Brussels, 30 October 2015

COST 036/15

DECISION

Subject: **Memorandum of Understanding for the implementation of the COST Action "Inclusive Radio Communication Networks for 5G and beyond" (IRACON) CA15104**

The COST Member Countries and/or the COST Cooperating State will find attached the Memorandum of Understanding for the COST Action Inclusive Radio Communication Networks for 5G and beyond approved by the Committee of Senior Officials through written procedure on 30 October 2015.

COST Association
Avenue Louise 149 I 1050 Brussels, Belgium
t: +32 (0)2 533 3800 I f: +32 (0)2 533 3890
office@cost.eu I www.cost.eu

MEMORANDUM OF UNDERSTANDING

For the implementation of a COST Action designated as

COST Action CA15104
INCLUSIVE RADIO COMMUNICATION NETWORKS FOR 5G AND BEYOND (IRACON)

The COST Member Countries and/or the COST Cooperating State, accepting the present Memorandum of Understanding (MoU) wish to undertake joint activities of mutual interest and declare their common intention to participate in the COST Action (the Action), referred to above and described in the Technical Annex of this MoU.

The Action will be carried out in accordance with the set of COST Implementation Rules approved by the Committee of Senior Officials (CSO), or any new document amending or replacing them:

a. "Rules for Participation in and Implementation of COST Activities" (COST 132/14);
b. "COST Action Proposal Submission, Evaluation, Selection and Approval" (COST 133/14);
c. "COST Action Management, Monitoring and Final Assessment" (COST 134/14);
d. "COST International Cooperation and Specific Organisations Participation" (COST 135/14).

The main aim and objective of the Action is to address the technologies for supporting wireless connectivity for any rates, type of communicating units, and scenario, in and beyond 5G. The envisioned Wireless Internet of Things of 2020 will in particular require revolutionary approaches in theoretical foundations of Radio Communication Technologies, Networks and Systems. This will be achieved through the specific objectives detailed in the Technical Annex.

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 128 million in 2015.

The MoU will enter into force once at least five (5) COST Member Countries and/or COST Cooperating State have accepted it, and the corresponding Management Committee Members have been appointed, as described in the CSO Decision COST 134/14.

The COST Action will start from the date of the first Management Committee meeting and shall be implemented for a period of four (4) years, unless an extension is approved by the CSO following the procedure described in the CSO Decision COST 134/14.

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Register of legal Entities Brussels: 0829090573

COST Association
Avenue Louise 149 I 1050 Brussels, Belgium
t: +32 (0)2 533 3800 I f: +32 (0)2 533 3890
office@cost.eu I www.cost.eu

OVERVIEW

Summary

Radio Communications have become one of the pillars on which our Society relies for performing many daily tasks. Today, the number of connected devices is increasing exponentially, reflecting not only enthusiastic smartphone adoption but also increasing connectivity of machines, sensors, vehicles and other devices for health and smart environments.

The Inclusive Radio Communications (IRACON) concept defines those technologies aimed to support wireless connectivity at any rates, for any communicating units, and in any type of scenarios. The Wireless Internet of Things beyond 2020 will require revolutionary approaches in Radio Access technologies, networks and systems. Some theoretical foundations have to be revisited and breaking technologies are to be discovered during the coming decade.

This COST Action aims at scientific breakthroughs by introducing novel design and analysis methods for the 5th-generation (5G) and beyond-5G radio communication networks. Challenges include i) modelling the variety of radio channels that can be envisioned for future inclusive radio, ii) capacity, energy, mobility, latency, scalability at the physical layer and iii) network automation, moving nodes, cloud and virtualisation architectures at the network layer, as well as iv) experimental research addressing Over-the-Air testing, Internet of Things, localization and tracking and new radio access technologies.

The group of experts supporting this proposal comes from both academia and industry, from a wide spread of countries all over Europe, with the support of some non-COST institutions and R&D associations and standardisation bodies worldwide. The proposers have also long experience on COST Actions in the Radiocommunications field.

Areas of Expertise Relevant for the Action	Keywords
● Electrical engineering, electronic engineering, Information engineering: Communications engineering and systems (select for additional explanation)	● Radio access networks ● Propagation modelling ● Wireless Internet of Things

Specific Objectives

To achieve the main objective described in this MoU, the following specific objectives shall be accomplished:

Research Coordination

- Agree on models for the variety of radio channels that can be envisaged for inclusive radios.
- Share views and discussions on Capacity, Energy, Mobility, Latency, Scalability at the Physical (PHY) and Medium Access Control (MAC) layers.
- Connect researchers in the area of Radio Access Network automation, moving nodes, cloud and virtualisation architectures at the MAC and network (NET) layers.
- Coordinate shared experimental research addressing Over-the-Air (OTA) testing, IoT, localisation, tracking and radio access.

Capacity Building

- Promoting collaborative research across different fields, such as radio channel characterisation, PHY, MAC and NET design, for both cellular and non-cellular radio network paradigms;

- Creating a generation of researchers with competences on both cellular and IoT-type radio networking;
- Fostering a generation of young researchers able to address wireless communication techniques relying on joint theoretical and experimental approaches;
- Consolidating some initiatives aiming to establish integrated pan-European laboratory facilities for testing the development of 5G-and-beyond networks;
- Supporting European industries with relevant and widely recognised initiatives including industrial, research centres and academia.

COST Association
Avenue Louise 149 I 1050 Brussels, Belgium
t: +32 (0)2 533 3800 I f: +32 (0)2 533 3890
office@cost.eu I www.cost.eu

DESCRIPTION OF THE COST ACTION

1. S&T EXCELLENCE

1.1. Challenge

1.1.1. Description of the Challenge (Main Aim)

The demand for mobile connectivity is continuously increasing, and by 2020 Mobile and Wireless Communications will serve not only very dense populations of mobile phones and nomadic computers, but also the expected multiplicity of devices and sensors located in machines, vehicles, health systems and city infrastructures. The ***Inclusive Radio Communication Networks*** concept defines the technologies for supporting wireless connectivity for any rates, type of communicating units, and scenario. It is expected to be implemented in and beyond the fifth generation (5G) of radio communication networks. Spectral and spatial efficiency are key challenges, in addition to constraints like energy consumption, latency, mobility, adaptability, heterogeneity, coverage, and reliability, amongst others. While many of these aspects are not especially new, the wireless Internet of Things (IoT) beyond 2020 will in particular require revolutionary approaches in Radio Access Technologies (RATs), networks and systems in order to overcome the limitations of the current cellular deployments, the layered networking protocols, and the centralised management of spectrum, radio resources, services and content. Theoretical foundations have to be fully revisited and disruptive technologies are to be discovered during the coming decade.

This Action, IRACON, aims to achieve scientific breakthroughs, by introducing novel design and analysis methods for 5G, and beyond-5G, radio communication networks. IRACON aims at proposing solutions for inclusive and multidimensional communication systems with a wide variety of devices, practical constraints and real-world scenarios, addressing systems ranging from very simple transceivers and sensors, to smartphones and highly flexible cognitive radios. Challenges include: i) modelling the variety of radio channels that can be envisaged for inclusive radios; ii) capacity, energy, mobility, latency, scalability at the physical (PHY) and Medium Access Control (MAC) layers; iii) network automation, moving nodes, cloud and virtualisation architectures at the MAC and Network (NET) layers; iv) experimental research on the practicality of the proposed techniques, addressing Over-the-Air (OTA) testing, IoT, localisation, tracking and radio access:

i.The current knowledge of radio channels needs to be extended over a wider span of frequency bands not previously considered, to allow system designers to fully employ radio channel models to improve performance in coverage, coexistence, data rate and capacity, delay and latency, reliability and dependability, setup and mobility, amongst many other metrics. Many aspects of the radio channel still need better understanding and modelling, such as depolarisation, frequency dependence, vegetation influence, new materials and interaction with human tissue. Antenna design and evaluation methods require new approaches for improved energy-efficiency, cost-effectiveness and capabilities to analyse human-antenna and antenna-channel interactions. New modelling methods should also build upon progress in computational power.

ii.Currently studied 5G technologies lie within the scope of IRACON for short term developments; however, the main challenges are to foresee the evolutions of radio communication in 5 to 10 years, to discuss the implications of theoretical fundamentals (energy/capacity/latency trade-offs, short vs. long packets, non-Gaussian environment, time and space dependence, waveform design, etc.) and to propose novel and practical approaches for joint channel and network coding, interference mitigation and overcoming technological limitations at higher frequencies.

iii. One of the major challenges in wireless networks continues to be the rapid increase in demand for capacity. Network densification is seen so far as the most efficient solution to meet this demand in addition to other improvements in spectrum allocation and its management. Some approaches in dense urban environments include mesh networks between base stations, deploying small-cells, necessary combined with the introduction of HetNets (Heterogeneous Networks)

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COST Association
Avenue Louise 149 I 1050 Brussels, Belgium
t: +32 (0)2 533 3800 I f: +32 (0)2 533 3890
office@cost.eu I www.cost.eu

technologies. HetNets implies the coordinated planning and operation of multiple RATs and of multiple cell-layers. In addition to the increasing number of cells, this also means increased complexity. This complexity calls for new solutions, and research is needed both towards the further evolution of 3GPP standards, and mostly for the design of 5G-and-beyond, in order for future networks to deliver the necessary performance as well as cost-efficiency. The further development of cooperative techniques at the physical layer means more interaction between traditional physical and network level functions.

iv.Experimental platforms will play an important role in IRACON in order to test communication (or localisation) propositions. While channel modelling is naturally confronted by measurements, PHY to NET layer solutions need specific test beds with real time implementation. Whether or not the solutions are evaluated theoretically or through simulations, the only feasible way to take all the parameters into account is to utilise experimental platforms like those included in IRACON.

This project will address the heterogeneous nature of future massive connectivity of humans and machines with embedded intelligence and the diversity of the wireless channels that will be used to create this connectivity. Ensuring that the RATs are capable of including them all is an essential challenge in the revolution brought about by Information and Communications Technologies (ICTs).

1.1.2. Relevance and timeliness

The improved knowledge of radio channels, including antenna-channel and antenna-human interactions, is a prerequisite for the development and standardisation of 5G-and-beyond cellular networks. It is anticipated that the most relevant 5G technologies will include: terminal characteristics, waveform design, resource availability, traffic patterns, embedded intelligence, flexibility and fault tolerance, massive MIMO (Multiple Input Multiple Output), intelligent antenna systems, energy-efficient communications, cooperative and cognitive radio networks, heterogeneity of cells and networks including extremely small, mobile femto-cells, etc. Most of these technologies will be addressed by IRACON. They are essential to the establishment of a networked society for “smart-city/building/grid”, factories of the future, medical and healthcare services, and emergency applications, among many other scenarios. Networking all the device types of the coming decade within IoT, as well as ensuring different services and reliability, and connecting all types of objects, are crucial aspects to be developed in Inclusive Radio Communication Networks.

Finally, experimental studies are being called upon more and more for the validation of the above-mentioned theories and technologies. Emphasising the experimental studies of novel OTA testing methods, IoT design and testing, practical environmental awareness, localisation methods and future RATs, is in line with the trends in innovative and practical solutions for 5G-and-beyond technologies.

1.2. Specific Objectives

1.2.1. Research Coordination Objectives

The development of 5G-and-beyond systems requires the joint consideration of all aspects related to the exploitation of radio resources: from the radio channel to the PHY, MAC and Network layers. The techniques envisioned for future wireless standards are in fact so revolutionary that they have impact on many separate aspects of the Radio Access Network (RAN). Massive MIMO and beamforming are good examples of this, as these techniques, implemented at the PHY layer, will heavily impact the strategies implemented for radio resource control at MAC and Network layers, and in turn are strongly dependent of the characteristics of the radio channel. Therefore, research developments on radio channel characterisation, PHY, MAC and NET layers need to be suitably coordinated. IRACON is organised into three Disciplinary Working Groups (DWGs) (see Section 3) respectively dealing with the radio channel, PHY as well as MAC/NET layers. Meetings will be organised in such a way that a proper coordination of activities among the three DWGs is achieved, namely via joint sessions regrouping documents with overlapping interests. This coordination will ensure that new techniques developed within IRACON will be jointly devised and assessed from all viewpoints.

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COST Association
Avenue Louise 149 I 1050 Brussels, Belgium
t: +32 (0)2 533 3800 I f: +32 (0)2 533 3890
office@cost.eu I www.cost.eu

Moreover, this coordination of research efforts is further demonstrated within IRACON by the creation of four Experimental WGs (EWGs, see Section 3) that will address specific topics through a transversal approach; experimental facilities will be made available by institutions to IRACON participants in order to test new algorithms, techniques and protocols in real-world contexts, enabling a coordinated effort among experts of separate disciplines, as complex test beds need a variety of suitably joint and coordinated competences. Coordination among theoretical and experimental activities will be ensured through a back-and-forward principle: new ideas, novel techniques envisioned within the DWGs will be considered as candidates for their testing on the experimental facilities made available within the EWGs. At the same time, real-world experiments conducted within the EWGs will provide useful databases of measurements for the theoretical activities brought forward within the DWGs.

1.2.2. Capacity-building Objectives

During the past decade, FP6 and FP7 funded Networks of Excellence (NoEs) in Europe (e.g., NEWCOM and its successors) together with successful COST Actions (e.g., 273, 2100 and IC1004) addressed mobile and wireless communications supporting long-term and pre-competitive research. They enabled a suitable interaction among academia and industry on topics of a pre-standardisation nature. In H2020, there are no longer such instruments allowing for pre-competitive research able to include many institutions, from academia, research centres and industries (both large companies and SMEs), around a wide topic like 5G-and-beyond. IRACON will provide a unique marketplace for the next years where industry (including 5G PPP (Public-Private Partnership) stakeholders) and universities can build altogether a strong and coordinated capacity in research.
The major capacity-building objectives refer to: promoting collaborative research across different fields, such as radio channel characterisation, PHY, MAC and NET design, for both cellular and non-cellular radio network paradigms; creating a generation of researchers with competences on both cellular and IoT-type radio networking; fostering a generation of young researchers able to address wireless communication techniques relying on joint theoretical and experimental approaches; consolidating some initiatives aiming to establish integrated pan-European laboratory facilities for testing the development of 5G-and-beyond networks; supporting European industry with relevant and widely recognised initiatives including industry, research centres and academia.

1.3. Progress beyond the state-of-the-art and Innovation Potential

1.3.1. Description of the state-of-the-art

Many challenges remain at a pure technology level, and many new ones have emerged; indeed recently proposed algorithms and tools are studied in a more global context and/or must be used in various environments. In fact, it is expected that new standards will include many situations that are currently studied separately. This inclusiveness is one of the main challenges in the coming years, as it can be illustrated by IoT; the traffic generated/destined by/to things will represent a significant part of the overall 5G data traffic. Including IoT in a more global communication standard is a real challenge, due to the huge difference in throughput, energy requirements, etc. Moreover, it is critical to jointly consider the radio channel, PHY, MAC and NET layers to support adaptability and heterogeneity.
A huge amount of work on radio communications has been going on in the scientific and industrial communities for several decades, however, inclusive radio requires further research and breakthroughs:

i. Channel modelling continues to be of fundamental importance. A rich spectrum of radio channel measurements, characterisation, and modelling results is available in [0.7, 6] GHz. For higher frequency bands (cm- and mm-waves), now being considered for some 5G implementations, there were studies made in previous projects [Ver12], but specific measurement campaigns and a global regulation of such spectrum for mobile services is still missing. The models available so far cover cellular access between base and mobile stations, vehicular communications and device-on-body

COST Association
Avenue Louise 149 I 1050 Brussels, Belgium
t: +32 (0)2 533 3800 I f: +32 (0)2 533 3890
office@cost.eu I www.cost.eu
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scenarios. A number of reference channel models are available, such as IEEE [Mal09], WINNER [Kyo07] and COST2100

[LPQ+1]. In addition, the impact of antennas “in free space” on the radio channel characteristics has been thoroughly investigated below 6 GHz, leading to a number of design criteria for a “good antenna array” on a small device and antenna evaluation methods [Lau11]. However, this does not cover all the characterisations that will be necessary in the near future. In particular, a standard for OTA testing of user equipment is only available for single-antenna cellular radio devices [3GP09]. Efforts to provide an OTA testing standard for multi-antenna MIMO devices are ongoing, and further standards will be needed after the first MIMO OTA standard is finalised [3GP14] to include temporal evolution of large-scale effects, uplink, etc.

ii.Novel PHY-layer techniques for 5G transmissions have been studied: massive MIMO [LTEM14], antenna arrays, spectrum-aggregating orthogonal multicarrier waveforms [BWAPK11], synchronisation and detection schemes, localisation and sensing methods, cooperative and cognitive radio, etc… However, these commonly make a lot of impractical assumptions, e.g.: all nodes have the same transmission requirements, infinite, continuous and not packetised data, common coding and modulation applied to each link. This is not the case for practical networks, and will certainly not be the case for future Inclusive Radio Communications. Moreover the idealised models commonly used by PHY researchers are increasingly inadequate for these techniques, and more accurate and relevant modes are required. In addition such techniques have generally been applied to individual links separately, rather than considering the PHY layer in the context of a complete wireless network.

iii. Efficient protocol design for future inclusive radio communication is a challenge for the heterogeneous IoT [ZGL10] including a wide range of applications with vastly different characteristics and requirements. Reducing overhead by efficient design of headers, link and network control information is essential for high spectral and/or energy efficiency. Access to the so-called context information on links and networks is considered as key to optimal or nearly-optimal reception quality, resource sharing, load balancing among networks, etc. Still, the problem of context information storage, representation and secure distribution for optimal 5G networks performance is open.
In order to address the inclusive communications challenges, one can also distinguish between theoretical works, simulations and test beds. The PHY layer is a good illustration of this; channel models are becoming extremely complex and the scale change (densification of networks) make the multiple user context very difficult to simulate with certain accuracy on the transmitted signals. Consequently, assumptions are made to enable analytical solutions, e.g., stochastic geometry approaches [Hae12], and physical layer network coding [DBY14]. If theoretical analyses are essential to understand how the radio communications work, the underlying assumptions have to be verified. On the other hand, many experimental facilities exist, but linking experiment and theory becomes extremely difficult, due to the heterogeneity of devices, networks and environments. Developing a coordinated group of experimental facilities will be one important goal of IRACON, in order to link theory and practice.

1.3.2. Progress beyond the state-of-the-art

Overcoming the actual limitations of the state of the art requires working along the following lines:
For Channel measurements and modelling:
 More accurate radio channel characterisation and modelling, including: (i) “new” deployment scenarios, such as very high mobility (vehicular, drone), different human body postures and tissues, harsh physical environments, ultra-dense device deployment, very-short links, highly directional front/backhaul links, among others; (ii) Multiband and wideband channel modelling with carrier frequencies above UHF up to TeraHertz; (iii) 3D modelling with site-specificity.
 Antenna systems that are self-reconfigurable (in radiating structure, antenna pattern, pass/stopband with beyond 6 GHz coverage, etc.) to optimise near/far-field interaction with channels in the deployment scenarios, under constraints of size and disturbances in the vicinity.
For a more global design of the new standards and more reliable interaction between layers:

 New PHY-layer algorithms and protocols for 5G-and-beyond will account for inclusiveness of heterogeneous networks, links and devices. Practical scenarios will be considered to optimise capacity, energy-consumption and resource usage in future massive communications.
 Inclusiveness of future networks calls for a different design of the communication system, in which the control information would be more integrated with the transmission protocol. Together with the context information properties, this will be studied to arrive at an optimal balance between the transmission overhead and PHY performance.
 Enablers of accurate position estimation, physical layer security, maximum capacity, energy efficiency, and other applications of these models for "upper layers".
For an efficient use of Spectrum resources by Radio Access Networks automation:
 Future RANs must become real cognitive automated networks, which goes far beyond the self-organising and self-optimising network functionalities that are now being introduced in LTE.
 Resource Management in RANs must also evolve to broaden the meaning of resource sharing to multi-technology, multiband, multiservice and multilink connectivity and content delivery.
 Future network architectures have to consolidate the concepts of Cloud RAN and virtual nodes, leaving the base station centric approaches for a more flexible device-centric architecture. The heterogeneity of devices may push to the use of Ultra-Flexible RANs [Car13].
 The new scenario of Moving Networks has to be introduced to support connected nodes in highly dense traffic areas, where ad hoc, high rate and low latency connectivity among the moving nodes and to the fixed RAN rely on multiple clouds and multiple paths.
For ease of access to experimentations:
Experimentation is necessary to validate theory, test new algorithms and to be confronted to practical situations that are difficult to model and simulate. One of the goals of IRACON is to make available several platforms on specific topics that will allow testing new solutions in real conditions.
 A platform on OTA testing will allow enhancing the realism of the test environments while keeping the complexity of the test to an acceptable level and running experiments under controlled conditions. This allows a precise evaluation of such techniques as adaptive antenna systems and smart receiver algorithms [Foe14] in realistic environments. For 5G, the OTA testing of base stations is imminent within a few years, as is the migration into bands beyond 6 GHz.
 A platform to test indoor localisation will allow to fairly compare various solutions via experimental activities based on open source, easy-to-use and flexible platforms: one for positioning algorithms at a small range based on several technologies (e.g., UWB, ZigBee, Wi-Fi) in addition to inertial and geomagnetic sensors, a motion tracking system composed of infrared cameras providing accurate positioning as a reference. A fully equipped platform for Global Navigation Satellite System (GNNS) based localisation will also be available.
 A RAN platform will have a special emphasis on open-source software defined radio. Some of the challenges that will be addressed include implementation issues of centralised baseband processing and cloud RAN, mobile edge computing, improving spectral efficiency via cooperative multipoint and (massive) MIMO, and enabling massive, low-latency connectivity of new devices and applications.
 A platform for evaluating MAC and NET layers for IoT in view of its integration to 5G. Partners will have access to two test beds: i) one hundred 802.15.4 devices located in fixed positions, where different routing protocols can run; ii) one hundred 802.15.4 mobile devices that could be carried by mobile nodes, allowing emulation of static and dynamic environments.
Other institutions might offer additional test beds to reinforce the test capability in the framework of IRACON. New contexts, new materials or simply other environments are necessary to evaluate the robustness and the efficiency of the proposed scheme in different communication conditions.

1.3.3. Innovation in tackling the challenge

5G-and-beyond implies an unprecedented scale change (density of connected objects, massive MIMO), a superposition of networks and devices with drastically different capabilities (computation, energy) that impacts the synchronisation quality, the ranging ability, the number of quantisation level, the sampling rate and many other parameters. Taking all these aspects into account is necessary and requires new research approaches. The networking among researchers involved in inclusive radio communications that will be offered by IRACON is essential to gather the different knowledge necessary to address the complexity of the 5G-and-beyond challenges. Other innovative approaches will allow new research angles and results:

 Radio channels require new measurement methods, such as multiband channel sounding for a wide frequency range including micro-/millimetre-wave bands, distributed massive MIMO channel sounding, and portable channel sounding for drone, sensors, body environments and near-field links. Enhanced methods will be proposed to characterise, model and simulate antennas and channels by covering full 3D physical environments, while maintaining the complexity-accuracy trade-off through a hybrid use of deterministic and statistical approaches, among many other potential methods.New channel emulation techniques will be developed for coping with carrier aggregation, isolating the different environments of multiple users, and testing objects up to the size of cars. New metrics for emulation accuracy are needed, which could be user-oriented (subjective), or application specific.

 PHY, MAC and NET-layer techniques for 5G are to be developed under the influence of practical physical, node-internal and external constraints and network configuration. The development of new PHY-layer and channel emulation techniques will be aligned with progress in channel modelling (DWG1), novel networking protocols (DWG3).

 Several partners of this proposal will provide access to experimental facilities in a coordinated way.

Concerning IoT, partners will have access to two test beds on IEEE 802.15.4: i) 100 fixed devices, where different routing protocols can run; ii) 100 mobile devices that can be carried by mobile nodes, allowing the emulation of static and dynamic environments. Concerning RAN, research and innovation needs to be carried out from the physical layer to the network. Such a holistic approach cannot be achieved by paper and simulation studies alone; test beds and experiments are needed to gain new insights and to validate new technologies. The proposed coordination of test beds and the close relation with theoretical works will offer opportunities to identify new problems and to better validate the proposed new algorithm, reducing the gap between research and products.

1.4. Added value of networking

1.4.1. In relation to the Challenge

A networked approach to address the challenges previously identified is definitely best, and indeed is what is required. It would be very difficult to provide a single research group, or even institution, with the human and material resources to undertake such a quest. The effects of networking in an Action in the area of mobile and wireless communications, like IRACON, are expected to come in several ways:

• Scientific networking: This proposal combines the efforts of a large group of experts from academia and industry working in all the different aspects of radio communications. Traditionally, the communities of antennas and propagation, signal processing, and networking, interact in a limited manner, which stems from the differences in the concepts involved and in the baseline scientific culture. These research activities require different theoretical developments, simulation approaches, and measurements, and given the human and financial effort required to perform all of these, a coordinated action through networking enables the desired excellent outcome by sharing measurements, simulation tools and models. The common framework of IRACON, where representative institutions in those three groups are working together in the same scenarios and objectives, will lead to innovative knowledge, significant scientific breakthroughs, and medium-term socio-economic impacts.

• Innovative Networking: The involvement of the Industry in the proposal, with a significant percentage of companies in IRACON, will provide participants with a view of market evolution, of innovation challenges, and of gaps in putting results into practice, as well as on their experience in development of terminals, equipment and networks. Also, the good relations that many academic proposers have with industry in research projects provide IRACON with a network of inter-project links which is still unavailable elsewhere, enriching the available information and skills of the overall group.

• Inter-disciplinary networking: This proposal deals with a topic that is inter-disciplinary regarding application scenarios, since in communications beyond 2020, the scope of elements to get connected to the IoT, through wireless communications, includes, amongst others, vehicles, environmental sensors, health devices, multimedia terminals, and machines. The EWGs have been built in order to favour interactions among experts from these communities, and the challenges that are addressed in these EWGs require joint progress on multiple aspects, as described in Section 3. Some of the revolutionary concepts of "beyond H2020" that can only be addressed in inter-disciplinary networks like this one are autonomous cars ecosystems, real-time health monitoring, generalised smart city networks, and massive deployment of connected objects in IoT. This level of inter-disciplinarity provides additional knowledge to IRACON participants, in areas that are complementary to their current work, and fosters the potential scientific and socio-economic impacts of IRACON's network.

• Open and new networking: In contrast to research projects in other frameworks, Actions in COST are open to the participation of any new expert from any European or international institution. This will enable new members to join the Action during its lifetime. The IRACON Steering Committee will coordinate efforts to expand the Action to new ECIs, institutions from ITC countries, and women from EU engineering research teams.

1.4.2. In relation to existing efforts at European and/or international level

An Action within the COST framework is obviously different from other research initiatives taken with the European Commission, e.g., H2020 co-funded R&D projects or ITNs. In contrast to the aforementioned initiatives an Action within the COST framework is open for collaboration without the burden of partnerships and other legal means. Thereby it facilitates the process of accession for researchers that would not have financial possibility to join such initiative and allows participation to a wider audience.

There are in fact efforts at the European level targeting research for 5G, as well as at the international level, the definition of the candidate technologies for 5G being currently the main discussion topic. This situation has led companies and academia worldwide to start setting up some new statements on wireless communications, mainly on Spectrum regulation and the identification of candidate technologies for the future standards. In any case, those efforts are addressing pre-defined agendas, while an Action can freely explore new topics and ideas, going beyond 5G, using the networking coming from its participants, and join the effort of mixing the various competences identified above. IRACON encompasses a sufficient group of institutions to influence some of these aspects along the Action lifetime, in particular by 2019 when the last ITU WRC conference of the decade takes place, and in which the new frequency bands for the next generation will be determined.

The value of the networking of researchers provided by Actions is recognised by the international community, since colleagues from other regions (e.g., North and South Americas, and Asia/Pacific) have been asking to join several Actions, namely those in the area of mobile and wireless communications. This world dimension of an Action enables a better exchange of results (at the various levels, i.e., theoretical, experimental, measurement, simulation, and so on), a wider assessment of models (contributing to a better acceptance of the resulting models), a "faster" path to contributions to standardisation bodies (given the full international dimension of the supporting institutions). Regarding IRACON's Network of Proposers, this Action will have the capability to provide technical inputs to many of the world standardisation and regulatory bodies, like ITU, ETSI, 3GPP, CTIA, and IEC. This is not a new experience in COST, as many of IRACON's proposers have participated in recent Actions providing inputs to the above mentioned entities on behalf of COST.

2.1. Expected Impact

2.1.1. Short-term and long-term scientific, technological, and/or socioeconomic impacts

The world history of mobile and wireless communications, namely from the 2nd Generation cellular systems onwards, and the role that European researchers from both industry and academia have played, is generally of common knowledge. The COST framework has also played a key part in this history, in which several Actions have contributed with various models adopted by international bodies, ranging from ITU to 3GPP and encompassing ETSI, in such a decisive way that these models were named after the Actions.

COST Association
Avenue Louise 149 I 1050 Brussels, Belgium
t: +32 (0)2 533 3800 I f: +32 (0)2 533 3890
office@cost.eu I www.cost.eu
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This Action in the area of wireless communications, focusing on its radio aspects, will follow the series of previous successful Actions in this area (207, 231, 259, 273, 2100, IC1004). Additionally, IRACON will follow as well the success of the series of previous Networks of Excellence in the same area (NEWCOM, NEWCOM++, NEWCOM#). Given the history of the European success and leadership in this economic sector, the COST framework cannot afford not to have an Action dealing with this area of technology, enabling the continuation of existing essential links in between industry and academia, in between theoretical breakthroughs and experimentation of ideas, in between experienced senior researchers and ECIs, and in between European research institutions and worldwide R&D organisations. Given the history of the past Actions in this area, IRACON aims at playing this role, contributing to keeping in Europe the leading role in this sector.

In what follows, IRACON's key impact goals are summarised, showing how they relate to the expected ones (indicating in between parentheses the contribution to short- and long-term impacts –ShT and LoT– in the scientific, technological, and socioeconomic components –SiC, TeC and SoC) :

• 5G-and-Beyond: IRACON aims to influence the future RAN technologies. The Action will run in parallel to the definition of 3GPP's 5G standards, its initial tests and prototypes, so it is completely aligned with the strategic view of European industries and research groups in this economic sector. Still, given the nature of the COST framework, IRACON will also address developments beyond the goals of 5G, ensuring that basic technological research goals are met. (**ShT, LoT; SiC, TeC, SoC**)

• A bridge to young talents: Participants in IRACON, namely ECIs, will be working in topics that are the basis for future technologies. As a consequence of COST's networking effect, they will be directly in touch with upcoming research projects in H2020, getting connected to the most relevant institutions and industries in the field. (**ShT; SiC, TeC**)

• From COST to standards: IRACON will produce White Papers and submit recommendations to standards, potentially impacting some decision makers and strategies for "beyond 2020". IRACON's Network of Proposers (NoP), together with their institutions, gathers many of the academic and industrial researchers in the area, and brings previously established links to international standardisation bodies and industry groups, namely ETSI, 3GPP-RAN4 (Radio Access Network), CTIA (USA) and 5G-PPP (EU). (**LoT; TeC**)

• Spreading European front-end knowledge area: IRACON's NoP encompasses the majority of COST Member Countries (31 from 35), and the Inclusiveness Target Countries (ITCs, 16 from 19), with 50% of the list of proposers being from ITCs). This fact, together with the open and bottom-up spirit of COST, is a key factor for spreading knowledge over every region in Europe, and to give research centres and institutions in ITCs the opportunity to link to the major players in the H2020 framework. (**ShT, LoT; SiC, TeC, SoC**)

• Addressing the Societal Challenges: It is commonly accepted that ICT is transversal to the Societal Challenges that have been identified by the EC for the H2020 framework. Mobile and wireless communications are key components of ICT that need to be used as a means to address the aforementioned challenges. For example, the challenges put by inclusiveness, and full connectivity among humans and objects, raise fundamental problems in radio communications (ranging from channel modelling to information and network theories) requiring effective and efficient solutions that are not available today. **(LoT; SiC, TeC**)

• Bridging with other areas: Many of the addressed problems (e.g., those relating to the fundamental problems referred to above) are not for exclusive application to cellular networks, rather being useful as well to WLANs, PANs, and IoT, among others. This means that the future impact of the developments in IRACON will not be of use only to major industrial companies, but also by SMEs, start-up technological companies, and other companies taking advantage of new business opportunities directly involved, or not, in communications. **(LoT; TeC, SoC**)

In conclusion, via the means that have been identified, IRACON will create short and long-term impacts in the scientific, technological, and socioeconomic components.

2.2. Measures to Maximise Impact

COST Association
Avenue Louise 149 I 1050 Brussels, Belgium
t: +32 (0)2 533 3800 I f: +32 (0)2 533 3890
office@cost.eu I www.cost.eu
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2.2.1. Plan for involving the most relevant stakeholders

In the area of R&D in wireless communications, more specifically in the aspects dealing with radio communications, one can identify a number of institutional stakeholders, as follows: universities (UNIs), institutional research centres (IRCs), network equipment and solutions vendors (NEVs), human and machine terminals manufacturers (TEMs), operators (OPEs), IT providers (ITPs), SMEs in the various technological areas related to the sector (SMEs), regulators (REGs), and policy makers (POMs).
IRACON plans to involve these key stakeholders to participate, include a number of actions listed below (indicating in between parentheses the corresponding stakeholders):
• The IRACON's NoP already includes many stakeholders in the area, encompassing key institutions and organisations (**UNIs, IRCs, NEVs, TEMs, OPEs, ITPs, SMEs**).
• Members of IRACON have significant links to industry, on top of those already in the NoP, who will be invited to join (**NEVs, TEMs, OPEs, ITPs, SMEs**).
• With the involvement of the IRACON's NoP, a list of the research groups in Europe with activity in the area of the Action will be established, and invited (**UNIs, IRCs, NEVS, TEMs, OPEs, ITPs, SMEs**).
• With the involvement of the IRACON's NoP, a list of the Graduate Schools (i.e., universities awarding a Ph.D. degree) in Europe with activity in the area of the Action will be established, so that the Action can reach Ph.D. students for its Training Schools (**UNIs**).
• The researchers from institutions outside Europe involved in the previous Actions in the area (e.g., USA, Canada, Colombia, South Korea, China, Japan, and Australia) will be invited to continue their involvement (**UNIs, IRCs, NEVS, TEMs, OPEs, ITPs**).
• Members of the IRACON's NoP are part of many H2020 R&D projects, easily enabling the establishment of links and joint collaborations with these projects (and the other projects can be reached via the EC Coordination Meetings), e.g., for the exchange of data or for the organisation of common training schools and workshops (**UNIs, IRCs, NEVS, TEMs, OPEs, ITPs, SMEs**).
• Members of the IRACON's NoP are part of key European bodies, e.g., the Networld2020 ETP and the 5G-PPP, hence, having direct access to the organisations participating in these bodies, to which the Action will be presented (**UNIs, IRCs, NEVS, TEMs, OPEs, ITPs, SMEs**).
• Members of the IRACON's NoP are involved in the Steering Committee of EuCNC (European Conference on Networks and Communications), the EC sponsored conference in the area of the Action (which also has some involvement from the COST and the CELTIC-PLUS frameworks), enabling direct contacts with its organisations (**UNIs, IRCs, NEVS, TEMs, OPEs, ITPs, SMEs**).
• IRACON has received the expression of interest3 from CTIA and 3GPP-RAN4, and the NoP will be pro-active in addressing standardisation and regulator stakeholders (at both the national and international level), by presenting the Action and inviting them to events on specific topics of their direct interest (e.g., methods on measurements or spectrum sharing) (**NEVS, TEMs, OPEs, ITPs, REGs, POMs**).
• IRACON will be pro-active in addressing the relevant commissions of the International Union of Radio Science, (URSI). The NoP has close links with URSI 3 at the national and international levels, including chair of relevant commissions and early career scientists. (**UNIs, IRCs, REGs, POMs**).
The NOP is confident that with this list of actions to actively involve the various stakeholders, IRACON will succeed in maximising its impact at the various levels, ranging from short- to long-terms, and encompassing the scientific, technological, and socioeconomic components.

2.2.2. Dissemination and/or Exploitation Plan

Dissemination is a key component of an Action, given its R&D dimension, together with the development of basic technology and the training of researchers. IRACON will address this matter by carrying out a number of initiatives as follows:

• organisation of Training Schools, with IRACON lecturers, which are open to the community at large;
• joint organisation of Training Schools, with lecturers from IRACON and from other Actions and H2020 R&D projects, open to the scientific community at large;

• establishment of strategic liaisons and joint activities (e.g. joint meetings and workshops) with other COST Actions and H2020 R&D projects in this area;
• organisation of topic specific Special Sessions and Workshops in conferences, namely EuCNC, but extending to key IEEE such as ICC, GLOBECOM, PIMRC, URSI GA, and WCNC;
• presentation of IRACON in EC Coordination Meetings, reaching projects in the same area;
• active participation in COST supervised and organised activities and events;
• issue of an Action Leaflet, by the beginning of activity, explaining the key aspects of IRACON, to be distributed to stakeholders;
• issue of: (1) a Quarterly Newsletter, with key news from IRACON, addressing major technical and scientific developments, and announcing future activities and events; (2) White Papers, with the views of IRACON on the future development and research challenges in wireless communications, focusing on its specific areas.

Exploitation of results is also a very important component of R&D, especially in the current days, where the cycle between research and product development has become shorter. Therefore, IRACON will enable the use of the knowledge and networking created by its members during its existence, by considering the following possibilities and actions:
• to set up consortia with some of its members for the proposal of projects within H2020;
• to develop models and methods coming from the joint work developed within the Action, to be published in the proper means (e.g., scientific journals, but not exclusively)
• to foster the conditions to submit contributions on models and methods to standardisation bodies, jointly with industry, towards the conclusion of the Action;
• to foster the creation of a confederation of experimental environments in research labs, so that experimentation can be made available to other research groups (in both academia and industry) as well as SMEs (e.g., to evaluate solutions before reaching the market) within the Action;
• to use the knowledge created in the Action by many of its members in teaching at graduate and post-graduate levels;
• to edit a book at the end of the Action, with its main results, to be published by a commercial company in the area of R&D.

In conclusion, the Action will be taking several actions in order to ensure that a proper dissemination of its activities will reach all stakeholders in due time and with the adequate impact. Furthermore, the exploitation of results will ensure that this Action will follow the footsteps of the previous ones in this area, i.e., it will ensure that COST remains one of the major players in the arena of very successful R&D frameworks acting in mobile and wireless communications worldwide.

2.3. Potential for Innovation versus Risk Level

2.3.1. Potential for scientific, technological and/or socioeconomic innovation breakthroughs

Innovation is commonly understood as the introduction of new things, ideas or ways of doing something. Since IRACON addresses a number of key technologies in the area of mobile and wireless communications, it really has a potential to make significant innovation breakthroughs (as it has been the case for the previous Actions in this area).

Significant developments are expected, as mentioned above. In the area of radio channels, with the (re)emergence of mm waves, new challenges are being faced, requiring new and/or consolidated models, to which one should add all the needs for models in the range of frequencies higher than UHF. The need for models encompasses various environments and scenarios, not only specific of cellular systems (e.g., outdoor vs. indoors, and macro- to small-cells) but also dealing with PANs and BANs, among others. Given the increasing wireless components in communications, with the necessary underlying radio technologies, one can easily perceive the potential (and the associated risk) in this area. In the past, SMEs (e.g., from France, Finland, Germany, and Switzerland) have taken results from this type of models from Actions, and have implemented them into products (at both the soft- and hardware levels); IRACON aims to work in the same way, and having the same potential for innovation breakthroughs in the scientific, technological and socio-economic dimensions.

COST Association
Avenue Louise 149 I 1050 Brussels, Belgium
t: +32 (0)2 533 3800 I f: +32 (0)2 533 3890
office@cost.eu I www.cost.eu

The proposed perspective and approach will be taken for all other topics that are part of this Action, i.e., the developments in the PHY and NET layers, as well as applications in OTA Testing, IoT, localisation and tracking, and radio access. All these areas require inclusive solutions that comprise the many components of radio technologies addressed within the Action. All these application areas have a large potential for the creation of start-up companies, as the recent history shows. Furthermore, the range of additional application areas for the technologies developed within IRACON is quite large, including Smart Cities, Smart Buildings, and Factories of the Future, just to mention a few. The fact that European researchers address these matters in a coordinated way under an Action has quite a large added value for Europe, in terms of scientific and technical leadership, and with the corresponding consequences in sociological and economic terms.
Naturally, from an innovation viewpoint, the risk level is simultaneously high and low. On the one hand, it is high, since research by itself is always a risky activity without guarantee of results within a given time frame. On the other hand, it is low, given the breadth of the objectives paired with the critical mass and the presence of many stakeholders (so that many different ways can be investigated and results do not rely on a single technology or solution).
In conclusion, IRACON does have a large potential for scientific, technological and socioeconomic innovation breakthroughs, with a well-managed risk level, as proven by previous Actions in the area.

3.1. Description of the Work Plan

3.1.1. Description of Working Groups

As specified in Section 1.2, three Disciplinary WGs (DWGs) will coordinate the activities of channel modelling and algorithmic/protocol developments for PHY and NET layers. Transversally, four Experimental Working Groups (EWGs) will enable the experimental validation of results produced within the DWGs, and will provide databases of measurement results and setups useful to feed the design activities performed within the DWGs. Therefore, the approach is to go from disciplinary work to the experimental validation, and back. In addition, the experimental platforms at the basis of the EWGs will serve as virtual labs for ECIs, enabling virtual short-term missions to complement physical exchanges. While the DWGs can be considered as a cooperative environment to share ideas, contribute to theories (information, radio propagation and communication, security, network, game theory, and other theories) and develop new models, algorithms and protocols, EWGs are envisaged to be the natural biotope for collaborative experimental works. The EWG activities will revolve around the test bed facilities provided by a virtual laboratory of wireless communications. The Proposers have already set up a coordinated laboratory made of several institutions across Europe. It is expected that during the four years of the Action other labs will provide additional facilities. Note that listed tasks are those envisaged at this stage, however, new tasks might be added based on the interests of participants.
DWG1: Radio Channels: The goal of DWG1 is to develop more accurate radio channel models for inclusive deployment scenarios (including but not limited to heterogeneous cells, body area networks and vehicular communications), using carrier frequencies above UHF up to TeraHertz as well to co-develop antenna systems that can cope with the inclusive aspects of the targeted deployments. Within the WG, as well as within its affiliated sub-working-groups (SWGs), denoted as DWG1.x, the same sequence of tasks will be followed over the planned four years of the Action: Task 1(.x)-1: identification of scientific and technical challenges and concerted establishment of goals ; Task 1(.x)-2: theoretical research and experimental campaigns towards improved radio channel knowledge ; Task 1(.x)-3: data analysis and model development ; Task 1(.x)-4: model integration and publication ; measurement database construction. The WG-specific deliverables will be concerted radio channel models, provided via open source platforms and joint publications or submitted to international bodies.
DWG2: PHY Layer: The goal of DWG2 is to propose improved theoretical frameworks to study inclusive radio networks, to investigate new PHY layer algorithms to face capacity/energy/mobility/latency challenges and to confront when possible the proposed solutions to real experiments in the EWGs.
With the other WGs, DWG2 will also address system level simulation issues because other test beds will not achieve the required scale to properly test some types of network. Within the WG, as well as

within its affiliated SWGs, denoted as DWG2.x, the same sequence of tasks will be followed over the planned four years of the Action: Task 2(.x)-1: identification of the innovative PHY layer for the future inclusive communications and concerted establishment of goals, Task 2(.x)-2: advances in theoretical foundations and system modelling; Task 2(.x)-3: development of a system level simulation, in relationship with DWG1 and DWG2; Task 2(.x)-4 :development of new algorithms (to be tested in the various EWGs). The WG-specific deliverables will be mostly joint publications.

DWG3: NET Layer: The goal of DWG3 is to investigate the NET layer aspects that will characterise the merger of the cellular paradigm and the IoT architectures, in the context of the evolution towards 5G-and-beyond. In particular, the following objectives will be pursued: 1) identifying and assessing the network architecture of 5G- and-beyond systems; 2) studying the impact of the "fog" networking/computing approach foreseen for 5G, on the evolution of the RATs; 3) evaluating radio resource management approaches compatible to the new requirements set by future mobile radio networks (e.g. on latency); 4) proposing new concepts and paradigms to take account of the plethora of new applications arising from the IoT context. Within the WG, as well as within its affiliated SWGs, denoted as DWG3.x, the same sequence of tasks will be followed over the planned four years of the Action : Task 3(.x)-1: identification of network architectures for 5G-and-beyond; Task 3(.x)-2: development of new algorithms and protocols and assessment through theoretical approaches; Task 3(.x)-3: development of new algorithms and protocols and assessment through experimental approaches (in collaboration with EWGs); Task 3(.x)-4: identification of new concepts and network paradigms. The WG-specific deliverables will be mostly joint publications.

EWG-OTA: Over-The-Air testing: The goal of this EWG is to investigate and validate new OTA testing methods. This will be covered by the following tasks over the planned four years of the Action: Task O-1: identification of scientific and technical challenges and concerted establishment of goals; Task O-2: co-design (with DWG1) of channel models for implementation in advanced OTA testing set-ups for inclusive networks (large objects, small ad-hoc networks, adaptive networks, etc.); Task O-3: development of advanced metrics for device and system performance ; Task O-4: experimental determination of the required degree of sophistication of models, metrics, and implementations, in line with current standardisation. The WG-specific deliverables are new metrics for OTA testing, after their evaluation in the round-robin experiments; technical inputs and liaison statement(s) to standardisation groups.

EWG-IoT: Internet-of-Things: The goal of this EWG is to support the evolution of 5G networks through the inclusion of the IoT component, via the investigation and assessment of the network architectures, the comparison among the many approaches currently devised for the development of an ecosystem of the IoT platforms and applications in terms of operating systems, and the experimental validation of different protocols for large scale applications of the IoT. Activities will be performed according to the following three (partially overlapping) tasks: Task I-1: IoT network architectures; Task I-2: IoT network operating systems; Task I-3: IoT protocols. The WG-specific deliverables include proposals of IoT network architectures, protocols and operating systems compatible with the parallel development of 5G standardisation, suitably assessed over experimental large scale (with hundreds of heterogeneous IoT nodes) platforms.

EWG-LT: Localisation and Tracking: The goal of this EWG is to follow the development of 5G standardisation, taking advantage of the new techniques implemented and defined (millimetre waves, massive MIMO, etc.) to design and test new localisation and tracking techniques for devices, working both in outdoor and indoor environments. Activities will be performed according to the following two (partially overlapping) tasks: Task L-1: localisation-oriented channel modelling; Task L-2: algorithm design through statistical signal processing techniques. The WG-specific deliverables include proposals of new localisation techniques suitable for 5G and the IoT, suitably assessed over experimental test beds.

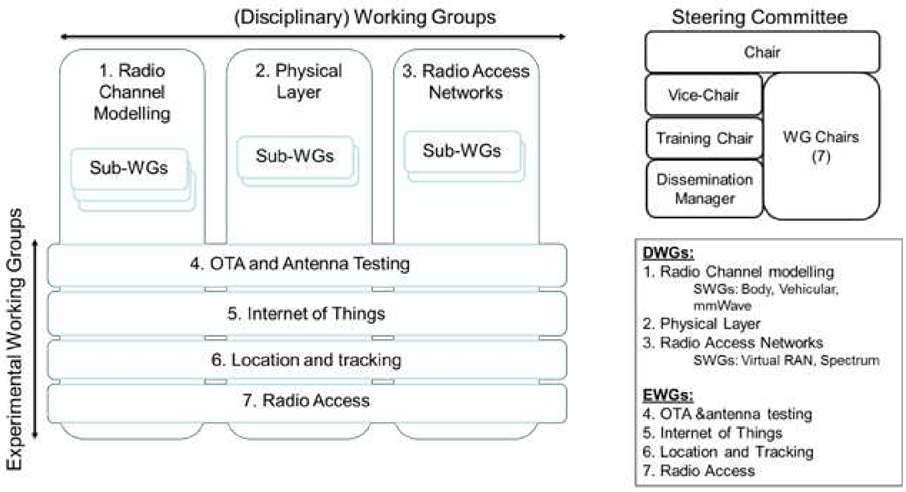
EWG-RA: Radio Access: The goal of this EWG is to experimentally validate the many techniques that will be implemented at the PHY and MAC layers of the radio access part of 5G, especially those developed within DWG2. New waveforms, cognitive radio approaches, or massive MIMO, are possible examples. Activities will be performed according to the following three (partially overlapping) tasks:

Task RA-1: cognitive radio based approaches; Task RA-2: Cloud RAN, cooperative and Massive MIMO; Task RA-3: Radio Access for machine type devices. The WG-specific deliverables include the assessment of 5G techniques for radio access through experimental platforms, and the further development of open source solutions.
Dissemination and Training: Dissemination and training will be supervised by the Dissemination Manager and the Training School Coordinator, respectively. Their tasks are summarised in Section 2.2.2 and will be spread over the various WGs, with the following deliverables: each WG will deliver one annual report on achievements and be responsible for the organisation of one tutorial (tutorials will be organised in conjunction with MC meetings) and one training school; all WGs will also organise workshops and special sessions in international conferences and contribute to WG- and Action-level white papers.
The milestones of the Action are defined below: TS.x: training school (every DWG/EWG will organise at least one training school in the course of the Action); JM.x: joint meetings (with external parties); SW.x: special sessions and workshops; CM.x: coordination meetings; NL.x: newsletter issues; B.x: planning of the final book (B.1: outline and editors; B.2: first draft; B.3: second draft; B.4: final version); RS: inputs to recommendations and standards.GANTT Diagram

3.1.2. GANTT Diagram (see next page)

3.1.3. PERT Chart (optional)

The PERT diagrams on the next figure summarise the interaction between the DWGs and EWGs as well as the organisation of the steering committees. As illustrated, the EWGs are transverse to disciplinary WGs, as they will be the focus of experimental validation and testing, merging knowledge from all three disciplines along a thematic point of view (OTA and antenna testing, IoT, Localisation and Tracking; Radio Access). The Steering Committee consisting of the Chair, Vice-Chair, WG Chairs, Training School Coordinator and Dissemination Manager will have all insights to the Action activities and will coordinate them towards the achievement of the Action's goals.



3.1.4. Risk and Contingency Plans

One implementation risk is that there is no contract among the participants in the Action, hence, not having a formal level of commitment as in other R&D frameworks (e.g., EC funded projects in FP7 or H2020). In COST Actions, work is carried out on a quasi-voluntary basis. This risk is fully acknowledged by the NoP. To mitigate it, the NoP includes researchers that are experienced in collaborative Actions, such as COST and Networks of Excellence, as well as their instruments (training schools, short term missions, joint publications and measurement campaigns); the previous commitment of many

COST Association
Avenue Louise 149 I 1050 Brussels, Belgium
t: +32 (0)2 533 3800 I f: +32 (0)2 533 3890
office@cost.eu I www.cost.eu

participants to COST Actions is also a significant asset, with strong links already existing within the Network from past networking activities, paired with a clear historical openness to new participants. For all these reasons, a low implementation risk is expected. Still, the monitoring by the MC and the frequent physical meetings (3 times/year) also ensure that the risks are well controlled. Finally, the size of the envisaged Action also guarantees a critical mass in terms of meeting the objectives (see Section 2.3).
A specific risk is associated to the implementation of experimental activities and virtual laboratories, which could be impaired by hardware failures, thereby compromising the realisation of some planned experimental works. However, the number of partners in possession of experimental equipment significantly minimises the risk of not being able to realise the planned works, as alternative hardware solutions will be found within the Action.

Project Year			1			2			3			4		
Project Quadrimester			1	2	3	4	5	6	7	8	9	10	11	12
WG / Task	Start	End												
DWG1: Radio Channels	1	12			TS.1									
Task 1-1: Identification	1	8												
Task 1-2: Theory and Measurements	2	12												
Task 1-3: Data Analysis	5	11												
Task 1-4: Model Integration	9	12												
DWG2: PHY Layer	1	8					TS.2							
Task 2-1: Identification	1	8												
Task 2-2: Advances in Theory	2	12												
Task 2-3: system level simulation	5	12												
Task 2.4: New Algorithms	8	12												
DWG3: NET Layer	1	12							TS.4					
Task 3-1: Identification	1	8												
Task 3-2: New Protocols (Theory)	2	10												
Task 3-3: New Protocols (Meas.)	4	10												
Task 3-4: New Paradigms	10	12												
EWG-O: OTA	1	12						TS.3						
Task O-1: Identification	1	8												
Task O-2: Model Co-Design	2	10												
Task O-3: Metrics	7	12												
Task O-4: Experiments	7	12												
EWG-I: IoT	1	12									TS.6			
Task I-1: Architectures	1	8												
Task I-2: Network OS	3	12												
Task I-3: New Protocols	5	12												
EWG-L: Localizat. & Track.	1	8											TS.7	
Task L-1: Channel-Based LT	1	11												
Task L-2: SP-Based LT	4	12												
EWG-RA: Radio Access	1	12								TS.5				
Task RA-1: Cognitive Radio	1	8												
Task RA-2: C-RAN, massive MIMO	1	12												
Task RA-3: RAN for Machines	5	12												
Dissemination	1	12												
White Paper	1	9						WP.1			WP.2			
Recomm. & Stds	10	12												RS
STSMs	3	12												
Contact Research.	1	9												
List Grad Sch.	1	3												
Joint Meetings	1	12			JM.1			JM.2			JM.3			JM.4
Sp. Sess. & Works.	1	12		SW.1			SW.2			SW.3			SW.4	
Coord. Meetings	1	12			CM.1			CM.2			CM.3			CM4
Newsletter	1	12	NL.1	NL.2	NL.3	NL.4	NL.5	NL.6	NL.7	NL.8	NL.9	NL10	NL11	NL12
Book	8	12								B.1		B.2	B.3	B.4

3.2. Management structures and procedures

This Action is proposed under the premise that one of the reasons for the success of COST Actions is the realisation of a collaborative and highly interactive network where MC members and experts, including a noticeable amount of ECIs, are free to discuss any activity or initiative undertaken, based on a bottom-up and open approach towards a concerted direction set up by the MC. The MC Chairperson will be elected by the MC at the kick-off among those who share this vision. To ensure that all Action activities are under the control of the MC, all General Meetings will start and end with MC Sessions, where the WG Chairs report to the MC on all discussions, initiatives and decisions held within the WGs.

The Action management will be coordinated by: i) the MC Chair, who will act as intermediary between the MC and the COST Association and will prepare all scientific reports, and ii) 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 DWG and EWG Chairs, a Training School (TS) Coordinator, and a Dissemination and Liaison (DL) Manager elected by the MC every two years. If sub-WGs are created, they will be chaired by a scientist elected by the members of the relevant WG, also every two years.

The DWG and EWG Chairs will be responsible for the preparation of WG meetings. They will draft WG meeting minutes and will report directly to the MC at each MC Meeting. All chairs (DWG, EWG, SWG) will be responsible for coordinating scientific exchanges and activities relevant to their WG, such as the organisation of workshops, training schools, etc. The DL Manager will supervise all dissemination events and liaisons with other projects. The TS coordinator will be responsible for making sure that all WGs organise at least one training school per group over the course of the Action.

The Steering Committee of the Action is composed of the Chair and Vice-Chairperson, the three DWG Chairs, the four EWG Chairs, the TS Coordinator and the DL 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 will take all relevant decisions on administrative and scientific issues, with two exceptions: i) the applications for STSMs received at 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; ii) assignment of grants to Training School students will be performed by the TS Coordinator. 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 in the next MC meeting on all decisions taken by the Steering Committee.

3.3. Network as a whole

The IRACON's NoP is truly unique in its breadth (disciplinary working groups covering key aspects of radio communications of channels, signal processing and network), depth (sub-working groups targeting specific application areas) and interdisciplinary dimension (experimental working group pooling together wide range of expertise). Furthermore, each of these aspects is covered by a large number of institutions from the COST countries. Plans for addressing stakeholders have also been mentioned in this proposal: this Action has the ambition to become a leading open forum enabling direct contacts between Industry and Academia. Beyond discussions on the most recent advances in research, development and standardisation, this setup will enable us to formulate new projects and solutions to meet the upcoming challenges in radio communications and networks. The NoP is also characterised by a strong expertise in the COST framework, since the key players have long experience with EU funded projects including COST Actions and NoEs.

In the specific area of channel measurements and experimental platforms (within EWGs), collaborative works are, in the opinion of the Proposers, the only way forward, given the cost and complexity of such equipment. To this end, the IRACON's NoP successfully gathers a very large number of the key European institutions in possession of channel sounding equipment, simulation platforms and channel emulators. This exceptional combination offers IRACON the unique capability of exploring and utilising original measurement techniques that cover all frequencies in the radio spectrum while mitigating the risks associated with experimental equipment.

International Partner Countries (IPCs) in IRACON are really key players in the area and they complement the work of the Network especially in the experimental area. Their inclusion also helps to facilitate possible contributions to standardisation, and provides the possibility to increase the impact and visibility of the Action outside Europe. The Network will therefore become a one-stop shop for international partners to learn about radio communications in Europe, and in return for the Network to benefit from new knowledge and perspectives of international partners outside Europe.

COST is supported by
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Horizon 2020
COST Association
Avenue Louise 149 I 1050 Brussels, Belgium
t: +32 (0)2 533 3800 I f: +32 (0)2 533 3890
office@cost.eu I www.cost.eu