?
  - The secondary scene is crowded and capacity is missing: How does the DUT react?

4.2.3 Protocol Testing Under Abnormal Conditions

- **Missing info about primary activity:**
  - Broken connection to the database: What is the secondary's behaviour?
  - Broken sensing engine: What is the secondary's behaviour?
  - In cooperative sensing, one node does not function anymore: What is the secondary's behaviour?
- **Malicious secondary user:**
  - A secondary user is using (or spamming) all available channels: What is the secondary's behaviour?

4.2.4 SDR Challenges

The usage of Software Defined Radio (SDR) technology can potentially lead to inappropriate spectrum usages. The product should be such that it minimizes the risks for the customer to emit in inappropriate bands. All SDR software updates offered by the manufacturer should be certified.

4.2.5 Real-World aspects

At last, we emphasize that the tests should be as close as possible to reality. As an example, the test stimulus sent to a 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 Measure, Modelling and Emulation (MME) approach developed in WP3 framework.

4.3 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, the equipment should 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, it

should be able to sense the bandwidth of the spectrum gap within a set accuracy. The equipment should be able to perform this sensing accurately in the presence of adjacent channel signals operating at a specified level.

The second issue to be addressed is the validation tests to identify if the equipment meets these specifications. This is detailed in 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 should support a range of tests conducted to provide validation of the equipment compliance. This may require that the equipment has suitable test 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.

5 References

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

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

[3] ITU-R 58 http://www.itu.int/pub/R-RES-R.58-2012