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Abstract

This report describes the activities taken to communicate and disseminate the results of the 5G NORMA project. It presents the objectives of communication and dissemination, the target audience and the activities taken to inform the intended target groups. It provides an overview on standardisation contributions as well as journal and conference publications covering ideas and concepts of 5G NORMA and on workshops, panels, special issues and demonstrations organized by 5G NORMA. Finally, it provides information regarding the activities of 5G NORMA to reach the general public, including the website, social media, interviews and videos as well as summer schools and other teaching activities.

Keywords

5G NORMA, dissemination, standardization, regulation, communication activities

[1] CO = Confidential, only members of the consortium (including the Commission Services)

PU = Public

Executive Summary

This Deliverable D6.2 summarizes the communication and dissemination activities performed in the H2020 project 5G NORMA during the whole project duration from July 2015 to December 2017. It describes i) the objectives of 5G NORMA's communication and dissemination activities and their orientation towards targeted audience groups, ii) the implementation of concrete dissemination activities in terms of standardization contributions, demonstrator exhibitions, presentations, scientific publications, organization of workshops and activities in social media, and iii) the impact that has been created.

More than commonly done in pure research projects, great importance has been given in 5G NORMA to the applicability of innovations and results to novel products and services in a mid- to short-term timeframe. Information of product designers and potential users of the 5G NORMA innovations, mainly expected in industry and business, has been ranked first, but without ignoring the importance of academic research and education for a long-term sustainable development of the communications industry.

5G NORMA has, via its consortium partners, fed its ideas and results in 63 contributions into 5 different standardization bodies. In particular in the specifications created by 3GPP SA2 several ideas of 5G NORMA on network slicing can be found. Three demonstrators and a techno-economic analysis tool address various technical and economic aspects of network slicing and convey an immediate impression of the feasibility and maturity of the 5G NORMA technology. A great part of the 75 scientific publications of 5G NORMA are allotted to high-profile journals published by IEEE or ACM and to internationally renowned IEEE conferences. In this respect, 5G NORMA has reached its targets stated in the Description of Work (DoW) both qualitatively as well as quantitatively. Beyond that, 5G NORMA has been looking actively for the scientific dialog, by organizing many workshops and by engaging in several 5G PPP working groups. 5G NORMA has initiated the successful series of 5G Architecture Workshops, held in parallel to major global conferences, and taken the lead of the 5G PPP Architecture Working Group.

In summary, dissemination and communication activities in 5G NORMA have achieved their objectives well in all respects and in some of them considerably exceeded the expectations.

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1 Introduction

1.1 Objective of the document

5G NORMA has developed a novel mobile network architecture that meets the demands from increasingly heterogeneous and rapidly changing service portfolios. Its "multi-service and context-aware adaptation of network functions" allows for a resource-efficient support of these varying scenarios and helps to increase energy-efficiency by always selecting the most energy efficient option. The "mobile network multi-tenancy" approach developed by 5G NORMA leverages the adaptability and efficiency of network functions and enables an inherent and dynamic sharing and distribution of network resources between operators. Multi-service and multi-tenant operation of 5G NORMA networks can be controlled by tenants and users of specific network functions through an open API, what supports innovative network services and business models.

It is obvious that the 5G NORMA architecture impacts not only the network infrastructure. Instead it is going to change the interactions between infrastructure providers, network operators and their tenants and enables completely new business models.

When a network architecture affects many groups and their interests, such network cannot be built and used without prior building a consensus among all affected groups. And although 5G NORMA is a European funded project, these groups are by no means limited to Europe. From this it becomes clear that worldwide communication and dissemination of 5G NORMA's research results to all affected parties are essential for the success of this project.

5G NORMA is an application-oriented research project and as such it can be considered successful if its results are applied in reality. Accordingly, it is not enough to share research results among researchers, but various societal groups have to be addressed:

- Researchers in academia and industry;
- product developers working for equipment manufacturers as well as for network operators;
- users, i.e. enterprise customers, but also Mobile Virtual Network Operators (MVNOs) and OTTs;
- the general public, to establish society-wide appreciation and acceptance for societal and technical changes caused by 5G NORMA in particular and by digitalization in general. Aside of that, the general public, represented by the EU Commission, has funded 5G NORMA's research and thus has an obvious right to learn about the results of this research.

This Deliverable D7.2 describes the activities undertaken to communicate and disseminate the results of 5G NORMA's research, and it tries to assess its impact as far as this is objectively possible.

Besides communication and dissemination of the research results to the public external of the project, the results have also been exploited by project partners internally for their economic and academic activities. This internal partner-specific exploitation is subject of the Deliverable D1.4 and not covered by this Deliverable D7.2.

1.2 Structure of the document

This deliverable D7.2 consists of three main sections and several annexes:

Section 2 first explains the objectives of 5G NORMA's communication and dissemination activities. Afterwards it identifies different targeted audience groups and describes the communication channels that have been used to address these audience groups.

Section 3 presents the various dissemination and communication activities. It starts with 5G contributions to standardisation bodies related to products and services, continues with communication with other 5G PPP projects and vertical industries, contributions to academic research and education and concludes with internet-based dissemination to the general public.

Section 4 summarizes the dissemination and communication activities described in Section 3 and compares them to the objectives in Section 2.

Lists containing all dissemination activities, papers, presentations etc. are available in the annex.

2 Objectives and Methodology

2.1 Objectives

As already mentioned above, the results achieved in 5G NORMA are relevant for different groups in society. Looking at these groups, 5G NORMA pursues the following four objectives:

1. Products:
   Contribute to the development of novel 5G products and services and to their adoption by the market.
2. Ecosystem:
   Inform the general public and promote the benefits of 5G networks to their users, in particular to vertical industries.
3. Academia:
   Contribute to the scientific discussion on 5G technologies and their further evolution.
4. Education and Training:
   Inform students and enable fresh graduates to apply 5G NORMA results in their industrial or academic career.

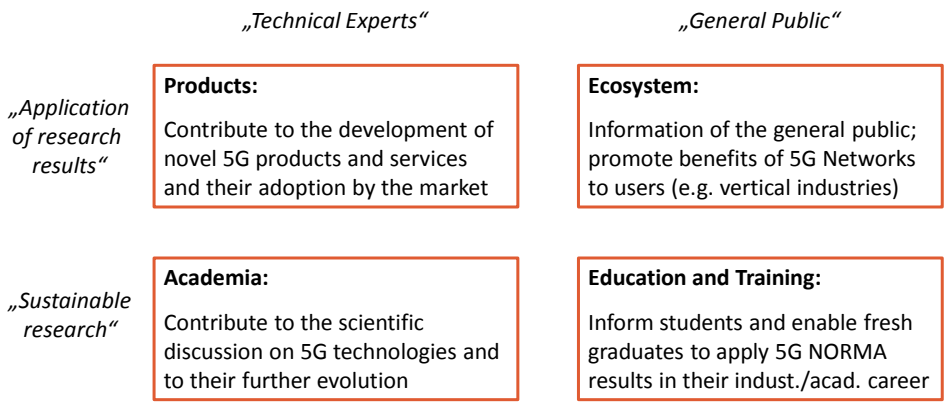

Figure 2-1: Objectives of 5G NORMA's communication and dissemination activities

The first two objectives are important already in the short term, while the latter two shall ensure long-term sustainability of European 5G research.

Contributions to 5G products and services:

The ultimate goal of 5G NORMA's architecture is to achieve economic and commercial impact by contributing to the development of new products and services. Such 5G products will be developed and sold by network suppliers; typically they comprise enhanced and flexible 5G base stations as well as SW for network functions, control functions and network management and orchestration functions. Aside such products, 5G NORMA concepts also enable novel services: Network operators can offer their tenants network slices with individual, service-specific properties. Furthermore OTT players can lease network slices that allow them to offer their customers services with well-defined quality. In order to achieve this objective, it is essential to disseminate project results to the most active players on 5G products and services.

Information of potential users of 5G NORMA networks and the general public:

Novel 5G products and services will not be economically successful unless they are accepted by their customers. Therefore the second of 5G NORMA's objectives is to inform customers about 5G NORMA's concepts and ideas and to convince them of the benefits of 5G NORMA based products and services.

A particularly important customer segment are the so-called vertical industries: Industries like automotive, utilities, healthcare, logistics etc., where companies produce products that are integrated by other companies, finally delivering a complex product to the end customer. 5G NORMA's network slicing capabilities are expected to enable new ways of interaction and production within vertical industries and possibly also new business models.

Aside vertical industries, 5G NORMA also affects society and general public. End-customers are expected to benefit from novel products and business models created by vertical industries thanks to 5G NORMA's capabilities.

Academia:

Frequently research topics are investigated first in academia, and later they are developed further in an industrial environment as soon as they have reached sufficient maturity. To achieve a long-term impact, results from projects in the industrial environment like 5G NORMA have to be conveyed in the reverse direction towards academia. By publishing scientific papers and by organizing conference workshops, 5G NORMA feeds back its results into academia and engages in their scientific discussion. This contributes to the sustainability of research on "5G and beyond".

Education and Training:

Publication of research results in the academic environment alone is not enough to stimulate continuous research in 5G. Just as well young academics have to be motivated to engage themselves in 5G research and start further investigations from the achieved 5G NORMA results.

5G NORMA aims to prepare students and young graduates during their education as well as by special trainings such that they can deepen and extend the results of 5G NORMA in their later academic research or that they can apply these results later in an industrial environment. The development of highly skilled engineers in the most advanced technologies is a crucial contribution to society and economy.

2.2 Target audiences and dissemination channels

The four objectives mentioned in the previous section target multiple audience groups. To reach these groups, different communication channels are needed. The following figure shows how 5G NORMA disseminates information on its key innovations via 12 different communication channels to the various target groups.

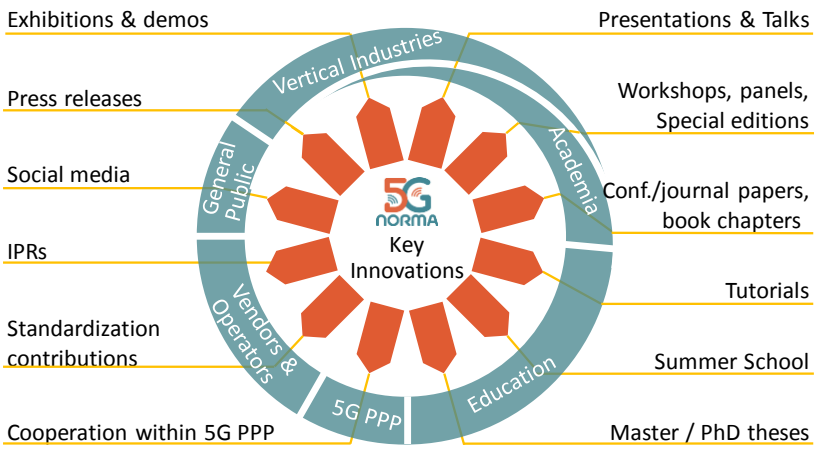

Figure 2-2: Audience groups and corresponding communication channels of 5G NORMA

Network equipment vendors and network operators:

The ultimate goal of 5G NORMA is, as said above, to make contributions to novel 5G products and 5G services. This goal mainly affects network equipment vendors and network operators. Like prior generations of network equipment, 5G is expected to have global reach and hence its technology has to be captured in standards. Contributions to standardization bodies are thus an essential part of 5G NORMA's dissemination activities. Several standardization bodies are affected, since 5G NORMA is looking at the network from an end-to-end perspective and because of 5G NORMA's end-to-end multi-service approach. 5G NORMA started its dissemination work in this area with identifying relevant standardization bodies, monitoring their activities and analysing their topics. As with prior mobile radio generations, 3GPP's WGs are of highest relevance, but also ETSI NFV, Broadband Forum, ONF, IETF and IEEE. To all these bodies, contributions have been submitted. Details will be described in Section 3.1 below.

Intellectual Property Rights (IPRs) are another way to contribute to the design of novel 5G products. This is particularly relevant for the vendors and operators involved in 5G NORMA to exploit project results. Several IPRs have been filed during the project duration of 5G NORMA. However, since these IPRs have to be kept confidential until they are published by the patent office, they cannot be discussed in further detail in this public deliverable.

5G PPP:

5G NORMA has been cooperating with other projects in the 5G PPP. The 5G PPP has defined a so-called "pre-structuring model", dividing the overall end-to-end communications system into parts to reduce its complexity. In this model, 5G NORMA shall cover the system architecture. Accordingly, 5G NORMA has taken the lead of the 5G PPP Architecture Working Group. Furthermore, 5G NORMA members have been contributing to other Working Groups as well and engaged in several bilateral discussions and workshops with other 5G PPP projects.

Vertical Industries

Vertical Industries are regarded as the most important group of 5G users in the future. Communicating the benefits of the 5G NORMA system to Vertical Industries is thus of high importance. The most compelling arguments for 5G NORMA are certainly demonstrators and prototypes that have been presented either live or by videos at various events.

Presentations and talks are another communications channel to reach Vertical Industries. A particular focus has been on industry conferences and organizations, like IWPC and NGMN, but 5G NORMA members have also been present at major academic conferences and workshops.

A third dissemination channel towards Vertical Industries are bilateral talks of equipment vendors and network operators to their enterprise customers. For obvious reasons, no further details on this can be given in this deliverable.

Academia:

The most important dissemination channel in academia are papers. 5G NORMA has published papers in various high-profile journals and at major conferences in Europe and overseas. Furthermore, 5G NORMA members have engaged as authors or editors for chapters of books that are expected to appear soon.

Presentations and talks are an important dissemination channel also towards academia, and 5G NORMA project members have given presentations at major academic conferences.

A third dissemination channel towards academia is the organization of workshops, panel sessions and special editions of journals. Such events are opportunities not only to inform about results of the 5G NORMA project, but allow to collect immediate feedback on these results and learn about related results from other 5G projects as well as other key players in the field. 5G NORMA members have been very engaged in the organization of such events.

Education:

As already explained above, 5G NORMA wants to make students and young graduates familiar with its research results, so that they can apply these results in their future academic career or in their industrial environment. Three dissemination channels have been used for this purpose:

Tutorials are a tool that can provide its attendees with a compact and consistent overview on the latest status of 5G research and network slicing.

The Summer School organized by 5G NORMA has been a three days event, allowing participants to obtain a broader overview on 5G and 5G NORMA. Experts from regulations authorities and vertical industries talked about the 5G ecosystem, and members from 5G NORMA and academia presented the latest state of research.

A third and most intensive way to transfer research knowledge is research work conducted by students as part of their Master's or PhD studies. Furthermore, results from 5G NORMA research are fed into the undergraduate and postgraduate courses of some of the involved universities.

General public:

Information to the general public has been provided mainly via 5G NORMA's project web site and via social media. Being easy to find and access, the web site serves as initial contact point for everybody who wants to obtain first-hand information on 5G NORMA. Furthermore, the web site contains many information on publications, standards contributions and demo videos providing in-depth insights for experts.

Having described the target audience and which communication and dissemination channels have been applied to address the various audience groups, the next sections will explain in detail how these channels have been used.

3 Dissemination Activities

3.1 Standardisation

Being relevant and having possible contributions to 5G standardizations, either technically or organizationally, is one of the planned targets for exploitation of 5G NORMA's outcomes [5GN-D71]. To this end, 5G NORMA has well achieved that target and made considerable contributions to 5G standardizations on at least the following technical areas:

- End to End network slicing;
- Architectural enablers for virtualized deployment;
- QoS flow based framework, including reflective QoS;
- Network slicing management and orchestration.

For more specific examples, Section 2.2 of [5GN-D42] provides an extensive description on standardization relevance and potentials of RAN architecture related technical innovations of 5G NORMA.

5G NORMA has addressed many practical technical issues which are in line with the 5G visions and directions provided by or reflected in the standardization bodies or fora listed below. A number of IPRs on some of those issues has been filed by 5G NORMA partners in the course of 5G NORMA which strengthen standardization potentials of 5G NORMA contributions in time, as 5G standardizations are evolving.

3.1.1 Major standardization bodies targeted by 5G NORMA

5G NORMA partners have been actively contributing to 5G developments in the following major standardization bodies or forums. In this section we identify the standardixation bodies of interest and the corresponding activities related to 5G NORMA, while in the next section we describe the contributions performed to each of these bodies.

3GPP has been progressing to complete Release 15 specifications which cover the first release of complete system specifications for 5G commercial cellular networks in June 2018. In architectures related working areas, Release 15 Stage 1 service requirements for 5G networks [22.261] was declared frozen in June 2017. Release 15 Stage 2 system architectures for 5G networks [23.501] is expected to be completed in December 2017. Release 15 Stage 2 5G RAN overall description [38.300] and Stage 3 5G RAN interface and protocol specifications for non-standalone and standalone 5G systems are expected in December 2017 and June 2018, respectively. In parallel, many study items for Release 16 have been underway. The following technical working groups of 3GPP are particularly relevant to 5G NORMA: SA1 on 5G use cases and services; SA2 on 5G network architectures; SA3 on 5G security; SA5 on 5G telecom management including management and orchestration of virtualized network functions and network slicing for 5G networks; RAN2 on 5G RAN overall description and radio interface protocols above layer 1; and RAN3 on network interfaces in 5G RAN and between 5G RAN and 5G CN. For the current releases, SA2 is working in particular on enabling and facilitating network slicing, which is one of the key features for 5G networks and plays a central role in the 5G NORMA architecture. Therefore SA2 has particularly high relevance for 5G NORMA.

ETSI covers many aspects on Network Function Virtualization (NFV), Mobile Edge Computing (MEC), Next Generation Protocols (NGP). ETSI NFV defines architectures, open Application Programming Interfaces (APIs) and reference points, leveraging open-source proof of concept (PoC) projects and communities to drive open standards for functional virtualization of network functions, management and orchestration (MANO) of network functions and services, and operation support system (OSS) interfaces. ETSI has established and hosted the Open Source Group OSG Open Source MANO. NFV and MANO topics are very closely related to 5G NORMA's concepts for the management of the network infrastructure platform and network slices established on this platform.

IETF develops and promotes standards that comprise the Internet protocol suite (TCP/IP). The Internet Research Task Force (IRTF) focuses on longer term research issues related to the Internet. There are several working groups at IETF and IRTF addressing topics very much related to 5G NORMA. The Distributed Mobility Management (DMM) WG is working on solutions for distributed mobility management, e.g. architecture and protocols for flexible support of different types of mobility such as ad-hoc mobility. These are aspects that are being tackled by 5G NORMA in the context of future 5G network architectures and 5G NORMA's SDN based mobile network controller concepts. The effort being done at the IETF can be seen as a preliminary effort that would then be taken up by 3GPP in future releases. The Service Function Chaining (SFC) WG is also very much aligned with 5G NORMA, as it is working on service function chaining aspects in the context of end-to-end service management and SDN management and orchestration. The lifetime of this WG is well aligned with that of 5G NORMA, offering a good potential for impact by the project.

BBF has been responsible for the definition of fixed line broadband access architectures for xDSL technologies in the beginning, and then for access fibre technologies (e.g. FTTH). Currently, BBF is working on the Cloud Central Office (CloudCO) project stream that is defining a reference architectural framework for the next generation of Central Offices to be deployed in the coming years by network operators to accommodate a mixture of physical and virtual network functions. In that respect, a network operator can evolve its current Central Offices to become Telco Cloud datacenters and become an Edge Cloud provider hosting VNFs for both fixed and mobile networks, in line with the migration path to 5G NORMA architectures at the infrastructure level.

IEEE has been active in working towards standardization of 5G communications technologies as well as developments within IEEE 802 for achieving 5G requirements or interworking with 5G licensed spectrum access through evolutions to IEEE 802.11 and 802.16 standards, for examples. IEEE Communications Society Standards Development Board (COM/SDB) has been running a series of meetings to call for possible items to standardize for 5G. Some outputs of this effort include "IEEE P1914.1: Standard for Packet-based Fronthaul Transport Networks", "P1915.1: Standard for Software Defined Networking and Network Function Virtualization Security", "P1916.1: Standard for Software Defined Networking and Network Function Virtualization Performance", "P1917.1: Standard for Software Defined Networking and Network Function Virtualization Reliability", and "P1918.1: Tactile Internet: Application Scenarios, Definitions and Terminology, Architecture, Functions, and Technical Assumptions".

In addition, 5G NORMA partners are also active in organizations such as **NGMN** alliance and **ITU-T IMT-2020**. These organizations provide, e.g., visions, requirements, relevant technologies and technical areas that influence and help shaping 5G standards and evolutions. Taking the network slicing, considered as one of the most essential features for 5G networks including 5G NORMA, for examples, NGMN provides frameworks for 5G network slicing [NGMN-NS] and network and service management and orchestration [NGMN-NSMO]. The network slicing framework includes concepts, terminologies and relations to the overall network and service management architecture which are later adopted or reflected in many research and standardization frameworks including 3GPP [28.801] and 5G NORMA.

3.1.2 Standardization related activities and achievements

5G NORMA has planned and carried out the following standardization related activities, as also stated in [5GN-D71]:

- To follow standardization trends and progresses in the respective bodies and forums, focusing on architectures related study and work items;
- To actively promote new standards and seek for opportunities to contribute 5G NORMA's results to relevant standards via 5G NORMA's partners;
- To cooperate with other projects of the 5G PPP for possible standards contributions.

These activities have been tracked and coordinated in the regular bi-weekly telco meetings of WP7.

For the course of 5G NORMA, 63 technical contributions were submitted by 5G NORMA partners to the above listed standardization bodies or forums: 36 to 3GPP, 15 to ETSI NFV, 5 to IETF, 5 to BBF, and 2 to IEEE.

3GPP contributions:

On RAN related topics, 5G NORMA partners submitted 22 contributions to 3GPP RAN, RAN2 and RAN3, as listed in Annex A: 1 to RAN addressing security requirements for NR and 21 to RAN2 and RAN3 addressing various topics related to the innovations of 5G NORMA, WP4 in particular. These standards contributions reflect 5G NORMA views and findings in some selected areas, including e.g.:

- Support of novel services in 5G beyond mobile broadband, in particular ultra-reliable low latency communications (URLLC) ([5GN-D41] Section 1.3 innovations 1, 3, 5 and 13);
- Requirements and principles for network slicing, including isolation between network slices and how these requirements can be supported in slicing the RAN ([5GN-D41] Section 3.3 and Section 1.3 innovation 2);
- RAN slicing, in particular radio resource isolation ([5GN-D41] Section 3.3);
- Multi-connectivity supports including tight interworking between LTE and 5G NR ([5GN-D41] Section 1.3 innovations 1, 3, 4, 5 and 7);
- RAN level QoS flow management and PDCP relocation ([5GN-D41] Section 1.3 innovations 11 and 12);
- Support of UE in an INACTIVE state with RAN level paging ([5GN-D41] Section 3.2.1.4 and Section 1.3 Innovation 6)
- Multi-connectivity support, as described in Section 6.1 of [5GN-D42];
- RAN support for network slicing in RAN slicing Option 3, described in Section 2.1.3 of [5GN-D42];
- SON based flexible configuration of 5G RAN protocol stacks aiming for possible support of flexible and dynamic on-the-fly adaptation of the RAN function decomposition (Figure 2-10) ([5GN-D41] Section 1.3 Innovation 9);
- UE agent based end-to-end connection decomposition concept, which is directly related to and goes beyond 3GPP Rel-14 study on context aware service delivery in RAN for LTE [36.933]. This innovation also provides an effective means for integrating and leveraging lower data rate satellite communications into 5G network systems ([5GN-D41] Section 1.3 Innovation 10).

To 3GPP SA1 and SA2, 14 contributions were submitted by 5G NORMA partners, addressing issues related to works carried out in 5G NORMA WP3 and WP5, e.g.:

- Service requirements on charging for multi RAT connections;
- Basic issues like coexistence among network slices, network slice abbreviation and network function granularity;
- Shared and dedicated network functions for network slicing;
- End-to-end QoS framework, application/context aware QoS frameworks, policy frameworks;
- Session management, including NAS signalling for PDU session setup, user plane path (re)selection;
- Mobility management and its relation to session management.

ETSI NFV contributions:

A total of 15 contributions (excluding the number of revisions) have been submitted and approved in ETSI ISG NFV. The contributions have been contributed to the Interfaces and Architecture (IFA) working group, which is mandated to specify the ETSI NFV MANO interfaces and information model. Out of these 15, one contribution is part of IFA012 (Application and Service

Management Interface and Information Model Specification) while the other 14 are part of IFA022 (Report on Management and Connectivity for Multi-Site Services).

The contribution to IFA022 proposes a use case enabling application function overlaying the NFV ecosystem, whereas the contributions made to IFA022 relate to the connectivity management of network service (i.e., network slices) across multiple sites over WAN infrastructure. The contributions have been co-authored with other industry players, including NEC, DT and Telefonica.

IETF contributions:

5 contributions have been submitted to IETF:

- RFC 7864: Proxy Mobile IPv6 Extensions to Support Flow Mobility was accepted;
- 2 drafts are on service function chaining (SFC), one on the SFC of data-plane elements in mobile networks and the other on use cases and metadata for SFC service, subscriber and host identification;
- 1 draft proposes adding Explicit Congestion Notification (ECN) to TCP Control Packets to improve the performance of services provided via a network with a distributed architecture as in 5G NORMA; and
- 1 draft addresses the essential aspects of network slice management from 3GPP, NGMN and ETSI relevant for the network slicing architecture and proposes a minimal alignment between these works to ensure compatibility between them.

BBF contributions:

5 contributions have been submitted to the Broadband Forum Cloud Central Office (CloudCO) project stream:

- 1 contribution on 5G Enablers and Requirements
- 1 contribution to WT-384 (“Cloud Central Office Reference Architectural Framework”) to include the possibility of reusing WAN infrastructure and integrating it when architecting a CloudCO;
- 1 general contribution (“ETSI WIM and Cloud CO”) exposing the need to align BBF CloudCO work with ETSI work on the WAN Infrastructure Manager (WIM) being worked on ETSI IFA 022 report;
- 2 contributions to WT-408 (“Cloud CO Migration and Coexistence”) that include 2 accepted new use cases that include the connection of compute hosts directly to existing WAN provider equipment (BNG and/or OLT).

IEEE contributions:

IEEE standards working group “P1918.1: Tactile Internet: Application Scenarios, Definitions and Terminology, Architecture, Functions, and Technical Assumptions” has been formed as the result of a collaboration of a 5G NORMA partner, King’s College London KCL, and Technical University of Dresden. One contribution based on multi-connectivity architectures considered in 5G NORMA [5GN-D41], was submitted and presented at the kick-off meeting by KCL.

3.2 Cooperation with other 5G PPP projects

Research on 5G is a global endeavor, with important players outside Europe. The cooperation between 5G PPP research projects is necessary to noticeably voice Europe’s expectation on future 5G technology and to push for a European leadership on 5G. Being aware of this, 5G NORMA has made a large effort to contribute to the most relevant 5G PPP working groups. 5G NORMA has been leading the Architecture working group; furthermore 5G NORMA members actively participated in the 5G PPP Steering Board and 5G PPP Technology Board as well as in several 5G PPP working groups, namely Architecture, Pre-standardization, Security, Vision and Societal Challenges, RAN and Scenarios, and Spectrum, in which it discussed and contributed its views and results.

3.2.1 Architecture WG

The 5G-PPP Architecture WG has continuously aligned and integrated the architecture work of all 5G-PPP Phase 1 projects. Regular phone calls as well as physical meetings have supported the preparation of the second version of the WG's white paper that provides major updates and further integrates different functionalities into a single and harmonized architecture framework.

5G NORMA has been among the main contributors to these activities. Particularly, the project's overall architecture has been used as a basis for the overall framework that guided the categorization and integration of different functions and technologies across multiple network domains and layers. Moreover, 5G NORMA's software-defined mobile network control (SDMC) concept served as guideline for achieving a high degree of programmability in the 5G-PPP architecture. More specifically, the project served as main author or delivered substantial contributions to the following sections and topics of the white paper:

- Overall architecture
    a. 5G Functional Layers
    The 5G NORMA layers (Service, Management & Orchestration, Control, and Data) are described as major building blocks of the overall architecture, complemented by Multi-Domain Network Operating System Facilities.
    b. Slice Moderation: Inter-Slice/Intra-Slice Control and Management
    5G NORMA's inter- and intra-slice control and management functions are integrated into the overall architecture. Together with novel functions from other 5G-PPP projects and the ETSI NFV MANO functions, they form the important functions of the Management & Orchestration layer.
    c. Business Realization and Stakeholders
    The 5G NORMA contribution has outlined how the concept of network slicing, that can also expose limited management and control options to external network tenants, can be used to host multiple networks on a partially shared infrastructure. It elaborates how private enterprise networks can be integrated with public networks (PLMNs) and what the impact is on cross-stakeholder interfaces.
- Radio access
    a. Software-controlled architecture definition
    The 5G NORMA contribution has outlined how network programmability and flexible architecture design is realized in 5G radio access networks. A special focus has been on RAN slicing options and their respective impact on common and dedicated network functions and the customization of individual network functions
- Softwarization and enabling technologies
    a. Multi-Tenancy Support
    The 5G NORMA analysis of novel as well as existing technologies (network slicing; virtualisation and VNFs; network sharing, in particular RAN sharing; spectrum sharing, etc.) and the means to combine them has provided insights into how the novel 5G architecture can support multi-tenant (and also multi-service) networks.

The WG's white paper (version 2) has been released in fall 2017. Beyond Phase 1, major 5G NORMA concepts and technologies will be maintained and further developed by 5G MoNArch, which will then also contribute according results to the continued work of the Architecture WG and potential future versions of the WP.

3.2.2 Pre-standardization WG

The 5G-PPP Pre-standardization WG has been discussing and keeping partners updated on relevant standardization and regulatory bodies or forums, creating and updating standardization roadmap, and coordinating standardization activities in 5G-PPP across all relevant projects. The

ultimate goal is set out to influence the works on pre-standardization of 5G, securing the leadership of Europe for the next generation networks.

5G NORMA is participating in the regular telco meetings of the Pre-standardization WG. In collaboration with the Pre-standardization WG, 5G NORMA has:

- followed and aligned 5G NORMA's standardization related activities with that of the Pre-standardization WG;
- taken part in shaping the vision and roadmap for 5G via, e.g., providing 5G NORMA's inputs for 5G-PPP coordinated white papers, demo sessions, tracking of 5G-PPP standards contributions, and deliverables of the Pre-standardization WG;
- promoted the "IEEE P1918.1: Tactile Internet: Application Scenarios, Definitions and Terminology, Architecture, Functions, and Technical Assumptions," as initiated by KCL, a 5G NORMA's partner.

The 5G-PPP Pre-standardization WG is preparing a document summarizing 5G PPP standardization results and activities in 5G PPP Phase 1 (2015-2017), as the end of 5G-PPP Phase 1 is approaching. 5G NORMA has provided inputs of 5G NORMA to the document.

3.2.3 Security WG

5G NORMA participated actively in the 5G PPP Security Working Group. We attended the regular phone calls as well as the face-to-face-meeting during the EuCNC 2016 in Athens, Greece. We contributed a paper and a presentation to the workshop "Network Management, Quality of Service and Security for 5G Networks" co-organized by the Security Working Group at the EuCNC 2016.

More general, we used the Working Group for exchanging and aligning views on 5G security, with focus on architectural aspects, and took the chance to disseminate our views and results to this group of security experts. We also contributed to the whitepaper "5G PPP Phase1 Security Landscape" (released by the Working Group in June 2017) as chapter editor of chapter 6 "Trust Model", and as contributor to other chapters, in particular chapter 2 "5G Security Architecture", where we added specific RAN security architecture considerations. This way, we increased the comprehensiveness of the whitepaper and disseminated the 5G NORMA security results into a wider audience.

3.2.4 Further cross-project activities

The 5G PPP Technology Board, with active support from 5G NORMA, produced a concrete view on the 5G PPP project landscape with its phase 1 projects cartography, tag cloud and the 15 "5G PPP Phase 1 Programme Golden Nuggets" [ABB17], where 5G NORMA contributed to GN '5G Flexible RAN' its "RAN Slicing" and to GN 'E2E Orchestration in Single and Multi-Domains 5G Virtualized Networks' with "Service and domain aware (re)orchestration" and "End-to-end orchestration". Furthermore, 5G NORMA experts supported the TB in monitoring the KPI (self) assessment.

5G NORMA contributed to the 5G PPP brochure "Business and Stakeholders Roles Transformations with 5G", that was prepared by the Vision WG and released at MWC 2017, with its view on new stakeholder roles in the 5G ecosystem, the latency reduction possible by suitable function selection and placement and enabled by its functionally decomposed architecture, and network programmability offered through its SDMC concept. 5G NORMA co-organized and presented at the Vision WG workshop "Business models and technoeconomic analysis for 5G networks" at EuCNC 2017.

The RAN and scenarios WG held its 3rd workshop in Athens, Greece, where 5G NORMA presented its RAN slicing, which complements the well-known network slicing in the non-access part to create real end-to-end slices up to the mobile users. Furthermore, the WG released version 2.0 of its living document on "5G-PPP use cases and performance evaluation", including

5G NORMA's evaluation results for the London city scenario to exemplify the economic benefits of multi-tenancy.

5G NORMA has monitored the Spectrum WG, and learnings from the discussions there have been incorporated into the business modelling work carried of WP2.

Finally, 5G NORMA contributed to a number of books jointly written by 5G PPP projects. In Patrick Marsch et al "5G System Design" book (Wiley), which is to be released prior to the first showcase of an early version of 5G at the Winter Olympics 2018, 5G NORMA co-authored chapters on end-to-end architecture, RAN architecture and network slicing. For Rui L. Aguiar "5G Networks – an European vision", we submitted the chapter "5G Radio Multiservice Adaptive Network Architectures", and in Al-dulaimi "5G Networks: Fundamental Requirements, Enabling Technologies, and Operations Management", we contributed chapter "Network Slicing for 5G Networks".

3.3 Communication to industries

In a global market, 5G NORMA innovations will be successful only when they are widely adopted by the main industrial players. For this reason industry-oriented dissemination is important to reach such industrial players and draw their interest to 5G NORMA's innovations and results. Being oriented to multi-tenant and multi-service support and implemented via an appropriate network slicing paradigm, the 5G NORMA architecture is an ideal candidate for a network to support the requirements from different vertical industries, in line with 5G general approach in that respect. This, in combination with the 5G NORMA innovations regarding network slice mobility management, QoS/QoE control and the e2e orchestration of slices that share specific network resources, enable the 5G NORMA architecture to fulfil very different requirements in terms of KPIs (latency, bandwidth, jitter, availability, etc.) as requested by different vertical industries.

Accordingly, it has been a priority of the project from the very beginning to reach the relevant stakeholders in this new paradigm of 5G as "a network for the verticals". These stakeholder include the vertical industries themselves, but also a broader audience, that includes industrial partners, that can adopt 5G NORMA concepts into their products, and network operators, that can deploy networks benefitting from the 5G NORMA innovations. As such, one of the key events that has been used to communicate the 5G NORMA architecture by means of demonstrations to the verticals supply chain as a whole is the Mobile World Congress, where 5G NORMA project has been present in 2016 and 2017. In addition to exhibitions and demonstrations, 5G NORMA project has also been presented in relevant conferences and workshops of IEEE, ETSI and NMGM to name a few.

3.3.1 Exhibitions and demonstrations

Demonstrators are very effective means to prove the feasibility of the 5G NORMA technology and to convey an immediate impression of its maturity to potential users in the industry. In the context of the Work Package 6, a set with four different demonstrators were developed in relation to three selected 5G NORMA key concepts:

1. Network Slicing (covering both: Network Control and NFV Management and Orchestration),
2. Security, and
3. The 5G NORMA Economic Feasibility.

Also, in these demonstrators, different specific proposals from other WPs are practically implemented (e.g.: SDM-C, SDM-O, NFV Management and Orchestration or certain security concepts among others) by means of different service types: Mobile Broadband (MBB), Massive

Machine Type Communication (mMTC) and Reduced Latency (RL) services. Specifically, the four developed demonstrators are the following:

- Demo 1: Native Multi-Service Architecture. This demo focuses on the Network Slicing concept, but considering specifically the network control capabilities of the 5G NORMA architecture, such as the Software-Defined Mobile Network Control and the multi-service and context-aware adaptation of network functions which are defined in WPs 3, 4 & 5. This shows a complete set of services, providing a pure eMBB service, a Low Latency service and also an mMTC example. This demo was jointly developed by AZCOM and NOMOR.

- Demo 2: Multi-slice service aware orchestration. This demo focuses as well on the Network Slicing concept, although from the NFVs Management and Orchestration perspective. It tries also to address some of the main concepts defined in WPs 3, 4 & 5, such as the notion of adaptive (de)composition of network functions with Software Defined Mobile Network Orchestration (SDM-O) and the novel concepts of network sharing and network slicing. It is designed also to showcase the multi-service paradigm, deploying both: an eMBB service and a Reduced Latency service. This demo is a joint effort of the University "Carlos-III" of Madrid (UC3M) and Atos.

- Demo 3: Secured Multi-Tenant Virtual Network Resources Provisioning via V-AAA. This demo relies on the authentication, authorization and accounting aspects of the architecture as they are defined in the WP3. The main concept covered by this demo is of course the Security concept as it is defined in the 5G NORMA architecture, so this is a backbone common feature for all type of services. This demo was developed by the Kings College of London (KCL).

- Demo 4: Online Interactive 5G NORMA Business Cases Evaluation Tool. This demonstrator is one of the outcomes of the WP2. This differs from the previous demonstrators since it is not hardware-based or demonstrating functionality; instead, this is a demonstration and evaluation tool developed by Real Wireless (RW) that can be used to enable the assessment and dissemination of the economic impact of the 5G NORMA innovations. URLLC, eMBB, and mMTC services are analysed in this demo.

By implementing these demonstrators we have also evaluated different qualitative KPIs, and a bunch of valuable lessons learned have been also collected. All of these are described in detail in the last WP6 deliverable D6.2 [5GN-D62].

While this document is written (Nov-2017) the final version of the demonstrators are still pending to be presented during the final audit review, which is scheduled to be in March-2018. However, early and intermediate versions of these demonstrators were already presented in certain relevant events during the whole project life-cycle; they were the following:

1. MWC 2016. An initial version of Demo 1 was presented during the Mobile World Congress 2016 at the European Commission booth. In this case a scale model rally car was driven using a commercial tablet as the steer to show the latency impact of moving the routing functions between simulated Edge and Central clouds (see Figure 3-1). Also, a software part of the demo was introduced showing interaction between multiple cells.

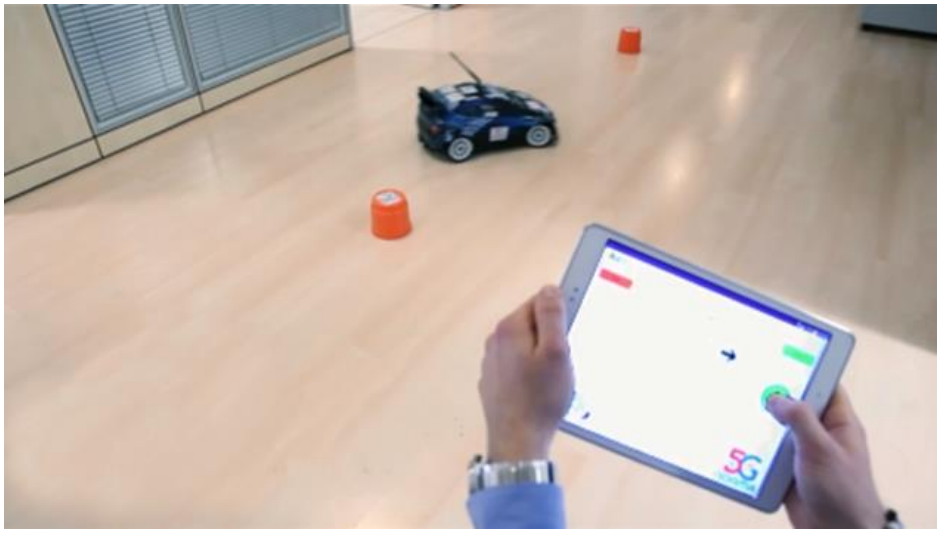

Figure 3-1: Demo 1 presentation during MWC'16

The demo was presented to a great number of relevant audience and was highly appreciated, receiving very positive feedback and attention not only from the general audience and representatives of telecommunication companies, but also from the delegates of the European Commission.

2. EuCNC 2016. The same Demo 1 was presented also at the EuCNC'16 conference, having a big success and receiving positive feedback as well. The demo was shown also to delegates of the European Commission who appreciate very much the presented work.

3. MWC 2017. A more advanced version of the same Demo 1 was also presented during the next edition of the Mobile World Congress. In this case, it was presented at the AZCOM technology booth. The demonstration showed the Native Multi-Service Architecture, and it was performed with two laptops where one of them was used by the hardware demo to show the impact of the reconfiguration of the network on the latency, and the second one was used to show the system-level simulator of the software demo. The following picture shows the demo set-up during the presentation:

Figure 3-2: Demo 1 presentation during MWC'17

Also, as we see in the picture, a poster introducing the other 5G NORMA demos (in the design and development phases at that moment) was also presented. As a whole, the

demonstration was explained to a great number of industrial and academic attenders, being highly appreciated.

4. ICC 2017. Early versions of demonstrators 2, 3 and 4 were presented during the IEEE International Conference on Communications workshops session the past May 25th in Paris. UC3M and Atos presented an initial static version of Demo 2 consisting on the deployment of the VNFs provided by the UC3M on the Atos virtualization environment. KCL also presented an initial version of their security demo, with a subset of Raspberry-PI cards, the SDN controller, the related V-AAA software and an initial version of their GUI. RW also presented its online interactive GUI showing the cost benefits resulting from the evaluation cases 1 and 2 addressed in the WP2; although this was an intermediate version of the demo, the layout and functionality of the GUI was already very similar to its final version. The following picture shows a moment during the presentation:

Figure 3-3: Demos 2, 3 & 4 presentation during ICC'17

5. EuCNC 2017. Demos 1 (Azcom and Nomor) and 4 (RW) were presented also during the EuCNC 2017 (past June). This was almost a final version of these demos. Demo 1 was mainly focused on the integration of the SDM-C component, which is defined in the WP3; an evolved implementation of this demo containing SW and HW components was presented. RW also presented an intermediate version of their Demo 4 in this event, with an almost final version of their online interactive GUI showing the cost benefits of 5G NORMA architecture, including NORMA features' selections such as flexible C-RAN and multi-tenancy.
   In this case, the booth was shared with the Fantastic 5G project, and was visited by many attenders, who were very impressed by both demos. The following picture shows the booth and some of the audience during this event.

Figure 3-4: Demos 1 & 4 presentation during EuCNC'17

Besides the attendance to conferences and relevant events, WP6 has also contributed to other dissemination activities in the form of technical papers, and also, contributions to the Open Source community. Regarding the papers, they are the following:

- A. Colazzo, R. Ferrari, R. Lambiase (AZCOM): "Achieving low-latency communication in future wireless networks: the 5G NORMA approach". FANTASTIC-5G WS on "Ultra-Reliable and Mission Critical Communication", EuCNC; Athens, Greece; June 2016;
- S. Khatibi, F. Sheikh: "Service-Aware Network Reconfiguration for 5G Networks". NOMOR Whitepaper; Nov. 2017;
- S. Wong et al. (KCL) : "Virtualized Authentication, Authorization and Accounting (V-AAA) in 5G Networks". 2017 IEEE Conference on Standards for Communications and Networking (CSCN); Sept. 2017.

Regarding the Open Source contributions, some of the partners contributed to the OS community by releasing part of their work for the demos in different OS repositories. This is the case of UC3M that released the modifications they implemented in the srsLTE software on GitHub; the code is available in the following url: https://github.com/GinesGarcia/ srsLTE_oaiCore under the GNU AFFERO General Public License. Also, they provided a thorough guide for the configuration of an Open Source mobile network stack with virtualized core, available at https://github.com/GinesGarcia/OpenAirInterface5G_CloudCore.

3.3.2 Presentations

From the outset 5G NORMA has successfully established a presence in predominantly academic conferences addressing the largest and most prestigious of the IEEE conferences through presentations and workshops. Building upon that success, with the intention of motivating the early stages of innovation promoting awareness within more industry oriented events has also been critical to the dissemination process. These presentations have typically promoted the concepts of the architecture research and sought to articulate the opportunities that are presented by these insights. The key innovation objectives and proof points from outcomes, techno-economic insights from WP2 and insights gained from some of the innovation management processes have resulted in conference organisations being happy to invite 5G NORMA participation to take part in events as panel chairs, presenters and panel participants. These opportunities enable the dissemination but also bring a rich set of data regarding the comments from the event or conference attendees. The project has delivered 44 presentations, over 90% of which were delivered by industrial members of the consortium.

The scope and scale of 5G NORMA positioned the project leadership team as thought leaders in the development of the key architectural concepts of 5G. The first IEEE conferences were addressed mid-2015; participating and presenting key messages into areas of critical architectural importance such as cloud-processing, next generation telecommunications architecture. The use case driven analysis process and the KPIs that were elicited in early stages of the project formed the basis for the participation in workshops in the latter part of 2015. Even at these early stages the Operator segment of the mobile industry was being addressed with the Operator led industry association of NGMN receiving a presentation. An important part of the early engagement was reaching out the Asian markets, and in late 2015 5G NORMA presented at the inaugural 5G Sino-Europe workshop in Beijing.

Having presented to NGMN in 2015, this continued into 2016 with another presentation on the topic of slicing and the high level architectural concepts that are important to support the slicing capability of future networks. A key success factor of the 5G NORMA project team has been the attention paid to the evolution of the standards, always and important enabler of new systems. However, in the case of a project like 5G NORMA which seeks to influence the development of the system architecture early engagement of the Standards bodies was always going to be important. In early 2016 the opportunity to present to ETSI SCN (Satellite Communications and Navigation Committee) allowed the opportunity to bring a different industry sector up to speed on the likely direction of future terrestrial networks.

A significant achievement in 2016 was the delivery of a very well attended summer school at King College London (see also Section 3.5.1 below). The majority of the Work Packages were represented, and several latest findings were presented, and supplemented with panel discussions in which 5G NORMA participants and participants of other projects were able to exchange views. Importantly the presence of the UK regulator (Ofcom) allowed for some early discussions on possible regulatory implications of the early findings. The opportunity to cover regulatory issues would emerge again in 2017 presenting to a more regulatory specialist audience which also had representatives of government departments responsible for digital strategy in the UK; the Westminster eForum.

Innovation themes were promoted through engagement in the UK with the Innovate-UK (UK Innovation funding agency) Catapult network where issues around the architectural challenges of mMTC were presented as the network formulated its strategy around 5G and IoT and possible test networks. Several specialist conferences on matters regarding future mobile networks within Germany provided platforms for 5G NORMA presentations; with Systems conferences, 5G expert days, and network and services implications. Deutsche Telekom hosted an ETSI NFV workshop on Network and Service Management for Future Networks which provided an ideal stage for a 5G NORMA presentation.

In 2017, in addition to continuing the predominantly technical architecture presentations the maturing of the techno-economic modelling enabled the addressing of a more diverse audience including more specialist economics oriented session of conferences (ISWCS) and sufficient knowledge was established to participate in business model oriented sessions at EuCNC, where 5G NORMA participated in creating the workshop programme and gave a keynote. The opportunity to chair a conference at which generational shifts in various technology areas were explored including the 5G platforms addressing a more startup and investor community in the Cambridge tech cluster in the UK.

Towards the latter stages of 2017, a panel presentation at ISWCS gave the opportunity to show the continuity of slicing research activity from 5G NORMA to a new project in H2020 Phase2. A virtualization workshop was carried out by the 5G NORMA innovation manager as RAN-World in Barcelona utilizing the outcomes from the techno-economic evaluation and exploring market readiness with a industrially oriented audience. During the course of 5G NORMA presentations have also been given on the topic of security in future networks with a particular focus on mMTC.

3.4 Scientific publications

3.4.1 Publications

The 5G NORMA project has an outstanding footprint in the dissemination activities. The total number of research publications is 75 articles including 14 papers published on highly rated journals with high visibility and 48 conference papers on top-tier ACM/IEEE as well as on European conferences. This provides an average of 2.5 papers accepted per month. In particular, 52% of the journal publications and 25% of conference/workshop papers have been jointly prepared by different project partners. Many publications have involved more than half of the consortium partners showing the great collaboration within the project frame. Interestingly, more than 60% of the dissemination activities have been carried out by industrial partners.

A relevant aspect is represented by the top-rank conferences and journal involved in dissemination activities that has brought a large visibility as witnessed by the significant number of citations that most of the recent published works have achieved. 5G NORMA was involved in top rank international journals, such as ACM/IEEE Transaction on Networking (TON), IEEE Transaction on Wireless Communications (TWC), IEEE Transaction on Mobile Computing (TMC), IEEE Journal on Selected Areas of Communication (JSAC) and IEEE Communications Magazine, characterized by a large impact factor (I.F.) ranging from 3.33 to 17.188.

It is also worth mentioning the competitive top-tier international conferences involved with very low acceptance rate, such as IEEE INFOCOM (3 papers accepted) and ACM CoNEXT(1 paper accepted) and with very-high visibility, such as IEEE GLOBECOM (4 papers accepted), IEEE PIMRC (3 papers accepted), IEEE ICC (4 papers accepted) and IEEE WCNC (1 paper accepted).

Last, 5G NORMA has also a great impact on the European technical area showing its contributions in the best European conferences such as EuCNC (European Conference on Networks and Communications) and CROWNCOM (Conference on Cognitive Radio Oriented Wireless Network). This involvement can help other European projects and researchers to learn about the results of 5G NORMA project and encouraging the future innovation and opportunities.

A full list of publications divided into different categories (book chapters, journals and workshops/conferences) can be found in the Annex C. In addition, it is also available the *popularity measure* only for the journal publications in terms of impact factor (I.F.) and number of citations achieved so far. A living documentation is available at the 5G NORMA website: https://5gnorma.5g-ppp.eu/dissemination.

3.4.2 Organisation of workshops, panel sessions, special editions of journal papers

5G NORMA has arranged a number of events throughout the project; some of the activities have been arranged together with other 5G PPP projects or with other partners worldwide. During this period, the following events can be highlighted:

- 5G NORMA organized two editions of the "5G Architecture Workshops" series, co-located with major conferences in the field.
- Two special issues on 5G NORMA related topics were organized in leading and high visibility journals in the area.
- Two panel on 5G topics in leading conferences.
- 5G NORMA contributed to three highly impactful industrial workshops.

The **5G Architecture Workshop** is the leading workshop in the area on 5G architectures. This workshop has been created by the 5G NORMA project, and has become the ***international reference event on 5G architectures***. The international impact of this workshop reflects the leading role of 5G NORMA and Europe in this area.

The first editions of the "5G Architecture Workshop" were held during the first part of the 5G NORMA project, and reported in D7.1. Over the second part of the project, two additional editions of this workshop have been organized, co-located with the following two conferences: EuCNC 2016 (in Athens, Greece) and IEEE ICC 2017 (in Paris, France). Note that these two conferences are among the most important ones in the field. As a matter of fact, all the editions of the 5G Architecture Workshop have always been ***co-located with major conferences***.

The two editions of the workshop held in EuCNC 2016 and ICC 2017 were very successful as they attracted the main drivers worldwide in 5G architecture, both from academy and industry, and served to exchange valuable technical views on the requirements, design and deployment of architectures.

It is worth mentioning that the EuCNC 2016 workshop was co-organized with the 5G architecture WG of 5GPPP, and thus served to align the European efforts on 5G architecture under the 5G NORMA leadership.

5G NORMA also edited two **special issues in leading journals** in the area, namely IEEE Communications Magazine and Elsevier Telecommunications Policy Journal, respectively.

The special issue of IEEE Communications Magazine focused on "Network Slicing and Softwarization in 5G: Technical enablers and Business perspectives". Network slicing is a very hot topic in 5G and 5G NORMA is playing a leading role in this topic. The special issue was very successful, and attracted so many submissions that two numbers of the magazine had to be published to accommodate all the accepted contributions.

The special issue of the Elsevier Telecommunications Policy Journal focused on "The implications of 5G networks: Paving the way for mobile innovation?". This is also a very hot topic, related to the commercial exploitation and innovation implications of 5G technology. 5G NORMA is also playing a leading role in that topic, as it is very closely related to the architectural stakeholders.

5G NORMA also organized **two panel sessions in leading conferences**: one on "5G architecture" at EuCNC 2016, and another one on "Network slicing" at CSCN 2016. These two conferences are very important in the area: EuCNC is the reference European conference on research and innovation, while CSCN is the main forum for research and standardization.

The above two sessions attracted key academic and industrial players in the area and focused on key topics for 5G NORMA, providing a forum to discuss disruptive and visionary ideas. The panel proved very fruitful to give visibility to 5G NORMA vision among a wide audience and also to gather feedback and complementary views from other major players.

5G NORMA was a key contributor to **two industrial events** during this period: (i) RAN World 2017, organized by Avren Events Ltd. in Sept. 2017 and (ii) URLLC Conference, organized by Executive Industry Events Ltd. in Nov. 2017. These events were very useful to reach the industrial community and show them the advantages of the 5G NORMA concepts as well as the potential commercial impact of such concepts.

The contributions of 5G NORMA in the leading journals and conferences in the area through the above activities shows the ***leading role that 5G NORMA has in the academic and industrial communities in the context of 5G architectures***. For further details on these events, the reader is referred to Annex D.

3.5 Educational activities

5G NORMA has been playing an important role in defining educational content and hosting or participating in activities such as Workshops, Tutorials and Summer Schools in order to maximise the impact on future generations of researchers and technologists of the pioneering research undertaken in the project. This is with a particular view to assisting towards the ends that Europe is well-tuned to future 5G developments, having an appropriate expertise within the vast technologically capable workforce to maximize the economic benefits from 5G, and other aspects

such as the societal benefits that will result from the better communication capabilities and new use cases in 5G.

The wealth of educational activities in 5G NORMA has spanned a range of locations and forms of event and content, ensuring that there is something for all levels of interest in future 5G technologies: From, e.g., the upper-level management that merely needs to know about the basic characteristics and capabilities of 5G to make business decisions, to the future experts that will be deeply-involved in running 5G networks, building equipment and devices, progressing research to beyond the capabilities and characteristics of 5G, and assessing and implementing the use cases for 5G—which are vastly expanded from what is possible in prior communications systems due to the novel capabilities such as URLLC, virtualization and multi-tenancy. Indeed, the latter conceptual shifts are vital to the understanding of 5G and future communications systems, and as being key topics in 5G NORMA they have been prominently featured in the educational outputs of the project.

3.5.1 Summer School

The 5G NORMA Summer School took place from June 20-22, 2016, in London, UK, at King's College London. It succeeded in bringing prominent people working in the mobile communication area together to discuss the path towards 5G networks, and managed to attract over 130 students and other attendees over the duration of the three days it took place.

The Summer School aimed to provide architectural views as well as technical details on the challenges and potential solutions from key leading researchers across Europe in the scope of 5G wireless communications. It touched upon issues related to network softwarization including wireless access and core network virtualization, multi-tenancy and solutions thereof, and architecture and capabilities of 5G, among others.

The 5G NORMA Summer School aimed to serve a range of interests, including network and radio engineers and researchers active or interested in 5G-related technologies, Post Doctoral researchers, PhD and Master students as well as participants from the mobile industry and other organizations (verticals) as stakeholders in the area given the vast new wealth of potential use cases that 5G implies. Some general interest participant groups also attended.

The event managed to attract estensive support; it was sponsored/supported by the Information Technology Society in the VDE, and the UK & Ireland chapter of both the IEEE Communications Society and the IEEE Vehicular Technology Society. Furthermore, it was included as part of the London Tech Week.

3.5.2 Tutorials

Tutorials aimed to assist learning in the novel areas of 5G relevant to 5G NORMA. They comprised formal tutorials as part of conferences programs, taking place at major venues such as IEEE ICC and IEEE Globecom, as well as more informal talks within technical societies, local universities and companies, and other locations. As well as providing a broad grounding, the tutorials delved into a lot of the technical detail in areas such as softwarised mobile network resources orchestration, and capabilities that arise from that. More specific topics covered by the tutorials have included virtualisation and network slicing approaches, protocols, theory, standards, etc., implications of decentralisation made possible through such technologies, and security in virtualised/sliced networks.

Keynotes have been presented, therefore educating the masses involved in mobile and wireless communications development, teaching and other areas, in this case from a higher-level conceptual perspective. These have been given at some of the most prominent venues available within the academic/research communities, such as IEEE ICC, IEEE Globecom, and others. One particularly strong keynote presented at IEEE ICC 2016 has covered the topic of the Tactile Internet as a 5G application, facilitated by network softwarization and slicing, among other technologies.

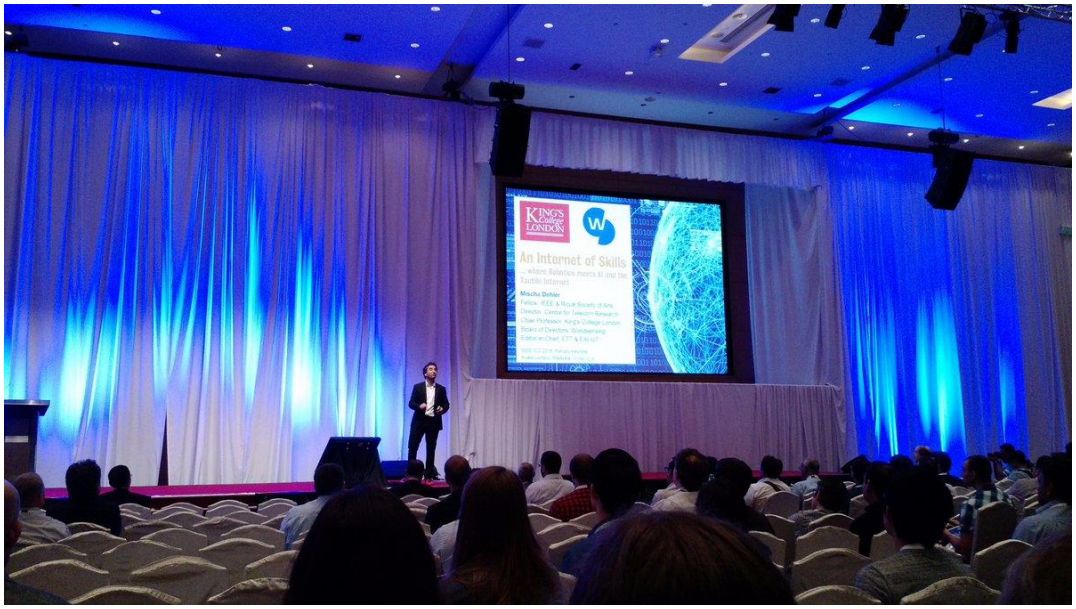

Figure 3-5: Photograph of the keynote given by Mischa Dohler at IEEE ICC 2016

3.6 Web site and social media

It is important for 5G NORMA to be in contact with the general public and other 5G PPP projects. This entails having a public face that is visible to anyone, and that helps disseminate and promote the work done in the project. 5G NORMA's outreach to the general public consists of a public website and various social media channels. In the next two subsections, a general description of the website and of those channels will be given, as well as any statistics that can be used to determine how effective they were in their dissemination.

3.6.1 Public Website

5G NORMA has a public website hosted at https://5gnorma.5g-ppp.eu/. It serves as the main channel for the dissemination of information on the project work and results to the general public. Anyone interested in the project will find plenty of useful information on the website. The website uses the Word Press platform.

Since the previous WP7 deliverable D7.1 [5GN-D71], there have been some changes to the website, aiming at improving the overview user experience. A general description of the website and detailed usage statistics can be found in Annex H below.

Usage of the web site has been monitored with Google Analytics. For the period 16.05.2016 – 20.11.2017, the total number of sessions was 8859, and the most visited pages have been the Home Page and the Public Deliverables section, which proves the high interest in the output of the 5G NORMA project. It can be concluded from the collected usage data that the website has a good visibility and that it has been visited regularly.

3.6.2 Social Media Channels

The 5G NORMA web site is the main dissemination channel to the general public. However, in order to engage with a larger audience, additional social media channels were opened, with the goal of announcing relevant news and events during the project. The target audience has been consisting of interested end-users, service providers, professionals, standardization bodies, network operators, 5G-PPP projects, and other 5G projects. In the subsections below, 5G NORMA's presence in three popular social media platforms (Twitter, Facebook and Youtube) will be further detailed.

YouTube has been an effective tool in disseminating 5G NORMA's results and as such a good complement to the web site. Other social media, i.e. Twitter and Facebook, instead achieved only moderate relevance for dissemination.

3.6.2.1 Twitter

5G NORMA's Twitter account is www.twitter.com/5G_NORMA. By 21 November 2017, 5G NORMA had 394 followers, including many professionals, research projects, companies, 5G PPP, 5G PPP projects, and 5G news accounts. Throughout the project, 5G NORMA tweeted around 50 times.

The project 5G NORMA is part of a list created by the project SELFNET which integrates many 5G European projects (https://twitter.com/5GPPP_SELFNET/lists/european5gprojects). This allows 5G NORMA to retweet other project's tweets and get its own tweets to reach a greater audience.

3.6.2.2 Facebook

5G NORMA also has a Facebook profile under www.facebook.com/5GNORMA. Facebook is another channel of information about the latest events and news from 5G NORMA, referring users to the 5G NORMA web site. Currently, the project's page has 52 "likes".

3.6.2.3 Youtube

5G NORMA project's Youtube channel can be found under www.youtube.com/channel/UCvbZdZ3oN-yiRa6-dXJQkMw. This channel hosts all demonstration videos, the recorded sessions from the 5G NORMA Summer School. When another channel features 5G NORMA's content (for instance, an interview on the 5G PPP channel), they are also shared in the 5G NORMA channel as well. By November 21 2017, the Youtube channel had 32 subscribers, 23 videos, 1527 views, and 4221 minutes of watch time.

The videos viewed most are:

1. 5G NORMA demo video – 1673 views - https://www.youtube.com/watch?v=lrAumMqIDNI
2. Simone Redana: View on 5G architecture – 358 views - https://www.youtube.com/watch?v=lZa7VB9SbWo (part of the 5G NORMA Summer School)
3. Marco Gramaglia: Software-Defined Mobile Network Control and Orchestration – 273 views - https://www.youtube.com/watch?v=jBouJb0-jYA (part of the 5G NORMA Summer School)
4. MWC16 Video AZCOM – 239 views - https://www.youtube.com/watch?v=CAlyQMUtv6k
5. Christian Mannweiler: 5G NORMA Concepts and Architecture – 167 views - https://www.youtube.com/watch?v=zQ1yBe4rDwQ (part of the 5G NORMA Summer School)

4 Conclusions

The communication and dissemination activities described in the previous section can be summarized quantitatively as shown in the following table.

Table 4-1: Quantitative impact of 5G NORMA communication and dissemination activities

Impact dimension	Channel	Results
Impact on future products and services	Standards contributions	63
	Demonstrations (at academic/industrial events)	14
Academic dissemination	Book chapters	4
	Journal papers	23
	Conference papers	48
	Tutorials and keynote speeches	8
	Presentations & Talks	47
	Workshops, Panels, Special editions organized	15
Education & Training	Summer School	130 participants, 236 registrations
Dissemination to the General Public	Web site	5297 users (16.5.2015 – 20.11.2017)
	Social media: YouTube videos, interviews, blog articles	YouTube: 1527 views Twitter: 394 followers Facebook: 52 likes (until 21.11.2017)
	Press releases	12

For an assessment in terms of quality, the impact dimension "Impact on future products and services" has received highest attention. 5G NORMA has been aiming to transfer innovative research results on SDN and NFV into novel product and business concepts for network slicing and prove their feasibility by demonstrators and prototypes.

Vertical industries, e.g. automotive, logistics, manufacturing etc., are seen as potential main users of network slices provided on a 5G NORMA-based infrastructure. To inform potential users in vertical industries about network slicing technology, 5G NORMA project members have organized several workshops, participated in various panel sessions and given many presentations, both at industrial / business events as well as at academic conferences. Furthermore, 5G NORMA's demonstrators have been presented almost 20 times, either live or by videos. The final demonstrations are planned for the Mobile World Congress 2018.

By these activities, the potential of network slicing has been successfully communicated to other equipment manufacturers, network operators and users outside the 5G NORMA project. This becomes apparent in the Network Slicing Task Force that has been established by the GSMA and that is led by one of 5G NORMA's project partners [GSMA]. Furthermore, with the Hamburg Port Authority, a company from the logistics industry could be convinced to join the 5G MoNArch project [5G MoNArch], which builds on the results of 5G NORMA and extends them during H2020 Phase 2.

With respect to standardisation, 5G NORMA's dissemination activities have been successful as well. As in earlier mobile radio generations, 3GPP is playing a dominant role in the standardisation of 5G. While in the past particularly 5G NR has been in the focus of 3GPP,

network slicing has increasingly gained attention in the meantime, and several of 5G NORMA's concepts and ideas are now being discussed in 3GPP RAN2, RAN3, SA2 and SA5. Examples of these ideas are RAN virtualisation, support for multi-connectivity, end-to-end QoS concepts, separation between shared and dedicated network functions.

With 36 out of 36 contributions in total, the majority of standardization contributions have been submitted to 3GPP. Nevertheless, important contributions on network slicing have been made to IETF, ETSI NFV and Broadband Forum (BBF) as well. Possibly 5G NORMA has even inspired an Open Source project: A presentation given by the OPEN-O project at ETSI NFV's Information Modelling Workshop, Dec. 2016 in Bonn, Germany, shows some parallels to 5G NORMA's network architecture [OPEN-O].

Also in the future, academic research will provide the foundation for innovative developments, products and business models. Therefore, the publication of its results in scientific journals and conferences has received high attention in 5G NORMA. In total, 5G NORMA published 70 peer-reviewed articles, many of them in high-profile journals, conferences and books. Among the most influential papers are three papers published by IEEE Communications Magazine: "Mobile Network Architecture Evolution toward 5G" by Peter Rost et al. with 45 citations, "From Network Sharing to Multi-tenancy: The 5G Network Slice Broker" by K. Samdanis et al. with 39 citations and "Spectrum and license flexibility for 5G networks" by O. Holland et al. with 15 citations.

A key contribution to society and economy is qualifying engineers in the most advanced technologies. 5G NORMA technology is taught in postgraduate courses by some of the partner universities. To encourage young academics, 5G NORMA has organized a Summer School and four tutorials; furthermore, 5G NORMA project members have given several keynote presentations and invited talks. With 130 participants, the Summer School has by far exceeded expectations. But also the acceptance of the tutorials on network sharing related topics as well as the invitations for keynote presentations impressively document the interest of young researchers in 5G NORMA's results.

As H2020 project, 5G NORMA has engaged in several 5G PPP working groups. Being a project dedicated specifically to 5G network architecture, 5G NORMA has been heavily engaged in the 5G PPP Architecture Working Group and provided major contributions to the two architecture White Papers published by this group. Other Working Groups where 5G NORMA has been active in were the Pre-Standards Working Group and the Security Working Group. Besides these groups, 5G NORMA also engaged in bilateral discussions with other 5G PPP projects and workshops organized by other 5G PPP projects.

In the Internet, 5G NORMA has been present with a web site as well as with YouTube, Twitter and Facebook accounts. Social media is primarily an amplifier of other content streams and channels. Typically, there is little posted on social media that has not been published on another channel in a longer, more detailed form. Nevertheless, this amplifier has worked quite effectively for 5G NORMA. In particular the videos on YouTube have found quite some interest.

All in all, it can be concluded that 5G NORMA has disseminated its research results effectively and thereby paved the ground for the H2020 Phase 2 project 5G MoNArch [5G MoNArch] which is going to build on 5G NORMA's results.

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[5GN-D42] EU H2020 5G NORMA, "D4.2: RAN architecture components – final report", Jun. 2017.

[5GN-D62] EU H2020 5G NORMA, "D6.2: Demonstrator design, implementation and final results", Nov. 2017.

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Annex A. Contributions to standardization bodies

Source	Body	Title	Reference	Date
NEC	3GPP (SA1)	Service requirement on charging for multi RAT connections	S1-153008	2015/10
O. Holland, M. Simsek, M Dohler, G. Fettweis	IEEE	“Standard for Tactile Internet” (position statement document and presentation, given to an invited IEEE Standards Board meeting and approved to move ahead with the formulation of a new standard on 5G)		2015/11/17
Nokia	3GPP (SA2)	Solution: QoS Framework	S2-161188	2016/02
Orange, DT, NEC	3GPP (SA2)	Key Issue on Policy Framework	S2-161238	2016/02
Nokia	3GPP (RAN3)	Key principles for RAN – CN Interface	R3-160733	2016/04
Nokia	3GPP (RAN3)	Key Requirements and Principles for Network Slicing	R3-160734	2016/04
Nokia	3GPP (RAN3)	Considerations for RAN architecture	R3-160737	2016/04
Nokia	3GPP (SA2)	Application Awareness in an End-to-End QoS Framework	S2-161622	2016/04
NEC	3GPP (SA2)	Solution: shared and Dedicated Network Functions for Network Slicing	S2-161785	2016/04
M. Gramaglia (UC3M / IMDEA) et al.	IETF	Service Function Chaining Dataplane Elements in Mobile Networks (draft-aranda-sfc-dp-mobile-00)	https://tools.ietf.org/html/draft-aranda-sfc-dp-mobile-00	2016/04/04
Carlos J. Bernardos (UC3M)	IETF	RFC 7864: Proxy Mobile IPv6 Extensions to Support Flow Mobility	https://tools.ietf.org/html/rfc7864	2016/05
Nokia	3GPP (RAN2)	Considerations for Ultra Reliable Low Latency Communications (URLLC) with High Mobility, May 2016	R2-163686	2016/05
Nokia	3GPP (RAN2)	Multi-connectivity in standalone NR	R2-163687	2016/05
Nokia	3GPP (RAN3)	Flexibility of RAN functions through configuration and deployment	R3-161099	2016/05
Nokia	3GPP (RAN3)	Requirements of Isolation between Network Slices	R3-161358	2016/05
Nokia	3GPP (SA2)	Update to Solution 2.3: Content Aware QoS Framework	S2-162706	2016/05
Nokia	3GPP (SA2)	Session Management to Enable (Re-)selection of Efficient User plane path	S2-162507	2016/05
Nokia	3GPP (SA2)	Solution for Mobility levels	S2-162526	2016/05

Orange	3GPP (SA2)	Network Slice abbreviation	S2-162957	2016/05
Orange	3GPP (SA2)	Update to QoS framework solution	S2-162901	2016/05
Orange	3GPP (SA2)	Guidelines for defining network function granularity	S2-163151	2016/05
O. Holland (KCL) et al.	IEEE	Multi-connectivity architectures supporting Tactile Internet services (IEEE P1918.1)		2016/05/28
NEC	3GPP (RAN)	Security Requirements for New Radio	RP-161208	2016/06
NEC	BBF (WWC)	5G Enablers and Requirements	SD-373	2016/06
Nokia	3GPP (SA2)	Relationship between Mobility Management and Session Management	S2-163605	2016/07
D. von Hugo (DT)	IETF	Service Function Chaining Service, Subscriber and Host Identification Use Cases and Metadata	https://www.ietf.org/internet-drafts/draft-sarikaya-sfc-hostid-serviceheader-03.txt	2016/07/05
Nokia	3GPP (RAN2)	Upper layer aggregation for NR-NR multi-connectivity	R2-164787	2016/08
Nokia	3GPP (RAN2)	NR Multi-connectivity in DU/CU architecture	R2-164956	2016/08
Zarrar Yousaf (NEC)	ETSI NFV	IFA022 - Use Cases Network Service for E2E Enterprise vCPE	IFA022, NFVIFA(16)000834r6 http://docbox.etsi.org/ISG/NFV/IFA/05-CONTRIBUTIONS/2016/NFVIFA%2816%29000834r6_IFA022_Use_Cases_Network_Service_for_E2E_Enterprise_vCPE.docx	2016/08/04
Michael Klotz (DT), Zarrar Yousaf, Fabio Giust (NEC)	ETSI NFV	Use case for an Application Function overlaying the NFV ecosystem	IFA012, NFVIFA(16)000296r6 http://docbox.etsi.org/ISG/NFV/IFA/05-CONTRIBUTIONS/2016/NFVIFA(16)000296r6_IFA012_5_17_Use_case_for_an_Application_Function_overlaying_.docx	2016/09/13
Nokia	3GPP (RAN2)	RAN Slicing in NR	R2-166170	2016/10
Nokia	3GPP (RAN2)	Radio resource isolation requirements	R2-166171	2016/10
Nokia	3GPP (RAN3)	Paging and Mobility in Inactive State	R3-162406	2016/10
Nokia	3GPP (RAN3)	Isolation using dedicated radio resources	R3-162404	2016/10
Nokia	3GPP (RAN3)	Definition for RAN support of slicing	R3-162401	2016/10
Nokia	3GPP (RAN3)	Generic QoS Framework over NG interface	R3-162400	2016/10

Nokia	3GPP (RAN3)	NG-U principle for QoS differentiation function	R3-162398	2016/10
Nokia	3GPP (SA2)	Interim agreement on Routing of NAS signalling and on How the AMF can select the proper SMF instance for a PDU session	S2-166351	2016/11
Nokia	3GPP (RAN2)	Radio resource isolation requirements	R2-167650	2016/11
Nokia	3GPP (RAN2)	Paging and location tracking in RRC_INACTIVE	R2-167708	2016/11
Nokia	3GPP (RAN2)	Discussion on Connectionless	R2-167714	2016/11
Nokia	3GPP (RAN3)	Paging and Mobility in Inactive State	R3-162948	2016/11
Telefonica	BBF	Cloud CO architecture scope consideration	bbf2017.039.02 https://aro.broadband-forum.org/bin/c5i?mid=4&rid=5&gid=0&k1=48418&tid=1487848102 (BBF members only)	2017/01
Nokia	3GPP (RAN2)	QoS flow relocation	R2-1700814	2017/02
Zarrar Yousaf (NEC), H. Dempo (NEC), A. Taniguchi (NT)	ETSI NFV	IFA022 Use Case#1 Analysis	NFVIFA(17)000080r3	2017/02/22
Nokia	3GPP (SA2)	Coexistence among network slices	S2-172230	2017/03
Zarrar Yousaf (NEC), Joan Triay et. Al (DOCOMO)	ETSI NFV	IFA022 Annex for a collection of variants of multi-site NS deployment	NFVIFA(17)000224	2017/03/13
Marcelo Bagnulo, Bob Briscoe	IETF	ECN++: Adding Explicit Congestion Notification (ECN) to TCP Control Packets (draft-bagnulo-tcpm-generalized-ecn-04)	https://tools.ietf.org/html/draft-bagnulo-tcpm-generalized-ecn-04	2017/05
Zarrar Yousaf (NEC), H. Dempo (NEC), A. Taniguchi (NT)	ETSI NFV	NFV(17)000000405 - IFA022 6 Proposal to add “use case analysis”	NFVIFA(17)000000405	2017/05/08

Zarrar Yousaf (NEC), H. Dempo (NEC), A. Taniguchi (NT)	ETSI NFV	IFA022 Use Case#2 Analysis	NFVIFA(17)000341r2	2017/05/18
Zarrar Yousaf (NEC), H. Dempo (NEC), A. Taniguchi (NT)	ETSI NFV	IFA022 Recommendations Architecture	NFVIFA(17)000502r3	2017/06/21
Zarrar Yousaf (NEC), H. Dempo (NEC), A. Taniguchi (NT)	ETSI NFV	IFA022 Recommendations Functional	NFVIFA(17)000528r3	2017/06/21
Zarrar Yousaf (NEC), H. Dempo (NEC), A. Taniguchi (NT)	ETSI NFV	IFA022 Recommendations Descriptors	NFVIFA(17)000530r2	2017/06/21
Rafael Lopez da Silva	BBF	ETSI WIM and Cloud CO https://aro.broadband-forum.org/bin/c5i?mid=4&gid=0&rid=5&k1=49321 (BBF members only)	bbf2017.568.00	2017/07
H. Flinck, C. Sartori, A. Adrianov, Chr. Mannweiler, N.Sprecher (Nokia)	IETF	Internet Draft Network Slicing Management and Orchestration	https://tools.ietf.org/html/draft-flinck-slicing-management-00	2017/07/03
Zarrar Yousaf (NEC), H. Dempo (NEC), A. Taniguchi (NT)	ETSI NFV	IFA022 Recommendations Reference Points	NFVIFA(17)000529r4	2017/07/25
Zarrar Yousaf (NEC), H. Dempo (NEC),	ETSI NFV	IFA022 Analysis: Analysis about WIM role.	NFVIFA(17)000714r2	2017/08/28
Zarrar Yousaf (NEC), H.	ETSI NFV	IFA022 Annex C: Gap analysis between WIM and Network Controller.	NFVIFA(17)000729r3	2017/09/01

Dempo (NEC)				
Rafael Lopez da Silva	BBF	Fabric-less migration use cases for WT-408 https://aro.broadband-forum.org/bin/c5i?mid=4&gid=0&rid=5&k1=49642 (BBF members only)	bbf2017.633.01	2017/09/11-14
Rafael Lopez da Silva	BBF	Switching fabric complemented with L2GW VNF https://aro.broadband-forum.org/bin/c5i?mid=4&gid=0&rid=5&k1=49695 (BBF members only)	bbf2017.684.00	2017/09/11-14
Rafael Lopez da Silva, Hiroshi Dempo, Zarrar Yousaf	ETSI NFV	IFA 022 use case: Use of WAN connectivity in compute-only NFVI-PoP deployments. Introduction section.	IFA022 https://docbox.etsi.org/ISG/NFV/IFA/05-CONTRIBUTIONS/2017/NFVIFA(17)000694r8_IFA022-Use_of_WAN_connectivity_in_compute-only_NFVI-PoP_depl.docx	2017/10/04
Rafael Lopez da Silva, Hiroshi Dempo, Zarrar Yousaf	ETSI NFV	IFA 022 use case: Use of WAN connectivity in compute-only NFVI-PoP deployments. Subsections 2 to 6.	IFA 022 https://docbox.etsi.org/ISG/NFV/IFA/05-CONTRIBUTIONS/2017/NFVIFA(17)000882_IFA022-Compute-only_NFVI-PoP_Use_case_subsections_2_to_6.docx	2017/10/10
Rafael Lopez da Silva, Hiroshi Dempo, Zarrar Yousaf	ETSI NFV	IFA022-Compute-only NFVI-PoP Use case analysis	NFVIFA(17)000961r2	2017/10/24

Annex B. Exhibitions and demonstrations

Authors	Title	Event	Date
M. A. Puente (ATOS), S. Redana (Nokia)	5G NORMA: A NOvel Radio Multiservice adaptive network Architecture for the 5G era (video demo)	ICT 2015, Lisbon/Portugal	2015/10/20-22
M. A. Puente (ATOS), P. Rost (Nokia)	5G NORMA: A NOvel Radio Multiservice adaptive network Architecture for the 5G era (video)	GlobeCom 2015, San Diego, USA	2015/12/06-10
M. A. Puente (ATOS), S. Redana (Nokia) D. Mariani, R. Lambiase (Azcom)	5G NORMA - A NOvel Radio Multiservice adaptive network Architecture for the 5G era	Mobile World Congress, Barcelona, Spain	2016/03/22-25
Simon Fletcher (RW)	5G NORMA: A NOvel Radio Multiservice adaptive network Architecture for serving the needs of business and society in the 5G era (Poster presentation)	ETSI 5G Summit: From Myth to Reality	2016/04/21
A. Banchs (UC3M), P. Rost (Nokia)	5G NORMA – A Novel Radio Multiservice adaptive network Architecture for the 5G era	ETSI workshop: From Research to Standardisation Sophia Antipolis, France	2016/05/10-11
J. Gonzalez (Atos), F. Sheikh (Nomor), A. Colazzo (Azcom)	5G NORMA HW- and SW-based demos (Video demo)	EuCNC 2016, Exhibition booth	2016/06/27-30
M. Breitbach (DT)	5G NORMA – A Novel Radio Multiservice adaptive network Architecture for the 5G era (video demo)	ISWCS 2016, Bologna, Italy	2016/09/21-23
F. Sheikh (Nomor), P. Rost (Nokia)	5G NORMA	Global 5G Event Rome, Italy	2016/11/9-10
AZCOM, NOMOR (S. Khatibi, F. Sheik)	Native Multi-Service Architecture	Barcelona, Spain	2017/02/27-03/02
King's College London	Secured Multi-Tenancy Virtual Network Resources Provisioning via V-AAA	IEEE ICC'17 (at Workshop on 5G Architecture)	2017/05/25
UC3M, ATOS	Service-aware QoE/QoS Control	IEEE ICC'17 (at Workshop on 5G Architecture)	2017/05/25
Real Wireless	Online Interactive Business Cases Evaluation Tool	IEEE ICC'17 (at Workshop on 5G Architecture)	2017/05/25
Real Wireless	Online Interactive Business Cases Evaluation Tool	EuCNC 2017 Oulu, Finland	2017/06/12-15

Nomor	Poster and Joint demo booth with Fantastic 5G	EuCNC 2017 Oulu, Finland	2017/06/12-15

Annex C. Scientific Publications

C.1. Book chapters

The following list comprises 5 book chapters that have been contributed to 3 different books. For the first book / first entry, the review of the chapter is currently pending. The other two book chapter have been accepted, and the books are planned to appear in 2018. Publisher of the first book is Cambridge University Press and of the second Wiley.

Main author	Chapter heading	Book title
M. Doll	RAN Architecture	Book “5G System Design - Architectural and Functional Considerations and Long Term Research”
M. Gramaglia, P. Rost, A. Kaloxylos, P. Spapis, V. Frascolla, X. Costa, A. Olivia, M. Di Girolamo, L. Murillo und R. Trivisonno	5G End-to-End Architecture	Book “5G System Design - Architectural and Functional Considerations and Long Term Research”
C. Mannweiler, P. Rost, G. Zimmermann, M. Di Girolamo, P. Marsch, J. Belschner, A. Tzanakaki, R. Trivisonno, Ö. Bulakci, P. Spapis, P. Arnold, N. Nikaein	Network Slicing	Book “5G System Design - Architectural and Functional Considerations and Long Term Research”
Zarrar Yousaf et al.	Network Slicing for 5G Networks	Book "5G Networks: Fundamental Requirements, Enabling Technologies, and Operations Management"

C.2. Journal papers

Authors	Title	Journal title	Date	Impact Factor
A. Kliks, O. Holland, A. Basaure, and M. Matinmikko	Spectrum and license flexibility for 5G networks	IEEE Communications Magazine, Vol. 53, No. 7	2015/07	I.F. 10.43 15 citations
D. Robalo, J. Oliveira, F. Velez, O. Holland, A. Aghvami	Dynamic Configuration and Optimization of WiMAX Networks with Relay Power Saving Modes:	Springer Wireless Personal Communications, Vol. 85, No. 3, December 2015	2015/12	I.F. 0.951 1 citation

	Measurement-Based Scenario in a Hilly Region			
Peter Rost, Albert Banchs, Ignacio Berberana, Markus Breitbach, Mark Doll, Heinz Droste, Christian Mannweiler, Miguel A. Puente, Konstantinos Samdanis, and Bessem Sayadi	Mobile Network Architecture Evolution toward 5G	IEEE Communications Magazine, Special Issue on LTE Evolution	2016/05	I.F. 10.43 45 citations
K. Samdanis, R. Shrivastava, A. Prasad, D. Grace, X. Costa-Perez	TD-LTE virtual cells: An SDN architecture for user-centric multi-eNB elastic resource management	Elsevier Computer Communications Vol. 83, pp. 1-98	2016/06	I.E. 3.338 7 citations
G. Chochlidakis, V. Friderikos (KCL)	Mobility Aware Virtual Network Embedding	IEEE Transactions on Mobile Computing	2016/07/18	I.F. 3.822 3 citations
K. Samdanis et al.	From Network Sharing to Multi-tenancy: The 5G Network Slice Broker	IEEE Communications Magazine, Standards Supplement	2016/07/15	I.F. 1.43 39 citations
D. Karamshuk, N. Sastry et al. (KCL)	Take-away TV: Recharging Work Commutes with Predictive Preloading of Catch-up TV Content	Journal on Selected Areas in Communication	2016/08	I.F. 8.085 1 citation
V. Sciancalepore, V. Mancuso, A. Banchs, S. Zaks, A. Capone	Enhanced Content Update Dissemination through D2D in 5G Cellular Networks	IEEE Transactions on Wireless Communications	2016/08/30	I.F. 4.951 5 citations
H. Droste, P. Rost, M. Doll, I. Berberana, Chr. Mannweiler, M. Breitbach, A. Banchs, M. A. Puente	An Adaptive 5G Multiservice and Multitenant Radio Access Network Architecture	Transactions on Emerging Telecommunications Technologies	2016/09	I.F. 1,535 5 citations

P. Rost, C. Mannweiler, D. Michalopoulos, C. Sartori, V. Sciancalepore, N. Sastry, O. Holland, S. Tayade, B. Han, D. Bega, D. Aziz, H. Bakker	Network Slicing to Enable Scalability and Flexibility in 5G Mobile Networks	IEEE Communications Magazine	2017/05	I.F. 10.43 6 citations
P. Caballero, A. Banchs, G. de Veciana, X. Costa-Pérez	Multi-Tenant Radio Access Network Slicing: Statistical Multiplexing of Spatial Loads	IEEE/ACM Transactions on Networking	2017/05	I.F. 3.376 2 citations
Dario Bega, Marco Gramaglia, Carlos J. Bernardos, Albert Banchs, Xavier Costa-Perez	Towards the network of the future: from enabling technologies to 5G concepts	Transactions on Emerging Telecommunications Technologies	2017/06	I.F. 1.535
C. Vlachos, V. Friderikos	MOCA: Multi-Objective Cell Association for Device-to-Device Communications	IEEE Transactions on Vehicular Technology	2017/10	I.F. 4.066
Zarrar Yousaf et al.	NFV and SDN – Key Technology Enablers for 5G Networks	JSAC, special issue on Emerging Technologies in SW-Driven Communication	2017/12	I.F. 8.085
I. Filippini, V. Sciancalepore, F. Devoti, A. Capone	Fast Cell Discovery in mm-wave 5G Networks with Context Information	IEEE Transactions on Mobile Computing	Accepted (Exp. public-ation date: Jan. 2018)	I.F. 3.822
Zainab Zaidi,Vasilis Friderikos, Zarrar Yousaf, Simon Fletcher, Mischa Dohler, Hamid Aghvami	Will SDN be part of 5G?	IEEE Communications Surveys and Tutorials	*Submitted, currently under revision*	I.F. 17.188
Rafael López da Silva, Rafael Cantó Palancar	Towards a Networked Telco Cloud	IEEE Journal on Selected Areas in Communications	*submitted*	I.F. 8.085
B. Han, O. Holland, V. Sciancalepore, M. Dohler, H. D. Schotten	D2D-Based Grouped Random Access to Mitigate Mobile Access	IEEE Communications Magazine	*submitted*	I.F. 10.43

	Congestion in 5G Sensor Networks			
B. Han, St. Wong, Chr. Mannweiler, M. R. Crippa, H. D. Schotten	Reliable Distributed Authentication in Multi-Access Mobile Edge Computing	IEEE Communications Magazine	*submitted*	I.F. 10.43
F. Z. Yousaf, V. Sciancalepore, M. Liebsch, X. Costa-Perez	MANOaaS – A Multi-tenant NFV MANO for 5G Network Slices	IEEE Communications Magazine	*submitted*	I.F. 10.43
J. Rendon-Schneir, K. Konstantinou, J. Bradford, G. Zimmermann, H. Droste, R. Canto, A. Ajibulu	Cost Analysis of a 5G Network with Multi-Tenancy Options	IEEE Communications Magazine	*submitted*	I.F. 10.43
V. Sciancalepore, I. Filippini, V. Mancuso, A. Capone, A. Banchs	A Multi-traffic Inter-cell Interference Coordination Scheme in Dense Cellular Networks	ACM/IEEE Transaction on Networking	*submitted*	I.F. 3.376
L. Zanzi, F. Cirillo, S. Mangiante, V. Sciancalepore, F. Giust, X. Costa-Perez, G. Klas	Evolving Multi-Access Edge Computing to Seamlessly Integrate IoT Platforms	IEEE Communications Magazine	*submitted*	I.F. 10.43

Two more papers reflecting 5G NORMA results on economic topics are planned to be prepared and submitted in the year 2018.

C.3. Conference papers

Authors	Title	Event	Date
A. Banchs et al.	A Novel Radio Multiservice adaptive network Architecture for 5G networks	VTC-Spring 2015, Glasgow, Scotland	2015/05/11-14
O. Holland et al.	To white space or not to white space: That is the trial within the Ofcom TV White Spaces Pilot	IEEE DySPAN 2015; Stockholm, Sweden	2015/09/30
Oliver Holland	Standardized Geolocation-Based System for Spectrum Sharing and Heterogeneous Access Management to Support 5G	IEEE CSCN 2015; Tokyo, Japan	2015/10-11/31-02

Oliver Holland	IEEE 1900.6b: Sensing Support for Spectrum Databases	IEEE CSCN 2015; Tokyo, Japan	2015/10-11/31-02
S. Filin, O. Holland, et al.	IEEE 1900.7 Standard for White Space Dynamic Spectrum Access Radio Systems	IEEE CSCN 2015; Tokyo, Japan	2015/10-11/31-02
Oliver Holland	Geolocation-Based Architecture for Heterogeneous Spectrum Usage in 5G	IEEE Globecom 2015 Workshops; San Diego, CA, USA	2015
K. Samdanis et. al.	A Service-oriented Network Resource Virtualization Framework for Evolving 5G TDD Networks	IEEE WCNC 2016; Doha, Qatar	2016/04/03-06
W. Hahn, et al.	Compound implementation of chained network functions and virtual resource management performance evaluation	IEEE NOMS 2016, 5GMAN Workshop Istanbul, Turkey	2016/04/25-29
Oliver Holland et al.	Virtualized VHF/UHF Transmission Paired with Mobile Access for the Tactile Internet	IEEE ICT'2016; Thessaloniki, Greece	2016/05
Chr. Mannweiler et al.	Cognitive management of multi-service multi-tenant 5G mobile networks	21st VDE Conference on Mobile Communications, 2016; Osnabrück, Germany	2016/05/11-12
Marco Gramaglia et al.	Flexible Connectivity and QoE/QoS Management for 5G Networks: the 5G NORMA view	IEEE ICC'16 workshop on 5G Architecture; Kuala Lumpur, Malaysia	2016/05/23
A. Ravanshid et al.	Multi-Connectivity Functional Architectures in 5G	IEEE ICC'16 workshop on 5G Architecture; Kuala Lumpur, Malaysia	2016/05/23
O. Holland, et al.	Aggregation in TV White Space and Assessment of an Aggregation-Capable IEEE 802.11 White Space Device	IEEE ICC 2016	2016/05/23-27
Bessem Sayadi et al.	SDN for 5G Mobile Networks: NORMA perspective	CLEEN Workshop 2016 CROWNCOM Conference, Grenoble, France	2016/05/30-06/01
P. Schneider	A New Radio Access Stratum Security Architecture	EuCNC 2016 WORKSHOP 6a: Network	2016/06/27-30

	Supporting Dynamic 5G Radio Access Networks	Management, Quality of Service and Security for 5G Networks Athens, Greece	
A. Colazzo, R. Ferrari, R. Lambiase (AZCOM)	Achieving low-latency communication in future wireless networks: the 5G NORMA approach	FANTASTIC-5G WS on “Ultra-Reliable and Mission Critical Communication” EuCNC; Athens, Greece	2016/06/27-30
J. Gang, V. Friderikos (KCL)	Control Plane Load Balancing in Wireless C/U Split	IEEE PIMRC 2016 Valencia, Spain	2016/09/06
V. Sciancalepore, K. Samdanis	A Service-tailored TDD Cell-Less Architecture	IEEE PIMRC 2016 Valencia, Spain	2016/09/07
D. Aziz, H. Bakker, A. Ambrosy, Qi Liao (Nokia)	Signalling Minimization Framework for Short Data Packet Transmission in 5G	IEEE VTC 2016-Fall Montreal, Canada	2016/09/18-21
V.Sciancalepore	A double-tier MEC-NFV architecture: design and optimization	IEEE CSCN 2016 Berlin, Germany	2016/10/31-11/02
Iñaki Ucar, Carlos Donato, Pablo Serrano, Andres Garcia-Saavedra, Arturo Azcorra, Albert Banchs	Revisiting 802.11 Rate Adaptation from Energy Consumption's Perspective	ACM MSWiM 2016 Malta	2016/11/13-17
D. Aziz, J. Gebert, A. Ambrosy, H. Bakker, H. Halbauer	Architecture Approaches for 5G Millimetre Wave Access Assisted by 5G Low-Band using Multi-Connectivity	IEEE GlobeCom 2016 Washington D.C., USA	2016/12/04-08
D. Bega, M. Gramaglia, A. Banchs, V. Sciancalepore, K. Samdanis, X. Costa-Perez	Optimising 5G infrastructure markets: The Business of Network Slicing	IEEE INFOCOM 2017 Atlanta, USA	2017/05/01-04
V. Sciancalepore, K. Samdanis, X. Costa-Perez, D. Bega, M. Gramaglia, A. Banchs	Mobile Traffic Forecasting for Maximizing 5G Network Slicing Resource Utilization	IEEE INFOCOM 2017 Atlanta, USA	2017/05/01-04
Pablo Caballero, Albert Banchs, Gustavo de Veciana, Xavier Costa	Network Slicing Games: Enabling Customization in Multi-Tenant Networks	IEEE INFOCOM 2017 Atlanta, USA	2017/05/01-04
Bin Han (TUKL), Stan Wong (KCL), Christian	Security Trust Zone in 5G Networks	ICT 2017, Limassol, Cyprus	2017/05/03-05

Mannweiler (Nokia), Mischa Dohler (KCL), Hans Schotten (TUKL)			
M. Breitbach, Chr. Mannweiler, P. M. Rost, D. Michalopoulos	Network Slicing: Considerations on the implementation of data, control, and management planes	22nd VDE Conference on Mobile Communications, 2017, Osnabrück, Germany	2017/05/09-10
M. R. Crippa, P. Arnold, V. Friderikos, B. Gajic, C. Guerrero, O. Holland, I. Labrador, V. Sciancalepore, D. v. Hugo, S. Wong, F. Z. Yousaf, B. Sayadi	Resource Sharing for a 5G Multi-tenant and Multi-service Architecture	European Wireless 2017, Workshop on COmpetitive and COoperative Approaches for 5G networks (COCOA); Dresden, Germany	2017/05/17-19
W. Hahn, B. Gajic et al.	Feasibility of Compound Chained Network Functions for Flexible Packet Processing	European Wireless 2017; Dresden, Germany	2017/05/17-19
F. Z. Yousaf, M. Gramaglia, V. Friderikos, B. Gajic, D. v. Hugo, B. Sayadi, V. Sciancalepore, M. R. Crippa	Network Slicing with Flexible Mobility and QoS/QoE Support for 5G Networks	IEEE ICC'17, Workshop on 5G Architecture; Paris, France	2017/05/25
Chr. Mannweiler, M. Breitbach, H. Droste, I. Labrador, I. Ucar, P. Schneider, M. Doll, Z. Yousaf	5G NORMA: System architecture for programmable multi-tenant 5G mobile networks	EuCNC 2017; Oulu, Finland	2017/06/12-15
D. v. Hugo, G. Eichler (DT)	Distributed Network Infrastructure for Community Services in the Framework of Next Generation Mobile Networks	17th International Conference on Innovations for Community Services; Darmstadt, Germany	2017/06-26-28
Bin Han, Shreya Tayade and Hans D. Schotten	Modeling Profit of Sliced 5G Networks for Advanced Network Resource Management and Slice Implementation	22nd IEEE Symposium on Computers and Communications (ISCC 2017); Heraklion, Greece	2017/07/03-06
S. Wong et al.	Virtualized Authentication, Authorization and Accounting (V-AAA) in 5G Networks	IEEE CSCN 2017; Helsinki, Finland	2017/09/18-20

B. Han, M. A. Habibi, H. D. Schotten	Optimal Resource Dedication in Grouped Random Access for Massive Machine-Type Communications	IEEE CSCN 2017; Helsinki, Finland	2017/09/18-20
Federico Montori, Marco Gramaglia, Luca Bedogni, Marco Fiore, Farid Sheikh, Luciano Bononi, Andrea Vesco	Automotive Communications in LTE: a Simulation-based Performance Study	IEEE VTC-Fall; Toronto, Canada	2017/09/24-27
Marie-Line Alberi Morel, Sabine Randriamasy	Quality of Experience-aware enhanced Inter-Cell Interference Coordination for Self-Organized HetNet	IFIP WMNC 2017; Valencia, Spain	2017/09/25-27
Chr. Mannweiler, P. Schneider	5G System Architecture and Security Concepts for Novel Vertical Application Domains	ITG-Fachtagung "Zukunft der Netze 2017", Poster session; Lübeck, Germany	2017/09/28-29
Diomidis S. Michalopoulos, Mark Doll, Vincenzo Sciancalepore, Dario Bega, Peter Schneider, Peter Rost	Network Slicing via Function Decomposition and Flexible Network Design	IEEE PIMRC 2017 (WS-09); Montreal, Canada	2017/10/08-13
A. Cuadrado Torre, M. Fiore, C. Casetti, M. Gramaglia and M. Calderon	Bidirectional Highway Traffic for Network Simulation	IEEE Vehicular Networking Conference (VNC); Torino, Italy	2017/11/27-29
B. Han, H. D. Schotten	Grouping-Based Random Access Collision Control for Massive Machine-Type Communication	IEEE GlobeCom2017, Mobile and Wireless Communication Symposium Singapore	2017/12/04-08
V. Sciancalepore	Slice as Service (SaS): Optimal IoT Slice Resources Orchestration	IEEE GlobeCom2017; Singapore	2017/12/04-08
Cristina Marquez, Marco Gramaglia , Marco Fiore, Albert Banchs, Cezary Ziemlicki, Zbigniew Smoreda	Not All Apps Are Created Equal: Analysis of Spatiotemporal Heterogeneity in Nationwide Mobile Service Usage	ACM CoNEXT 2017; Seoul / Incheon, South Korea	2017/12/12-15
P. Schneider, S. Kerboeuf, Chr. Mannweiler	Providing Strong 5G Network Slice Isolation for Highly Sensitive Third Party Services	IEEE Wireless Communications and Networking Conference (WCNC 2018)	*Accepted*

		Barcelona, Spain	
Jinwei Gang, Vasilis Friderikos (KCL)	Resource Sharing in Multi-Tenant 5G Networks	IEEE Wireless Communications and Networking Conference (WCNC 2018) Barcelona, Spain	*Accepted*
L. Zanzi, F. Giust, V. Sciancalepore	M2EC: A Multi-tenant Resource Orchestration in Multi-access Edge Computing Systems	IEEE Wireless Communications and Networking Conference (WCNC 2018) Barcelona, Spain	*Accepted*
A. Banchs	Network Slicing for Guaranteed Rate Services: Admission Control and Resource Allocation Games	INFOCOM 2018; Honolulu, Hawai, USA	*Submitted*
R. Gouareb, V. Friderikos, H. Aghvami	Delay Sensitive Virtual Network Function Placement and Routing	IEEE Globecom 2018	*Submitted*

It is planned to disseminate results from architecture and system verification (see Deliverable D3.3, Sec. 6 [5GN-D33]) and considerations on migration from legacy networks to networks based on the 5G NORMA architecture as well (see Deliverable D3.3, Sec. 7 [5GN-D33]) as paper(s) in the beginning of the year 2018.

C.4. Talks and presentations

Presenter	Title	Event	Date
S. Redana (Nokia)	5GPPP project: 5G NOvel Radio Multiservice adaptive network Architecture (5G NORMA)	ICC2015, 2nd Intl. Workshop on Cloud-Processing in Heterog. Mobile Communication Networks (IWCPM 2015) London, UK	2015/06/08-12
S. Redana (Nokia) et al.	5G NORMA: A NOvel Radio Multiservice adaptive network Architecture for 5G networks	EuCNC 2015, Paris, France	2015/06/29-07/02
S. Redana (Nokia)	Architecture in the 5G era: 5G NORMA approach and Nokia view	ISWCS2015, Brussels, Belgium	2015/08/25-28
B. Sayadi (Nokia)	Key Performance Indicators: From 5G NORMA perspective	METIS-II RAN Design workshop Stockholm, Sweden	2015/09/28
P. Rost	5G NORMA: A NOvel Radio Multiservice adaptive network Architecture for 5G networks	METIS-II RAN Design workshop Stockholm, Sweden	2015/09/28

K. Martiny, M. Breitbach (DT)	5G NORMA: A NOvel Radio Multiservice adaptive network Architecture for the 5G era based on Network Slicing	NGMN Forum Montreal, Canada	2015/10/13
S. Redana, M. Doll	5G NORMA: A NOvel Radio Multiservice adaptive network Architecture for the 5G era	1st Sino-Europe 5G Techn. Workshop FuTURE FORUM 5G SIG Beijing, China	2015/11/05
S. Redana (Nokia)	5G NORMA: A NOvel Radio Multiservice adaptive network Architecture for the 5G era	2015 Future 5G ICT Summit and Series FuTURE FORUM 5G Beijing, China	2015/11/07
S. Redana (Nokia)	5G NORMA: A NOvel Radio Multiservice adaptive network Architecture for the 5G era	3rd 5G Global Summit (5G Forum) Seoul, South Korea	2015/12/03
Nishanth Sastry (KCL)	The role of user analytics in edge caching	Virtual Networks SIG event on 'Pushing NFV/SDN to the edge through Mobile Edge Computing' Cambridge, UK	2015
Nishanth Sastry (KCL)	5G Network Architecture as an Online Optimisation Problem	Conference "'Towards 5G Mobile Technology – Vision to Reality" London, UK	2015
Christian Mannweiler (Nokia)	A Novel Radio Multiservice Adaptive Network Architecture for the 5G Era	Expert Workshop on "5G System Architecture" Munich, Germany	2015
S. Redana (Nokia)	5G NORMA - A NOvel Radio Multiservice adaptive network Architecture for the 5G era	ETSI SCN #14 Sophia Antipolis, France	2016/01/26
C. Sartori (Nokia)	A NOvel Radio Multiservice adaptive network Architecture for the 5G era based on Network Slicing	NGMN Forum Taipei, Taiwan	2016/03/17
S. Fletcher (RW)	Nascent Business Models in 5G	IEEE ICC Kuala Lumpur, Malaysia	2016/05/23
S. Fletcher (RW)	Verticals, Business, Architectural Control Points	IEEE ICC Kuala Lumpur, Malaysia	2016/05/24

K. Samdanis (NEC) et al.	Flexible Connectivity and QoE/QoS Management for 5G Networks	CLEEN Workshop 2016, CROWNCOM Conference Grenoble, France	2016/05/30-06/01
D. v. Hugo (DT)	Mobile Tactile Internet services with 5G NORMA	49. ITG 524 Workshop "5G Mobile Networks - Towards the Tactile Internet" Dresden, Germany	2016/06/10
Chr. Mannweiler, H. Sanneck (Nokia)	Cognitive Network Management – Automation for Multi-tenant 5G Mobile Networks	IWPC congress "Forging a Path to Autonomous 5G Networks" Cologne, Germany	2016/06/14-16
M. Breitbach (DT)	5G NORMA: A NOvel Radio Multiservice adaptive network Architecture for the 5G era	IWPC congress "Forging a Path to Autonomous 5G Networks" Cologne, Germany	2016/06/14-16
B. Sayadi (Nokia)	5G end-to-end Architecture: 5G NORMA vision	Summer School London, UK	2016/06/16
P. Rost	5G NORMA – Introduction	5G NORMA Summer School London, UK	2016/06/20-22
Ch. Chambers	Aspects of the economics of mobile communications systems	5G NORMA Summer School London, UK	2016/06/20-22
Chr. Mannweiler	5G NORMA-Architecture And Concepts	5G NORMA Summer School London, UK	2016/06/20-22
M. Doll	Adaptive allocation of network functions	5G NORMA Summer School London, UK	2016/06/20-22
M. Gramaglia	Software-Defined Mobile Network control and orchestration	5G NORMA Summer School London, UK	2016/06/20-22
P. Rost, A. Galis	5G Overall Architecture	EUCNC 2016 International Workshop on 5G Architecture Athens, Greece	2016/06/27-30
P. Rost (Nokia)	5G NORMA: An adaptive mobile network architecture	EUCNC 2016 workshop W04a – “Next Generation fronthaul/backhaul	2016/06/27-30

		integrated transport networks," Session 1 Athens, Greece	
J. Rendon Schneir (DT)	A Cost Model for a 5G network	ITS conference Cambridge, UK	2016/09/07-09
Chr. Mannweiler (Nokia)	What is relevant research for 5G Advanced? (Panel presentation)	IEEE PIMRC 2016 Valencia, Spain	2016/09/05
Chr. Mannweiler (Nokia)	5G NORMA - An adaptive multi-tenant, multi-service architecture for 5G mobile networks	5G Expert Day Munich, Germany	2016/09/14
M. Breitbach (DT)	5G NORMA - An E2E platform for 5G networks (Panel presentation)	ISWCS2016 Poznan, Poland	2016/09/22
P. Rost (Nokia)	Participation in the panel session "Leveraging the Full Potential of 5G Networks with Network Slicing and NFV"	IEEE GlobeCom 2016 Washington D.C. USA	2016/12/4-8
Henning Sanneck, Christian Mannweiler	Cognitive Network Management – automation for multi-tenant 5G mobile networks	Information Modelling Workshop on "Network and Service Management for Future Networks" Bonn, Germany	2016/12/07
Stan Wong (KCL)	Brief Introduction of LoRa	Things Connected Open Call Clinic London, UK	2016/12/09
P. Rost (Nokia)	Panel session: "Industry Panel and Interactive Session on Cellular Systems beyond 5G"	11th Int. ITG Conference on Systems, Communications and Coding Hamburg-Harburg, Germany	2017/02/06-09
Stan Wong (KCL)	Brief Security for LoRa application	Things Connected Open Call London, UK	2017/02/28
P. Rost (Nokia)	5G NORMA - A NOvel Radio Multiservice adaptive network Architecture for the 5G era	5G PPP Workshop on RAN Architecture and Integration Chertsey, UK	2017/03/30-31
H. Osman (RW)	5G Innovations	SmartEx, Lebanon	2017/05/13
S. Fletcher (RW)	5G NORMA project: Principal Techno-Economic	Workshop on "Business models and techno-	2017/06/12-15

	considerations in the 5G flexible networking era	economic analysis for 5G networks", EuCNC 2017	
S. Fletcher (RW)	Chairing of conference on generation innovations (including 5G debate)	CWIC2017 Cambridge, UK	2017/06/21
Abhaya Sumanasena (RW)	Keynote Seminar: Priorities for UK spectrum policy: demand, developing 5G, and the UK's international role	Westminster eForum London, UK	2017/07/06
J. R. Schneir, Ch. Chambers, J. Bradford, K. Konstantinou, G. Zimmermann, H. Droste, R. Canto, A. Ajibulu	Cost Analysis of a 5G Network with Multi-Tenancy Options	28th European Regional Conference of the International Telecommunications Society (ITS) Passau, Germany	2017/07/30 - 08/02)
M. Breitbach (DT)	Panel presentation: Bringing Network Slicing from Theory to Practice	Network Slicing in 5G: From Theory to Practice. ISWCS 2017 Bologna, Italy	2017/08/29
S. Wong (KCL)	Overview of Standardization on 5G Security	ITU (SG/WP20) Geneva, Switzerland	2017/09/04
S Fletcher (RW)	Virtualisation workshop introduction	RAN World Virtualisation Workshop Barcelona, Spain	2017/09/20
P. Arnold, D. v. Hugo	Future integrated communication network architectures enabling heterogeneous service provision	Kleinheubacher Tagung; Miltenberg, Germany	2017/09/25-27
S Fletcher (RW)	Aspects of slicing	Self-Organising Networks World London, UK	2017/10/16

Annex D. Workshops and Panel Sessions

D.1. 1st International Workshop on 5G Architecture (5G Arch 2015) at VTC 2015 Spring

This workshop took already place before the 5G NORMA project had its official start on July 1st, 2015.

Date	2015/05/11
Place	Glasgow, Scottland, UK
Scope	Challenges to future networks that cannot be solved by existing 4G networks; considerations on future mobile network architectures that can flexibly adapt their operations to requirements of specific services
Contributions	Organization and chair Presentation "A NOvel Radio Multiservice adaptive network Architecture for 5G networks"
Organization Committee	S. Redana, Nokia
Website	http://www.ieeevtc.org/vtc2015spring/workshops.php#wkshp_4

D.2. 5G Architecture Panel at VTC 2015 Fall

Date	2015/09/08
Place	Boston, USA
Scope	Panel discussion on 5G Architecture aspects; (panelists: Naseem Khan, Verizon; Reinaldo A. Valenzuela, Alcatel-Lucent Bell Labs; Andrew Clegg, Google; Andy Lippman, MIT Media Lab)
Contributions	Organization and panel moderation
Organization Committee	S. Redana, Nokia
Website	http://www.ieeevtc.org/vtc2015fall/industry.php

D.3. 1st Sino-Europe 5G Technical Workshop

The 1st Sino-Europe 5G Technical Workshop took place on November 5th in Beijing, hosted by the FuTURE FORUM 5G SIG and co-organized by 5G NORMA and METIS II. The event has attracted a large number of participants. 5G NORMA innovations, reference architecture and scenarios definition for the validation of the architecture design have been presented and discussed. METIS II has presented recent results on the RAN design and on the performance evaluation scenarios and models. Xhaul has also presented the definition of the fronthaul/backhaul integrated architecture. The 5GPPP session has been closed with a panel. The FuTURE FORUM 5G SIG has contributed to

the discussion with recent results on ultra dense network, full duplex, mMIMO and high frequency; as well as the 5G activities in the national funded projects.

The event continued on November 6th and 7th with the 2015 Future 5G ICT Summit where the version 2.0 of the White Paper from the FuTURE FORUM 5G SIG has been launched and where METIS II and 5G NORMA projects have been presenting the ongoing research work.

Date	2015/11/05
Place	Beijing, China
Scope	
Contributions	Co-organization Presentations "5G NORMA A NOvel Radio Multiservice adaptive network Architecture for the 5G era"
Organization Committee	FuTURE FORUM 5G SIG, 5G NORMA, METIS-II
Website	None

D.4. 5GPPP Architecture panel at Globecom 2015

Date	2015/12/09
Place	San Diego, USA
Scope	Design of a novel mobile network architecture that provides the necessary flexibility to offer new services in an efficient way and inherently can share or distribute infrastructure resources dynamically
Contributions	Organization
Organization Committee	S. Redana (Nokia), B. Barani (EU Commission)
Website	http://globecom2015.ieee-globecom.org/program/industry-program/panels#IF15

D.5. 3rd International Workshop on 5G Architecture at ICC'2016

Date	2016/05/23
Place	Kuala Lumpur, Malaysia
Scope	Novel End-to-End Network Architecture designs, covering RAN, Core and Transport Networks, based on flexible allocations of functions, Network Function Virtualization and software-defined implementations

Contributions	Organization and Chair Papers and presentations: - Flexible Connectivity and QoE/QoS Management for 5G Networks: the 5G NORMA view - Multi-Connectivity Functional Architectures in 5G Video demos
Organization Committee	S. Redana, A. Banchs, M. Breitbach
Website	http://icc2016.ieee-icc.org/content/workshops#W01

D.6. International Workshop on 5G RAN Design at ICC 2016

Date	2016/05/27
Place	Kuala Lumpur, Malaysia
Scope	Foster the discussion and consensus building on key 5G RAN design aspects (5G PHY, MAC, RLC, PDCP and RRC concepts, in particular related to an efficient integration of multiple novel 5G air interfaces among each other, and with evolved legacy technology)
Contributions	Co-organization
Organization Committee	METIS-II, FANTASTIC-5G, mmMAGIC and 5G NORMA
Website	http://icc2016.ieee-icc.org/content/workshops#W09

D.7. 4th Workshop on Cloud Technologies & Energy Efficiency in Mobile Communication Networks

The Fourth International Workshop on Cloud Technologies and Energy Efficiency in Mobile Communication Networks (CLEEN 2016) was co-organized by 5G NORMA, Speed 5G and Flex5Gware. The focus of the workshop was on the application of the cloud-paradigm to the radio access and backhaul network, covering technologies across PHY, MAC, and network layers. This is a well-established workshop whose focus is specifically aligned with the scope of 5G NORMA. The workshop attracted the attention of key players in the area, including those in the aforementioned projects as well as other ones. 5G NORMA contributed to the workshop with two presentations (one focusing on the SDMC concept and another one with the orchestration concept) as well as the participation in the panel, which served to exchange viewpoints of the different players on the direction of cloud technologies in mobile networks. Overall the workshop proved very useful to disseminate the key concepts of 5G NORMA as well as to gain understanding on the view of other key player in the field on the evolution of 5G NORMA elated technologies.

Date	2016/05/31-06/01
Place	Grenoble, France

Scope	Application of the cloud-paradigm to the radio access and backhaul network
Contributions	Paper "SDN for 5G Mobile Networks: NORMA perspective"; Paper "Flexible Connectivity and QoE/QoS Management for 5G Networks"
Organization Committee	Flex5Gware, Speed 5G, 5G NORMA
Website	www.flex5gware.eu/cleen2016/

D.8. International Workshop on 5G Architecture at EuCNC 2016

On 27 June 2016, the international workshop on 5G architecture organized as full-day workshop by the 5G-PPP Working Group Architecture, co-located with the EuCNC in Athens, Greece. The workshop primarily served as a platform to present the progress of the working group and the individual projects participating in the 5G-PPP WG Architecture. Furthermore, the event has been used to present and to discuss the first white paper of the working group, covering the areas of requirements and challenges, overall architecture, logical and functional architecture, physical architecture, and software network technologies.

Date	2016/06/27
Place	Athens, Greece
Scope	Presentation of White Papers produced by the 5G PPP Architecture Working Group and by the 5GMF Network Architecture
Contributions	Presentation on Overall Architecture
Organization Committee	S. Redana (Nokia), A. Kaloxylos (Huawei)
Website	http://www.eucnc.eu/2016/www.eucnc.eu/indexe1e4.html?q=node/110

D.9. 5G Architecture Panel at EuCNC 2016

Date	2017/06/29
Place	Athens, Greece
Scope	Panel discussion on architecture design principles and building blocks for the 5G era, related implementation aspects and standardization roadmap
Contributions	Organisation and panel moderation
Organization Committee	S. Redana (Nokia)
Website	http://www.eucnc.eu/2016/www.eucnc.eu/indexd662.html?q=node/108

D.10. RAN World 2016 (by Avren Events Ltd.): Working Group on MEC

Date	2016/09/27-28
Place	Dusseldorf, Germany
Scope	Prior to the event a questionnaire was designed and utilized by the conference organizers to establish key discussion areas for a panel. The workshop consisted of four panel participants from the mobile and satellite industry exploring the current and possible future use of Edge computing in networks and the various use cases.
Contributions	Chairman of working group on MEC
Organization Committee	Simon Fletcher (Real Wireless)
Website	n/a

D.11. Panel "Network Slicing and Softwarezation in 5G: Technical enablers and Business perspectives" at CSCN 2016

Date	2016/10/31-11/02
Place	Berlin, Germany
Scope	Panel session with Mr. Hans Einsiedler (Deutsche Telekom, Germany) Prof. Thomas Magedanz (Fraunhofer Fokus, Germany) Dr. Dario Sabella (Telecom Italia, Italy) Dr. Kostas Pentikousis (Travelping, Germany) Dr. Ishan Vaishnavi (Huawei, Germany)
Contributions	Organization and moderation
Organization Committee	Kostas Samdanis
Website	http://cscn2016.ieee-cscn.org/IEEE-CSCN-2016-Detailed-Program.pdf

D.12. Special Issue on "Network Slicing in 5G Systems" in IEEE Communications Magazine

The IEEE Communications Magazine is a well-known scientific journal with global reach. A special issue on "Network slicing in 5G Systems" has been scheduled for publication in May 2017. Its scope is covering many topics closely related to 5G NORMA:

- Network Slicing architectures and deployment practices
- Network slicing and multi-tenancy support in service overlay networks

- Network function (de)composition and allocation considering "atomic" functions
- QoE support management mechanisms in network slices
- Multi-service and multi-connectivity network slicing
- Next generation of orchestration architectures combining SDN and NFV
- Network resource programmability and developments on the Northbound-APIs
- Mobile Edge Computing and service optimization
- Network slicing and backhaul /fronthaul mechanisms
- Network slicing for converged fixed-wireless 5G networks

Date	Volume 55, Issue 5, May 2017
Place	IEEE Communications Magazine
Scope	Application of the cloud-paradigm to the radio access and backhaul network
Contributions	Guest editors
Organization Committee	5G NORMA: K. Samdanis, A. Banchs Non-5G NORMA: St. Wright, A. Capone, M. Ulema, K. Obana
Website	http://ieeexplore.ieee.org/document/7926919/ http://www.comsoc.org/commag/cfp/network-slicing-5g-systems

D.13. 4th International Workshop on 5G Architecture at IEEE ICC 2017

On 25 May 2017, the 4th international workshop on 5G architecture has been organized as a full-day workshop by 5G NORMA, co-located with IEEE ICC 2017 in Paris, France. The workshop featured a number of invited talks by representatives from industry and academia, e.g., Samsung, Huawei, Nokia, NEC, Orange, and Deutsche Telekom. Furthermore, 5G NORMA used the opportunities to show its demonstrators during the breaks and discuss with attendees recent research results of the project. The workshop received considerable interest by the conference attendees and provided an effective platform for discussing research results of 5G NORMA as well as other projects and companies. The main discussions were centered around network slicing and its realization in the 5G mobile network architecture including aspects of radio access networks, core network, as well as data center specific aspects.

Date	2017/05/25
Place	Paris, France
Scope	Discussion of network slicing wrt. its enablers, impact to RAN, Core and Transport Network
Contributions	Organization of the workshop Paper/presentation on "Network Slicing with Flexible Mobility and QoS/QoE Support for 5G Networks" Moderation of a panel, participation as panelists Presentation of 5G NORMA demonstrators

Organization Committee	NORMA: Peter Rost, Albert Banchs Non-NORMA: Alexandros Kaloxylos (Huawei), Matthew C. Valenti (West-Virginia University, USA)
Website	http://icc2017.ieee-icc.org/program/workshops#WT01

D.14. RAN World 2017: Working Group 7 Virtualization

Date	2017/09/20
Place	Barcelona, Spain
Scope	Prior to the event a virtualisation questionnaire was designed which was issued to the participants prior to the event. Responses to the questionnaire, a keynote from the workshop chair and then four further presentations on various aspects of virtualisation from core to RAN were discussed in a panel. Panelists: - Luis Velasco, Professor - Universidad Politécnica de Catalunya - Mansoor Hanif, Director of Converged Networks, Research and Innovation - BT - Raj Singh, Vice President and General Manager - Cavium - Sergey Lagutik, Head of Operations - Velcom
Contributions	Chairman of working group on Virtualization
Organization Committee	Avren Events Ltd, Simon Fletcher (RW)
Website	http://www.ranworldevent.com/conference/agenda Summary from workshop: http://www.ranworldevent.com/working-groups/virtualisation-working-group-20-september-2017

D.15. Track on "Building the Foundations of URLLC" at Executive Industry Events Ltd

Date	2017/11/14
Place	London, UK
Scope	An initial approach in mid-2016 from a conference organizer to investigate new themes around 5G led to a dissemination of key challenges observed from the 5G NORMA project, This dialogue led to RW being asked to join the committee and then involvement in various plenary and track sessions during the one day conference. The format of the event was based on plenary and parallel track session. Content covered investigation of key 3GPP features and release dates, 5G-IA project landscape. With a focus on architectural considerations the implications of slice provision based on URLLC requirements were

	important. Focussed vertical led sessions were established to illicit requirements in the form of use cases and KPIs from the verticals (public safety, transport, energy, advanced manufacturing), these were presented by Senior people working in the verticals. 5G NORMA was able to influence the agenda setting and ensure that costs and business model discussions were part of the overall agenda. In post event meetings the organizing committee agreed that the event would be held again in 2018. As the agenda is developed and speakers are invited to the event in 2018, continuity of thought is assured through from 5G NORMA into 5G MoNArch as liaison to the conference hands to 5G MoNArch at the end of 2017.
Contributions	Plenary and Tracks Chair and member of the inaugural organizing committee
Organization Committee	Simon Fletcher (RW)
Website	http://urllc2017.executiveindustryevents.com/Event/programme

Annex E. Tutorials and invited talks

Author	Title	Event	Date
M. Dohler (KCL) et al.	Plenary keynote presentation: An Internet of Skill ... where Robotics meets AI and the Tactile Internet	IEEE ICC 2016	2016/05/26
M. Valenti (West Virginia University), P. Rost (Nokia) & A. Checko (MTI Radiocomp)	Tutorial: Centralized Radio Access Networks: Moving Baseband to the Cloud	IEEE ICC 2016	2016/05/23-27
T. Taleb, V. Sciancalepore, K. Samdanis	Tutorial: On Network Slicing and Network Softwarisation: Enablers for 5G Mobile Systems	IEEE ICC'17	2017/05/25
P. Schneider (Nokia)	Keynote speech: Securing 5G Mobile Networks Built on Distributed Telco Clouds	ETSI Security Week	2017/06/15
P. Rost (Nokia)	Keynote speech: Enabling Communication Services for Vertical Industries through Network Slicing and Mobile Edge Cloud	CLEEN workshop	2017/06/22
F. Z. Yousaf (NEC)	Invited Talk: NFV & SDN: Technology Enablers for 5G – The Twain Shall Meet!	IEEE 5G Summit 2017	2017/10/09
K. Samdanis (Huawei), V. Sciancalepore (NEC), O. Holland (KCL)	Tutorial: Network Slicing in 5GNetworks: Concepts, theory, standardization and practice	IEEE Globecom 2017	2017/12/08
V. Sciancalepore	Tutorial: 5G Network Slicing: Concepts, Use Cases, Solutions & Practice	IEEE ICC 2018	2018/05/20

Annex F. Summer School

The 5G NORMA Summer School took place from June 20-23, 2016, London, UK, kindly hosted by the King's College London.

The 5G NORMA Summer School has been tailored towards network and radio engineers and researchers active or interested in virtualized and programmable future mobile networks, targeting Post Doctoral researchers, PhD and Master students as well as participants from the mobile industry and other organizations (verticals) interested in the area of 5G networks and how this emerging technology can shape their business.

The aim of the 5G NORMA Summer School has been to provide architectural views as well as technical details on the challenges and potential solutions from key leading re-searchers across Europe in the scope area of 5G wireless communications. The aim was to touch upon on issues related to network softwarization, wireless access and core network virtualization, which undoubtedly constitute some of the most popular topics in the wired and the wireless networking domains among both the academic and the industrial communities.

The event was sponsored by the UK & Republic of Ireland chapters of IEEE Communications Society and IEEE Vehicular Technology Society, as well as by the Information Technology Society in the VDE. Furthermore the 5G NORMA Summer School was part of the London Tech Week.

Agenda overview:

Day 1: 5G eco system

- Keynote speeches by EU commission, network operators, vertical industries
- Panel on RAN architecture
- Panel on Software network architecture

Day 2 and Day 3: Technical sessions (by 5G NORMA and external researchers)

- Requirements and economics
- Architecture and virtualization
- Data plane
- Security
- SDN and NFV
- Network Control, Orchestration and Management

Annex G. Press Releases

Source	Title	Link	Date
5G NORMA	Telecom industry and European academia join forces to develop a multiservice mobile network architecture for the 5G era	https://5gnorma.5g-ppp.eu/nokia-press-release-1-july-2015/ http://networks.nokia.com/news-events/press-room/press-releases/telecom-industry-and-european-academia-join-forces-to-develop-a-multiservice-mobile-networ	2015/07/01
Real Wireless	Telecom industry and European academia join forces to develop a multiservice mobile network architecture for the 5G era	http://www.realwireless.biz/2015/07/01/telecom-industry-and-european-academia-join-forces-to-develop-a-multiservice-mobile-network-architecture-for-the-5g-era/	2015/07/01
IMDEA / UC3M	Telecom industry and European academia join forces to develop a multiservice mobile network architecture for the 5G era	https://5gnorma.5g-ppp.eu/imdea-press-release-7-july-2015/	2015/07/07
DT	With joint forces to a multiservice network architecture for 5G	http://www.telekom.com/media/company/281544	2015/07/07
Azcom	Azcom joins 5G NORMA to develop a multiservice mobile network architecture	http://www.azcom.it/index.php/newsroom/press-releases/telecom-industry-and-european-academia-join-forces-to-develop-a-multi-service-mobile-network-architecture-for-the-5g-era/	2015/07/29
Nokia	Nokia Networks unveils its programmable 5G multi-service architecture #NetworksPerform	http://networks.nokia.com/sites/default/files/document/nokia_networks_2015_09_02_en_5g_launch.pdf	2015/09/02
NEC	NEC joins industry and academia in Europe to develop a multi-service mobile network architecture for the 5G era	http://www.nec.com/en/press/201509/global_20150923_01.html	2015/09/23
AZCOM	Azcom to Showcase C-RAN, Network In a Box Solutions and Demo 5G Network Architecture Concepts at Mobile World Congress 2016	http://www.azcom.it/index.php/newsroom/press-releases/azcom-to-showcase-c-ran-network-in-a-box-solutions-and-demo-5g-network-architecture-concepts-at-mobile-world-congress-2016/	2016/02/18
NOMOR Research	Nomor Research shows 5G E2E Demonstration at the MWC 2016	http://www.nomor.de/home/company/company-news/news/news/nomor-research-shows-5g-e2e-demonstration-at-the-mwc-2016	2016/02/19
ATOS	Atos impulsa el 5G	http://es.atos.net/es-es/home/quienes-somos/noticias-y-eventos/noticias/2016/pr-2016_04_19.html	2016/04/19

NOMOR Research	Nomor Research shows 5G E2E Demonstration at the MWC 2017	http://www.nomor.de/home/company/company-news/news/news/nomor-research-shows-5g-e2e-demonstration-at-the-mwc-2018#idC4V_983d6HDSQzdieXFWpw	2017/02/22
AZCOM	Azcom Gains Momentum in 5G 5G demo to showcase NORMA Multiservice Architecture	http://www.prnewswire.co.uk/news-releases/azcom-gains-momentum-in-5g-614862814.html	2017/02/27

Annex H. Social Media and other Dissemination Activities

5G NORMA is present in the internet and the following social media:

- 5G NORMA web site: https://5gnorma.5g-ppp.eu/
- Twitter: 5G NORMA project @5G_NORMA
- Facebook: facebook.com/5GNORMA
- YouTube: https://www.youtube.com/channel/UCvbZdZ3oN-yiRa6-dXJQkMw

H.1. Organization of the Website

There are two main components: the common layout and the main content area with the current page in the center. As the user navigates through the various menus, only the content in the center page changes. Within the common layout, the main components are:

- Header with the project logo and title;
- Menu bar with all sections and subsections;
- Footer with easy access links to project information, dissemination and the 5G PPP website
- Area on the right-hand side with a search field, direct links to social media channels, latest news and press releases, and embedded windows showing the 5G NORMA twitter account.

Figure H-1 shows the home page of the 5G NORMA project website.

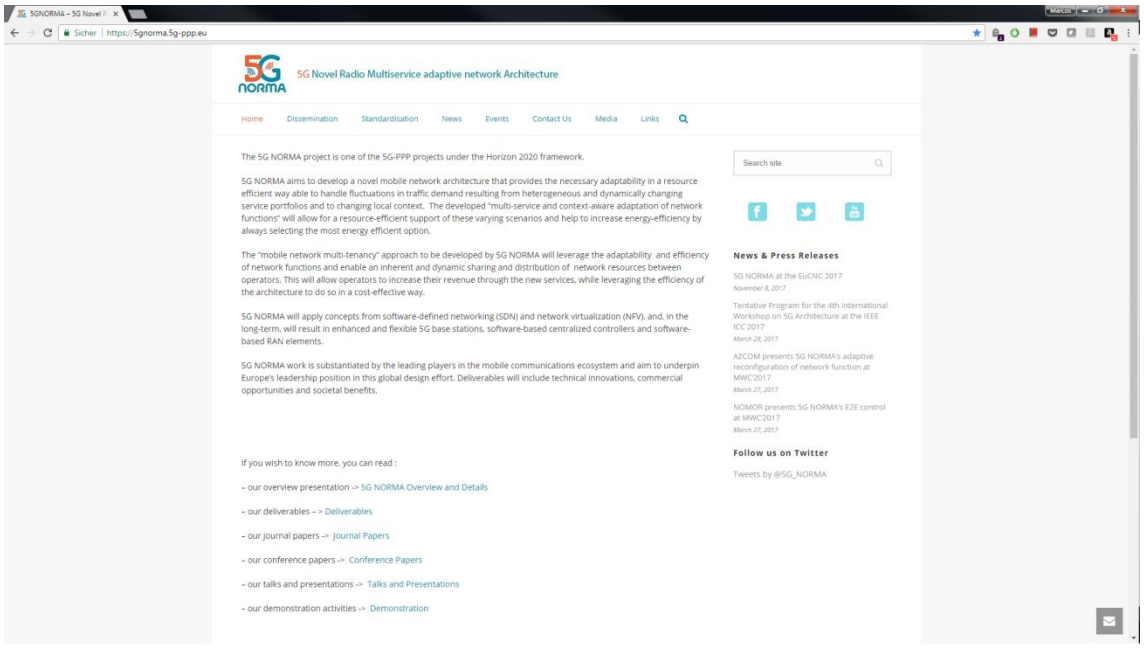

Figure H-1: Home page of the 5G NORMA project website

Here is the breakdown of sections and subsection, all accessible through the menu bar:

- Home
  - Rationale and Objectives
  - Consortium
- Dissemination
  - Public Deliverables

    - Journals
    - Conference Papers
    - Talks and Presentations
    - Summer School
    - Demonstration
- Standardisation
- News
    - Latest News
    - Press Releases
- Events
- Contact Us
- Media
    - Image Gallery
    - Videos
- Links

As can be seen, the menus and submenus cover all relevant items of interest for a curious visitor, and follow an intuitive design. In order to access the subsection in the navigation menu, the user has to hover over with a cursor and then click. The 5G NORMA website is periodically updated with project achievements, deliverables, news and events. It will be accessible until three years after the project ends.

H.2. Usage Statistics for the website

The Google Analytics tool can be used to collect statistics on the website. The following statistics have been collected for the period 16.05.2016 – 20.11.2017:

- Total number of sessions in this period was 8859;
- the maximum number of sessions in one week was 219 (19 Jun 2016 – 25 Jun 2016, i.e. the week when the 5G NORMA Summer School took place at King's College London);
- the number of users that accessed the website in this period was 5297;
- the number of page views was 21107;
- average session duration was 2:18.
- about 40 % of the users have accessed the website more than once.

Figure H-2 shows all the mentioned statistics and a diagram of sessions per week.

It can be concluded from all this data that the website has a good visibility and that it is regularly visited. Number of sessions per week range from 40 to 220. The most visited pages are the Home Page and the Public Deliverables section, which proves the high interest in the output of the 5G NORMA project.

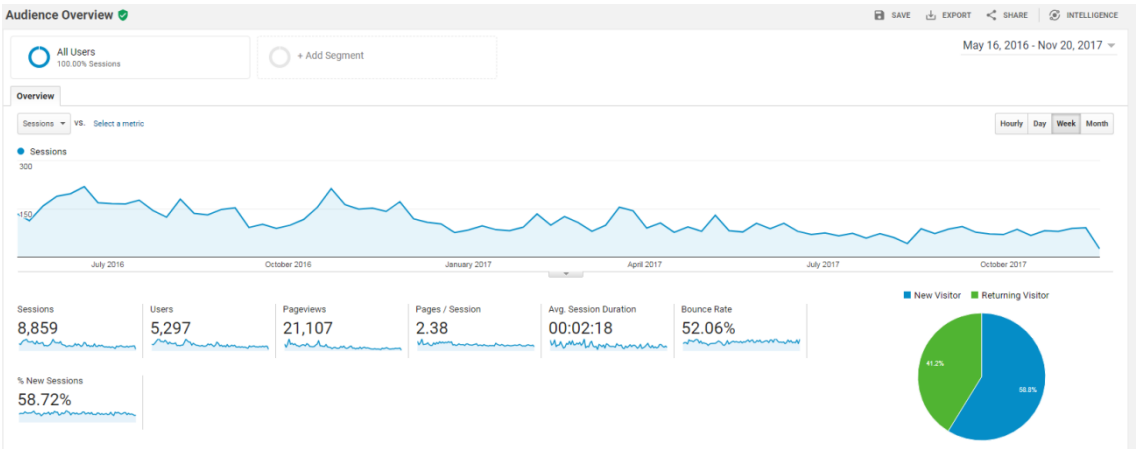

Figure H-2: Google Analytics on the usage of 5G NORMA web site.

H.3. Social Media

Twitter

5G NORMA's Twitter account is www.twitter.com/5G_NORMA. The following figure shows 5G NORMA's Twitter account.

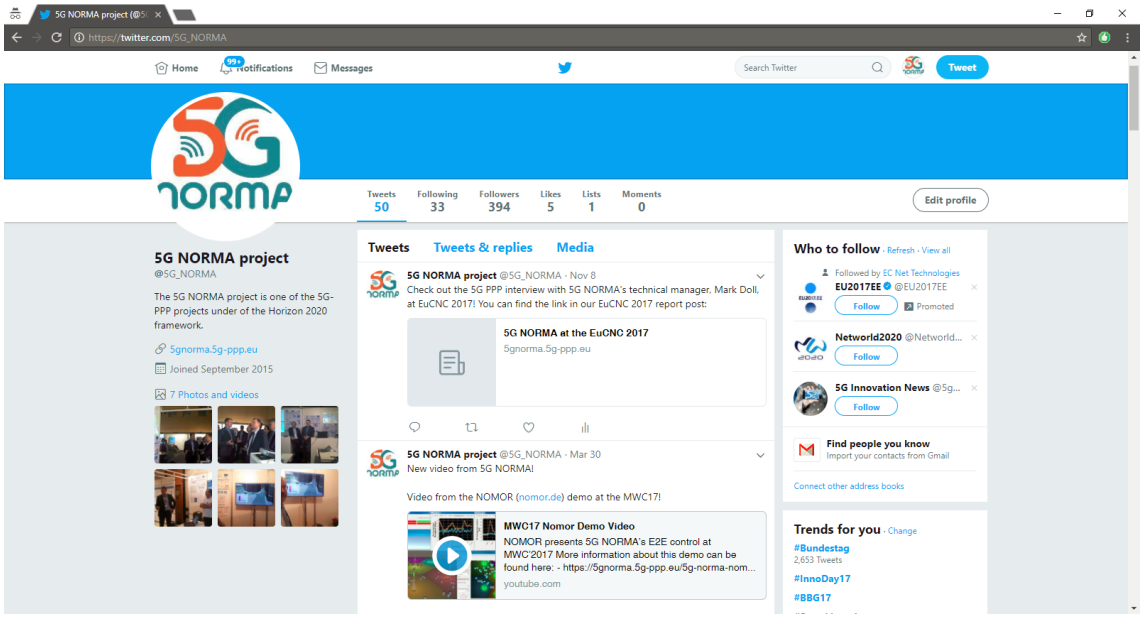

Figure H-3: 5G NORMA's Twitter account

Facebook

5G NORMA also has a Facebook profile under www.facebook.com/5GNORMA. The appearance of the corresponding web page is shown in the next figure.

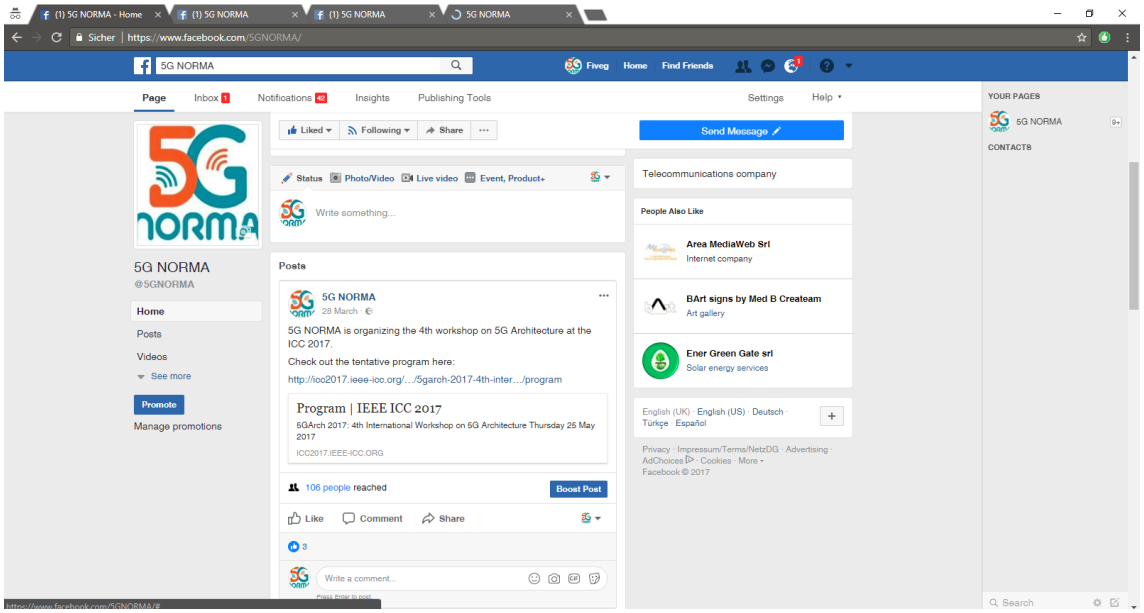

Figure H-4: 5G NORMA's Facebook page

Youtube

5G NORMA project's Youtube channel can be found under www.youtube.com/channel/UCvbZdZ3oN-yiRa6-dXJQkMw. This web page is shown in the figure below.

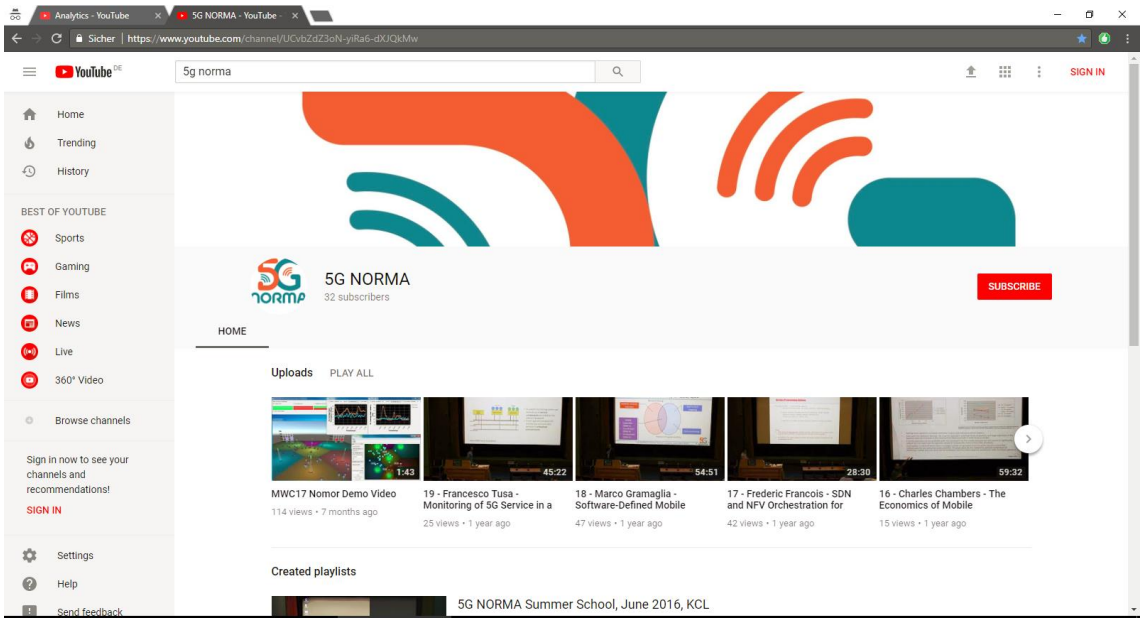

Figure H-5: 5G NORMA's Youtube channel

H.4. Communication and dissemination activities on these media

Source	Title	Activity	Date
Real Wireless, Pulborough, UK	Real Wireless joins prestigious consortium to assess the socioeconomic benefits of 5G Network Architectures https://www.real-wireless.com/real-wireless-joins-prestigious-consortium-to-assess-the-socioeconomic-benefits-of-5g-network-architectures/	Blog article	2015/07/01
S. Redana (Nokia)	5GPPP@EuCNC2015: Simone Redana, 5GNORMA https://www.youtube.com/watch?v=6hGgntQ6JIY	Interview	2015/07/08
S. Redana (Nokia)	5G PPP – THE CONTRIBUTION OF THE 5G PPP PROJECTS TO 5G https://www.youtube.com/watch?v=UjipiIayAZ4	Interview	2015/10/09
M. A. Puente (ATOS)	5G NORMA: A Novel Radio Multiservice adaptive network Architecture for the 5G era; https://www.youtube.com/watch?v=lrAumMqIDNI	YouTube video	2015/10/28
5G NORMA	1st Sino-Europe 5G Technical Workshop hosted by the FuTURE FORUM 5G SIG and co-organized by 5G NORMA and METIS II https://5gnorma.5g-ppp.eu/1st-sino-europe-5g-technical-workshop-hosted-by-the-future-forum-5g-sig-and-co-organized-by-5g-norma-and-metis-ii-2/	News post on 5G NORMA web site	
Markus Breitbach (DT)	News post on 5G NORMA F2F meeting in Madrid https://5gnorma.5g-ppp.eu/5g-norma-f2f-meeting-on-nov-24-26-2015-in-madrid/	News post on 5G NORMA web site	2015/12/03
Chr. Mannweiler (Nokia)	Contributions to 5G Infrastructure Association (5G IA) White Paper “5G empowering vertical industries” https://5g-ppp.eu/wp-content/uploads/2016/02/BROCHURE_5PPP_BAT2_PL.pdf	White paper, released at MWC 2016, Barcelona, Spain	2016/02/22-25
Markus Breitbach (DT)	News post on 5G NORMA F2F meeting in Paris https://5gnorma.5g-ppp.eu/5g-norma-plenary-meeting-on-march-15-17-2016-paris/	News post on 5G NORMA web site	2016/03/23
Simon Fletcher (RW)	Engaging with vertical markets for 5G planning TelecomTV: http://www.telecomtv.com/articles/etsi-5g-summit/engaging-with-vertical-markets-for-5g-planning-13592/	TV interview	2016/04/21

Markus Breitbach (DT)	News post on ETSI 5G Summit, 2016/04/21 https://5gnorma.5g-ppp.eu/simon-fletcher-engaging-with-the-vertical-markets-for-5g-standards-planning/	News post on 5G NORMA web site	2016/06/01
Azad Ravanshid (NOMOR)	Video of 5g NORMA's SW demo at MWC'2016: https://www.youtube.com/watch?v=nJVS2wZs5iQ	YouTube video	2016/06/01
Roberto Lambiase (AZCOM)	Benefit of low latency communication in wireless networks. Video of 5G NORMA's HW demo at MWC'2016 https://www.youtube.com/watch?v=CAlyQMUtv6k	YouTube video	2016/06/01
Peter Rost (Nokia), Mischa Dohler (KCL) Simone Redana (Nokia)	5G NORMA at King's College London: Special Report from 5G NORMA Summer School at King's College London http://www.telecomtv.com/articles/5g/why-5g-norma-is-central-to-the-evolution-of-telecoms-networks-13807/	TV Interview	2016/06/30
P. Rost (Nokia), M. Breitbach (DT	5G NORMA: A Novel Radio Multiservice adaptive network Architecture for the 5G era based on Network Slicing Updated version (10/2016): https://bscw.5g-ppp.eu/pub/bscw.cgi/d117642/Euro%205G%20Annual%20Journal%202016.pdf Original publication (07/2016): https://bscw.5g-ppp.eu/pub/bscw.cgi/d106832/EURO-5G_Annual%202016_July%202016_V2.pdf	European 5G Annual Journal	2016/07
M. Dohler (KCL)	Opening of 5G Summer School (London Tech Week) https://www.youtube.com/watch?v=k9PNtFpZ74Y	YouTube video	2016/07/02
P. Rost (Nokia)	5G NORMA: Interview with P. Rost, taken at EuCNC 2016 https://youtu.be/0ktkO6tjNcU	YouTube video	
NOMOR	MWC17 Nomor Demo Video https://www.youtube.com/watch?v=13FWyeQ7WXk	YouTube video	
H. Droste (DT)	5G Architecture Design Verification https://5gbook.org/2017/04/20/5g-architecture-design-verification/	Web site of the "5G Book"	2017/04/20
M. Gramaglia (UC3M)	5G NORMA: A NOvel Radio Multiservice adaptive network Architecture for the 5G era based on Network Slicing https://bscw.5g-ppp.eu/pub/bscw.cgi/d200818/Euro%205G%20Annual%20Journal%202017.pdf	European 5G Annual Journal	2017
M. Doll (Nokia)	Interview taken at EuCNC 2017 https://www.youtube.com/watch?v=xagsRS8JatA	YouTube video	2017/10/09

M. Rates Crippa (TUKL)	News report on 5G NORMA's booth at EuCNC 2017 https://5gnorma.5g-ppp.eu/5g-norma-at-the-eucnc-2017/	News report on 5G NORMA web site	2017/11
Diomidis Michalopoulos, Mark Doll, Peter Rost (Nokia)	Multi-service RAN customization: A 5G NORMA Approach	Eurescom Magazine	not yet published
S. Khatibi, K. Shah, Y. Li (NoMoR)	Flexible Virtual Cell for 5G Heterogeneous Networks	NoMoR Company web site	not yet published
S. Khatibi, F. Sheikh (NoMoR)	Service-Aware Network Reconfiguration for 5G Networks	NoMoR Company web site	not yet published

Annex I. Cooperation with 5G PPP projects

Activity	Title	Audience	Date
Phone conference	Bilateral cross-project discussion between 5G NORMA and METIS-II	5G PPP project METIS-II	2015/09
Workshop	METIS-II Workshop	5G PPP project METIS-II	2015/09/28-29
Meeting	Bilateral cross-project discussion between 5G NORMA and 5G Crosshaul	5G PPP project 5G Crosshaul	2015/11/26, Madrid, Spain
Workshop	METIS-II Workshop	5G PPP project METIS-II	2016/01/21-22
Presentation	5G NORMA: A NOvel Radio Multiservice adaptive network Architecture for the 5G era; 5G NORMA Functional Architecture	5G PPP project mmMAGIC	2016/02/02
White Paper	5G-PPP use cases and performance evaluation modeling	Civil society	April 2016
Presentation	5G NORMA: An adaptive mobile network architecture; (EuCNC 2016 workshop W04a – "Next Generation fronthaul/backhaul integrated transport networks")	5G PPP projects; scientific community	2016/06/27-30 Athens, Greece
White Paper	View on 5G Architecture https://5g-ppp.eu/wp-content/uploads/2014/02/5G-PPP-5G-Architecture-WP-July-2016.pdf	Civil society	July 2016
Workshop	5G NORMA – RAN Slicing	5G PPP projects; scientific community	2017/02/06-07; Athens, Greece
White Paper	5G Innovations for new Business Opportunities https://5g-ppp.eu/wp-content/uploads/2017/03/5GPPP-brochure-final-web1-with-Author-credits.pdf	Civil society	March 2017
Workshop	5G NORMA A NOvel Radio Multiservice adaptive network Architecture for the 5G era	5G PPP projects; scientific community	2017/03/30-31; Chertsey, UK
White Paper	5G PPP Phase1 Security Landscape	Civil society	2017/06
White Paper	5G-PPP use cases and performance evaluation	Civil society	2017/07/17
White Paper	Revised 5G Architecture White Paper	Civil society	Public consultation finished; publication planned for Q4/2017

Paper	Leading Innovations Towards 5G: Europe's Perspective in 5G Infrastructure Public-Private Partnership (5G-PPP)	Scientific community	CRAFT 2017 (PIMRC'17 WS-02)
Report	5G PPP Standardization results and activities in Phase 1, 2015-2017	5G PPP projects, Pre-Standardization WG	Publication pending

Annex J. References to 5G NORMA

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7. SecuPedia: “5G-NORMA-Projekt” (in German). http://www.secupedia.info/wiki/5G#5G-NORMA-Projekt; visited 2017-11-14