European Cooperation in Science and Technology
- COST -

Secretariat

Brussels, 16 December 2010

COST 4209/10

MEMORANDUM OF UNDERSTANDING

Subject :	Memorandum of Understanding for the implementation of a European Concerted Research Action designated as COST Action IC1004: Cooperative Radio Communications for Green Smart Environments

Delegations will find attached the Memorandum of Understanding for COST Action IC1004 as approved by the COST Committee of Senior Officials (CSO) at its 180th meeting on 1 December 2010.

MEMORANDUM OF UNDERSTANDING
For the implementation of a European Concerted Research Action designated as

COST Action IC1004
COOPERATIVE RADIO COMMUNICATIONS FOR GREEN SMART ENVIRONMENTS

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 4159/10 "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 increase knowledge of cooperative communications applied to Green Smart Environments, by exploring and developing new methods, models, techniques, strategies and tools.

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 104 million in 2010 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

Smart Environments (SEs), like the human body, energy efficient buildings, vehicular or urban environments, are populated by many devices connected by wireless networks. The radio channel is central to SEs, as it impacts the design of transmission techniques and communication protocols. Radio communications in SEs need to be green and based on cooperative paradigms to mitigate the effect of interference and improve efficiency. This Action addresses research issues in the field of cooperative radio communications to make our society cleaner, safer, and more energy efficient. The main goal of the Action is to increase knowledge of cooperative communications applied to Green SEs (GSEs), by exploring and developing new methods, models, techniques, strategies and tools, in a context enriched by deep industry-academia links. Training of young researchers is also one of its main objectives, to be pursued e.g. via annual training schools. Europe will benefit from the activities of this Action, as GSEs will be one of the key components of the broader field (and exploding market) of the Internet of Things, a domain of interest to many large and small companies in Europe. COST is the ideal framework, as it allows very efficient cooperation among industries and academia.

Keywords: Green Cooperative Radio Communications, Radio Channel, Radio Links and Networks, Smart Environments, Energy Efficiency

B. BACKGROUND

B.1 General background

A Smart Environment (SE) is a physical space (e.g. the human body, vehicles on a road, a building, an urban area) populated by sensors, actuators, embedded systems, user terminals and any other type of communicating device, which cooperatively pursue given tasks by exchanging information and share all types of resources such as radio spectrum or energy. Radio communications clearly constitute an essential element of SEs.

SEs are delimited in space but not in scope. For example, wireless devices *on* or *inside* the human body can improve everyday life for patients needing continuous health care (Smart Health), but can also help the professional sports-man/woman to improve his/her performance; inter-vehicular and vehicle-to-infrastructure communications can assist the driver and increase road safety (Smart Cars) or enable the provision of Internet services in the car; wireless sensors in buildings can provide information helpful for energy control purposes (Smart Energy) or support rescue teams in emergency situations.

SEs can provide better safety and lifestyle and can help reduce global energy consumption by contributing to an intelligent distributed management of the energy resource. SEs may be green (GSEs) because of their application: especially in enabling energy efficient lifestyles, for example in enabling home working and teleconferencing to reduce the need for travel. However they need to become green themselves; ICT is responsible today for 2 to 10% of the world power consumption and this might increase in the coming years. The impact on the environment and global energy consumption of ICT must be minimised; SEs must be green also in the sense that their deployment and use must follow energy efficient paradigms, regardless of their goals and application areas. Progress will come from better hardware design but also improved transmission techniques and protocols. This Action will address GSEs in either of the two senses.

Moreover, GSEs need to be efficient overall, with better use of energy (Joule/bit), radio spectrum (bits/s/Hz/sqm), computing resources, etc. To achieve this goal, GSEs have to make proper use of the concept of cooperation among network nodes, both at link level (to maximise end-to-end throughput between nodes, through relaying, network coding or other forms of cooperation) and at network level (to maximise network capacity in a dense heterogeneous environment). Cooperation also involves the proper detection, mitigation and management of inter-network interference which arises from the possibility of autonomous networks merging and splitting.

The radio channel is central to the paradigm of GSEs: multiple antenna systems, interference recognition and the high degree of cooperation among separate network nodes, require a multi-dimensional description of the radio channel characteristics (joint modelling of space, time, frequency, polarization, etc). Moreover, the deployment contexts include the human body (inside or around it), the vehicular environment, and other areas where characterisation of radio propagation is complex. All this motivates the need for accurate models describing radio propagation in a multi-dimensional fashion, and proper evaluation of how the radio channel characteristics affect the link and network performance, and vice-versa.

The high node density and heterogeneity require new paradigms in cooperative network design; GSEs being based on a variety of air interfaces, frequency bands, protocols and network topologies and involving devices of very different processing capabilities. The fourth generation (4G) of wireless systems includes new approaches like femto-cells and multi-hop relaying. Therefore, radio resource management aspects and network organisation/maintenance are becoming increasingly complex.

From the technical viewpoint, this Action will 1) provide accurate radio channel models for different types of GSEs, defining test methods and experimental methodologies, 2) develop cooperative transmission techniques and assess their performance, 3) design self-organising and energy efficient protocols and algorithms based on the knowledge acquired about the radio channel.

Some FP7 projects, as well as many industry fora/initiatives have recently been launched in Europe, dealing with the topics of green communications. The FP7 ICT WP 2011/12 addresses those issues under Challenges 1, 5, 6 and 7. However, there is currently no framework in Europe where these separate initiatives can aggregate their efforts, leading to a risk of fragmentation and reduced penetration of research results. In this context, past experience has unquestionably demonstrated that a COST Action is an ideal instrument for fostering the sharing and cross-fertilizing knowledge and achievements, especially through the fruitful combination between industrial and academic goals.

Europe will benefit from the activities of this Action, as GSEs will be one of the key components of the broader field (and exploding market) of the Internet of Things, a domain of interest to many large and small companies in Europe.

B.2 Current state of knowledge

1. Radio Channel

Radio propagation for wireless networks has been extensively investigated for over 20 years, mainly towards networks planning for 2G, 3G and 4G mobile communications. Simple and sophisticated models have been developed and some of them incorporated into standards, following the activities of COST 207, 231, 259, 273, 2100, WINNER in Europe and bodies such as 3GPP, ETSI and IEEE 802 among others, internationally. There is a strong body of knowledge for outdoor, rural and urban channels, covering "classical" use cases of communication between e.g. a mobile terminal and a base station. However emerging cases such as body area networks, vehicle to vehicle links or wireless sensor networks are much less known from the radio channel point of view. Cooperation and relaying being one of the major mitigation techniques to combat channel attenuation and consequent power consumption, initiatives have only started to assess multi-link channels. There is also a significant lack in knowledge of radio propagation for the more unusual environments considered for SEs (inside/outside buildings, vehicles), a lack in the knowledge about transitions from one kind of SE to another (required by efficient and power saving communications), a lack of models for heterogeneous communication systems, a lack of models for the behaviour of real world terminals in real environmental conditions and a lack of interference models in the crowded spectrum conditions determined by a very large number of co-existing wireless objects. Summarizing, open issues that need to be treated from the viewpoint of the radio channel include**:**

- Point to multi-point or multi-point to multi-point and cooperative channel models;
- Time variability in dynamic channel models;
- Channel models including the realistic characteristics of smart communicating objects;
- Very wide bands or multi-band channel models in SE;
- Characteristics of the complex propagation in unusual media of some types of SEs;
- Global channel modelling from channel models dedicated to specific SEs;
- Advanced interference models based on realistic channel models;
- Improved localization performance from limited channel information.

2. Transmission Techniques

In comparison with existing wireless communication networks, GSEs will involve large numbers of autonomous interacting nodes. To implement communication across such an environment requires a step change away from the currently dominant paradigm in which the links between pairs of nodes are treated separately, with traditional physical layer techniques such as modulation and coding being applied on a link level only. This approach treats interactions between links as interference which is always deleterious and to be avoided by scheduling and resource management handled at higher layers. The insights of multiterminal and network information theory show that such an approach is highly inefficient in dense networks involving many nodes such as will occur in SEs. A much more efficient paradigm is provided by cooperation between nodes, enabled by the distributed physical layer, in which physical layer techniques such as modulation and coding are applied across many cooperating links, and link interactions may bring benefits rather than detriment. In recent years a number of techniques have begun to introduce this new paradigm, especially virtual MIMO, cooperative diversity, distributed processing in relay networks, and interference alignment, but wider adoption will be necessary in true cooperative SEs. Cooperation has the potential to improve efficiency, as mentioned, but will be only one approach for this. Open issues that need to be treated from the viewpoint of transmission techniques include:

- Cooperative relaying and diversity;
- Virtual supernodes and virtual MIMO;
- Network distributed channel coding and modulation;
- Interference alignment;
- Distributed channel parameter estimation;
- Source coding for correlated sources;
- OFDM for cooperative systems;
- Energy-efficient signal processing;
- Minimizing electromagnetic radiation;
- Low latency physical layer design;
- Location awareness.

3. Radio Networks

Wireless terminals, sensors and nodes operating in SEs are expected to cooperate with each other to create local ad-hoc networks, as well as to access networking infrastructures to establish connectivity to global networks and services. Some of the state of the art technologies could be applied to cope with the smart networking concept. There are several solutions for dynamic radio access and ad-hoc networking that are already part of current standards. LTE-Advanced, the 4G approach of 3GPP, includes the concepts of femto-cells, self-configuration, cooperative multipoint and relaying, among others, which address the goal of a fully adaptive radio access network, but are still very dependent on the infrastructure deployment and the centralised control provided by the fixed network nodes. On the other hand, ad-hoc wireless communications standards [e.g. IEEE 802.15, IEEE 802.11s,…] define nodes and terminals that can adapt dynamically how they connect to each other and how to create a local information wireless network, e.g., a mesh network. Nevertheless, from the radio networking point of view SE means above all that a large number of heterogeneous elements co-exist in a relatively small space, producing individual information at different rates but giving raise to a huge demand for communications capacity, that measured in terms of its spatial density or “smart data dust” could be in the order of several Mbits/s/sqm. A SE is also able to manage the lack of fixed infrastructure and scarce spectrum, as well as the need for keeping energy consumption to the minimum. Many paradigms remain open for research at network level:

- Context-aware networking concepts for the self-configuration of terminals and nodes;
- Sharing the spectrum in space, time and power;
- Self-organising radio access;
- Cooperating for Radio Resource Management (CoRRM) to overcome the limitations of site-based RRM;
- Opportunistic radio access networking;
- Overcoming the layered and cross-layer restrictions of current access networks;
- Improving the overall energy efficiency, by properly combining techniques traditionally separated;
- Exploiting the capabilities of the all-IP and fibre-to-the-antenna technologies at the radio access network.

B.3 Reasons for the Action

While the large and still growing contribution of the ICT sector to the world's GDP is well recognized, its non-negligible impact on the global energy consumption shifted into focus only recently. In the field of wireless technologies alone, there is a great variety of viable approaches to tackle the challenges in this area (see e.g. the scientific programme of this Action in Section D), and they require proper consideration to achieve a consolidated view. This is testified by the amount of scientific literature currently seeking to provide such a consolidation (see e.g. the IEEE Network Magazine Special Issue on Energy-Efficient Networks to be published in April 2011). This Action will help this process of consolidation, with a benefit from both the technical and societal viewpoint.

Considering the global dimension of green aspects in ICT, reducing the fragmentation of European research through the co-ordinated interdisciplinary network of experts of this Action will bring a decisive advantage.

Although many industry fora/initiatives have been launched recently at national and international levels (see www.greentouch.org for a relevant example: GreenTouch is a consortium of leading ICT industry, academic and non-governmental research experts dedicated to fundamentally transforming communications and data networks, including the Internet, and significantly reducing the carbon footprint of ICT devices, platforms and networks), there is indeed no framework in the ERA where the latter can meet and interact under an a-la-carte flexible framework like that offered by COST. To provide such a framework for a better integration of European research is the immediate goal of this Action. It will be supplemented during its course by contributing to the scientific and technological advances in the area of radio communications for SEs, towards a European energy efficient and low carbon economy. The main outcomes of this Action will be expert publications, newsletters, meetings and events addressing the beneficiary target audiences, together with the training of Early Stage Researchers (ESRs) who will subsequently migrate to industry or academia and will leverage the Action results. Maximal productivity will be achieved by the participation of relevant stakeholders while setting up and running the Action's Working Groups.

B.4 Complementarity with other research programmes

Some FP7 projects deal with GSEs, but none has the potential to combine the scientific skills and capacities of many tens of industry and academic research groups, including relevant non-European institutions (e.g. from China, Japan, North America). FP7 STREPs and IPs address specific problems and are based on closed consortia of no more than 20 partners in most cases. Networks of Excellence do not provide a proper means for industry-academia exchange. Only a COST Action has this potential.

Some COST Actions have goals that are somewhat related: IC0902 deals with cognitive radio networks; IC0905 addresses the radio access from the regulatory viewpoint; IC0906 treats similar topics only from the networking viewpoint. However, none of these Actions dedicate specific attention to the radio channel and all related issues (such as body communications, etc). This Action considers the radio channel as the central element around which the three “dimensions” of green, efficiency and cooperation evolve. Finally, IC0802 addresses the radio channel for the satellite segment. This Action will create proper synergies with the abovementioned Actions by organising joint events, workshops, schools.

C. OBJECTIVES AND BENEFITS

C.1 Main/primary objectives

The main objective of the Action is to increase knowledge of cooperative communications applied to Green Smart Environments, by exploring and developing new methods, models, techniques, strategies and tools. This will be achieved through proactive networking inside the Action (three meetings per year) and continuous interaction (two joint workshops per year) with other FP7 Projects and COST Actions. Both academic and industry researchers will be impacted by these activities. The Action scientific outcomes will include: - joint papers published over the scientific literature (co-authored by scientists of separate institutions/countries participating to this Action); -

joint papers presented at major IEEE Conferences (co-authored by scientists of separate institutions/countries participating to this Action); - organisation of workshops and events co-located with major conferences, related to GSEs; - joint and shared (i.e. pre-discussed at Working Group meetings of this Action) technical contributions to standardisation fora (3GPP, IEEE802.15 groups, etc.); - shared visions of technical nature transferred to other projects where scientists of this Action contribute; - submissions of Integrated Projects or STREPs originating from exchanges within and between the Working Groups of this Action; - World level dissemination through publication of one book after the first two years and another at the end of the Action.

C.2 Secondary objectives

As a secondary objective, the Action will play a supporting role to European industry, similar to that played by previous Actions in the mobile and wireless communications area. That is, it will contribute to the deployment of future wireless systems (e.g. LTE-Adv, IEEE802.11p or IEEE802.15.6) that are now very close to completion of their standardisation phase.

This will be achieved by ensuring all Working Groups are focused toward aspects of interest to industry.

As an additional objective, the Action will train ESRs in the field of cooperative radio communications for GSEs**.**

To this aim, the tool of Training Schools will be extensively used at a rate of (at least) one per year. Training Schools will be of inter-disciplinary nature, and include lecturers from both academia and industry.

Some quantitative targets of the success of the Action are as follows. They are based on the past experience of COST Action 2100.

Number of institutions involved from COST Countries: 100

COST Countries involved: 28

Institutions from non-COST Countries: 10

Percentage of institutions from the industry segment: 25%

Action participants: 500

Attendees to meetings (on average): 140

Number of technical presentation per meeting (on average): 70

Joint journal papers with acknowledgment to the Action per year: 50

Joint conference papers with acknowledgment to the Action per year: 100

Workshops organised per year: 2

Attendees to Training Schools: 100

Submission of IPs or STREPs to EC FPs, originated from the Action: 20

C.3 How will the objectives be achieved?

The objectives of this Action will be achieved by realising a cooperative, interactive environment where scientists and researchers from academia, industry and research centres will be allowed to meet and exchange their ideas and experiences. This environment will involve:

- Professors, who will dedicate manpower to the provision of lectures at Training Schools, and to attending the WG meetings; they will bring experienced visions of the future of radio communications for GSEs and select the activities within their research portfolios better tuned to the objectives of this Action;

- PhD students and ESRs, who will bring new and disrupting ideas to discuss, spending part of their manpower in attending the WG meetings and preparing Temporary Documents where their research results will be harmonised to those of the other Action participants; moreover, they might contribute to shared visions by dedicating effort to the Action through the performance of STSMs;
- Senior researchers from industry, who will bring experienced contributions in the form of Temporary Documents;
- Equipment at the institutions' premises that will be made available by participants through the STSM tool;
- Databases including measurement data owned by the Action participants and made available to other researchers;
- Software modules owned by the Action participants and made available to other researchers.

The Action, based on the interest declared by all experts who participated in COST2100, will have a very large number of participants, with a ratio between the number of MC members (who receive travel reimbursements for their participation in MC and WG meetings) and the overall number of participants to each meeting, of about 1 to 4**.**

The Action will invest in training PhD students and ESRs, thus ensuring proper renewal of the participants' skills. Moreover, the Action will foster participation of scientists and researchers from new institutions, by organising joint events with other projects and through the various dissemination activities mentioned in Section H.

C.4 Benefits of the Action

This Action addresses research issues arising in the field of cooperative radio communications for SEs, in particular in the areas of self-organising and efficient protocols and algorithms, cooperative transmission techniques, and radio channel models, to make our society and economy cleaner, safer, and more efficient.

The expected benefits are thus of industrial, societal and scientific nature.

- European industry and SMEs will benefit from a stronger industry-academia link in the field of green wireless communications; the industry interest in the green dimension is testified by many industry initiatives; moreover, GSEs will be an essential part of the broader and expanding context of the Internet of Things, a domain of high commercial interest to many European companies.
- Society as a whole will benefit from the availability of wireless technologies able to provide the same or better services as today with decreased energy consumption or environmental impact; the technologies addressed by this Action will help realising smarter cities, cars, homes, and will foster the development of new systems able to improve everyone's daily lives.
- The scientific society will benefit from the Action. From the scientific viewpoint, the role of cooperation in future wireless communications is testified by many papers; this Action will create proper background for understanding the mechanisms that maximise radio link and network capacities.
- The European Research Area will gain by a better integration of European research efforts.
- Individual researchers, especially in their early stages, and newly established research groups will find a stimulating environment for their cutting-edge work and education in this technical field. Thus strengthening their future participation in European and other international research initiatives.
- The institutions expressing interest to this proposal are active in COST2100, and comprise both large and small enterprises, research centres and Universities from 26 COST countries (plus some non-COST institutions). The COST framework will therefore continue benefiting from the presence of a large COST Action which, based on a deep knowledge of the radio channel, can provide an inter-disciplinary view to research in wireless communications.

The final outcome of this Action, apart from the scientific and technical advances, will be the creation of a widely shared consciousness of how the paradigm of green communications will be crucial for improving the communication services and their capabilities in all circumstances, and hence population lifestyle, in an environmentally sustainable way. This consciousness will be transferred from the experts participating in the Action to their respective national policy and regulation bodies, as well as to public opinion, by means of the dissemination plan detailed in section H below.

C.5 Target groups/end users

The likely end users of the Action outcomes (which will take the form of e.g. expert publications and standardisation inputs) naturally come from the beneficiary target audience and include:

- Individual researchers, in particular in their early stages,
- Universities and research institutions,
- Industry, both large **and** small enterprises, and
- Standardisation **bodies**.

Even members of non-beneficiary target groups, like political and societal actors at national and European level, may use the information arising from the Action as well-structured evidence-based input for policy making in this matter of high economical/ecological significance. For the same reason it is expected that media (e.g. scientific and non-scientific press) and the general public will have an interest in the Action outcomes.

Major stakeholders from all areas were involved in the preparation of this Action in order to increase the potential application of Action results and fostering their commercial exploitation, where appropriate.

D. SCIENTIFIC PROGRAMME

D.1 Scientific focus

It is critical for the efficient and green design of wireless systems in SEs to assess, account for and exploit the interactions between the radio propagation, signal processing and networking aspects. For this reason, the Action will intrinsically be strongly interdisciplinary and will concentrate on those issues which will technically condition the successful advent of SEs. In particular, given that the physical limits to wireless propagation in the relevant media will remain a major challenge, effort will be devoted to the radio channel and related aspects, its characterisation and modelling, its impact on transmission techniques at the signalling level and the resulting management of radio resources at the network level.

Globally speaking, wireless terminals, sensors and nodes operating in SEs are expected to cooperate with each other, forming local ad hoc networks, and to access networking infrastructures and establish connectivity to global networks and services. A SE will have a large number of heterogeneous elements co-existing in a relatively small space, producing individual information at different rates but combining to impose a huge demand for communications capacity, which measured in terms of its spatial density could be in the order of several Mbits/s/sqm. A smart network should also cope with the lack of fixed infrastructure reinforcing the need to establish links and relays among terminals, with consequences in the way the radio channel is used, the spectrum is managed and the network links are created. The scarcity of spectrum, as well as the need for reducing the energy consumption to a minimum, necessitate considering cooperative communications in transmission and networking levels, for which a proper model of the radio channel is mandatory. Disruption to the usual infrastructure-based and layered approach for the RAN is also a challenge, since some degrees of freedom can be gained for radio resources management. This will be crucial in dynamic and dense scenarios and require considering simultaneously evolved transmission techniques and dynamic resource management strategies. All these aspects will dominate the research efforts of the Action for its duration.

1. Scientific focus on the radio channel

The Action will focus on the poorly known aspects of the radio channel that will critically impact the performance of cooperative and energy saving techniques. Some specific issues, requirements and gaps in knowledge about the radio channel in this context are as follows:

- The antennas are generally small/low cost/inefficient and are strongly disturbed by a highly variable environment. Unfortunately there is very little knowledge or evaluation of these effects;
- The propagation media are often not very well known, especially for example for sensors embedded in materials, within the body and for unusual wireless devices locations;
- The frequency and spatial correlations of the channel characteristics of interest for dense wireless networks and crowded spectra need to be known;
- Point to multi-point or multi-point to multi-point channel models are expected to ease the assessment of cooperative network approaches;
- The connectivity between SEs or between smart and other environments require combining differing channel models to create a global multi-environment channel model;
- The extraction of accurate location information from approximate channel measurements need to be improved.

Therefore, a first focus will address the development of statistical channel models involving multiple objects or nodes, especially regarding the various spatial correlation effects. These models will allow for the proper assessment of the information exchange capabilities and performance of communicating devices, according to their characteristics, density and spatial distribution in the SE. They will be developed in a frequency-wise approach, owing to the many standards of interest for short/medium distance propagation (from ~400 MHz up to 60 GHz including ultra wide band). Propagation in unusual media (e.g. agricultural areas, media with embedded sensors, etc.) will also be addressed by the Action, as well as interference assessment and modelling in densely populated environments with smart communicating objects.

A second focus will be the effective performance of wireless objects used in real world conditions that are often dramatically affected by the strong influence of nearby objects or bodies entering the antenna near field. The statistics of these effects will be analysed and modelled, in relation to the type of devices of interest (frequency band(s), size) and the nature of their placement (on a human body, in a car interior, on indoor appliances etc.). The standardisation of the characterisation methods for radio devices, which is a necessity and of great interest for manufacturers and control authorities, will be part of this effort.

A third focus will be the time dependencies, especially in fast varying environments (cars for V2V or V2I communications, trains…), for which the channel may be highly non stationary and transitions from one type of environment to another may be abrupt. Keeping the connectivity will require fast switching from one system/standard or one network to another, which requires suitably designed protocols and physical layer benefiting from an accurate knowledge of the channel characteristics for the economical dimensioning of the fixed network architecture.

2. Scientific focus on signalling aspects

In comparison with existing wireless communications networks, GSEs will involve large numbers of autonomous interacting nodes. To implement communication across such an environment requires a step change away from the currently dominant paradigm in which the links between pairs of nodes are treated separately, with traditional physical layer techniques such as modulation and coding being applied on a link level only. This approach treats interactions between links as interference which is always deleterious and to be avoided by scheduling and resource management handled at higher layers.

The insights of multi-terminal and network information theory show that such an approach is highly inefficient in dense networks involving many nodes such as will occur in smart environments. A much more efficient paradigm is provided by cooperation between nodes, enabled by the distributed physical layer, in which physical layer techniques such as modulation and coding are applied across many cooperating links, and link interactions may bring benefits rather than detriment. In recent years a number of techniques have begun to introduce this new paradigm, especially virtual MIMO, cooperative diversity, distributed processing in relay networks, and interference alignment, but wider adoption will be necessary in true cooperative SEs. This new paradigm will therefore be the main focus of research within the Action on radio signalling within what might be described as the enhanced physical layer.

Moreover a truly GSE requires new attention to energy efficiency at all levels, from the antenna to the network topology. Cooperation has the potential to improve efficiency, as mentioned, but will be only one approach for this. Hence a second focus for the Action will be energy efficiency, encompassing energy overall expenditure in signal processing at baseband and at RF, as well as minimising transmitted energy.

Another requirement of SEs is the capability to meet delay constraints, since in many applications information delivery is extremely time-critical. These deadlines may be very close, requiring low latency, or further away but highly critical, which will pose new challenges. This leads to a third focus on timely signal delivery and processing, requiring renewed attention to error control coding and data compression, and a new perspective on all signal processing functions.

3. Scientific focus on radio network aspects

Making wireless mobile networks smart and efficient in future high dense and heterogeneous scenarios will imply facing some open challenges, among others:

- Context-aware networking techniques for the self-configuration of terminals and nodes to local transmissions, meaning that terminals react to changes in the environment and adapt their radio profile and their role in the local network.

- Sharing the spectrum in space, time and power, with no pre-assignment of specific spectral bands to the individual communications within the smart space.
- Self-organisation of the radio access, with no reservation of radio resources assumed at the network end and with terminals capable of sharing radio resources and managing them without a centralised coordination entity.
- Cooperative Radio Resource Management (CoRRM) to overcome the limitations of site-based RRM, which will delegate to the mobile terminals and nodes decisions on physical channels assignment, relaying and mobility, which will thereby become cooperative actions.
- Opportunistic Radio Access Networking (RAN), creating RAN “on the fly”, as in mesh or ad-hoc approaches.
- New approaches to cross-layer issues, joining the lower part of OSI stacks to create a single radio access protocol layer and eventually standardising cross-layer protocols to make the RRM procedures more flexible and quicker.
- Improving the overall energy efficiency, by properly combining the abovementioned issues with physical layer techniques.
- Exploiting the capabilities of the all-IP and fibre-to-the-antenna technologies at the infrastructure radio access network including, among others, the efficient implementation of Cooperative Multi-Point (CoMP), spectrum aggregation, dynamic RRM, femtocells coordination and self-organising networking.
- Exploiting location awareness towards more efficient routing and RRM techniques.

D.2 Scientific work plan—methods and means

The work plan will be determined by the objectives of four Topical Working Groups (TWGs) addressing specific SEs, supported by Disciplinary Working Groups (DWGs) whose achievements will be available to the TWG. The reason for such a structure is that many scientific results from the DWGs will benefit several and not only one type of SE. The TWGs selected for their potential major societal and economic impact are WGB (Body Environment), WGV (Vehicular Environment), WGI (Indoor Environment) and WGU (Urban Environment).

1. Scientific objectives and work plan for WGB – Body Environment

Body area networks are important for many existing and future applications in the health, sport, leisure and numerous other domains. Smart Health will be one of the hot topics of research in Europe in the next five years as testified by the current FP7 ICT WP. In spite of increased international efforts, much more work is required for the standardisation of channel models and physical layer schemes, given the various frequency bands considered and the variety of needs (low data rate, medium/high data rate), device locations (in-body/on-body/off-body) and the low consumption and radiated power requirements, which motivate device cooperation. Radio channel modelling when different gestures and motion habits are considered is a field almost completely unexplored. Inter-body communications will also become a relevant field of research interest, to exploit all possible means of node cooperation. These topics require joint consideration of mobility, radio channel model, cooperative transmission techniques and MAC/network aspects.

The work plan over 4 years is as follows: 1. – providing enhanced channel models covering the most important applications and scenarios (with WG1); 2. – exploiting these models towards the optimization of (especially, cooperative) transmission schemes (with WG2) and MAC/network layers designs (with WG3); 3. – validation in a few exemplary cases (in liaison with relevant projects and bodies such as IEEE 802.15, BANET, BASUMA, including telemedicine aspects).

2. Scientific objectives and work plan for WGV – Vehicular Environment

The integration of vehicles into a vast global information system is anticipated, having benefits in the area of safety, low fuel consumption/vehicle electrification and provisioning of internet and multimedia technologies to passengers. This is the vision indicated by the term Smart Cars. Wireless communications now penetrate the vehicle interior for both engine and control systems and for the supply of multimedia services, and create a permanent or occasional connectivity between neighbouring vehicles or with a fixed outside infrastructure. The Action will address the modelling of relevant radio channels (inside/outside cars or trains) and will use these models for the efficient design of physical layer and networking schemes. Given the various critical requirements for wireless links in moving vehicles, the security and reliability aspects will receive a special focus. Liaison will also be established with the relevant projects, bodies and industrial consortia within Europe (Car2car, Safespot, CVIS, etc.)

The work plan over 4 years is as follows: 1. – providing enhanced channel models covering the most important applications and scenarios (with WG1); 2. – exploiting these models towards the optimization of transmission schemes (with WG2) and MAC/network layers designs (with WG3), including security and reliability aspects; 3. – validation in a few exemplary cases (in liaison with relevant projects and bodies such as WAVE).

3. Scientific objectives and workplan for WGI – Indoor Environment

Application of radio communications inside buildings is currently one of the most relevant applications of wireless technologies for green applications. By endowing buildings with tiny sensors of power consumption over the electrical grid, and of other types (temperature, motion, etc.) in all spaces, the building becomes a GSE where all energy sources and sinks can be controlled in real time significantly reducing power consumption (Smart Energy). This sets up an ad hoc network made up of hundreds or thousands of devices sharing the radio channel under a self-organising approach in an unpredictable environment. Proper knowledge of radio channel characteristics is needed to achieve performance characterisation of these networks taking into account interference problems arising form the heterogeneity of wireless devices used in indoor environments. Moreover the indoor environment remains a major and expanding locus for telecommunication applications, including wireless LANs, femto-cellular communication, and a plethora of short range high rate communication standards, including UltraWideBand systems.

The work plan over 4 years is as follows: 1. – providing enhanced channel models covering the most important applications and scenarios (with WG1); 2. – exploiting these models towards the optimization of transmission schemes (with WG2) and MAC/network layers designs (with WG3), including security and reliability aspects; 3. – validation in a few exemplary cases (in liaison with relevant projects and bodies).

4. Scientific objectives and workplan for WGU – Urban Environment

The urban environment is intrinsically more complex than the other ones above discussed. Urban areas are characterised by a high density of population, a mixture of pedestrian and vehicular users, and a high usage of bandwidth-hungry applications. Furthermore, the urban environment is complex also from a propagation point of view. The presence of different layers of base stations, ranging from low micro- and picocells to rooftop base stations, requires taking into account the actual three-dimensional structure of the city. The requirements for every type of terminal in terms of quality and performance are quite different, as well as mobility behaviour.

The major challenge for urban communications in the coming decade will be to provide seamless connectivity and services at high throughput and excellent QoS at affordable costs and low energy consumption for the consumer (Smart Cities). This can be achieved only by cooperative techniques, supplemented by efficient use of distributed multiple antennas and single/multi-antenna relays. Multiple standards operation within a given device and smart handovers will help reach these goals. This will require technical developments and performance evaluation/proof-of-concept at both the terminal and network levels.

The work plan over 4 years is as follows: 1. – providing enhanced channel models covering the most important applications and scenarios (with WG1); 2. – exploiting these models towards the optimization of transmission schemes and MAC/network layers designs, including security and reliability aspects; 3. – validation in a few exemplary cases (in liaison with relevant projects and bodies).

5. Scientific objectives and work plan for WG1 – Radio Channel

The major objective of WG1 is to develop a body of radio channel models suited to the new challenges posed by the emerging GSEs, densely populated with cooperating and data exchanging objects, under stringent efficiency and environmental constraints. These models will have to meet the requirements described in section D.1, to cover all environments selected by the Action and to obtain inputs from and provide outputs to the other concerned WGs. The models will be consolidated by the large combined expertise of the contributing members of the Action, guaranteeing a wide European and international acceptance, well beyond the circle of its members.

The work plan over 4 years is as follows: 1. – identification of scientific and technical challenges and goals; 2. – specification and implementation of works in order to enrich radio channel knowledge and construct databases; 3. – data analysis and models extraction.

6. Scientific objectives and work plan for WG2 – Radio Signalling

The major objective of WG2 is to accommodate the requirements of physical layer implementation in SEs, and especially improving energy efficiency, exploiting cooperative techniques. This will require the development of the new paradigm of the distributed physical layer, as described above. This will cover a range of new approaches and challenges, including: cooperative relaying and cooperative diversity, virtual supernodes and virtual MIMO, network MIMO, network distributed channel coding and modulation, interference alignment, distributed channel parameter estimation, source coding for correlated sources, implementation on broadband channels, OFDM for cooperative systems, energy-efficient signal processing, energy-efficient waveforms, minimizing EM radiation, low latency physical layer design, PHY design to meet delay deadlines.

The work plan over 4 years is as follows: 1. – identification of scientific and technical challenges resulting from the requirements of GSEs; 2. – a definition of the distributed physical layer paradigm and its application to GSEs; 3. – development of new cooperative physical layer and signal processing techniques; 4. - investigating implementation of these techniques.

7. Scientific objectives and work plan for WG3 – Radio Networks

The objective of WG3 is to develop networking protocols that suit the paradigms created for GSEs, where a large number of heterogeneous elements will co-exist in a relatively small space, producing individual information at different rates but giving rise to a huge demand for communications spatial capacity, in the order of several Mbits/s/sqm. The scenarios addressed must also cope with a lack of fixed infrastructure and scarcity of spectrum, as well as the need for reducing the energy consumption to a minimum, so some approaches must be taken which will be disruptive of the usual layered approach for RAN protocols, losing the benefits of modular systems, but gaining several degrees of freedom for radio channel resources management, which will be crucial in such dynamic and dense communications scenarios.

The work plan for the 4 years is as follows: 1. - evaluation of the networking requirements in smart and green scenarios; 2. - development of Cooperative RRM algorithms; 3. - development of techniques for extremely efficient spectrum usage; 4. - inclusion of energy efficiency architectures and protocols into the smart networks; 5. - evaluation of the new techniques on specific scenarios, both by simulations and lab test-beds.

E. ORGANISATION

E.1 Coordination and organisation

This Action is set up under the proposition that one of the reasons for success of COST Actions is the realisation of a collaborative and highly interactive framework where MC members and experts can discuss every activity/initiative undertaken with a bottom-up approach, in an open context, under a concerted framework where every scientist has the same right to make proposals. MC members share the responsibility of Action management, but all participants to the Action, let them be MC members or not, should feel free to contribute to all discussions. The MC Chairperson will be elected by the MC at the kick-off meeting among those who share this vision. To ensure that all Action activities are under the control of the MC, all General Meetings (see Section E.2) will start with a MC meeting, and end with a MC meeting where the WG Chairpersons will report to the MC on all discussions and decisions held within the WGs. The WG Chairpersons will be elected every two years by the MC members.

The day-by-day Action management will be coordinated by two people: 1) the MC Chairperson, who will act as intermediary between the MC and the COST Office and will prepare all scientific reports, and 2) the MC Vice-Chairperson, who will act as Grant Holder responsible and will take care of the financial reports. The Vice-Chairperson will also be responsible for the logistics of all meetings, together with the local organiser; in this way, the MC Chairperson will concentrate his/her efforts on the proper development of all scientific activities. He/she will be supported by the three DWG Chairpersons, and a Training, Dissemination and Liaison (TDL) Manager elected by the MC every two years, who will manage the organisation of Training Schools, all dissemination events and liaisons with other projects. A Steering Committee is defined, composed of the Chair and Vice-Chairperson, the three DWG leaders and the TDL Manager; the Steering Committee will be supported by the Secretary, who will also keep up to date the Action website, set up and technically maintained by the Grant Holder, and manage the e-COST tool.

The MC, which will meet every four months (see Section E.2), will take all relevant decisions on administrative and scientific issues, with two exceptions: 1) the applications for STSMs received by the MC Chair will be periodically assessed by the Steering Committee members (if no conflicts of interest arise), which will provide consensus to STSM performance; 2) assignment of grants to Training School students will be performed by the TDL Manager. These exceptions will allow smooth and dynamic management of the events (Training Schools and STSMs) that will happen between two consecutive MC meetings. The MC Chairperson will report to the next MC meeting on all decisions taken by the Steering Committee.

The agenda of each MC meeting will include an item dedicated to the milestones to be achieved in the next year, including organisation of next meetings, Training Schools, workshops.

The Action website will be set up during the first three months after the kick-off meeting. It will:

- Give general information on the Action objectives, and its organisation;
- Provide all official COST documents;
- Offer all information needed for the participation to meetings, schools, workshops;
- Provide open access to the titles, Author lists and abstracts of Temporary Documents;
- Include a Members' Area, open only to the Action participants, with the PDFs of all Temporary Documents;
- Host WG pages to have a better sharing of information;
- Host advertisements on job opportunities, other initiatives organised by institutions or research projects/fora;
- Include an ftp site for the exchange of documents;
- Distribute the Action Newsletters.

A general reflector including email addresses of all Action participants will be maintained, and WG reflectors as well.

E.2 Working Groups

As specified in Section D, four Topical WGs (TWGs) will address specific types of GSEs and three Disciplinary WGs (DWGs) will provide the scientific support to the TWGs. Such a large number of WGs is justified by the ambition and coverage of this Action and by the targeted number of members. Most experienced scientists who expressed an interest in contributing to this Action already participated in COST2100; therefore they have a proven experience on cooperation and networking through large COST Actions.

The three Disciplinary WGs will be chaired by scientists elected by the Management Committee every two years. Each Topical WG will be chaired by a scientist elected by the WG members every two years. If sub-WGs are created, they will be chaired by a scientist elected by the members of the relevant WG.

The (sub-)WG Chairs will be responsible for the preparation of WG meetings and for the animation of scientific exchanges and activities relevant to their WG (organisation of workshops, etc.). They will draft WG meeting minutes and will report directly to the MC at each MC Meeting.

The Action will organise three General Meetings per year, normally with a duration of three days. Each General Meeting will include:

- a Management Committee Meeting (half day),
- a Scientific Meeting open to all experts participating to the Action.

The Scientific Meeting will start with (parallel) sessions of the Disciplinary WGs, and then will continue with (parallel) sessions of the Topical WGs and (if any) sub-WGs. During the WG meetings, technical presentations of Temporary Documents, provided to all participants to the Action a few days before the General Meeting via the ftp site, will be given. The WG Chairs will ensure sufficient time is given to have thorough and open discussion of the topics presented. Proper sessions will be planned in the WG meetings for open discussions on general scientific topics.

Between successive General Meetings, coordination of scientific activities will be achieved by using email reflectors containing all email addresses of WG participants, and through the information shared at the Action website.

E.3 Liaison and interaction with other research programmes

The Action will organise every year at least one (possibly two) workshop(s), to be co-located with the General Meetings, the day before or after them, with other consortia: COST Actions, FP7 Projects, industry fora, standardisation groups, etc. Depending on the type of consortium addressed, this might bring to open (e.g. circulated externally to the Action) call for papers and peer scientific reviews, call for technical contributions limited to the two consortia but open to all their participants, or invitation of specific contributions.

A Memorandum of Understanding might be signed with relevant consortia having interests and scopes similar to those of the Action (Networks of Excellence, European Technology Platforms, etc), to allow sharing of resources (databases, software, etc).

Liaison with standardisation bodies like ETSI, URSI Commissions B, C, E, K, IEEE Technical Groups 802.15, 802.11, 3GPP Working Groups, will be sought by means of official actions (like e.g. letters sent by the MC Chairperson, participation to the meetings of these groups by Action participants delegated by the MC, etc) and contacts generated by the Action participants at individual level.

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 MC will place this as a standard item on all its MC agendas. The Action will also be committed to considerably involve ESRs. This item will also be placed as a standard item on all MC agendas.

Specific activities will be devoted to ESRs, like the Training Schools. Moreover, they will be involved at the highest degree, inviting them to submit proposals of sub-WGs and chair them. Possibly, some TWGs will also be chaired by ESRs.

F. TIMETABLE

The Action will remain in force for a period of four years.
The activities associated with each WG, and the possible Sub-WGs that will emerge as the need arises, can be grouped into the following packages:

1. development of common reference scenarios to allow better comparability of results, also taking advantage of previous activities carried out in former Actions, and their maintenance according to the feedback received by package two and first phase of package three (duration: one year and a half, starting at T0 – kick-off meeting);
2. identification and selection of the most promising techniques to be investigated and evaluated in detail (duration: one year and a half, starting at T0);
3. development of models, algorithms, methods for the areas under consideration, and realisation of simulations and measurements (duration: two years and a half, starting at T0+12months);
4. assessment of models, algorithms, and methods by comparing their results with the ones from simulations and/or measurements, possibly under common reference scenarios (duration: two years and a half, starting at T0+12months);
5. writing of the final report (duration: one year, starting at T0+36months).

The Final Report, which will be delivered at the end of the fourth year, will be prepared according to a continuous process of identification, during the four years of activities, of the most relevant results obtained. However, the most significant effort for its preparation will be carried out in the last year. Annual Reports will be also published at the end of each year, and a detailed schedule for the preparation of these reports will be decided in the kick-off meeting of the Action.

G. ECONOMIC DIMENSION

The following COST countries have actively participated in the preparation of the Action or otherwise indicated their interest: AT, BE, BG, CH, CY, CZ, DE, DK, EL, ES, FI, FR, HR, IE, IL, IT, NL, NO, PL, PT, RO, RS, SE, SI, SK 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 104 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.

Canada, China, Columbia, Japan, Singapore and USA have also expressed their interest to participate to the Action.

H. DISSEMINATION PLAN

H.1 Who?

Dissemination of results outside the Action is of outmost importance in any scientific activity, hence, this Action will address several audiences for dissemination of its work and results, using different instruments according to the target audience: in some cases, the results may directly benefit others working in the same area; in other cases, the dissemination may lead to the valuable exchange of information between the target audience and participants in the Action, benefiting both sides; still, in other situations, the dissemination to several bodies will benefit the Action, increasing its visibility at the international (beyond Europe) level, and consequently that of the COST framework as well; finally, results of the Action being input to standardisation bodies will constitute a benefit to the society at large, creating additional value for the work performed by the researchers in the Action. Furthermore, dissemination should also be seen as an activity to be developed inside the Action, as it enables a better exchange of information within the Action's participants.

The target audience for dissemination will be:

- Ph.D. students, as they are a valuable resource for R&D in academia and many of them will join industry later, performing research work during the development of the thesis that may be in direct relation with the Action;
- Professors, as they may be directly interested in the results of the Action in their supervision and own research work as well as its networking and emulation effect;
- Researchers in R&D centres, as they may be directly interested in the results of the Action in their research work as well as its networking and emulation effect;
- Researchers in industry centres, as they may be directly interested in the results of the Action in their research work, especially concerning standardisation;
- Universities and R&D centres at the institutional level, as they may have an interest in having their researchers collaborating in the COST framework;
- Industries (operators, manufacturers, and SMEs), as they may benefit directly from the results of the Action, and also fostering contributions to standardisation, besides increasing the Action visibility;
- Projects' Consortia at the European (i.e., FP7 and FP8, including JTIs and PPPs) and national levels, with goals similar to Industry ones;
- European Technological Platforms (namely, *e*Mobility), aiming at increasing the Action's visibility;
- Standardisation Bodies and Industry Associations (e.g., 3GPP, IEEE, CTIA, and ETSI), concerning contributions to standardisation, and increasing the Action visibility;
- finally, policy bodies and the public in general, with the objective of increasing the Action's visibility.

This Action includes, among its proponents, researchers that are actively involved in all of the above mentioned institutions and bodies, and that have experience in dissemination activities of this kind, therefore, the target audience can effectively be reached with the instruments described below.

H.2 What?

Dissemination instruments have to be taken as a wide variety, not only because different audiences are to be targeted, but also because there is the need to use different approaches according to the objectives to be reached. As a consequence, dissemination has to range from the "traditional" publication of papers to the more novel use of social networks, aiming not only at reaching all the targeted audiences but also to convey the different "messages" that the Action has as objective. The Action will use the following instruments to reach the target audiences:

- public website, containing all the relevant information concerning the Action;
- private file server, for exchange of Action's documents, namely Temporary Documents;
- internal email reflectors, for the circulation of all the information inside the Action;
- external email reflectors, for circulating information to both Action's participants and external interested parties of general interest (e.g., Newsletter);
- professional social networks, by establishing an interest group in one or more of the available Internet based platforms (e.g., LinkedIn);
- Temporary Documents, to be presented and discussed in Action's meetings;
- joint papers (by Action's participants), in journals and conferences;
- contributions to standardisation, submitting the results of joint work within the Action to the relevant bodies;
- Newsletters, to be issued after each meeting, describing the main results, with a selection of papers, and having the widest circulation possible;
- contributions to the COST Secretariat upon request, generally with high level results and broad scope, for a wider dissemination at policy bodies and the general public;
- Tutorials (half- or one-day long), adjacent to meetings, given by internal researchers, enabling the dissemination of work in a deeper way;
- Proceedings of Annual Workshops, where the progress of the Action will be shown;
- Proceedings of Joint Workshops with other projects (ranging from NoEs to IPs, and encompassing national initiatives as well), to be organised together or adjacent to the Annual Workshops, fostering the exchange of information between the corresponding participants;

- Proceedings of Annual Training Schools, where external researchers together with Action's participants will lecture the latest outcomes on specific topics;
- Topical Sessions in Conferences, showing results from the Action on given topics;
- Book(s) (Technical Reports), containing the main results achieved in the Action, structured by topical chapters, thus, creating conditions for them to be a reference for further work.

Again, the Action proposal includes, in its proponents, researchers that are experienced in all of the above mentioned instruments, therefore, maintaining a low implementation risk.

H.3 How?

The previously identified instruments will be used according to their specific characteristics, as well as to the intended target audiences. Not only one needs to consider the specific characteristics of a COST Action (e.g., number of meetings per year, bottom up approach, and mixed profile of participants), but also the means that are available to implement these instruments. Action's meetings will be scheduled on the basis of 3 per year, typically around January, May, and October. Accordingly, the dissemination instruments will be set up as follows:

- public website, which will be set up at the beginning of the Action, and continuously updated, containing information for all audiences;
- private file server, which will be set up at the beginning of the Action, and updated according to the meetings schedule, containing information for Action's participants;
- internal email reflectors, which will be set up at the beginning of the Action, and continuously updated, aiming at Action's participants;
- external email reflectors, which will be set up at the beginning of the Action, and continuously updated, aiming at Action's participants as well as external parties;
- professional social networks, by setting up an interest group at LinkedIn (other networks may be considered) at the beginning of the Action, aiming at Action's participants as well as external parties;

- Temporary Documents, authored by Action's participants (containing either individual or joint work), for discussion at Action's meetings, aiming at Action's participants;
- joint papers, authored by Action's participants, as a result of the work put together in the Action, aiming at Action's participants as well as external parties;
- contributions to standardisation, authored by Action's participants, as a result of the work put together in the Action, aiming at external parties;
- Newsletters, to be issued after each meeting, aiming at Action's participants as well as external parties;
- contributions to the COST Secretariat, upon request, containing the requested information, for a wider dissemination at policy bodies and the general public;
- Tutorials (half- or one-day long), adjacent to meetings, aiming at Action's participants, but open also to external parties;
- Proceedings of Annual Workshops, adjacent to the meeting at the end of year Action year, aiming at both Action's participants and external parties;
- Proceedings of Joint Workshops adjacent to a meeting, aiming at both Action's participants and external parties;
- Proceedings of Annual Training Schools, potentially (but not necessarily) adjacent to a meeting, aiming at both Action's participants and external parties;
- Topical Sessions in Conferences, to be organised in major international conferences, according to their schedule, aiming at external parties;
- Book(s) (Technical Reports), to be published by the end of the Action (and possibly one after the first two years), aiming at both Action's participants and external parties.

The experienced gathered by the Action proponents in previous Actions ensures that the implementation of all these instruments will be performed in a timely and duly way, hence, projecting an image of excellence to the outside world, not only of the Action itself but of the COST framework as well.