Project**:** H2020-ICT-2014-2 5G NORMA

Project Name:

5G Novel Radio Multiservice adaptive network Architecture (5G NORMA)

Intermediate Report D7.1

Communication and Dissemination – Intermediate Report

Date of delivery:	30/06/2016	Version:	1.0
Start date of Project:	01/07/2015	Duration:	30 months

Document properties:

Document Number:	H2020-ICT-2014-2 5G NORMA/D7.1
Document Title:	Communication and Disemmination
Editor(s):	Konstantinos Samdanis (NEC)
Authors:	Konstantinos Samdanis (NEC), Ignacio Labrador Pavon (ATOS), Markus Breitbach (DT), Mark Doll, Simone Redana, Jukka Salo, Vinh Van Phan (Nokia), Friderikos Vasilis (KCL), Ignacio Berberana (Telefonica), Marcos R. Crippa (TUKL)
Contractual Date of Delivery:	30/06/2016
Dissemination level:	PU[1]
Status:	Final
Version:	1.0
File Name:	5G NORMA D7.1

Revision History

Revision	Date	Issued by	Description
1.0	30.06.16	5G NORMA WP7	Final version

Abstract

This report describes our approach to dissemination activities of the 5G NORMA project. It presents the journal and conference publications, the workshops, panels, special issues and demonstrations organized by 5G NORMA. It also provides information regarding the public reaching activities of 5G NORMA including the website, social media, interviews and videos as well as summer schools and other teaching activities. Finally, it provides a roadmap of 5G NORMA for standardization contributions and partner dissemination activities.

Keywords

Dissemination, standardization, regulation.

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

PU = Public

Executive Summary

This deliverable provides information on the dissemination and exploitation plan and activities that took place so far within the 5G NORMA project. Beside the academic publications in conferences, workshops, and journals, 5G NORMA has (co-)organized a number of workshops, panels, Proof of Concept (PoC) demonstrations, widely published results and organized a summer school and other teaching and training activities for students, set-up a website for the project and participated in social media dissemination such as Facebook and Twitter; 5G NORMA has further provided a number of High Definition-videos and interview material to the public. 5G NORMA has also cooperated with other 5G Public Private Partnership projects, aligning ideas regarding the network architecture and pre-standardization activities and has created a roadmap plan for disseminating in standards considering NGMN, 3GPP, ETSI, ITU-T, IETF and IEEE.

Table of Contents

List of Figures

List of Acronyms and Abbreviations

3GPP	Third Generation Partnership Project
5G	Fifth Generation Mobile Communications
5G PPP	Fifth Generation Public Private Partnership
API	Application Programming Interface
DMM	Distributed Mobility Management
DoW	Description of Work
ETSI	European Telecommunications Standards Institute
HD-video	High Definition-video
ICT	Information and Communications Technology
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
eDCN	evolved Dedicated Core Network
eNB,	evolved Node B
IoT	Internet of Things
IMT-2020	International Mobile Telecommunications - 2020
IRTF	Internet Research Task Force
ITU	International Telecommunication Union
ITU-T	ITU – Telecommunication Standardization Sector
KPI	Key Performance Indicator
LTE	Long Term Evolution
MAC	Medium Access Control
MANO	Management and Orchestration
MEC	Mobile Edge Computing
MIMO	Multiple-Input Multiple-Output
mm-Wave	millimeter Wave
MWC	Mobile World Congress
NFV	Network Function Virtualization
NGMN	Next Generation Mobile Networks
OAM	Operations, Administration and Management
OSS	Operation Support System
PHY	Physical Layer
PoC	Proof of Concept
QoS	Quality of Service
RAN	Radio Access Networks
RAT	Radio Access Technology
SDMC	Software Defined Mobile Controller
SDN	Software Defined Networks
SFC	Service Function Chaining
S-GW	Serving Gateway
SME	Small and Medium Enterprises
TCP/IP	Transport Control Protocol / Internet Protocol
VNF	Virtual Network Function
V2X	Vehicular-to-anything
UE	User Equipment
UHF	Ultra High Frequency

1 Introduction

1.1 Objective of the document

This deliverable provides information on the 5G NORMA dissemination activities carried out since the beginning of the project, while introducing also a gap analysis and planning for standardization efforts for the ongoing 5G NORMA project. The main objective of 5G NORMA is to investigate the emerging 5G mobile network architecture considering a novel management and orchestration architecture as well as mechanism for the emerging data and control layers. 5G NORMA will significantly shape the future 5G systems considering the network architecture and deployment perspective, while at the same time influencing global pre-standardization and regulation processes. This report elaborates the 5G NORMA project's plan for exploitation and dissemination activities and summarizes the achievements and activities so far providing an assessment of their impact.

5G NORMA aims to contribute to the evolution of mobile radio networks towards 5G in a way that meets the needs and requirements of the whole society in general and of users, network operators and equipment manufacturer in particular. To achieve this objective, the dissemination and communication activities have been structured in five areas:

- Communication to the General Public: (i) contributing to discussions about 5G in the society and (ii) interactive communication with potential users. More details are provided in section 2.
- Standardization: (i) introducing a plan for contributing the 5G NORMA Research and Development (R&D) at the most relevant standardization bodies including 3GPP, NGMN, ETSI, IEEE and IETF and (ii) contributing on the 5G PPP Architecture Working Group, Pre-standardization WG and Security WG. More details on standardization bodies are provided in section 3, while the activities of 5G PPP WGs are provided at section 5.
- Scientific dissemination and PoC demonstrations: (i) scientific publications in journals, conferences and workshops, (ii) organizing workshops at major scientific conferences (iii) delivering talks at conferences and industry events, (iv) providing PoC at industry events and European/academic conferences. More details are provided in section 4.
- Cooperation with other 5G PPP projects: 5G NORMA is actively seeking for cooperation with other projects in the H2020 5G PPP program, by participating in several working groups of the 5G PPP program as well as in bilateral discussions with other projects. More details are provided in section 5.
- Partners specific exploitation plan elaborating the ways that each partner can use the results of the 5G NORMA project in section 6

1.2 Structure of the document

The remainder of this report is organised as follows. Section 2 addresses the communication to the general public, i.e. to the society as a whole as well as to vertical industries as potential users. Section 3 elaborates the standardization gaps considering different bodies in where 5G NORMA can have an impact, providing also a roadmap for potential contributions. Section 4 summarizes the dissemination activities with respect to scientific contributions to journals, conferences and workshops as well as the PoC demonstrations at industry events and conferences. Section 5 presents the cooperation of 5G NORMA with other 5G PPP projects. Section 6 concludes with a summary and an outlook onto dissemination and communication activities in the remaining 1.5 years of 5G NORMA project work. Finally, Annex A-I provide detailed lists of dissemination activities.

2 Dissemination to the general public

2.1 Overview

The task 7.1 aims at promoting the outcomes and activities of 5G NORMA to the general public. Through multiple channels, 5G NORMA can communicate its benefits, and interested parties can follow the progress of the work.

In the next section, the main dissemination activities carried out since the beginning of the project for the general public will be listed and detailed. These activities included: the project's website (https://5gnorma.5g-ppp.eu/), which acts as a central point of contact with the general public; social media channels, where 5G NORMA can directly talk to interested parties, promote its events, and interact other 5G projects; press releases, used by the individual partners to promote their activities within the project; and the 5G NORMA 2016 Summer School, the main public dissemination of this first phase of the project, hosted by King's College London, bringing together researchers, verticals and the mobile industry to discuss 5G networks and promote 5G NORMA.

Section 2.3 will wrap this chapter by an overall evaluation of all dissemination activities, as well as the current and foreseen impact they have.

2.2 5G NORMA activities

2.2.1 Public website

The public 5G NORMA website was established for the project in order to disseminate information on the project work and results. A unique domain name, https://5gnorma.5g-ppp.eu/, was purchased for that purpose and the website was built using the Word Press platform.

This section gives an introduction to the 5G NORMA website and includes statistics on how the website has been accessed by the wide audience. The website has the following main pages: **Home**, **Dissemination**, **Standardization**, **News**, **Contact Us**, and **Links**. The navigation menu appears at the top of each page and makes it easy for visitors to find the information. Some of the items in the navigation menu have submenus which are visible when hovering over with a cursor.

The website audience is monitored thanks to Google Analytics. It allows monitoring the 5G NORMA website audience versus time, location and visitors' behaviour.

2.2.1.1 Introduction to 5G NORMA website

The 5G NORMA website is one of the main communication tools from the project towards the public audience. The website was designed to satisfy high-standard requirements of accessibility and efficiency, without being overcomplicated or difficult to use. It is periodically being updated promoting achievements, news and events during the progress of works. It will be functional until three years after the project closure.

All pages of the website share a common layout:

- A header with the project logo and title;
- A menu bar with folding lists giving the direct access to any page;
- A main content area;
- A footer with links to the project and dissemination information; and
- The latest news and updates are located on the right-hand side of each page.

As an example of the different pages, Figure 1 includes the screenshot from the 'Home' page, which is the front space of the website. It is structured in such a way that it provides a brief overview and basic information about the 5G NORMA project. This page has also two sub-pages: 'Rationale and Objectives', and 'Consortium'.

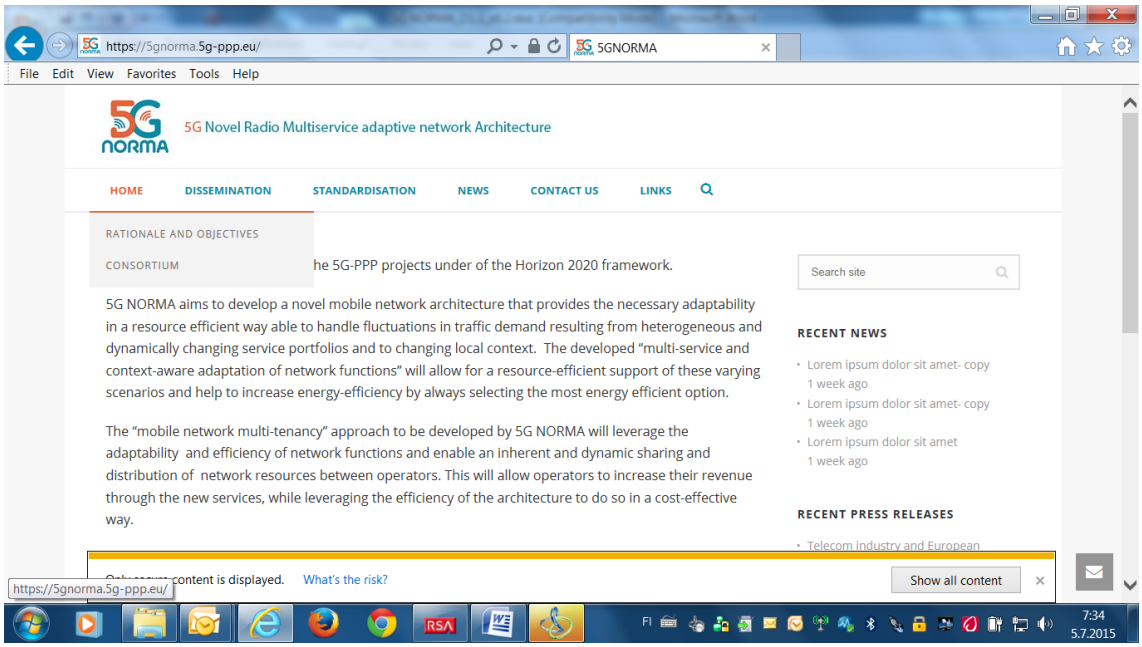

Figure 1: Home page of the 5G NORMA website.

2.2.1.2 Statistics on the usage of 5G NORMA website

The 5G NORMA web site has been a good means for disseminating the results from the project work within and outside the 5G research and development community. The Google Analytics tool was used to collect statistics on accessing the website. The statistics from the period 1.10.2015 – 15.5.2016 show that

- total number of sessions in this period was 3,864;
- the maximum number of sessions in one week was 271 (22 Nov 2015 – 28 Nov 2015);
- the number of users accessed the website in this period was 2,703;
- the number of page views was 9,621;
- the average session duration was 2:21.

The diagram in Figure 2 shows that since the beginning of the year the average number of sessions per week has been quite steady, i.e., about 100.

About 30 % of the users have accessed the website more than once. This share of all users is expected to grow, when more deliverables will be available for reviewing and downloading.

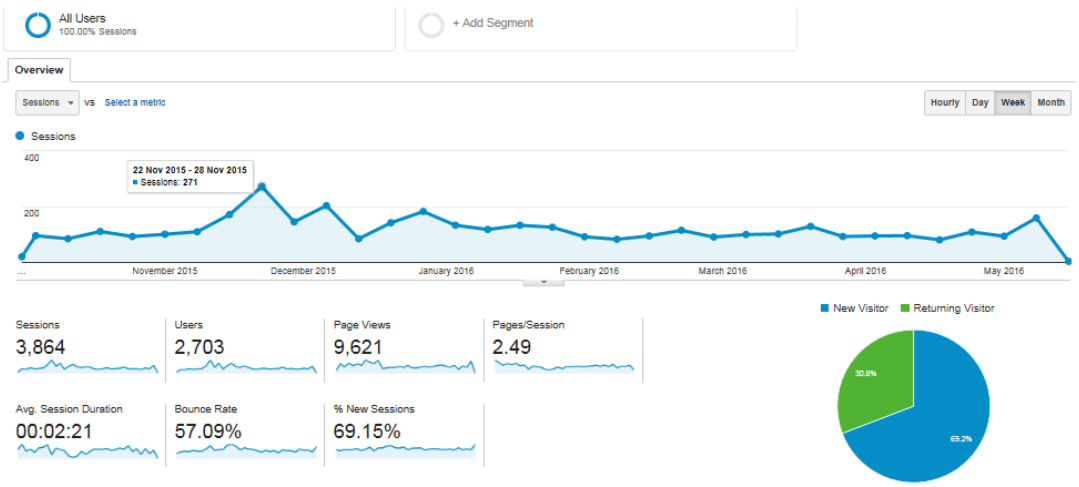

Figure 2: Google Analytics on the usage of 5G NORMA web site.

2.2.2 Social media

The 5G NORMA website is the main portal for all relevant information someone might want to get about NORMA. In order to establish more lines of communication with the general public, 5G NORMA created profiles in the currently most popular social media platforms: YouTube, Twitter and Facebook. The target audience here encompasses interested end-users, service providers, professionals, standardization bodies, network operators, 5G-PPP projects, and other 5G projects, among others.

All these channels are used to announce face-to-face meetings, talks, workshops, and presentations on conferences and congresses. Facebook and Twitter allow interested professionals to keep track of the latest events from 5G NORMA. YouTube provides us an easy-to-use and free hosting platform for audio and visual material. 5G NORMA has created a demo video presenting the main concepts and innovations of the project, which can be accessed anywhere in the world, hosted in YouTube.

Twitter

The URL to 5G NORMA's Twitter account is www.twitter.com/5G_NORMA.

Twitter connects 5G NORMA with other 5GPPP projects, which helps promoting the projects involved in the partnership. It is used to make followers aware of 5G NORMA activities like conferences, workshops or Calls for Papers. Details related to these announcements are provided on 5G NORMA's web site.

In terms of followers, 5G NORMA has 97 followers, including many professionals, research projects, companies and 5G news accounts. Furthermore Tweets from other 5G PPP projects are re-tweeted to announce them to a wider community. For this purpose, 5G NORMA follows 26 Twitter accounts, mostly 5G-PPP and 5G projects. Some accounts to note are:

- @5GPPP
- @metis2020
- @Crosshaul_eu
- @ict_ijoin
- @Superfluidity5g
- @FANTASTIC5G

Facebook

5G NORMA can be found on Facebook under www.facebook.com/5GNORMA. Like Twitter, Facebook is used to inform about the latest events from 5G NORMA, referring users also to

detailed announcements on the 5G NORMA web site. Facebook doesn't count followers, but how many "likes" your page has. Currently, the project's page has 42 "likes".

YouTube

The 5G NORMA project has setup its own channel on YouTube under www.youtube.com/channel/UCvbZdZ3oN-yiRa6-dXJQkMw. This channel is used to share e.g. demo videos that have been presented at conferences like ICT or ICC with people that could not attend these conferences or want to see the demos again. 5G NORMA's demo video from ICT'2015 has 721 views (379 in NORMA's YouTube channel, 327 in 5GPPP's YouTube channel, and 15 views in Facebook).

Other video channels

The project has been featured in other video channels. 5GPPP`s YouTube has two videos related to NORMA:

- 5GPPP@EuCNC2015 Simone Redana 5GNORMA
  www.youtube.com/watch?v=6hGgntQ6JIY, published on 08.07.2015

  Simone Redana from Nokia Networks explains the 5G PPP 5G NORMA project and his vision on 5G and why 5G PPP is an important initiative.

  Video shot at the European Conference on Networks and Communications EuCNC 2015 conference in Paris in July 2015 by the 5-Alive project supported by the European Commission

- 5G PPP - THE CONTRIBUTION OF THE 5G PPP PROJECTS TO 5G
  www.youtube.com/watch?v=UjipiIayAZ4, published on 10.09.2015

  Interventions from Simone Redana, 5G NORMA, and other 5G PPP project leaders explaining how the first 5G PPP projects will contribute to 5G.

- 5GPPP@EuCNC2016 Peter Rost 5GNORMA
  During EuCNC 2016, an interview with Peter Rost (Project Manager) has been recorded and will be published early July 2016.

Another place that featured 5G NORMA was Telecomtv.com, an online TV channel dedicated to the global Information and Communications Technology (ICT) sector. An interview with Simon Fletcher (Chief Technology Officer (CTO) of Real Wireless) called "Engaging with the vertical markets for 5G standards planning" was published on their website on 16.05.2016. The interview can be found in http://www.telecomtv.com/articles/etsi-5g-summit/engaging-with-vertical-markets-for-5g-planning-13592/.

5G NORMA's YouTube channel has "liked" these videos, so any user checking the channel can find them easily.

2.2.3 Press releases

Similar to the announcements in social media, press releases have been issued by 5G NORMA partners to inform the general public about the 5G NORMA research activities and to announce opportunities to learn about 5G NORMA achievements.

Several press releases issued at the start of the 5G NORMA project inform about the 5G NORMA project and the research interests of the authoring partners. At Mobile World Congress 2016, press releases by AZCOM and NOMOR announced the demonstrations that they were showing at the booth of the European Commission.

A list of press releases issued in the first year of 5G NORMA can be found in Annex F.

2.2.4 Summer school

The 5G NORMA Summer School took place between the 20th and 22nd of June 2016 at King's College London. The 5G NORMA Summer School managed to bring prominent people together to discuss the path towards 5G networks. The event has been tailored towards network and radio engineers and researchers active or interested in virtualized and programmable future mobile networks. The event proved to be very popular and as can be seen in Figure 3 below the number of registrations reached 236 which was well above anything that we have foreseen. During the 3 days event the number of people who have actually participated reached 130. The high number of attendees led to a highly successful event with interesting interactions and discussions between the presenters, panel members and the attendees.

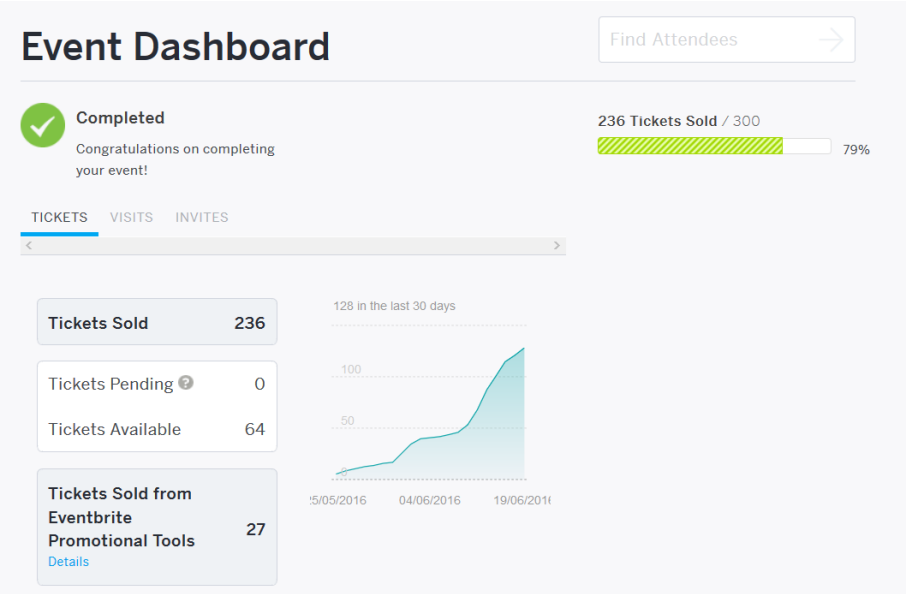

Figure 3: Total registrations on the event and evolution over time before the event took place

Figure 4 below shows the number of page views of the Summer School as they have accumulated over time; it is worth pointing out that the total number of pages views reached just above 1600.

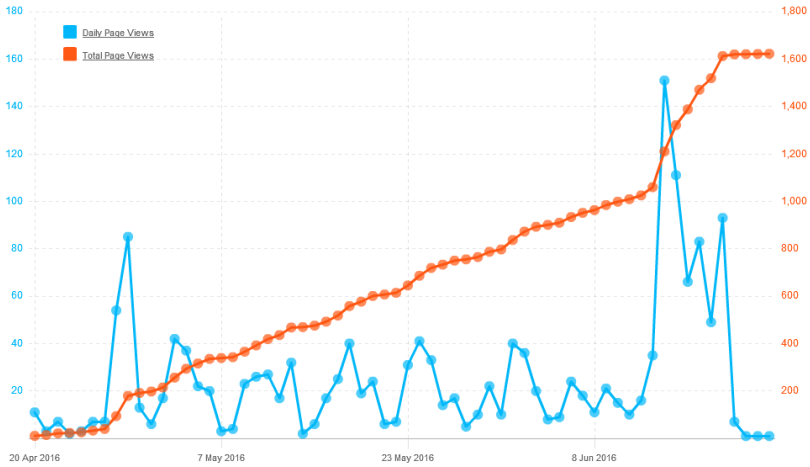

Figure 4: Number of page views of the Summer School at the Eventbrite portal

In terms of publicity the event appeared at King's College London website of the School of Natural and Mathematical Sciences, in the EPSRC CommNet website, the IEEE Vehicular

Technology Society website, the website of the Information Technology Society in the VDE, and the event was also part of the London Tech Week.

For further details on the 5G NORMA Summer School, see Annex E.

2.3 Evaluation and impact

In this section, an overall evaluation of the dissemination activities to the general public conducted in this first phase of the project shall be given.

The most easily accessible dissemination tools of 5G NORMA are the public website and its social media channels. They are all globally accessible with up-to-date information about the project in English. Their setup was successful, and as the view counts given in the last section have indicated, there was clear interest on their content. It is difficult to measure the real influence of these dissemination activities on the public discussion on 5G.

One potential point of improvement in this area would be to offer a newsletter for anyone interested in keeping up with the 5G NORMA project. The registration interface could reside in the website.

When it comes to the cooperation with independent media, the project started with a strong showing, with many partners putting out press releases announcing their involvement in the project. Besides that, our successful demos at Mobile World Congress (MWC) 2016 got press releases from Nomor and Azcom. In this point, the goal for the future would be to maintain a growing public interest by issuing additional press releases.

In the realm of higher education, the 5G NORMA Summer School is the vehicle used by the project to disseminate toward academia, graduates, researchers and industry professionals. Its main goal was to present 5G and 5G NORMA to a highly qualified audience, which succeeded by bringing more than 130 participants for the three-day event.

Many of the partners in the 5G NORMA consortium had discussions with representatives from vertical industries. Discussions built on direct, bilateral contacts and in this sense were no “official” 5G NORMA activities. Improved efficiency and outreach to a wider audience in the vertical industries, as well as seek for contacts in industry organizations and presence at industrial workshops beyond MWC will be further intensified. Events specifically focused in certain vertical industries, like webinars or web conference, will be organized.

3 Dissemination to standardization bodies and industry forums

The 5G-PPP is aiming to secure the leadership of Europe for the 5th Generation of mobile networks via delivering innovative visions, solutions, architectures, technologies and standards. 5G NORMA's partners are active members of many relevant standardization bodies and industry forums. The targeted ones for 5G NORMA are briefly described below in Section 3.1.

5G NORMA has planned the following standardization related activities:

- To follow standardization trends and progresses in the respective bodies and forums, focusing on architecture related study and work items (this is the subject of section 3.1);
- To actively promote new standards and seek for opportunities to contribute 5G NORMA's results to relevant standards via 5G NORMA's partners (this is the subject of section 3.2);
- To cooperate with other projects of the 5G PPP for possible standards contribution (this is addressed in section 5.2 below).

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

3.1 Current Status of 5G in standardization bodies and industry forums

The following standardization bodies and industry forums are among the most recognized ones for 5G of which 5G NORMA's partners are already active members and contributors. These are also the most relevant for expected innovations and outcomes of 5G NORMA.

3.1.1 NGMN

The Next Generation Mobile Networks (NGMN) Alliance is responsible for developing operator requirements shaping the forthcoming 5G systems, by accelerating the adoption of innovative technologies and the standardization support. One of the main contributions for 5G systems is the definition of network slicing that allows a multi-tenant, modular network architecture and functional design that can support efficiently diverse services in a sustainable and cost-efficient manner, ensuring a consistent customer experience. In particular, NGMN analysed a number of uses cases identifying eight group families including: broadband access in dense areas, broadband access everywhere, higher user mobility, massive Internet of Things (IoT), extreme real-time communications, lifeline communication, ultra-reliable communications, and broadcast-like services. Such a list is not exhaustive and is meant to capture the most significant emerging business requirements associated with 5G. NGMN whitepaper [NGMN] elaborates such a 5G vision, which considers the support of vertical industries, the integration of services through a rich and software oriented capabilities and the need for enhanced flexibility and exposure of specific network capabilities as an end to end service. Further information about the NGMN Alliance can be found at: ww**w.ngmn.de**.

3.1.2 3GPP

3GPP has started working towards 5G initially by considering a stage 1 use case analysis within the Service Working Group SA 1 in a study called SMARTER [TR 22.891] where more than 70 uses cases were elaborated. These use cases have later been arranged into four main categories associated with a separate study document. In particular, TR 22.861 focuses on massive IoT service, TR 22.862 on critical communications considering low latency, reliability and high availability, TR 22.863 on enhanced mobile broadband and TR 22.864 on network operation

considering network slicing, efficient user plane, network capability exposure and multi-network connectivity.

The 3GPP Architecture Working Group SA2 has initiated the NextGen study [TR 23.799] to explore high-level architecture requirements following a bottom-up approach starting from assembling particular functions into processes that collectively compose the overall network architecture. In an effort to support different service characteristics and vertical market players SA2 is continuing the study on enhanced Dedicated Core Networks (eDCN) [TR 23.711] offering specific services and network functions including RATs based on subscription information. Furthermore, SA2 has nearly finalized an early study on user/control-plane separation in TR 23.714 analyzing potential architecture enhancements for core network elements to further enable flexibility for the network deployment and operation.

The 3GPP Telecom Management Working Group SA5 has completed a study on management of virtualized networks [TR 32.842] considering partially and fully Virtual Network Functions (VNFs) focusing on macro-base stations and core network elements with the objective to identify requirements interfaces and procedures. In Release 14 SA5 has introduced a specification on architecture requirements for virtualized network management [TS 28.500], considering complementary specifications on configuration, fault performance and life-cycle management. In addition, SA5 is extending the legacy network management architecture to accommodate network sharing based on long term contractual agreements [TS 32.130] focusing on the exchange of network performance and control.

The 3GPP RAN Working Groups have initiated a study work considering a “new radio” for 5G, in [TR 38.913] concentrating initially on the use cases supporting the next generation radio access technologies, Key Performance Indicators (KPIs) and on the deployment services and requirements. The aim of this study is to bring light into the physical and access network architecture producing a follow-up study on each of the RAN group and a complementary study that would span across all RAN groups.

Further information about the 3GPP can be found at: www.**3gpp**.org.

3.1.3 ETSI

3.1.3.1 Network Function Virtualization (NFV)

5G networks are envisioned to be based on a native SDN and NFV architecture that leverages the structural separation of hardware and software as well as the programmability in many aspects, including network infrastructures, network functions and services and all management functions to orchestrate 5G network systems [NGMN]. The ETSI NFV Industry Specifications Group (ISG) has been working to facilitate development and transformation of an open, interoperable ecosystem for NFV, applied for 3GPP LTE evolution and 5G revolution [TR 32.842]. The 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. The current works of the ETSI NFV on user cases, requirements, and MANO for examples are really relevant for expected innovations of 5G NORMA, including flexible and adaptive functional architectures with dynamic functional allocation and placement of function blocks, Software Defined Mobile Controller (SDMC), supports of network slicing and multi-tenancy, etc. Further information about ETSI NFV can be found at: http://www.etsi.org/technologies-clusters/technologies/nfv.

3.1.3.2 Mobile Edge Comminuting (MEC)

Many evolving 5G services are envisioned to be offered closer to the user at the network edge in order to enhance latency and in general end-user perceived performance, e.g. adopting the ETSI

MEC paradigm. Edge servers can also be exploited for storage, computation and dynamic service creation by verticals or third parties, supporting multi-tenancy. MEC is currently working towards defining technical requirements [MEC 002 v0.5.1] associated with the identified use cases and on a related framework and reference architecture [MEC 003 v0.3.2]. At the same time there is an ongoing study focusing on the interference between external tenants and the MEC platform. Further information about ETSI MEC can be found at: www.**etsi**.org/technologies-clusters/technologies/mobile-edge-computing.

3.1.4 ITU-T IMT-2020

ITU-T has studied the standardization gaps caused by the emergence of 5G networks and introduced a set of recommendations for enhancing current networks [TD 208]. This document explores five main areas without claiming that the study is exhaustive, considering flexibility through the introduction of softwarization. The following three areas out of five identified are relevant for the 5G NORMA:

- **High level architecture** enhancements for increasing flexibility to support services with diverse performance requirements in terms of bandwidth, delay, mobility, signaling, etc. To address flexibility, the evolving 5G architecture would need to accommodate a tight integration of various existing and forthcoming RATs and offer an end-to-end Operations, Administration and Management (OAM), introducing a converged data plane to users, which should be served via an access technology-agnostic network core.
- **Network softwarization** introduces the trend for designing, implementing, deploying, managing and maintaining network equipment and network components by software programming. It also exploits characteristics of software such as flexibility and rapidity of design, development and deployment throughout the lifecycle of network equipment and components, for creating conditions that enable the re-design of network and service architectures and allow optimization of costs.
- **End-to-End Quality of Service (QoS)** focuses on access agnostic QoS provision. IMT-2020-specific use cases need new approaches in areas of definition of end-to-end connectivity supervision and integrity, QoS parameters, performance objectives, QoS classification, budget allocation, measurement/monitoring methodology, etc.

Further information about ITU-T IMT-2020 can be found at: http://www.itu.int/en/ITU-T/focusgroups/imt-2020/Pages/default.aspx

3.1.5 IETF

The Internet Engineering Task Force (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 the IETF and research groups at the IRTF addressing topics very much related to 5G NORMA. The Distributed Mobility Management (DMM) WG is working on solutions for distributed mobility management, an aspect that is being tackled by 5G.NORMA in the context of future 5G network architectures. 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. This lifetime of this WG is well aligned with that of 5GNORMA, which therefore there is a good potential for impact by the project.

Further information about IETF DDM can be found at: https://datatracker.ietf.org/wg/**dmm**

On the IRTF, there is a SDN Research Group which is a very good venue for discussion of some of the software-defined mobile network control algorithms developed in the project. Besides, the NFV RG has been recently created, where 5G NORMA can contribute with research aspects around network function virtualization in mobile networks. Last but not least,

there are also some additional WGs, such as NVO3, NETEXT, INTAREA, and FORCES where 5G NORMA can also submit useful contributions.

5G NORMA, through DT and UC3M, is monitoring these groups and contributing to those where good opportunities for impact are identified. As explained in the next section, some of these contributions have already been performed.

3.1.6 IEEE

The IEEE has been active in working towards standardization of 5G communications technologies. As well as activities within IEEE 802 that might eventually be capable of achieving 5G requirements or interworking with 5G licensed spectrum access through evolutions to IEEE 802.11 and 802.16 standards, for example, the 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", and "P1917.1: Standard for Software Defined Networking and Network Function Virtualization Reliability".

More recently, a collaboration of King's College London KCL and Technical University of Dresden has brought forward, and seen approved, a proposal for a new IEEE standards working group to be formed on the Tactile Internet, the baseline standard (IEEE P1918.1) being "Tactile Internet: Application Scenarios, Definitions and Terminology, Architecture, Functions, and Technical Assumptions". The kick-off meeting of this working group was on the 27-28 May 2016, coordinated with IEEE ICC 2016 in Kuala Lumpur, Malaysia. A good participation—including prominent industrials—was seen in this kick-off meeting, and seven wide-ranging contributions were brought to this meeting on topics such as architecture, scenarios and use cases, functionalities and further topics (particularly, codecs for the Tactile Internet), requirements for the Tactile Internet, and the technical definition of the Tactile Internet, among others.

Further information about IEEE P1918.1 Tactile Internet can be found at: https://standards.ieee.org/develop/project/1918.1.html

3.2 5G NORMA plans and activities

To 5G NORMA as one of the 5G-PPP projects, 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. The expected outcomes of 5G NORMA towards operators, manufacturers and standards (use cases, social and economic analyses, novel network concepts and solutions, demos, standards contributions) may all contribute to impact visions, standardization road-maps, and standards.

5G NORMA has been considering and pursuing the following possibilities for standardization related contributions:

- Novel architecture contributions: 3GPP, ETSI and IEEE
- Interfaces with the software-design controller: ETSI
- Network-related protocols: IETF

The standards contributions of 5G NORMA are listed in Annex A. One of 5G NORMA's contributions to IETF has been accepted in RFC 7864 on Proxy Mobile IPv6 Extensions to Support Flow Mobility.

RFC 7864 describes protocol extensions to allow for offloading and local breakout by means of network based flow mobility. It updates one of the network based mobility protocols adopted by 3GPP (Proxy Mobile IPv6) to allow a User Equipment (UE) for using several anchors in the

network. This piece is therefore very important to enable scenarios in which anchors are deployed dynamically in the network to cope with certain traffic and service demands.

Regarding IEEE standards, Nokia has been driving the preparation of a contribution to the kick-off meeting of the aforementioned IEEE Tactile Internet working group, on the 27-28 May 2016. This contribution was presented by KCL, who also input some additional ideas and content. The contribution emphasized the importance of using multi-connectivity in Tactile Internet cases in order to attain both delay and reliability requirements, and also discussed the use of Multiple-Input Multiple-Output (MIMO) and massive MIMO as a further option for milimeter wave (mm-Wave) and the multi-connectivity of mm-Wave access with more conventional microwave (UHF) frequencies. Although it is noted that the IEEE Tactile Internet working group does not yet consider Medium Access Control/Physical Layer (MAC/PHY), there is the possibility that it may do in the short-to-medium term future. Moreover, IEEE P1918.1 agreed on the importance of this 5G NORMA contribution, and ensuring that the items that it is currently covering (e.g., architecture, functionalities and use cases) do take into account and adequately support such multi-connectivity capabilities.

5G NORMA will continue to contribute to P1918.1, noting the importance of the Tactile Internet as a use case reflecting some of the most challenging 5G requirements, and that many of the technologies that will need to be involved towards such ends are prominently being worked on in 5G NORMA. Moreover, the current estimation of P1918.1 is that it will complete its baseline standard in April 2018, and continued 5G NORMA contributions will therefore be possible until approximately late 2017 or early 2018. Given that P1918.1 has only recently held its kick-off meeting and is a very new working group, its precise timeline is not yet defined; however, 5G NORMA work will certainly integrate well with that.

Figure 5 illustrates some schedules of the planned outcomes or deliverables of 5G NORMA in relation with provisioned timelines of 3GPP standardization for 5G.

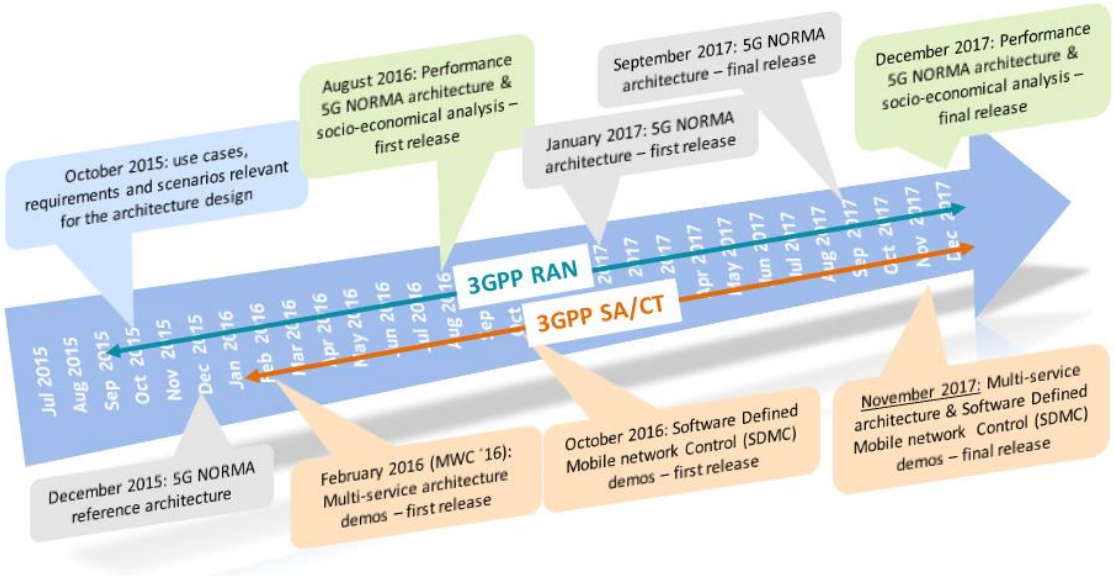

Figure 5: Illustration of planned 5G NORMA's outcomes

A particularly influential standardization body in mobile communications is 3GPP. Most of 5G NORMA's industrial partners are active partners and contributors of 3GPP. 5G NORMA may consider possible contributions to 3GPP via those partners. Topics like network slicing, multi-service and multi-tenancy operations received particularly high attention during the last months. As can be seen from Annex A, 5G NORMA partners submitted 1 contribution to 3GPP RANP, 2 contributions to 3GPP RAN2, 5 contributions to 3GPP RAN 3, 1 contribution to 3GPP SA1 8 contributions to 3GPP SA2. Furthermore, one contribution has been submitted to BBF.

To further intensify 5G NORMA's impact on 3GPP and other relevant standardization bodies, an internal review of the Internal Reports IR4.1, IR5.1 and IR3.1 is planned for July/August 2016, to identify potential contributions.

4 Scientific dissemination and PoC demonstrations

4.1 Overview

The 5G NORMA project targets to publish its outcome results towards the general public as well as particular academic and industry conferences and publications within the scope of telecommunication networks, cloud computing and business aspects. 5G NORMA also plan to organize workshops, special sessions and other events within the scope of the evolving 5G RAN architectures and provide talks, presentations and at the respective institutions. 5G NORMA plans to provide a number of PoC demonstrations showing its major innovations at key industry evens and conferences including high visibility international and European events.

In addition, 5G NORMA plans to integrate the major results into courses that are going to be delivered by partners at summer schools and at their respective institutions considering also integration at both PhD and Master course levels providing the opportunity for corresponding students to gin a deep understanding of the emerging 5G RAN architectures.

Partners can also exploit 5G NORMA results by offering consultancy services and tools such as simulation platforms that can be commercially exploited.

4.2 5G NORMA activities

4.2.1 Conference and journal papers

From an early stage, during the first year, the 5G NORMA project has established a significant footprint in dissemination activities, in where all partners are involved. So far 10 articles on highly rated journal have been accepted and 20 conference papers on high visibility IEEE as well as on European conferences. Especially, the presence of 5G NORMA on top European conferences such as EUCNC and CROWNCOM can help other European projects to understand and benefit from the results of 5G NORMA, stimulating further innovation and establishing network opportunities.

From the aforementioned publications more than 40% were the outcome of collaboration among different partners, while in 30% the collaboration included more than half of the consortium partners demonstrating a great collective effort. It is worth noting that 50% of the conference and journal dissemination was produced by the industry.

A full list of publications can be found in the Annex C, while a leaving documentation is available at the 5G NORMA website: https://5gnorma.5g-ppp.eu/dissemination.

4.2.2 Organization of workshops and panels

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. In particular, 5G NORMA initiated a series of "5G Architecture Workshops" that were held in conjunction with renowned global conferences such as IEEE VTC and IEEE Globecom.

In the sequel, a brief outline of these activities is provided. For further details on these events, the reader is referred to Annex D.

The series of 5G Architecture Workshops was opened even prior to the start of the 5G NORMA project with the 1st International Workshop on 5G Architecture in May 2015 in conjunction with the IEEE VTC 2015-Spring in Glasgow, Scotland. The workshop served to inform about the

ideas, key innovations and ambitions of 5G NORMA and to learn about related ideas from researchers worldwide. The workshop was well attended and generally well received.

A panel session titled "5G architectures" was held in the industry track of IEEE VTC 2015-Fall in Boston, USA. The panel participants represented network operators, equipment suppliers and service providers and discussed about service requirements vs. technical architecture design options. The event was considered as highly successful and motivated further panel sessions.

Together with two other 5G PPP projects, 5G NORMA was invited by the Chinese "FuTURE FORUM 5G SIG" to co-organize the 1st Sino-Europe 5G Technical Workshop. The workshop took place in November 2015 in Beijing, China and attracted a large number of participants. It was a great opportunity to build a common understanding on benefits and challenges of 5G and to convey the message that European network operators need 5G as enabler for new business and a pure increase in data rates is not sufficient.

In December 2015, a second 5G PPP Architecture panel session was held at the IEEE Globecom 2015 conference with participants from the US, China, Japan and Korea. The discussions provided views from different regions outside Europe on weaknesses of current 4G networks and expected improvements from 5G architectures.

5G NORMA has been involved in the organization of two workshops in conjunction with IEEE ICC 2016: 5G NORMA has organized the 3rd International Workshop on 5G Architecture and co-organized a Workshop on 5G RAN Design with METIS-II and other 5G PPP projects. Both events took place in Kuala Lumpur, Malaysia on May 23rd and May 27th, 2016, respectively.

The workshop series on Cloud Technologies & Energy Efficiency in Mobile Communication Networks was initiated by the iJOIN project in 2013. 5G NORMA is continuing ideas of iJOIN and consequently engaged in the 4th edition of this workshop, which took place in Grenoble, France in May 2016. Organization was done together with the 5G PPP projects Flex5Gware and Speed5G.

Special editions in scientific journals and magazines play a similar role like workshops and panels in the bi-directional exchange of ideas and thoughts about 5G NORMA related topics. Therefore members of 5G NORMA have initiated a special edition on "Network Slicing in 5G Systems" in the IEEE Communications Magazine and are serving as guest editors. The issue is scheduled to appear in May 2017.

4.2.3 Invited talks and keynotes

5G NORMA partners have been invited to provide talks, participate in panel discussions and presentations in various conferences, workshops and industry events elaborating the vision of the project as well as various technical and architecture aspects including project results. 5G NORMA has also been visible in various standardization activities and related workshops including NGMN Forum meetings, the 1st Sino-Europe 5G technical workshop, the 3rd 5G Global Summit (5G Forum), at ETSI SCN #14, ETSI 5G Summit: From Myth to Reality and the 5G Global Event in China. A full list of invited talks, panel presentations and contributions to industry events and standards is summarised in Annex C.3.

4.2.4 PoC demonstration activities

With the aim of demonstrating the feasibility of the 5G NORMA concepts, the potential benefits of the architecture and to publicize the project to the general public, 5G Norma is involved in public conferences and events all over the world.

5G NORMA has been present at MWC'16 showing two different demos:

- A software-based demo, which deals with multi-service and context-aware scheduling. Using a network simulator, two different services are simulated, i.e. HD-video streaming traffic for pedestrians and car-to-car communication via infrastructure (V2X).

We demonstrate that by re-locating the RRM unit to a central cloud, the throughput for HD-video users will be improved due to the interference mitigation using a centralized coordinated scheduling, whereas on the other hand for autonomous driving service shifting the mobile network functions to the network edge improves the end-to-end latency as the key service requirements for such a time-critical service. A video of this demo is available on YouTube under https://www.youtube.com/watch?v=nJVS2wZs5iQ

- A hardware-based demo, where a scale model rally car is driven using a commercial tablet as steering wheel, both connected to the LTE evolved Node B (eNB), in two different situations. In the first one the Evolved Packet Core (EPC) serving gateways (S-GW) are moved into the eNB baseband board. This solution guarantees the lowest latency possible with this hardware setup and the video shows that it's possible to drive remotely the car with a very good control feedback. The second situation mimics a commercially deployed LTE network, in which an average end-to-end latency of hundreds of milliseconds (ms) is experienced. The driving experience is perceivably worse due to the great delay between the command and the response of the model car. A video of this demo is available under https://www.youtube.com/watch?v=CAlyQMUtv6k.

5G NORMA has also participated at EuCNC'16 held in Athens, with its own booth showing a video with the hardware-based demo and a real software simulator for the sw-based demo. Furthermore, we welcomed Director Mario Campolargo (Net Futures, DG CONNECT) at the booth of 5G NORMA and explained the 5G NORMA architecture, its implications for 5G services and businesses (see Figure 6). In addition, the booth well complemented the attendance at multiple EuCNC workshops where specific aspects of 5G NORMA have been explained.

Figure 6: Explaining 5G NORMA to Director Mario Campolargo at EuCNC 2016

5 5G PPP Collaboration

5.1 Architecture WG

The 5G-PPP Working Group Architecture has been appointed by the 5G-PPP Steering Board in order to allow for discussing architecture relevant topics across projects. The following projects are members of the WG: 5G Ensure, 5GEx, 5G NORMA, 5G-Xhaul, CHARISMA, COHERENT, CogNet, Flex5gware, METIS-II, mmMAGIC, SELFNET, SESAME, SONATA, SPEED-5G, SUPERFLUIDITY, and 5G Crosshaul. Its relationship to the 5G-PPP is shown in Figure 7.

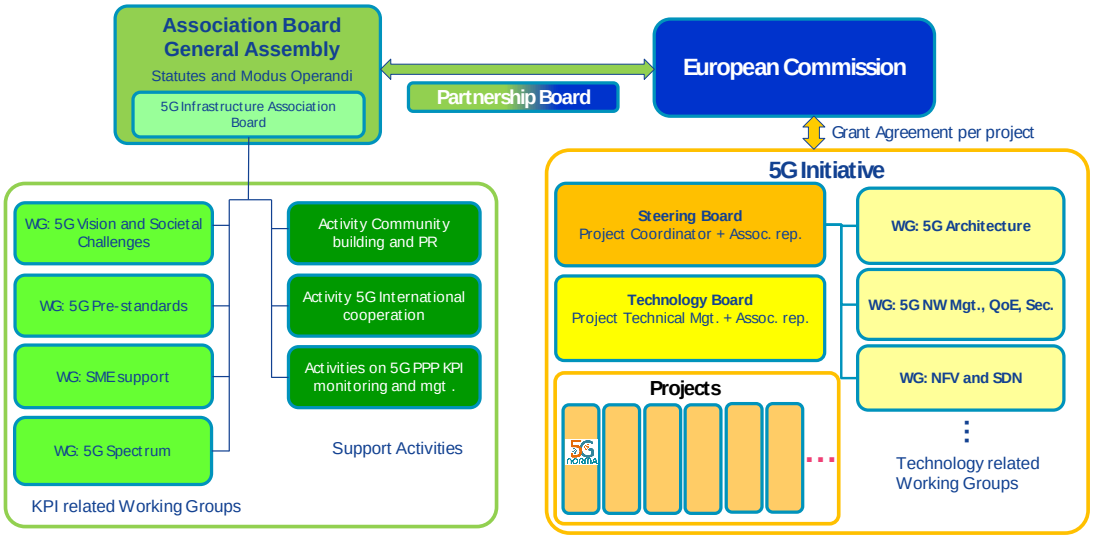

Figure 7: 5G-PPP Overview

So far, the WG has been very active with overall 10 phone conferences and two physical meetings. 5G NORMA presented its innovations and objective during an early phone conference and afterwards actively participated in the discussion with other projects. Furthermore, the WG issued a white paper on 5G mobile network architecture where all WG members contributed. 5G NORMA also contributed to various sections and was actively involved in the edition. This white paper is a major milestone for the WG as well as the 5G-PPP in general as it represents the consolidated view on the 5G mobile network architecture by all 5G-PPP projects. Although this view may not be fully coherent, it allows for identifying commonalities and alternatives for future 5G systems.

Furthermore, the WG organized public events such as panel discussions and workshops at IEEE Globecom 2015, IEEEICC 2016, and EuCNC 2016. 5G NORMA actively supported these events during the proposal phase as well as the organization of the events.

5.2 Pre-standardization WG

The 5G-PPP Pre-standards Work Group (WG) helps identifying relevant standardization and regulatory bodies to align, creating standardization roadmap and coordinating standardization activities in 5G-PPP across all the projects. The ultimate aim is set out to influence the works on pre-standardization of 5G, securing the leadership of Europe for the next generation networks.

There are some initial views of the Pre-standards-WG provided in 5G PPP Pre-standards WG 2015[2].

5G NORMA is participating in the regular meeting of the Pre-standards WG (bi-weekly teleconference). In collaboration with the Pre-standards WG, 5G NORMA has planned:

- To follow and align 5G NORMA's planned standardization activities with the Pre-standards WG;
- To take part in shaping vision and roadmap for 5G via, e.g., providing 5G NORMA's inputs for 5G-PPP coordinated white papers, demo sessions, deliverables of the Pre-standards WG;
- To promote new standards (IEEE Tactile Internet).

5.3 Security WG

5G NORMA is envisioned to contribute to the 5G-PPP security working group. together with the 5G PPP projects (5G-ENSURE, 5GEX, Charisma, CogNet, SelfNet, Superfluidity, Virtuwind and Sesame) This working group's objective is to bring 5G-PPP projects together to consolidate on research issues related to security in 5G networks. This working group will ensure the projects are working in a complimentary manner towards consistent goals, exchanging ideas, minimising the duplication of effort, contributing towards relevant standards and where possible cooperating on the development of compatible components, demonstrators, the exchange of data and results and the interworking of communication layers, where applicable:

1. Work in a coordinated manner on 5G Security and drive the 5G Security Vision. This with a clear focus on areas of shared concerns (e.g. 5G Security architecture, 5G security enablers for areas such as IAM, Privacy, Trust and etc.).
2. Exchange ideas on the design of the security solutions (also relevant Standards and/or SDOs that apply) with the aim to get them shared/agreed also interoperable.
3. Work on validation and/or adoption of the security solutions (in terms of usage to date and to come also enablement) as well as testbed and/or experimentations facilities.

The aim of 5G-PPP Security Working Group is to drive the 5G security vision and align the projects on it. Furthermore, this working group will interact and contribute outcome to the following 5G-PPP working groups: i) 5G-PPP Vision WG in security vision, ii) 5G-PPP Architecture WG in security architecture, iii) 5G-PPP Pre-standardization WG to standards.

5.4 Bilateral discussions with other 5G PPP projects (METIS-II, 5G-Crosshaul, mmMAGIC)

During summer 2015 bi-lateral discussions and a phone conference took place between 5G NORMA and METIS-II. The goal was to identify possible topics for collaboration. Both projects seem to complement each other well, with similar goals and limited overlap, but different approaches pursued, as 5G NORMA starts from full flexibility narrowing it down, while METIS-II starts from 3GPP adding flexibility as required. The possible way forward for collaboration was that METIS-II may provide developed RAN functionalities to 5G NORMA according to the dissemination plan of METIS-II, i.e. early considerations end of 2015 and details in summer 2016, and 5G NORMA may provide feedback on these functionalities w.r.t. their suitability for decomposition and multi-tenancy spring and fall 2016, respectively (months 9 after METIS-II output in month 5 and 16 after METIS-II output in month 12). In 2016,

[2] https://5g-ppp.eu/wp-content/uploads/2014/02/5G-PPP-Pre-standards-WG-Issues-Paper-for-20-Oct-15-WS_final-edited.pdf

though, interaction between 5G NORMA and METIS-II shifted to the 5G PPP Architecture WG, cf. section 5.1.

In February 2016 mmMAGIC invited 5G NORMA to present their reference architecture in an mmMAGIC-internal workshop with focus on the 5G NORMA functional architecture. mmMAGIC considers supporting mm-wave by below 6 GHz access to enable seamless "edge-less" connectivity, which may be considered by 5G NORMA as a special case of its general multi-connectivity approach.

During the 2nd 5G NORMA meeting in Madrid a workshop took place to discuss how to align the 5G NORMA concepts with the fronthaul/backhaul work of 5G-Crosshaul. The discussion focused on the management/orchestration architecture that is adopted by the two projects and on investigating how to combine them. In particular, operations such as functional decomposition and allocation that is studied in 5G NORMA considering the RAN and Core Network as well as the multi-service and multi-tenancy support can have a significant impact by the 5G-Crosshaul procedures and ideally should be align considering the parameters from both project sides.

6 Partner-specific exploitation plans

The impact of the 5G NORMA project will ultimately be realised through the commercial exploitation of the project results by the partners of the consortium. In the following, we describe the specific exploitation plans of each partner, indicated which commercial products and services are planned for exploitation and how these will benefit from the results of 5G NORMA.

6.1 Nokia

Nokia is a front runner in the area, with its flexible designed product lines Liquid RAN, Liquid Core and Liquid Application. For the latter (which combines base station with IT servers), a next level of innovations can be expected from 5G NORMA results, by integrating cloud technologies directly into the base station and allowing flexible allocation of functions in the base station or in more centralized servers. Furthermore, the anticipated new level of flexibility in functions allocation may lead to a redesign of the architecture and may change the current RAN and CN definition and a tighter integration of Liquid RAN and Liquid Core functions.

Nokia also expects a new level of efficiency for small cell products; indeed, ultra dense deployment would be possible only if the equipment costs are decreased. Research results of 5G NORMA may be utilized in Nokia Networks' Flexi Zone controller to provide on one hand cheap base station design, and on the other hand efficient spectrum utilization by centralized processing and coordination.

Furthermore, the project results may improve multi-tenancy and multi-operator capability of future Nokia products. Cloud technology and SDN provide inherent capabilities for infrastructure sharing that allow adaptation to the varying loads of different operators while ensuring that overall resource sharing complies with pre-arranged SLAs.

The 5G NORMA project will support Nokia Networks to maintain and extend its technical and market position in the mobile networks market for the next 5G generation. The leading position can further be aided by securing the key concepts with IPRs to be made by the project.

The project target to reach pre-standardization consensus on 5G architectural concepts may later have a positive impact for the efficiency of creating the 5G standards in 3GPP, but also in other related bodies.

6.2 NEC

As one of the market leaders for Mobile Network solutions in Japan, NEC will use the results of 5G NORMA to evolve the current product portfolio towards the on demand multi-tenancy and network function virtualization (NFV) paradigms impacting the following development divisions: Mobile Radio Access Networks and Mobile Wireless Networking. NEC is committed to expand its range of Small Cell Solutions and maintain its position as the industry's leading expert in the small cell market (http://www.nec.com/en/global/solutions/nsp/sc/). Moreover, NEC has been leading in the area of network virtualization focusing on Software-Defined Networking (SDN) and network functions virtualization (http://www.nec.com/en/global/solutions/nsp/sdn/). In solving the telecom operators' challenges, NEC has been the first to commercialize OpenFlow solutions, vEPC (Virtualized Evolved Packet Core: vMME and vS/P-GW) and vMVNO-GW.

5G NORMA results are expected to provide specific answers about the level of multi-tenancy, functional flexibility and dynamicity that can be introduced in the architecture of NEC's future wireless technologies as guidance for product development releases. In addition, 5G NORMA results will be used to further improve NEC's Centralized RAN (C-RAN) solutions. Thus, strengthening and accelerating NEC's product roadmap. Key technical innovations will be used

as a basis for contributions to standardization bodies, e.g., 3GPP and ONF, and to generate patents that increase NEC's IPR protection in the area. Finally, project results will be used to demonstrate the benefits of the proposed architecture evolution both to NEC development groups and potential customers, e.g., European network operators.

6.3 ATOS

Specific Atos' products, assets and services that can leverage 5G NORMA's outcomes in a direct fashion are the following.

Atos' Next Generation Intelligent Networks[3] (NGIN) focuses on the deployment of next generation services over heterogeneous networks. Atos has already deployed the solution for eight major European operators, and sees the NGIN concept as aligned with the nature of services envisaged for 5G (i.e. convergence). As part of its roadmap, Atos can integrate the 5G-supported NGIN for telecom customers adopting 5G NORMAs NFV and SDN approaches.

Atos' cloud services can benefit from 5G NORMA by improving virtualization (NFV), optimization and scalability as part of its extension into 5G. The Canopy brand, containing all of Atos cloud offerings (IaaS, PaaS, SaaS and consulting), has been expanding greatly in recent years, and has been met by the cloud portfolio of recently acquired French provider, Bull, to form the second largest cloud provider in Western Europe in terms of combined revenue. 5G NORMA's outcomes with regards cloud aspects, such as the centralized controller prototype and the SDMC and adaption functional allocation concepts of the project, can be leveraged for Atos' Cloud Services.

Atos has also a solid track in BSS integration for telecom operators (billing, service platforms, etc.). 5G NORMA is an excellent opportunity for Atos to anticipate customers' demands for future services in 5G, for example integrating the deployment of Virtual Functions and their interfaces, or even providing hosting services for those functions playing the role of CIP (Cloud Infrastructure Provider).

The Connected Train[4] is an Atos' innovation initiative which aims to enable people to continue their online lives whilst travelling on the train. Currently the Connected Train is under proof-of-concept using rail infrastructures in the UK. 5G NORMA's outcomes with regards delay and resource optimization can be leveraged to extend the infrastructure including 5G technologies, which will be necessary taking into account the evolution of the user bandwidth requirements.

Finally, under the Atos Consulting brand, the company focuses on internal technology and knowledge transfer of such projects to support clients in commercializing innovative products and services. Atos' experience in 5G NORMA's concepts, technologies and solutions will provide a source to better position the company's consulting services for telecom operators actively upgrading their networks for 5G.

6.4 Deutsche Telekom

Products of Deutsche Telekom target consumers, business customers, vertical industries and the public sector (e.g. PPDR). Deutsche Telekom aims to provide its customers virtually any kind of innovative telecommunications service, including (i) broadband communications at the highest technically feasible data rates, (ii) real-time communications with ultra-low latency, e.g. for telemedicine or industrial automation, (iii) communications with network functionalities optimized for cost-sensitive applications like smart metering etc., and (iv) communication for PPDR achieving maximum reliability and security. It is expected that demand for

[3] http://atos.net/content/dam/global/your-business/Atos_whitepaper_NGIN_LowRes.pdf

[4] http://atos.net/content/dam/global/ascent-whitepapers/ascent-whitepaper-the-connected-train.pdf

communication services will grow significantly over the next years, in particular for the vertical industries such as the automotive industry. For PPDR services, 5G broadband services may complement the existing TETRA communications systems.

All the above services shall be produced using a single communications platform that comprises fixed network, mobile network and a cloud platform for data processing and storage. 5G NORMA will develop the technical means to adapt such a common platform to the requirements of these services and the demands of the customers. By means of this platform, Deutsche Telekom expects to offer its customers an increased service variety and improved network experience in terms of quality of service/experience (QoE/QoS). The dynamic adaptive allocation of functionalities allows matching service requirements to the physical infrastructure in the best possible way and thus is a pre-requisite for cost-effective production of services meeting the quality expectations of their users.

Deutsche Telekom is one of the initiators of NFV and is currently investigating how virtualization and cloudification technologies can be implemented in its networks in the field. In 5G NORMA, Deutsche Telekom will extend and deepen the understanding on how virtualization and cloudification can be applied particularly to future mobile access networks. Results will be considered in preparation of own 5G technology & architecture studies as well as in RFI/RFP/RFQ business processes.

6.5 Orange

Orange is currently rolling out 4G networks, while it is getting prepared for the next step, involving 5G research and innovations activities. Orange does not consider 5G as 4G+1, but rather as a Future Internet. While Orange will continue improving spectral efficiency and throughputs,the three major aspects that will guide all the 5G research and standardization phases in Orange are: (i) energy efficiency, (ii) total cost of ownership reduction and (iii) network services flexibility. Indeed, 5G aims to be the infrastructure platform supporting a variety of new services for all European citizens and enterprises and not only the next generation of mobile broadband. As a matter of fact, 5G networks will leverage on key evolutions towards network convergence, cognitive network management, network virtualization and software networks.

Orange will first use 5G PPP research and innovation projects to build a common vision among European networking industry players regarding functional and non-functional requirements of 5G. It is crucial to take into account the needs and concerns of citizens and enterprises in this vision and Orange will propagate the ones of its customers. This vision will be reused by Orange to motivate 5G infrastructure investments and build the rolling plan according to related business.

5G NORMA will also provide the benchmark and select technologies and architectures for future standards and infrastructure enablers. This selection is key for Orange to ensure that future network services will offer the best experience to our customers and will be sustainable (in terms of energy, costs and social issues) and operationally manageable.

Orange will also use this project to foster its internal research activities: it will be the trigger job creation (especially postdoctoral funding) and will also allow Orange to take part in software developments that would not be reachable for Orange otherwise due to the required critical mass.

In a first phase, Orange will rely on 5G NORMAto improve its understanding and skills in designing and deploying NFV/SDMC-based, flexible, services and users centric radio access networks. In a second phase, Orange will use the concepts developed in 5G NORMA as enablers for deploying cost and energy efficient radio access networks by ensuring that the deployed capacity scales closely with the traffic demand.

Orange also considers5G NORMA as a toolbox to provide operators with the necessary tools for designing and deploying new services for the residential and corporate markets. For example, a

service for the corporate market on which Oranges plan to focus its efforts is RAN as a Service (RAN-aaS), which will enable Orange to leverage the cost of its infrastructures.

6.6 Telefonica

Several initiatives, common to most European projects Telefónica I+D is involved in, will be undertaken:

- Internal "evangelization" through the dissemination of the main project results, through the organization
  - Telefónica Excelence School
  - Telefónica's 5G Interest Group
  - Internal communication channels (eKISS, ThinkBig blog,…)
  - Presentation of the main innovations developed in the project to the entrepreneurship initiatives of Telefónica, Wayra and Amerigo.
- Use of the ideas, concepts and solutions in the procurement processes (RFI, RFP) for future network systems acquisitions. This is facilitated by the fact that the Innovation team is in the same organization that leads these processes at corporate level.
- Other initiatives
  - Registering patents of the main innovations developed in the context of the project
  - Contributions to standardization bodies (3GPP, IETF) and dissemination fora (NGMN, 4G Americas, GSMA)

More specifically related to 5G NORMA scope and results, it is important to highlight that Telefonica commitment to the network virtualization is exemplified by the initiative called UNICA, which will provide the framework for the company's global end-to-end virtualization deployment and expansion plans for its network infrastructure. Telefónica's objective is to have more than 30 percent of the company's new infrastructures managed in accordance with UNICA model by 2016.

So far, the scope of UNICA has been limited to the fixed network (both access and core) and mobile core network infrastructures, but it is not considering the support for the radio access network. Telefónica expects to reduce its operating expenditures by up to 30% through the adoption of network virtualization solutions.

5G NORMA is expected to be a significant input into the definition of the next generation of UNICA, in order to ensure that 5G systems requirements are taken into account, and extending it to the mobile access networks. UNICA shares with 5G NORMA some the project objectives of multi-tenancy and Network as a Service support. In this sense, additional levels of efficiency to those indicated above can be achieved, taking into account the high costs of the RAN infrastructure.

6.7 Azcom

Azcom Technology plans to exploit 5G NORMA concepts and related technologies in a number of ways.

The key concept of flexible allocation poses the challenge of deploying the network functions in network elements that would not host them in the traditional architecture. This challenge needs to be tackled by redefining the software architecture to allow such flexibility. The current idea is to use the Virtualization Layer, which would allow deploying of the same software on diverse hardware architectures. This approach needs to be tested in terms of real-time performance and also needs to be explored in terms of supported architectures and underlying hardware.

One of the possible deployments of the 5G NORMA flexible architecture is to place one or more CN functions in the RAN. Such deployment gives the opportunity to develop new products NIAB-like (Network In A Box), where all the network functions are implemented in a small portable box.

Another possible deployment of the 5G NORMA flexible architecture is to place one or more RAN functions in the cloud. Several software blocks of the Azcom IP will be ported on the cloud, hence such an approach will be verified in terms of performance and complexity. In turn, this will give the opportunity for new product ideas such as a potential Cloud-EPC.

The SDMC approach envisioned by5G NORMA also provides some exploitation opportunities to Azcom. Azcom's software blocks can expose a custom interface, through which the external SDMC agents can instruct the blocks themselves on the expected behaviour and network functions to run. Such an approach may eventually force a complete software redesign on Azcom's products. A partial implementation of this concept by 5G NORMA would be of great benefit for Azcom products and will serve as a basis for future new implementations.

All the above potential developments and applications of 5G NORMA fit Azcom's business strategy, which focuses on the continuous improvement of the existing Small Cell hardware and software platforms. This platform will potentially incorporate several of the technologies involved in 5G NORMA, such as cloud techniques, the virtualization of network functions and the software-programmable networking. By integrating such innovative concepts earlier, Azcom will be able to foresee the future difficulties and challenges in the Small Cell platforms implementation domain.

6.8 Nomor Research

Nomor Research has been involved in 3G and 4G research and standardisation for a decade and is known as an independent consulting company for emerging technologies since 2004. By using its knowledge and expertise in system level simulation and rapid prototyping, Nomor's primary business is to provide R&D related services and to develop software modules that might be licensed or used in respective projects.

5G radio algorithms are essential to proceed and expand Nomor's future business. Nomor is already implementing algorithms for LTE-Advanced (like eICIC, CoMP, Advanced MIMO and advanced Self-Organising Networks). Nevertheless solutions for a decentralized LTE architecture are quite different from a centralized or more flexible approach in 5G. Based on a harmonized 5G NORMA architecture, Nomor can gain a competitive advantage by developing centralized Radio Resource Management, scheduling and interference coordination algorithms for 5G at an earlier point of time. Nomor will carry out performance evaluation for the developed algorithms.

Additionally, Nomor is known for its system simulation tools (www.nomor.de/simulation) – Nomor may be the only SME globally to own a comprehensive system simulator that fully conforms to the 3GPP and NGMN simulation methodology. Within 5G NORMA, Nomor will extend its simulators towards 5G, to be ready for commercial use. The initial simulator will form the basis for a system emulator within the prototype development of the project that includes several functions of a centralized radio network controller module potentially interacting with other nodes over specified interfaces. The prototype will be available to Nomor as Proof of Concept of 5G and to demonstrate our capabilities in latest technology to our customers, extending our track history in successful prototyping (www.nomor.de/demonstration).

As a side business, Nomor offers technology training for LTE (www.nomor.de/training) to a large number of customers within Europe. Nomor will develop 5G technology training courses and use the training as door opener for future project acquisition. 5G NORMA will also allow Nomor to involve highly qualified students, PhD students and graduates in a 5G project to develop not only R&D skills, but also skills that are required in leading edge and high quality industry projects with strict timelines.

6.9 Real Wireless

Real Wireless carries out business case analysis for a range of customers including (i) businesses who are users of wireless looking to acquire cost effective networks that fit their needs; (ii) regulators looking to stimulate innovation and value for consumers; (iii) wireless equipment vendors and industry forums looking to promote the benefits of their equipment; and (iv) wireless operators looking to expand their networks to optimize quality of service with cost effectiveness and overall value generation.

Real Wireless has developed a series of wireless business modelling tools and, through its involvement in 5G NORMA, plans to enhance these tools with the latest thinking on mobile networks. The enhanced tools will enable Real Wireless to serve the needs of a wider range of customers. In particular, Real Wireless currently has a network cost modelling and optimization tool called *CAPisce*, which examines demand in particular areas and optimizes the network in terms of spectrum, technology and topology and associated costs to serve this demand most effectively. Involvement in 5G NORMA will enable Real Wireless to add 5G and more flexible service orientated architectures to this tool.

Real Wireless also provides a range of wireless advisory services to its customers in both the wireless industry and in key wireless user industries, such as transportation, public venues, utilities and government departments. Involvement in 5G NORMA will increase the range of these advisory services to include 5G and novel service orientated network architectures.

6.10 King's College London

King's College London is envisioning a rich multi-faceted exploitation plan that captures the traditional core academic values such as high calibre publications of international merit and organization of international events and technical talks as well as bridging the gap between providing sophisticated designs, solutions and systems which capabilities remain largely unused when moved to industry. Focus will be to reach to industrial partners and in a synergetic way fill this void, i.e., between the theoretical analysis and the design of a product. This is in-line with the overall strategy of the centre to become and viewed worldwide as a think tank of international technical knowledge and expertise, with expanded reach of activities via multidisciplinary work with influence in areas such as regulation and the environment. KCL has a strong track record of developing, standardizing and patenting solutions within the core technical space of the 5G NORMA project and has an excellent record of transferring solutions to industry. In particular, KCL will focus on the area of flexible function placement, where there are opportunities to develop application-specific solutions that are very attractive to operators due to the increased flexibility that they provide. In addition, utilizing developed policies across the College focus will also be placed in nurturing and developing talented researchers and the potential of start-up companies in the scope areas. Finally, 5G NORMA research findings will be utilized to drive our post-graduate studies in order to enrich the experience of students and create the next generation of wireless network communication engineers.

6.11 Technical University of Kaiserslautern

The Technical University of Kaiserlautern (TUKL) expects the results of 5G NORMA not only to determine the architecture of 5G and future wireless systems but to become a key enabler for new classes of mobile service offers. The 5G NORMA outcome will be a first step towards mobile computing networks integrating communication and computing at the edge. Thus, besides the area of mobile communications, mobile service creation, soft engineering for services at the edge, implementation strategies for dependable services, e.g., in automotive, robotics, etc. will be affected by 5G NORMA.

TUKL will use the results developed in 5G NORMA in education and research. Graduate and postgraduate courses in the area of wireless communication, mobile services, and dependable

systems as well as research excellence clusters in these areas, TUKL is partner of, will benefit from 5G NORMA's results.

Being involved in the Cluster for Commercial Vehicles (www.cvc-suedwest.com) and being associated with the German Research Center for Artificial Intelligence (www.dfki.de), TUKL is working with many industrial partners in the areas of mobile communication and service delivery as well as dependable systems (wireless automation, factory of the future, automotive). Here, the results achieved in 5G NORMA will be used as reference architecture for future projects.

6.12 University Carlos III of Madrid

University Carlos III of Madrid (UC3M) plans to exploit 5G NORMA results by providing PhD students with the knowledge of innovative technologies and solutions that prepare them to work on technologically advanced jobs, which is a way of transferring the knowledge in 5G NORMA to society. In particular, 5G NORMA will provide the PhD students involved in the project with a mixed background that combines wireless with cloud-based technologies. Given the current trends of convergence of IT and CT, such a background is very attractive and useful for future engineering positions. UC3M will use knowledge and IPR created in 5G NORMA to transfer the technology to large industrial partners and SMEs in its environment, with particular emphasis on companies located in the technical business park "Parque Científico Leganés Tecnológico." Among others, specific solutions that may be suitable for this are the scheduling algorithms and the mobility protocols that UC3M will work on. UC3M has already a strong track record of developing, standardizing and patenting solutions in this space and transferring these solutions to industry. The research group involved in this proposal has developed more than twenty networking solutions, some of which have been transferred to industry, and has authored a substantial number of standards at the IETF and the IEEE.

University Carlos III de Madrid has a successful track record of creating companies based on its scientific activities, having currently more than 20 successful spin-offs hosted it its Scientific park. 5G NORMA results will be a very valuable asset in this effort. In particular, UC3M will focus on the area of software-defined design, where there are opportunities to develop software-based solutions that are very attractive to operators due to the increased flexibility that they provide. Last but not least, UC3M will publish and actively disseminate technical 5G NORMA results through top level international journals and conferences, organisation of workshops and journal special issues.

7 Conclusions and future work

This Deliverable D7.1 "Communication and Dissemination – Intermediate Report" has summarized and evaluated the communication and dissemination activities of the 5G NORMA project during the first 12 month of the project duration. The activities have been grouped in four different areas:

Communication to the general public is intended to address all members of the civil society in general and vertical industries in particular. For the society-wide communication, a project web site as well as several social media channels have been setup and used according to the Description of Work (DoW).

Besides that, 5G NORMA has established contacts with vertical industries to inform them about the capabilities of future communication networks and learn about their requirements as users of these networks. Up to now, such discussions mainly built on direct contacts between 5G NORMA partners and representatives of vertical industries. In the future, 5G NORMA will try to improve its presence on industrial workshops and address industry organizations to reach a wider audience that might be affected by 5G network technologies.

With respect to **standardisation**, 5G NORMA has mostly monitored the activities and topics discussed in all relevant standardization bodies, but has also submitted its first contributions to IETF, IEEE and 3GPP. Beyond that 5G NORMA has been engaged in the 5G PPP Pre-Standardisation working group.

In the upcoming months, the research results of 5G NORMA will mature further and thus become more and more relevant for these standardization bodies. It is expected that more contributions will emerge in the second part of the project and create even higher impact to all major standardization bodies.

In the area of **scientific dissemination and PoC demonstrations**, 5G NORMA is almost in line with expectations: Almost one third of the publications that are predicted in the DoW have been created within the first 12 month of the project duration, and it is expected that the number of scientific papers will increase in the second half of the project duration. 5G NORMA's ambition is to focus on high-impact journal papers. The number of workshops and panel sessions organized by 5G NORMA exceeds what has been assumed in the DoW, and the feedback from the audience has been positive in general. Last but not least, 5G NORMA is proud that it was permitted to show a demo at the MWC'2016 booth of the EU Commission and it has had its own demo booth at the EuCNC'2016.

Regarding **cooperations with other 5G PPP projects**, 5G NORMA has been active as expected. Since end-to-end architecture is a major aspect in the 5G NORMA work, 5G NORMA has taken the lead of the 5G PPP 5G Architecture Working Group and driven the work towards a 5G Architecture White Paper. The successful work in this and other 5G PPP working groups will be continued in the remaining project duration.

All in all, dissemination and communication activities in 5G NORMA are on track to meet the expectations set out in the DoW. 5G NORMA's ambition for the future is to intensify communication to vertical industries and standardization bodies. This is regarded as essential to achieve the impact onto the European IT industry that the EU Commission is striving for.

8 References

[NGMN] NGMN Alliance, NGMN 5G White paper, version 1, Feb 2015.

[TR 22.891] 3GPP TR.891, Feasibility Study on New Services and Market Technology Enablers, Rel.14, Mar. 2016

[TR 23.799] 3GPP TR 23.799, Study on Architecture for Next Generation System, Rel.14, Apr. 2016.

[TR 23.711] 3GPP TR 23.711, Enhancement pf Dedicated Core Network selection mechanisms, Rel.14, May 2016.

[TR 32.842] 3GPP TR 32.842, Telecommunication management; Study on network management of virtualized networks, Rel.13, Dec. 2015

[TS 28.500] 3GPP TS 28.500, Management Concept, Architecture & Requirements for Mobile Network that include Virtualized Network Functions, Rel.14, Apr. 2016.

[TS 32.130] 3GPP TS 32.130, Telecommunication management; Network Sharing; Concepts and requirements, Rel.12, Dec. 2014.

[TR 38.913] 3GPP TR 38.913 Study on Scenarios and Requirements for Next Generation access Technologies, Rel. 14, Mar. 2016

[TR 32.84200] 3GPP TR 32.842, Telecommunication Management; Study on Network Management of Virtualized Networks, Rel. 13, Dec. 2015.

[MEC 002 v0.5.1] ETSI MEC, Mobile-Edge Computing (MEC), Technical Requirements, v0.5.1, Feb. 2015

[MEC 003 v0.3.2] ETSI MEC, Mobile-Edge Computing (MEC), Framework and reference architecture, v0.3.2, Feb. 2016

[TD 208] TD 208 (PLEN/13), Report on Standards Gap Analysis ITU-T, SG13, 2015

Annex A. Contributions to Standardization bodies

Source	Body	Title	Reference	Date
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
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
O. Holland (KCL) et al.	IEEE	Multi-connectivity architectures supporting Tactile Internet services (IEEE P1918.1)	https://ieee-sa.imeetcentral.com/p19181/file/45866589/ [5]	2016/05/28
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)	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 (RAN3)	Flexibility of RAN functions through configuration and	R3-161099	2016/05

[5] Internal document; contact the author via e-mail oliver.holland@kcl.ac.uk to arrange access to the document server.

		deployment,		
Nokia	3GPP (RAN3)	Requirements of Isolation between Network Slices,	R3-161358	2016/05
Nokia	3GPP (SA2)	Solution: QoS Framework	S2-161188	2016/02
Nokia	3GPP (SA2)	Application Awareness in an End-to-End QoS Framework,	S2-161622	2016/04
Nokia	3GPP (SA2)	Update to Solution 2.3: Content Aware QoS Framework,	S2-162706	2016/05
NEC	3GPP (RAN)	Security Requirements for New Radio	RP-161208	2016/06
NEC	3GPP (SA1)	Service requirement on charging for multi RAT connections	S1-153008	2015/10
NEC	3GPP (SA2)	Solution: shared and Dedicated Network Functions for Network Slicing	S2-161785	2016/04
NEC	BBF (WWC)	5G Enablers and Requirements	SD-373	2016/06
Orange, DT, NEC	3GPP (SA2)	Key Issue on Policy Framework	S2-161238	2016/02
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

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 demo)	GlobeCom 2015, San Diego, USA	2015/12/06-10
M. A. Puente (ATOS), S. Redana (Nokia)	5G NORMA – A Novel Radio Multiservice adaptive network Architecture for the 5G era (HW demo, SW demo)	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
P. Rost (Nokia) A. Banchs (UC3M)	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 – A Novel Radio Multiservice adaptive network Architecture for the 5G era (Video demo)	EuCNC 2016, Exhibition booth	2016/06/27-30

Annex C. Scientific Publications

C.1. Journal papers

Authors	Title	Event	Date
A. Kliks, O. Holland, A. Basaure, and M. Matinmikko	Spectrum and license flexibility for 5G networks	IEEE Communications Magazine, Vol. 53, No. 7	July 2015
D. Robalo, J. Oliveira, F. Velez, O. Holland, A. Aghvami	Dynamic Configuration and Optimization of WiMAX Networks with Relay Power Saving Modes: Measurement-Based Scenario in a Hilly Region	Springer Wireless Personal Communications, Vol. 85, No. 3, December 2015	December 2015
Peter Rost et al. (9 authors from Atos, UC3M, TID, DTAG, Nokia, NEC)	LTE Mobile Network Architecture Evolution towards 5G	IEEE Communications Magazine, Special Issue on LTE Evolution	2016/06
H. Droste, P. Rost, M. Doll, I. Berbe-rana, Chr. Mann-weiler, M. Breit-bach, A. Banchs, M. A. Puente	An Adaptive 5G Multiservice and Multitenant Radio Access Network Architecture	Emerging Telecommunications Technologies	2016/06
K. Samdanis et al.	From Network Sharing to Multi-tenancy: The 5G Network Slice Broker	IEEE Communications Magazine, Standards Supplement	2016
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	Accepted
Albert Banchs, Marco Gramaglia, Xavier Costa-Perez, and Peter Rost	Re-architecting Cloudified Mobile Networks: New Concepts and Research Challenges	IEEE Communications Magazine, special issue on 5G Radio Access Network Architecture and Technologies	Submitted (Nov. 2016)
A. Tsiopoulos, V. Friderikos	Mobility-Aware Multi-Path Routing, Placement and Chaining of Virtual Network Functions	Computer Networks (Elsevier)	Submitted
G. Chochlidakis, V. Friderikos (KCL)	Mobility Aware Virtual Network Embedding	IEEE Transactions on Mobile Computing	Accepted
B. Panzner, P. Rost, L. Rauch-haupt, H. D. Schotten, A. Dekorsy, M. Düngen	„Integrated 5G Networks to Facilitate the Digitization of Industries,"	IEEE Communications Magazine SI Industrial IoT	Submitted June 2016

C.2. 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
Oliver Holland	Geolocation-Based Architecture for Heterogeneous Spectrum Usage in 5G	IEEE Globecom 2015 Workshops; San Diego, CA, USA	2015
Oliver Holland	Standardized Geolocation-Based System for Spectrum Sharing and Heterogeneous Access Management to Support 5G	IEEE CSCN 2015; Tokyo, Japan	2015
Oliver Holland	IEEE 1900.6b: Sensing Support for Spectrum Databases	IEEE CSCN 2015; Tokyo, Japan	2015
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	2015/09/30
S. Filin, …, O. Holland, et al.	IEEE 1900.7 Standard for White Space Dynamic Spectrum Access Radio Systems	IEEE CSCN 2015	2015/10-11/31-02
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	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	IEEE ICC 2016	2016/05/23-

	and Assessment of an Aggregation-Capable IEEE 802.11 White Space Device		27
Bessem Sayadi et al.	SDN for 5G Mobile Networks: NORMA perspective	CLEEN Workshop 2016 CROWNCOM Conference, Grenoble, France	2016/05/30-06/01
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. Rendon Schneir (DT)	A Cost Model for a 5G network	ITS conference	Accepted 2016/09/07-09
J. Gang, Vasilis Friderikos	Control Plane Load Balancing in Wireless C/U Split	IEEE PIMRC 2016	Submitted (Sept. 2016)
V. Sciancalepore, K. Samdanis	A Service-tailored TDD Cell-Less Architecture	IEEE PIMRC 2016	Submitted (Sept. 2016)
D. Aziz et. al.	Signalling Minimization Framework for Short Data Packet Transmission in 5G	VTC Fall 2016	Accepted (Sept. 2016)

C.3. Talks and presentations

Presenter	Title	Event	Date
S. Redana	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	2015
P. Rost	5G NORMA: A NOvel Radio Multiservice adaptive network Architecture for 5G networks	METIS-II RAN Design workshop	September 2015
S. Redana et al.	5G NORMA: A NOvel Radio Multiservice adaptive network Architecture for 5G networks	EuCNC 2015, Paris, France	2015
S. Redana	Architecture in the 5G era: 5G NORMA approach and Nokia view	ISWCS2015, Brussels, Belgium	2015
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	1st Sino-Europe 5G Techn. Workshop;	2015

	Architecture for the 5G era	FuTURE FORUM 5G SIG Beijing, China	
S. Redana	5G NORMA: A NOvel Radio Multiservice adaptive network Architecture for the 5G era	3rd 5G Global Summit (5G Forum), Seoul, Korea	2015
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
Chr. Mannweiler (Nokia)	A Novel Radio Multiservice Adaptive Network Architecture for the 5G Era	Expert Workshop on "5G System Architecture" (organized by VDE ITG 5.2.4); Munich, Germany	2015
S. Redana	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
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, Kuala Lumpur, Malaysia	2016/05/23-27
K. Samdanis (NEC)	Flexible Connectivity and QoE/QoS Management for 5G Networks (invited talk)	CLEEN Workshop 2016 CROWNCOM Conference, Grenoble, France	2016/05/30-06/01
S. Redana (Nokia)	Presentation	5G Global Event, Beijing, China	2016/05/31-06/01
D. v. Hugo (DT)	Mobile Tactile Internet services with 5G NORMA	49. ITG 524 Workshop "5G Mobile Networks - Towards the Tactile Internet"	2016/06/10
Chr. Mannweiler,	Cognitive Network	IWPC Workshop	2016/06/14

H. Sanneck (Nokia)	Management – Automation for Multi-tenant 5G Mobile Networks	"Forging a Path to Autonomous 5G Networks", Cologne, Germany	
M. Breitbach (DT)	5G NORMA	IWPC Workshop "Forging a Path to Autonomous 5G Networks", Cologne, Germany	2016/06/14
B. Sayadi (Nokia)	5G end-to-end Architecture: 5G NORMA vision	Summer School Rescom, Lorient, France	2016/6/16
P. Rost (Nokia)	5G NORMA: An adaptive mobile network architecture	EUCNC 2016 workshop W04a – "Next Generation fronthaul/backhaul integrated transport networks," Session 1	2016/06/27-30

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. 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	2017/05 (Publication date)
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://www.comsoc.org/commag/cfp/network-slicing-5g-systems

Annex E. 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 popu-lar topics in the wired and the wireless networking domains among both the aca-demic 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 F. 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

Annex G. 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

Communication and dissemination activities on these media:

Source	Title	Activity	Date
5G NORMA	5G NORMA kick off meeting took place in Munich on July 7-8 2015	News report on 5G NORMA web site	2015/07
Real Wireless, Pulborough, UK	Real Wireless joins prestigious consortium to assess the socioeconomic benefits of 5G Network Architectures http://www.realwireless.biz/2015/07/01/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 report on 5G NORMA web site	
Markus Breitbach (DT)	News report on 5G NORMA F2F meeting in Madrid https://5gnorma.5g-ppp.eu/5g-norma-f2f-meeting-on-nov-24-26-2015-in-madrid/	News report on 5G NORMA web site	2015/12/03
Chr. Mannweiler	Contributions to 5G Infrastructure Association (IA) White Paper “5G empowering vertical	Released at MWC 2016,	2016/02/22-25

	industries"	Barcelona, Spain	
Markus Breitbach (DT)	News report on 5G NORMA F2F meeting in Paris https://5gnorma.5g-ppp.eu/5g-norma-plenary-meeting-on-march-15-17-2016-paris/	News report 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 report on ETSI 5G Summit, 2016/04/21 https://5gnorma.5g-ppp.eu/simon-fletcher-engaging-with-the-vertical-markets-for-5g-standards-planning/	News report 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)	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)	Interview on 5G NORMA; to be taken aside of EuCNC; details tbd.	Interview	2016/06/30
P. Rost, M. Breitbach	5G NORMA: A Novel Radio Multiservice adaptive network Architecture for the 5G era based on Network Slicing	European 5G Annual Journal	Q3 / 2016

Annex H. Cooperation with 5G PPP projects

Activity	Title	Audience	Date
Phone conference	Bilateral cross-project discussion between 5G NORMA and METIS-II	METIS-II	2015/09
Meeting	Bilateral cross-project discussion between 5G NORMA and X-haul	X-haul	2015/11/26, Madrid, Spain
Presentation	5G NORMA: A NOvel Radio Multiservice adaptive network Architecture for the 5G era; 5G NORMA Functional Architecture	mmMAGIC	2016/02/02

Annex I. References to 5G NORMA

Source	Title	Link	Date
Golem	Nokia, Telekom und Telefónica wollen 5G entwerfen (in German)	http://www.golem.de/news/5g-norma-projekt-nokia-telekom-und-telef-nica-wollen-5g-festlegen-1507-114984.html	2015/07/01
Telecom TV	5GPPP launches its NORMA trials and looks beyond 5G	http://www.telecomtv.com/articles/5g/5gppp-launches-its-norma-trials-and-looks-beyond-5g-12602/	2015/07
Telecom TV	Nokia unveils its SDN-based Network-as-a-Service 5G architecture	http://www.telecomtv.com/articles/5g/nokia-unveils-its-sdn-based-network-as-a-service-5g-architecture-12789/	2015/09