Flexible and Spectrum Aware Radio Access through Measurements and Modelling in Cognitive Radio Systems

FARAMIR

Document Number D7.1

Project Presentation

Contractual date of delivery to the CEC:	**30.06.2010**
Actual date of delivery to the CEC:	**30.06.2010**
Project Number and Acronym:	**248351 - FARAMIR**
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Participants:	**TREL, RWTH, IMEC, FT, UPC, UKIM, HWSE**
Workpackage	**WP7**
Security:	**PU**
Nature:	**R**
Version:	**1.0**
Total number of pages:	**19**

Abstract:

The FARAMIR project is aimed at moving the state-of-the-art cognitive radio technologies from concepts to factual engineering. The project is committed to disseminate the research results and exchange ideas with different target audiences. This document gives an overview of the key objectives of the project as well as some of the ways of communication the FARAMIR consortium has chosen to effectively present its output and to disseminate its results.

Keywords: Cognitive radio, Spectrum Sensing, Radio environment maps, prototype, spectrum measurements, radio resource management, dissemination strategy

Document Revision History

Version	Date	Author	Summary of main changes
0.1	07.06.2010	Siva Subramani, Mahesh Sooriyabandara (TREL)	Table of contents
0.2	23.06.2010	Siva Subramani, Mahesh Sooriyabandara (TREL)	Initial structure and contents
0.3	28.06.2010	Siva Subramani, Mahesh Sooriyabandara (TREL)	Included contributions from IMEC, FT, Huawei, UKIM, RWTH and UPC.
1.0	30.06.2010	Janne Riihijärvi	Final integrated version compiled for delivery to the EC
1.0f	30.06.2010	Petri Mähönen	Coordinator review and approval

Contents

Glossary and Definitions

Term	Description
3GPP	3rd Generation Partnership Project
CMOS	Complementary metal-oxide semiconductor
CR	Cognitive Radio
DSA	Dynamic Spectrum Access
eICIC	Enhanced Intercell Interference Coordination
ETSI	European Telecommunications Standards Institute
FP7	7th Framework Programme
FT	France Telecom
HetNet	Heterogeneous Network
HWSE	Huawei Sweden
IMEC	Interuniversity Microelectronics Centre
IMT	International Mobile Telecommunications
LTE	Long Term Evolution
LTE-A	Long Term Evolution-Advanced
REM	Radio Environment Map
RRM	Radio Resource Management
SCC41	Standards Coordinating Committee 41
STREP	Specific Targeted Research Projects
SSE	Spectrum Sensing Engine
TREL	Toshiba Research Europe Limited
UKIM	University of St. Cyril and Methodius
UPC	Universitat Politecnica de Catalunya
WS	White Space

1 Introduction

The FARAMIR project is aimed at moving the state-of-the-art Cognitive Radio (CR) and Dynamic Spectrum Access (DSA) concepts to factual engineering. The main goal of the project is to research and develop techniques for increasing the radio environmental and spectral awareness of future wireless systems. The proposed holistic approach starts from the development of spectrum sensing hardware investigating how such functionality could be efficiently integrated to handheld devices. In the next step, we will combine measurements performed at multiple nodes in a cooperative fashion on a network level, not only to identify spectrum opportunities but also to localize any sources of primary transmissions or interference. This information will be fused to a radio environmental map, which provides the basis for system optimisation.

The consortium will also conduct extensive spectrum measurements at several locations in Europe to provide a valuable basis for spectrum modelling and increase the understanding how spectrum use changes in time, frequency, and space. The project will take a practical approach and prototype most of the project innovations showing their real-world value in radio resource optimisation.

FARAMIR is strongly committed to disseminate the research result and share the extensive spectrum measurements to the community to raise awareness about the capabilities and potential of cognitive radios among different groups of target audiences. This document describes how the project presents itself to different audiences and the strategies chosen for communicating with the target audience groups.

The research results will be published in the academic forums in the form of journal, magazine and conference articles. The general project outcomes, deliverables and publications will be made available through the project website. The website will also serve as a platform to showcase the extensive spectrum measurement results. The spectrum sensing hardware and prototype will be demonstrated in the major conferences, tradeshows and company organised events. Finally, the project will vigorously pursue standardization and liaison activities through selected standardization bodies (such as IEEE SCC41 [4], ETSI RRS [3], 3GPP [5] etc.,) to have significant impact. In addition to outlining the project objectives, this document will serve as a guide to the plans of the consortium towards addressing these different audiences.

2 Project Overview

FARAMIR is a 7th Framework Programme (FP7) STREP research project started in January 2010. FARAMIR has a budget of €5.37 million, including €3.46 million from European Commission. It has a project period of 30 months ending June 2012. FARAMIR project brings together a consortium of industrial, research, and academic partners with the specific expertise in academia and standardization necessary to achieve the objective. For additional information please refer to Appendix A - project factsheet.

The main goal of the FARAMIR project is to "*Develop radio-environment aware optimisation technologies for spectrum-aware future radio systems and architectures, and especially for enabling efficient spectrum sharing based on enhanced radio environmental knowledge.*"

The objectives of FARAMIR are closely related to key problems that need to be *urgently* solved in order to construct Cognitive Networked Systems that can be commercially exploited. More precisely:

- FARAMIR will develop a comprehensive technology chain and show how radio environmental information can be measured, collected, and represented efficiently employing Radio Environmental Map (REM) techniques.

- FARAMIR will conduct spectrum occupancy measurements in several European sites with different equipment and frequency bands to provide real-world data for the spectrum occupancy modelling community.

- The project will develop necessary data models, software and protocol frameworks for exchanging spectrum data, and studies the tradeoffs between exchanging a large amount of data and possible errors in the data modelling

- FARAMIR will develop new empirical spectrum occupancy models.

- The project will develop CMOS Spectrum Sensing Engine (SSE) prototype.

- FARAMIR will develop a novel "neighbourhood and direction of interference source" concept.

- FARAMIR will develop radio resource management concepts that significantly increase operational efficiency of both legacy and future networks

- FARAMIR will evaluate the developed spectrum sensing, REM and Cognitive Resource Management technologies in the context of full system models that provide both short- and long-term exploitation possibilities.

- FARAMIR will vigorously pursue standardization and liaison activities towards selected appropriate standardization bodies based on existing links.

2.1 *FARAMIR Work-plan and Methodology*

In this section we shall outline how the project will be executed to reach the objectives. The project is organised into seven work packages, following the high-level architecture illustrated in Figure 1.

WP1 is the management work package carrying out administrative work as well as technical project management, including management of IPR issues. The work package WP2 is responsible for the study of different possible system architectures and deployment scenarios that will be followed throughout the project lifetime. The three core research and development work packages are:

WP3 – Spectrum Sensing Concept and Empirical Models of Spectrum Use
WP4 – Cooperative Spectrum Sensing and Neighbourhood Mapping
WP5 – Resource Management for Adaptive and Flexible Spectrum Systems

The spectrum measurement campaigns and spectrum sensing prototype developments are critical to the success of the FARAMIR project and warrants having a prototype-specific work package, namely WP6 ("Prototyping and Field Testing").

Finally, work package WP7 ("Dissemination and Exploitation") is responsible for disseminating technical results and exploitation through standardization bodies.

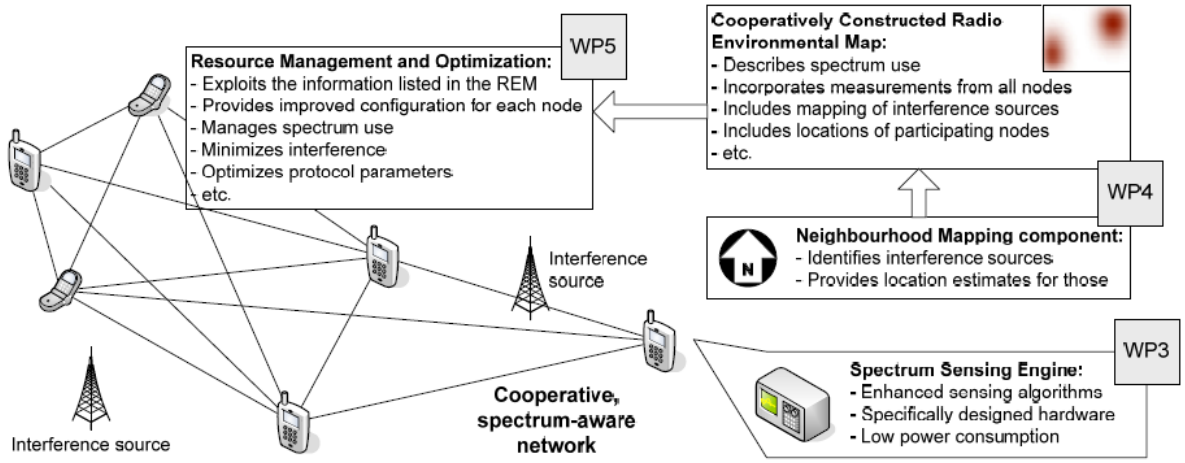

Figure 1: FARAMIR high-level architecture.

3 General Dissemination Strategy

FARAMIR is a focussed technical project with an objective to perform quality research in the domain of cognitive radio network and in making the technology become a reality. Hence the major dissemination strategy is towards scientific and industrial research community. The consortium is also actively directing the exploitation opportunities towards standardization bodies that are involved in standardizing dynamic spectrum access networks such as IEEE SCC41, ETSI RRS and 3GPP.

The FARAMIR project is committed to streamline its efforts towards dissemination following clear ground rules. In order to achieve maximum impact while efficiently using project resources, consortium will liaise with other projects in dissemination activities. The primary goal of the project presentation is towards the technical and research community, this warrants using most of our limited resources. The following dissemination strategy rules are thus followed:

1. FARAMIR project results will be communicated through best channels to achieve maximum impact. We would avoid unnecessary waste of resources on works that would not produce any results.

2. The primary dissemination route is technical presentations in the form of journal articles, magazines and conference papers which speaks volume of the FARAMIR project to the experts in the field.

3. Consortium would put in effort to disseminate project results to wider audiences including standardisation bodies.

4. As the spectrum measurement campaign results would benefit the community, appropriate channels would be created to present the data and results.

5. The goal is to make the make the work visible not only for outside technical community through research papers and other dissemination, but also to realise/implement them within our own organisations early on to prepare for later exploitation

4 Project Presentation Modalities

The consortium would present the project to different modalities such that it reaches wider community and will have significant impact.

4.1 *The project Portal for all different audiences*

The FARAMIR project has created a website (http://www.ict-faramir.eu) [1] that will serve as the portal to the external world. The portal is online from February 2010 (M2). The portal is implemented on a general Typo 3 content management platform enabling easy management and updating of the content therein. The webpage also hosts all the deliverables and general information about the project. Within limitations of copyrights, the publication articles will also be made available. A new professional logo is being designed by RWTH for FARAMIR to deliver a corporate image to the project.

In addition to the general information, deliverable and publications, the results of spectrum measurement and trials will also be made available on our web portal. The extensive spectrum occupancy measurement in the major European cities would attract wide audiences and serve for strategic purposes. The consortium would follow the open access paradigm to provide the spectrum measurements results to third parties.

4.2 *Scientific and Industrial Research Community*

The scientific and industrial research community is one of the primary target audiences to disseminate the research ideas and results that are carried out as a part of the FARAMIR project. The consortium plans to achieve this through presentations, scientific papers, and well targeted magazines.

Research publication is seen as the important method to increase visibility and credibility of FARAMIR project. The consortium members plan to publish the project results in competitive international conferences and journals. The paper presentations at the conferences attract the scientific community who are present to have a closer look on FARAMIR. Publications also create awareness about the project ideas and aid in disseminating the technical findings of the project to an international group of academic and industrial researchers.

IEEE journals, transactions and magazines expect rigorous and quality results and envisaged as a top quality route to reach wider scientific audience. Elsevier Physical Communication (PHYCOM) Journal is an international and archival journal providing complete coverage of all topics of interest to those involved in all aspects of physical layer communications. Theoretical research contributions presenting new techniques, concepts or analyses, applied contributions reporting on experiences and experiments, and tutorials are published.

Topics of interest include, among others, different FARAMIR related topics such as: Propagation and Channel Characterization; Cognitive Radio System Architectures; Platforms and Hardware Implementations for the Support of Cognitive, Cognitive Radio Resource Management and Dynamic Spectrum Sharing

In particular FARAMIR consortium is envisaging sending a tutorial paper on Cognitive Radio issues in the next fall 2010 issue.

One of the most important dissemination platforms towards the academic community is the IEEE DySPAN conference on dynamic spectrum access and related cognitive radio technologies, including radio environment maps. Over the past few years DySPAN has established itself as the premier conference on these topics, attracting all key figures active in these topics from both the academic community as well as industrial research groups. The next DySPAN at the time of writing will take place in Aachen, Germany, with the coordinator of FARAMIR acting as the general chair of the conference, and many of the other project partners from RWTH and other beneficiaries playing major roles in the organization of the conference. The project is aiming to have a significant presence in DySPAN 2011 (and, of course, in DySPAN 2012 as well) through several submissions of demonstrations and research papers.

Prototype demonstration is another presentation route to the scientific and industrial research community. The spectrum sensing engine (SSE) hardware prototype and spectrum occupancy measurement set up would be demonstrated in the upcoming IEEE DySPAN conference and ICT Future Networks and Mobile Summit.

Versatile spectrum sensing engines (SSE) are a key enabler to build the radio environmental maps envisioned in the FARAMIR project. A main target of IMEC is to develop and demonstrate such a CMOS Spectrum Sensing Prototype (SSE). The IEEE DySPAN demonstration track is chosen as dissemination channel. Currently, the plan for the 2011 DySPAN is to present an embedded sensing engine building on an SDR analog IC and a digital ASIP for synchronization and sensing, resulting in a hardware proof-of-concept of an embedded flexible spectrum sensing engine

In addition to SSE hardware prototype, FARAMIR technology will be demonstrated on an LTE-TDD platform which will integrate essential modules and enabling technologies that show a system's ability of dynamically using and managing spectrum, along with managing interference so as to achieve high performance and spectral efficiency.

4.3 *Standardization Committees and Industrial Relevance*

FARAMIR consortium recognises the importance of participating in standardization and industrial forums and is committed to be actively involved. With the vast technical expertise from TREL, FT and HWSE, the FARAMIR consortium will use a targeted approach for exploiting the long-term impact of FARAMIR results through standardization. However, as the overhead for standardization is high, and the processes are slow one has to carefully select where to participate in. There are two main approaches that have been followed, the first aiming at the standardization of reconfigurable radio systems within ETSI RRS. The second effort, in the context of the IEEE – SCC41 (Standards Coordination Committee 41 – Dynamic Spectrum Access Networks) [4], a standard for advanced spectrum management and management architectures. Industry relevant standards body 3GPP [5] is also being considered as a dissemination route and currently being investigated. Other standardization bodies working in related areas are IEEE 802.22, IEEE 802.11af, IEEE 802.19 and IEEE 802.21.

Several FARAMIR members are currently actively contributing to ETSI TC RRS on "Reconfigurable Radio Systems" [3]. ETSI TC RRS has taken the responsibility to study the feasibility of standardization activities related to RRS, encompassing radio solutions related to Software Defined Radio and Cognitive Radio research topics and to collect and define the related RRS requirements. The main tasks of TC RRS initially are to produce Technical Reports and feasibility studies taking into account the current, technically most advanced development.

The list of already published outcomes includes feasibility reports on the following topics: Mobile Device SDR Reference Architecture (TR 102 680), Reconfigurable Base Stations (TR 102 681, SDR status, implementation and costs aspects), Functional Architecture (TR 102 682), Cognitive Pilot Channel (TR 102 683) design, Cognitive Radio System Concept (TR 102 802), Potential regulatory

aspects of Cognitive Radio and Software Defined Radio systems (TR 102 803)and Standardization issues in the area of Software Defined Radio (TR 102 838).

The work of RRS is now becoming twofold:

1. Potential standardisation for White Space (WS) with a starting point within the broadcasting frequency bands:

- "Operation in White Space Frequency Bands" to investigate i) Operation of Cognitive Radio Systems in UHF White Space Frequency bands and ii) Methods for protecting the primary/incumbent users (TV broadcasts, wireless microphone transmissions)
- "Coexistence Architecture for Cognitive Radio Networks on UHF White Space Frequency Bands" to define system architecture for spectrum sharing and coexistence between multiple (potentially different) Cognitive Radio Networks.

2. More operator-oriented, a focus for Radio Systems operating in current and future licensed spectrums to identify concrete Use Cases with SDR/reconfigurability features (regarding GSM, UMTS and LTE/LTE-A) and derive appropriate systems requirements:

- “Use Cases definition for Reconfigurable Radio Systems (RRS) operating in IMT bands” to collect intra-operator network scenarios for which the spectrum resources are assigned to and managed by a single operator

From the standardization perspective, the scope of FARAMIR Project is in line with the topics addressed within the ETSI RRS. The FARAMIR presentation during the RRS TC meeting in Athens (May, 2010) revealed a real interest for the definition/operation of REM as defined in FARAMIR as well as for the characterisation of White Space opportunities which is key for the system requirements. Use cases and Scenarios, REM and WS description/characteristics are therefore a real potential for the FARAMIR dissemination towards ETSI TC RRS.

The consortium is currently considering participation in the IEEE Standards Coordinating Committee 41 (SCC41) that is involved in standardizing Dynamic Spectrum Access Networks. This standardization group focuses in the “areas of dynamic spectrum access, cognitive radio, interference management, coordination of wireless systems, advanced spectrum management, and policy languages for next generation radio systems”. The consortium actively involves in participating in the SCC41 through submitting technical proposals and participating in face-to-face meetings and teleconferences. Participating industrial members share the experiences and the trends observed in the SCC41 with the consortium members through discussions and presentations.

The consortium will carefully monitor the work in 3GPP so as to identify opportunities to disseminate results of the project into this standardization body. In networks with unbalanced transmit power nodes, sharing the same frequency, interference conditions are expected to change from location to location and from time to time. Coordination of control and data channel interference is important to maintain the downlink and uplink cell coverage and thus good data channel performance.

Therefore, a current work item in 3GPP Rel.10 is “Enhanced ICIC for non-CA based deployments of heterogeneous network for LTE” (“HetNet”), to be finished by June 2011. Its objectives are to 1) identify and evaluate *strategies of heterogeneous network deployments* (other than those based on carrier aggregation), and to determine the standardization work necessary to support *enhanced inter-cell interference coordination* solutions for control and data channels if need is identified, and 2) following completion of the above feasibility evaluation, specify suitable solutions considering *enhanced ICIC techniques* for control and data channel.

The prototype that demonstrates an online construction of the REM from spectrum measurements can be included in the bi-annual research exhibition of FT/Orange Labs, called as *Orange Labs Research Exhibition*. This event is a major dissemination of research activities of FT/Orange Labs with more than 50 demos and 10 lectures including panel sessions; about 1500 visitors and a dozen of groups of external visitors (customers, partners, subsidiaries, international research laboratories etc.). The research activities displayed during this big dissemination event are also visited by a dozen of organized tours for groups of policy makers of the FT/Orange Group and several members of the General Management Committee. Thales would be presenting the prototype in their annual *Thales Techno day* presenting the technologies to their employees and external visitors. TRL intends to showcase FARAMIR results to business divisions and potential business customers during Toshiba's annual R&D fair.

4.4 *Graduate and Undergraduate Students*

FARAMIR project aims to aid undergraduate and graduate students majoring telecommunications and wireless networking. It will provide real world data for spectrum occupancy and facilitate better understanding of the wireless spectrum usage phenomena. As a result, the students will be able to have a closer inspection in the actual wireless technologies and users' behaviour leveraging the gap between theoretical class work and practical field tests. Undergraduate students will use FARAMIR results to extend their theoretical knowledge about wireless systems and spectrum occupancy with practical results, whereas graduate students will be able to have real data for performing different analysis (e.g. cross-correlations, higher order statistics, curve fitting etc.) within their Master and Doctoral thesis. Furthermore, FARAMIR will assist the building of curricula for spectral measurements as students will be introduced to different measurement devices (from high-end signal analyzers to low-end spectral sensors) and different additional equipment (e.g. filters, antennas, switches, cables etc.) allowing them practical hands-on training. This will strengthen the wireless networking courses and enable the students to perform laboratory and field experiments and measurements. FARAMIR project's overall objectives will show the students how to better understand the engineering of a practical cognitive radio system and cognitive resource management within.

In the rest of this subsection, we shall briefly outline the activities targeting graduate and undergraduate students in the different partner organizations.

At RWTH the project will have direct link and influence on teaching activities. We have already initiated several thesis projects for Master students on topics directly related to the project. Our specific aim is to produce together with students original scientific results that can be published in conferences and journals with acknowledgments to FARAMIR. We are also encouraging as many graduate students as can be accommodated for working in the project to participate into joint work and meetings in order to have them gain wider knowledge on cognitive radio research and application, and on industrial collaboration as well.

In addition to thesis work, we are integrating selected components from our FARAMIR work to the lectures of our related advanced courses. Strongly influenced by FARAMIR, RWTH has introduced into the study program of Electrical Engineering (Communications Engineering Track) a specialized course in Cognitive Radio Technologies. For example the key part of FARAMIR-project, REMs, is already included into the course schedule, and we plan to update the course content and depth as FARAMIR results get deeper. RWTH is also modifying one of its practical laboratory courses towards SDR and CR technologies. Currently we plan to add similar or the same platform as used in FARAMIR research into these practical laboratories. In this way we will be feeding the real research relevance to M.Sc. level teaching, and there is also a feedback loop towards projects and industry by educating students with highly relevant skills.

During the last 15 years the Mobile Communication Research Group (MCRG-UPC) of UPC has considerably reinforced its technical background and expertise as well as its potential to carry out innovative research in mobile radio communications through its participation in more than fifteen European research projects as well as projects carried out in co-operation with national mobile operators. As a result, the MCRG-UPC has been able to support doctoral and post-doctoral research of a large number of engineers thus supplying the mobile communications sector in Spain with highly qualified engineers.

The topics covered in the FARAMIR project will be incorporated in the program of the Concentration Course **Advanced Mobile Communications,** which aims at providing an overview of the relevant characteristics of the new multimedia mobile communications systems, which are being currently deployed and designed.

The same course is also taught in the context of another Master, entitled "Master of Science in Information and Communication Technologies (MINT)" [2]. MINT is a Telecommunications Engineering International Master designed to prepare professionals highly qualified in the development and applications of information and communication technologies. This Master program is offered by the School of Telecommunications Engineering of Barcelona (Escola Tècnica Superior d'Enginyeria de Telecomunicació de Barcelona, ETSETB) of UPC, and it is addressed to students who want to receive a highly qualified education in the development and applications of information and communication technologies.

Next, the members of the MCRG-UPC team also participate actively in the Signal Theory and Communications Doctorate program (see http://doctorat.upc.edu/estudis/programa.php?idprog=276) of UPC. The program is structured in two phases. First of all the so-called "Taught stage" where the students shall follow a minimum of 60 ECTS credits identified for this purpose, either from a university master's degree associated with the doctoral program (for instance MERIT) or from the doctoral program itself. The second phase called "Research stage", consist in the enrolment for several thesis tutorials as well as the presentation of a thesis proposal, which must detail the research topic agreed between the student and the thesis supervisor. After the positive review from external reviewers, the student must defend the proposal in front of a panel of examiners comprising three teaching and research staff members in possession of PhDs designed by the Academic Committee. Once the student has passed this exam is able to start his research in order to prepare his Thesis document, which first of all is again reviewed by two external reviewers and when the observations of these reviewers have been resolved will be defended in front of a panel of five examiners.

In the last five years the members of the MCRG-UPC team have been advisors of 7 doctoral thesis deeply related to the topics addressed in the FARAMIR project (see http://www.tsc.upc.edu/grcm/en/start/research/tesis.html for details). In particular, currently three PhD theses are being carried out related with FARAMIR topics, specifically spectrum measurements and modelling, context acquisition based on spectrum sensing data and spectrum decision strategies based on primary pattern characterisation.

4.5 *General Material*

The consortium has created a set of slides and made available through the web portal. This will help all the partners to make quick demonstrations and talks on the FARAMIR project. It will also reach out to the university students and the public by summarizing the project reports in a few easy-to-read slides.

For more scientific and corporate purposes we use customized presentations. A short general summary of the FARAMIR project is produced for short presentations that can be used by partners.

One such presentation introducing FARAMIR project to ETSI RRS in Athens meeting in May 2010 is also made available.

A two page general flyer was produced for different meeting and EU concentration purposes; see Appendix A.

5 Conclusions

FARAMIR project aims to develop enabling technologies to realise cognitive wireless networks. The original philosophy is to fill the current gap in the knowledge and experience in practical cognitive radio systems, by demonstrating advance cognitive radio techniques in real and near-term deployment environments. To achieve this, firstly FARAMIR expects to use off-the-shelf equipments and already allocated frequency bands. Secondly, instead of focusing only on radio resource management, FARAMIR will consider the whole protocol stack empowering the various modules within a terminal and hence associated stakeholders including users, application developers, network operators etc.

The consortium is committed to make significant contribution to research knowledge and make cognitive radio to become factual engineering. Partners have identified numerous dissemination and exploitation avenues to realize this vision. Primary audience for FARAMIR will be the research and scientific community in academia and industry. They will be reached through publication and presentation in research results in relevant conferences, workshops and journals.

The project also intends to make the spectrum measurement results and hardware prototype of the developed technologies publically available for use by anyone. The motivation for this will be to promote wider adoption of open and standardized cognitive network frameworks as an evolutionary path to realise fully cognitive communication systems in the future. Consortium would raise awareness mainly through participation in industrial forums and collaboration with other research projects. The industrial partners are committed to exploit the technology by participating in relevant standardization such as IEEE SCC41, ETSI RRS and 3GPP.

Industrial members of the project are planning ways to exploit project results in their own products and services. With better visibility, and first hand know-how and knowledge, they are in a better position to use the FARAMIR technology in innovative ways. Further, they have identified importance of raising the profile of FARAMIR project within the wider industry since multi-vendor and/or multi-operator deployment scenarios are expected to be a common feature of many of future wireless systems.

Overall, consortium is fully committed to exploit the opportunities that will be created by the FARAMIR project. They have already identified the potential stakeholders and suitable strategies to maximize impact of FARAMIR in cognitive wireless networking research.

References

[1] http://www.ict-faramir.eu
[2] http://mastersuniversitaris.upc.edu/mint
[3] ETSI Reconfigurable Radio Systems http://www.etsi.org/website/technologies/RRS.aspx
[4] IEEE SCC41 Standards Coordination Committee for Dynamic Spectrum Access Networks http://www.scc41.org
[5] 3GPP LTE Advanced http://www.3gpp.org/LTE-Advanced

Appendix A FARAMIR Project Factsheet

The two-page project factsheet summarizes the FARAMIR project and is publicly available on the FARAMIR website [1] and has been disseminated in different EU and national meetings. Figure 2 and Figure 3 depicts the pages of the factsheet.

FP7 ICT Objective 1.1 The Network of the Future

FARAMIR

FARAMIR: Enabling Spectrum-Aware Radio Access for Cognitive Radios

The main goal of FARAMIR is to research and develop techniques for increasing the radio environmental and spectral awareness of future wireless systems. Holistic approach is taken in order to coverer technology development from spectrum sensing to spectrum use models and their application in network optimization.

At A Glance: FARAMIR

Flexible and spectrum-Aware Radio Access through Measurements and modelling In cognitive Radio systems

FARAMIR

A Cognitive Radio Project
Making Cognitive Radios Reality

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Duration: *January 2010 – June 2012*

Funding scheme: *STREP*

Total Cost: €5.37*m*

EC Contribution: €3.46*m*

Main Objectives

The next generation mobile radio technologies must be optimised better to exhibit cost, spectrum and energy efficiency. The previous decades long approach has been based on "generations game" (1G, 2G, 3G), where increasingly more complex standards with massive efforts have been developed.

FARAMIR moves the state of the art in cognitive radios from concepts to factual engineering science and business

Although this mainly air interface and standardization driven work has been successful so far it is starting to have problems due to diminishing return of investment. Recent measurements have also indicated that although spectral efficiency of many technologies is remarkably good, the spectrum itself is mostly under utilized. Moreover the reallocation of spectrum to different services or providers is a slow and cumbersome process because the interests of numerous stakeholders have to be considered and international coordination is required.

Recently cognitive radio (CR) and cognitive wireless network technologies have been proposed as a new paradigm to reduce management complexity, enabling heterogeneous networking, and as a technique to exploit spectrum more efficiently. This is achieved either through Dynamic Spectrum Access (DSA) or by employing other flexible and more optimal spectrum and resource allocation techniques.

FARAMIR-project is specifically designed to change this by moving the state of the art in CR and DSA **from "concepts and order of magnitude estimates" to the "factual engineering science and business by providing facts, field trials and *focused technology development*".** As a focused project FARAMIR has measurable and targeted technology goals, which have been chosen to provide a good science and exploitation basis both in the short- and long term. The overall goal of FARAMIR is to develop advanced and pragmatic sensing mechanisms, and enable their exploitation to increase the spectral efficiency of wireless systems.

European Commission
Information Society and Media

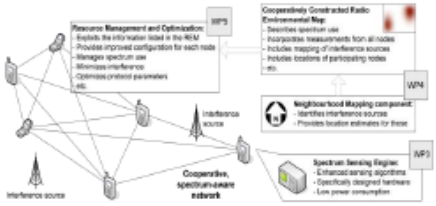
Figure 2: FARAMIR project factsheet (page 1).

Technical Approach

The work in FARAMIR is organized into following technical work packages.

WP2 develops the system architecture and reference, and studies in depth the possible use cases and scenarios for applications and prototyping. The main components include distributed spectrum sensing and spectrum management. The developed architecture will be extended to include hybrid networks that are able to support both cellular type of operations and ad-hoc type of operations. The system architecture will consider coordination between the different networks and elements that share the spectrum as well as the enabling elements and procedures. Moreover, it will take into account the required capabilities of the different types of radios and functional components such as sensing, databases, reconfigurability, decision-making, etc.

WP3 has two major thrust areas. One is the development of new spectrum sensing concepts and empirical models of spectrum use. The work package also coordinates and conducts several long-term measurement campaigns in different European countries. The work on spectrum sensing will consider algorithmic and implementation aspects. This integrated approach will guarantee practical relevance of the project. This work package will also develop new low-cost CMOS based spectrum sensing technologies that will be prototyped.



WP4 develops algorithms and protocols for cooperative spectrum sensing. In addition to coherent and energy detection approaches, feature detection techniques will be investigated. Moreover novel interference localization algorithms will be studied. We will also develop the required information models for the radio environment maps. We also make trade-off analysis, which takes in the account accuracy, costs of information exchange, data fusion algorithms and architectures complexity of cooperative sensing systems.

WP5 applies the project results to radio resource management (RRM) problems. Parameters necessary for the terminal to enable cognition and context-awareness for achieving near-optimal capacity and spectral efficiency will be analyzed and novel optimization techniques will be developed.

Finally, **WP6** integrates the outcomes of the technical work of other work packages, and will develop prototype implementations that will be extensively tested and verified in field trials.

Key Issues

The core task of the project is the development of functional and realistic reference architecture for cognitive radio networks that utilize radio environment maps (REM). We apply the developed architecture and REMs to develop novel optimization technologies for future radio systems. FARAMIR will develop a comprehensive technology chain for this and will show how radio environmental information can be measured, collected, and represented efficiently.

Consortium

The consortium consists of ten partners from nine different countries. The participants have a proven track record on research and many of its partners have been the first movers in the domain of cognitive radios. The consortium is also striking a strong balance between academia, industry and regulators. The partners are well connected not only in the research community but also have strong contacts to standardization groups.

Expected Impact

Apart of building core-scientific competence for European academic and industrial partners we actively seek to apply methods and developed techniques to products and standardisation process. The project aims to enhancing the competitiveness of European industry in the area of *wireless devices, networks and new applications,* specifically by innovating better radio and spectrum optimisation methods, adding intelligence and machine-learning capabilities to RRM and REM modules. FARAMIR is also strengthening of the Information Society by providing technologies that *ensure affordable, robust and resource-friendly wireless access methods* towards information sources.

Developed tools and methodologies will be published. The project will also distribute most of the data that is generated by spectrum measurement campaigns. This open dissemination of the results and tools is expected to influence cognitive radio networks community and other project. The FARAMIR partners will also actively contribute to the appropriate standardisation.

FARAMIR
January 2010

Figure 3: FARAMIR project factsheet (page 2).