



Mobile and wireless communications Enablers for the Twenty-twenty  
Information Society-II

# **Deliverable D7.4**

## **Dissemination and exploitation report**

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<http://www.5g-ppp.eu/>

# Deliverable D7.4

## Dissemination and exploitation report

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## Abstract

This document reports the dissemination and exploitation activities performed in the METIS-II project during the period of activity, from July 2015 to June 2017. A complete list of workshops, conferences, events, publications is provided, together with the exploitation outcome from the partners of the consortium.

# Revision History

Revision	Date	Description
0.1	2017-01-19	First draft with ToC ready
0.2	2017-04-17	Second draft with exploitation plans
0.3	2017-05-15	Third version with references added
0.4	2017-05-19	Version for internal review ready
1.0	2017-06-30	Final version after external review
1.1	2017-11-30	Updated with suggestions from final project review



## Executive summary

This deliverable has the objective to report the achievements of the project METIS-II for the dissemination, standardization and exploitation activities carried out during the two years of the activity, from July 2015 to June 2017. METIS-II project inherited from its predecessor project METIS the same structure of the consortium and the ambition to represent one of the most significant research activities for the 5G topics in H2020 collaborative framework.

METIS-II prepared and attended an impressive number of workshops, conferences and events, all based on the main technical objective of the performed research, i.e. the 5G system design. In doing so, METIS-II aimed to cooperate with the most impacting and significant projects in Strand 1 of 5G-PPP projects' structure. All the events and the dissemination activities were advertised through 5G-PPP channels, and made available on the project site and through social media advanced exploitation.

Some of the achievements of METIS-II were also valuable input for the standardization bodies in this very challenging period that has seen the start of the actual standardization of the first 5G systems. METIS-II is probably one of the most mentioned project in 3GPP and all the partners in the consortium referred to METIS-II for many contributions they made to 3GPP and other SDOs.

In this sense, the project has achieved the goals that were outlined at the start in the exploitation and dissemination plans of the single partners. A per partner based report on the achievement of the ambitious plans stated at the project foundation is given in this deliverable as well.



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# List of Abbreviations and Acronyms

<b>3GPP</b>	Third Generation Partnership Project
<b>5GAA</b>	5G Automotive Association
<b>5G NORMA</b>	5G Novel Radio Multiservice adaptive network Architecture
<b>5G-PPP</b>	5G Private Public Partnership
<b>BBF</b>	Broad Band Forum
<b>CEPT</b>	European Conference of Postal and Telecommunications Administrations
<b>CN</b>	Core Network
<b>CP</b>	Control Plane
<b>CSI</b>	Channel State Information
<b>CSCN</b>	Conference on Standards for Communications
<b>CU</b>	Central Unit
<b>DoW</b>	Description of Work
<b>DL</b>	DownLink
<b>DT</b>	Deutsche Telekom
<b>DU</b>	Distributed Unit
<b>DySPAN</b>	Dynamic Spectrum Access Networks
<b>ECC</b>	Electronic Communications Committee
<b>EPC</b>	Enhanced Packet Core
<b>ETSI</b>	European Telecommunications Standards Institute
<b>EuCNC</b>	European Conference on Networks and Communications
<b>Fantastic-5G</b>	Flexible Air iNTErFace for Scalable service delivery wiTH wireless Communication networks of the 5th Generation
<b>Globecom</b>	Global Communications Conference
<b>GSMA</b>	GSM Association
<b>H2020</b>	Horizon 2020

<b>ICC</b>	International Conference on Communications
<b>IEEE</b>	Institute of Electrical and Electronics Engineers
<b>IMT</b>	International Mobile Telecommunications
<b>IoT</b>	Internet of Things
<b>ITRI</b>	Industrial Technology Research Institute
<b>ITU</b>	International Telecommunication Union
<b>KPI</b>	Key Performance Indicator
<b>KTH</b>	Royal Institute of Technology
<b>LTE</b>	Long Term Evolution
<b>METIS-II</b>	Mobile and wireless communications Enablers for the Twenty-twenty Information Society -II
<b>mmMAGIC</b>	Millimetre-Wave Based Mobile Radio Access Network for Fifth Generation Integrated Communications
<b>mMTC</b>	Massive Machine Type Communications
<b>MWC</b>	Mobile World Congress
<b>NGMN</b>	Next Generation Mobile Networks
<b>NR</b>	New Radio
<b>ONF</b>	Open Networking Foundation
<b>PIMRC</b>	Personal, Indoor and Mobile Radio Communications
<b>PMT</b>	Project Management Team
<b>RAN</b>	Radio Access Network
<b>RAT</b>	Radio Access Technology
<b>RCM</b>	RAN Configuration Mode
<b>RFI</b>	Request For Information
<b>RFQ</b>	Request For Qualification





<b>SDO</b>	Standards Developing/Development Organization
<b>SME</b>	Small/Medium Enterprise
<b>SoC</b>	System On Chip
<b>UC</b>	Use Case
<b>UHF</b>	Ultra High Frequencies
<b>UKL</b>	University of Kaiserslautern

<b>UL</b>	UpLink
<b>UP</b>	User Plane
<b>UPV</b>	Universitat Politecnica Valencia
<b>V2V</b>	Vehicle-To-Vehicle
<b>V2X</b>	Vehicle-To-Vehicle, Infrastructure or Network
<b>WRC</b>	World Radio Conference
<b>xMBB</b>	eXtreme Mobile BroadBand

# 1 Introduction

## 1.1 Objective of the document

This Deliverable summarizes the main achievements of the project in terms of dissemination and standardization activities performed in the two years' timeframe during which METIS-II represented one of the most world-acknowledged research activities in the framework of H2020 European funding initiative. The dissemination and exploitation plan was outlined at the beginning of the project in the deliverable D7.1 ([MII15-D71]).

The deliverable also includes a review of the industrial, academic and SME exploitation plans prepared by the partners at the project start.

## 1.2 Structure of the document

Section 2 contains the summaries of the main achievements in terms of dissemination activities, including workshops, conferences, industry forums, events, publications, talks and presentations, cooperation activities in 5G-PPP and public website and social channels. It also gives an overview on how this activity could be useful also in the future, having paved the way for the new projects to come. The detailed list of events about dissemination is reported in Annexes A, B and C.

Section 3 gives an overview of the standardization activities that were impacted by METIS-II activities through the actions of its single partners, or after a coordination within the consortium.

Section 4 is about the references to METIS-II that appeared in the press or in other sources.

Section 5 finally is a review, partner per partner, of the exploitation and dissemination plans declared at the project start. The complete list of declarations is in Appendix D.



## 2 METIS-II dissemination activities

### 2.1 Workshops and Conferences

The project organized more than 20 workshops and conferences in the two-year period of work, and the full list of them is reported in Annex A - Workshops, conferences and events. In this section the main achievements are briefly outlined (see the METIS-II website as well [MET2S]).

A series of workshops have been organized by METIS-II on the theme of “5G RAN Design”, that is one of the main technical objectives of the project. In May 2016 a first workshop on these topics was organized in ICC2016 in Malaysia and this workshop was highly participated by the research community and well attended at the conference (an ad hoc Internet site was used <http://www.5g-ran-design.org/>).

The second workshop in the series was held in Globecom2016 in USA, with a good participation as well, and the series has been completed with the third workshop at ICC2017 in Paris.

Following a specific objective mentioned in the DoW, METIS-II also organized a series of workshops within the community of 5G-PPP Strand 1 projects. Three of these workshops were directly organized by the project itself, the first one being in Kista in September 2015, joint with a project plenary meeting, the second one after the Valencia plenary meeting in January 2016 and the third one in Athens in February 2017.

METIS-II co-organized also the workshop with mmMagic [MMMagic], Fantastic-5G [FAN5G], 5G NORMA [5GNORMA] and many other 5G-PPP projects that took place in London in March 2017.

Regarding the conferences, METIS-II was also very active. Among the most important ones that were considered for dissemination it is important to mention VTC Fall in September 2015, a panel session in CSCN15, EuCNC in 2015, 2016 and 2017, PIMRC 2016 in Valencia and Globecom in 2015 and 2016.

### 2.2 Industry forums and events

As well as participating to the most important conferences on the topic of 5G development in the years 2015-2017, METIS-II also attended some of the most impacting industry forums and events in the same period.

In October 2015 the project was invited to be one of the few that showcased the first achievements in the booth of the European Commission at the event ICT 2015 in Lisbon. In such event, widely acknowledged as one of the most important in that period, the project presented the visualization platform for the first time.

The same platform, additionally including already some of the innovations brought by the partners working in METIS-II, was one of the demos that METIS-II presented at the Mobile World Congress 2016, in the European Commission booth. In that event the project also presented a V2V demo implemented by the University of Valencia.



In April 2016 the ETSI event on 5G, hosted in Sophia Antipolis, saw the presence of METIS-II with the first visualization platform based on a tablet version. In the same period the project was also at the NetFutures 2016 edition in Brussels. In May 2015 the project was once again in Sophia Antipolis for the ETSI Event “From Research to Standardization”.

In October 2016 METIS-II was one of the 5G-PPP Phase 1 projects invited at the NGMN celebration event in Frankfurt for the 10 years activity of the group. While in November the same year METIS-II prepared a booth for the 2nd 5G Global Event held in Rome. The final demonstration of the project was held at EuCNC in Oulu June 2017.

## 2.3 Publications

Even if the consortium representing METIS-II is mostly industrial and the number of academic partners is a little bit lower than, as an example, in METIS parent project, the commitment in the preparation of papers and contributions to conferences and events has been very high. Moreover the quality of the METIS-II publications has always been very high, and with high acceptance rate.

Among the papers developed in the project it is worth mentioning a couple of white papers, one on 5G RAN Design [MD16\_WP], and one on the KPIs to evaluate the new 5G systems [MEA16\_WP].

Moreover, METIS-II promoted and coordinated the preparation of a Wiley book on 5G system design, authored by METIS-II participants, with a preface from the European Commission. The book counts more than 100 contributors from many 5G-PPP projects and is one of the biggest achievements in the dissemination activities of 5G-PPP Phase 1 projects.

The complete list of the METIS-II Publications is in Annex B.

## 2.4 Talks and presentations

As stated in Section 2.2 the project has been very active in the organization of and participation in the largest industry forums and the most important events in the 5G-PPP framework and in the general 5G environment.

As well as participating to these large events METIS-II has made also a large number of talks and presentations to showcase the results achieved in the project, both in industrial and in more academic events.

The complete list of these participations is available in Annex C.

## 2.5 Cooperation in 5G-PPP

METIS-II has been one of the most active projects contributing to the 5G-PPP coordinated activities.

In Section 2.1 the participation to the workshops organized by METIS-II together with the main other projects in Strand 1 of 5G-PPP have been mentioned.



METIS-II was also actively involved in the 5G-PPP Initiative Boards, contributing to the Steering and the Technical board of the partnership, also with management roles. Moreover, on a technical side, METIS-II was one of the projects with large commitment to the 5G-PPP Working Groups. In the 5G-PPP “Architecture” WG METIS-II participated with the role of vice-chairman and contributed with full commitment to the preparation of the “Architecture” White Papers, some of the most relevant achievement of the 5G-PPP community in 2015-2017 timeframe.

Also in WG “Pre-Standardization” and “Spectrum” METIS-II was active with continuous support and with specific contributions, as well as with some leading roles of responsibility in the management of such groups.

Finally, METIS-II also promoted many dissemination initiatives together with 5G-PPP. In particular, as already mentioned, in February 2017 the project started the preparation of a book on “5G system design” that will be edited by Wiley&Sons and will be prepared together with many contributors from other 5G-PPP projects authors.

## 2.6 Public website, social channels

METIS-II site has been regularly updated and maintained in the 5G-PPP page (available at this link: [MET2S]). The activities during METIS-II work have constantly been posted in the project’s social channels, in particular in Twitter [MET2TW] and Facebook [MET2FB] accounts, reaching a high level of visibility in the research community.

## 2.7 Further exploitation in the future

The dissemination and the related exploitation activities in METIS-II have been fundamental for the partners involved and for the research ambitions of the project. The role and the momentum of the project received a widespread consideration inside and outside the consortium.

Many of the activities performed in the project have paved the way for a successful start of the 5G standardization process in 3GPP and ITU-R. Fully exploiting the legacy with its parent project METIS, METIS-II successfully published its deliverables and White Papers that are a reference point for any activity related to the 5G RAN design topics.

In this sense METIS-II successfully achieved the objectives that were declared at the start of the activity in 2015 for the definition and the initial standardization of the new radio system.

What has been conducted in the project will be a kick-off for some activities that will continue in the next years. This is true in particular for the visualization platform, developed in METIS-II as an open platform for the interaction with other interested entities, both during and especially after the completion of METIS-II. Most of the partners that introduced the platform and worked on it will likely continue to develop the platform in the future, aiming to make it a reference for any possible visualization of the new concepts brought by the 5G system, also interactively.

### 3 Standardisation and regulation impact

The activity performed in the project during the period of activity, 2015 to 2017, has been very relevant for the standardization process taking place in the same years towards the introduction of the first 5G systems. METIS-II has been considered as a direct continuation of the “parent” project METIS, which was the first one to study the details of the new 5G systems in 2012 to 2015 timeframe.

As such, METIS and METIS-II have been both considered with the maximum attention by the research community. Both consortia included some of the most important and influential partners also in the standardization forums and some of the achievements in the standardization discussions in these years have been first analyzed and studied in METIS and METIS-II environments.

More in details, METIS-II prepared the contributions to the standards as reported in Table 3-1 and more inputs by different partners to 3GPP work were inspired by METIS-II work, but due to company interests no dedicated references to METIS-II were applied. For example, the connected inactive state and RAN based paging, discussed in section 5.1, are ideas that originated in METIS-II and were brought into standardization.

**Table 3-1: Contributions to the standards.**

Date	Event	Title	Number	Description
19-21.01.2016	ECC PT1 #51	Discussions on evaluation methodology for IMT-2020	ECC PT1(16)025	Proposal for submission to WP5D #23 for consideration in the development of the new report ITU-R M. [IMT-2020.EVAL] co-signed by ERI, NOKIA, UPV and UKL
28-29.01.2016	3GPP TSG-RAN ad hoc, Barcelona, Spain	Requirement for next generation access	RPa160063	TDoc number RPa160063, co-signed by ALU, DCM, ERI, HUAWEI, ITRI, NOKIA. Input captures summary of METIS-II use cases and related deployment scenarios for performance evaluation covered in R1.1/D1.1 and R2.2/D2.1
7-11.03.2016	3GPP RAN Plenary	Realistic Environmental Model for Next Generation Radio Access Technology evaluation	RP160557	TDoc presented at the 3GPP RAN Plenary and cosigned by Telefonica, ITRI and Telecom Italia, in the collaboration of UPV
5-8.06.2017	3GPP RAN Plenary	Motivation for change request on Self Evaluation towards IMT-2020 Submission Study Item	RP170913	TDoc presented to RAN Plenary #76 in June 2017 to influence the Self Evaluation of 3GPP towards ITU-R



## 4 References to the project and press

Considered as one of the most impacting projects for the 5G-PPP Phase 1, METIS-II was quite often mentioned in the press. A complete list of press is reported in the Appendix B.3 together with the press releases issued by the project.

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## 5 Achieved impact and exploitation goals

In the two years of activity METIS-II project played a significant role in the research community towards the introduction of 5G, in due cooperation with the other projects in 5G-PPP Phase 1. The activity performed in the project has had a relevant impact also on the single partners' exploitation plans, as declared at the beginning of the project. For every partner the specific exploitation outcome is reported in Annex D.

In this section a synthesis is given considering the declarations from industrial partners, SMEs and academic partners.

### 5.1 Industrial exploitation

METIS-II has been an industry oriented project by nature and for the specific composition of the consortium. The most important industrial players in Europe for the 5G introduction have all been active in METIS-II, manufacturers, system integrators, and operators.

For the operators, METIS-II has been a unique opportunity to exchange views and plans for the 5G introduction in Europe. As reported in Annex E, many operators have declared that METIS-II has been fundamental to raise the awareness of the importance of 5G for their specific objectives, and helpful to open certain specific experimental activities in their countries (Torino5G for TIM [TIMTO5G], 5G:haus for DT [DT5G], 5Tonic [TEF5G] for Telefonica to mention some examples). The quantitative techno-economic assessment [MII17-D12] will be reused by the operators to motivate 5G infrastructure investments and build the rolling plan according to related business. The outcome of METIS-II will generally help operators to push the finalization of initial 5G standards and to deploy and operate future 5G networks from an early stage on. Especially the flexibility, scalability, and programmability covered by the METIS-II RAN design is a prerequisite in terms of creating a cost-efficient 5G network platform and provisioning of an increased service variety in combination with enabling faster service rollouts compared to existing platforms, meeting the quality and service expectations of the customers.

For the manufacturers, they have managed to achieve early industry consensus through the discussions and collaborations among the partners on important topics for standardization, e.g. on the "connected inactive state" which in turn has sped up the standards process allowing for a more rapid deployment plan than originally envisioned for 5G. The participation in the project has allowed for better dialogues with customers and operators. For spectrum topics, as an example, the consensus obtained in the METIS-II project has been valuable to be able to drive the view of the mobile industry when discussing with other parties that also use spectrum, e.g. the satellite and the broadcasting industries. The work in the consortium was essential to move forward on various 5G design aspects that were not covered so far, such as the notion of air interface harmonization and integration in 5G, mobility and initial access schemes. For the mobile devices manufactures, METIS-II had in the consortium Samsung, which, as part of the strategy to





research advanced technologies for mobile terminals and next generation standards, considers research activities within METIS-II inspiring for new innovations and implementation ideas which may contribute to the future competitiveness of Samsung products and solutions. Finally, INTEL has considered METIS-II as a valuable support to pave the way towards a fully networked world by providing innovative, fine-tuned mobile communications solutions.

In particular, we can mention two ideas generated, developed and researched in the project. These ideas have been further refined and brought into standardization by the respective partner's standardization teams. During the standardization discussions in 3GPP these have been further refined/changed and input from other companies has been taken into account. The concepts are first documented in technical reports in 3GPP and finally, it is foreseen that the ideas will be written into the standards, i.e. TS 38.331. as part of the standalone mode of Rel-15. These ideas are described below:

The connected inactive state is a new activity state for terminals in the network. It allows the terminal to be inactive and release radio resources while state information is kept in the network. This allows a quicker and more efficient transition from inactivity to the active (communicating) state. It is implemented with new functions in the protocol stack. The advantage is less signaling overhead and reduced energy consumptions.

## **5.2 One design goal for METIS-II has been to “push down” functionalities to the RAN that formerly needed CN – RAN signaling in order to reduce the CN-RAN signaling and improve efficiency. One way to do this is to enable a more RAN based paging. The enhanced RAN based paging concept benefits from the new Connected Inactive which allows the network to be able to page the UE more accurately and fewer NBs broadcasting the paging.SME exploitation**

The METIS-II project has been supported by the presence of two small to medium sized enterprises, Janmedia and IDATE. Both of them covered some essential aspects in the technical activities performed in the consortium: the visualization platform and the techno-economic assessment.

Janmedia has been the main driver for the visualization platform, which in its turn played the role of the “demonstrator” of the main activities of the project. Janmedia gained a lot of expertise in driving these activities, being in close contact with the most influential players in the 5G arena in



Europe. The Unity3D based abilities gained during METIS-II allowed Janmedia to develop commercial solutions (important from the company's business perspective), supporting the spread of 5G awareness as well as widening the portfolio. In the world of ever-changing technology it was a defining period in Janmedia history.

IDATE has increased the level of expertise in the field of understanding the evolution of vertical markets and their use of wireless networks and will exploit the gained knowledge also for future collaborative projects in the field. IDATE personnel has gained expertise, which allows to be ready and in an excellent position for preparing future research techno-economic assessment work regarding 5G development and mobile communications in general.

## 5.3 IPR Generation and Management

The 10 patent applications generated by the project are listed in the P2 report. It should be noted that the processing time for patents in general is longer than the project duration and at the moment, there are no decisions whether a patent is granted for these applications.

All the large partners in the project file many patent applications each year and have an extensive process in place for handling these matters. For the patents that are relevant for implementing a standard they must be made available on fair and non-discriminatory terms (FRAND). For each new generation all standards essential patents are aggregated to packages that can be licensed to the ones wishing to make devices adhering to the standard. For the partners that are actively contributing to the 3GPP standards the handling of patents is a well-established process with its own control and management. From METIS-II there is little value that can be added to this process.

For the IPRs generated in the project the Consortium Agreement (CA) defines the terms that the inventions should be possible to use by other partners in the consortium. It is the responsibility of each partner to declare the IPRs generated inside the project. For partners with personnel working on multiple tasks careful judgement has to be used to determine if an invention was generated in the context of METIS-II or in the context of individual work of that partner. It should also be noted some ideas may be very useful while at the same time not possible to patent.

## 5.4 Academic exploitation

Academia has been widely represented in the METIS-II project with some of the most influential Universities in the field of 5G research community in Europe, and also worldwide. KTH, UKL and UPV, together with New York University and Rutgers/Winlab have represented a very significant academic support in a project that has been quite industry oriented by choice. The inclusion of NYU and Winlab has also provided a good opportunity to interact with the 5G research conducted in US.

The METIS-II environment has been helpful for Universities in particular to increase the level of expertise in the 5G topics, to train the young professionals and PhD students and to increase the business opportunities and further collaboration, as well as for the important exchange of knowledge with the industrial partners.



In particular, KTH worked on various subjects which are central to the design and evaluation of 5G RAN, UKL contributed to both the user plane and control plane design of 5G RAN, inspecting also the 5G evaluation framework, UPV has been especially active in air interfaces for 5G systems.

Most of the academic partners have been key players moreover in the preparation and development of the visualization platform ([MII16-D72], [MII16-D73]), with specific input to the Unity3D implementation, in close cooperation with Janmedia. ITRI contributed to this platform with dedicated D2D use cases.

## 6 References

- [MII15-D71] METIS-II Deliverable D7.1, "Dissemination and exploitation plan", 2015-09-30
- [MII17-D12] METIS-II Deliverable D1.2, "Quantitative techno-economic feasibility assessment", 2017-06-15
- [MII16-D72] METIS-II Deliverable D7.2, "Preliminary 5G visualisation", 2016-12-31
- [MII17-D73] METIS-II Deliverable D7.3, "Final 5G visualization", 2017-06-30
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# A Annex A - Workshops, conferences and events

## A.1 2015-09 Panel session at VTC Fall

Panel was the best attended, approximately 100 participants. The panel was popular and also referenced in the Verizon keynote.

<b>Date</b>	Sep. 7, 2015
<b>Place</b>	Boston, USA
<b>Scope</b>	See in the following
<b>Contributions</b>	Organizer / Moderator / Panelists
<b>Organization Committee</b>	METIS-II
<b>Website</b>	<a href="http://www.ieeevtc.org/vtc2015fall/">http://www.ieeevtc.org/vtc2015fall/</a>

Moderator: Patrick Marsch Nokia Networks. Panelists: Ömer Bulakci Huawei, Icaro da Silva Ericsson, Tod Sizer Alcatel-Lucent, Maziar Nekovee Samsung.

This panel was organized by the 5G-PPP project METIS-II, which has the objective to provide a comprehensive and detailed 5G RAN design for an efficient start of 5G standardization, and will address the most controversially discussed aspects related to 5G RAN design, e.g. 1) how a reasonable and meaningful subset of 5G functionality can already be standardized in 3GPP Rel. 14, in order to enable early 5G roll-outs in 2020, without limiting the longer-term potential of 5G, 2) to which extent novel air interfaces introduced in 5G can be scalable to different needs and carrier frequencies, and how these will divide the overall requirements space among themselves, 3) what the role of evolved legacy radio interface technology (e.g. LTE-A) will be in the 5G era, and 4) which precise trade-off between flexibility and complexity should be chosen for 5G, for instance considering RAN virtualization?

## A.2 2015-10 ICT 2015 Booth

<b>Date</b>	October 20-22, 2015
<b>Place</b>	Lisbon
<b>Scope</b>	Show demonstrator in the 5G PPP booth.
<b>Contributions</b>	Booth exhibitor
<b>Organization Committee</b>	5G PPP / EU
<b>Website</b>	<a href="http://ec.europa.eu/digital-agenda/en/ict2015-innovate-connect-transform-lisbon-20-22-october-2015">http://ec.europa.eu/digital-agenda/en/ict2015-innovate-connect-transform-lisbon-20-22-october-2015</a>

METIS-II was invited at the 5G-PPP booth at the ICT 2015 Event in Lisbon, and in that big event the project showed for the first time the visualization platform in its initial version.



### A.3 2015-10 Panel session at IEEE CSCN

Panel received significant attention with almost all the conference attendees present during the session. It generated a lot of interesting questions and discussions during the conference as well.

<b>Date</b>	Oct 29, 2015
<b>Place</b>	Tokyo, Japan
<b>Scope</b>	The audience will obtain a brief insight and latest status on the METIS-II project, and get to know the particular viewpoints on the most controversial aspects related to 5G RAN design from leading network operators, vendors and academia in this field.
<b>Title</b>	5G-PPP METIS-II - Developing the 5G RAN Design
<b>Contributions</b>	Organizer: Patrick Marsch and Athul Prasad / Moderator: Athul Prasad / Panelists: Ömer Bulakci, Anass Benjebbour, Fang-Chu Chen, Yoshio Honda, Ingolf Karls
<b>Organization Committee</b>	METIS-II
<b>Website</b>	<a href="http://www.ieee-cscn.org/panels.html">http://www.ieee-cscn.org/panels.html</a>

### A.4 2015-11 Sino-Europe 5G Technical Workshop

METIS-II co-organized the Sino-Europe 5G Technical Workshop on November 5th. The workshop was hosted by Future Forum at the Beijing Xiyuan Hotel. The workshop was part of the 2015 Future 5G ICT Summit and Series.

METIS-II presented our project as well as the current thinking about design principles and architecture for the radio access network. In addition we showed the work we have done on scenarios and preparations for the evaluation of these scenarios.

<b>Date</b>	Nov 5, 2015
<b>Place</b>	Beijing Xiyuan Hotel
<b>Scope</b>	
<b>Contributions</b>	Session Organizer / Panelists
<b>Organization Committee</b>	Future Forum 5G SIG, METIS-II, 5G NORMA
<b>Website</b>	

### A.5 2015-12 Globecom 2015 Booth

METIS-II was demoed over the course of two half-days as part of the 5G-PPP booth at IEEE Globecom 2015 in San Diego. On both of these days a METIS-II representative was present with the Unity3D demo (updated version of the ICT2015 demo). In addition, the METIS-II video was shown on one of the days on a continuous loop multiplexed with videos from other 5G-PPP projects. On the whole a total of ~15 conference attendees stopped by for a discussion - this included North American colleagues interested in how EU funding works, European colleagues working (or having worked) on other EU projects, as well as colleagues working on a specific aspect of 5G (notable example being V2X and spectrum access) interested in how METIS-II is tackling those specific aspects.



<b>Date</b>	December 6-10, 2015
<b>Place</b>	San Diego
<b>Scope</b>	Show demonstrator in the 5G PPP booth.
<b>Contributions</b>	Booth exhibitor
<b>Organization Committee</b>	5G PPP / EU
<b>Website</b>	<a href="http://globecom2015.ieee-globecom.org/">http://globecom2015.ieee-globecom.org/</a>

## A.6 2016-02 MWC 2016

<b>Date</b>	February 22-25, 2016
<b>Place</b>	Barcelona
<b>Scope</b>	Show demonstrator in the EU booth.
<b>Contributions</b>	Booth exhibitor
<b>Organization Committee</b>	EU
<b>Website</b>	

METIS-II was one of the few projects invited at the European Commission booth in the MWC 2016 edition. The project showed the visualization platform on laptops and tablets and a V2V demo prepared by UPV.

## A.7 2016-04 ETSI Event on 5G

The one day conference organized by ETSI together with DG Connect attracted more than 150 visitors from all over the world. METIS-II had the opportunity of showing a poster, together with some other 5G-PPP Projects in the ETSI Foyer, and also the visualization demo on an Android tablet.

<b>Date</b>	April 21, 2016
<b>Place</b>	ETSI Headquarters, Sophia Antipolis (F)
<b>Scope</b>	The 5th generation of mobile communication networks has attracted a lot of attention from industry, research centres, academia, press and conferences in the recent past. Although 5G is intended to support a very wide range of innovative services, there are three specific classes of use cases emerging as candidates for early prioritization: enhanced mobile broadband, massive machine type communications and ultra-reliable/low latency communications.
<b>Contributions</b>	Exhibitor
<b>Organization Committee</b>	METIS-II
<b>Website</b>	<a href="http://www.etsi.org/news-events/past-events/1025-2016-04-5g-from-myth-to-reality">http://www.etsi.org/news-events/past-events/1025-2016-04-5g-from-myth-to-reality</a>

## A.8 2016-04 NetFutures 2016 Demo

The demo was well visited on the first day of the conference, the second day there were still visitors, but not as many. We presented METIS-II to other projects that were there. We also



presented the project to people from DG Connect who got a firsthand chance to see what we do. There were roughly 700 persons registered for the conference.

<b>Date</b>	April 20-21, 2016
<b>Place</b>	The Egg, Brussels
<b>Scope</b>	NetFutures brings together the researchers, industry and entrepreneurs from across Europe, with a focus on the EU research projects. NET FUTURES wishes to maximize competitiveness of the European technology industry.
<b>Contributions</b>	Exhibitor
<b>Organization Committee</b>	METIS-II
<b>Website</b>	<a href="http://netfutures2016.eu/">http://netfutures2016.eu/</a>

## A.9 2016-05 Demo at ETSI event From Research To Standardization

The two-day workshop gathered around 50 persons working with research and/or standardization to spread information on how to move from research to standards and to give persons working on standards an opportunity to understand what areas will be important in future standardization. METIS-II showed the demo of the visualization platform. The event provided good opportunities to network with people, especially since there were representatives from what we typically call "the verticals".

<b>Date</b>	May 10-11, 2016
<b>Place</b>	ETSI Headquarters, Sophia Antipolis (F)
<b>Scope</b>	The workshop offers a great opportunity for both stakeholder communities to come together, to discuss and to identify common interest areas. Industrial representatives will have first-hand access to state-of-the-art knowledge and get aware of future trends in an early stage. Researchers will be able to present latest research results to industry, to jointly identify the components which are best suitable for standardization and product development activities and to agree on specific next steps.
<b>Contributions</b>	Exhibitor
<b>Organization Committee</b>	METIS-II
<b>Website</b>	<a href="http://www.etsi.org/news-events/past-events/1016-2016-05-ws-from-research-to-standardization">http://www.etsi.org/news-events/past-events/1016-2016-05-ws-from-research-to-standardization</a>



## A.10 2016-05 Demo at VDE-ITG Workshop "Radio for 5G - Solutions for tomorrow's connected world"

The one-day workshop gathered around 140 persons from telecommunications industry, vertical industries, regulatory bodies, and academia (mainly from Germany). METIS-II showed the demo of the visualization platform as well as provided an overview about project activities. The booth enjoyed a lively discussion with visitors.

<b>Date</b>	May 12, 2016
<b>Place</b>	Deutsche Telekom premises, Darmstadt (D)
<b>Scope</b>	<p>The workshop provided an introduction to status and perspectives of worldwide research, development, standardisation, and regulatory activities on 5G.</p> <p>Vendors like Ericsson, Huawei, and Nokia as well as representatives of operators Deutsche Telekom and Vodafone gave an overview about key technologies for 5G radio and architectural concepts.</p> <p>The German regulator BNetzA explained the processes for IMT-2020 at ITU-R and gave an overview about possible frequency bands above 6 GHz.</p> <p>In addition also stakeholders from vertical industries (e.g., VW) showed their view how 5G may support their future business.</p>
<b>Contributions</b>	Exhibitor
<b>Organization Committee</b>	VDE-ITG Technical Committee FA7.2 "Radio Systems"
<b>Website</b>	<a href="https://www.vde.com/de/veranstaltungen/">https://www.vde.com/de/veranstaltungen/</a>

## A.11 2016-05 IEEE ICC 2016 Industry Panel

METIS-II co-organized (together with mmMAGIC) an Industry Panel at IEEE's flagship telecommunications conference ICC 2016. The Panel, titled "Industry Roadmap to 5G: Standards Timeline and Spectrum Requirement" was accepted from an open call following a review process by the conference organizers. The idea from the panel and its structure arose from considerable amassed expertise of METIS-II and mmMAGIC on emerging 5G standardisation roadmap. The panel included high-profile delegates from major cellular operators and leading global vendors and was chaired by a mmMAGIC (and Samsung) representative on behalf of mmMAGIC and METIS-II. Following a short presentation on the goals of the panel and brief introductions into both mmMAGIC and METIS-II, the panel evaluated the unique 5G requirements and assessed if/how the current standardization and spectrum regulatory models will be workable in 5G, with invaluable input from all panel members and the audience. Around 40 conference attendees from all corners of the globe were in attendance.

<b>Date</b>	May 23-27, 2016
<b>Place</b>	Kuala Lumpur, Malaysia



<b>Scope</b>	Industry Roadmap to 5G: Standards Timeline and Spectrum Requirement
<b>Contributions</b>	Panel organization
<b>Organization Committee</b>	METIS-II, mmMAGIC
<b>Website</b>	<a href="http://icc2016.ieee-icc.org/content/industry-panels">http://icc2016.ieee-icc.org/content/industry-panels</a>

## A.12 2016-05 Workshop at ICC2016

This workshop on 5G RAN design was jointly organized by the 5th Generation Public Private Partnership (5G PPP) projects METIS-II, FANTASTIC-5G, mmMAGIC and 5G NORMA at the IEEE ICC 2016. It aimed to foster the discussion and consensus building on key 5G RAN design aspects. The workshop provided the opportunity to share and discuss results from the mentioned projects and other 5G research activities, and to elaborate on how the 5G RAN design shall be best taken forth in the standardization which is expected to start in this time frame.

<b>Date</b>	May 23- 27, 2016
<b>Place</b>	Kuala Lumpur, Malaysia
<b>Scope</b>	Foster the discussion and consensus building on key 5G RAN design aspects.
<b>Contributions</b>	Workshop
<b>Organization Committee</b>	Workshop Chairs: Dr. Patrick Marsch, Nokia Networks  Dr. Didier Bourse, Alcatel-Lucent
<b>Website</b>	<a href="http://www.5g-ran-design.org/gc16/index.html">http://www.5g-ran-design.org/gc16/index.html</a>

## A.13 2016-06 EuCNC

5G PPP METIS-II project actively contributed to EuCNC 2016.

- METIS-II organised the special session 6 on “METIS-II views on 5G RAN design and architecture” on 29 June at 16:30. The session was chaired by Olav Queseth (Ericsson, Sweden).
- METIS-II participated in workshop 1 on “International workshop on 5G architecture” on 27 June at 9:00. The workshop was chaired by Simone Redana (Nokia, Germany) and Alexandros Kaloxylas (Huawei, Germany).
- METIS-II also participated in panel 2 on 5G Architecture on 29 June at 14:30.

<b>Date</b>	June 27-30, 2016
<b>Place</b>	Athens, Greece
<b>Scope</b>	Show demonstrator in METIS-II booth and arrange a special session
<b>Contributions</b>	Booth exhibitor, session organizer

<b>Organization Committee</b>	EU Commission
<b>Website</b>	<a href="http://www.eucnc.eu/">http://www.eucnc.eu/</a>

## A.14 2016-09 PIMRC Panel

The panel was the most visited panel with around 110 participants. In the introduction we managed to give different perspectives on the future developments ranging from devices to networks, applications and visions from verticals. The ensuing discussion ranged from very detailed questions, e.g. need for CSI transmissions, to questions wide in scope, e.g. what is the technology most likely to fail?.

<b>Date</b>	September 5, 2016, 14:10 – 15:50 pm
<b>Place</b>	Valencia, Spain
<b>Scope</b>	Start to discuss the topics relevant for future research beyond the first release of standards.
<b>Contributions</b>	Organizer / Moderator / Panelists
<b>Organization Committee</b>	METIS-II, mmMAGIC, 5G NORMA
<b>Website</b>	<a href="http://www.ieee-pimrc.org/panels.html">http://www.ieee-pimrc.org/panels.html</a>

## A.15 2016-10 Demo at NGMN Industry Conference and Exhibition

<b>Date</b>	October 12-13, 2016
<b>Place</b>	Steigenberger Airport Hotel, Frankfurt, Germany
<b>Scope</b>	10 Year celebration of NGMN.
<b>Contributions</b>	Exhibitor
<b>Organization Committee</b>	METIS-II
<b>Website</b>	<a href="https://ice2016.ngmn.org/">https://ice2016.ngmn.org/</a>

The Industry Conference & Exhibition brought together key players from the entire mobile ecosystem and offered a unique networking platform throughout the 2 days. The event featured the announcement of leading, international operators' and vendors' requirements for the future 5G technology platform. This was complemented by an in-depth presentation of new 5G enabled business opportunities and use-cases introduced by executives and subject-matter experts.

## A.16 2016-10 Panel at IEEE CSCN 2016

<b>Date</b>	October 31 - November 2, 2016
<b>Place</b>	Berlin
<b>Scope</b>	Panel discussion on "possible game changers in the 5G RAN"
<b>Contributions</b>	Panel organizer



<b>Organization Committee</b>	METIS-II
<b>Website</b>	<a href="http://cscn2016.ieee-cscn.org/">http://cscn2016.ieee-cscn.org/</a>

METIS-II organized a panel discussion on "possible game changers in the 5G RAN" at IEEE CSCN in Berlin, Oct 31st 2016. The participants were: Patrick Marsch (moderator, Nokia), Milos Tesanovic (Samsung), Yang Yang (Intel), Venkatkumar Venkatasubramanian (Nokia), Malte Schellmann (Huawei), Anass Benjebbour (Docomo). After a short overview on the METIS-II project provided by Patrick, each panelist gave a short presentation, raising some topics/considerations on the 5G RAN. This was followed by a good discussion, also with various questions from the audience. The feedback from the audience was generally positive.

## A.17 2016-11 5G Global event demo

<b>Date</b>	November 9-10, 2016
<b>Place</b>	Rome
<b>Scope</b>	Showcasing the latest version of the visualization platform
<b>Contributions</b>	Exhibitor
<b>Organization Committee</b>	METIS-II
<b>Website</b>	<a href="https://5g-ppp.eu/event/second-global-5g-event-on-9-10-november-2016-in-rome-italy">https://5g-ppp.eu/event/second-global-5g-event-on-9-10-november-2016-in-rome-italy</a> "Official" photos: <a href="https://5g-ppp.eu/global-5g-event-rome-photos/">https://5g-ppp.eu/global-5g-event-rome-photos/</a>

METIS-II organized a booth at the Second 5G Global event kept in Rome in November 2016, showcasing the latest version of the visualization platform to the big audience of such event.

## A.18 2016-12 Globecom

METIS-II was the main organizer of the second edition of the 5GDES workshop along with other 5G PPP projects, namely FANTASTIC 5G, mmMAGIC, 5G-Crosshaul, and Flex5Gware. The event was co-located with IEEE Globecom in Washington DC, USA. The event consisted of four sessions, each of them initiated with a keynote speaker followed by a technical sessions, three of them being oral sessions and one a poster session. In addition to the organization tasks (i.e., creation of the program, contact to keynote speakers, etc) METIS-II also provided technical oral presentations and posters coming from the different work packages. The event was successful in terms of attendance and quality of the technical contents presented.

<b>Date</b>	December 8, 2016
<b>Scope</b>	Workshop aimed to foster the discussion and consensus building on key 5G RAN design aspects. The workshop provided the opportunity to share and discuss results from the mentioned projects and other 5G research activities, and to elaborate on how the 5G RAN design shall be best taken forth in the recently started 3GPP standardization.
<b>Contributions</b>	Organization, papers, posters

<b>Organization Committee</b>	5G PPP / EU
<b>Website</b>	<a href="http://www.5g-ran-design.org/gc16/index.html">http://www.5g-ran-design.org/gc16/index.html</a>

## A.19 2017-02 3rd 5G PPP Workshop

<b>Date</b>	February 8-9, 2017
<b>Place</b>	Athens, Greece
<b>Scope</b>	The scope of the workshop is to share results and current thinking of the projects as well as getting together to discuss and align on a number of topics that stretches accross projects and topics where there is still a bit of discussion needed to reach consensus.
<b>Contributions</b>	Organizer, presenter
<b>Organization Committee</b>	METIS-II, FANTASTIC 5G, 5G-ENSURE, flex5Gware, mmMAGIC
<b>Website</b>	External website: <a href="https://5g-ppp.eu/event/5g-cross-project-workshop-february-6-7-2017-athens/">https://5g-ppp.eu/event/5g-cross-project-workshop-february-6-7-2017-athens/</a> BSCW site: <a href="https://bscw.5g-ppp.eu/sec/bscw.cgi/122115">https://bscw.5g-ppp.eu/sec/bscw.cgi/122115</a>

METIS-II arranged the third iteration of the 5G PPP cross project workshop on ran design and architecture in Athens on February 6th -7th. There were around 50 participants. The workshop was appreciated and triggered a lot of discussions. There were also some points of common interest where there will be further cross-project collaboration.

## A.20 2017-03 5G-PPP Workshop

<b>Date</b>	March 30-31, 2017
<b>Place</b>	Chertsey, UK
<b>Scope</b>	5G PPP Architecture and RAN Integration
<b>Contributions</b>	Workshop co-organiser/co-contributor
<b>Organization Committee</b>	mmMAGIC, METIS II, 5G-Crosshaul, 5G NORMA
<b>Website</b>	Workshop site: <a href="https://5g-mmmagic.eu/5g-arch-workshop-london/">https://5g-mmmagic.eu/5g-arch-workshop-london/</a> Presentations: <a href="https://bscw.5g-mmmagic.eu/pub/bscw.cgi/191166">https://bscw.5g-mmmagic.eu/pub/bscw.cgi/191166</a>

There were around 70 persons attending from academia and industry including regulator like Ofcom. The first day was dedicated to the key take aways from 5G PPP projects on the architectural aspects, where there was also overview presentations from WG Architecture and 5G IA. The second day was tailored towards 5G general issues including standardization roadmap. METIS-II has presented main highlights of the 5G RAN design comprising common control plane design, functional split options, agile resource management framework, and example functional considerations. For instance, results on multi-slice resource management were illustrated. The audience was interested in METIS-II concepts with particular questions towards the realization of network slicing, SLA and QoS fulfillment, and radio link feedback needed among centralized and distributed units. The event was successful from METIS-II perspective, where main architectural findings were discussed with a wide-range stakeholders.



## A.21 2017-05 IWPC Workshop

<b>Date</b>	May 23-25, 2017
<b>Place</b>	Madrid, Spain
<b>Scope</b>	Consideration for the overall 5G radio access network design and technical enablers needed for efficient integration and use of the various 5G technologies and components being developed. Exploring 5G collaboration frameworks, timeframe acceleration and innovation.
<b>Title</b>	5G New Radio Evolution Towards 2020
<b>Organization Committee</b>	Telefonica / METIS-II
<b>Website</b>	<a href="http://www.iwpc.org/workshops/2017/2017-05_Telefonica/agenda.html">http://www.iwpc.org/workshops/2017/2017-05_Telefonica/agenda.html</a>

The demo was a big success and there were many questions and interaction with the audience. Most of them after the demo expressed how impressive and effective the demo was. Virtual reality and android version were also demonstrated, which allowed the audience to interact during some minutes with the visualization tool.

Workshop organizers for METIS-II: Luis M. Campoy (Telefonica) and Jose F. Monserrat (UPV).

## A.22 2017-05 ICC Workshop

<b>Date</b>	May 25, 2017
<b>Place</b>	Paris, France
<b>Scope</b>	5G RAN design workshop
<b>Organization Committee</b>	METIS-II, mmMAGIC, flex5GWare, FANTASTIC-5G, 5G Crosshaul
<b>Website</b>	Workshop site: <a href="http://www.5g-ran-design.org/">http://www.5g-ran-design.org/</a> ICC site: <a href="http://icc2017.ieee-icc.org/workshop/3rd-international-workshop-5g-ran-design">http://icc2017.ieee-icc.org/workshop/3rd-international-workshop-5g-ran-design</a>

The workshop went well although the attendance was not extremely large. Possibly because this was the last day of the conference and that the day of the workshop was a bank holiday in many parts of Europe. The attendance in the four sessions were: 18, 25, 15 and 8 including the presenters. The keynotes (Frederick Pujol, from IDATE and Antonio Barciela from MPSA) generated a discussion and questions on the future direction of 5G.

## A.23 2017-06 EuCNC 2017

<b>Date</b>	June 12-16, 2017
<b>Place</b>	Oulu, Finland
<b>Scope</b>	Exhibition at the EuCNC2017 and participation to workshops; papers presented
<b>Organization Committee</b>	METIS-II



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<b>Website</b>	<a href="http://www.eucnc.eu/">http://www.eucnc.eu/</a>
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METIS-II participated to the EuCNC 2017 with a project booth with the latest version of the visualization platform including all the innovations from the partners and with a set of papers presented by the respective authors in the main sessions of the conference.

## B Annex B - Publications

### B.1 Conference papers

Title	Authors	Title (Conference)	Date	Publisher	Place	Year
5G Radio Access Network Design - A Brief Overview on the 5G-PPP Project METIS-II	Patrick Marsch, Olav Queseth, Salah-Eddine El Ayoubi, Michał Maternia, Mikko A. Uusitalo, Rauno Ruismaki, Milos Tesanovic, Alexandros Kaloxylos, Icaro Da Silva and Mauro Boldi	EuCNC Special 5GPP session	29 Jun - 2 Jul 2015	European Commission	Paris, France	2015
Technical Rate of Substitution of Spectrum in Future Mobile Broadband Provisioning	Yanpeng Yang and Ki Won Sung	IEEE DySPAN	29 Sept - 2 Oct 2015	IEEE	Stockholm, Sweden	2015
Agile Resource Management for 5G – A METIS-II Perspective (Invited Paper)	Ömer Bulakci, Athul Prasad, Jakob Belschner, Mårten Ericson, Ingolf Karls, Haris Celik, Milos Tesanovic, Roberto Fantini, Luis M Campoy, Emmanouil Pateromichelakis, Fernando Sanchez Moya, Gerd Zimmermann and Icaro Da Silva	Conference on Standards for Communications and Networking (CSCN)	28-30 Oct 2015	IEEE	Tokyo, Japan	2015
Directional initial access for millimeter wave cellular systems	C. Nicolas Barati, S. Amir Hosseini, Marco Mezzavilla, Parisa Amiri-Eliasi, Sundeep Rangan, Thanasis Korakis, Shivendra S. Panwar, Michele Zorzi	2015 49th Asilomar Conference on Signals, Systems and Computers	8-12 Nov 2015	IEEE	Monterey, CA, USA	2015
Towards a flexible harmonised 5G air interface with multi-service, multi-connectivity support	Milos Tesanovic, Malte Schellmann, Petra Weitkemper, Daniel Calabuig, Osman Aydin, Caner Kilinc, Venkatkumar Venkatasubramanian	ETSI WORKSHOP ON FUTURE RADIO TECHNOLOGIES – AIR INTERFACES	27-28 Jan 2016	ETSI	Sophia Antipolis, France	2016
Comparative analysis of initial access techniques in 5G mmWave cellular networks	Marco Giordani, Marco Mezzavilla, C. Nicolas Barati, Sundeep Rangan, Michele Zorzi	2016 Annual Conference on Information Science and	16-18 Mar 2016	IEEE	Princeton, NJ, USA	2016





		Systems (CISS)				
MTC Value Network for Smart City Ecosystems	Amirhossein Ghanbari, Oscar Alvarez, Jan Markendahl	IEEE WCNC 2016	6-9 May 2016	IEEE	Doha, Quatar	2016
Framework to Support Mobility Context Awareness in Cellular Networks	Nandish P. Kuruvatti, Hans Schotten	VTC-Spring 2016	15-18 May 2016	IEEE	Nanjing, China	2016
Mobility Prediction of Diurnal Users for Enabling Context Aware Resource Allocation	Nandish P. Kuruvatti, Wenxiao Zhou, Hans Schotten	VTC-Spring 2016	15-18 May 2016	IEEE	Nanjing, China	2016
Adaptive Filtered OFDM with Regular Resource Grid	Petra Weitkemper, Jamal Bazzi, Katsutoshi Kusume, Anass Benjebbour, Yoshihisa Kishiyama	5G RAN design Workshop, ICC 2016	27 May 2016	IEEE	Kuala Lumpur, Malaysia	2016
On the impact of network slicing on 5G radio access networks	Icaro da Silva, Gunnar Mildh, Alexandros Kaloxylos, Panagiotis Spapis, Enrico Buracchini, Alessandro Trogolo, Gerd Zimmermann, Nico Bayer	5G RAN design Workshop, ICC 2016	27 May 2016	IEEE	Kuala Lumpur, Malaysia	2016
A novel state model for 5G radio access networks	Icaro da Silva, Gunnar Mildh, Mikko Säily, Sofonias Hailu	5G RAN design Workshop, ICC 2016	27 May 2016	IEEE	Kuala Lumpur, Malaysia	2016
A Framework for End-to-End Evaluation of 5G mmWave Cellular Networks in ns-3	Russell Ford, Menglei Zhang, Sourjya Dutta, Marco Mezzavilla, Sundeep Rangan, Michele Zorzi	Proceedings of the Workshop on ns-3 - WNS3 '16	15-16 June 2016	ACM Press	Seattle, WA, USA	2016
On the Use of Serious Game Engineering for 5G System Performance Evaluation	Carlos Herranz, David Martin-Sacristan, Saúl Inca, José F. Monserrat, Narcís Cardona	EuCNC 2016 (METIS-II Special Session)	29 June 2016	European Commission	Athens, Greece	2016
Air interface design for 5G: a METIS-II perspective	Milos Tesanovic, Venkatkumar Venkatasubramanian, Malte Schellmann, Jamal Bazzi, Miltiades C. Filippou, Daniel Calabuig, Osman Aydin, and Caner Kilinc	EuCNC 2016 (METIS-II Special Session)	29 June 2016	European Commission	Athens, Greece	2016



5G Service Requirements and Operational Use Cases: Analysis and METIS II Vision	Salah Eddine Elayoubi, Mikael Fallgren, Panagiotis Spapis, Gerd Zimmermann, David Martín-Sacristán, Changqing Yang, Sébastien Jeux, Patrick Agyapong, Luis Campoy, Yinan Qi, Shubhranshu Singh	EuCNC 2016	27-30 June 2016	European Commission	Athens, Greece	2016
Interference Management for 5G: A METIS-II Perspective	Emmanouil Pateromichelakis, Haris Celik, Roberto Fantini, Ömer Bulakci, Luis M. Campoy, Ahmed M. Ibrahim, Javier Lorca, Mehrdad Shariat, Milos Tesanovic, Yang Yang	EuCNC 2016 (METIS-II Special Session)	29 June 2016	European Commission		2016
FQAM-FBMC Design and Its Application to Machine Type Communication	Yinan Qi, and Milos Tesanovic	PIMRC 2016 Workshops	4-7 Sept 2016	IEEE	Valencia, Spain	2016
Hardware Testbed for Sidelink Transmission of 5G Waveforms without Synchronization	David Garcia-Roger, Josue Flores de Valgas, Nicolo Incardona, Jose F. Monserrat, Narcís Cardona	PIMRC 2016	4-7 Sept 2016	IEEE	Valencia, Spain	2016
Value Creation and Coopetition in M2M Ecosystem - The Case of Smart City	Amirhossein Ghanbari, Andres Laya, Jan Markendahl	PIMRC 2016	4-7 Sept 2016	IEEE	Valencia, Spain	2016
Enabling RAN Moderation and Dynamic Traffic Steering in 5G	Athul Prasad, Fernando Sanchez Moya, Mårten Ericson, Roberto Fantini, Ömer Bulakci	IEEE VTC-Fall 2016	18-21 Sept 2016	IEEE	Montréal, Canada	2016
Interference Management Enablers for 5G Radio Access Networks	Emmanouil Pateromichelakis, Haris Celik, Roberto Fantini, Ömer Bulakci, Luis M. Campoy, D.M. Gutierrez-Estevez, Ahmed M. Ibrahim, Javier Lorca, Mehrdad Shariat, Milos Tesanovic, Yang Yang	CSCN 2016	31 Oct-2 Nov 2016	IEEE	Berlin, Germany	2016
Design framework and suitability assessment proposal for 5G air interface candidates	Milos Tesanovic, Venkatkumar Venkatasubramanian, Malte Schellmann, Jamal Bazzi, Miltiades C. Filippou, Daniel Calabuig, Osman Aydin, Caner Kilinc	CSCN 2016	31 Oct-2 Nov 2016	IEEE	Berlin, Germany	2016



Air interface for 5G: PHY design based on pulse shaped OFDM	Malte Schellmann, Zhao Zhao, Xitao Gong, Qi Wang	CSCN 2016	31 Oct-2 Nov 2016	IEEE	Berlin, Germany	2016
An Enabling Waveform for 5G - QAM-FBMC: Initial Analysis	Yinan Qi, Mohammed Al-Imari	CSCN 2016	31 Oct-2 Nov 2016	IEEE	Berlin, Germany	2016
Post-Resource Sharing Power Allocation in Cellular Networks to Coexist with D2D Underlay	Nandish P. Kuruvatti, Hans D. Schotten	International conference on Network of the Future NoF 2016	16-18 Nov 2016	IEEE	Buzios, Brazil	2016
New Radio 5G User Plane Design Alternatives	Caner Kilinc, Jose F. Monserrat, Miltiades C. Filippou, Nandish P. Kuruvatti, Ali A. Zaidi, Icaro Da Silva, Marco Mezzavilla	GlobeComm 2016	4-8 Dec 2016	IEEE	Washington, USA	2016
Reflection Environment Maps for Enhanced Reliability in 5G Self-Organizing Networks	Athul Prasad, Mikko A. Uusitalo, Zexian Li, and Petteri Lundén	Globecom - Workshops (5GSON)	4-8 Dec 2016	IEEE	Washington, USA	2016
Architecture Approaches for 5G Millimetre Wave Access Assisted by 5G Low-Band using Multi-Connectivity	Danish Aziz, Jens Gebert, Anton Ambrosy, Hajo Bakker and Hardy Halbauer	Globecom 2016 - 5G RAN Design Workshop	4-8 Dec 2016	IEEE	Washington, USA	2016
Interference-Aware Flexible TDD Design for Massive MIMO 5G Systems	David M. Gutierrez-Estevez	IEEE WCNC 2017	19-22 Mar 2017	IEEE	San Francisco, CA, USA	2017
Selection and Dimensioning of slice-based RAN controller for adaptive Radio Resource Management	Emmanouil Pateromichelakis, Chenghui Peng	IEEE WCNC 2017	19-22 Mar 2017	IEEE	San Francisco, CA, USA	2017
Mobility Context Awareness to Improve Quality of Experience in Traffic Dense Cellular Networks	N.P. Kuruvatti, J.F.S Molano and H.D. Schotten	ICT 2017	03-05 May 2017	IEEE	Limassol, Cyprus	2017
Split Options for 5G Radio Access Networks	Paul Arnold, Nico Bayer, Jakob Belschner, Gerd Zimmermann	ITG Fachtagung Mobilkommunikation	9-10 May 2017	VDE	Osnabrück, Germany	2017



A Novel Serious Game Engineering Based Interactive Visualization and Evaluation Platform For Cellular Technologies	P. Chakraborty, N.P. Kuruvatti and H.D. Schotten	ISNCC 2017	16-18 May 2017	IEEE	Marrakech	2017
On the Asymptotic Behavior of Ultra-Densification under a Bounded Dual-Slope Path Loss Model	Yanpeng Yang, Jihong Park, Ki Won Sung	European Wireless 2017	17-19 May 2017	IEEE	Dresden, Germany	2017
Context-aware Cluster Based Device-to-Device Communication to Serve Machine Type Communications	Ji Lianghai, Liu Man, Hans D. Schotten	IEEE ICC 2017 - International workshop on 5G RAN design	21-25 May 2017	IEEE	Paris, France	2017
Design for High Mobility LTE-A V2V Communication Systems	Juinn-Horng Deng, Su-Hua Chen, Chorng-Ren Sheu, Hua-Lung Tsai, Shubhranshu Singh, Jen-Shun Yang	IEEE ICC 2017 - International workshop on 5G RAN design	21-25 May 2017	IEEE	Paris, France	2017
Enhanced Random Access: Initial Access Load Balance in Highly Dense LTE-A Networks for Multiservice (H2H-MTC) Traffic	Mohammad Istiak Hossain, Amin Azari, Jan Markendahl, and Jens Zander	ICC 2017	21-25 May 2017	IEEE	Paris, France	2017
Flexible Network Deployment in 5G	Taylan Sahin, Ömer Bulakci, Panagiotis Spapis, Alexandros Kaloxylos	IEEE VTC 2017-Spring	4-7 June 2017	IEEE	Sydney, Australia	2017
RAN Moderation in 5G Dynamic Radio Topology	Ömer Bulakci, Alexandros Kaloxylos, Josef Eichinger, Chan Zhou	IEEE VTC 2017-Spring	4-7 June 2017	IEEE	Sydney, Australia	2017
5G Multi-RAT integration evaluations using a common PDCP layer	Marten Ericson, Patrik Rugeland, Ali A. Zaidi, Icaro Da Silva, Osman Aydin, Venkatkumar Venkatasubramanian, Miltiades C. Filippou, Marco Mezzavilla, Nandish P. Kuruvatti, Jose F. Monserrat, Caner Kilinc	IEEE VTC 2017-Spring	4-7 June 2017	IEEE	Sydney, Australia	
Energy Efficient Coordinated Self-Backhauling for Ultra-Dense 5G Networks	Athul Prasad, Mikko A. Uusitalo, Andreas Maeder	IEEE VTC 2017-Spring	4-7 June 2017	IEEE	Sydney, Australia	2017



Radio Link Enabler for Context-aware D2D Communication in Reuse Mode	Ji Lianghai, Andreas Weinand, Michael Karrenbauer, Hans D. Schotten	IEEE VTC 2017-Spring	4-7 June 2017	IEEE	Sydney, Australia	2017
Monitoring Vehicular User Mobility to Predict Traffic Status and Manage Radio Resources	Nandish P. Kuruvatti, Julian F. Saavedra Molano and Hans D. Schotten	IEEE VTC 2017-Spring	4-7 June 2017	IEEE	Sydney, Australia	2017
RACH Dimensioning for Reliable MTC over Cellular Networks	Amin Azari, Mohammad Istiak Hossain, and Jan I Markendahl	IEEE VTC 2017-Spring	4-7 June 2017	IEEE	Sydney, Australia	2017
Traffic Safety in the METIS-II 5G Connected Cars Use Case: Technology Enablers and Baseline Evaluation	David Martín-Sacristán, Carlos Herranz, Jose F. Monserrat	EuCNC 2017	12-15 June 2017	European Commission	Oulu, Finland	2017
Transparent spectral confinement approach for 5G	Jamal Bazzi, Katsutoshi Kusume, Petra Weitkemper, Kazuaki Takedaz, Anass Benjebbour	EuCNC 2017	12-15 June 2017	European Commission	Oulu, Finland	2017
Joint Transmission with Dummy Symbols for Dynamic TDD in Ultra-Dense Deployments	Haris Celik, Ki Won Sung	EuCNC 2017	12-15 June 2017	European Commission	Oulu, Finland	2017
5G Radio Access Network Architecture Based on Flexible Functional Control / User Plane Splits	Paul Arnold, Nico Bayer, Jakob Belschner, Gerd Zimmermann	EuCNC 2017	12-15 June 2017	European Commission	Oulu, Finland	2017
Cooperative Transmissions in Ultra-Dense Networks under a Bounded Dual-Slope Path Loss Model	Yanpeng Yang and Ki Won Sung	EuCNC 2017	12-15 June 2017	European Commission	Oulu, Finland	2017
On the Integration of Grassmannian Constellations into LTE Networks a Link-level Performance Study	Jorge Cabrejas, David Martín-Sacristán, Sandra Roger, Daniel Calabuig and Jose F. Monserrat	IEEE IWCMC 2017	26-30 June 2017	IEEE	Valencia, Spain	2017
Interference Management via Space and Frequency Domain Resource Partitioning	Yinan Qi, David M. Gutierrez-Estevez, Mehrdad Shariat, Milos Tesanovic and Maziar Nekovee	IEEE ISWCS 2017	28-31 Aug. 2017	IEEE	Bologna, Italy	2017



An Agile Resource Management Framework for 5G	Ö. Bulakci, D. M. Gutierrez-Estevez, M. Ericson, A. Prasad, E. Pateromichelakis, G. Calochira, J. Belschner, P. Arnold, F. Sanchez Moya, A. M. Ibrahim, F. Bronzino, H. Celik, G. Fodor	IEEE CSCN 2017	18-21 Sept 2017	IEEE	Helsinki, Finland	2017
RAN Enablers for 5G Radio Resource Management	D. M. Gutierrez-Estevez, Ö. Bulakci, M. Ericson, A. Prasad, E. Pateromichelakis, J. Belschner, P. Arnold, G. Calochira	IEEE CSCN 2017	18-21 Sept 2017	IEEE	Helsinki, Finland	2017
Holistic Resource Management and Air Interface Abstraction Models	P. Karimi, F. Sanchez Moya, Ö. Bulakci, D. M. Gutierrez-Estevez, M. Ericson, A. Prasad, G. Fodor	IEEE CSCN 2017	18-21 Sept 2017	IEEE	Helsinki, Finland	2017
LAA-as-a-Service as Key Enabler in 5G Dynamic Radio Topologies	E. Pateromichelakis, Ö. Bulakci	IEEE CSCN 2017	18-21 Sept 2017	IEEE	Helsinki, Finland	2017

## B.2 Journal Papers

Title	Authors	Journal Name	Publisher	Year
Directional Cell Discovery in Millimeter Wave Cellular Networks	C. Nicolas Barati, S. Amir Hosseini, Sundeep Rangan, Pei Liu, Thanasis Korakis, Shivendra S. Panwar, Theodore S. Rappaport	IEEE Transactions on Wireless Communications	IEEE	2015
Non-Coherent Open-loop MIMO Communications Over Temporally-Correlated Channels	Jorge Cabrejas, Sandra Roger, Daniel Calabuig, Yaser M. M. Fouad, Ramy H. Gohary, Jose F. Monserrat and Halim Yanikomeroglu	IEEE Access	IEEE	2016
On Regular Resource Grid for Filtered OFDM	Petra Weitkemper, Jamal Bazzi, Katsutosh Kusume, Anass Benjebbour, and Yoshihisa Kishiyama	IEEE Communications Letters	IEEE	2016



Waveform, Numerology, and Frame Structure to Support 5G Services and Requirements	Ali A. Zaidi, Robert Baldemair, Hugo Tullberg, Håkan Björkegren, Lars Sundström, Jonas Medbo, Caner Kilinc, Icaro Da Silva	IEEE Communciaitons Magazine	IEEE	2016
Mobile telecommunications ecosystem evolutions with 5G	F. Pujol, S. El Ayoubi, J. Markendahl, L. Salahaldin	DigiWorld Economic Journal	IDATE DigiWorld	2016
METIS-II contribution to 5G Annual Journal	M. Boldi et. al	The European 5G Annual Journal	Euro 5G	2016 - 2017
5G Radio Access Network Architecture – Design Guidelines and Key Considerations	Patrick Marsch, Icaro Da Silva, Ömer Bulakci, Milos Tesanovic, Salah Eddine El Ayoubi, Thomas Rosowski, Alexandros Kaloxylas, Mauro Boldi	IEEE Communications magazine	IEEE	2016
Emerging network architecture and functional design considerations for 5G radio access	Patrick Marsch, Icaro Da Silva, Ömer Bulakci, Milos Tesanovic, Salah Eddine El Ayoubi, Mikko Säily	WILEY Transactions on emerging telecommunications technologies	Wiley	2016
Micro-Operator Networks – A Key Enabler for 5G in New Verticals and Markets	Athul Prasad, Zexian Li, Silke Holtmanns, Mikko A. Uusitalo	IEEE Communications Magazine	IEEE	2017
Fast - RAT Scheduling in a 5G Multi-RAT Scenario	Victor Monteiro (University of Fortaleza), Märten Ericson	IEEE Communications Magazine	IEEE	2017
Some Radio Resource Management Aspects for 5G millimeter wave radio access networks	Yilin Li, Emmanouil Pateromichelakis, Nikola Vucic, Jian Luo, Wen Xu, Giuseppe Caire	IEEE Communications Magazine	IEEE	2017
A Performance Comparison of In-Band Full Duplex and Dynamic TDD for 5G Indoor Wireless Networks	Osama Al-Saadeh and Ki Won Sung	EURASIP Journal on Wireless Communications and Networking	Springer	2017
Applying Device-to-Device Communication to Enhance IoT Services	Ji Lianghai, Bin Han, Man Liu, Hans D. Schotten	IEEE Communications Standards Magazine	IEEE	2017
Service-tailored User-Plane Design Framework and Architecture Considerations in 5G Radio Access Networks	E. Pateromichelakis, J. Gebert, T. Mach, J. Belschner, W. Guo, N. Kuruvatti, V. Venkatasubramanian, C. Kilinc	IEEE Access	IEEE	2017

## B.3 Press releases and references to the project

The press releases of METIS-II:

- 2015 July 15, Press release



Press release: METIS-II issues first press release “EU project METIS-II to lead the next phase of 5G radio access network research”. See the complete press release [PREL15-1]

- 2015 Sep 28, Press release

Press release: METIS-II issues press release: “EU project METIS-II hosts workshop on 5G system with 5G PPP projects”. See the complete press release [PREL15-2]

The references to the project:

- 2016-04-05 E&T Magazine has just published an article on the visualization platform shown by METIS II at MWC16 <http://eandt.theiet.org/news/2016/apr/5g-car-to-car.cfm>
- 2016-01 Information brochure on the participation of Polish entrepreneurs from Lower Silesia in projects related to the Horizon 2020 program. An interview with Kamil Pawłowicz (in polish) is a part of the brochure on this topic published by WCTT - [http://rpk.wroclaw.pl/patrz-w-przyszlosc-dolnoslaczacy-w-programie-horyzont-2020\\_artykul\\_461.html](http://rpk.wroclaw.pl/patrz-w-przyszlosc-dolnoslaczacy-w-programie-horyzont-2020_artykul_461.html).
- 2017-02-20 Polish Digitization Minister talks about the evolution of mobile technologies:<http://www.wirtualnemedi.pl/artykul/anna-strezynska-likwidacja-barier-dla-rozwoju-technologiei-mobilnych#>. The paragraph reads: "In Europe the 5G standards are the subject and research field of METIS program, initiated by the European Commission. The program is based on cooperation between operators, telecommunication service providers and European universities."





## C Annex C - Talks and presentations

Date	Event	Title of Talk	Presenter
September 1st, 2015	IEEE PIMRC 2015	Panel: From 4G to 5G and IoT: changing business models and new revenue opportunities	Narcis Cardona
September 7th, 2015	IEEE VTC Fall 2015	Panel: Key Aspects on 5G RAN Design	Moderator:
September 7th, 2015	IEEE VTC Fall 2015	Industry Talk	Ömer Bulakci
September 21st, 2015	36th IEEE Sarnoff Symposium	Panel: 5G: Challenges and Opportunities	Ivan Seskar
September 22, 2015	5G Summit Taipei <a href="http://www.5g.org.tw/">http://www.5g.org.tw/</a>	METIS II and Xhaul Projects in 5G PPP	Fang Chu Chen
October 1st, 2015	IEEE DySPAN 2015	Panel: Spectrum crunch below 6GHz? 5G trends	Du Ho Kang
October 14th, 2015	NGMN Forum Meeting, Session on Research & Innovation, Montreal	METIS-II 5G Radio Access Network Design	Olav Queseth
October 14th, 2015	NGMN Forum Meeting, Session on Research & Innovation, Montreal	Panel: Architecture	Olav Queseth
October 29th, 2015	IEEE Conference on Standards for Communications and Networking, 2015	Panel: 5G RAN Design	Moderator:
November 5th, 2015	Sino-Europe 5G Technical Workshop	METIS-II 5G RAN Design	Patrick Marsch
November 5th, 2015	Sino-Europe 5G Technical Workshop	METIS-II Performance evaluation scenarios and models	Changqing Yang
November 6th, 2015	5G ICT Summit Beijing	METIS-II 5G RAN Design	Patrick Marsch
November 10th, 2015	GENI NICE 2015	European Collaboration Report	Ivan Seskar
November 11th, 2015	Panel at 2nd 5G Verticals Workshop: Panel on 5G use cases and technical requirements to identify commonalities	5G use cases from METIS-II perspective	Salah El Ayoubi
November 11th, 2015	Panel at 2nd 5G Verticals Workshop: Panel on 5G business models	5G business models from METIS-II perspective	Frédéric Pujol
November 12th, 2015	Digital Union - WG Spectrum Panel	Laying the foundations for 5G	Olav Queseth



November 20th, 2015	Workshop on millimetre-wave Technology for High-speed Broadband Wireless Networks	METIS-II introduction and views on mmW	Jose F. Monserrat
November 24, 2015	3GPP Summit: Standards Timeline for 5G	H2020: Future Internet Program ITRI's Participation	Fang Chu Chen
December 3, 2015	5G Global Summit by 5G Forum in Seoul, Korea.	The METIS-II view of 5G RAN Design	Olav Queseth
December 4, 2015	9th Congress of the Portuguese Committee of URSI - "5G and the Internet of the future", Lisbon • Microsoft Portugal	5G Mobile Networks. A Revolutionary Evolution Towards the Wireless Internet of Things	Narcis Cardona
December 4, 2015	Local seminar at Yonsei University	METIS-II view of Spectrum and 5G RAN Design	Olav Queseth
December 10, 2015	VDE/ITG Workshop on 5G System Architecture, Munich, Germany	PRELIMINARY 5G SPECTRUM SCENARIOS AND WRC-15 RESULTS	Thomas Rosowski
January 26, 2016	"5G and satellite" workshop (held at ETSI during the Satellite Communications and Navigation group meeting)	METIS – II: 5G Radio Access Network Design	Milos Tesanovic
April 11, 2016	Verizon Open Innovation 5G Academic Roundtable	5G RAN and Core Systems	Marco Mezzavilla
April 20, 2016	NYU WIRELESS - Board meeting pre Brooklyn 5G Summit	Standardization-oriented activities	Marco Mezzavilla
May 23, 2016	IEEE ICC 2016	Industry panel: Industry Roadmap to 5G: Standards Timeline and Spectrum Requirement	Organizers: Mythri Hunukumbure, (mmMAGIC), Rauno Ruismaki (METIS-II), Milos Tesanovic (METIS-II), Maria Fresia (mmMAGIC), Oemer Bulakci(METIS-II)
June 21, 2016	5G NORMA summer school	The METIS-II View on 5G RAN Architecture	Michael Meyer
August 12, 2016	Wireless@kth seminar	5G RAN architecture: METIS-II view	Ki Won Sung
August 30, 2016	Presentation to Spectrum Technology Team @ Ofcom	The METIS-II View on 5G RAN Architecture	Milos Tesanovic
May 25th, 2017	ICC - 5G RAN Design workshop	Mobile telecommunications ecosystem evolutions with 5G	Frederic Pujol

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# D Annex D - Achieved impacts and exploitation

## D.1 Ericsson AB

Currently the standardization for the first release of the 3GPP NR specification is ongoing where Ericsson is one of the main contributors. The first set of usable specifications for non-standalone operation is expected to be ready by the end of 2017, and the first complete release will be ready mid-2018. In parallel, development of trial networks and the first iteration of 5G products is ongoing in order to be ready for the first rollouts and the 2018 winter Olympics. By initiating and driving METIS-II (and its predecessor METIS) Ericsson has managed to achieve early industry consensus through the discussions and collaborations among the partners on important topics for standardization, e.g. on the “connected inactive state” which in turn has sped up the standards process allowing for a more rapid deployment plan than originally envisioned for 5G. Driving METIS-II and METIS has also enhanced Ericsson’s technology leadership allowing for better dialogues with customers and operators.

The METIS-II project builds on the success of the METIS project. In both projects the consortium was formed by a similar set of partners, representing a large part of the mobile industry. An important role that METIS-II has had for Ericsson is that it has allowed continuation and refinement of the vision and consensus established in METIS and by this made it possible to bring that vision all the way into the standardization of NR in 3GPP. Ultimately this has allowed for a more rapid progress in 3GPP and for bringing products to the market earlier than was envisioned when the first 5G discussions were started in 2012.

The work for identifying and allocating more spectrum for 5G has been going on since the preparations for WRC-15 and will continue to the end of 2019 with the WRC-19 conference. Ericsson has been able to use the METIS-II results on spectrum, e.g. on which bands that are suitable for specific deployments, to discuss with and influence regulators on the WRC-15 conference and in the preparatory work for WRC-19. The consensus obtained in the METIS-II project has been valuable to be able to drive the view of the mobile industry when discussing with other parties that also use spectrum, e.g. the satellite and the broadcasting industries.

The METIS-II results have also been utilized to define and refine the Ericsson 5G strategy, for example by serving as a guide for understanding the requirements of future networks as well as capabilities of 5G. The METIS-II activities on Machine Type Communication (MTC), which is an integral part of the METIS-II 5G design and architecture, is providing valuable input to Ericsson’s strategy and technology development. The work in METIS-II has also opened doors for further bilateral projects and collaborations when exploring how 5G can be used in various industries.

## D.2 Alcatel-Lucent Deutschland AG

With the acquisition of Alcatel-Lucent S.A. by Nokia on January 14, 2016, Alcatel-Lucent Deutschland AG became part of the Nokia Group. The research team from Stuttgart involved in Metis II is now part of Nokia Bell Labs which is the largest research, technology and innovation organization in the world focused on communications technology. People involved in Metis II from Bell Labs in Stuttgart were not directly impacted by the acquisition and followed the planned studies as described in the DoW for METIS II. Of course the exploitation of results concerning the development and standardization of the next generation technologies for mobile communications, 5G, as well as the impact of the project e.g. on the company strategy has to be seen in the wider context of Nokia (see chapter F.13).

Within METIS-II the main targets of ALUD were on definition of a new disruptive control architecture, more effective integration of multiple RATs, advanced spectrum usage concepts and integration of air interface concepts. Also further refinement of uses cases and scenarios especially targeting on extreme mobile broadband, very low latency applications and machine to machine communication was seen as of high relevance to guide the technical work. Definition of a 5G performance evaluation framework and metrics within Metis II in collaboration with all project partners was another goal of high value in order to provide a common basis for measurements and quantifications performed by different people and organizations.

Following contributions from ALUD to related results have to be highlighted:

- Overall 5G RAN system and control architecture design e.g. providing study results on analysis of alternative solutions for Multi-Connectivity protocol options and flexible combinations of UL/DL and CP/UP. In March 2017 ALUD took over the role of the Technical Manager from Nokia Poland. As a consequence, ALUD drove the consolidation of a coherent view on system design with inputs from Workpackage 3, 4, 5 and 6.
- Investigation of Multi-operator spectrum sharing solutions, design and evaluation of a radio resource scheduler for multi-operator network that guarantees fairness with respect to resource and rate experience. Developed a novel technique that enables spectrum sharing within Multi-Operator environment by fulfilling certain QoS requirements and specified Service Level Agreements.
- 5G air interface design activities and discussion on the comparison and performance evaluation of different 5G waveforms for various use cases. Developed, presented and discussed access protocols for small packet transmission in uplink.
- Definition of a 5G performance evaluation framework and metrics e.g. with the analysis of the outcome of former projects 5GNow, Green Touch, and Fantastic 5G with respect to simulation models, scenarios, and key performance indicators. Delivered calibration results for UC4: Massive distribution of sensors and actuators.
- New control- and user-plane protocol stack with a focus on the interface between the 5G RAN and the 5G Core. This allows reduction of the control plane signaling for 5G and efficiently supports a flexible 5G service mix. New method for connectionless packet



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switching in and between the NextGen RAN and Core” which avoids the mobility-tunnel establishment for each radio bearer by using aggregated tunnels which are denoted as “fat pipes”.

- Dissemination of results by several Metis II multi-partner conference publications as well as contributions to standardization and regulation. Involvement in organization of conference panels and sessions, workshops, and project demos.

## D.3 Deutsche Telekom AG

Since the preparation of the 5G White Paper by the NGMN Alliance [NGMNWP] Deutsche Telekom (DT) is heavily involved in the 5G topic in different worldwide forums, e.g., standards developing organizations (SDOs) like 3GPP, ETSI, IEEE, BBF, and ONF, regulatory bodies like ITU-R and CEPT, and other interest groups like NGMN, GSMA, and 5GAA. Already for the NGMN 5G White Paper, results from the FP7 METIS project [METSITE], both on scenarios/test cases as well as on technology enablers and system concepts, were closely taken into consideration through a continuous information exchange within DT between research & innovation units involved in the project and the business- and operation-oriented units. This process has been extended also for 5G PPP projects like METIS-II [METSITE] and 5G NORMA [5GNORMA].

The results of METIS-II are especially important for DT’s internal 5G Program with respect to pre-selection and assessment of 5G technology components and possible RAN architectures proposed within the initial study phase of 5G New Radio (NR) at 3GPP in Rel. 15 and following work on 5G specifications. 5G will not only cover NR aspects, but also the evolution of LTE-A Pro as well as the interworking with legacy 4G RAN and CN (EPC). Therefore, migration aspects from existing 4G networks to 5G are relevant from a mobile network operator’s perspective. METIS-II addressed those topics e.g. with respect to interfaces between RAN and CN as well as between central and distributed units (CUs/DUs) within the RAN. The results provide useful guidelines to be applied in DT-internal techno-economic evaluations of deployment strategies for 5G RAN components on top of existing network topologies. In addition, these evaluations consider also traffic steering and multi-connectivity approaches performed in METIS-II to address the fulfillment of KPIs raised by novel 5G vertical use cases, e.g., from automotive industries. Also the spectrum topics covered in METIS-II are considered in DT’s spectrum strategy with respect to 5G. DT’s 5G Program also covers the “5G:haus” (see [DT5G]), a 5G laboratory and demo platform for developing and testing new technology enablers for the 5G architecture in cooperation with leading telco equipment vendors, start-up companies, research institutes, and vertical industry partners. The demo and visualization platform derived within METIS-II based on Unity 3D was fed to this 5G:haus framework.

The outcome of METIS-II and other 5G-PPP projects will generally help DT to push the finalization of initial 5G standards and to deploy and operate future 5G networks from an early stage on. Especially the flexibility, scalability, and programmability covered by the METIS-II RAN design is a prerequisite in terms of creating a cost-efficient 5G network platform and provisioning of an increased service variety in combination with enabling faster service rollouts compared to existing platforms, meeting the quality and service expectations of DT’s private and business customers.



Project results are also applied in preparation of own 5G technology & architecture studies as well as in RFI/RFP/RFQ business processes.

## **D.4 DOCOMO Communications Laboratories Europe GmbH**

DOCOMO Communications Laboratories Europe GmbH (DCME), together with NTT DOCOMO (DCMJ), has contributed to consolidate mapping of the 5G requirements and use cases from METIS-II, and co-signed the resulting METIS-II joint input to 3GPP RAN.

A particular focus has been then put on the identification of new waveform as well as related frame design issues that are relevant for 5G to address the identified requirements. The results obtained in METIS-II have been actively input to 3GPP RAN1 New Radio study as eight technical documents that have effectively driven the discussions and made impacts on the key relevant agreements in 3GPP RAN1.

The waveform and frame design results have been published as three academic papers including one journal paper. Additionally, DCME contributed also to three joint papers with METIS-II partners such as one paper on METIS-II use cases and two papers on air interface design. Other forms of contribution include support of the preparation for 5G PPP work shop and ETSI air interface workshop as well as METIS-II RAN design white paper.

Besides the research results on waveform and frame design, DCME together with DCMJ plans to exploit the wide variety of 5G RAN design outcomes from METIS-II that capture various perspectives of the METIS-II partners for the future steps towards the successful launch of 5G services and beyond.

## **D.5 Kabushiki Gaisha Enu TI TI DOCOMO**

NTT DOCOMO (DCMJ) together with DOCOMO Communications Laboratories Europe (DCME) has contributed to the consolidation of 5G requirements and use cases by METIS-II and new waveform proposals for New Radio (NR) to 3GPP and academia. DCMJ has served as Rapporteur for 3GPP RAN 5G requirements and also cosigned METIS-II inputs on 5G requirements to 3GPP RAN. DCMJ has co-organized two IEEE CSCN workshops on 5G (IEEE CSCN 2015 and 2016), gave presentations and served as panelist. METIS-II work has been relevant to drive the 5G requirements in 3GPP and ITU-R and also to boost operator/vendor collaborations on 5G experimental trials. METIS-II results on new waveforms and the whole RAN design will be useful to position DCM's strategy on future deployments towards 5G and beyond.

## **D.6 Huawei Technologies Duesseldorf GmbH**

Huawei Technologies Duesseldorf GmbH (HWDU) has contributed to all the work packages in the project, with a strong focus being put on the topics of air interface harmonization, user plane design, control plane design, agile resource management framework, network slicing, use case analysis and prioritization. Spectrum analyses were performed in close collaboration with HWHQ.





The developed mechanisms and concepts have been contributed to the overall 5G RAN design and evaluation framework; the latter was contributed and successfully impacted corresponding discussions in 3GPP. One of the main targets in the project was the consensus building in particular between the vendors and mobile operators, and hence HWDU has closely collaborated with other partners on topics of common interest, which was expressed by various jointly written conference papers and journal papers as well as several co-signed 3GPP contributions. The first global consensus with respect to common design principles for the 5G RAN was expressed in the METIS-II white paper, which was published early in the project already, reflecting common view points of the projects partners with contributions from all work packages, where HWDU contributed substantially. This white paper clearly influenced the discussions in 3GPP standardization towards the system design and enabling technologies for NR. As part of the PMT, HWDU has substantially contributed to the METIS-II wide joint actions, such as, international conference and workshop organizations, 5G PPP working group contributions and 5G PPP workshops. HWDU has served as Architecture Working Group Vice-chairman and has contributed to Architecture White Papers together with other 5G PPP projects.

The main technical contributions of HWDU in the project can be summarized as follows:

- Air interface design based on pulse shaped OFDM to cover the requirement space of the 5G system, spanning different services, frequency bands and deployments. Intensive discussions with the project partners lead to a design that is finally compatible with latest agreements in 3GPP on the waveform to be used for NR.
- A service-tailored user-plane (UP) design framework was proposed, which incorporated the analysis of new functional requirements, the enhancement of RAN protocol stack for different services and the proposal of service-tailored protocol configurations. HWDU lead the UP design area topic and collaborated with the involved partners in order to shape the final METIS II UP design framework. As an outcome of this work, a joint publication is prepared, led by HWDU.
- HWDU led the development of agile resource management framework toward common control plane and overall RAN design. Within the framework, HWDU developed novel mechanisms for interference management in dynamic radio topologies, dynamic spectrum usage and multi-slice resource management. The joint efforts with the other partners in these areas led to joint publications and aligned METIS-II visualization views.
- HWDU has performed the analysis of frequency bands for 5G, such as in the analysis of the E-band (71-76/81-86 GHz). Additionally, together with the HWHQ, HWDU has worked on the definition of the methodology for the identification of the spectrum demands and participated in the joint architecture tasks.
- HWDU co-designed the METIS-II RAN slicing concept with the introduction of the use case-driven RAN Configuration Modes (RCMs). HWDU provided analyses of the functions per protocol for optimization on a per service/slice basis, which were then included in the final METIS-II visualization. Novel mechanisms on optimized initial access for service prioritization and efficient group-based initial access for mMTC developed in the project have been submitted as T-Docs for 3GPP NR RAN2, where the vision on service

prioritization is well aligned with NR. Additionally, HWDU developed and evaluated concepts for vehicular groups' mobility management and signaling optimization for traffic engineering based on data analytics schemes.

- The above-mentioned concepts and analyses have substantially contributed to the overall 5G RAN design as well as overall KPI assessment. The findings are disseminated in joint publications, international conferences/workshops, 5G PPP workshops, and the working group architecture..
- HWDU has led four visualization views that were demonstrated in MWC 2016 and ICT 2015, and substantially contributed to the final visualization work including architecture views, network slicing design, and framework description of multi-slice RM. HWDU also substantially contributed to METIS-II led workshop and panel organizations to maximize the impact of developed innovations. As part of joint work with other 5G PPP projects, HWDU co-led the feature topic in IEEE communications magazine on agile resource management together with the Fantastic-5G project.

## D.7 Huawei Technologies CO LTD

Huawei has contributed extensively in WP1/2/3 in METIS-II, especially on refinement of use cases, building the evaluation framework and spectrum estimation framework. Some highlights are listed below.

- Overall evaluation framework including the requirement of selected use cases, deployment scenarios, evaluation models and KPIs, which forms the base for the following evaluation campaign in METIS-II. To be specific, Huawei contributed the mapping between different use cases and deployment environments in order to match the models with specific requirements of use cases. In terms of models, Huawei contributed the network energy consumption model and other key parameters for system level evaluation. Huawei also provided all sets of calibration results for use case 1/2/3, together with system level evaluation on traffic area capacity, user experience data rate and network energy efficiency for dense urban information society.
- Spectrum demand analysis framework and results on xMBB use cases. Huawei provided the framework on spectrum demand analysis based on the performance requirements of specific use cases. Taking into account of specific requirements defined in METIS-II, Huawei also derived the spectrum bandwidth demand of each use case considering various deployment solutions.

Huawei has been actively disseminating the findings in METIS-II to standard and other forum. The following activities have to be highlighted.

- Huawei made the presentation on use cases and evaluation framework of METIS-II in Euro-Sino workshop in Future Forum in 2015.
- Huawei contributed several technical papers in 3GPP on evaluation framework for 5G, e.g., the energy efficiency evaluation and the generic evaluation framework.





- Huawei co-signed the joint paper from METIS-II on evaluation methodologies to 3GPP to help achieve consensus on deployment scenarios and related models.

## **D.8 Institut de L'audiovisuel et des Télécommunications en Europe – IDATE**

IDATE has published one journal paper directly related to its activity in METIS-II in the DigiWorld Economic Journal #102. The paper “mobile telecommunications system evolutions with 5G” was written with Orange, KTH and Telecom Ecole de Management.

Regarding exploitation of results, IDATE has increased the level of expertise in the field of understanding the evolution of vertical markets and their use of wireless networks. IDATE has also worked on the drivers and barriers to adoption of 5G technologies by vertical sectors. Through collaboration with mobile operators, equipment manufacturers and universities, IDATE has increased its knowledge regarding network dimensioning and on the management of mMTC devices in future networks. 5G value chain was addressed in the first deliverable and IDATE studied in detail potential new comers in the 5G value chain and their impact on the existing ecosystem.

As far as market forecasts are concerned, IDATE has been closely monitoring market trends and users demands for more than twenty years. The better understanding of technological evolution which will lead to the definition of 5th generation cellular networks (5G) will enable us to better anticipate future evolutions in the mobile market.

IDATE personnel has gained expertise, which allows us to be ready and in an excellent position for preparing future research techno-economic assessment work regarding 5G development and mobile communications in general.

After project completion, IDATE plans to exploit the research results, widely in its future research publications. Research results emerging from METIS-II will impact our market forecasts and our assumptions in future works on evolution of the mobile sector.

## **D.9 INTEL Mobile Communications GmbH**

Intel Deutschland GmbH (INTEL) develops and markets innovative semiconductor products and solutions for mobile communications. Most notably, it provides mobile platform solutions for all market segments: from cost-efficient 2G/3G single-chip platforms for ultra-low-cost mobile phones and entry-level smart phones systems-on-chip (SoC), to leading-edge 3G and 4G slim modem and RF solutions for smart phones and tablets. At the same time, INTEL is closely monitoring market trends and users demands and studying the evolution of those technologies, which will lead to the definition of 5th generation cellular networks (5G). Special attention will be dedicated to the convergence between communication and computing, and to features such as improved flexibility, energy efficiency and scalability within networks and platforms for a superior mobile user experience.



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METIS-II results, amongst the ones of other 5G PPP projects, will support INTEL paving the way towards a fully networked world by providing innovative, fine-tuned mobile communications solutions. Joining forces with the parent company, INTEL aims at integrating mobile communications technology and application processors in intelligent solutions contributing to INTEL roadmaps for the Internet of Things (IoT) and 5G. INTEL is collaborating with equipment and device manufacturers, network operators, service providers, academic institutions and others to accelerate 5G standards development and solve key technical challenges. Through these collaborations, INTEL is applying its unique combination of computing, networking and wireless communications expertise to develop 5G solutions that integrate intelligence across the entire network, end-to-end, from the data center down to the device level and throughout systems in between. This systems-level approach will enable more functional devices, more cost-effective and efficient networks and user experiences that are more intuitive, enriching and immediate than ever before. INTEL is developing wireless radio access and device processing technologies for PCs, smartphones, tablets, wearables, ground and aerial vehicles, as well as many future connected devices and sensors. As part of this effort, INTEL is offering an open, general purpose platform for network operators and is investing in transforming the network in four key areas, including advancing open source and standards, enabling open networking platforms, and building out an open ecosystem on INTEL architecture, along with accelerating trials and deployments. To help accelerate future deployments, INTEL is working on a variety of initiatives and proofs of concept with industry leaders to shape future service aware networks and devices.

After project completion, INTEL plans to exploit the research results, concepts, algorithms, technology modules and demonstrations widely in its future mobile chip sets, as well as for SoCs intended for small- and macro cell station, solutions and products. Research results emerging from METIS-II will impact future technologies as part of INTEL Mobile Broadband solution portfolio. INTEL expects that METIS-II results together with other Horizon 2020 results on 5G will allow design and development of products entering the mass market in 2020 and onwards.

## **D.10 Industrial Technology Research Institute Incorporated**

The Industrial Technology Research Institute (ITRI) has contributed to METIS II WP1, WP2, WP6 and WP7. ITRI all along during the METIS II project, presented, discussed and contributed different research outcomes, design and evaluation results, for example, specific to device to device communication in 5G and high mobility solution design. Besides, ITRI worked on interactive visualization for demonstration purposes and provided demo module based on MATLAB implementation of D2D mobility control scenarios and solution design. Research outcomes were provided as inputs to different work packages reports and deliverables, including R1.1, D1.1, D2.3, D6.1 and D6.2.



ITRI standards team has been involved and continues to explore opportunities to exploit METIS II outcomes. Towards this effort, ITRI along with other METIS II partners worked on 3GPP contributions which were then submitted to RAN meetings. For example 3GPP technical document numbers RP160557 and RPa160063 were jointly contributed and submitted to RAN plenary meetings.

ITRI also made several presentations and talks to highlight METIS II project and its outcomes, etc. For example, ITRI made presentation and talks to these conferences: 38th Meeting of the Wireless World Research Forum held in Taiwan, 3GPP Summit: Standards Timeline for 5G held in Taiwan, 5G Summit Taipei.

After METIS II project completion, ITRI plans to continue dissemination and exploitation of METIS II results through publications in conferences or by joining workshops. In addition ITRI will use the gained expertise for possible technology enhancements to and value added design service and consultation for its industry partners. Finally ITRI will use the gained expertise as basis for new research projects.

## **D.11 Janmedia Interactive Sp. z o.o.**

Janmedia, as promised in the dissemination and exploitation plan, focused their activities on the Visualization Platform development. As the task turned out to be a bigger challenge than expected, we decided to invest a little bit more effort (compared to what was foreseen in the project proposal) into it, thus allowing the dissemination processes of the project to be more convincing.

Thanks to METIS-II we were able not only to master our staff's skills in Unity3D based application creation, but also to share the knowledge with the other partners encouraging them to have a creative input in the project's outcome dissemination. What is more, Janmedia employees were, and are, able to be in touch with the newest findings in the technological evolution leading to 5G era, which in sequence allows us to educate our clients as well as the new employees.

The Unity3D based abilities gained during METIS-II allowed us to develop commercial solutions (important from our company's business perspective), supporting the spread of 5G awareness as well as widening our portfolio. In the world of ever-changing technology it was a defining period in Janmedia's history. We worked with global partners on global challenges utilizing individual approach to relatively new tools.

When it comes to dissemination, other than the current project support materials, we were able to release METIS-II and Unity3D based articles on our website as well as spread the METIS-II related posts through our social media channels. We've also supported METIS-II during MWC 2016.

## **D.12 Kungliga Tekniska Högskolan**

As an academic partner, KTH focused on making an impact to the research community. KTH has published nine conference papers and one journal paper, as well as three conference papers



under review. Besides, several journal papers are in progress out of the outcomes of the METIS-II project.

KTH has contributed to various subjects which are central to the design and evaluation of 5G RAN. These include the value chain analysis of IoT services, network dimensioning framework for 5G xMBB and mMTC services, spectrum bandwidth demand analysis methodology, system-level energy efficiency evaluation methodology, a cooperative system concept for broadcast and unicast in UHF band, an analysis for the asymptotic behavior of ultra-densification, and interference management schemes for dynamic TDD and in-band full duplex.

KTH has exploited the METIS-II project extensively for the educational purposes. Three PhD students successfully finished their Licentiate degree (a half way of doctoral study in Swedish higher education system) with the outcome they obtained in the project. In addition, two more PhD students will finish the Licentiate shortly after the project lifetime. METIS-II has been used as a foundation for the doctoral studies of five PhD students. In the long-run, it will strengthen the competitiveness of European industry. KTH has further exploited the outcome of the project for creating and revising the educational contents of Master programme.

Another direction of the exploitation is to spawn further research projects. The project participants and KTH has gained good insights on 5G RAN design, and utilized the knowledge for continuing the study for 5G systems development. For example, KTH has established a joint research project with Teracom, the digital terrestrial broadcasting service provider in Sweden, about the cooperative use of UHF spectrum for TV broadcasting and rural broadband services. The METIS-II results became the direct input to the project.

## **D.13 NOKIA (Poland and Finland)**

A key benefit for Nokia from participating and technically driving METIS-II was to align on key 5G RAN design aspects among the main network vendors and key mobile network operators and academic players. In this respect, METIS-II was able to obtain an earlier alignment on controversial aspects than expected, as for instance visible through the early publication of a common White Paper already in month 9, and a coherent consortium input to the 5G PPP Architecture White Paper. Further, the work in the consortium was essential to move forward on various 5G design aspects that were not covered so far, such as the notion of air interface harmonization and integration in 5G, mobility and initial access schemes etc. Additionally, Nokia fostered the development of an evaluation framework, which was the first holistic approach for the assessment of 5G performance. The outcome of this work was contributed to 3GPP as well as ECC, and a final evaluation framework foreseen by these bodies for 5G shows strong correlation with the METIS-II proposal. Another impact that can be associated with the evaluation framework is the editorship of the Joint 5G-PPP document of use cases and models, which helped to streamline the viewpoints of different 5G-PPP projects. We expect that the pre-standardization alignment obtained in METIS-II has helped to visibly focus and accelerate the discussion in 3GPP.



Our dissemination efforts target also regulatory topics, by making public the outcome of spectrum investigations from Internal Report 3.1 for WRC'15. Spectrum related activities helped Nokia to understand new technical enablers for the efficient usage of higher frequency regimes.

Nokia has provided a strong input to the work on RRM, presenting novel work on dynamic TTI configuration and on multi-air interface traffic steering. A significant progress was also achieved in the area of initial access, where discussion with other METIS-II partners allowed to consolidate viewpoints and improve weak points of proposed 5G design concepts. A new energy efficient state of RRC Connected Inactive is a good example, which was quickly adopted in 3GPP.

Nokia has exploited the work in METIS-II in the form of patent filings, and expects to utilize the gained know-how in the first product roll-out for 5G.

## **D.14 Polytechnic Institute of New York University corp**

NYU WIRELESS is a multi-disciplinary academic research center that offers an unprecedented and unique set of skills. Centered at NYU Tandon School of Engineering, and involving faculty and students throughout the entire NYU community, NYU WIRELESS offers its industrial-affiliate sponsors, faculty members, and students a world-class research environment that is creating the fundamental theories and techniques for next-generation mass-deployable wireless devices across a wide range of applications and markets. This center combines NYU Tandon's School of Engineering program with NYU's School of Medicine and the Courant Institute of Mathematical Sciences, and offers a depth of expertise with unparalleled capabilities for the creation of new wireless networks.

Participating in METIS-II has brought a rich set of insights, which provided the center with a wider understanding of non-US based 5G research. NYU has co-authored various papers related to the 5G radio access layers, particularly focusing on communications advances related to mmWave communications. Thanks to METIS-II, NYU could propagate the internal finds, influence the pre-standardization activities, and ultimately gain multiple industrial insights to better drive the research, making sure to hit the real pain-points.

## **D.15 Orange SA**

METIS-II project helped Orange in consolidating its vision regarding the 5G radio access network design. This vision helped Orange in determining its position within the standardization bodies, especially 3GPP, on New Radio. Orange also profited from the techno-economic assessment of METIS-II in order to understand the RAN ecosystem evolutions with 5G and the role of operators in the 2020-2030 time frame. The quantitative techno-economic assessment will be reused by Orange to motivate 5G infrastructure investments and build the rolling plan according to related business. METIS-II was also the place to benchmark 5G RAN technologies and solutions. This selection is key for Orange to ensure that future network services will offer the best experience to our customers and will be sustainable (in terms of energy, costs and social issues) and



operationally manageable. Last but not least, METIS-II offered to Orange valuable technical information for selecting technical components to test in early 5G trials.

## **D.16 Samsung Electronics (UK) limited**

Samsung is the world's highest-selling mobile phone company and number one in global and European smart phone sales. The growth in the volume of smart phones and other mobile devices, coupled to ever-increasing sophistication and capabilities of these devices to support a wide range of enhanced and new applications will be one of the key drivers for 5G telecommunication standards and its supporting technology components.

Samsung Electronics (UK) utilized the METIS-II project as an important opportunity to enhance global R&D in 5G systems by leveraging cooperation with key vendors, operators, leading research centres and universities across Europe.

As part of Samsung strategy to research advanced technologies for mobile terminals and next generation standards, research activities within METIS-II inspired new innovations and implementation ideas which may contribute to the future competitiveness of Samsung products and solutions.

Samsung used METIS-II use cases to further enhance its 5G application space and to ensure future 5G trials encompass such valuable vision carrying significant weight in the European research community (and beyond).

Samsung also used analysis carried out by METIS-II to identify preferred spectrum ranges, to combine this knowledge with its existing deep understanding of band allocations, to ensure a harmonized 5G offering and to avoid fragmented device market space. Samsung exploited METIS-II spectrum discussions, quantitative and qualitative analysis as an important contributor to ITU-R WRC'15 activities and beyond – looking towards WRC'19.

Results from METIS-II on RAN design helped Samsung to understand the views of a wider European community on the technologies that may underpin future device and networking products. This helped in providing opportunities to build industry consensus driven towards 5G standardization in 3GPP (on 5G-NR working plan).

In addition to disseminating the project results within the wider 5G PPP initiative and to various working groups of Horizon 2020 5G Infrastructure Association, Samsung supported and promoted spreading the results of METIS-II to other international 5G forums and research collaborations where Samsung is a key member, including the 5G Forum in Korea, NGMN and GSMA.

## **D.17 Telecom Italia S.p.A**

Telecom Italia (TIM being now the brand with which the company presents itself to the commercial market) underwent a complete turnaround in the technological and commercial proposal during the METIS-II time of activity and the activities performed in the project helped to set a clear innovative and future looking perspective to the company positioning.





TIM is now strongly committed to confirm its achievements in terms of coverage and quality of service for the existing mobile network while at the same time investing heavily on the development of the network of the future (fiber coverage at 95% of the Italian population in 2018, 99% in 2019; 4G coverage at 99% in 2019). At the same time TIM is actively involved in many initiatives for the successful introduction of the 5G system.

As a direct outcome of the participation to METIS-II project, TIM started some collaborations with the most relevant players in the race towards 5G, some of them being key participants to METIS-II as well. More recently, TIM has also announced the start of dedicated trials to test the first achievements in 5G introduction (like “Torino 5G”, see [TIMTO5G]).

The specific activities in the METIS-II Work Packages helped TIM to make an in-deep analysis of the most relevant topics for 5G evolution, especially in the field of spectrum, SON and collaborative solutions.

## **D.18 Telefónica Investigación y Desarrollo SA**

Telefónica group is deeply involved in the development and test of innovative solutions towards 5G networks deployment in near future. The strategic roadmap for evolving current multi-generation RAN networks, to the envisioned 2020 and beyond networks is a keystone for Telefónica investments plan.

In this sense METIS II project has shaped Telefónica strategic proposal for 5G adoption, internally known as “The Journey to 5G (TJ25)”, which is also being used for the preparation of external analysts presentations.

The deep technical analyses carried out in METIS II project of different Technical components performance, evaluated in more realistic environments that the ones currently used in standardization forums (as 3GPP), have been of paramount importance.

Taking into account these results and the overall RAN architecture approach developed in METIS II, Telefónica has participated in GSMA forum as well as in 3GPP, setting the achievable requirements expected for New Radio specification, and also promoting the adoption of more valuable solutions.

Furthermore, the participation in METIS II has fostered the establishment of memorandums of understanding with some of the top vendors (also contributing to METIS II), for the joint deployment of 5G Technology pilots.

The outcomes of these pilots, and on the constant evaluation of the Technology evolution carried out in the [TEF5G], participated by Telefónica and two main METIS II contributors (Ericsson and Intel, impacts Telefónica vision of 5G deployment and exploitation.

Also the spectrum analysis for 5G deployments carried out in METIS II are used by Telefónica Spectrum Policy Group, in order to take appropriate positions in the current debates opened in several forums (including regulatory and 3GPP standardization), in order to support the most valuable positions for the early deployment of 5G technology.



## D.19 Technische Universität Kaiserslautern

In METIS-II, UKL has contributed to both the user plane and control plane design of 5G RAN. Moreover, the 5G evaluation framework has also been inspected and developed, in order to provide a platform to deliver reliable results for different 5G technologies. Together with that, a visualization platform has been established based on Unity3D, to achieve an attractive approach to demonstrate the 5G evaluation results.

Due to the closed collaboration with the vertical industries, UKL has exploited its gained expertise from METIS-II to provide connectivity solutions for different verticals (e.g., railways, car manufacturing and automation industry), in the context of 5G cellular systems. For instance, UKL is working on the application of 5G solutions in several national projects (e.g., 5G-Netmobil and 5Gang), to enable a better user experience for the public safety and IoT services. Moreover, UKL contributed to the dissemination of 5G METIS II results in vertical industries by giving talks, acting as advisor to vertical industries and policy makers, initiating collaborative projects with vertical industries, and supporting business development activities. UKL in particular co-organized and led a panel on 5G for industry at the Hannover fair 2016, gave plenary talks on 5G and automation in industry at several conferences (KommA 2016, GI 2016, Wireless Congress 2016), acts as scientific advisor to the 5G task force of the German automation industry association ZVEI, consults Deutsche Bahn AG (German railway operator) on 5G for broadband access, gave presentations and participated in panels at German broadband forum events where political decision makers are preparing broadband strategies, acts as advisors for the ICT expert group of the German Bundesrat (German 2nd chamber) on 5G related policy making, acts as advisor to the German government on the benefits of 5G for the digitalization of industry, acts as advisor to the Austrian government for the Austrian 5G for industry work program, etc.

UKL has disseminated its conducted work from METIS-II to multiple partner-individual publications, including eight conference papers and one magazine paper, which have been published or accepted. Together with that, UKL has also contributed to several METIS-II joint papers and the 5G RAN Design book.

The gained expertise from METIS-II has been used to train the young professionals and PhD students. Specifically, three PhD students have directly contributed to METIS-II and the work lay a critical foundation for their final dissertation. Moreover, the developed concepts and results of METIS-II have been used in teaching in courses of master students (e.g., “Wireless and Multimedia Systems”, and “Wireless Communications”), to demonstrate innovation and advanced system engineering solutions. Additionally, several master students carried out their master or bachelor thesis under the direct impact of METIS-II.

## D.20 Universitat Politècnica de València

UPV has published five conference paper and one journal paper directly related to its activity in METIS-II. Two additional journal papers are under evaluation, and could be published in the next months. Apart from the more academic part, the development of this project has increased the





business opportunities and further collaboration of the UPV. Moreover, UPV considers that some of the ideas identified along the project (mainly on waveform harmonization and use of grassmanian signaling) could disrupt the current technological evolution towards 5G systems and beyond and will be considered as patent candidates in the coming months by the UPV.

Regarding exploitation of results:

- The simulation platform capabilities have been extended, thus giving more added value for future licensing to this important tool. One of the current consultancy contracts of the UPV depends on the outputs generated in METIS-II.
- UPV has increased the level of expertise in the field of air interfaces for 5G systems, which could result in further opportunities for consultancy on the design, testing and evaluation of similar solutions. UPV is further looking for identifying potential interested institutions to cooperate with in order to develop this expertise.
- UPV personnel has gained expertise, which allows us to be ready and in an excellent position for preparing courses and other education activities. In general, the participation in the project has been used as a means for training Ph.D. students (three PhD have collaborated in the project, Carlos Herranz, Sonia Gimenez and Josué Flores de Vargas) as preparation of future European mobile communication experts.
- Visualization capabilities have been extended, thanks to the activity performed in METIS-II, to the use of a virtual reality approach. These capacities are expected to result in new ideas for products and means for exploitation. In particular, we are currently planning to go for a totally mobile virtual reality experience, aspect that could be of interest for many companies.

## **D.21 Rutgers, the State University of New Jersey (Winlab)**

WINLAB (Wireless Information Network Laboratory), an industry-university cooperative research center focused on wireless technology, was founded at New Jersey's Rutgers University in 1989. Its research mission is to advance the development of wireless networking technology by combining the resources of government, industry and academia. Since its inception, WINLAB has been supported by a broad cross section of leading wireless industry sponsors, including several major wireless equipment vendors, chip manufacturers and service providers based in the United States, Europe and Japan. WINLAB currently has a number of research activities related to 5G including dynamic spectrum access, massive MIMO, next-gen mobile network and connected car applications.

Specific capabilities developed thanks to the participation in the METIS-II project include the network virtualization capabilities and the expansion of the OMF control software for testbed management to support novel 5G interfaces. The METIS-II visualization platform was extended to support trace replay on the sub-6GHz ORBIT channel emulator that is part of sandbox4 and specific prototype for virtualized LTE was developed using the OAI software base.



WINLAB also has significantly improved capabilities in the area of cognitive radio technology for algorithms/protocols and dynamic spectrum access. Participating in METIS-II has provided Winlab with a wider knowledge of EU-based 5G research. Similarly, results from METIS-II were widely disseminated in various venues including numerous presentations at WINLAB Industrial Advisory Board meetings, GENI Engineering Conferences (GEC) and a number of US conferences.