



IRACON

COST Action CA15104 Fourth and Final Scientific Annual Report

COST Action CA15104 (IRACON) aims to achieve scientific networking and cooperation in novel design and analysis methods for 5G, and beyond-5G, radio communication networks.

The scientific activities of the action are organized according to two types of Working Groups: disciplinary and experimental Working Groups. In total, IRACON consists of 6 working groups: Radio Channels (DWG1), PHY layer (DWG2), NET Layer (DWG3), OTA Testing (EWG-OTA), Internet-of-Things (EWG-IoT), Localization and Tracing (EWG-LT) and Radio Access (EWG-RA). A sub-working group of EWG-IoT was also recently created: IoT for Health.

This report details the achievements of IRACON as a whole and of its Working Groups during the fourth grant period, summarizing the main activities and scientific results.

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List of acronyms

BER	Bit Error Ratio
BPSK	Binary Phase Shift Keying
CoMP	Cooperative Multi Point
D2D	Device-to-Device
DTT	Digital Terrestrial Television
DWG	Disciplinary Working Group
ECI	Early Career Investigator
EMF	Electro-Magnetic Field
ETSI	European Telecommunications Standards Institute
EWG	Experimental Working Group
GNSS	Global Navigation Satellite System
GP	Grant Period
HeNB	Home eNode B
HW	Hardware
IEEE	Institute of Electrical and Electronical Engineers
IET	Institute of Engineering and Technology
IoT	Internet-of-Things
ITS	Intelligent Transportation Service
ITU-R	International Telecommunication Union – Radio
LSA	License Shared Access
LT	Localization and Tracking
LTE	Long-Term Evolution
MAC	Medium Access Control (layer)
MIMO	Multiple-Input Multiple-Output
MOSG	MIMO OTA Sub-Group
MRC	Maximal Ratio Combining
MTC	Machine Type Communication
NET	Network (layer)
NFV	Network Functions Virtualization
OTA	Over-the-Air
PHY	Physical (layer)
PLNC	Physical Layer Network Coding
RA	Radio Access
RAT	Radio Access Technology
RAN	Radio Access Network
RRM	Radio Resource Management
SC-FDMA	Single Carrier Frequency Division Multiple Access
SDN	Software Defined Network
SDR	Software Defined Radio
SG	Study Group
STSM	Short Term Scientific Mission
TD	Temporary Document
URSI	Union Radio Scientifique Internationale
V2X	Vehicle-to-Infrastructure
VNO	Virtual Network Operator
WG	Working Group
ZF	Zero-Forcing

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1. Introduction

1.1 Scientific objectives of IRACON

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.

In this context, 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.

1.2 Objectives of the fourth grant period

For the fourth grant period, IRACON's objectives have been defined at the kick-off meeting as follows:

1. promote the use of pan-European laboratory facilities and networks for shared experimental research addressing Over-the-Air (OTA) testing, IoT, localization, tracking and radio access, using a shared web platform;
2. facilitate the collaboration between ECIs through STSMs (at least 6 missions over the GP);
3. provide technical inputs and liaison statements to Standardisation Groups on metrics for Over the Air (OTA) testing;

4. finalize a set of IRACON concerted radio channel models for 5G and beyond;
5. maintain liaisons with international standardisation bodies, via the identification of liaisons and invited speakers at each IRACON technical meeting: the MIMO OTA Sub-Group (MOSG) of CTIA, the RAN4 of 3GPP that pursue standardised OTA tests for LTE User Equipment, the ETSI Technical Committee on ITS, and the URSI Commission C, among others;
6. maintain on-going links with existing H2020 projects (Clear5G, 5G-car, etc.), by organizing one joint workshop in the grant period;
7. train PhD students through the organization of at least two training schools, with a focus on the network layer;
8. disseminate IRACON position and results via the ongoing publication of a newsletter, the animation of a blog and the issue of one position paper (white paper) on experimental platforms for performance evaluation; the organization of at least two special sessions/workshops at international conferences (EuCAP, PIMRC);
9. discuss COST gender policy through women-only meetings at MC meetings, with inputs to the newsletter or to the blog;
10. write the final book of the Action.

1.3 Working Groups: structure and coordination

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) 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 ensures that new techniques developed within IRACON are jointly devised and assessed from all viewpoints.

Moreover, this coordination of research efforts is further demonstrated within IRACON by the creation of four Experimental WGs (EWGs) 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.

1.4 Working Groups: practical implementation

As mentioned, IRACON technical content is organised in Working Groups (WGs) to facilitate the coordination and networking between participants. During technical meetings many of the sessions deal with several of the WGs' interests, being identified as "joint" sessions in such sense.

Every IRACON participant is at least interested in two types of WG: one disciplinary WG, on the basics of (WG1) Radio Propagation and Channel Modelling, (WG2) Communications Physical Layer and (WG3) Radio Network Aspects; plus one Experimental WG related to application scenarios and testbeds: (EGW-LT) Location and Tracking, (EGW-IoT) Internet of Things, (EGW-RA) Radio Access Systems, (EGW-OTA) Over-the-Air Testing.

Essentially, the relationship between the Disciplinary WGs (DWGs) and the Experimental WGs (EWGs) is based on the fact that every of the new algorithms, techniques and protocols developed in the context of a DWG is suitable to be tested in some of the application scenarios described by the EWGs, and on this basis the technical meetings and the discussions are organised. On the other way round, experiments conducted within the EWGs will provide useful feedback and databases of measurements for the theoretical activities brought forward within the DWGs.

2. Final Book

2.1 Introduction

The final book is divided into 9 chapters, corresponding to the work carried out by the various Working Groups:

- Chapters 2 and 3 report on the work of WG1 and WG-RA, dealing respectively with new modelling tools and measurement-based channel models,
- Chapter 4 reports on OTA testing (WG-OTA),
- Chapter 5 summarizes the work of WG2 on coding and processing for advanced wireless networks,
- Chapter 6 is dedicated to the work and results produced by WG3 in the area of beyond 5G networks,
- Chapter 7 deals with IoT protocols, architectures and applications (WG-IoT)
- Chapter 8 outlines the results of WG-IoT-Health,
- Chapter 9 reports on the achievements in terms of localization and tracking.

A preliminary table of content is provided in Section 2.2, also including the page count. The final book will be published in the second half of 2020.

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3. Conclusions

During the final year of the Action, the various Working Groups have continued working towards the objectives of the Action. As will be described in the final book, all WGs have progressing according to plan and have completed the assigned objectives for the fourth grant period and the Action as a whole.

The following table illustrates the achievements over the fourth GP as compared to the GP objectives detailed in Section 1.

1	Promote the use of pan-European laboratory facilities and networks for shared experimental research addressing Over-the-Air (OTA) testing, IoT, localisation, tracking and radio access, using a shared web platform.	Updated list online http://radiokom.eti.pg.gda.pl/IRM/
2	Facilitate the collaboration between ECIs through STSMs, with at least 6 missions over the Grant Period (GP)	37 STSMs funded over the course of the Action (8 submitted in GP4, 5 accepted)
3	Provide technical inputs and liaison statements to Standardisation Groups on metrics for Over the Air (OTA) testing	Production of Deliverable 8: <i>New Metrics for Over-The-Air Testing</i>
4	Finalize a set of IRACON concerted radio channel models for 5G and beyond	<ul style="list-style-type: none"> • Production of Deliverable 9: <i>IRACON concerted radio channel models for 5G and beyond</i> • Publication of open-access paper in ITU Journal: IRACON PROPAGATION MEASUREMENTS AND CHANNEL MODELS FOR 5G AND BEYOND
5	Maintain liaisons with international standardization bodies	<ul style="list-style-type: none"> • On-going action (members of IRACON are active members of the MIMO OTA Sub-Group of CTIA and the 3GPP RAN4) • Contribution to ITU-R SG3 • IRACON liaisons: <ul style="list-style-type: none"> ➔ 3GPP – Aki Hekkala ➔ URSI – Sana Salous ➔ ITU-R – Sana Salous and Belen Montenegro ➔ IEEE 1900.6 – Kostas Katzis
6	Maintain on-going links with existing H2020 projects (Clear5G, 5G-car, etc.), by organizing one joint workshop in the grant period (at EuCNC 2018).	IRACON liaisons: <ul style="list-style-type: none"> ➔ H2020 METIS-II – Narcis Cardona ➔ H2020 mmMAGIC – Mark Beach ➔ H2020 5G X-haul – Mark Beach

		<ul style="list-style-type: none"> ➔ CommNet (EPSRC network) – Mark Beach ➔ ITN WiBEC – Narcis Cardona ➔ 5G-VINNI – Per Hjalmar Lehne ➔ 5G-HEART – Per Hjalmar Lehne ➔ 5G-EVE – Florian Kaltenberger ➔ EMPOWER – Per Hjalmar Lehne ➔ 5G initiative – Fernando Velez
7	Train ECIs through the organization of two training schools with a focus on the network layer	<p>Three training schools were organized during the fourth grant period</p> <ul style="list-style-type: none"> ➔ http://www.iracon.org/training-schools/
8	Disseminate IRACON position and results via the ongoing publication of a newsletter, the animation of a blog and the issue of one position paper (white paper) on new localization techniques suitable for 5G and the Internet of Things; the organization of at least two special sessions at international conferences (EuCNC, EuCAP); the organization of one full-day IRACON workshop in conjunction with an MC meeting.	<ul style="list-style-type: none"> • Publication of quarterly newsletters ➔ http://www.iracon.org/newsletters/ • Animation of an online blog ➔ http://www.iracon.org/blog/ • Publication of two white papers ➔ http://www.iracon.org/whitepapers/ • Organization of workshops ➔ http://www.iracon.org/workshops/ • Organization of special sessions (e.g. at EuCAP2020) ➔ http://www.iracon.org/special-sessions/
9	Discuss COST gender policy through women-only meetings at MC meetings, with inputs to the newsletter or to the blog	The newsletters often highlight the role of women within the Action.
10	Write the final book of the Action	In its final stage (see Section 2).

Annex: List of Temporary Documents

	TD number	Title	Authors
1	TD(19)10001	Vehicular Networks Simulation with Realistic Physics	Esteban Egea-Lopez, Fernando Losilla, Juan Pascual-Garcia And Jose Maria Molina-Garcia-Pardo
2	TD(19)10002	Dynamic Ray Tracing: Introduction and Concept	D. Bilibashi, E. M. Vitucci, V. Degli-Esposti
3	TD(19)10003	Four Pillars of IoE in Health	Tamara Škorić, Konstantinos Katzis, Slađana Jovanović, Dragana Bajić
4	TD(19)10004	Novel Over-the-Air Test Method for 5G Millimetre Wave devices, based on Elliptical Cylinder Reflectors	David Reyes, Mark Beach, Moray Rumney, Evangelos Mellios, and John Haine
5	TD(19)10005	Bluetooth Low Power Portable Indoor Positioning System Using SIMO Approach	Stanislav Rozum, Jan Kufa, Ladislav Polak
6	TD(19)10006	Ray-based Deterministic Channel Modelling for sub-THz Band	Gregory Gougeon, Yoann Corre, Mohammed Zahid Aslam
7	TD(19)10007	Spatial Properties of Industrial Wireless Ultra-Reliable Low-Latency Communication MIMO Links	Stefan Zelenbaba, Markus Hofer, David Löschenbrand, Thomas Zemen, Georg Kail, Martin Schiefer
8	TD(19)10008	Performance Analysis of Hierarchical Decision Aided 2-Source BPSK H-MAC CSE with Feed-Back Gradient Solver for WPNC Networks	Petr Hron, Jan Sykora
9	TD(19)10009	The Study of the Probability Density Function of the Total Intensity in a Trunk Dominated Forest	Saúl A. Torrico, Cuneyt Utku, and Roger H. Lang
10	TD(19)10011	On the clustering of radio channel impulse responses using sparsity-based methods	Ruisi He, Wei Chen, Bo Ai, Andreas F. Molisch, Wei Wang, Zhangdui Zhong, Jian Yu, and Seun Sangodoyin
11	TD(19)10012	RANSAC for Exchanging Maps in Multipath Assisted Positioning	Markus Ulmschneider and Christian Gentner
12	TD(19)10013	LTE Multipath Component Delay Based Simultaneous Localization and Mapping	Junshi Chen, Meifang Zhu, Fredrik Tufvesson
13	TD(19)10014	Channel Static Antennas	Gerald Artner
14	TD(19)10015	Machine Learning Methods for SIR Prediction in Cellular Networks	Orit Rozenblit, Yoram Haddad, Yisroel Mirsky, Rina Azoulay
15	TD(19)10016	3D MIMO V2V Channel Measurements and the Cluster-based Channel Modeling	Mi Yang, Ruisi He, Bo Ai, Jianzhi Li, Chen Huang, Zhangdui Zhong
16	TD(19)10017	Performance Analysis of Two Link Adaptation Algorithms for Relay-Assisted Links Governed by H-ARQ Protocols	Vasile Bota, Mihaly Varga

17	TD(19)10018	Empirical Validation of the Polarised Off-Body Channel Model with Dynamic Users	Slawomir J. Ambroziak, Kenan Turbic, Luis M. Correia
18	TD(19)10019	Multi-objective optimisation of massive MIMO 5G wireless networks towards power consumption, uplink and downlink exposure	Michel Matalatala, Margot Deruyck, Emmeric Tanghe, David Plets, Sotirios Goudos, Luc Martens, Wout Joseph
19	TD(19)10020	Trajectories and Resource Management of Flying Base Stations for C-V2X	Silvia Mignardi, Chiara Buratti, Alessandro Bazzi and Roberto Verdone
20	TD(19)10021	Experimental IoT Testbed for Testing the 6TiSCH and RPL Coexistence	Gordana Gardasevic, Predrag Plavsic, Dragan Vasiljevic
21	TD(19)10022	Statistical models for 5G: interference in IoT.	Laurent Clavier, Troels Pedersen, Ignacio Rodriguez Larrad, Malcolm Egan
22	TD(19)10023	Impact of Deficient Array Antenna Elements on Downlink Massive MIMO Performance in RIMP and Random-LOS Channels	Andrés Alayón Glazunov
23	TD(19)10024	Indoor Double-directional 3D Measurements at 190 GHz for 5G and Beyond	Diego Dupleich, Robert Müller, Sergii Skoblikov, Markus Landmann, Giovanni Del Galdo, and Reiner Thomä
24	TD(19)10025	Millimeter-wave channel characterization and modeling for intra-wagon communication	Danping He, Xiping Wang, Chunfu Zheng, Ke Guan, Bo Ai, Zhangdui Zhong
25	TD(19)10026	Channel Static Antennas for Compensating the Movements of a Partner Antenna	Gerald Artner
26	TD(19)10027	Position Awareness for Drones to facilitate Beamforming	Michael Schweins, Jukka Talvitie, Mike Koivisto, Thomas Kürner
27	TD(19)10028	Evaluation of Veins and NS-3 for 802.11p based vehicular communication	Nils Dreyer, Eicke Arne Janas, Thomas Kürner
28	TD(19)10029	Injection Locking in Optical Access Networks for Broadband 5G Mobile Networks	Jakup Ratkoceri, Bujar Krasniqi and Boštjan Batagelj
29	TD(19)10030	Performance Profiling of Open MANET Radio Models and Multi-Hop Scenarios	Fred Wagen, Victor Adalid, Gilles Waeber, Francois Buntschu and Gerome Bovet
30	TD(19)10031	Device2Device Security Mechanism implementation on SDR platform	T. Balan, A. Balan, F. Sandu, M. Alexandru
31	TD(19)10032	On Simple Scattering Models and the GGX Directional Model for Point Cloud Predictions	Jean-Frederic Wagen
32	TD(19)10033	Characterisation of Specular Reflection of Different Building Materials at 26 GHz	Alberto Loaiza Freire, Mark Beach, Geoffrey Hilton
33	TD(19)10034	Channel characterization in industrial environment with high clutter	Raffaele D'Errico
34	TD(19)10035	Effects On Polarization Characteristics of Off-Body Channels with Dynamic Users	Kenan Turbic, Luis M. Correia

35	TD(19)10036	Ground user localization in UAV-based wireless networks	Sami Mezhoud, Jianqiao Cheng, Ke Guan, Francois Quitin
36	TD(19)10037	Optimizing Computational Resources Usage in C-RAN	Mojgan Barahman, Luis M. Correia and Lúcio S. Ferreira
37	TD(19)10038	Ray Tracing for Antenna Arrays	Lawrence Sayer, Andrew Nix
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