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Final plan for using and disseminating knowledge

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Abstract

This deliverable presents the plans for using and disseminating the knowledge obtained during the QUASAR project in future activities. To set the scene for the plans a brief overview of the QUASAR results and conclusions are given.

Keywords List

Exploitation, dissemination

[1] Dissemination level codes: **PU** = Public
PP = Restricted to other programme participants (including the Commission Services)
RE = Restricted to a group specified by the consortium (including the Commission Services)
CO = Confidential, only for members of the consortium (including the Commission Services)

Executive Summary

The purpose of this document is to describe the plan for use and dissemination of the knowledge generated during the QUASAR project, aiming to assess the realizable benefits of secondary spectrum access. To set the scene for the future plans of QUASAR partners, a brief overview of the conclusions and obtained knowledge is presented. The main finding is that the most promising business route to follow is to aim at short range indoor communication scenarios. The overall capacity provided by TV white spaces – despite the considerable amount of bandwidth – is often low. However, findings also indicate that use of TV white spaces to provide last hop rural broadband connectivity may be viable for traditional fixed-line operators.

The QUASAR project has during the project successfully disseminated and exploited results through scientific publications, hosting workshops, organizing the CROWNCOM 2012 conference, and through input to the regulatory arena via contributions to ECC CEPT SE43.

The plans for future dissemination of use follow this successful path but also extend into other directions such as contributions to Ofcom, and as indicated by the interest from business partners to extend the investigations of various commercially viable ways to realize the benefits of spectrum sharing and secondary spectrum access to underutilized spectrum.

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1 Introduction

Dynamic spectrum sharing techniques ("Cognitive Radio") where secondary users opportunistically utilize temporarily or locally unused spectrum has been named one of the prime candidate technologies to relieve the spectrum shortage for primarily mobile internet access, but also other applications, e.g. rural broadband access. The many spectrum measurements that have been made in the last decade indicate rather low spectrum occupancy. Can this low occupancy be turned into opportunities for secondary users without harming the primary system performance? Some of the experiments and trials made seem to indicate that this is the case. However, the business success of this technology that will take it beyond niche applications depends on the scalability of secondary access. Can large numbers, thousands or even millions of users be supported? Making a realistic assessment of this scalability has been the objective of the EU FP7 QUASAR project. The project has aimed at quantitatively assessing the amount of spectrum available for secondary services for a number of commercially interesting usage scenarios.

Already during the project, knowledge has been disseminated to regulatory bodies, through extensive scientific publication, invited publications and by arranging workshops for various stakeholders. In this report, the key results and knowledge obtained during the QUASAR project are recapped and plan for exploitation and dissemination beyond the project is presented.

The rationale for devising this kind of plan is that the way forward beyond the QUASAR project becomes more defined and the reader may be provided a good overview of the research areas that are still open. The reader will also gain insight into the perspectives of the various stakeholders on the outcome and general conclusions drawn in the QUASAR project. The plan includes also the overall future key dissemination events at which QUASAR partners will disseminate the results and knowledge gained during the project.

The structure of the deliverable is as follows: next section introduces the main findings of the project to set the scene for the plans for using this knowledge. It also list the references in the form of published papers and deliverables to allow the interested reader to find relevant information and detailed motivations of the overall conclusions. The section also includes the overall plan for continued dissemination of the QUASAR findings. The final section details the individual QUASAR partner plans for use and spreading of the generated knowledge.

2 Knowledge generated and planned dissemination

In this section we give an overview of the results and insights generated during the QUASAR project as well as an overall plan for disseminating the knowledge.

2.1 Overall conclusions and recommendations from QUASAR

The main outcomes of the QUASAR project are: The commercial sweet-spot for secondary spectrum access is found to be short range or indoor communication scenarios. Aggregated interference from multiple secondary transmitters is the key bottleneck limiting the potential for secondary spectrum access and hence controlling it is of extreme importance. QUASAR has highlighted suggested solutions to problems related to aggregate interference in current and proposed regulatory frameworks. The use of a geo-location database is found more effective than spectrum sensing approaches. Cooperation between primary and secondary systems and among secondary systems is possible and may provide benefits but introduces overhead. The overall capacity provided by TV white spaces – despite the considerable amount of bandwidth – is often low. However, findings also indicate that use of TV white spaces to provide last hop rural broadband connectivity may be viable for traditional fixed-line operators. The radar and aeronautical bands show potential for secondary usage but there are large regulatory issues to resolve before this potential could be realized.

Below the overall conclusions related to the various work packages are presented to set the scene for the plan for future use and dissemination of the knowledge.

2.1.1 WP1 – Scenarios, Business and Regulatory impact

This work package was tasked to first set the scene for the rest of QUASAR by providing an initial analysis of scenarios and sharing and schemes for secondary sharing, as well as their regulatory and business feasibility, which would be researched in other work packages for technical feasibility. Subsequently, based on the inputs received from other work package perform a more in-depth feasibility analysis, as well as providing recommendations on regulations and policy in order to remove the remaining roadblocks to secondary sharing.

Regulatory feasibility assessment performed has shown that secondary sharing of TV white spaces using a master-slave approach combined with a geolocation database is both feasible (and desirable in order to provided guaranteed protection to primary systems in these bands), while sensing were found to remain problematic. This conclusion was also shared through interactions with the wider regulator community and industry, including a one day semi-open regulatory workshop at BT’s Headquarter in November 2010, and the master-slave approach was proposed to and (taken up by) the CEPT SE43 working group as a first QUASAR contribution to the work of this group. Reviewing regulatory progress in secondary access in Europe, the United States, UK and elsewhere around the world in a contribution which was also presented to the CEPT SE43 group (as an input contribution) the QUASAR team came to the conclusion that almost all regulators has focused on protecting primary users (TV transmitters and wireless microphones) against a single cognitive operating in white spaces. On the other hand, real life deployment of technology, e.g. for Wi-Fi-like or cellular use, will always involve large collection of cognitive radios, e.g. Wi-Fi access points, LTE base stations of small cells, using white spaces, thereby generating aggregate emissions which may violate protection limits, although interference from a single device may cause no harm. This problem could cause a potential obstacle to large scale exploitation of TVWS for the provision of Wi-Fi and cellular services by operators.

In collaboration with WP2 and WP4 this issue was further investigated and it was found that in dense urban deployment this is indeed problematic. Subsequently, QUASAR submitted in two subsequent contributions to the CEPT SE43 working group on how the aggregate interference problem could be addressed in a practical manner. These contributions are currently under the review by the group and a subsequent complimentary contribution is to be submitted in July. In addition, QUASAR's study of the scheme proposed by CEPT SE43 for allocation of location-dependent transmit power of white space devices discovered a mathematical flaw in the derivation which in some scenarios could result in the violation of TV transmitters protection limits. This was communicated in another QUASAR contribution to the group, and has resulted in an amendment in the final report by the group, which is likely due in September 2012. Finally, work in WP1 has also shown that the precise protection rules implemented in geolocation has a great impact on the amount of white space availability, in particular applying the FCC rules and the current CEPT SE43/Ofcom proposal can result in differences as large as 40% in white space availability in some cases. This has also been raised with Ofcom and the QUASAR team is invited to present the findings to Ofcom.

In addition to TVWS, regulatory feasibility of opening radar bands and aeronautic bands for distance measurement equipment (DME) to secondary sharing with cognitive radios was investigated. In the case of radar bands, main obstacles to sharing which have been identified are large variations in radar's protection requirements, unavailability of detailed information on location and characteristics of most radars, and, most importantly great concerns expressed by the primary users of these bands regarding safety-of-life and security implications of secondary access to this bands, in particular is this is regulated on a licence-exempt basis similar to the way access to TVWS is being approached by the FCC and Ofcom. Main conclusion here is that there are important opportunities for secondary sharing of radar spectrum, and some of the main obstacles to sharing of this band could be overcome by developing sharing methods that exploit a geolocation database approach, possibly complimented by sensing. As demonstrated in the case of TV bands, the database approach has the ability to offer guaranteed protection against interference from secondary users, which is not possible by use of sensing. Furthermore, alternative secondary licensing of radar bands could be implemented via a geolocation database. This would enable regulators, or primary users, better control secondary access to these bands via authorization mechanisms or the use of "no-go/exclusion zones" such that safety-of-life and security are not compromised. Just as in the case of TV white space use, we have found that current regulatory framework for the secondary use of 5.9GHz radar bands probably need to be amended in order to incorporate the impact of aggregate interference.

The second strand of the work in WP1 has focused on developing methodologies and approaches to investigate business feasibility of secondary spectrum access, both in terms of service provision and potentially new opportunities such as secondary spectrum trading. It was found that the question of business feasibility is very much dependent on the utility gained by actors/players involved in creating a business as well as the service required. Different combinations of actors and services will results in a multitude of scenarios, each of which is characterized with a different balance of CAPEX and OPEX costs versus revenue. Considering three types of players, a mobile operator, a fixed line operator and a new entrant, various service provisioning scenarios were analysed based on technical input on spectrum availability and achievable capacity as obtained from WP5, and cost structure (sites, backhaul, equipment's, running costs etc). QUASAR's techno-economic analysis shows that in the case of existing mobile operators in Europe the balance between site, equipment and backhaul cost versus spectrum costs is such that the use of TVWS to offer macro-cellular services is unattractive and that an additional repurposing of the TV bands (a second digital dividend) for mobile broadband services would be more beneficial for cellular operators. The balance, however, changes when considering indoor-type usage making this type of services attractive to operators (including LTE femtocells and data offloading). Taking BT as a proto-typical example of a fixed line operator, the analysis have shown that such operators can significantly gain from the availability of "free" white space spectrum in the UHF bands. In particular, in the case of UK the spectrum could be used to offer affordable broadband wireless access to isolated rural communities which could not serve cost-effectively using ADSL or Fibre. Since in the UK, there are currently around 2.6 million users without access to broadband (i.e., minimum peak data-rates of 2Mbps), the proposed business model is highly attractive, and is currently is being seriously evaluated by BT. However, such a solution relies on new forms of licensing, e.g., soft-licensing that would render the service a prioritized use of the TVWS opportunities. Such licensing would give the rural broadband provider some certainty of the return of investment in equipment. In the case of new entrants, due to the need by this actors to acquire new sites, equipment and backhaul, even if spectrum is available for free, building microcellular business using TVWS were found to be an economical “non-starter”. On the other hand, from a cost analysis perspective new entrants and fixed-line operators could benefit from TVWS availability in order to build or extend indoor and possibly outdoor Wi-Fi-type services.

2.1.2 WP2 – Performance of opportunity discovery schemes

One of the main outcomes of QUASAR was to develop a mathematical definition for spectrum opportunity. The proposed definition distinguished between the concepts of spectrum availability and spectrum opportunity. The spectrum availability is related to the primary system protection limits while, the spectrum opportunity incorporates also the discovery scheme for deciding whether the spectrum is available or not. Besides providing the definitions, WP2 also outlined a general process for estimating the spectrum opportunity through numerical computation. The proposed computational process has multiple stages and specifies which aspects of the primary and the secondary system has to be modelled in each stage. The proposed definition and computational process are broad enough to capture not only the spectrum sharing scenarios within the context of QUASAR but also they can embrace emerging spectrum sharing use cases by future communication technologies.

The practical implementation of spectrum allocation can be based on a centralized database, so-called geo-location database, or on spectrum sensing made by secondary users. It is worth mentioning that the assessment framework proposed in WP2 has considered the recently published ECC report 159 on secondary operation over the TV white spaces under geo-location approach. Also, WP2 set the stage for extending the recent approach for spectrum allocation under geo-location from a single secondary user to multiple secondary systems.

Our analysis suggested that the current FCC and ECC approaches do not always guarantee the protection of primary users against aggregate interference from large number of secondary transmitters. Our results also suggest that the current ECC regulation framework is overly conservative when it comes to adjacent channel protection. To remedy the situation, we proposed generic power allocation algorithms for multiple secondary devices that guarantee the protection of primary system against co-channel and adjacent channel interference. Also, we considered multiple cooperating secondary devices looking for transmission opportunities by using spectrum sensing. Our results confirm that in the presence of fading the identification performance for a single white space device (WSD) deteriorates. The detection performance can be enhanced by allowing many WSDs to collect cooperative spectrum measurements. Two problems still remain. The first one is the additional overhead required for the WSDs to share the measurement information and the second one is the problem related to controlling the aggregate interference caused by multiple WSDs simultaneously accessing the spectrum. The first problem can be mitigated by developing efficient protocols for reporting the sensing information but the second one still remains an open problem.

Besides the geo-location and the sensing-based opportunity detection methods in WP2 we studied collaborative spectrum sharing methods by using overlay transmission where secondary acts as a relay and information theoretical approaches to primary and secondary collaboration. We found that the secondary transmission opportunity can be enhanced by relaying the primary system’s signal. The proposed framework was tested in the so-called TV black space where additional margin inside the TV coverage area is generated by boosting the TV signal. The information theoretical work on the cooperation of primary and secondary systems identified the conditions where various cooperation strategies between primary and secondary systems work well.

Practical feasibility and application of different spectrum availability and spectrum opportunity discovery schemes necessitates implementation on market available equipment and subsequent extensive laboratory tests. The practical implementation provides hands-on insight into the performances and the implementation complexities of various spectrum discovery schemes allowing their reliable evaluation and comparison. In WP2, the performance of various sensing methods was verified ranging from simple energy detection to complex cooperative detection schemes. Obtained results prove the feasibility and viability of practical spectrum sensing solutions that may foster the future development towards more reliable secondary spectrum usage. Geo-location database and collaborative sensing can be used together to get more reliable and accurate propagation estimates for the primary system. Polarization discrimination can provide benefits in an indoor environment, but the used antennas must be carefully chosen.

2.1.3 **WP3 – Primary system performance under secondary interference**

One of the two main outcomes of the work in WP3 has been the evaluation and modelling of the interference tolerance of primary receivers when a secondary transmitter is active. The second main outcome has been the evaluation of enabling technologies, as well as impact, constraints, and benefits, of primary/secondary cooperative strategies for realizing prioritized spectrum sharing.

The interference tolerance of primary receivers in digital TV broadcast systems and radar systems in particular were investigated and modelled. An extensive measurement campaign was conducted on the impact of secondary co-channel and adjacent-channel interference in a DVB-T system. It was concluded that the total interference must be below a threshold. A method was developed for estimating the aggregate interference that a primary DVB system can tolerate given a secondary system operating outside a primary protection zone. Analytical results were also obtained on the interference limits for radar applications in terms of interference-to-noise ratio, leading to limits of spatial separation and transmit power for co-existence. As a particular example of secondary usage in radar bands, we considered an LTE femto-cell deployment, and determined sufficient separation distances to allow for co-existence within different radar bands.

With the introduction of cooperation it is possible for primary and secondary systems to jointly coordinate transmissions such that primary performance demands are met, while the secondary system gains best-effort spectrum access. The modes of cooperation investigated were in terms of information sharing, i.e., sharing channel state information (CSI) and/or actual messages to be transmitted, or in terms of active assistance, i.e., secondary relaying, dirty-paper coding, or supportive jamming. Based on the considered modes of cooperation, the additional primary systems costs were found to be in terms of: 1) signalling and transmission overhead to share CSI and/or information messages; and 2) receiver complexity to accommodate overlay strategies involving cooperative coding and transmission schemes. The secondary systems costs involve the same issues, and as well: 3) transceiver complexity (advanced beam-forming, rejection filtering, and cooperative coding); and 4) transmit power for assisting the primary system through relaying and supportive jamming.

The expected primary gain of cooperation depends on the cooperation strategy. Within the white space and underlay paradigms, there is little-to-no primary gain on offer. In all investigated cases, secondary access was achieved with the cooperation of the primary (in terms of sharing channel state information) but with no direct performance gain. Therefore, in these cases some other incentives must be offered to the primary system encouraging cooperation or regulatory decisions must be made. In case of cooperative overlay strategies the secondary system can assist the primary system, leading to potential primary performance improvements. In a best-case scenario the primary system performance is improved in terms of rate, reliability and/or secrecy, while the secondary system benefits by gaining opportunities for spectrum access. The challenges are to realize cost-efficient signalling and message sharing strategies, and to design power- and complexity-efficient primary and secondary transceivers.

It is debatable whether the use of cooperative strategies will be introduced in the first generation of commercial cognitive radio systems. However, increasing levels of cooperation is a likely solution-path for future generations of such systems. As prospective cooperation-enabling technologies, we have identified multiple antenna systems, cooperative dirty-paper coding, and secondary relaying of primary messages, and obtained fundamental insight into the achievable gains given a particular cooperative strategy and enabling technology. Our overall conclusions are that cooperation can significantly enhance overall spectrum efficiency by improving the interference tolerance of both primary and secondary transceivers. With simple cooperative schemes, such as beam-forming and space-time coding, secondary transmission opportunities are created without affecting the service requirements of the primary users. With more advanced and active cooperative strategies both primary and secondary throughputs can be improved.

2.1.4 WP4 – Secondary sharing schemes

The main outcomes of WP4 work have been to develop and evaluate several secondary sharing schemes applicable in various cases as well as models for aggregated interference. A general conclusion is that secondary opportunity sharing will be possible and the key is to control the aggregated interference. The aggregated interference will be a bottleneck when using secondary spectrum opportunities for communication. Therefore a proper modelling of the aggregated interference is very important and WP4 has developed good models suitable for different situations. Further, using a geo-location database for opportunity discovery seems to be the most suitable way to control the aggregated interference.

2.1.5 WP5 – Spectrum availability assessment

The main outcomes form the activities in WP5 and the knowledge generated can be summarized as follows. First a secondary spectrum assessment methodology was developed by combining all the necessary components such as modelling of primary and secondary users, modelling of the radio environment and the aggregate interference, secondary user scenarios, and finally regulatory rulings for primary user protection.

Second, using the assessment methodology, thorough quantitative analysis for finding out general secondary spectrum availability and exploitable opportunities were carried out for four use case and a number of countries and different locations in Europe. As a result of these detailed studies several essential findings emerged: i) It is observed that the aggregate interference considerably reduces the availability of secondary access opportunities for macro-cellular deployments. Contiguous cellular coverage in TVWS is difficult to achieve and the use of TV white spaces as a capacity booster in limited local areas looks more plausible. It was found that mostly microcells in urban areas with low coverage requirements would benefit from TVWS. Additionally it is worth noting that the existing protection rules are not appropriate for cellular SU deployment. Compared to ECC and FCC usage rules, the power density based secondary power allocation can provide more capacity and protect the primary users more efficiently ii) The investigations of operating Wi-Fi-like secondary networks in TVWS in Germany showed that outdoor operation of such systems was not viable. It was also found that indoor operation might be viable, but only for low-rate applications iii) A large part of the 2.7-2.9 GHz radar band, used by air traffic control (ATC) radars, is found to be available for dense deployments of low-power secondary users. This in particular applies to secondary users in urban areas, which are typically far from the primary radars. The study of the possibilities of secondary spectrum access to the aeronautical spectrum band (960-1215 MHz), used by distance measurement equipment (DME), have shown that under conservative assumptions a bandwidth of at least 50MHz would be available to a dense deployment of secondary users in any location of Germany or Sweden. In summary, the radar and aeronautical bands provides promising opportunities for low-power secondary systems. However there are still large regulatory issues to be sorted out before the opportunities may be realized in practice.

The third outcome of the WP5 work is a software tool that allows assessing the feasibility and utility of secondary spectrum access beyond simple whitespace availability evaluation. The tool is aligned with the assessment methodology developed and provides a unified framework to conduct studies on the performance of secondary systems with dynamic spectrum access and is composed of an extensive primary spectrum usage database, a graphical interface for user interaction, and an interface to a backend for numerical calculations**.**

2.1.6 **WP6 – Dissemination**

Already during the project, knowledge has been disseminated in several ways:

- Regulation: Active participation of QUASAR partners in regulatory and standardization bodies. In particular the focus has been on the CEPT ECC/SE43 working group on secondary spectrum access, where the project and its partner have participated and provided several technical input documents that have been included in SE43 recommendations.
- Publications: The project has so far produced around 80 scientific publications in high quality journals and conferences (detailed in section 2.2).
- Invited presentations: Project management and partners have received invitation and held invited/keynote talks on the progress and results of the project at EC workshops and international conferences.
- Workshops: The project has arranged several workshops, one public final workshop in June 2012 and two semi-open workshop (by invitation) for regulators and industry (in 2010).
- CROWNCOM 2012/Final Workshop: The project coordinator took on arranging CROWNCOM 2012 in Stockholm one of the premier events for presentation and discussion of cognitive radio and secondary spectrum access issues. The conference attracted more than 130 participants, mainly from Europe and the US. The QUASAR final public workshop was co-located with CROWNCOM, which gave a good attendance of about 80. At the final workshop, QUASAR results were discussed and in a panel discussion where industry and regulators discussed the implications of the project.

2.2 Scientific publications

The knowledge that has been obtained during the course of the QUASAR project has been disseminated through publications and associated presentations at a lot of conferences but also in several recognized journals. A complete list of the QUASAR publications is given in below. This list is intended to serve as a reference for the reader to find relevant detailed information on the topics of interest as well as emphasizing the high scientific quality of the QUASAR results by showing the large number of published peer-reviewed publications produced.

Worth to note in the list of publications is that two QUASAR papers have received awards for their scientific quality, and one has been nominated for BT Innovation Award 2011 in the category of *Best Paper of Innovation*.

To give an overview of the number of publications and the respective status a summary is given in Table 2-1 below.

Table 2-1: Number of publications and their respective status at the time of writing.

Paper type	Submitted	Accepted	Published	Total
Conference	14	3	64	**81**
Journal	7	4	11	**22**

2.2.1 Published conference papers

1. K. Koufos, K. Ruttik, and R. Jäntti, “Feasibility of Voice Service in Cognitive Networks over the TV Spectrum,” CROWNCOM 2010, Cannes, France, June 2010.
2. E. Obregon, L. Shi, J. Ferrer, and J. Zander, “Experimental Assessment of Indoor TV White Space Opportunities prediction model,” CROWNCOM 2010, Cannes, France, June 2010.
3. L. Gavrilovska and V. Atanasovski, “Cooperative Spectrum Sensing in Ad-Hoc Networks,” ADHOCNETS 2010, Victoria, BC, Canada, August 2010.
4. E. Stathakis, N. Schrammar, L. K. Rasmussen, and M. Skoglund, “On Performance Trade-Offs in Cognitive Networks,” IEEE ICWIT 2010, Honolulu, USA, Aug 28 - Sept 3, 2010.
5. J. Kronander, J. Zander, M. Nekovee, S.-L. Kim, K. W. Sung, and Andreas Achtzehn, “QUASAR scenarios for white space assessments and exploitation,” invited paper, URSI EMC Europe 2010, Wroclaw, Poland, September 2010.
6. V. Pavlovska, D. Denkovski, V. Atanasovski, and L. Gavrilovska, “RAC2E: Novel Rendezvous Protocol for Asynchronous Cognitive Radios in Cooperative Environments,” IEEE PIMRC2010, Istanbul, Turkey, September 2010.
7. V. Atanasovski, and L. Gavrilovska, “Resource Management in 2-Tier Opportunistic Spectrum Access Scenario,” WPMC 2010, Recife, Brazil, October 2010.
8. O. Ognenoski, B. Jankuloska, V. Atanasovski, and L. Gavrilovska, “Performance of Resource Sharing and Borrowing in Opportunistic Access Systems,” CogART 2010, Rome, Italy, November 2010.
9. M. Tercero, K. W. Sung, and J. Zander, “Impact of Aggregate Interference on Meteorological Radar from Secondary Users,” IEEE WCNC 2011, Cancun, Mexico, March 2011.
10. J. Kerttula, and R. Jäntti, “DVB-T receiver Performance Measurements Under Secondary System Interference,” COCORA 2011, Budapest, April 2011.
11. R. Jäntti, J. Kerttula, K. Koufos, and K. Ruttik, “Aggregate interference with FCC and ECC white space usage rules: case study in Finland,” IEEE DySPAN 2011, Poster session, Aachen, Germany, May 2011.
12. K. W. Sung, E. Obregon, and J. Zander, “On the Requirements of Secondary Access to 960-1215 MHz Aeronautical Spectrum,” IEEE DySPAN 2011, Aachen, Germany, May 2011.
13. E. Obregon, L. Shi, J. Ferrer and J. Zander, “A model for aggregate adjacent channel interference in TV white space,” IEEE VTC Spring 2011, Budapest, May 2011.
14. K. W. Sung, and J. Zander, “Aeronautical Communication Systems as Potential Primary Users in Secondary Spectrum Access,” ADHOC ’11, May 2011.
15. N. Schrammar, M. Andersson, and M. Skoglund, “Approximate Capacity of the General Gaussian Parallel Relay Network,” IEEE ISIT 2011, St. Petersburg, Russia, July 2011.
16. M. Hamid, and N. Björsell, “Geo-Location Spectrum Opportunities Database in Radar Bands for OFDM Based Cognitive Radios,” CCSIE 2011, London, UK, July 2011.

17. J. Zander, and K.W. Sung, “Opportunistic Secondary Spectrum Access - opportunities and limitations,” invited paper, URSI General Assembly 2011, Istanbul, August 2011.
18. X. Li, J. Nasreddine, M. Petrova, and P. Mähönen, “Cross-layer optimal spectrum sensing duration and scheduling in cognitive networks,” ACM CoRoNet 2011, Las Vegas, US, September 2011.
19. A. Achtzehn, M. Petrova, and P. Mähönen, “Deployment of a Cellular Network in TV whitespaces: A case study in a challenging environment,” ACM CoRoNet 2011, Las Vegas, US, September 2011.
20. Y. Selén, R. Baldemair and J. Sachs, “A short feasibility study of a cognitive TV black space system,” IEEE PIMRC 2011, Toronto, Canada, September 2011.
21. M. Tercero, K. W. Sung, and J. Zander, “Aggregate Interference from Secondary Users with Heterogeneous Density,” IEEE PIMRC 2011, Toronto, Canada, September 2011.
22. V. Pavlovska, and L. Gavrilovska, “Collaborative Spectrum Sensing Scheme: Quantized Weighting with Censoring,” ADHOCNETS 2011, Paris, France, September, 2011.
23. M. A. Girnyk, M. Xiao, and L. K. Rasmussen, “Optimal power allocation in multi-hop cognitive radio networks,” IEEE PIMRC 2011, Toronto, Canada, September 2011.
24. M. I. Rahman, and J. S. Karlsson, “Feasibility evaluations for secondary LTE usage in 2.7-2.9GHz radar bands,” IEEE PIMRC 2011, Toronto, Canada, September 2011.
25. K. Ruttik, K. Koufos, and R. Jäntti, “Model for computing aggregate interference from secondary cellular network in presence of correlated slow fading,” IEEE PIMRC 2011, Toronto, Canada, September 2011.
26. K. Koufos, K. Ruttik, and R. Jäntti, “Controlling the interference from multiple secondary systems at the TV cell border,” IEEE PIMRC 2011, Toronto, Canada, September 2011.
27. J. Markendahl, and Ö. Mäkitalo, “Analysis of business opportunities of secondary use of spectrum - The case of TV white space for mobile broadband access,” Regional European ITS2011 Conference, Budapest, September 2011.
28. B. Jankuloska, V. Atanasovski, and L. Gavrilovska, “Spectrum Sharing Concepts: Secondary Usage of TV White Spaces,” ETAI 2011, Ohrid, Macedonia, September 2011.
29. M. Tercero, K. W. Sung, and J. Zander, “Temporal Secondary Access Opportunities for WLAN in Radar Bands,” WPMC 2011, Brest, France, October 2011.
30. M. Hamid, and N. Björsell, “A novel Approach for Energy Detector Sensing Time and Periodic Sensing Interval Optimization in Cognitive Radios,” CogART 2011, Barcelona, Spain, October 2011.
31. D. Denkovski, V. Atanasovski, and L. Gavrilovska, “Policy enforced spectrum sharing for unaware secondary systems,” CogART 2011, Barcelona, Spain, October 2011.
32. B. Jankuloska, V. Atanasovski, and L. Gavrilovska, “Combined power/channel allocation method for efficient spectrum sharing in TV white space scenario,” CogART 2011, Barcelona, Spain, October 2011.
33. V. Rakovic, V. Atanasovski, and L. Gavrilovska, “Clustered Network Coordinated Beamforming for Cooperative Spectrum Sharing of Multiple Secondary Systems,” CogART 2011, Barcelona, Spain, October 2011.
34. J. M. Park, J. Hwang, and S.-L. Kim, “An Efficient Contention-based Reporting Protocol for Collaborative Spectrum Sensing,” CogART 2011, Barcelona, Spain, October 2011.
35. M. Denkovska, P. Latkoski, and L. Gavrilovska, “Geolocation Database Approach for Secondary Spectrum Usage of TVWS,” TELFOR 2011, Belgrade, Serbia, November 2011.

36. B. Jankuloska, V. Atanasovski, and L. Gavrilovska, “Opportunistic spectrum sharing scheme for secondary WiFi-like devices in TV white spaces,” UBICOMM 2011, Lisbon, Portugal, November 2011.
37. S. Kawade, and M. Nekovee, “Broadband Wireless Delivery Using An Inside-Out TV White Space Network Architecture,” IEEE GLOBECOM 2011, Houston, USA, December 2011.
38. M. Nekovee, “Current Trends in Regulation of Secondary Access to TV White Spaces Using Cognitive Radio,” IEEE GLOBECOM 2011, Houston, USA, December 2011.
39. J. Markendahl, and B. G. Mölleryd, “On network deployment strategies for mobile broadband services taking into account amount of spectrum and fixed line penetration - Comparison of network deployment in Europe and India,” Regional India ITS Conference, New Delhi, February 2012.
40. C. Wang, M. Xiao, and L. Rasmussen, “Performance Analysis of Coded Secondary Relaying in Overlay Cognitive Radio Networks,” IEEE WCNC 2012, Paris, France, April 2012.
41. J. Karamacoski, P. Latkoski, and L. Gavrilovska, “On Estimation Aspects of WLAN Secondary Spectrum Availability in ATC Radar Band,” EW 2012, Poznań, Poland, April 2012.
42. V. Pavlovska, V. Atanasovski, and L. Gavrilovska, “Performance Evaluation of Cooperative Spectrum Sensing in Multiband Radio Environments,” EW 2012, Poznań, Poland, April 2012.
43. B. Jankuloska, V. Atanasovski, and L. Gavrilovska, “Novel spectrum sharing algorithm for maximizing supported WiFi-like secondary users in TV white spaces,” EW 2012, Poznań, Poland, April 2012.
44. M. Hamid, K. Barbe, W. Van Moer, and N. Björsell, “Spectrum Sensing through Spectrum Discriminator and Maximum Minimum Eigenvalue Detector: A Comparative Study,” IEEE I2MTC 2012, Graz, Austria, May 2012.
45. L. Gonzales, K. Barbe, W. Van Moer, and N. Björsell, “Cognitive Radios: Discriminant Analysis Finds the Free Space,” IEEE I2MTC, Graz, Austria, May 2012.
46. M. Hamid, and N. Björsell, “Maximum Minimum Eigenvalues Based Spectrum Scanner for Cognitive Radios,” IEEE I2MTC, Graz, Austria, May 2012.
47. E. Stathakis, M. Skoglund, and L. K. Rasmussen, “On combined beamforming and OSTBC over the cognitive radio Z-channel with partial CSI,” IEEE ICC 2012, Ottawa, Canada, June 2012.
48. L. Simic, M. Petrova, and P. Mähönen, “Wi-Fi, but not on Steroids: Performance Analysis of a Wi-Fi like Network Operating in TVWS under Realistic Conditions,” IEEE ICC 2012, Ottawa, Canada, June 2012.
49. A. Achtzehn, M. Petrova, and P. Mähönen, “On the performance of Cellular Network Deployments in TV Whitespaces,” IEEE ICC 2012, Ottawa, Canada, June 2012.
50. F. Gabry, N. Schrammar, M. Girnyk, N. Li, R. Thobaben, and L. K. Rasmussen, “Cooperation for secure broadcasting in cognitive radio networks,” CoCoNet workshop, IEEE ICC 2012, Ottawa, Canada, June 2012.
51. X. Li, and P. Mähönen, “Grid based Cooperative Spectrum Sensing in Cognitive Networks under Correlated Shadowing,” CROWNCOM 2012, Stockholm, Sweden, June 2012.
52. S. Kawade, “Long-Range Communications In Licence-Exempt TV White Spaces: An Introduction To Soft-Licence Concept”, CROWNCOM 2012, Stockholm, Sweden, June 2012.
53. V. Rakovic, M. Angjelicinoski, V. Atanasovski, and L. Gavrilovska, “Location estimation of radio transmitters based on spatial interpolation of RSS values,” CROWNCOM 2012, Stockholm, Sweden, June 2012.
54. P. Latkoski, J. Karamacoski, and L. Gavrilovska, “Availability assessment of TVWS for Wi-Fi-like secondary system: A case study,” CROWNCOM 2012, Stockholm, Sweden, June 2012.

55. N. Schrammar, H. Farhadi, L. K. Rasmussen, and M. Skoglund, “Average Throughput in AWGN Cognitive Fading Interference Channel with Multiple Secondary Pairs,” CROWNCOM 2012, Stockholm, Sweden, June 2012.
56. L. Shi, K. W. Sung, and J. Zander, “On the Permissible Transmit Power for Secondary User in TV White Space,” CROWNCOM 2012, Stockholm, June 2012.
57. J. Markendahl, P. Gonzalez-Sanchez, and B. G. Mölleryd, “Impact of deployment costs and spectrum prices on the business viability of mobile broadband using TV white space,” received the *Best Paper Award*, CROWNCOM 2012, Stockholm, June 2012.
58. J. Markendahl, and T. R. Casey, “Business opportunities using white space spectrum and cognitive radio for mobile broadband services,” CROWNCOM 2012, Stockholm, June 2012.
59. J. Kerttula, K. Ruttik, and R. Jäntti, “Dimensioning of secondary cellular system in TVWS,” CROWNCOM 2012, Stockholm, June 2012.
60. K. Koufos, K. Ruttik, and R. Jäntti, “Aggregate interference from WLAN in the TVWS by using terrain-based channel model,” CROWNCOM 2012, Stockholm, June 2012.
61. E. Stathakis, M. Skoglund, and L. K. Rasmussen, “On combined beamforming and OSTBC over the cognitive radio S-channel with partial CSI,” CROWNCOM 2012, Stockholm, June 2012.
62. L. Shi, K. W. Sung, and J. Zander, “Controlling Aggregate Interference under Adjacent Channel Interference Constraint in TV White Space,” CROWNCOM 2012, Stockholm, June 2012.
63. A. Achtzehn, J. Riihijärvi, G. Martinez Vargas, M. Petrova, and P. Mähönen, “Improving coverage prediction for primary multi-transmitter networks in the TV white-spaces,” paper received the award *Honorable Mentions*, SECON 2012, Seoul, Korea, June 2012.
64. A. Achtzehn, J. Riihijärvi, and P. Mähönen, “Error Distribution in Maximum Likelihood Estimation of Radio Propagation Parameters,” IEEE SECON 2012 (poster session), Seoul, Korea, June 2012.

2.2.2 Published journal papers

1. M. Nekovee, “A Survey of Cognitive Radio Access to TV White Spaces,” nominated for BT Innovation Award 2011 in the category of *Best Paper of Innovation*, International Journal of Digital Multimedia Broadcasting, vol. 2010.
2. K. Ruttik, K. Koufos, and R. Jäntti, “Modeling of the secondary system’s generated interference and studying of its impact on the secondary system design,” Journal Radio Engineering, Vol. 19, Number 4, Dec. 2010.
3. L. Gavrilovska, and V. Atanasovski, “Cooperative Spectrum Sensing in Ad-Hoc Networks,” Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering 2010, Vol. 49, Part 3, DOI: 10.1007/978-3-642-17994-5_10, pp. 146-159, 2010.
4. K. Ruttik, K. Koufos, and R. Jäntti, “Computation of Aggregate Interference from Multiple Secondary Transmitters,” IEEE Communications Letters, vol. 15, no. 4, 2011.
5. K. W. Sung, M. Tercero, and J. Zander, “Aggregate Interference in Secondary Access with Interference Protection,” IEEE Communications Letters, vol.15, no.6, 2011.
6. K. Koufos, K. Ruttik and R. Jäntti, “Distributed sensing in Multiband Cognitive Radios,” IEEE Transactions on Wireless Communications, Vol.10, No. 5, May 2011.
7. L. Gavrilovska, and V. Atanasovski, “Spectrum Sensing Framework for Cognitive Radio Networks,” Springer Wireless Personal Communications, DOI: 10.1007/s11277-011-0239-1, 2011.
8. J. M. Park, and S.-L. Kim, “Time-efficient Multiple-stage Spectrum Sensing for Cognitive Radio Systems,” IEICE Transactions on Communications, Vol. E95-B, No. 1, pp.341-344, January 2012.

9. J. Zander, and K. W. Sung, "Opportunistic Secondary Spectrum Access: Opportunities and Limitations," Radio Science Bulletin, No. 340, pp.29-33, March 2012.
10. Y. Zhang, R. Yu, M. Nekovee, Y. Liu, S. Xie, and S. Gjessing, "Cognitive machine-to-machine communications: visions and potentials for the smart grid," IEEE Network, vol. 26, no. 3, pp 6-13, May 2012.
11. K. Koufos, K. Ruttik, and R. Jäntti, "Voice Service in Cognitive Networks over the TV Spectrum," IET Communications 2012, special issue in cognitive communications, 2012.

2.2.3 Invited presentations

1. J. Kronander, J. Zander, M. Nekovee, S.-L. Kim, **K. W. Sung**, and Andreas Achtzehn, "QUASAR scenarios for white space assessments and exploitation," invited presentation, URSI EMC Europe 2010, Wroclaw, Poland, September 2010.
2. **M. Nekovee**, "Cognitive radio for secondary spectrum access", invited presentation, International Symposium on Advanced Radio Technologies, Boulder, Colorado, USA, July 2010.
3. **M. Nekovee**, "An operators perspective and point of view", IEEE Workshop on Dynamic Spectrum Access, September 2011, Washington D.C., USA, Invited Panel
4. **J. Zander**, and K.W. Sung, "Opportunistic Secondary Spectrum Access - opportunities and limitations," invited presentation, URSI General Assembly 2011, Istanbul, August 2011.
5. **J. Zander**, "The commercial Sweetspot of Secondary Spectrum Access, EC Flexible Spectrum Usage (FLEXUS) workshop, Brussels, February 2012
6. **J. Zander**, "QUASAR & The commercial Sweetspot of Secondary Spectrum Access, Yonsei University Workshop of Future Wireless Technologies, Seoul, Korea, April 2012.
7. **M. Nekovee,** "Secondary spectrum access: a gap filler technology", Panel, CrownCom 2012, June 2012, Stockholm, Sweden
8. **M. Nekovee,** invited panel, ACROPOLIS Workshop, in conjuncture with Wireless Innovation Forum European Conference, Brussels, Belgium, June 2012.

2.2.4 Deliverables

The results produced within the project are presented in detail in the public deliverables that are available via the official webpage (www.quasarspectrum.eu) this has served as a means for dissemination of knowledge and the QUASAR partners will continue to refer to them in future dissemination events.

The deliverables that have been made available for the public in this way are (list sorted according to topic):

1. QUASAR deliverable D1.2, "Regulatory feasibility assessment," public deliverable, December 31, 2010.
2. QUASAR deliverable D1.3, "Business Impact Assessment," public deliverable, June 31, 2012.
3. QUASAR deliverable D1.4, "Final report on regulatory feasibility," public deliverable, June 31, 2012.

4. QUASAR deliverable D2.2, "Preliminary methodology for assessing secondary spectrum usage opportunities," public deliverable, December 31, 2010.
5. QUASAR deliverable D2.3, "Detection Performance of Cooperate Schemes – Final Report," public deliverable, October 31, 2011.
6. QUASAR deliverable D2.4, "Detection performance with multiple secondary interference," public deliverable, March 31, 2012.

7. QUASAR deliverable D2.5, “Laboratory test report,” public deliverable, March 31, 2012.

8. QUASAR deliverable D3.1, “Initial report on the tolerance of legacy systems to transmissions of secondary users based on legacy specifications,” public deliverable, June 30, 2010.
9. QUASAR deliverable D3.2, “Refined models for primary system performance as a function of secondary interference,” public deliverable, December 31, 2010.
10. QUASAR deliverable D3.3, “Report on Cooperation Strategies Between Primary and Secondary Users,” public deliverable, March 31, 2012.

11. QUASAR deliverable D4.1, “Sharing strategies for unaware secondary systems,” public deliverable, March 31, 2011.
12. QUASAR deliverable D4.2, “Cooperation Strategies for Secondary Users,” public deliverable, April 5, 2012.
13. QUASAR deliverable D4.3, “Combined secondary interference models,” public deliverable, March 31, 2012.

14. QUASAR deliverable D5.1, “Model Integration and Spectrum Assessment Methodology,” public deliverable, March 31, 2011.
15. QUASAR deliverable D5.2, “Methods and tools for estimating spectrum availability: case of single secondary user,” public deliverable, December 31, 2011.
16. QUASAR deliverable D5.3, “Methods and tools for estimating spectrum availability: case of multiple secondary users,” public deliverable, March 31, 2012.
17. QUASAR deliverable D5.4, “Final Report on Models with Validation Results,” public deliverable, June 31, 2012.

18. QUASAR deliverable D6.1, “Project presentation,” public deliverable, June 30, 2010.
19. QUASAR deliverable D6.2, “Dissemination and exploitation plan,” public deliverable, June 30, 2010.
20. QUASAR deliverable D6.3, “Dissemination and exploitation report,” public deliverable, December 31, 2010.
21. QUASAR deliverable D6.4, “Dissemination and exploitation report 2,” public deliverable, December 31, 2011.
22. QUASAR deliverable D6.5, “Final plan for using and disseminating knowledge,” (this document) public deliverable, June 31, 2012.

2.3 Regulatory input

During the course of the project QUASAR partners has contributed actively to the work of the ECC CEPT Spectrum Engineering Project Team 43 (SE43). QUASAR partners has disseminated results by providing information input but also by using obtained insight to highlight potential problems and propose corresponding solutions in the current proposed regulatory framework for secondary access to the TV bands.

List of contributions to CEPT SE43:

1. QUASAR WP1, SE43(10)12 “QUSAR deliverable 1.2”, information input, CEPT SE43 meeting, Copenhagen, April 2011.
2. Ericsson AB, “SE43(10)87: Managed geo-location database queries.” Accepted for inclusion in the working version of the CEPT ECC report 159. Document number: SE43(10)87
3. Ericsson AB, “SE43(10)118: Master/slave configuration - clarification and implementation examples.” Accepted for inclusion in the working version of the CEPT ECC report 159. Document number: SE43(10)118

4. Aalto University and BT research, “SE43(11)23 Control of Aggregate Interference from WSDs.” A well received contribution that SE43 wanted even more detailed in a follow-up contribution. Document number: SE43(11)23
5. KTH and Ericsson AB, “'SE43(11)52: On the permissible transmit power for WSDs in TV White Space.” A well received contribution and actions have been taken to update the CEPT ECC report 159. Document number: SE43(11)52
6. Aalto University and BT research, “SE43(11)97 Control of Aggregate Interference from WSDs.” The follow-up contribution to SE43(11)23. A well received contribution that will be followed up by more information of the usability of the method. Document number: SE43(11)97

2.4 Planned future dissemination

The future dissemination and use of the knowledge and insights obtained during the project will mostly be based on scientific publication at conferences and in journals, but also by presentations in various fora. The partners will execute on the proven successful path of publishing the remaining unpublished QUASAR results at conferences and journals.

Below we give a complete list of the submitted and accepted papers that will serve as dissemination of the obtained results. We also outline the envisioned key dissemination events and activities to realize a large impact and spreading of the project conclusions.

2.4.1 Scientific papers submitted for review

Submitted conference papers

1. S. Kawade, and M. Nekovee, “Rural broadband in TV White Spaces Revisited,” submitted to IEEE DySPAN 2012.
2. L. Shi, K. W. Sung and J. Zander, “Secondary Spectrum Access in TV-Bands with Combined Co-Channel and Adjacent Channel Interference Constraints,” submitted to IEEE DySPAN 2012.
3. E. Obregon, K. W. Sung and J. Zander, “Availability Assessment of Secondary Usage in Aeronautical Spectrum,” submitted to IEEE DySPAN 2012
4. T. Dudda, T. Irnich, “Capacity of cellular networks deployed in TV White Space,” submitted to DySPAN 2012.
5. Y. Selén, and J. Kronander, “Optimizing power limits for white space devices under a probability constraint on aggregated interference,” submitted to IEEE DySPAN 2012.
6. J. Markendahl, and T. R. Casey, “Business opportunities using white space spectrum and cognitive radio for mobile broadband services,” submitted to IEEE DySPAN 2012.
7. A. Achtzehn, L. Simic, M. Petrova, P. Mähönen, P. Latkoski, V. Atanasovski, and L. Gavrilovska, “A Generic Software Tool For Assessing Secondary System Opportunities,” submitted to IEEE DySPAN 2012, demo session.
8. P. Latkoski, M. Zahariev, B. Jankuloska, J. Karamacoski, and L. Gavrilovska, “Opportunistic Usage of TV Band for Multiple Secondary WLAN Users,” submitted to CAMAD 2012.
9. X. Li, M. Petrova, and P. Mähönen, “The Impact of Reporting MAC on Cooperative Spectrum Sensing in Multiband Cognitive Networks,” submitted to IEEE GlobeCom 2012.
10. E. Stathakis, C. Wang, L. K. Rasmussen, and M. Skoglund, “Low complexity adaptive antenna selection for cognitive radio MIMO broadcast channels,” submitted to IEEE GlobeCom 2012.
11. M. Hamid, W. VanMoer, and N. Björsell, “Peeling off the primary users from a cognitive radio spectrum,” submitted to IEEE GlobeCom 2012.
12. M. Zahariev, V. Atanasovski, and L. Gavrilovska, “Practical implementation of efficient cyclostationary based detectors,” submitted to ISWCS 2012.

13. V. Rakovic, V. Pavlovska, V. Atanasovski, and L. Gavrilovska, “Cooperative spectrum sensing based on noise power estimation,” submitted to MILCOM 2012.
14. N. Schrammar, C. Wang, L. K. Rasmussen, and M. Skoglund, “On the Discrete Superposition Model of Partially Cognitive Interference Channels,” submitted to Asilomar SSC 2012.

Submitted journal papers

1. A. Achtzehn, L. Simic, M. Petrova, and P. Mähönen, “Feasibility of Secondary Networks in TVWS: Quantitative Study of Cellular and Wi-Fi-like Deployments,” submitted to IEEE JSAC.
2. E. Obregon, K. W. Sung, and J. Zander, “On the Feasibility of Low-Power Secondary Access to 960-1215 MHz Aeronautical Spectrum,” submitted to IEEE Transactions on Vehicular Technology.
3. S.-L. Kim, H.-K. Lee, D.M. Kim, Y.J. Hwang, S.M. Yu, and S. Kim, “Business Value of Cognitive Machine-to-Machine Communication Using Cellular Bands,” submitted to Telecommunications Policy.
4. J. Markendahl and Ö. Mäkitalo, “Analysis of business opportunities of secondary use of spectrum - The case of TV white space for mobile broadband access”, submitted to Telecommunications Policy, issue on cognitive radio.
5. B. Cho, K. Koufos, K. Ruttik, and R. Jäntti, “Power allocation in the TV white space under constraint on secondary system self-interference”, submitted to Journal of Electrical and Computer Engineering.
6. K. Koufos, K. Ruttik, and R. Jäntti, “Sensing-based power allocation for a secondary device under unknown primary activity,” submitted to IET communications
7. E. Stathakis, M. Skoglund, and L. K. Rasmussen, “On beamforming and orthogonal space-time block coding in cognitive radio networks with imperfect CSI and correlated noise,” submitted to IEEE Transactions on Communications.

2.4.2 Scientific publications accepted for publication

Accepted conference papers

1. F. Gabry, N. Li, N. Schrammar, M. Girnyk, E. Karipidis, R. Thobaben, L. K. Rasmussen, M. Skoglund, and E. G. Larsson, “Secure broadcasting in cooperative cognitive radio networks,” accepted to FNMS 2012.
2. M. A. Girnyk, M. Vehkaperä, and L. K. Rasmussen, “On the asymptotic sum-rate of the relay-assisted amplify-and-forward cognitive MIMO channel,” accepted to IEEE PIMRC 2012.
3. X. Li, M. Petrova, and P. Mähönen, “FCSS: CSMA/CA based Fast Cooperative Spectrum Sensing over Multiband Cognitive Networks,” accepted to IEEE PIMRC 2012.

Accepted journal papers

1. Y. Hwang, K. W. Sung, S.-L. Kim, and J. Zander, “Scenario Making for Assessment of Secondary Spectrum Access,” IEEE Wireless Communications, accepted for publication.
2. M. Nekovee, T. Irnich, and J. Karlsson, “Current Trends in Worldwide Regulation of Secondary Access to White Spaces Using Cognitive Radio,” IEEE Wireless Communications, accepted for publication.
3. M. Tercero, K. W. Sung, and J. Zander, “Exploiting Temporal Secondary Access Opportunities in Radar Spectrum,” Wireless Personal Communications, special issue on WPMC 2011, accepted for publication.
4. S. Lee, K. W. Choi, and S.-L. Kim, “Maximum Likelihood Detection of Random Primary Networks for Cognitive Radio System,” IEICE Transactions on Communications, accepted for publication.

Invited book chapters

1. M. Nekovee, and P. Anker , “Regulation, Policy and Economics of Cognitive Radio for Secondary Spectrum Access,” to appear in Cognitive Communications, D. Grace and H. Zhang (eds.), John Wiley & Sons, 2012.
2. M. Nekovee, and D. Wisely, “Cognitive Radio Networks in TV White Spaces,” to appear in Cognitive Communications, D. Grace and H. Zhang (eds.), John Wiley & Sons, 2012.

2.4.3 Future key dissemination paths

A future key dissemination event for QUASAR results will be the IEEE DySPAN 2012 conference that will be held in the fall 2012. This conference provides a possibility of making a big impact not only on the research community but also on the regulatory community. The latter motivated by the large focus on regulatory issues on the IEEE DySPAN 2011 conference. The impact and dissemination of QUASAR results will be ensured by the six submitted contributions, one of which is intended to demonstrate the developed assessment framework.

Further, the plan is to be present to disseminate results at the well renowned IEEE PIMRC 2012 and IEEE GlobeCom 2012 conferences. This will be ensured by the submitted and accepted papers to the respective conference.

Significant impact is also expected by the large number of submitted or accepted journal papers. In particular two articles, one on regulations and one on business scenarios, will appear in a forthcoming issue of the IEEE Wireless Communication Magazine on cognitive radio. These will ensure that the findings are very effectively disseminated to the wider industry, regulator and policy community through publication in this impactful IEEE Magazine.

The QUASAR partners are also preparing a summary overview paper of the overall conclusions from the project. This paper is intended to be submitted as soon as possible to the IEEE Communications Magazine and is thus expected to reach a wide audience.

The QUASAR results will also continue to be used as input to the European regulatory ECC CEPT SE43 working group. In particular a planned input is to providing updates and refinements on the previous contributions, this is intended to be discussed during the July 2012 meeting.

In addition to dissemination via contributions to the CEPT SE43 working group, QUASAR findings will be disseminated effectively to the regulatory arena by participation in Ofcom’s Technical Working Group on TV White Spaces (possibly in July 2012).

In December 2010 QUASAR proposed and motivated the need for a European White Space Facility. Such a facility would allow development, regulatory evaluation and business development of secondary spectrum access technologies, as a way to create confidence in technology among European policy makers and regulators. It would also allow interested industry to investigate and develop proof-of-concept use cases. As such it would provide a common playground for industry and regulators to facilitate experimentation and knowledge exchange. This idea has been taken up in several countries and some have taken steps to realize this type of facilities. If realized some QUASAR partners will likely be involved in the experimentation and hence use the knowledge obtained during the project.

3 Partner plans for using and disseminating knowledge

This section details the plan and vision for each partner in the QUASAR project regarding the project generated knowledge. To simplify for the reader to find the relevant information the partner contributions is sorted according to what category (academia, company or regulator) a partner belongs to.

3.1 Academic partners

3.1.1 Kungliga tekniska högskolan (KTH)

KTH investigated the availability of secondary spectrum access from both technical and business perspectives. In particular two directions were examined.

In the first direction we mainly focused on scenarios of massive-scale secondary use of low-power broadband systems in TVWS as well as radar and aeronautical spectrum. From a technical perspective, our main findings are two-fold: Firstly, aggregation of adjacent channel interference plays a critical role in the utilization of TVWS. Secondly, significant availability is observed in radar and aeronautical frequency bands. From a business perspective, we found that the key issues are related to the kind of actors that provide the secondary services. Even if the technology works well and at a low cost, there may still not be a business case because new actors need to make other types of investments while competing solutions provide better cost performance. The largest potential for use of TV spectrum is found by existing operators that want to reduce the number of new sites or delay the new deployment. These findings should be disseminated effectively to research community, regulators, and industry in order to facilitate efficient use of spectrum.

In the second direction we mainly focused on the fundamental benefits of cooperation between primary/secondary systems or between secondary users within a secondary system. Our overall conclusions are that primary/secondary cooperation can significantly enhance overall spectrum efficiency by improving the interference tolerance of both primary and secondary transceivers. Likewise, cooperation between secondary users can also provide improved spectrum usage for a given present primary system. The cost of these gains are in terms of signalling and transmission overhead to share CSI and/or information messages, and receiver complexity to facilitate cooperative coding and transmission schemes. It is debatable whether the use of cooperative strategies will be introduced in the first generation of commercial cognitive radio systems. However, increasing levels of cooperation is a likely solution-path for future generations of such systems.

Our exploitation plan can be categorized into three parts. First, international conferences and journals are the most typical places to disseminate the knowledge to global research community. We have published a number of papers to renowned conferences and journals such as IEEE DySPAN, IEEE WCNC, IEEE PIMRC, IEEE ICC, IEEE ISIT, CROWNCOM, URSI GASS, ITS conferences, and IEEE Communications Letters. We will continue publishing papers to selected conferences and journals. Our targets include IEEE DySPAN, IEEE Wireless Communications Magazine, IEEE Communications Magazine, IEEE Transactions of Wireless Communications, IEEE Transactions of Wireless Communications, IEEE Transactions on Vehicular Technology, and Telecommunications Policy.

Second, we will provide inputs to regulators, standardization bodies, and policy discussion fora. We have already proposed a correction of ECC report 159, which has been accepted by SE43 working group. We plan to provide SE43 with our finding about the aggregate adjacent channel interference in TVWS. We have also been active in COST-TERRA to study the regulatory and business aspects of the secondary access. Our effort in COST-TERRA will continue. We have a strong relationship with our partner regulators, particularly PTS, the Swedish regulator. We believe that our results about the radar and aeronautical spectrum are an excellent input to the regulators for them to go beyond TVWS.

Finally, the QUASAR results will be used as inputs to other research projects. In particular, KTH will be involved in METIS project which is a FP7 IP project starting in the autumn 2012. In METIS, we will investigate the spectrum policies and coexistence technologies for future mobile systems. The METIS consortium is looking forward to having the QUASAR knowledge.

3.1.2 Rheinish-Westfaelishe technische hochschule Aachen (RWTH)

The dissemination and exploitation plan of RWTH Aachen University consists of the traditional academic dissemination and also specific actions that are planned to enable technology transfer or pre-commercialization of results.

First, the gained expertise and results will be used to enhance our teaching. The initial steps for this have been already done by introducing a new post-graduate (Masters) level course in cognitive radios. A significant portion of the course material has benefited from QUASAR results. The currently running course was attracting over 30 registered students. We plan to feed in the final QUASAR results with the experiences learned from this semester to a renewed course offering in 2013. Moreover, we plan to continue disseminating QUASAR results further to European research community through ACROPOLIS NoE.

Second, we will continue the active dissemination of QUASAR results through high quality conferences and journal publications. The target publication venues include IEEE DySPAN, IEEE ICC, IEEE GLOBECOM, ACM CoRoNET, IEEE WCNC, and journals such as IEEE Transactions of Wireless Communications, IEEE Communications Magazine, and IEEE JSAC.

Third, we are certain that knowledge, contacts and tools that have been built during the project will help us to disseminate and exploit the results through new project, national and European. We are already actively seeking out not only cooperative pre-competitive projects, but also consider specific one-to-one cooperation with selected industrial partners. Such projects will also act as vehicles for technology transfer between academia and industry.

The results from QUASAR have been and will be also contributing to several Ph.D. theses, and will be a core part of research work reported in few of those.

The new cooperation links that RWTH has also built during the project to other leading European Universities will be kept active also after the project through research visits, joint publications, and possible later joint projects.

QUASAR project has also increased our links and sensitivity on regulation, including considering impact of regulation to research. We plan to continue the discourse with regulators in general, and advice specific regulators on technology based issues in the future. These new links have already resulted also new opportunities in research domain, such as BNetzA awarding experimental spectrum license to RWTH Aachen University, which provides a tremendous research capabilities to the university.

As mentioned above we plan to exploit and technology transfer some of our results also directly towards commercial companies, most likely through one-to-one projects. Furthermore, the university is currently launching a due-diligence process related to the software that has been developed by RWTH (mainly the spectrum availability modelling tool-chain and some of the visualization and GUI tools). The aim is to understand what the best licensing model for these tools is. At minimum the process will generate the suitable licensing model for researchers and companies to have an access to the tools, but we are also currently having internal discussions and seeking a professional advice on possible commercial licensing options, including an option to launch a start-up company to exploit the generated knowledge in the group, which has partially benefited from QUASAR research.

3.1.3 Aalto University

In QUASAR project Aalto has gained expertise in the areas of TV white space and TV black space spectrum availability assessment, cooperative multiband spectrum sensing, aggregate interference modelling and polarization discrimination measurements in indoor and outdoor environments.

Our exploitation plan consists of three parts: 1) Dissemination, 2) Impacting regulation and 3) use the acquired knowledge in follow-up projects.

1)
Aalto will use the results of QUASAR to strengthen the academic impact of the University by disseminating the knowledge through high visibility international conferences and journals as well as produce doctoral thesis. Part of the results have been already published in high quality journals and conference proceedings as of IEEE Transactions on Wireless Communications, IET Communications, IEEE Communications Letters, Radio Engineering Journal, PIMRC, CROWNCOM, COCORA and DySPAN. Aalto will extend the studies carried out in QUASAR and continue disseminating the results to academic and industrial research community also as a means for establishing further cooperation with academic and industrial partners. The work of QUASAR has resulted in one doctoral thesis and greatly impacted one thesis under preparation.

2)
Within the QUASAR project Aalto had the opportunity to participate in CEPT meetings and interact with the SE43 working group. Aalto in cooperation with BT provided CEPT with 3 contributions on aggregate interference modelling and power allocation rules in a system setup incorporating realistic user density map and terrain-based radio propagation. The contributions received positive feedback because they allow reducing the complexity in a practical spectrum allocation database implementation and further studies were requested by the SE43 working group. Aalto plans to continue the interaction with industrial project partners and standardization bodies in order to align the academic research with the industrial needs.

3)
In the QUASAR project Aalto has developed a web-based visualization tool on the top of Google Maps for visualizing the findings of the undergoing research in the TVWS. In the QUASAR project, the tool has been used to visualize the spectrum availability assessment results in Finland and UK by using ECC and FCC power allocation rules. The visualization tool will be an excellent basis for future collaborations because it can be easily extended to incorporate other study areas and standardization rules without the need to install any additional software.

Following the active participation in QUASAR project, Aalto will take part also in EU FP7 IP METIS where the knowledge gained in QUASAR will be extended. In METIS project Aalto will built on QUASAR results and develop interference models and control methods to enable co-existence of heterogeneous wireless networks and co-primary sharing of the spectrum under different spectrum licensing/authorization assumptions. Besides METIS, Aalto will develop control methods for the aggregated interference and black space (overlay) methods further in Finnish Funding Agency for Technology and Innovation (TEKES) funded project “End-to-end Cognitive Radio Testbed (EECRT)” that aims at building a testbed system covering not just the radio part but also spectrum management and higher layer (transport) protocols.

3.1.4 Educational foundation Yonsei University

In the QUASAR project, Yonsei University actively carried out research tasks both in business and technical contexts of secondary spectrum access.

Firstly, in business perspective, we participated in deriving the secondary access scenarios, which are considered promising and used within the QUASAR project as the basic business cases. In particular, we developed the secondary usage of cognitive machine-to-machine (M2M) communications that support both mobile (ad hoc) and stationary (infrastructure) M2M devices. We also investigated the business feasibility of cognitive M2M services operating in cellular spectrum in comparison with that of machine-type communication (MTC) in 3GPP. Our finding is that congestion and control overhead problems from a large number of M2M devices can be solved by our cognitive M2M, where cluster headers hierarchically gather each M2M data using CR techniques. This cognitive M2M may have larger business potential in the services where the traffic pattern is bursty and short. In that sense, smart grid/smart metering service is suitable for using cognitive M2M and our findings can have influence on the industry including cellular operators and electric power companies. In addition, our knowledge on this secondary usage scenario can be disseminated to the relevant standard bodies such as 3GPP, under a spectrum sharing agreement between the service provider and cellular operators.

Secondly, in technical perspective, we analyzed secondary spectrum access in two directions. First, we verified the impact of cooperation through secondary relaying and through using a database, respectively. Second, we investigated on the performance of spectrum sensing in term of sensing report. Our main finding is that taking advantage of the contention or interference environment can be more effective in secondary spectrum access than avoiding those unfavourable situations. Also, by assessing the requirements on the database in database-driven approach, we suggested the design principles based on a generic system architecture. These findings will be helpful for designing a 'technically feasible' cognitive radio system.

Our knowledge from the QUASAR project will be effectively disseminated in the form of practical terms such as business and regulation as well as in the form of research papers. As a non-European partner of this international project, we were active in developing secondary usage scenarios and analyzing the business and technical feasibility, which have never been done in Korean research trends. We will provide a lot of inputs to Korean regulatory bodies such as KCC (Korea Communications Commission) and policy discussion among business operators. Moreover, as the smart metering service is drawing much attention, we will collaborate with communication network industry as well. To stimulate the tech biz related to cognitive M2M communications, more specific and innovative business models for cognitive M2M services can be invented based on the findings from the QUASAR project.

For publication of our project results, we consider notable international journals and conferences. Several papers have already been published in IEEE Wireless Communications, IEICE Transactions on Communications, and cognitive radio related conferences. We are also preparing paper submissions targeting at, including the above journals, IEEE Transactions on Vehicular Technology, IEEE Communications Letters, IEEE Transactions on Wireless Communications, Telecommunications Policy, and high-quality IEEE and ACM conferences.

3.1.5 **Ss. Cyril and Methodius University in Skopje (UKIM)**

The QUASAR project has strengthened UKIM's expertise and knowledge in the areas of spectrum sensing, spectrum sharing and spectrum availability assessment. As a result, the QUASAR generated knowledge built upon UKIM's previous experience in similar FP7 projects and strongly affected UKIM's reputation and relevance in the international research. The work in QUASAR allowed UKIM to gain more theoretical knowledge in the mentioned areas that completely complements UKIM's extensive practical experience in developing test beds for various flexible spectrum usage solutions. This resulted in establishing UKIM as a relevant and highly competent research institution.

UKIM was heavily involved in the development of the QUASAR's spectrum assessment tool and also contributed with a specific case study for Macedonia applying the QUASAR methodology. This is an area that UKIM targets as a future potential research track analyzing different scenarios (e.g. Wi-Fi-like, cellular like etc.) and different bands (e.g. radar) that may be exploited in more details. In this direction, UKIM is currently in the process of applying for a NATO funded project that will deal with extensive field measurements of the spectrum occupancy in Macedonia and will engineer a secondary spectrum usage system architecture.

The QUASAR project also aided UKIM's efforts towards closer integration into the European research community establishing fruitful links for possible future cooperation. Additionally, UKIM continuously uses QUASAR as a potential collaboration platform with local telecom operators and regulators by introducing them with the QUASAR's knowledge.

Regarding the QUASAR obtained results, UKIM already submitted and published papers on high-profile communications forums worldwide (e.g. IEEE conferences) and will continue with this approach in the near future. This helps UKIM stay on the top-edge of relevant research in the area.

Last, but not least, the QUASAR experience fosters UKIM's teaching. The exchanged expertise and knowledge with the industrial partners allows more relevant hands-on teaching content.

3.2 Business partners

3.2.1 Ericsson AB

Ericsson’s take on secondary communication is that it is an interesting area and that there is more research to be carried out to fully understand the possibilities and benefits for our customers, i.e., mobile operators around the world. For this reason our future investigations we will use the overall QUASAR finding and focus on further investigations of indoor and short range applications. For this we will likely focus on secondary use of higher frequencies where the propagation characteristics is favourable for isolating secondary transmissions to limit the effects of aggregated interference.

Ericsson also plans to extend our TVWS capacity simulations to include more types of deployments for mobile cellular networks, e.g., heterogeneous deployments. The study will extend the investigated area from only Germany to also include the US territory and corresponding spectrum situation and regulation. This extension is intended to get a more complete picture of the value and benefits of various deployment options in TVWS usage.

Also a comparison between the business cases of using licensed spectrum and TVWS opportunities will likely be included in the abovementioned study. The business comparison for the German TVWS situation, presented in QUASAR deliverable D1.3, possibly extended with results based on various deployment scenarios, will be disseminated through at least one publication.

The outcomes of these extended investigations may result in viable business cases for cellular operators, and then technical solutions to realize the benefits of secondary spectrum access may be included in future releases of 3GPP standards.

The results and insights gained during the QUASAR project will be disseminated internally and will be used as a foundation when discussing feasible options with our customers. The knowledge will also provide a basis for work to be conducted in WP5 of the EU FP7 project METIS, where Ericsson is project coordinator. This work will focus on spectrum sharing and thus be related to the sharing strategies developed in QUASAR.

We will also use the obtained results a decision basis when setting our strategies regarding spectrum. This work will then be contributed to various regulatory standardization fora, e.g., ECC CEPT WG FM and WG SE43. In particular, we will use the knowledge of the importance of guaranteed spectrum access in TVWS for wireless communication businesses that requires large infrastructure investments to argue for implementing appropriate regulatory schemes for various spectrum bands.

Ericsson also plans to use the QUASAR results when considering possible future products, in particular our 3GPP RAN and Wi-Fi products (Ericsson recently acquired the Wi-Fi manufacturer BelAir) and our geo-location database solutions and implementations. This spring Ericsson acquired the company Telcordia, and as Telcordia has received a preliminary FCC approval for operating a TVWS database in the US we will use the QUASAR generated knowledge, in particular the benefits and drawbacks of various sharing schemes, to further develop the already available database solution to make it the preferred choice to customers wanting means for spectrum sharing and secondary access.

As a database solution has been identified as an important enabler for spectrum sharing and licensed secondary access we will continue to contribute to the IETF PAWS (protocol to access a white space database) standardization working group. This working group has lately expanded its scope to include feedback mechanisms from secondary devices; as such the QUASAR results may be particularly suitable for dissemination in this forum.

Ericsson will also use the gained knowledge when monitoring and possibly contributing to the NGMN work on “cognitive radio technology applied to LTE networks” to ensure that all relevant aspects of secondary spectrum access are properly considered, especially related to the aggregated interference generated from multiple secondary users.

In brief: Ericsson will use the generated knowledge as a basis for further investigations, for setting internal strategies, for input to regulatory fora, and also provide guidance when deciding on future product directions.

3.2.2 British telecommunications public limited company (BT)

BT is a key industry player in the development and deployment of cognitive radio-based technologies for secondary access to spectrum in order to offer new and improved broadband services to our customers. In particular, currently there are over 2 million households in rural Britain which do not have adequate access to broadband. Research carried out at BT and within the QUASAR project has shown that broadband delivery using cognitive radio access to unused TV bands is a technically and commercially serious contender, at least in the UK to close this “digital divided”. The UK regulator, Ofcom, is currently finalizing regulation of the cognitive access to TV White Spaces operating under geolocation databases, with commercial services expected to be able to start operations by 2013.

BT will be using the knowledge and expertise developed in the QUASAR project, in assessing white space availability and capacity, geolocation databases, protection requirements of primary systems, and cooperative sensing, in order to further assess and develop the required technologies for exploitation of white spaces for a range of services, starting with rural broadband which is currently being down streamed to our lines of business. BT is also actively contributing to regulation of cognitive radio in the UK (through the newly established Ofcom technical working group on white spaces) and on a European level (through CEPT) as well as leading work in the newly established ETSI BRAN on white spaces and the IETF Working group PAWS (Protocols for Access to White Space Databases). BT will use the result of the projects in providing input to the abovementioned regulator and industry fora.

As a fixed line operator, BT is also interested in the secondary use of spectrum in other bands in order to address the growing need for wireless connectivity inside homes and elsewhere. Results from the QUASAR project on regulatory, technical and commercial feasibility of other bands beyond TV White Spaces, would provide a very valuable input to BT in order to asses potential opportunities here, and to provide input the current regulatory debate in the UK and on a European level on the need for further spectrum sharing.

3.3 Regulatory partners

Through out the project the regulatory partners have provided useful input by answering questionnaires and attending workshops. Even though the regulatory partners have had a small effort allocated to the project some of them, most notably the Swedish regulator PTS, has provided extensive input and contributions to the work and discussions as well as to deliverables. Further, the role of the regulators in the project has been an important dissemination path to get the QUASAR results to the attention of the national regulators, helping to build an understanding of the possibilities and obstacles associated with secondary spectrum access.

Below the plans form the most active regulatory partners of the project are stated.

3.3.1 Post & Telestyrelsen (PTS)

Radio communication and other radio services are getting a more and more central role in the society of today. The increasing use of radio based systems in almost all sectors puts an increased pressure on frequency regulators to respond to the increasing demand for spectrum. This is especially true in the frequency range that is currently preserved as the sweet spot for radio communication in-between 300 MHz and 6 GHz. In this frequency range there is no unallocated frequencies. That is, all frequencies are designated for one or more usages, so there is no new spectrum readily available. To be able to allocate more frequency spectrum to some usage there is only two options. Either you refarm spectrum, clearing a frequency band or part of a frequency band from the current usage and repurpose it for a new use. Or you introduce sharing between the incumbent user and some new user with a different usage.

While refarming will be an option for some frequency bands, PTS believes that only relaying on refarming will not give the necessary flexibility to response to the changing needs of the frequency users.

This is why we perceive sharing as an increasingly important tool in the area of spectrum regulations. Today sharing between different usages in the same frequency band is often based on the principle that you allocate different parts of a frequency band and/or the geography to different users, for example mixing satellite terminals and point to point radio links in the same frequency band.

Going forward PTS see room for introduction of new methods and mechanisms for facilitating sharing in a frequency band. The development of cognitive radio based sharing could be an extremely powerful tool for sharing. This however relies on that a suitable protection of the incumbent user can be guaranteed and that the spectrum recourses identified by the cognitive system is usable for a new user.

And it is here that the results developed in the QUASAR project have made a difference. Within QUASAR methodologies and tools for technical and commercial assessments of sharing possibilities have been developed. This will be an increasingly important part of the work a regulator performs and having tools for supporting these assessments will be of outermost importance.

The assessment work made in QUASAR have already been and will be used internally at PTS in the work with future strategies for sharing in the licensing of spectrum. Here it should be noted that even if the result seems a bit disappointing from a pure cognitive radio point of view, that information is also of importance and the results as such gives us good input for our strategy work.

The results regarding the usability of TVWS for different use-cases have been used as a major input in our work on defining an internal policy for the TVWS. These results have been used for accessing our implementation options and have already had a large impact.

The work regarding sharing with other types of services such as aeronautical and radar services have dual usage for PTS. First it has allowed us to discuss other frequency bands than the TV-band in an international context. The result as such will also be used in our internal work with prioritizing which bands will be first in line, going forward in our work with increased sharing.

The work done on aggregate interference will also be valuable to PTS. In this case the usability of the results is not limited to sharing based on cognitive radio. The results will also be valuable when designing the technical conditions in case of sharing by different uses on a licensed and license exempt basis. So, in this case we see direct value in the results even outside the field of cognitive radio.

The more advanced work in QUASAR with different forms of cooperative sharing schemes also gives us confidence in that in the long term there will be additional gains coming from cognitive radio techniques. The full gain of these schemes can only be archived if the incumbent is participating, therefore these results would have implications on how licensing conditions should be written. This is one additional and more long-term issue that PTS will be working on as a result of the QUASAR project.

As a whole, PTS sees that for us as a regulator the research done in the QUASAR project has been extremely valuable. Especially in supporting PTS work in developing a strategy for how sharing in-between different usages should best be implemented in the future. We would also like to highlight the methodologies and tools developed to support technical and commercial assessments as an extremely important output from the QUASAR project.

3.3.2 **Finnish Communications Regulatory Authority (FICORA)**

In Finland the use of cognitive radio systems has been possible since the end of year 2009 in the UHF band 470-790 MHz. The cognitive radio system cannot claim protection nor cause harmful interference to other radio communication systems in the band. The result from the QUASAR project will be evaluated when developing a national framework for real TV white space use.

New sharing methods and mechanisms are seen as a vital tool for the evolution towards more efficient spectrum management. The QUASAR project has provided valuable information related to sharing with other frequency bands than the broadcasting bands e.g. sharing with radars and aeronautical systems. We believe that cognitive techniques should be used all over spectrum to facilitate sharing in the bands where it has been seen impossible earlier.

Also, we see these results useful when defining the licensing regime for different applications using cognitive techniques, i.e., what kind of licensing scheme should be used - licensed or license exempt. Parts of the results will be used in our internal study related to the introduction of cognitive radio systems in the TV band (470-790 MHz).

In addition to this, FICORA sees that participation in the QUASAR project has provided useful contacts to the Finnish academia and other international partners. These contacts have already created valuable input to the European regulatory work, mainly in the CEPT Spectrum Engineering Project Team 43 (SE43).