European Cooperation in the field of Scientific and Technical Research - COST -

Secretariat

Brussels, 11 June 2009

COST 236/09

MEMORANDUM OF UNDERSTANDING

Subject :	Memorandum of Understanding for the implementation of a European Concerted Research Action designated as COST Action IC0902: Cognitive Radio and Networking for Cooperative Coexistence of Heterogeneous Wireless Networks

Delegations will find attached the Memorandum of Understanding for COST Action IC0902 as approved by the COST Committee of Senior Officials (CSO) at its 174th meeting on 26-27 May 2009.

MEMORANDUM OF UNDERSTANDING

For the implementation of a European Concerted Research Action designated as

COST Action IC0902

COGNITIVE RADIO AND NETWORKING FOR COOPERATIVE COEXISTENCE OF HETEROGENEOUS WIRELESS NETWORKS

The Parties to this Memorandum of Understanding, declaring their common intention to participate in the concerted Action referred to above and described in the technical Annex to the Memorandum, have reached the following understanding:

1. The Action will be carried out in accordance with the provisions of document COST 270/07 "Rules and Procedures for Implementing COST Actions", or in any new document amending or replacing it, the contents of which the Parties are fully aware of.

2. The main objective of the Action is to integrate the cognitive concept across all layers of communication systems, resulting in the definition of a European platform for cognitive radio and networks.

3. The economic dimension of the activities carried out under the Action has been estimated, on the basis of information available during the planning of the Action, at EUR 44 million in 2009 prices.

4. The Memorandum of Understanding will take effect on being accepted by at least five Parties.

5. The Memorandum of Understanding will remain in force for a period of 4 years, calculated from the date of the first meeting of the Management Committee, unless the duration of the Action is modified according to the provisions of Chapter V of the document referred to in Point 1 above.

A. ABSTRACT AND KEYWORDS

This Action will coordinate research in the field of cognitive radio and networks. The cognitive concept applies to coexistence between heterogeneous wireless networks, that share the electromagnetic spectrum for maximum efficiency in resource management. Several efforts are currently in place in European research centres and consortia to introduce cognitive mechanisms at different layers of the communication protocol stack. This Action goes beyond the above trend by integrating the cognitive concept across all layers of system architecture, in view of joint optimization of link adaptation based on spectrum sensing, resource allocation, and selection between multiple networks, including underlay technologies.

The cross-layer approach will provide a new perspective in the design of cognitive systems, based on a global optimization process, that integrates existing cognitive radio projects, thanks to the merge of a wide-range of expertise, from hardware to applications, provided by over 30 academic and industrial partners.

The final result will be the definition of a European platform for cognitive radio and networks. To reach this goal, algorithms and protocols for all layers of the communications stack will be designed, and a set of standard interfaces as well as a common reference language for interaction between cognitive network nodes will be defined.
Keywords: Cognitive radio and networks, Coexistence, Spectrum sharing, Flexible spectrum use, Context awareness

B. BACKGROUND

B.1 General background

Contemporary wireless system design must typically incorporate increased bandwidth requirements due to the persistent trend for higher wireless multimedia data rates. Increased bandwidth can be achieved by developing efficient strategies for spectrum management, that include spectrum sharing, coexistence, and cooperation among different wireless networks. This approach has been

widely recognized by standardization and regulation bodies in Europe as well as worldwide. As a matter of fact, the International Telecommunications Union (ITU) has indicated that a flexible approach to spectrum sharing, ranging from liberalization to spectrum trading among different systems and operators, will be a priority issue for the deployment of future wireless systems (ITU New Initiatives, Workshop on "The Regulatory Environment for Future Multimedia Services", Mainz, Germany, June 2006.). This trend gave rise to the IMT-Advanced specification defined by ITU, that is addressed within the Institute of Electrical and Electronics Engineers (IEEE) by the 802.16 Task Group m. The IMT-Advanced specification is characterized by a large bandwidth (over 100 MHz), targeting data rates up to 1 Gb/s, whereby an ultimate goal is to guarantee seamless connectivity to the mobile user (ITU-R Rec. M.1645, "Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000", 2003.), (IEEE 802.16 TGm, http://wirelessman.org/tgm). In a parallel effort towards increased efficiency in spectrum usage, the IEEE Standards Coordinating Committee 41 on Dynamic Spectrum Access Networks is currently focusing on the development of new standards, able to provide improved flexibility in access mechanisms (IEEE SCC41, http://www.scc41.org). The introduction of new technologies, such as Ultra Wide Band (UWB), allowing for underlay systems to silently coexist with primary systems is an additional driving force towards the introduction of novel strategies for spectrum management. Within this context, the cognitive radio concept provides a potential solution for the coexistence of unlicensed secondary with primary licensed systems (J. Mitola, G.Q. Maguire, "Cognitive radio: Making software radios more personal", IEEE Personal Communications, Volume 6, Issue 4, pp. 13–18, April 1999).

Significant research efforts that focus on flexibility in spectrum management are currently underway in Europe and worldwide, as detailed in Section B.2, and resources for research on specific aspects of cognitive communication systems are in most cases already in place. Coordination between research teams and organizations is, however, still lacking, leading to potential duplication of work, and overall inefficient use of research funding. This Action will provide a perfect framework for coordinating and harmonizing research activities on cognitive communication systems, by defining a global vision for cognitive radio and networking, and by allowing stronger interaction and integration between partners and projects working on specific aspects of cognitive radio and flexible spectrum access.

The COST program offers the appropriate framework for the Action, given that the primary aim of the COST program is to favour networking. This is particularly important for a research topic such as the one addressed by the Action, that is interdisciplinary in nature. Innovative research and design can be generated by bringing together the competence of experts of different fields; the Action will, indeeed, integrate the cognitive concept across all layers of the system architecture, and this can only be achieved by creating a joint effort of telecommunications, computer sciences, and electronics communities. Researchers in these fields have little chance to get together and merge efforts towards creative thinking in traditional meetings, such as conferences, since these are rarely interdisciplinary. The cross-layer approach proposed in the Action can be pursued only where a unified framework for interaction were created. There is no existing COST Action that addresses the topic addressed, nor other instrument that can provide this framework. The COST program therefore offers a unique opportunity within which the proposed innovations may find their natural promotion and development.

The Action aims at becoming the reference point for interaction and cooperation between research groups working on cognitive radio and networks. Projects and partners joining the Action would therefore have the chance to interact with experts working on similar topics and related aspects of cognitive systems, with direct benefits on research quality as well as scientific and industrial advances. As an added value, graduate students and young researchers would have direct access to up-to-date research results, and the possibility to interact with experienced researchers from all over the world, with an obvious beneficial effect on their scientific skills and professional experience.

B.2 Current state of knowledge

Efficiency in spectrum access and efficient resource allocation management has recently been pushed beyond its traditional limits by introducing spectrum sharing and coexistence. This goal has been achieved by typically adopting one of the following strategies:

- Flexible use of the spectrum among different primary systems;
- Cooperative spectrum sharing among primary and secondary licensed systems;
- Spectrum sharing and coexistence among primary licensed systems and unlicensed systems, based on a cognitive radio approach.

Important technical challenges still need to be overcome, however, in order to achieve successful coexistence and cooperation among heterogeneous systems. Open research issues cover a wide range of system aspects, from the hardware component to the physical up to network layer design. In order to address these issues, experts in various aspects of radio design must come together for a joint effort towards system design optimization. Specific aspects that strongly need to be addressed for a successful development in cognitive radio and networks are:

- Design of hardware for reliable spectrum sensing: this is fundamental to unlicensed secondary systems operation (A. Ghasemi and E. S. Sousa, "Spectrum sensing in cognitive radio networks: requirements, challenges and design trade-offs," IEEE Communications Magazine, Volume 46, Issue 4, pp. 32-39, April 2008);
- Definition of algorithms for efficient, dynamic link adaptation (M. B. Pursley and T. C. Royster, "Low-Complexity Adaptive Transmission for Cognitive Radios in Dynamic Spectrum Access Networks," IEEE Journal on Selected Areas in Communications, Volume 26, Issue 1, pp. 83 - 94, January 2008),
- Design of protocols for cooperation in spectrum sensing and spectrum sharing (J. Ma, G. Zhao and Y. Li, "Soft Combination and Detection for Cooperative Spectrum Sensing in Cognitive Radio Networks," IEEE Transactions on Wireless Communications, Volume 7, Issue 11, Part 2, pp. 4502 – 4507, November 2008);
- Definition of network functions, such as routing and admission control, that incorporate internal and external network status (L. De Nardis and M.-G. Di Benedetto, "Cognition in routing for low rate UWB networks," IEEE International Conference on UWB 2008 (ICUWB2008), Hannover, Germany, Volume 3, pp. 97 – 100, September 10 – 12, 2008);
- Definition of communication and representation languages for cognitive information exchange (J. Mitola III, "Cognitive Radio Architecture: The Engineering Foundations of Radio XML", Wiley Interscience, August 2006).

The Action will address these challenges and therefore bring a significant and practical contribution to the development of cognitive engines for wireless communications.

Research projects both within and outside Europe are currently quite active in investigating the field. More specifically, within the 7th IST research framework, the European Union has allocated significant resources in the field of smart and flexible radio systems. In particular, EU-funded projects address three main aspects: 1) cognitive radio algorithms design, 2) novel physical layer technologies for improving spectrum efficiency, 3) cooperative solutions for dynamic spectrum allocation. Specific active projects in these three main areas can be listed as follows:

- Cognitive radio algorithms - the E3 project, aiming at the integration of cognitive wireless systems in the Beyond 3G (B3G) world, moving from heterogeneous wireless system infrastructures to an integrated B3G cognitive system framework, and the ARAGORN project, focusing on the application of machine intelligence and adaptive communication technologies, towards the optimisation of resource management in wireless networks;
- Novel physical layer technologies for improving spectrum efficiency - the CODIV project, focusing on the exploration of diversity at both physical and network layers, and the PHYDYAS project, investigating new Multi-Carrier physical layers more suitable than traditional OFDM for dynamic spectrum access scenarios;
- Cooperative solutions for dynamic spectrum allocation - the ROCKET project, focusing on cooperative networks adopting a reconfigurable OFDMA access strategy to maximize opportunistic spectrum usage, and the SENDORA project, focusing on cognitive radio in the sensor network scenario.

Furthermore, the EU supports projects aimed at the definition of new underlay technologies, with particular focus on UWB. This category includes the EUWB project, dealing with the application of cognitive concepts to a UWB platform in four application scenarios ranging from intelligent home to automotive environments, from public transportation systems to heterogeneous wireless networks. In the same group, the UCELLS project focuses on the application of UWB to cellular communications, aiming at coexistence of secondary UWB cells with primary wireless systems, while the WALTER project aims at building a UWB platform for interoperability testing. The EU also supports projects aiming at the integration of different radio technologies, such as the WHERE project, focusing on the integration of communications and positioning/navigation systems in order to improve efficiency in radio access, and the OMEGA project, combining wireless technologies such as UWB and mesh networks with wired technologies in order to have a seamless gigabit access in the home environment.

Consistent research efforts were also put in place outside Europe. Both the DARPA agency in US and the National Institute of Information and Communications Technology (NICT) in Japan promote several ongoing research projects on cognitive radio and networks (DARPA's Wireless Network after Next Program webpage, available at the address: http://www.darpa.gov/sto/solicitations/WNaN), (DARPA's XG Program webpage, available at the address: http://www.darpa.mil/sto/smallunitops/xg.html), (National Institute of Information and Communications Technology – Ubiquitous Mobile Communications group webpage, available at the address: http://www2.nict.go.jp/w/w121/index-e.html). An efficient coordination and cooperation of active research projects in Europe is therefore of paramount importance to guarantee alignment of European research centers and companies with worldwide advances in the field.

This Action will meet this need by providing: 1) coordination across different projects that is currently missing and makes this Action of great importance, 2) a framework for the integration of the cognitive paradigm at all layers of the communication architecture, 3) a technology platform to identify complementary skills from various projects and to create synergies to leverage heterogeneity. The cross-layer cognitive paradigm will allow in fact the design of a device-wide cognitive platform, and associated language semantics, thanks to the merge of a wide range of expertise, from hardware to applications, provided by over 30 academic and industrial partners involved in most of the relevant EU projects.

B.3 Reasons for the Action

The most important reason for launching the Action is to allow for coordinated and organic research and development in the field of flexible spectrum use, spectrum sharing, and intersystem coexistence based on cognitive radio and cognitive networks. The analysis presented in Section B.2 highlights that, while current research efforts focus on cognition at specific layers of the communication protocol stack, a clear need is present for a coordinated effort to unify research at different layers and harmonize technologies. It is of primary importance to create a reference point within the EU research community. By this way, research fragmentation can be reduced or even eliminated, paving the ground for technological advances through the accurate definition of new communication standards as well as new applications. The Action will support research efforts within EU, and complement coordination EU activities such as EU concertation activities that led to the formation of the Radio Access and Spectrum Cluster.

The Action will provide a common research platform for the development of radio technologies, algorithms, network protocols, and applications relevant to the deployment of systems capable of coexisting and cooperating in order to optimize radio resource access.

The most important expected result of the Action is the definition and development of a cognitive platform, that will prove the feasibility of cognitive systems and will show the potential economic benefits of cognitive radio. This result will be used in the Action to impact standardization bodies in Europe and abroad, as well as to stimulate the European regulation process. The platform will also form the baseline for the development of cognitive engines by European industries, since these will benefit from interacting with European research groups by either directly joining the Action, or indirectly exploiting dissemination outputs produced by the Action.

B.4 Complementarity with other research programmes

As previously indicated, research activities on key aspects of cognitive radio are currently ongoing in several European laboratories and industries. The Action foresees the presence in the consortium of these research groups and therefore is directly bound to these groups. The Action will therefore provide support to these activities, and extend and complement the individual actions in three specific ways:

1. Given that all relevant EU projects will be represented in the Action duplication of work will be avoided, and EU research funding on cognitive radio will be managed in a more efficient way;
2. The Action will provide a unifying framework for the work, by defining a network-wide cognitive framework, that will harmonize activities of different research groups and projects;
3. The Action will favour integration of results towards the definition of a European cognitive radio and network platform.

C. OBJECTIVES AND BENEFITS

C.1 Main/primary objectives

The main objective of the Action is to allow for coordinated research and development activities in the field of flexible spectrum use, spectrum sharing, and intersystem coexistence, based on cognitive radio and cognitive networks.

The Action enables a vision where networks of communication devices that operate according to scalable cognitive capabilities, interact in order to maximize efficiency in resource utilization. The Action will investigate all aspects relevant to the embodiment of the above vision, by adopting a cross–layer design approach, aiming at the definition of cognitive mechanisms encompassing all layers of the protocol stack, from physical to application layers. This approach will open up new possibilities for the definition and implementation of cognitive algorithms and protocols. Reaching above the network layer, up to the application layer, will allow to benefit from the multiplicity of physical interfaces, as well as incorporating application requirements in the selection of an optimal wireless interface and configuration.

The cross-layer approach will provide a new perspective in the design of cognitive systems, since it will introduce a global optimization process that integrates and completes existing cognitive radio achievements in single projects. The final result will be the definition of a European platform for cognitive radio and networks. To reach this goal algorithms and protocols for all layers of the protocol stack will be defined, and a set of standard interfaces as well as a common reference language for interaction between network nodes will be provided.

A parallel but primary objective of the Action is to actively participate and impact the standardization activities and regulation processes inside and outside Europe.

Deliverables - the dissemination plan foresees the organization of an annual Workshop that will allow Action participants to present the results achieved during the year. Each Workshop will lead to the preparation of a Book of Proceedings, including all contributions by participating parties; this will constitute the major yearly deliverable of the Action. In addition yearly activity reports will be produced by each Working Group, as requested by Action Rules and Procedures.

Expected Action Impact - the expected impact of the Action is to significantly increase the effectiveness of EU-funded research in the field of radio spectrum access and intersystem coexistence, by allowing research groups across Europe to share results and coordinate efforts in an effective way, leading to the deployment of standards in the field of cognitive radio. The Action will foster technical advances beyond the state-of-the-art, by optimizing the use of the available human and economical resources.

Performance indicators to measure the success of the Action will consist in:

- Number and the quality of inputs to European and international standardization bodies generated by Action activities;
- Degree of interaction between projects, in terms of joint events, common research activities, joint publications, and official cooperation agreements.

C.2 Secondary objectives

1. Technical advancement in specific research areas
   In order to achieve its primary objectives, the Action will lead to innovative results and deployment of top-notch technical solutions in specific research areas identified in Section D, and addressed by Working Groups and Special Interest Groups, as defined in Section E.
   The scientific impact of the Action will be measured by the advances fostered in such specific areas, in terms of scientific and technical publications in international fora.

2. Formation of Early Stage Researchers
   Thanks to the organization of events gathering the experts participating in the Action, Early Stage Researchers (ESRs) will be exposed to a wide range of opportunities in all research fields covered by the Action scientific objectives, as specified in Section E.4. Fostering the development of a new generation of researchers in the field of cognitive radio is a challenging objective of this Action, that can be reached thanks to the standard of excellence of the participating partners.

C.3 How will the objectives be achieved?

The objectives defined in Sections C.1 and C.2 will be achieved as follows.

Main objective - coordination research and development activities*:*

- Organization of events, annual workshops and regular meetings, according to the timetable provided in Section F.

Increasing efficiency in EU-funding management*:*

- Combine COST Action events with major conferences and workshops dealing with cognitive radio and networks, in order to facilitate participation by the largest number of partners.

Impact on standardization and regulation*:*

- Active participation of Action representatives in major standardization fora, by presenting innovative contributions resulting from the Action and published in deliverables.

Definition of a European cognitive platform*:*

- Creation of a common scientific and technical reference on cognitive radio, through the common research activities within the Action and the dissemination activities described in Section H.

Technical advancements in specific research areas:

- Technical advancements in specific areas will be the main focus of Working Groups and Special Interest Groups defined in Section D. Activity of each Group will lead to advances in the corresponding research area.

Formation of Early Stage Researchers:

- Organization of training schools, summer schools and training courses; involvement of ESRs in both organizational and scientific aspects of the Action, as detailed in Section E.

C.4 Benefits of the Action

The research activities scheduled within the Action are expected to provide significant scientific, industrial, economic, and social benefits. From a scientific point of view, the Action will lead to:

- The definition of standards for the interaction and cooperation between primary systems for efficient spectrum sharing;
- The definition of algorithms and protocols for cognitive radios, networks and systems allowing efficient coexistence between primary and secondary systems;
- The definition of a common language for cross-layer application of cognitive algorithms and protocols, allowing cognitive engines and entities running at different layers of the protocol stack to interact by means of a standard interface.

In terms of industrial benefit, the action of sharing scientific results among parties will form the basis for the submission of joint proposals within ITU and IEEE standardization bodies, as well as ETSI recent technical committee “Reconfigurable Radio Systems” in which several partners of the consortium are involved. This Action will pave the way for deployment of commercial solutions based on its technical results.

Current actions in the US for liberalization of radio frequencies are mainly driven by companies aiming at opening new markets (J. S. Marcus et al., “Towards More Flexible Spectrum Regulation”, ITU Workshop on “The Regulatory Environment for Future Mobile Multimedia Services”, Mainz, Germany, June 2006); similar efforts should be put in place in Europe in order to keep a leading role in wireless system design. In this view the availability of commercial products enabling a more efficient use of radio resource will give a chance to European developers to open the way to new market opportunities.

In terms of social/education benefits, the Action will provide the ideal framework for supporting and fostering the formation of ESRs. The strong presence in the consortium of academic and industrial partners with a high profile will form a perfect ground for learning thanks to the wide range of dissemination and formation activities planned within the Action and described in the Sections H and E.4, respectively.

C.5 Target groups/end users

The major end users of the expected results of the Action are:

- Industries and companies interested in implementing products based on the cognitive platform resulting from Action activities, as specified in Section C.1;
- Researchers in the broad field of wireless communications, and in particular on cognitive radio and networks, who will take advantage of the innovative results obtained in the topics addressed within the |Action, as detailed in Section C.2;
- Operators offering wireless networking services;
- The society as a whole, since the radio frequencies must be considered as a social good, and the application of the cognitive paradigm favours fairness in the exploitation of such good.

In the long run, end users will consist of general public, and in particular consumers and professional users of IT products and wireless networking devices, which will benefit from more efficient products and lower prices made possible by the standardization of new products based on the platform developed in the framework of the Action.

D. SCIENTIFIC PROGRAMME

D.1 Scientific focus

The Action will enable the design of cognitive devices and networks by coordinating research activities capable of addressing five key Technical Challenges (TCs). Four of such technical challenges are related to open scientific and technical issues at specific layers/aspects in the design of cognitive wireless devices, namely: physical layer, MAC, network, and inter-network coordination algorithms and protocols. Based on a bottom-up approach research activities focusing on the above TCs will provide the building blocks for the design of an optimized cognitive engine based on a cross-layer optimization strategy approach in order to be able to receive inputs from and provide outputs to entities working at each layer in the device. The implementation of such a cognitive engine is the fifth TC of the Action. Detailed descriptions of these five TCs can be given as follows.

- TC1 - Definition of cognitive algorithms for adaptation and configuration of a single link according to the status of external environment.

  Research topics relevant to this TC are: spectrum sensing, adaptive modulation and coding based on spectrum sensing and physical layer design for a single link based on upper layer received inputs. Spectrum sensing must include design of effective hardware and efficient algorithms, ranging from simple energy detection to advanced feature extraction for identifying emissions from a variety of wireless systems. Adaptive modulation and coding based on spectrum sensing must include the design of transmission filters, pulse shaping as well as of selection algorithms capable of mapping transmitter characteristics onto requirements imposed by the observation of the radio environment.
- TC2 - Definition of cooperation-based cognitive algorithms, that take advantage of information exchange at a local level.

  Operational requirements imposed on cognitive radios may occasionally exceed the capabilities of a single device; in such cases cooperation at a local level among neighbouring devices can lead to significant performance enhancements. Examples of research topics relevant to TC2 are:
  - Design of cooperative spectrum sensing algorithms, where groups of cognitive devices exchange information in order to increase reliability and accuracy in spectrum sensing, probability of detection of alien wireless systems, and classification of features of radio emissions;
  - Design of cooperative relaying schemes, in order to efficiently address limitations in coverage and network connectivity due to emission limits imposed on secondary cognitive radio devices;
  - Design of advanced network coding schemes, aiming at optimal use of available power based on node cooperation towards throughput maximization, while meeting coexistence requirements;
  - Definition of an efficient representation language for information exchange between cooperating nodes.

- TC3 - Definition of network-wide mechanisms for enabling the cognitive approach.
  Research issues relevant to TC3 encompass all network-wide functions required for the deployment of cognitive networks of smart secondary devices that cooperate in order to coexist with primary systems. Research topics to be addressed in the framework of TC3 include:
    - Design of admission control strategies capable of introducing cognitive aspects in the decision on whether to admit new devices in the network, while maintaining the network in a condition of stability;
    - Design of routing protocols capable of selecting end-to-end paths based on observations that are carried out at lower layers. To this aim the impact of the observed wireless environment on link and path performance, as well as the expected impact of the environment on network topology must be correctly modelled.
- TC4 - Definition of mechanisms for intersystem coexistence and cooperation.
  Although spectrum sensing will play a key role in ensuring coexistence between cognitive devices and legacy radio systems, the definition of intersystem communication and coexistence mechanisms will enable efficiency in flexible spectrum sharing between secondary devices and primary systems. Particular attention will be devoted to the definition of explicit communication mechanisms, such as cognitive pilot channels (CPC). The definition of such mechanisms encompasses both scientific aspects, such as information representation languages, and standardization aspects, that are fundamental in order to guarantee a widespread adoption of the proposed communication mechanisms.
- TC5 - Definition of a cross-layer cognitive engine.
  The design of a cross-layer cognitive engine will be carried out by allowing the engine to receive inputs from entities running at all layers of the device. The cognitive engine will also provide inputs to the same entities based on the decisions it has taken. The design of a cross-layer cognitive engine will include:
    - The capability of taking advantage of multiple network interfaces that are often available in modern radio terminals, and determining the optimal behaviour for the device, by gathering information on the status of all network interfaces;
    - The possibility of combining heterogeneous information in selecting the best strategy, i.e. direct spectrum sensing measurement and Quality of Service requirements imposed by the application;

- Definition of an efficient representation language for the exchange of information between the application layer engine and lower layers; such language should be able to describe concepts and variables related to all aspects of the device, from radio parameters to network performance indicators, to application requirements.
- Definition and deployment of advanced artificial intelligence algorithms, capable of determining the optimal strategy for all aspects of the device operations on the basis of widely heterogeneous information, and to learn from previous decisions.

D.2 Scientific work plan – methods and means

Research activities will be organized in Working Groups (WG) that map 1 to 1 the Technical Challenges defined in Section D.1:

- WG1 will focus on the research issues related to TC1, and will thus address all aspects related to single link adaptation, such as spectrum sensing, measurement and shaping, and interference suppression.
- WG2 will focus on the definition of cognitive mechanisms taking advantage of cooperation of devices in spatial proximity, according to the research issues identified as part of TC2.
- WG3 will deal with all research aspects relevant to TC3, with particular focus on the extension of cognition from the single network device to the whole network.
- WG4 will address intersystem cooperation and coexistence under both technical and standardization/regulation points of view. From a scientific point of view, WG4 will address the research issues relevant to the challenge TC4 previously described. Furthermore, given the strong importance of regulation and standardization in the activities carried out in TC4, this Working Group will also act as a gathering point for the organization and coordination of contributions to regulation and standardization bodies from partners of the Action.
- WG5 will focus on the introduction of cognition in devices above the network layer, exploring the definition of a cross-layer cognitive engine. The Working Group will take advantage of the results obtained in the other Working Groups in order to identify the main capabilities required for the cross-layer engine to enable an effective use of available information and device characteristics, such as the presence of multiple wireless interfaces, when available, while taking into account application requirements.

A few research topics belonging to the scientific focus (see Section D.1) are vertical, and encompass TCs. An excellent example of such a topic is the definition of information representation languages as well as the introduction of learning and artificial intelligence methods in the design of the components forming the cognitive engine.

These vertical research topics will be addressed by Special Interest Groups (SIGs), which will be defined and created in addition to the Working Groups as a dynamic transversal texture of the Action.

SIGs will gather experts from different WGs on common research issues. According to the Action scientific focus three SIGs are foreseen in the initial phase of the Action:

1) Information representation languages – the SIG will involve experts of traditionally distant fields (radio, computer science, artificial intelligence). This topic instrumental for both intra-device cognitive entities, and intra and inter-network cognitive protocols. This SIG will investigate innovative solutions in the definition of representation languages by taking advantage of synergies between experts working on different topics in different WGs.
2) Learning and artificial intelligence – the SIG will allow experts to work together and possibly generate new knowledge towards the application of machine learning and artificial intelligence to the conception of the cognitive platform.
3) Mobility management for cognitive wireless networks – the SIG will allow experts to conceive models that are adequate to specific network typologies, and analyze techniques related to the topology control in cognitive mobile radio networks.

The work plan of the Action will furthermore foresee the possibility of creating additional SIGs, should additional vertical research topics be identified during the activities of the Action. A

representation of the relationship between WGs and SIGs is presented in Figure 1.

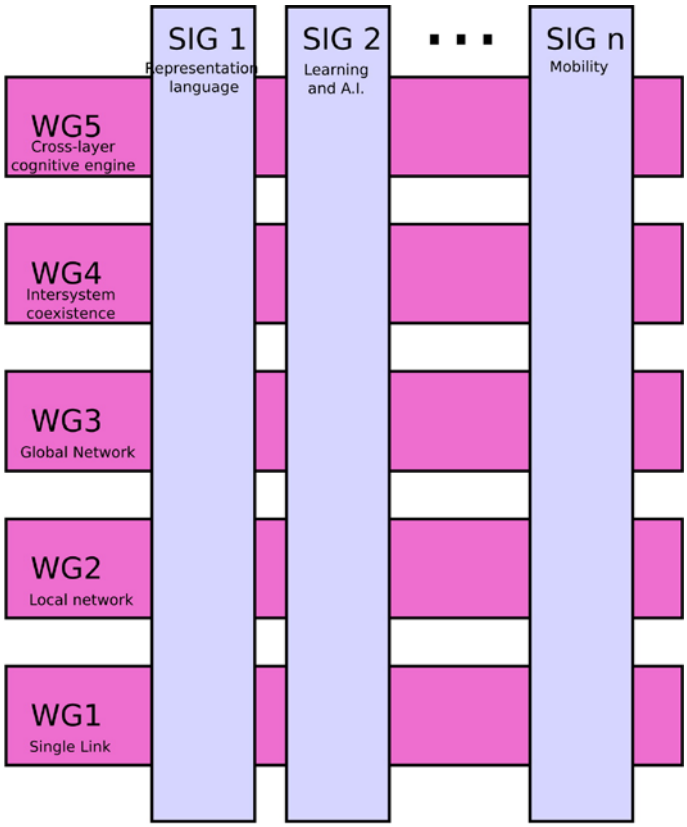

Figure 1 – Relationship between WGs and SIGs

E. ORGANISATION

E.1 Coordination and organisation

The Action will be coordinated by the Management Committee (MC). The MC will consist of one Chair, one Vice-Chair, a Secretariat, and the MC members nominated from each participating country, according to the COST Guidelines. The nominating COST countries will be encouraged to nominate young researchers as MC members. The Action will begin with the kick-off MC meeting. Following the kick-off, MC meetings will take place every six months. The MC will also be in charge of coordinating the editorial production of the Annual Reports due at the end of each Year.

The first Annual Report (Month 12) will specifically contain an extensive state-of-art review, followed by two progress reports at months 24 and 36, and finally the last report (Month 48) containing the conclusions of the Action.

The research lines of the Action will be monitored by the Working Groups (WG), through their Chairs and Vice-Chairs. In order to promote collaboration among researchers, partners will be encouraged to additionally form Special Interest Groups (SIGs) targeting specific applications and research problems within or across WGs.

WG meetings will be organized every three months in order to allow for strong interaction between Action partners. Two of the four WG meetings per year will be held jointly with the semi-annual MC meetings at M6 and M12 of every year, while the remaining two WG meetings will be scheduled independently. SIG meetings will also take place at least twice a year, as part of the MC meetings; additional SIG meetings will be held in conjunction with WG meetings when deemed as necessary by SIG Chairs.

In order to guarantee visibility to the MC of all activities going on in the Action, for each meeting a report will be produced in the form of meeting minutes, that the organizer of the meeting will communicate to the MC.

Details of the initial SIGs and their composition will be settled at the kick-off MC meeting. SIG Chairs will be designed as well.

SIGs have a special role within the Action as they will become the basis of collaboration between researchers participating in different WGs, thus fulfilling the overall objective of the Action to bring together WG topics. Moreover, SIGs reflect the flexibility of the Action to accommodate new members and new applications. Young researchers as well as female researchers will be encouraged to take an active role in starting and leading new SIGs.

In order to optimize interactions between different WGs and facilitate SIG meetings, meeting plans for the different WGs will be harmonized in order to reduce the number of trips and allow researchers to participate in more than one WG. Harmonization and coordination of different WG activities will be the main duty of the WG Coordinator, which will be designed by the MC during the kick-off meeting.

The two following entities will be also defined during the kick-off meeting:

- The Dissemination Board (DB), in charge of preparing and putting in place the Action dissemination plan. The DB will also act as the reference point within the Action for organizing, classifying and making easily available all publications produced by Action activities to Action partners, to interested individuals, and companies that are external to the Action. The DB will also be responsible for creating, maintaining, and improving the Action website described later in this section and in Section H.
- The Liaison Manager, to be selected among DB members, in charge of identifying and proposing potential liaisons and cooperation initiatives with research programs relevant to Action activities.

According to the above description, the Action organization is represented in Figure 2.

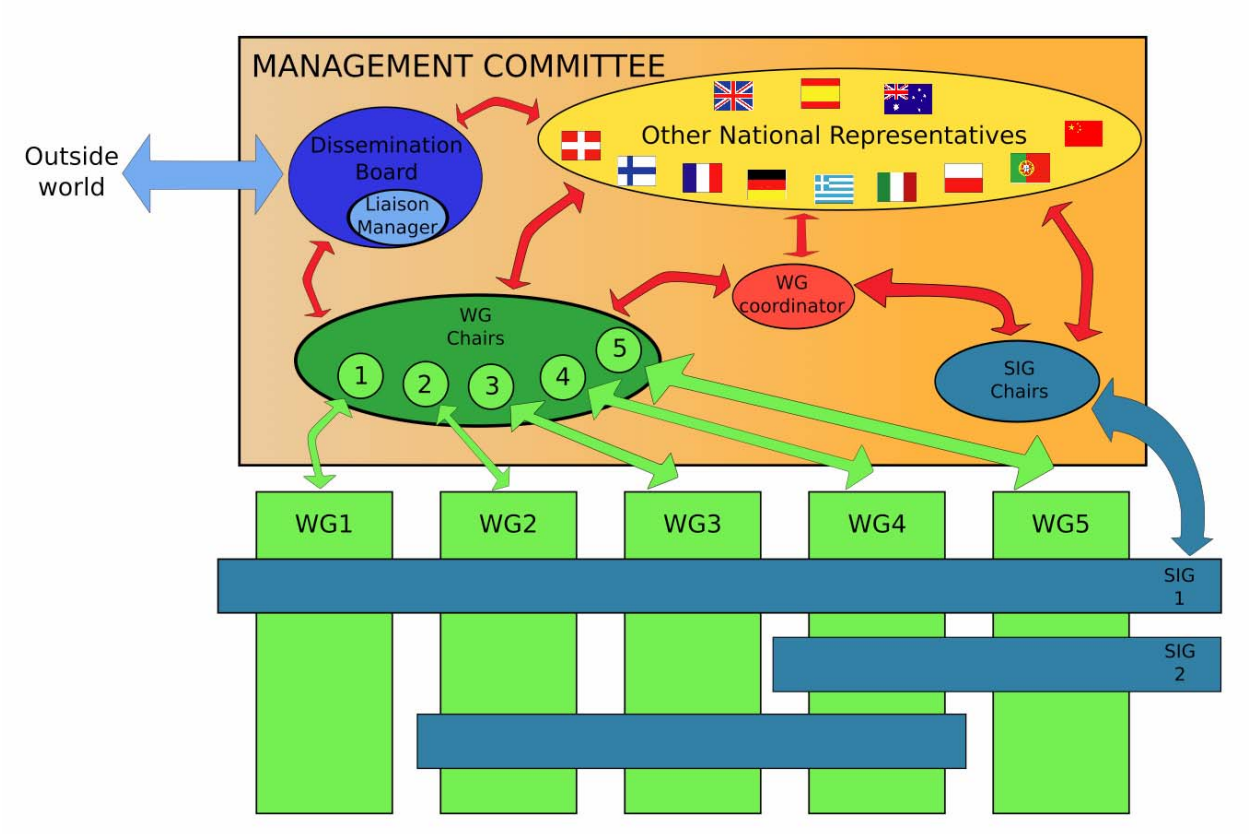

Figure 2 - Action organization

A Workshop (WS) will be organized once a year, contextually of the MC meeting. The WS will be open to the scientific/engineering community and, when possible, will be held jointly with other events/Conferences. Experts external to the Action will be invited to give talks at the WS.

A website for the Action will be set up immediately following the kick-off meeting. This website will be the portal of the Action to the external world, and will assist in the exploitation and dissemination of the results of the Action, providing information about the Action objectives and milestones to the scientific community. In addition, it will serve as an internal, password accessible database for the partners, providing access to the various technical reports, job openings, related Ph.D. projects, and Short Term Scientific Missions (STSMs).

Knowledge sharing and spreading will also be a key aspect in the Action activities. In addition to the yearly dissemination workshop described above, training courses and tutorials will be organized by participating partners and offered to ESRs and experts in the framework of SIG and WG meetings, in order to maximize the exchange of competencies among researchers working on different topics.

A Gantt chart presenting Action activities, meeting schedules and expected delivery dates of deliverables from each WG is presented in Figure 3. Additional information on the expected timetable of the Action is provided in Section F.

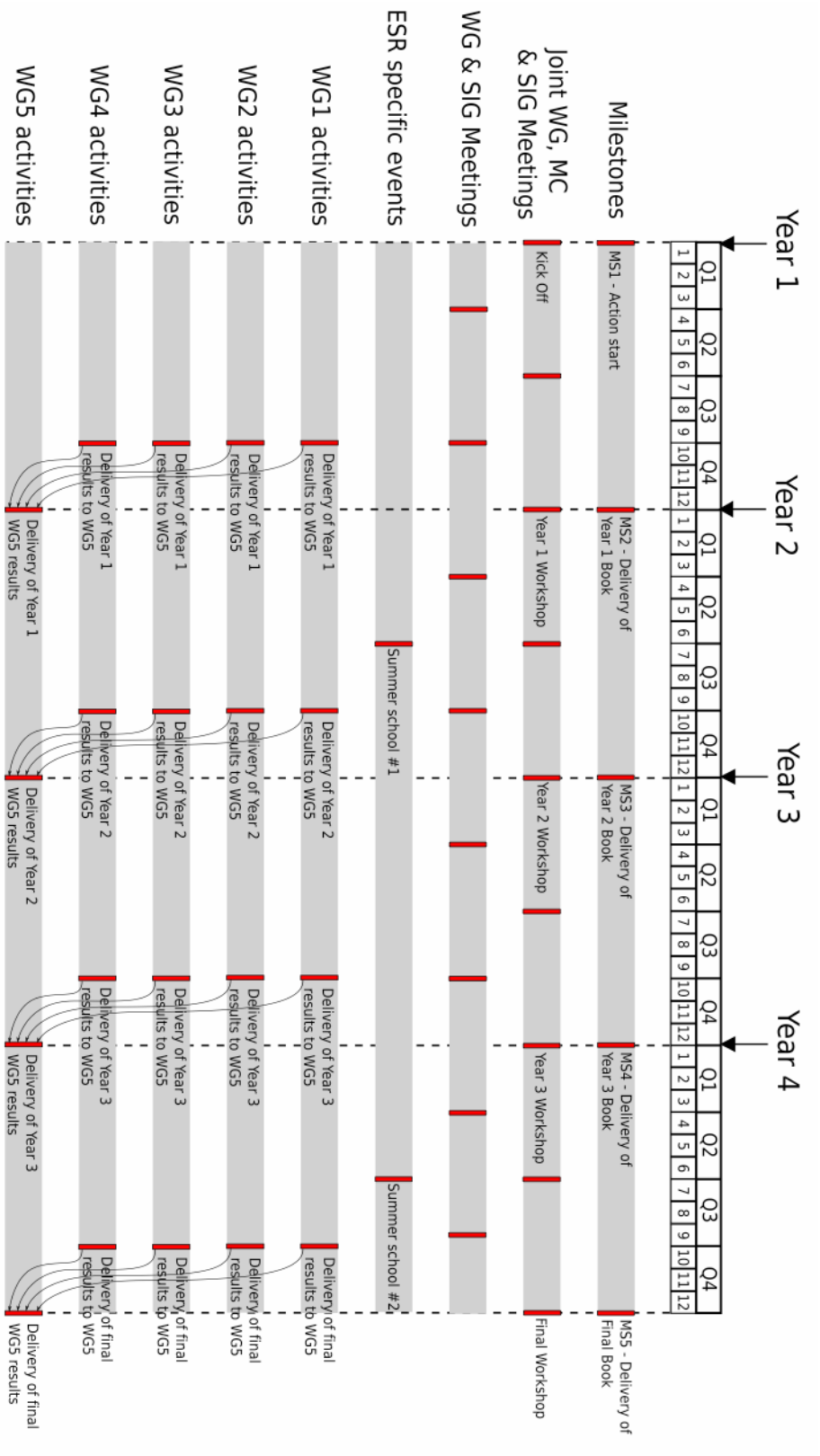

Figure 3 – Gantt chart of the COST Action: activities, meeting schedules and deliverables

E.2 Working Groups

As discussed in Section D.2, five Working Groups will be defined, according to a 1-to-1 mapping on the Technical Challenges identified in Section D.1.

Participants to the Action will join one or more Working Groups according to their research interests.

The Management Committee will select a chair for each Working Group. The Management Committee will review Working Group activities during MC meetings, and actions will be taken to solve organization or scientific issues identified for each WG during such review.

In order to maximize ESR participation to all aspects of Action activities, an ESR will be appointed as co-chair for each Working Group, as detailed in Section E.4.

E.3 Liaison and interaction with other research programmes

The Action will establish and expand liaisons with other COST Actions. COST Actions that will be contacted include Action 2100, focusing on Pervasive Mobile & Ambient Wireless Communications, Action IC0804, focusing on Energy efficiency in large scale distributed systems, and Actions IC0603 an IC0803, dealing with Antenna Systems & Sensors for Information Society Technologies and RF/Microwave Communication Subsystems for Emerging Wireless Technologies, respectively. Liaisons will be established with all projects funded by European research programs that are deemed relevant to the objectives of the COST Action, starting from the projects listed in Section B. Additionally, a connection will be established with FP7 Clusters, and in particular with the Spectrum and Enablers Group (SEG) of the FP7 Radio Access Spectrum (RAS) Cluster, focusing on research topics relevant to WGs 1 and 2 of the Action.

Interaction with other European research programs will be achieved through the study of specific application-oriented problems that are the focus of such research programs. This desired interaction is the outcome of participation of the individual researchers within such programs that are directly funding research.

The industrial partners will play a leading role in directing research towards new and promising applications and fostering such collaborations. The outcome of such interactions will be joint publications as well as product development between partners of this Action and researchers external to the Action.

Liaisons with other COST Actions will be established by joint meetings, that can be set up during the yearly WS organization, as a part of a commonly organized conference, for example.

The list of experts proposing and supporting this Action proposal includes participants to most of the research projects and COST Actions identified above. This will guarantee effective liaisons and efficient information and knowledge exchange with such projects. As already described in Section E.1, a Liaison Manager (LM) will be designed among members of the Dissemination Board.

E.4 Gender balance and involvement of Early Stage Researchers

This COST Action will respect an appropriate gender balance in all its activities and the Management Committee will place this as a standard item on all its MC agendas. The Action will also be committed to considerably involve Early Stage Researchers. This item will also be placed as a standard item on all MC agendas.

Involvement of Early Stage Researchers (ESRs) is a priority in the Action. As a matter of fact, the formation of ESRs is mentioned in Section B as one of the explicit objectives of the Action. In order to guarantee a maximum participation of young researchers to Action activities, ESRs will be involved in both scientific and organizational aspects of the Action. From a scientific point of view, ESRs will be granted the possibility of research specific topics by allowing them to propose and put in place Short-Term Scientific Missions (STSMs). Short training courses will also be planned during WG and SIG meetings, and summer schools will be held every other year during the Action; this will provide the ESRs with the opportunity of being exposed to new research topics.

ESRs will also have the opportunity of develop their skills in the framework of industrial research teams, by carrying out research activities relevant to WG, SIGs and STSMs at the premises of industrial partners supporting the Action.

From an organization point of view, ESRs will be involved in the management of Action activities by selecting some of them every year as ESR co-chairs in the 5 Working Groups. The ESR co-chairs will support the WG chairs in setting-up and managing WG activities, and will have, in particular, the duty and opportunity of proposing and organizing training courses and summer schools.

This same approach will be adopted for ESR involvement in SIGs activities.

F. TIMETABLE

The expected duration of the Action is 4 years. According to the foreseen work plan and organization presented in Sections D and E, respectively, the following timetable will characterize Action activities.

Year 1:

Time	Event	Milestones / Expected results
M0	Kick-off meeting and first MC meeting (Milestone 1)	– Define research topics relevant to the different TCs – Elect WG chairs and vice-chairs – Elect SIG chairs and vice-chairs – Define website structure and draft a plan for dissemination activities – Design members of the Dissemination Board
M3	WG meetings	– Define detailed work plan – Define WG meetings calendar
M6	Joint MC, WG and SIG meetings	– Presentation of website – Report on status of WGs and SIGs organization and potential issues – Report on status of dissemination activities – Presentation of early results – Training courses for ESRs

M9	WG meetings and SIG meetings	– Presentation of results – Preparation of contributions to Year 1 Workshop and internal delivery of results from WGs 1-4 to WG 5 – Training courses for ESRs
M12	MC meeting	– Analysis of Year 1 activities – Discussion of proposals for creation of new SIGs and conclusion of existing SIGs – Definition of ESRs-related activities for following Year (summer school, draft plan of training courses) – Website and dissemination activities report
M12	Year 1 Workshop	– Presentation of Year 1 results – Delivery of contributions by each WG and SIG for Year 1 Action Book of Proceedings (Milestone 2)

Years 2-4:

Time	Event	Milestones / Expected results
M3	WG meetings and SIG meetings	– Revision and update of work plans
M6	Joint MC,WG and SIG meetings	– Report on status of WGs and SIGs organization and potential issues – Report on status of dissemination activities – Presentation of results by WG
M6	Summer School for ESRs	– (Years 2 and 4 only)
M9	WG meetings and SIG meetings	– Presentation of results – Preparation of contributions to yearly Workshop and internal delivery of results from WGs 1-4 to WG 5

M12	MC meeting	– Analysis of year activities – Discussion of proposals for creation of new SIGs and conclusion of existing SIGs (Years 2 and 3 only) – Definition of ESRs-related activities for following Year (summer school for Year 4, draft plan of training courses)
M12	Yearly Workshop	– Presentation of Year results – Delivery of contributions by each WG and SIG for Action Book of Proceedings (Milestones 3 - 5)

G. ECONOMIC DIMENSION

The following COST countries have actively participated in the preparation of the Action or otherwise indicated their interest: DE, DK, ES, FI, FR, GR, IE, IT, PL, PT and UK. On the basis of national estimates, the economic dimension of the activities to be carried out under the Action has been estimated at 44 Million € for the total duration of the Action. This estimate is valid under the assumption that all the countries mentioned above but no other countries will participate in the Action. Any departure from this will change the total cost accordingly.

In addition to parties from COST countries listed above, research entities from three non-COST countries, Australia, China and USA, have expressed interest in the Action and contributed to the preparation of Action proposal.

The estimate has been obtained according to the assumptions on resources involved in the Action presented in the Table 1.

	Persons	Total PMs	PM average cost (€)	Total (M€)
Members of Management Committee	22	600	10000	6
Members of Working Groups	75	3000	7500	22.5
Early Stage Researchers	150	6000	2500	15
Total				44

Table 1 – Estimate of resource allocation for the COST Action activities

H. DISSEMINATION PLAN

H.1 Who?

The intended target audience for the dissemination of the Action results and findings includes the academic world, the European standardization and regulation bodies, the industry and the general public. Specifically, intended targets for dissemination of results include:

- The participating Members within the Action, with special attention to young researchers;
- International research community involved in the cognitive networks and cooperative coexistence field;
- Researchers from other related fields, such as learning algorithms, artificial intelligence, applied mathematics – numerical optimization;
- Industry players, related to wireless systems, networks and equipment;
- EU projects and initiatives in the area of communication subsystems, both in terms of RF/microwave circuit design and signal processing.

Thanks to its global vision for cognitive radio and networking, the Action addresses the whole scientific community focused on specific aspects of cognitive radio and flexible spectrum access, allowing stronger interaction and integration between partners and projects and providing common strategies, algorithms and specifications able to unify the research on different layers and technologies and provide a solid reference for future developments in the cognitive area. The definition and implementation of cognitive cross-layer design strategies has in particular the potential to address research institutions and individual researchers even if not directly involved in cognitive radio research activities. Furthermore, graduate students and young researchers working within the project will have direct access to up-to-date research results, with obvious benefits for their scientific skills and professional experience.

The Action will also address European standardization and regulation bodies and its results and innovative solutions can have a significant role to set the guidelines for a flexible approach to spectrum sharing and trading among different systems and operators. These guidelines are considered by the ITU, for example, a priority issue for the deployment of future wireless systems. In terms of industrial benefit, the sharing of scientific results among parties of the Action will form the basis for the submission of joint proposals within ITU and IEEE standardization bodies, as well as the ETSI “Reconfigurable Radio Systems” technical committee.

This Action will pave the way for deployment of commercial solutions based on its technical results. Consequently, industries and companies interested in implementing products based on the cognitive platform resulting from the project activities are addressed by the Action. Finally, target groups of the Actions include consumers and professional users of IT products and wireless networking devices, which will benefit from more efficient devices and lower prices made possible by the standardization of new products based on the platform developed in the framework of the COST Action.

H.2 What?

The results of this Action will be disseminated using the following methods:

- Action website: the website will properly provide information regarding upcoming and past activities, the Action itself, obtained results, partners' publications, and Action's progress reports. The website will contain discussion areas to be used by the partners to exchange opinions and comments about the project. A public area of the website will also give the possibility to people outside the project to express their opinion, to provide comments and to ask questions about the Action's activities. The website will also host links to other websites, research projects or events related to wireless cognitive systems;
- Workshop: the Action will organize an annual Workshop in order to present the results obtained by partners of the Action. The Workshop will be an open-doors event, targeting companies and public entities interested in the topic of spectrum usage optimization and innovative solutions in intersystem coexistence, and more generally in wireless systems design and commercialization. Invited speakers with different background related to the topics close to the project will give a talk and will form a round table discussion. Workshop proceedings will be posted on the Action's website. Each Workshop will lead to the preparation of a Book of Proceedings, including all contributions by participating parties; this will constitute the major yearly output of the Action;
- Annual reports: the Annual Reports produced by the Action will be published on the Action's website;
- Publications: journal and conference papers will be one of the most powerful means of dissemination of the Action's results and each partner involved in the project will actively contribute to their production. The Action will encourage co-publications between partners and the participation to all the international events related to the Action's topics;
- Internal dissemination: each WG will organize meetings every three months, while SIG meetings also planned every three months will ensure cross-WG communication, knowledge sharing and a better understanding of each aspect of the project to each partner involved;

- Technical reports: project partners will create internal technical reports containing a detailed description of the obtained results: technical reports will be available in a private part of the Action website. These reports will be used as basis for journal and conference papers publication;
- Seminars and courses: In addition to the annual Workshop, training courses and tutorials will be organized by participating partners and offered to ESRs and experts in the framework of SIG and WG meetings, in order to maximize the exchange of competencies among researchers working on different topics;
- Standardization bodies: contributions to standardization bodies and invitation to such bodies to participate in scheduled standardization meetings.

H.3 How?

The Action Dissemination Board (DB) will prepare a general and continuously update dissemination plan. The plan will be revised and modified, if necessary, during the Action.

In particular, the website accesses and other related statistics will be collected and analyzed on a periodical basis, so that the website's impact (in terms of format and content) can be evaluated and updated as needed during the course of the Action. Besides the website will include invitations to join the Action and recruitment of new collaborators for open research positions related to the Action's activities will be announced in the academic press, at international and regional conferences. Furthermore, specially appointed Action members will act as contact persons to the external scientific community for recruiting new Action partners, supporting researchers outside the Action interested in integrating the Action scientific results and tools in their research (with special attention to graduate students, post-doctoral fellows, and other young researchers), and communication with industry representatives. These activities will be collected and analyzed on an annual basis, and included in the yearly Action progress report.

The annual meeting of the Action will be the perfect occasion for strengthening the dissemination by inviting key actors of the domain (for instance people from industry, non-EU country, IEEE). The DB will make sure that all dissemination methods are properly addressed and implemented during and after the Action run time.

For dissemination activities during the Action runtime, the DB will prepare a general time schedule for each dissemination tool within the first months of the Action. Dissemination activities that should take place after the Action run time will be collected during the first half of the Action and written into the dissemination plan. Partners will be asked to agree on a common time frame within which dissemination activities will take place.