COST Action CA15104
Deliverable 3
Submission of contributions to international bodies on concerted 5G radio channel models

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.

This Deliverable details the achievements of Working Group 1 (WG1) on IRACON's radio channel models during the first two years, focusing on the coordinated inputs to international standardization bodies on 5G radio channel models.

Authors: Sana Salous, Katsuyuki Haneda

Editors: Sana Salous, Katsuyuki Haneda

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List of acronyms

3GPP	The third generation partnership project
5G	Fifth generation
CG	Correspondence group
DWG	Disciplinary working group
IoT	Internet-of-Things
ITU-R	International Telecommunication Union – Radio
MIMO	Multiple-input multiple-output
SG	Study Group
URSI	Union Radio Scientifique Internationale
WG	Working Group

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1. Introduction

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 beyond 2020 will in particular require revolutionary approaches in Radio Access Technologies, 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. The working group 1 (WG1) aims at tackling one of the challenges defined in IRACON, i.e., modelling the variety of radio channels that can be envisaged for inclusive radios. As a first Deliverable from WG1, concerted inputs to international standardization bodies on 5G radio channel models are summarized.

2. Inputs to the International Telecommunications Union Radiocommunication Sector (ITU-R)

Contributions to the International Telecommunications Union, Radiocommunications, Study Group 3, ITU-R SG3 with the name of 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 June 2016 and 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.

Further input on residential path loss model is planned for submission to the June meeting of 2018.

A joint contribution between the UK and JRC, Italy was also submitted to the ITU-R June 2016 meeting, for information regarding the use of ray tracing tools in the mm wave band for 5G applications.

A correspondence Group CG 3K-5 led by the United Kingdom provides guidelines on measurement equipment and keeps a list of equipment specification for data providers to the ITU data bank.

3. Scientific results and dissemination activities

This section first summarizes main scientific outcomes and study trends discussed during the technical meetings. A list of dissemination activities emanating from WG1 is then mentioned.

3.1 Scientific results

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

- Novel channel sounding techniques, e.g., angularly highly-resolved massive MIMO indoor measurements at various radio frequencies, distributed MIMO measurements, reflections, scattering and electrical parameter measurements for various building materials up to 300 GHz. Comparison of different measurement methods for estimating the same parameter to cross-validate the methods.
- Novel channel sounding campaigns in various emerging scenarios, including dynamic body centric, outdoor-to-indoor, industrial, high speed train to infrastructure, train-to-train, vehicle-to-pedestrian, in-tunnel, long-range over-the-coast, maritime, rain forest and rescue scenarios from an aircraft, and self-interference channels in in-band full-duplex communications.
- New channel sounding campaigns for unexplored radio frequency bands above 6 GHz, such as outdoor and indoor channels at 28, 39, 52, 60 and 73 GHz, train-to-train channels at 60 GHz, and indoor ultra-wideband 70, 90 and 140 GHz channels. Long-term measurements of mm-wave channels for fixed links to study the impact of precipitation are currently being carried out.

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

- Studies of improved channel characterization and modelling methods. An extension of high-resolution propagation path parameter estimation methods for ultra-wideband signals is presented as an example. Also, a propagation graph theory is extended to simulate polarimetric diffuse scattering.
- Discussion on radio propagation models and frameworks. These include physical-statistical models of radio channel propagation such as a map-based model and the suitability of the 3GPP channel model for 5G simulations.
- Analysis of radio channel characteristics. For example, it is reported that frequency dependency of large-scale parameters is not apparent, and is highly dependent on sites. Also, terrain clutter models, time-correlation of mobile-to-mobile links, elevation-dependence of building entry loss, over-the-rooftop radio wave propagation, frequency dependency of wave de-polarization, and improved modelling of diffuse scattering are

reported.

- Theory of characteristic modes for terminal antenna design that provides superior decoupling of antenna elements in an array and hence improved multi-antenna link performance.
- Three correspondence groups (CG) have been formed towards an IRACON channel model: CG1: channel models approaches (38 participants), CG2: mmWave channel model (63 participants), CG3: localization channel model (41 participants)

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

- Propagation channel simulations, which are mainly implemented through optical approximation of radio propagation called ray-tracing, including vegetation loss prediction, the use of graph-theory, the radiosity method and the point cloud ray-tracing for frequencies below- and above-6 GHz.
- Proposals for an improved standard channel model, e.g., inclusion of two-path ground reflection at millimetre-waves.
- Validation of numerical radio wave propagation simulation tools through comparison with measurements, and cross-validation among different simulation tools such as comparison of ray-tracing and a field integral equation solver.
- Performance analysis of antennas and links, such as a reconfigurable MIMO antenna mounted on a car roof and self-interference cancellation in time-varying scenarios for in-band full-duplex radios.
- New simulation methods of radio propagation and coverage, such as Laplacian transform based physical optics, volume electric field integral equations.
- Improved tools of radio coverage analysis. Cloud-computing-powered ray-tracing platform with library of different radio environments, e.g., train carriage and outdoor hotspots is introduced. Approaches to reduce computational complexity in ray-tracing and volume integral equations solutions are addressed. Other reported on radio coverage simulators including human body and bus blockage models for millimetre-waves, and a massive antenna array at the base station.

3.2 Dissemination activities

The following are the main highlights of DWG1 during the first two years:

- as a continuation from the COST IC1004, WG1 published a white paper on “Channel measurement and modelling for 5G networks in the frequency bands above 6 GHz”;

  http://www.iracon.org/wp-content/uploads/2016/03/SanaSalous.pdf.

- organization of convened sessions in the 11th European Conference on Antennas and Propagation (EuCAP2017), Paris, France and in EuCAP, London, UK; one of the sessions in EuCAP2018 is a joint session with COST WIPE Action: http://www.eucap.org/
- presentation of an invited paper in EuCAP2017 on 'Towards a channel model for 5G';
- organization of a workshop on 'Radio Propagation and Technologies for 5G', Durham University, United Kingdom, on 03 October 2016, with about 58 participants;

  http://www.iracon.org/workshops/radio-propagation-and-technologies-for-5g/
- organization of an IRACON Workshop on Propagation and Channel Modelling Challenges for 5G and beyond inclusive radio communications in EuCAP2018 in London, UK. Representatives from different working group of the IRACON action present their results for the first two years. The workshop is concluded by a panel that summarizes the remaining important tasks and challenges toward the end of the action.

  http://www.eucap.org/iracon-workshop-on-propagation-and-channel-modelling-challenges-for-5g-and-beyond-inclusive-radio-communications
- liaison with the General Assembly of URSI Commission C on Radiocommunication systems and signal processing, and with the European Union Horizon 2020 projects mmMAGIC and 5G X-haul;
- a number of collaborative publications made by participating institutions about joint radio channel sounding and modelling;
- 10 short-term scientific missions have been organized by WG1 partner institutions.
- contribution to the 5G Alliance white papers: the Measurement Verification White Paper and the Modelling White paper, to be published in 2018;
- several documents were submitted to 3GPP from the UK via Keysight Technologies: R4-1706875, R4-1706898, R4-1706881 and R4-1706882:
  http://www.3gpp.org/ftp/tsg_ran/WG4_Radio/TSGR4_AHs/TSGR4_NR_Jun2017/Docs/

4. Future activities

The WG has recently set up three Correspondence Groups (CGs) towards the development of an IRACN channel model. The three groups address channel characterisation for 5G topics such as the mmWave band, internet of things, massive MIMO for frequency bands below 6 GHz. More than 60

participants joined these three CGs. To facilitate the running of the CGs each CG has two co-chairs to aid in the direction and running of the CG. In identifying the topics of the CGs future input into the international standards was taken into account such as the further development of the clutter model, integration of the clutter model and the building entry loss model recently developed by the ITU in the two new recommendations listed under the ITU input. In addition input to the 3GPP was also considered. Therefore, the aim of the WG is to generate a comprehensive channel model will be used by academia, industry and the international standards.