FARAMIR
Mapping Your Radio Environment

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

FARAMIR

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Final Plan for the Use and Dissemination of Foreground

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Editor:	Tim Farnham, Siva Subramani (TREL)
Authors:	Petri Mähönen (RWTH), Janne Riihijärvi (RWTH), Liljana Gavrilovska (UKIM), Mahesh Sooriyabandara (TREL), Jaap van de Beek (HWSE), Iaonnis Dagres (IASA), Andreas Zalonis (IASA), Andreas Polydoros (IASA), Berna Sayrac (FT), Pascal Cordier (FT), Jordi Perez Romero (UPC), Lorenzo Iacobelli (TCS), Antoine Dejonghe (IMEC), Peter Van Wesemael (IMEC).
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Abstract:

This document describes the project partners' dissemination and exploitation plans. The project consortium is committed to disseminate the research results and exploit the technologies developed in the project. This document describes the partners' plans to pursue extensive exploitation after the end of the FARAMIR project.

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1 Introduction

This document describes the project partners' dissemination and exploitation plans. The project consortium is committed to disseminate the research results and exploit the technologies developed in the project. This document describes the partners' plans to pursue extensive exploitation after the end of the FARAMIR project.

The technical objective of FARAMIR was to research and develop technologies for increasing environmental awareness in wireless networks through radio environment map technologies. In addition to fulfilling the technical objectives, the FARAMIR consortium members will be remaining motivated and committed to disseminate the research results and exchange ideas with the community to raise awareness about the capabilities and potential of radio environment maps in operations and management of future wireless networks.

During the project the consortium members jointly and individually have been working to meet this objective by disseminating FARAMIR results and vision through research publications, standardization participation and collaboration with external projects. The achieved dissemination results are reported in other deliverables, most notably in D7.3 and the second management report D1.2. In this deliverable we will focus to give shortly the future plans for use and dissemination of FARAMIR results.

This document focuses on general use and dissemination plans as consortium public document. Consortium members may have also internal exploitation plans through use and dissemination. Each member of the consortium is naturally available for more detailed and confidential discussions with evaluators and European Commission.

The rest of this report is organised as follows. Section 2 discusses joint consortium plans for use and dissemination of FARAMIR results. Section 3 provides individual partner plans. Finally, Section 4 concludes this report by summarising overall use and dissemination plans.

2 Joint Dissemination and Exploitation Plans

2.1 Dissemination Towards Research Projects

The main FP7 project that has been identified to benefit from FARAMIR results is the NoE ACROPOLIS. We intend to promote the FARAMIR results to other projects through individual contacts and common project partners. Moreover, the consortium members are committed to disseminate FARAMIR results towards ongoing and future national projects and research initiatives.

The web page and through that the public deliverables will be kept alive for at least two years, most likely even longer period, and through this we ensure that the results achieved by FARAMIR are freely available for forthcoming and existing EU projects. The coordinator stays committed to answer to possible queries from other projects. Additionally, the spectrum measurements repository developed in the project will be kept online until the foreseeable future by the coordinate to ensure widespread access to the results gathered during the project.

2.2 Standardization Plans

The project partners are committed to continue to monitor the relevant developments in different standardization communities, as well as to continue to make standards contributions from the relevant FARAMIR work and related follow-up activities. The project has already been very active in ETSI RRS and in NGMN as discussed in more detail in deliverable D7.3. The project members are also actively participating to IEEE DySPAN-SC as well as 3GPP as discussed in more detail below.

TREL are one of the early members of IEEE DySPAN-SC (formerly known as IEEE SCC41) and have been actively contributing to several working groups, including the published standards IEEE 1900.4-2011 and IEEE 1900.4a-2012 standards.

TREL will continue monitoring the developments in P1900.7 particularly the TV white space and potential interfaces with REM and also the activities in P1900.6a towards contributing to specifications for the exchange of sensing related between the data archive and other data sources. However, as a result of the deployment considerations (reported in Deliverable D2.4), TREL have identified interfaces and critical data models in the IEEE DySPAN-SC standards, particularly 1900.4a, and 1900.6a that can be used for supporting REM functionality without modification. Hence, much of the FARAMIR solution approach can already be implemented using these standards and this will be evaluated further by TREL.

Having highlighted that DySPAN-SC standards can be used to support FARAMIR solutions in certain deployment scenarios, TREL also recognise that the standards may not be universally accepted on a global scale or for all deployment scenarios, and so other standards are required. In fact the FARAMIR solution approach is sufficiently flexible to exploit several standardised approaches for measurement collection and representation of REM data. Hence reliance on any single standard is not necessary.

Regarding 3GPP, HWSE plans to vividly pursue the participation to 3GPP's standardization activities. After the FARAMIR project has finished, we will continue to contribute to the standardization process, mainly in working groups RAN WG1/WG2/WG3.

In particular, we will closely continue to monitor any developments related to the creation, manipulation, signalling and use of radio environmental maps or related database/measuring concepts. We will continue to disseminate the importance of these concepts for the efficient operation of future cellular networks, both in informal contacts with other companies' delegates to these working groups, and in formal contributions to the meetings. We will also be alert on any indications/changes in the general 'climate' related to the acceptance of the REM concepts such that we can rapidly anticipate with well-prepared technical contributions when the time is ripe, in order to further capitalize on the work and the IPR protected within the FARAMIR project.

2.3 Prototype and Demonstrations plans

Also the developed prototypes play a key role in the overall dissemination and exploitation plans within the consortium. For example, UKIM plans to extend the REM backend technology in several directions:

- Support for additional Measurement Capable Devices (MCDs) and support for other spectrum sensing techniques (other than energy detection);
- Support for increased radio environmental awareness by extending the REM Manager with additional functionalities such as multiple and moving transmitter(s)' localization;
- Support for distributed database organization and distributed radio environment information storage;
- Support for extensive historical spectrum occupancy analysis.

Also, UKIM plans to integrate its REM architecture with the previously developed policy system (within the FP7 funded ARAGORN project) in order to provide a comprehensive autonomous self-x technology for future flexible wireless systems.

RWTH has also prepared new REM manager modules with strong dissemination and exploitation potential. The focus on these developments has been especially on scalability towards very large data sets, such as potentially arising in application related to minimization of drive tests (MDT) in 3GPP. First demonstration of these prototype components will take place in IEEE DySPAN 2012, and further exploitation and extension of the work is planned as well.

The enhancements of the REM backend technology will be used for establishing contacts with international telecom vendors and operators, local telecom operators as well as international academia partners in order to establish the FARAMIR-conceived technology and use it for future possible cooperation. Additionally, every opportunity of disseminating the prototype at international and local events will be used as UKIM's team designed and developed the FARAMIR's REM backend in a manner that allows easy transportation and quick setup on various locations.

3 Individual Partner Dissemination and Exploitation Plans

In this section we describe the individual dissemination and exploitation plans of the project partners.

3.1 RWTH

During the FARAMIR project, the RWTH Aachen team has gained expertise in different domains and in particular spatial and time-domain estimation and modeling problems for spectrum use, current operations and management problems in cellular and femtocell networks, propagation analysis and modeling, importance of model robustness for radio resource management problems, understanding the structure and impact of modeling error on resource management and performance evaluation, and usage of modern database technologies for storage and analysis of spatio-temporal data. This expertise gained in the project will be exploited to investigate new dimensions of wireless communications problems. In addition, the acquired expertise from FARAMIR will be used in order to develop new courses and projects for the students.

In the research domain, we have already started to exploit the results of FARAMIR in ongoing and upcoming projects related to cognitive radio and dynamic spectrum access. For example, we have collaborated and interacted with several partners in the FP7 ACROPOLIS project on diverse topics, such as on spectrum measurements, storage and reasoning on spectrum usage data, and propagation modeling. RWTH is also continuing to develop REM estimation and storage technologies further in internal projects. A part of this research thrust area is to increase efficiency and architectural stability of REM solutions towards levels that could be exploited commercially. In this domain RWTH is also entering to the pre study phase of possible spin off company formation. The pre study phase includes a closer evaluation of the commercial potential and meetings with dedicated risk financing companies that we have worked successfully with in earlier occasions.

The members of FARAMIR team from RWTH are also discussing about possibility to contribute, or even joining up, to the due diligence and business planning process of a possible spin-off company that is planned by QUASAR-term of RWTH. The most likely contributions would be coming from the developed software technology, and spatial spectrum occupancy statistic algorithms specifically, and the built expertise in the project in general.

We are also planning to prepare new proposals for next EC calls to exploit further the REM concepts and especially their application towards cellular networks that were developed in the project.

RWTH has already provided the traces for the extensive measurement campaign that was performed by the University for public download from http://download.mobnets.rwth-aachen.de. These traces showed interesting characteristics of spectrum patterns and are already used by several research groups to study the performance of DSA algorithms. Based on our gained expertise in spectrum measurement and modelling, including indoor measurements and study the spatiotemporal correlation of the propagation losses, we have developed new and highly effective

techniques for coverage estimation problems and stochastic resource management approaches based on time-domain models of spectrum use. We are planning to exploit these technologies extensive in future research projects.

Finally, we are planning to continue to disseminate the work of FARAMIR in journals, conferences and different meetings.

There are a number of research papers in the submission phase and we are writing several continuation articles that are strongly based on our FARAMIR results or build upon the gained expertise. In this avenue we expect that dissemination continues at least for full year ahead after the end of the project.

In teaching domain, we have recently incorporated cognitive radio and SDR concepts into a new graduate level course "Principles and Architectures of Cognitive Radios" and laboratories. The course was redesigned in 2012 and we were heavily using FARAMIR final results and demonstrations as a part of course material. The work in FARAMIR is also exploited by our PhD and Master students focusing on characterizing spectrum and radio environment, as well as radio resource management problems.

3.2 IMEC

Imec has extensive experience in cooperation with top-tier industry partners in shared research programs. Results from the FARAMIR project, and in particular the developed sensing engine, will be reused in different research initiatives for evaluation, development, demonstration etc. These topics are part of programs with both industrial partners as academic partners such as universities. Results will also be presented by means of different papers and articles and presentations at top rated international conferences.

More specifically, the key results from the FARAMIR project will be included in imec's IP portfolio and will be exploited through:

- Bilateral contracts with national and international industry and universities,
- IMEC 's Industrial Affiliation Program (IIAP)' partnerships; and
- Technology transfers and licensing of proven technology to industry and spinoff companies.

The imec sensing engine has also been integrated into the IBBT iLab.t technology centre, which offers the experimentation environments, the hardware, the measurement equipment and the software tools needed to develop ICT innovations, and/or test their performance and service quality and the benefit associate with the new sensing techniques.

3.3 UPC

The participation in FARAMIR project has opened to UPC a new research perspective in a strategic field of future technology of the telecommunications disciplines and related market applications. Since UPC is not a commercial organisation, the main use of the results and hands-on experiences

obtained in the project is in shaping and updating the educational programs. Nevertheless, FARAMIR results allow UPC continuing to carry out advanced research and training, under the framework of R&D programmes either public or private and consultancy and transfer of technology to industrial partners through the establishment of new R&D contracts.

UPC also plans to exploit the measurement database and associated behavioral models in the different bands that have been obtained in the framework of FARAMIR for continuing research in the area of cognitive radio.

3.4 HWSE

HWSE plans to vividly pursue the participation to 3GPP's standardization activities. After the FARAMIR project has finished, we will continue to contribute to the standardization process, mainly in working groups RAN WG1/WG2/WG3. In particular, we will closely continue to monitor any developments related to the creation, manipulation, signalling and use of radio environmental maps (REMs), or related database/measuring concepts. We will continue to disseminate the importance of these concepts for the efficient operation of future cellular networks, both in informal contacts with other companies' delegates to these working groups, and in formal contributions to the meetings. We will also be alert on any indications/changes in the general 'climate' related to the acceptance of the REM concepts such that we can rapidly anticipate with well-prepared technical contributions when the time is ripe, in order to further capitalize on the work and the IPR protected within the FARAMIR project.

Huawei will also continue its participation in ETSI RSS WG1 either through direct participation in the meetings or, alternatively, through influencing internal contact with colleagues in Huawei China. Also here, HWSE will continue to stress the importance of the radio environmental map (REM) and related concepts.

HWSE plans to continue prototyping related to the operation of future cellular networks in TV white space spectrum. The LTE radio front-end prototype we have developed and integrated in FARAMIR will likely be upgraded to a second generation prototype with extended functionality and closer to actual commercialisation of the conceptual solution.

Furthermore, HWSE will include the REM concept, along with the anticipated dense deployment and presence of radio sensors, in its upcoming concepts for future cellular radio networks.

Finally, based on the many fruitful experiences in FARAMIR and the valuable technical outcomes, HWSE plans to continue intensive participation in suitable future European collaborative research projects, in particular those where a network's environmental awareness is put in focus, to the benefit of its operational efficiency (in terms of cost, energy and spectrum).

3.5 TREL

TREL will continue its exploitation strategy of demonstrating the REM approaches developed within FARAMIR at key events. This approach is essential in gaining sufficient credibility and

momentum to facilitate commercial exploitation. The next event will be the Toshiba Research and Development Centre Fair in November 2012, which is held in Tokyo Japan. Subsequent events will also be sought to further the exploitation and commercialisation possibilities for REM based systems, particularly for future small cell related solutions.

For longer term exploitation, TREL will continue to track the progress within related standards, regulatory and industry groups in order to determine other commercial deployment possibilities for REM based solutions. For instance, within TV white space exploitation or other opportunistic radio resource sharing scenarios.

TREL have now built up a major capability in REM based solution standards, demonstrations and expertise that will be exploited in future research projects and technology transfers. This will included forthcoming EU FP7 projects such as ICeWater (ICT Solutions for Efficient Water Resources Management) and DIWINE (Dense Cooperative Wireless Cloud Network), that TREL are involved in, which will bring novel solution approaches to wireless sensor systems for water utilities, industrial and smart city scenarios. These new approaches will build on the ideas and solutions developed in FARAMIR.

3.6 IASA

IASA team continues the work in the research fields of radio source localization and cognitive resource allocation. The outcomes of these efforts will be mainly disseminated through submission of papers to technical conferences and workshops, and/or selected journals in field. Furthermore, IASA will pursue the practical exploitation of the developed results in cooperation with the industrial partners of the project.

IASA's work on ***multi-source*** localization in log-normal fading addresses a very important and difficult topic that affects a variety of scenarios. For example, with the capability to sense and record radio activity in the surrounding environment, Cognitive Radio systems (e.g., IEEE 802.19 and 802.22) can efficiently plan, decide upon and then execute the appropriate actions. The operators will be able to improve network operation and traffic management, while the regulators will be able detect and locate malicious and non-licensed spectrum users. The key characteristic in the proposed algorithm is the low complexity, which make it implementable. The complexity grows *only linearly* with the number of sources, a major advantage in comparison with the full-blown Maximum Likelihood approach. Furthermore, the accuracy of the algorithm was assessed both via simulation and via real experiments. Both these characteristics make this work a candidate for direct implementation into a real system. This possibility will be exploited with the cooperation of the industrial partners of the consortium. Additionally, a patent application is under consideration.

IASA's work on Interference management in two-tier networks with femtocells will be expanded to cover a larger variety of heterogeneous networks (HetNets) scenarios. IASA is currently working on new distributed resource allocation techniques for scenarios that include small cells (femtocells, picocells, metrocells, and microcells). All the outcomes of the Faramir project will be taken into

consideration in this effort. For example the Radio Environment Map (REM) related context information will be exploited, and the accuracy of the developed sensing and localization techniques will be used in the design of novel robust context-aware optimization algorithms. IASA plans to continue the cooperation with the industrial partners in this framework, targeting in pragmatic solutions for next generation (multi-tier, HetNets) cellular networks.

IASA is also working together with UKIM in the exploitation of WP4 and WP6 related research results. A joint proposal to FP7-CREW (Cognitive Radio Experimentation World) project is under preparation. The main target of CREW is to establish an open federated test platform, which facilitates experimentally-driven research on advanced spectrum sensing, cognitive radio and cognitive networking strategies. In this framework, external experimenters are able to use the CREW infrastructure for their experiments in the field of cognitive radio and/or cognitive networking. IASA and UKIM plan to participate in the second Open Call in October 2012. This proposal, if successful, will benefit the Faramir project visibility since it will disseminate the project results in an active research community in the field. Furthermore, the two institutions will have the opportunity to get funding to continue their Faramir-related work and produce new novel results.

IASA's participation in two Network of Excellences, the ACROPOLIS (Advanced coexistence technologies for radio optimization in licensed and unlicensed spectrum) and the NEWCOM# (Network of Excellence in Wireless COMmunications #), will be used for the dissemination of the outcomes of the Faramir project and of the Faramir-inspired future research activities

3.7 TCS

The exploitation of FARAMIR results after the end of the project will basically consist in tight collaboration with teams in charge of developing products to share the acquired experience and to adapt the algorithms conceived and developed during the project to be compliant to product requirements. Some collaborations are already established and discussions are on-going on the possibility to include FARAMIR concepts in the road map of future products development.

Further dissemination activities and demonstrations of the obtained results will be held in the future months throughout internal presentations and probably the participation to the Thales techno days in order to increase the visibility of the obtained results in the optic of future implementation of FARAMIR concepts in commercial products (i.e. PMR radios).

3.8 UKIM

UKIM's involvement in FARAMIR resulted in substantial expertise acquired in the field of practical development of radio environmentally aware solutions, spectrum measurements, modelling of spectrum usage, design of advanced spectrum sensing solutions, reliability of spatial interpolation techniques and transmitters' localization algorithms. Stemming from these, UKIM's future dissemination and exploitation plans will focus on:

- Preparation of the results for submission in journals and/or magazines (this will ensure greater visibility of FARAMIR's system concepts);

- Exploiting the benefits of the developed REM architecture in various scenarios;
- Upgrading the REM architecture with more capabilities (e.g. learning mechanisms, connections with a policy system etc.);
- Development of novel techniques for radio environment prediction (apart from spatial interpolation) and transmitter(s)' localization;
- Conduction of distributed spectrum measurements and spectrum measurements campaigns in various bands of interest (the necessary prerequisites were already acquired throughout FARAMIR's duration);
- Continuous contacts with local regulators and operators introducing the benefits of the REM system and the radio awareness in general;
- Contacts with international industry partners and standardization bodies for project's results exploitation and possible inclusion in products/standards;
- Public dissemination (e.g. a 1-day workshop) at UKIM for interested parties.

Also, UKIM plans to extend its knowledge and developed systems by using them as a basis for increased participation in future FP7 projects.

Finally, UKIM plans to use the knowledge and the expertise from FARAMIR for enhancing its curricula in wireless communications

3.9 FT

FT plans to use/exploit the work/outcome of FARAMIR in developing ways/tools/means of geo-located measurement use to ease network operations and to decrease operational expenditures.

As one of the leading mobile operators of Europe, FT/Orange has to confront the exponentially increasing wireless broadband data traffic in the upcoming years. Operating and managing the increasingly complex and heterogeneous mobile networks together with the competitive market conditions and flat rates add up to those challenges. In such conditions, decreasing operational expenses become of vital importance for the mobile operators. One of the most prominent ways for such a decrease is to automate expensive network operation and management tasks. A prominent example is the recently emerging trend to use geo-located user terminal measurements to minimize the number of drive tests. Drive tests consist of sending out vehicles with specialized equipment and expert team to collect thorough measurements on the identified geographical zone for purposes such as troubleshooting, optimization, QoS verification etc. Drive Tests is one of the most expensive tasks in network operation and therefore decreasing the need to perform manual drive tests has the potential to provide substantial savings for the operators.

This is why 3GPP has launched a feature called as Minimization of Drive Tests (MDT) in Rel.10 [3GPP TS 37.320 Universal Terrestrial Radio Access (UTRA) and Evolved Universal Terrestrial Radio Access (E-UTRA); Radio measurement collection for Minimization of Drive Tests (MDT); Overall description; Stage 2], a feature that has witnessed a tremendous momentum/interest in the community and an incredibly short time-to-market. Due to the foreseen considerable savings provided by MDT, operators have identified a clear benefit in MDT and therefore are in favour of having MDT features

in vendors' product releases as soon as possible. MDT provides a standardized measurement framework for the collection of geo-localized measurements from the user terminals under operator control, i.e., the operator determines how, when and where to make/report measurements. Besides, MDT can provide measurements in indoor environments where a significant amount of the traffic (80%) lies and which are inaccessible to the drive tests. MDT measurements are collected at the operator's OSS to be processed by the operator for troubleshooting, optimization purposes.

FARAMIR work on intra-operator REMs perfectly fits into this picture by providing solutions on how to use these MDT measurements to construct REMs. In other words, MDT provides a standardized framework for the collection of geo-located measurements for intra-operator REM-based network operations. Particularly, the intra-operator femtocell scenario, through the architecture work and the prototype/demonstrator, has been a concrete showcase of the possibility of future MDT-based network optimization for FT.

To sum up, FT plans to use FARAMIR work in developing REM-based solutions which use MDT data as an efficient means to reduce its operational expenses; and to pursue further innovative paths in this promising area of future "environment-aware" network operations

3.10 BNetzA

As a governmental regulatory organization and an unfinanced partner BNetzA does not have a similar specific and strict dissemination and exploitation plans for FARAMIR results as other partners. The participation and the use of information from FARAMIR are fully in the line of the general duties and planning of BNetzA as a regulatory agency.

BNetzA will utilize the experiences gained from the project as part of its work on cognitive radio related regulatory issues, and will benefit from discussions with the industrial and academic partners as well as from the outcomes of the measurement campaigns in the form of increased understanding of the issues related to dynamic spectrum use and especially database driven approaches to spectrum sharing. The main exploitation and benefits for BNetzA are to disseminate the regulatory realism and information towards other partners and through the project to European Community, and gaining information from and cooperating with the FARAMIR partners to understand better the development of cognitive radio technologies and thus being prepared for any possible challenges that may or may not require regulatory changes. It should be also noted that the development of REM database technologies and conducted measurement have a direct value for BNetzA as these are a part of operational activities of BNetzA already in different context. Any specific exploitation or considerations in the regulatory changes domain cannot be commented due to obvious governmental confidentiality rules.

4 Conclusions

In this document we have discussed the plans of the consortium to exploit the technologies developed under FARAMIR framework, as well as for future dissemination activities. The members of the consortium have gained considerable expertise in a number of different domains from spectrum sensing to technological foundations of the different components of the REM architecture. This expertise gained in the project will be exploited to investigate new dimensions of wireless communications problems in the contexts of exploitation within the industrial partners, new projects, and academic dissemination. The academic partners will also use their expertise to develop new courses that introduce the new concepts to the students and thus strengthening the competences of the future European engineers and researchers in the field.

The FARAMIR consortium has also already played a vital role in refining and developing some of the standards. The partners have identified several working groups in respective standards and contributed extensively. As the standardization process effort requires consensus building, the partners are committed to pursue this effort further. For instance, HWSE has identified several work items relating to MDT in 3GPP RAN2 and planned to pursue even after the project. In IEEE DySPAN-SC, TREL has identified interfaces and critical data models, particularly 1900.4a, and 1900.6a that can be used for supporting REM functionality without modification. TREL will continue monitoring the developments in P1900.7 particularly the TV white space and potential interfaces with REM and also the activities in P1900.6a towards contributing to specifications for the exchange of sensing related between the data archive and other data sources.

The prototype development activities have been one of the key highlights of the project. Several successful demonstrations in high profile events ranging from scientific conferences to company research exhibitions have gained significant attention to the work. The existing prototypes showcased in these demonstrations also form a solid foundation for future research, dissemination, and exploitation activities. Several partners are already proceeding to develop individual prototype components further, and to use them as foundations for future research and experimentation. Finally, several unique measurement data sets have been obtained in the dedicated measurement activities within the project, as well as during experimentation with the integrated prototypes. These data sets form a powerful resource for future study both by the consortium members, as well as for dissemination of project results through sharing of these data sets with the research community.

In summary, the consortium will work after the end of FARAMIR to use the concepts and results of the projects in different industrial and academic contexts and make them available for other EU projects and the research community in order to contribute in the evolution of future wireless communications.

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