COST Action CA15104
Second 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 second grant period, summarizing the main activities and scientific results, and providing perspectives for the next period.

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Date: August 2018

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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 second grant period

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

1. discuss and submit contributions about concerted 5G radio channel models to international bodies (namely, ITU-R);
2. define IRACON Reference Scenarios and provide assessment of 5G radio access techniques through experimental platforms;
3. 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;

4. facilitate the collaboration between ECIs through STSMs (at least 6 missions over the GP);
5. establish or maintain liaisons with international standardization 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 standardized 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, exploring the possibility of organizing one joint workshop in the grant period;
7. train ECIs through the organization of two training schools, with a focus on basic and advanced competences;
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;
9. discuss COST gender policy through women-only meetings at MC meetings, with inputs to the newsletter or to the blog.

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, (EWG-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. DWG1: Radio Channels

2.1 General aspects of DWG1 work

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.

DWG1 is chaired by Sana Salous and Katsuyuki Haneda.

2.2 Technical progress

2.3 Technical progress

In the area of **channel sounding and measurements**, the following major technical trends have been observed.

- Distributed massive MIMO measurements.
- Angularly highly-resolved beamforming using massive antenna arrays.
- Multi-frequency measurements below- and above-6 GHz up to 300 GHz at the same site.
- Measurements in emerging scenarios, including dynamic body-centric, outdoor-to-indoor, car-to-pedestrian, train-to-infrastructure/train, in-tunnel, long-range backhaul, industrial and maritime scenarios.
- Measurements from various wall materials up to 300 GHz to study reflection, penetration and scattering.
- Different measurement methods of penetration loss were also cross-validated.

Concerning **radio channel modelling theory**, the following trends can be mentioned:

- Improved theories in radio channel models such as the enhanced room electromagnetic reverberation model through graph theory including path arrival rate, mixing time and polarization properties.
- A novel method to estimate permittivity of building materials through on-site channel sounding.
- Comparisons and cross-validation of different channel modeling methods and theories. Examples are among different high-resolution propagation path estimation methods and among different channel simulation methods such as integral equations and ray-tracing.
- Analysis of measured radio channels leading to improved understanding of radio propagation mechanisms, e.g., 1) dominant radio wave scatterers in train-to-train channels, 2) elevation-dependence of building

entry loss, 3) almost constant multipath richness of omni-directional channels up to 300 GHz, 4) noticeable influence of diffuse scattering in outdoor environments at 28 and 38 GHz especially for deep non-line-of-sight cases, 5) extra losses due to vegetation and precipitation in long-range backhaul links and finally 6) robustness of simple beamforming schemes at millimeter-waves.

Finally, in the area of **channel models, simulation and prediction**, the main results are as follows.

- New radio channel models, e.g., 1) spatially consistent line-of-sight probability over space, 2) self-interference channel models for in-band full duplex relays, 3) train or car-to-infrastructure channels taking into account track-side poles, 4) combination of graphs and rays to analyze radio channels in various scenarios, 5) frequency dependence of large-scale parameters such as delay spread in urban street canyons and indoor environments and finally 6) terrain clutter models in urban macro-cellular pathloss estimation.
- New methods for simulating radio-wave propagation, i.e., 1) reduction of computational complexity in ray-tracing by adapting to physical environments, 2) use of laser-scanned point cloud database of environments for ray-tracing and finally 3) incorporating vibration model into very-short-range millimeter-wave radio link simulations.
- New radio channel simulation studies, including indoor massive MIMO channels, outdoor millimeter-wave cellular scenarios and finally below-1 GHz channels in Amazon forest, Brazil and mountainous areas.
- Theory of characteristics modes for terminal antenna design that provides superior decoupling of antenna elements in an array in the presence of operator's fingers.

The following are the main highlights of DWG1 reports and events during the second year.

- Three contributions were submitted to the International Telecommunications Union, Radiocommunications, Study Group 3. ITU-R SG3 meeting in March 2017 from the United Kingdom, concerning clutter loss, rms delay spread and path loss in residential areas all in the millimetre wave band for future 5G systems;
- Organization of four convened sessions and a scientific workshop in the 12th European Conference on Antennas and Propagation (EuCAP2018), London, UK, i.e., 1) mm wave and THz channel modelling, 2) frequency dependency modelling of radio channels, 3) measurements and simulations in channel modelling in wireless body area networks, 4) a joint convened session with COST WiPE Action on beamforming techniques for information and power transmission and finally 5) workshop on propagation and channel modelling challenges for 5G and beyond inclusive radio communications.
- Contributions to the International Telecommunications Union, Radiocommunications, Study Group 3, ITU-R SG3 from the United

Kingdom, regarding synthesis of omni-directional path loss from directional measurements (ITU-R P. 1407), rms delay spread (ITU-R P. 1411 and ITU-R P. 1238), building entry loss (ITU-R P. 2109), and path loss in various indoor and outdoor environments (ITU-R P. 1238 and ITU-R 1411) all in the millimetre wave band for future 5G systems were submitted in March 2017. Also input from the UK contributed to the site general path loss model submitted to the ITU as input from Correspondence Group CG 3K-6 for suburban environments for line of sight, non-line of sight, above and below rooftops. An information document concerning clutter loss was also submitted from the United Kingdom. Other contributors to the clutter loss model (ITU-R P. 2108) from the COST action included input from Nokia and Ericsson. The various contributions were approved in the updated or new recommendations;

- ITU-R P.1238-9 https://www.itu.int/rec/R-REC-P.1238/en
- ITU-R P.1411-9 https://www.itu.int/rec/R-REC-P.1411/en
- ITU-R P.1407-6 https://www.itu.int/rec/R-REC-P.1407/en
- ITU-R P. 2109-0 https://www.itu.int/rec/R-REC-P.2109/en
- ITU-R P. 2108-0 https://www.itu.int/rec/R-REC-P.2108/en

Collected data in suburban outdoor environments and building entry loss data collected in the UK were submitted to the data bank of the ITU. Ericsson also contributed data collected for building entry loss and participated in the model formulation.

- Three correspondence groups (CGs) are formed to address the important challenges of channel models: CG1 is concerned with channel model approaches, CG2 targets mmWave channel models and CG3 focusses on localization channel models. Each CG has a small number of people aiming at establishing concrete channel models used by the CG members.
- Liaison with the General Assembly of URSI Commission C on Radiocommunication systems and signal processing, and with the European Union Horizon 2020 projects WAVECOMBE;
- An input was made to 3GPP about “myth and truth” of 5G channel models, led by Keysight.
- A number of collaborative publications on radio channel sounding and modelling were prepared by participating institutions.

3. DWG2: PHY Layer

3.1 General aspects of DWG2 work

DWG2 focuses on a very wide area of PHY layer related aspects in wireless communication networks. It includes all issues related to coding, signal processing, estimation and decoding, HW imposed constraints and solutions, distributed processing in wireless networks. This huge diversity of areas together with a limited number of researches involved affects the form and the focus of the research results.

The areas and some selected achievements that were addressed during the first period are in the next section. DWG2 is quite diverse and in principle quite universally applicable and the results form rather tools than 'turn-key' solutions.

DWG2 is chaired by Hanna Bogucka and Jan Sykora.

3.2 Technical progress

The technical achievements of WG2 form a mosaic of many contributions that develop a proper understanding of complex theory and implementation in three major areas: (1) coding, signal processing, estimation and synchronization, (2) distributive and cooperative coding and processing in radio networks, (3) advanced HW implementation and impairment modeling related problems. A number of major theoretical achievements were reached, particularly in these areas.

- Perfomance analysis and coding and processing design for Massive-MIMO (distributed processing and optimised quantisation of relay-to-destination signals, KLT transform based CSI compression in M-MIMO), low complexity algorithms for MIMO and beamforming and channel state information estimation (beamforming in M-MIMO systems with cluster-based COST2100 channel model), advanced code design (improved LDPC decoding with list erasure post-processing, advanced diversity precoding for OFDM).
- PHY layer network coding design and performance analysis (PLNC code design and iterative decoding in parametric channel, bit-wise hierarchical constellation mapping for physical layer network coding, information-theoretic assessment of side-information aided broadcast coding, and advanced adaptive ARQ blocking probability analysis in relay based networks), various interference mitigation techniques, and advanced cooperative coding and processing.
- Ultra-low-power HW radio node design, full duplex communication nodes (optimal HW compesated analog duplex front-end) and analog HW processing-in-the-loop algoritms (ultra low-power equalizer) and experimental testbeds (transmission detection scanners, low power optimised transmitters, experimental high-speed USRP based tesbed).

4. DWG3: NET Layer

4.1 General aspects of DWG3 work

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.

During the first Management Committee Meeting, DWG3 attendees agreed in the main keywords of the working group. Considering the research papers discussed at the sessions, but also the research activity of the members, as well as topics from the Radio Networks Group of the past COST IC1004 action, we grouped into six main “umbrella” topics:

- 5G and beyond Networks architecture
- RRM & scheduling
- Protocols
- Spectrum management and sharing
- SDN and NFV
- Scenarios

A second list of subtopics was also approved: 4G + cellular, Beamforming, Cloud RAN, Green Networks, Network architecture, Network optimization, Network planning, Network deployment, Network simulation, Network virtualization, Relaying, Scenarios, Scheduling and RRM, Small cells, Spectrum management, Spectrum sharing, Standards, Ultra-low latency, Internet of Things, Network failure management and trouble shooting.

DWG3 is chaired by Silvia Ruiz Boqué and Hamed Ahmadi.

4.2 Technical progress

Technical progress of DWG3 was not only limited to its main areas of activities and this working group had technological progress in interdisciplinary fronts too. In addition to individual works DWG3 members had joint publications and TDs. An example for these joint works is the 5G reference scenarios deliverable which was also presented as a TD at IRACON’s plenary in Nicosia meeting. In this work, DWG3-affiliated researchers provide a set of simulation scenarios that can be considered as reference scenarios for 5G standardization.

In the second year DWG3 presented 11 TDs in Lund, 12 TDs in Graz and 12 TDs in Nicosia which shows the level of activities in this working group. The main topics that was covered in the second year is summarized below:

- **Small cell networks:** interference avoidance, spectrum sharing, small cell position planning and resource management in small cell networks were the areas that have been studied, modelled and simulated.
- **C-RAN:** novel optimization methods for enhancing the efficiency of C-RANs have been proposed and the effect of using service level agreement has also been investigated.
- **Sharing and coexistence:** sharing network infrastructure and spectrum using virtualization techniques has been deeply studied by our researchers. Algorithms for efficient and fair sharing have been proposed. SDN as one of the key means for flexible networking and resource sharing had TDs proposing new sharing and routing techniques with real implementation results.
- **Airborne networks:** the importance, achievements and challenges in realising airborne networks have been presented in a keynote speech at Nicosia meeting. Moreover, DWG3 TDs studied resilience of airborne networks, affordable airborne infrastructure and drone placement.

5. EWG-OTA: Over-The-Air Testing

5.1 General aspects of EWG-OTA work

The goal of this EWG is to investigate and validate new OTA testing methods, channel models (in coordination with DWG1) for implementation in advanced OTA testing set-ups for inclusive networks (large objects, small ad-hoc networks, adaptive networks, etc.).

EWG-OTA is chaired by Wim Kotterman and Moray Rumney.

5.2 Technical progress

A lesson learned from last year's activities is that emulation methods (for testing large objects) of general applicability will not be available on the short-term. However, this does not hamper continuing research into the theoretical limits of 3-D emulation methods for electrically large Devices-under-Test. Such Devices-under-Test are either large antenna arrays for Massive MIMO, arrays for beam-steering at millimetre waves, or are vehicles. All of these "devices" have dimensions that typically are much larger than the relevant wavelength.

Specific applications for OTA testing, as opposed to general methods mentioned before, could be provided by Standardisation (f.i., 3GPP in the context of 5G New Radio). One would expect 3GPP to come forward with applications for which support with respect to testing would be welcome. Earlier OTA specialist groups also focussed on standardisation issues, supporting the activities employed by the standardisation bodies. However, at this moment, the outlook is rather bleak in this respect. First, the accelerated time schedule for the introduction of 5G New Radio seems to deprioritise mobile applications in favour of fixed wireless access and backhaul. This situation sadly persists and makes it impossible to "prepare the ground" for standardisation by investigating designing potential test methods. Additionally, testing radiated performance seems to be frozen by standardisation, for some time to come. Another obstacle, of more general nature, is that channel models, especially for the beam-steering mode of operation at millimetre wave bands, are inadequate concerning beam dynamics.

Problems of a different nature are the lack of millimetre-wave experimental facilities for emulation as this type of equipment still is very expensive due to the high carrier frequencies, the enormous data bandwidths requiring very powerful base-band processing, and the large number of channels that are necessary due to the short wavelengths. Many institutes only have a vector network analyser available for these bands, meaning a single channel. Multi-port capability is not widely available and yields a few more channels but their numbers are still insufficient. This means, experiments will concentrate on simulations.

6. EWG-IoT: Internet-of-Things

6.1 General aspects of EWG-IoT work

The goal of EWG-IoT 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. The SWG: IoT-Health (Sub Working Group – Internet of Things for Health) as part of EWG-IoT aims to focus on the design, development, performance evaluation and experimentation of IoT in healthcare applications such as health monitoring and Telemedicine.

EWG-IoT is chaired by Erik Ström and Chiara Buratti, while the SWG IoT-Health is chaired by Kamran Sayrafian and Slawomir J. Ambroziak.

6.2 Technical progress

During the second year, EWG-IoT presented 7 TDs in Lund, 5 TDs in Graz and 9 TDs in Nicosia. For Sub-WG IoT-Health there were 9, 5 and 3 TDs, respectively. The experimental facilities made available by partners have been identified and their features and results have been reported in the white paper "Experimental Facilities Report". In particular, these facilities are: FIT/CorteXlab, IMEC w-iLab.t, EuWIN@Bologna, Resource for Vehicle Research (Revere), BAAL@ITU (Computer Networks Research Laboratory @ Istanbul Technical University), RADIOCOM@GUT-HMS, UNIBL-IoT Lab, Smart-campus Network@UMA, IoTWorld @CTTC.

These facilities are also included into the webpage of the IRACON website (see http://radiokom.eti.pg.gda.pl/IRM/).

The main research topics and trends of the EWG-IoT briefly summarized below.

- **Vehicular Communications**. This research regards the study of communication network architecture for future railway, aiming at developing high-data rate wireless connectivity, such as the investigation of IEEE 802.11p/LTE hybrid solutions for vehicle-to-X communications.
- **SDN-based IoT networks**. Novel architectures for enabling the SDN paradigm into the IoT world have been proposed. A joint Bologna-Montenegro testbed has been setup, with devices located in the two Institutions and controlled by a unique Controller located in Bologna, able to program and manage the two IoT networks. An extensive measurement campaign has been carried out. Another solution is based on Locator Identifier Separation Protocol (LISP).
- **Routing and MAC protocols for Industrial IoT**. A novel joint scheduling and routing algorithm for centralised IoT networks has been

proposed and integrated into the 6TiSCH (IPv6 over the TSCH mode of IEEE 802.15.4e) protocol stack. The solution has been tested via experimentation in the framework of a joint research activity between UNIBO and UNIBL. Another joint research between Technical University of Lisbon and UNIBL aims to improve the existing RPL routing protocol for deterministic IoT applications.

- **Low Power Wide Area Networks**. The research regards the study via experimentation of new solutions for the IoT, such as LoRa and NB-IoT. New results have been achieved in terms of analysis and performance evaluation of NB-IoT, considering both, uplink and downlink.

The EWG-IoT in this second year organised a Joint Workshop with EWG-Loc on “Dependable Wireless Communications and Localization for the IoT” which took place in Graz on September 12 2017, where a keynote speech was given from Jean-Marie Gorce (University of Lyon, France) and then 6 papers have been presented. The topics addressed were related to NB-IoT, 6TiSCH, sparse code multiple access and vehicular communication.

The main research topics and trends of the SWG IoT-Health are also summarized below.

- **Radio channel modelling in Body Area Networks**. Wearable and implantable sensors in body area networks are fundamental component of IoT-Health. This research focuses on statistical modelling of radio channels inside, on the surface and in the vicinity of the human body. During the second year, a dynamic channel model for off-body communications and a motion model for wearable antennas in body area networks have been developed. A simple model for body shadowing in off-body and body-to-body channels has also been proposed. New empirical results have been achieved for different static and dynamic scenarios in a ferry environment at 868 MHz and 2.45 GHz. The latter is the result of joint research activities between GUT and IST.
- **Adaptive energy detection threshold in Body Area Networks**. Several low complexity strategies to adaptively control the energy detection threshold in IEEE802.15.6 have been proposed. These strategies can be used to enhance the QoS performance in scenarios with multiple adjacent Body Area Networks.
- **Localisation of UWB capsule endoscopy**. This research focuses on the accuracy of the RSS-based techniques for two-dimensional localisation of capsule endoscopy using Ultra-Wideband (UWB) frequencies. The project employs a novel two-layer experimental liquid phantom to obtain physical measurements.
- **RF Exposure & SAR Evaluation**. Research results on a computational model validation of wireless devices for SAR evaluation has been presented. Additionally, the effect of human morphology on the measurement uncertainty of a multi-band body-worn distributed exposimeter has been investigated. Also, the results of in-situ determination of downlink signal levels emitted by GSM 900, GSM 1800,

UMTS, and LTE networks in urban areas and body exposure induced by the corresponding networks has been presented.

- **IoT-Health Supporting Services & Infrastructure**. A heterogeneous IoT-based architecture for remote monitoring of physiological and environmental parameters by employing Bluetooth and IEEE 802.15.4 wireless protocols has been presented. Healthcare applications in crowd sensing environment have been discussed and an alternative solution in creating computationally efficient procedures for unsupervised processing in resource-limited environments has been proposed. In addition, the idea of using TV white spaces to establish a healthcare network infrastructure for remote monitoring has been presented.
- **IoT-Health for Animals**. An IoT-based architecture as a wireless communication and tracking system for dairy cows have been proposed. This research provides experimental results indicating the accuracy and efficiency of the proposed system.
- **Nano-Communications**. This research focuses on nano-communication using Foerster Resonance Energy Transfer (FRET) signals for in-body medical applications. Models of the communication system along with analysis of the achievable throughput and bit error rate have been provided.

In the second year, the SWG IoT-Health organised a workshop titled “IoT-Health 2018: IRACON Workshop on IoT Enabling Technologies in Healthcare”. The workshop was held along with the IEEE WCNC in Barcelona, Spain on April 15, 2018. In addition, one convened session titled “COST Action CA15104 (IRACON): Measurements and Simulations and Channel Modelling in Wireless Body Area Networks,” was organised during EuCAP in London, UK, on April 12 2018.

The following two STSMs were also completed during the second period: “Simulations of the radio channel in off-body communications in a passenger ferry environment” (18-29.09.2017, GUT to IST); and, "Polarised Off-body Channel Measurements with Dynamic User” (05-16.02.2018, IST to GUT).

7. EWG-LT: Localisation and Tracking

7.1 General aspects of EWG-LT work

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.

EWG-LT is chaired by Carles Anton-Haro and Klaus Witrisal.

7.2 Technical progress

During the second year, the EWG-LT has organized several sessions at the Lund, Graz and Nicosia meetings. The number of TDs presented were six, five and two, respectively. Besides, a number of joint activities (special sessions, workshops, whitepapers, etc) were undertaken by several IRACON partners. The technical sessions were in general well attended (up to some 30 participants) and a number of interesting and lively discussions took place.

As far as research activities are concerned, priority has been given to the following areas in the second year of IRACON:

- **Localization and positioning techniques for 4G and 5G communication networks and the IoT**: Different wireless technologies have been investigated regarding their potential use for positioning. e.g., based on massive-MIMO antenna arrays, authors have investigated the use of phase-based narrowband measurements, a machine-learning based fingerprinting approach using convolutional neural networks, and classical angle-of-arrival estimation using MUSIC. The machine-learning technique showed very promising interpolation capabilities to areas which had not been covered by the collected database, however many open issues remain. Other contributions have been dealing with the pilot placement for uplink positioning in 5G vehicular networks, NLOS detection, and a positioning system using magnetic near-field measurements. Finally, a performance study has been presented for LTE-based V2I positioning.
- **Channel modelling, propagation and positioning**: Here, EWG members have investigated the use of ray tracing channel simulations for fingerprint-based indoor positioning (for BLE) and passive position measurements that could be extracted from communications signal in order to observe the presence of different road users like cars, bikes, and pedestrians. The ray-tracing approach towards fingerprinting could simplify the tedious process of fingerprint acquisition. It has been validated successfully with measurement results, particularly in LOS situations, but also points at the need for a reduction of the complexity of the ray-tracing tool in future work.
- **Multipath-assisted positioning and data fusion techniques** have been a topic in another group of contributions. Multipath assisted positioning would make use of the geometry of reflected, deterministic multipath components, leading to a potential reduction in the infrastructure needed and an enhancement of the robustness. SLAM algorithms have been discussed to automatically build a map of the environment, addressing the data association issue. One contribution shows a factor-graph formulation of the SLAM algorithm which scales well in all relevant parameters and thus yield a reasonable complexity. Another paper demonstrated how a multipath-resolved channel model – as provided by the SLAM algorithm– could be used to characterize the channel capacity of the wireless link at a certain agent position. Finally,

one TD discussed a data fusion approach with IMU measurements to reduce the number of anchor points needed.

As for joint activities, a very successful **workshop** on “Dependable Wireless Communications and Localization” was organized by researchers from the EWG on Localization and Tracking (TU Graz, CTTC) in collaboration with the EWG on IoT (UNIBO) and the Lead Project of TU Graz "Dependable Internet of Things in Adverse Environments" (Graz, Austria, Sept. 12, 2017). The workshop included (i) two Keynote Speeches by Prof. Henk Wymeersch (Chalmers University, Sweden) on "5G mmWave: a unique synergy between positioning and communication?", and Prof. Jean-Marie Gorce (University of Lyon, France), "Toward reliable, reactive and energy efficient bursty multi-user communications"; (ii) 15 technical presentations organized in 4 sessions; and one demo. The workshop was very well attended (around 70 registered participants) and the papers are available for download from: http://www.tugraz.at/go/iracon-ws-2017. Besides, a number of **special sessions** were organized in IEEE conferences: “Evolution and Perspectives of 5G Cellular Localization” at PIMRC’17 (by UAB, and DLR); and a double special session on “Localization in Current and Emerging Networks” at IEEE WCNC’18 (by UAB, Chalmers, and DLR).

In addition, a **White Paper** on “Localization Techniques for 5G and the IoT” was produced by the EWG-LT. The two EWG chairs acted as editors and it was authored by 43 IRACON members and non-members. The white paper includes a specific section devoted to experimental research activities. The White Paper has been posted on IRACON’s website and in other repositories like Research Gate for increased visibility and dissemination. Besides, one STSMs was organized to coordinate activities towards channel modelling for localization systems between TU Graz and Chalmers. Finally, a total of 19 **papers jointly authored** by researchers from more than one IRACON partner have been published during this reporting period.

8. EWG-RA: Radio Access

8.1 General aspects of EWG-RA work

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.

EWG-RA is chaired by Florian Kaltenberger and Mark Beach.

8.2 Technical progress

During the three technical meetings of the second grant period, a total of 8 technical documents were presented, which is almost 50% less than during the first year. Moreover, during the first year of the project, the TDs in this working group were focused on topics like massive MIMO and full duplex radio, whereas during the second year the topics and the testbeds on which the experiments were carried out became more diverse making their coordination harder.

TD(17)05001	Dynamic Spectrum Access research and development in South Africa	Albert A. Lysko
TD(17)05003	Load balance performance analysis with a quality of experience perspective in LTE networks	María Luisa Marí Altozano, Salvador Luna Ramírez, Matías Toril Genovés
TD(17)05009	5G for Factories of the Future: an Introduction to H2020 Clear5G Project	Haibin Zhang
TD(17)05020	A new QoE-based approach for HO parameter tuning in LTE networks	C. Gijón, S. Luna-Ramírez, M. Toril
TD(18)06003	Suitability of LTE Random Access Schemes for State Estimation in Smart Electricity Grids	Achilleas Tsitsimelis, Charalampos Kalalas, Jesus Alonso-Zarate, Carles Anton-Haro
TD(18)06021	An Optimisation Technique for Mobility Load Balancing in Dense Small Cells	Karim M. Nasr and Klaus Moessner
TD(18)06042	Airborne Wireless Network Infrastructure for Affordable Broadband, Emergence Services and Monitoring of Radio Astronomy	L Mfupe, K Katzis
TD(18)06047	Channel modelling and spatial performance requirements for 3GPP mmWave New Radio	Moray Rumney, Pekka Kyosti, Lassi Hentila

It should also be noted that a lot of experimental activities especially in the 5G topic is carried out in other projects, most notably in the 5G-PPP projects of H2020 (5g-ppp.eu). In some rare cases, these projects present their results also in COST IRACON.

One **special session** with the title **Advances in Wireless Communications Through Experimentation** has been organized at **SPAWC 2018 in Kalamata**

(Greece). The special session had 7 different papers from distinguished research institutions that are also represented in COST IRACON and draw a good number of visitors.

9. Conclusions and Perspectives

9.1 Conclusions

During its second year, the various Working Groups have continued working towards the objectives of the Action. As described in the previous sections, all WGs are progressing according to plan and have completed the assigned objectives for the second grant period.

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

1	Discuss and submit contributions about concerted 5G radio channel models to international bodies (namely, ITU-R)	Covered by DWG1 (see Section 2)
2	Define IRACON Reference Scenarios and provide assessment of 5G radio access techniques through experimental platforms	Covered by DWG3 and EWG-RA (see also deliverable 2)
3	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 now online http://radiokom.eti.pg.gda.pl/IRM/
4	Facilitate the collaboration between ECIs through STSMs, with at least 6 missions over the Grant Period (GP)	11 STSMs funded
5	Establish or maintain liaisons with international standardization bodies	• 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 (see Section 2.3) • IRACON liaisons: ➔ 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, exploring the possibility of organizing one joint workshop during the grant period	IRACON liaisons: ➔ H2020 METIS-II – Narcis Cardona ➔ H2020 mmMAGIC – Mark Beach ➔ H2020 5G X-haul – Mark Beach ➔ CommNet (EPSRC network) – Mark Beach

		➔ ITN WiBEC – Narcis Cardona ➔ 5G initiative – Fernando Velez
7	Train ECIs through the organization of two training schools	Three training schools were organized during the second grant period ➔ 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.	• 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 five workshops ➔ Radiofrequency Localisation Techniques – May 29, 2018 Cartagena, Spain ➔ IEEE WCNC 2018 – IRACON Workshop on IoT Enabling Technologies in Healthcare – Apr. 15, 2018 Barcelona, Spain ➔ EuCAP 2018 – IRACON Workshop on Propagation and Channel Modelling Challenges for 5G and beyond inclusive radio communications – Apr. 13, 2018 London, UK ➔ Software Defined Radio Hands-On: FPGA Prototyping with Over-the-Air Signals – Jan. 31, 2018 Nicosia, Cyprus ➔ Dependable Wireless Communication and Localization for the IoT – Sep. 12, 2017 Graz, Austria • Organization of four special sessions at EuCAP2018 ➔ http://www.iracon.org/special-sessions/special-sessions-at-eucap-2018/
9	Discuss COST gender policy through women-only meetings at MC meetings, with inputs to the newsletter or to the blog	Such meeting was held, while the newsletters often highlights the role of women within the Action.

9.2 Success stories

A few success stories are outlined below:

- at each management committee and technical meeting, the attendance is largely above the strict number of management committee members (around 100 attendants per meeting, including many ECIs): this illustrates that IRACON WGs are really seen as a natural biotope by

many PhD students;

- a very large number of technical documents have already been produced (see the full list in annex), many of them by ECIs;
- quarterly Newsletters are being published, highlighting a number of important scientific topics (each issue is downloaded more than 300 times);
- IRACON published two white papers on “”,
- contributions were submitted to the ITU-R SG3 in the area of millimetre wave channel modelling for future 5G systems,
- the structuring of pan-European laboratory facilities and networks for shared experimental research was expanded: the list can be consulted on IRACON website.

9.3 Perspectives for the third grant period

In the next period, IRACON will intensify its activities, in particular with respect to scientific dissemination. The GP objectives have been set as follows:

1. Discuss and review future architecture and protocols for the Internet of Things (including the production of one deliverable)
2. 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.
3. Facilitate the collaboration between ECIs through STSMs (12 missions over the GP)
4. Establish or 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.
5. Maintain on-going links with existing H2020 projects (Clear5G, 5G-car, etc.), by organizing one joint workshop in the grant period (at EuCNC 2018).
6. Train ECIs through the organization of two training schools, with a focus on 5G waveforms and on the transmission of small information quantities in dense networks (both covering aspects going from theory to practice)
7. 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 (EuCNC, EuCAP, PIMRC).

8. Define radio channel models to cover gaps in existing models, in particular for the mmWave band and for localization
9. Propose new schemes at PHY and MAC layers for 5G, with a focus on interference mitigation, ultra low power and latency.
10. Discuss COST gender policy through women-only meetings at MC meetings, with recommendations to the COST office.
11. Discuss the content of the final book of the Action and identify key editors.

Annex: List of Temporary Documents

	TD number	Title	Authors
1	TD(17)04001	A Fair Mechanism of Virtual Radio Resource Management in Multi-RAT Wireless Het-Nets	Behnam Rouzbehani, Luis M. Correia, Luísa Caeiro
2	TD(17)04002	Implementation and measurement of 5G waveform candidate using OpenAirInterface	Kun Chen-Hu, Florian Kaltenberger and Ana Garcia Armada
3	TD(17)04003	Association of Transmitters in Multipath-Assisted Positioning	Markus Ulmschneider, Christian Gentner, Thomas Jost and Armin Dammann
4	TD(17)04004	Line-Of-Sight Massive MIMO Channel Characteristics in an Indoor Scenario at 94 GHz	Frédéric Challita, Maria-Teresa Martinez-Ingles, Martine Liénard, Jose-Maria Molina-Garcia-Pardo and Davy P. Gaillot
5	TD(17)04005	Evaluation of Large-Scale Parameters in Urban Microcells at 3.8 GHz	Claude Oestges, Natalia Dementieva and Evgenii Vinogradov
6	TD(17)04006	/	/
7	TD(17)04007	Reducing the gap between bounds and LDPC decoding performance	I. Bocharova, V. Skachek
8	TD(17)04008	Radio Channel Measurements in 868 MHz Off-Body Communications in a Ferry Environment	Krzysztof K. Cwalina, Slawomir J. Ambroziak, Piotr Rajchowski, Luis M. Correia
9	TD(17)04009	Link-Level WLAN Simulator: Performance Analysis of IEEE 802.11 Technologies	Jiri Milos, Ladislav Polak, Martin Slanina, Tomas Kratochvil
10	TD(17)04010	Tools for Evaluation of Social Relations in Mobility Models	D. Hrabcak, M. Matis, L. Dobos, J. Papaj
11	TD(17)04011	Extreme Wideband Arbitrary Waveform Generator Based on Frequency Multiplexing	Andreas Czylwik, Stefan Bieder, and Marius Sichma
12	TD(17)04012	Factor Graph Based Simultaneous Localization and Mapping using Multipath Channel Information	Erik Leitinger, Florian Meyer, Fredrik Tufvesson, and Klaus Witrisal
13	TD(17)04013	Effect of network architecture on power consumption in mobile radio systems	Claudia Carciofi, Paolo Grazioso, Francesco Matera
14	TD(17)04014	Health applications in crowdsensing environment	Dragana Bajic, Tamara Skoric
15	TD(17)04015	Performance Analysis of a Repetition Redundancy HARQ Algorithm with Decode-Forward Two-Hop Relaying over Rayleigh Channels	Agota Antal, Vasile Bota

16	TD(17)04016	Novel adaptive method for data streams allocation based on the estimate of radio channel parameters in heterogeneous WBAN network	Krzysztof K. Cwalina, Sławomir J. Ambroziak, Jacek Stefański, Jarosław Sadowski
17	TD(17)04017	Massive MIMO Performance – TDD Versus FDD: What Do Measurements Say?	Jose Flordelis, Fredrik Rusek, Fredrik Tufvesson, Erik G. Larsson, and Ove Edfors
18	TD(17)04018	Performance Evaluation of the Dynamic Trajectory Design for an Unmanned Aerial Base Station in a Single Frequency Network	Margot Deruyck, Alberto Marri, Silvia Mignardi, Luc Martens, Wout Joseph, Roberto Verdone
19	TD(17)04019	Implementation of high-speed data transmission technological demonstrator using software defined radio technology	Krzysztof K. Cwalina, Paweł T. Kosz, Piotr Rajchowski, Jarosław Sadowski, Jacek Stefański
20	TD(17)04020	Evolutionary Design of a Dual Band E-shaped Patch Antenna for 5G Mobile Communications	S.K. Goudos, A. Tsiflikiotis, D. Babas, K. Siakavara, F. Mira, C. Kalialakis, G.K. Karagiannidis, M. Deruyck, D. Plets, W. Joseph
21	TD(17)04021	Towards an ITU channel model for 5G	S. Salous
22	TD(17)04022	Defining and Surveying Wireless Link and Network Virtualization	Jonathan van de Belt, Hamed Ahmadi, Linda E. Doyle
23	TD(17)04023	Adaptive Energy Detection Threshold in Body Area Networks	Martina Barbi, Kamran Sayrafian, Mehdi Alasti
24	TD(17)04024	Geometry-based modelling of self-interference channels for outdoor scenarios	Sathya N. Venkatasubramanian, Chunqing Zhang, Leo Laughlin, Katsuyuki Haneda and Mark A. Beach
25	TD(17)04025	On-Site Permittivity Estimation at 60 GHz through Scatterer Identification in the Point Cloud	Usman Tahir Virk, Sinh Le Hong Nguyen, Katsuyuki Haneda, and Jean-Frederic Wagen
26	TD(17)04026	Performance improvement of mmWave communications through macrodiversity in outdoor scenario	Aleksandra Lopusina, Enis Kocan, Milica Pejanovic-Djurisic
27	TD(17)04027	Hybrid mode MIMO terminal antenna with low correlation and enhanced bandwidth	Hui Li, Buon Kiong Lau
28	TD(17)04028	Characteristic mode based MIMO terminal antenna design with user proximity	Zachary Miers, Buon Kiong Lau
29	TD(17)04029	Totally Connected Healthcare with TVWS	Konstantinos KATZIS, Richard W. JONES and Georgios DESPOTOU
30	TD(17)04030	Low Complexity Scheduling and Beamforming in Massive MIMO Systems with COST 2100 Channel Model	Manijeh Bashar, Alister Burr and Kanapathipillai Cumanan

31	TD(17)04031	Quantisation, Compression and Network Coding in Cloud-RAN and Cell-free Massive MIMO	Alister Burr and Qinhui Huang
32	TD(17)04032	Robust Phase-Based Positioning Using Massive MIMO With Limited Bandwidth	Xuhong Li, Kenneth Batstone, Kalle Åström, Magnus Oskarsson, Carl Gustafson, Fredrik Tufvesson
33	TD(17)04033	Deep Convolutional Neural Networks for Massive MIMO Fingerprint-Based Positioning	Joao Vieira, Erik Leitinger, Muris Sarajlic, Xuhong Li, Fredrik Tufvesson
34	TD(17)04034	Joint Compression and Feedback of CSI in Correlated multiuser MISO Channels	Maha ALODEH; Symeon CHATZINOTAS; Bjorn OTTERSTEN
35	TD(17)04035	Internet-of-Animals: wireless communication and location tracking	David Plets, Jens Trogh, Said Benaissa, Wout Joseph, Luc Martens
36	TD(17)04036	Indicative Measurements of mmWave Building Penetration and Exploitation of Gaps	T. W. C. Brown, R. Xie, P. Chambers
37	TD(17)04037	Preliminary evaluation of signal to interference and noise characterisation in massive MIMO	Tim Brown, Martin Hudlicka, David Humphreys, Tian Hong Loh
38	TD(17)04038	Evaluating the Impact of Network Layer Attacks in WSNs and the IoT	Christiana ioannou and Vasos Vassiliou
39	TD(17)04039	Spatially Consistent LOS/NLOS State Model for Statistical Monte Carlo Simulations	Rimvydas Aleksiejunas
40	TD(17)04040	Utilizing Mobile Nodes for Network Recovery in Wireless Sensor Networks	Natalie Temene, Charalambos Sergiou, Vasos Vassiliou, and Chryssis Georgiou
41	TD(17)04041	Carrier Frequency-offset Compensation by Inter-carrier Symbol Precoding at the Transmitter in OFDM Transmissions	Razvan Onica, Vasile Bota
42	TD(17)04042	Dynamic Channel Model with Overhead Line Poles for High-Speed Railway Communications	Lai Zhou, Zhi Yang, Fengyu Luan, Andreas F. Molisch, Fredrik Tufvesson, Shidong Zhou
43	TD(17)04043	A motion model for wearable antennas in BANs	Kenan Turbic, Luis M. Correia, Marko Beko
44	TD(17)04044	Reduced Rank Based Joint DoA Estimation with Mutual Coupling in Massive MIMO Networks	Amit Kachroo and M. Kemal Ozdemir
45	TD(17)04045	Frequency Dependency Analysis of SHF band Directional Propagation Channel in Indoor Environments	Kentaro Saito, Panawit Hanpinitsak, Jun-ichi Takada, Wei Fan, Gert F. Pedersen
46	TD(17)04046	Channel Models, Requirements and Test Methods for 3GPP NR	Moray Rumney, Pekka Kyosti, Aki hekkala
47	TD(17)04047	A Model of Path Arrival Rate for In-Room Radio Channels with Directive Antennas	Troels Pedersen

48	TD(17)04048	Predicting Reverberant Room-to-Room Radio Channel by Using Graphs and Rays in Combination	Yang Miao, Troels Pedersen, Mingming Gan, Evgenii Vinogradov, and Claude Oestges
49	TD(17)04049	A Simulation Framework for Multiple Terminal Antennas in Massive MIMO Systems Evaluated Against Measurements	Erik L. Bengtsson, Peter C. Karlsson, Fredrik Tufvesson, Fredrik Rusek, Steffen Malkowsky, Ove Edfors
50	TD(17)04050	NLOS Channel Detection with Multilayer Perceptron in Low-Rate Personal Area Networks for Indoor Localization Accuracy Improvement	Klemen Bregar, Andrej Hrovat, Mihael Mohorčič, Tomaž Javornik
51	TD(17)04051	On Long-term MIMO Phase Measurement of 2×2 Microwave LOS-MIMO Systems	Lei Bao, Bengt-Erik Olsson, Karl Rundstedt
52	TD(17)04052	/	/
53	TD(17)04053	/	/
54	TD(17)04054	Angular Resolved Pathloss Measurements in a US Suburban Scenario at 28 GHz	Christina Larsson, Bengt-Erik Olsson, Martin Johansson, Henrik Asplund
55	TD(17)04055	Frequency-Dependence of Channel Delay Spread in an Outdoor Environment	Cheikh A. L. Diakhate, Jean-Marc Conrat, Jean-Christophe Cousin, Alain Sibille
56	TD(17)04056	Pilot Placement for Power-Efficient Uplink Positioning in 5G Vehicular Networks	José A. del Peral-Rosado, M. Angélica Barreto-Arboleda, Francesca Zanier, Massimo Crisci, Gonzalo Seco-Granados and José A. López-Salcedo
57	TD(17)04057	Measurement and Analysis of LTE Coverage for Vehicular Use Cases in Live Networks	Taulant Berisha, Gerald Artner, Bujar Krasniqi, Besnik Duriqi, Marigona Muçaj, Sadri Berisha, Philipp Svoboda, Christoph F. Mecklenbräuker
58	TD(17)04058	In-body Communication between Mobile Proteins using FRET	Jakub Kmiecik, Pawel Kulakowski, Krzysztof Wojcik, Andrzej Jajszczyk
59	TD(17)04059	Signal-to-Noise Ratio Measurements and Statistical Characterization in Gen2 RFID	Zoran Blažević, Petar Šolić, Maja Škiljo, Maja Stella, Čedomir Stefanović, Petar Popovski, Gert Frølund Pedersen
60	TD(17)04060	Sectored MPAC OTA setup for testing of mm-wave devices	Pekka Kyösti, Lassi Hentilä, Aki Hekkala, Moray Rumney
61	TD(17)04061	Metrics for evaluating MPAC OTA setups for mm-wave devices	Pekka Kyösti, Lassi Hentilä, Aki Hekkala, Moray Rumney
62	TD(17)04062	Generic system level simulation for advances resources management solutions: a holistic approach for complex network deployments	Paula Rodríguez, Paula Sarasúa, Luis Diez, Ramón Agüero

63	TD(17)04063	On modelling of OTA channel emulation systems	Mario Lorenz, Wim Kotterman, Giovanni Del Galdo
64	TD(17)04064	Analysis of RMS Delay Spread of Outdoor Channel at 60 GHz	Alberto Loaiza Freire, Angelos A. Goulianos and Mark A. Beach
65	TD(17)04065	Experimental Evaluation of User Influence on Test Zone Size in Multi-probe Anechoic Chamber Setups	Wei Fan, Lassi Hentila, Pekka Kyosti, Yilin Ji and Gert F. Pedersen
66	TD(17)04066	Wideband mm-Wave Estimation Algorithms and Their Impacts on Channel Characteristics	Wei Fan, Yilin Ji, Fengchun Zhang, and Gert F. Pedersen
67	TD(17)04067	Time Varying Multi-path Components at 28 GHz from Mobile Channel Sounding	Mamadou Dialounké Balde, Aki Karttunen, Katsuyuki Haneda, Bernard Uguen, Sinh H. L. Nguyen
68	TD(17)04068	Channel Characteristics and User Body Effects in an Outdoor Urban Scenario at 15 and 28 GHz	Kun Zhao, Carl Gustafson, Qingbi Liao, Shuai Zhang, Thomas Bolin, Zhinong Ying and Sailing He
69	TD(17)04069	On the Frequency Dependency of Large-scale Radio Channel Parameters: Analyses and Findings from mmMAGIC Multi-frequency Channel Sounding	Sinh L. H. Nguyen, Jonas Medbo, Michael Peter, Aki Karttunen, Aliou BamBa, Raffaele D'Errico, Naveed Iqbal, Cheikh Diakhate, and Jean-Marc Conrat
70	TD(17)04070	Advanced Low Power High Speed Nonlinear Signal Processing: An Analog VLSI Example	Werner G. Teich, Giuseppe Oliveri, Mohamad Mostafa, Juergen Lindner, Hermann Schumacher
71	TD(17)04071	Measurement study of cable influence on channels inside vehicles	Irfan M. Yousaf and Buon Kiong Lau
72	TD(17)04072	Validation of Numerical Models of Portable Wireless Devices for Specific Absorption Rate Evaluation	Balint Horvath, Peter Horvath, Zsolt Badics, Jozsef Pavo
73	TD(17)04073	Communication in Dynamic Interference	Malcolm Egan, Laurent Clavier, Mauro de Freitas, Louis Dorville, Jean-Marie Gorce1 and Anne Savard
74	TD(17)04074	On the Effect of Phase Noise and Local Oscillator Sharing on Self-Interference Cancellation	Chunqing Zhang, Leo Laughlin, Mark Beach, Kevni Morris, and John Haine
75	TD(17)04075	LoRaWAN: Evaluation of Link- and System-Level Performance	Luca Feltrin, Chiara Buratti, Enrico Vinciarelli, Roberto De Bonis, Roberto Verdone
76	TD(17)04076	Impact of Propagation Model on Capacity in Small-cell Networks	Sofia Sousa, Fernando J. Velez and Jon M. Peha
77	TD(17)04077	Development of minimum cost forwarding (MCF) and source routing MCF routing protocols over 6TiSCH in OpenWSN	Fardin Derogarian, Gordana Gardasevic and Fernando J. Velez

78	TD(17)04078	Preliminary evaluation of NB-IOT technology and its capacity	Luca Feltrin, Alberto Marri, Michele Paffetti, Roberto Verdone
79	TD(17)04079	/	/
80	TD(17)04080	Comparison on Cluster spreads with channels estimated from different algorithms	Yilin Ji, Wei Fan
81	TD(17)04081	Geometry Based Channel Models with Cross- and Auto-correlation for Simulations of V2V Wireless Networks	Christian Nelson, Nikita Lyamin, Alexey Vinel, Fredrik Tufvesson
82	TD(17)04082	Initial results on the performance of fixed mm-wave wireless links with relaying	Carl Gustafson, Sofie Pollin and Liesbet Van der Perre
83	TD(17)04083	/	/
84	TD(17)04084	Frequency Reuse Trade-off and System Capacity in Small Cell Networks in the Millimetre Wavebands	Emanuel Teixeira, Sofia Sousa, Rui R. Paulo and Fernando J. Velez
85	TD(17)04085	TDD channel reciprocity calibration in hybrid beamforming massive MIMO systems	Xiwen Jiang and Florian Kaltenberger
86	TD(17)05001	Dynamic Spectrum Access research and development in South Africa	Albert A. Lysko
87	TD(17)05002	UWB Millimeter-Wave and Terahertz Monostatic Near field Synthetic Aperture Imaging	María-Teresa Martínez-Inglés, Jose-Maria Molina-Garcia-Pardo, Davy P. Gaillot, J. Romeu, L. Jofre
88	TD(17)05003	Load balance performance analysis with a quality of experience perspective in LTE networks	María Luisa Marí Altozano, Salvador Luna Ramírez, Matías Toril Genovés
89	TD(17)05004	Low-Complexity Equalization for Orthogonal Time and Frequency Signaling (OTFS)	Thomas Zemen, Markus Hofer and David Loeschenbrand
90	TD(17)05005	Measurement based Spatial Characteristics of MPCs in Train-to-Train Propagation	Paul Unterhuber, Thomas Jost, Wei Wang, Thomas Kurner
91	TD(17)05006	Scenarios and Architectures for RRM and Optimization of Heterogenous Networks	Sofia C. Sousa, Fernando J. Velez, Kazi Huq, Shahid Mumtaz and Jonathan Rodriguez
92	TD(17)05007	Angle of Elevation dependence on building entry loss models	Satyam Dwivedi, Jonas Medbo, Dennis Sundman

93	TD(17)05008	Effect of Human Body Morphology on Measurement Uncertainty of A Multi-Band Body-Worn Distributed-Exposimeter	Reza Aminzadeh, Arno Thielens, Patrick Van Torre, Sam Agneessens, Mathias Van den Bossche, Stefan Dongus, Marloes Eeftens, Anke Huss, Roel Vermeulen, René de Seze, Paul Mazet, Elisabeth Cardis, Hendrik Rogier, Martin Röösli, Luc Martens, and Wout Joseph
94	TD(17)05009	5G for Factories of the Future: an Introduction to H2020 Clear5G Project	Haibin Zhang
95	TD(17)05010	Volume Integral Equation Based In-Building Propagation Modelling	Ian Kavanagh and Conor Brennan
96	TD(17)05011	Radio Resource and Service Orchestration for Virtualised Multi-tenant Mobile Het-Nets	Behnam Rouzbehani, Luis M. Correia, Luísa Caeiro
97	TD(17)05012	Measurements of High-Speed Data Transmission Radio Link for Special Applications	Pawel T. Kosz, Piotr Rajchowski, Krzysztof K. Cwalina, Jacek Stefanski, Jaroslaw Sadowski
98	TD(17)05013	Radio Channel Measurements in Off-Body Communications in a Ferry Passenger Cabin	Pawel T. Kosz, Slawomir J. Ambroziak, and Luis M. Correia
99	TD(17)05014	Research and Analysis of High-Speed Data Transmission Radio Link Designed for Maritime Environment	Piotr Rajchowski, Krzysztof K. Cwalina, Pawel T. Kosz, Jacek Stefanski, Jaroslaw Sadowski
100	TD(17)05015	New Method for Increasing Precision of Position Estimation of a Moving Person in Hybrid Inertial Navigation System	Piotr Rajchowski, Jacek Stefański, Jarosław Sadowski
101	TD(17)05016	Increased reliability of outdoor millimeter-wave link simulations by leveraging Lidar point cloud data	Julien Stéphan, Yoann Corre, Romain Charbonnier and Yves Lostanlen
102	TD(17)05017	Vibration Effects of Train Wagons on the mmWave Wagon-to-Wagon Channel	Mohammad Soliman, Youssef Dawoud, Emanuel Staudinger, Stephan Sand, Andreas Schütz and Armin Dekorsy
103	TD(17)05018	Channel Capacity Analysis of Indoor Environments for Location-aware Communications	Anh Nguyen Hong, Michael Rath, Erik Leitinger, Stefan Hinteregger, Khang Nguyen Van, and Klaus Witrisal
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