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Abstract

This report provides the final summary for administrative, technical, and innovation management in the full project period of 5G NORMA.

Keywords

5G NORMA, Administrative Management, Technical Management, Innovation Management

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

PU = Public

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List of Acronyms and Abbreviations

Term	Description
5G-PPP	5G Public Private Partnership
AAA	Authentication, Authorisation, and Accounting
AB	Advisory Board
B2B	Business to Business
B2B2C	Business to Business to Consumer
ARPU	Average Return Per User
CSP	Communication Service Provider
EB	Executive Board
EC	European Commission
EPC	Evolved Packet Core
GA	General Assembly
GSM	Global System for Mobile Communications
GUI	Graphical User Interface
H2020	Horizon 2020
ICT	Information and Communication Technologies
IM	Innovation Management
IMD	Innovation Management Database
InP	Infrastructure Provider
KPI	Key Performance Indicator
MAC	Medium Access Control
MANO	Management and Orchestration
MBB	Mobile Broad Band
MEC	Mobile Edge Computing
MM	Mobility Management
mMTC	Massive Machine Type Communication
MNO	Mobile Network Operator
MSP	Mobile Service Provider
MTC	Machine Type Communications
MVNO	Mobile Virtual Network Operator
MWC	Mobile World Congress
NBI	Northbound Interface
NF	Network Function
NFV	Network Functions Virtualization
ONF	Open Networking Foundation
OTT	Over the Top

PC	Project Coordinator
PPDR	Public Protection and Disaster Relief
QMR	Quaterly Management Report
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RRC	Radio Resource Control
RRM	Radio Resource Management
SBI	Southbound Interface
SDMC	Software Defined Mobile network Control
SDM-C	Software Defined Mobile Network Controller
SDM-O	Software Defined Mobile Network Orchestrator
SDM-X	Software Defined Mobile Network Coordinator
SDO	Standards Defining Organization
TCO	Total Cost of Ownership
TDD	Time Division Duplex
TETRA	Terrestrial Trunked Radio
TM	Technical Manager
V2I	Vehicle to infrastructure
V2X	Vehicle to anything
VNF	Virtual Network Function
WG	Working Group
WP	Work Package
WPL	Work Package Leader

1 Executive Summary

This is the final report of Work Package 1 “Project and Innovation Management” describing the administrative project management, technical project management, and innovation management for the full project period.

In particular, the report describes the final milestone achieved, i.e., the final 5G NORMA architecture, the final evaluation and socio-economic impact, and final demonstrators, which are described in Section 3. In this report, a high-level summary is provided with references to the relevant reports issued by other work packages.

Section 4 further details the project’s innovation management approach, activities, and outcomes, which are essential in order to ensure future impact of the 5G NORMA project. The section details the innovations considered from each work package within the project, provides a market context oriented view, and provides a summary how the innovations align with the impact objectives.

2 Administrative Project Management

2.1 General Assembly and PMT

The members of the Project Management Team are

- Project Coordinator and WP1 Lead: Peter Rost, Nokia
- Technical Manager and WP4 Lead: Mark Doll, Nokia (former Alcatel Lucent)
- Innovation Manager and WP2 Lead: Simon Fletcher, Real Wireless
- WP3 Lead: Christian Mannweiler, Nokia
- WP5 Lead: Marco Gramaglia, Universidad Carlos III Madrid
- WP6 Lead: Ignacio Labrador, Atos
- WP7 Lead: Markus Breitbach, Deutsche Telekom

In addition, the composition of the General Assembly is as follows:

- Nokia and Project Coordinator: Peter.Rost, peter.m.rost@nokia.com
- Nokia (former Alcatel-Lucent) and Technical Manager: Mark Doll, mark.doll@nokia.com
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- Universidad Carlos III de Madrid: Albert Banchs, banchs@it.uc3m.es

The General Assembly (GA) met at least once per quarter, usually on the first day of each physical plenary meeting. The purpose of GA meetings has been to discuss and decide on the budget or effort re-allocations, defaulting partners, potential amendments of the Grant Agreement, inclusion of additional partners, and management procedures. Each partner is represented in the GA by at least one representative. Furthermore, GA meetings are used to provide an update on the overall status of the project, next steps and upcoming reports, expected results and work during each quarter, and upcoming dissemination deadlines.

In general, a GA meeting has been co-located with each physical project meeting, i.e.

- 06 July 2015 at Nokia, Munich
- 24 November 2015 at Universidad Carlos III Madrid, Madrid
- 15 March 2016 at Orange, Paris
- 22 June 2016 at King's College London, London
- 23 September 2016 via WebEx telco
- 14 November 2016 at Telefonica, Madrid
- 14 February 2017 at Deutsche Telekom, Darmstadt
- 22 May 2017 at Nokia, Paris
- 12 September 2017 at Technical University of Kaiserslautern, Kaiserslautern

Furthermore, the PMT met once per month online in a WebEx telco.

2.2 Administrative project management activities

The main activities covered by project management according to the Grant Agreement include

1. Coordination and monitoring of the project work and progress through regular online meetings. This included periodic meetings of the Project Management Team, the General Assembly, and work package meetings.
2. Representation of 5G NORMA towards the EU Commission, e.g., in the 5G-PPP Steering Board, 5G-PPP Working Groups, European events, and other European activities. In particular, 5G NORMA actively supported multiple 5G-PPP working groups and took a leading role in the 5G-PPP working group on architecture [5GN-D7.2].
3. Reporting the General Assembly on directives from the EU Commission, and reporting decisions to project partners. This included particularly the conclusions of 5G-PPP Technical and Steering Board meetings, and the preparation of Grant Agreement amendments.
4. Managing physical meetings, telcos, and collaboration platform; 5G NORMA made use of the collaboration platform bscw, which is used by a majority of 5G-PPP projects as well as 5G-PPP working groups. Teleconferences were organized using WebEx, which provided a flexible and stable platform.
5. Management of documents such as submission to EU Commission; All 5G NORMA reports followed a well-defined process to ensure high quality deliverables, including peer-review phases within work packages and across the project.
6. Quarterly management reports on work progress, achievements, and efforts. The project provided for each quarter a detailed report on the efforts spent by each partner per task including brief descriptions of the activities, main results, and expected next steps. These reports allowed for efficiently reporting the project's status to the European Commission and overseeing the progress within the project to take early corrective measures.
7. Financial administration and reporting towards the EU Commission, and Coordination of legal and contractual matters. This has been performed by the project coordinator in close cooperation with the project officer in order to ensure the timely delivery of all necessary documentation.
8. Overseeing gender equality; the 5G NORMA management and partners ensured gender equality and diversity during the course of the project by implementing an open and inclusive work environment.
9. Maintenance of the Project Handbook and the overall project plan (Description of Work), and
10. Maintenance of the project's website, Youtube channel, and social media channels.

2.3 Dissemination activities

The communication and dissemination activities of 5G NORMA are aligned along the following four main objectives:

1. Contribute to the development of novel 5G products and services and their adoption by the market;
2. Contribute to the scientific discussion on 5G technologies and to their further evolution;
3. Education and training; and
4. Information of the general public, in particular vertical industries, about the potential of 5G networks.

Table 2-1~~Table 2-1~~ gives an overview of the dissemination results of 5G NORMA. Some key results of the project include overall 63 contributions to SDOs including 3GPP, IETF, IEEE, BBF, NFV, and ONF. Furthermore, the project has been very active in presenting demonstrators at international events (overall 14 appearances).

5G NORMA further contributed very actively to academic events and journals with overall 73 publications, 47 presentations, and 15 workshops and panels co-organized by the project. In addition, the project organized a highly successful summer school with 130 attendees during which the concepts and recent results of the project have been discussed. Finally, the project ensured that its activities were also presented to the general public, e.g., on its website, youtube channel, and social media accounts. Further details on the dissemination activities are given in report [5GN-D7.2].

Table 2-1: Overview dissemination statistics of 5G NORMA [5GN-D7.2]

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

3 Technical Project Management

3.1 Activities

The main activities covered by technical project management according to the Grant Agreement include

1. Monitoring of the project's technical work and progress, and ensuring the overall technical quality and consistency, by overseeing the work package mailing list discussions, checking online meeting minutes, and management reports. This includes periodic meetings with the work package leaders in the Project Management Team and providing technical progress summaries as part of the quarterly management reports.
2. Reviewing of all deliverables for quality and consistency.
3. Representation of 5G NORMA's technical views and results within 5G-PPP in the 5G-PPP Technology Board, selected 5G-PPP Working Groups (Architecture, Vision), European events such as EuCNC, and other cross-project activities.
4. Organizing and presenting, in conjunction with the Project Management Team, 5G NORMA results to the External Advisory Board and collecting technical feedback for sharing within the project.

3.2 Milestones and Achievements

3.2.1 Final 5G NORMA architecture

The system architecture for 5G networks must incorporate the performance and flexibility to support multiple telecommunications services, with heterogeneous KPIs and sharing the same infrastructure. 5G NORMA gives vendors, mobile service providers, and infrastructure providers the opportunities for fine-grained offerings in order to target new customers on the B2B level, such as private companies, non-profit organisations, or public authorities. To support their requirements, the 5G NORMA functional architecture is designed in a modular manner and incorporates four layers. For each of these layers, it defines the architectural elements that deliver the system's functionality. It includes the key functional elements, their responsibilities, the interfaces exposed, and the interactions between them.

3.2.1.1 Overall Architecture

The functional perspective of the overall 5G NORMA system architecture is depicted in Figure 3-1~~Figure 3-1~~. It shows the separation into four layers as well as the differentiation into intra-slice and inter-slice functions.

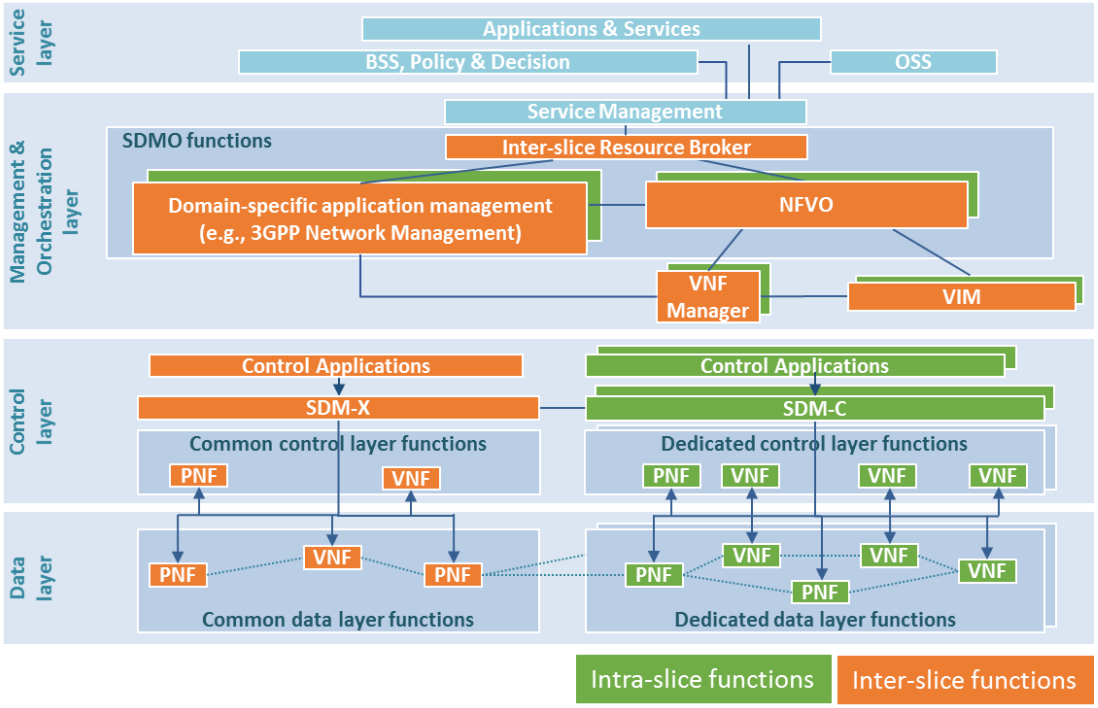

Figure 3-1: Functional perspective of the overall 5G NORMA architecture

The **Service Layer** comprises Business Support Systems and business-level Policy and Decision functions as well as applications and services operated by the tenant. Except for the reference point between Service Management function and functions in the Service Layer, this layer is not in the scope of the project. Rather, the reader is referred to related projects such as 5G-Ex [5GEx].

The **Management & Orchestration (MANO) Layer** realizes 5G NORMA's Software-defined Mobile network Orchestration (SDMO) concept by extending the ETSI NFV management and orchestration (NFV MANO) architecture towards multi-tenant and multi-service networks. The layer therefore comprises the Virtual Infrastructure Manager (VIM), the VNF Manager (VNFM) and the NFV Orchestrator. Further, the layer accommodates application management functions from various domains, e.g., the 3GPP domain, IEEE domain, or private enterprise network domains. For example, in the case of 3GPP domain, this can comprise Element Managers (EM), Network Management (NM), and selected OSS functions. Such functions shall also implement ETSI NFV MANO-defined reference points between VNFM and EM as well as between the NFVO and OSS/NM. The Inter-slice Resource Broker (ISRB) determines and enforces policies for cross-slice resource allocation, particularly in the case of shared network functions. Finally, the Service Management is an intermediary function between the Service Layer and the ISRB. It transforms consumer-facing service descriptions into resource-facing service descriptions and reports selected key performance indicators to the Service Plane functions.

The **Control Layer** accommodates the two main controllers: (1) the Software-Defined Mobile Network Coordinator (SDM-X) for the control of common (shared) NFs (depicted in orange) and (2) Software-Defined Mobile Network Controller (SDM-C) for dedicated NFs (depicted in green). Following the SDN principles, SDM-X and SDM-C abstract form the technological and implementation-related details of controlled network functions. They translate decisions of the control applications into commands towards Virtualized NFs (VNFs) and Physical NFs (PNFs) in both Data and Control Layer.

Finally, the **Data Layer** comprises the VNFs and PNFs needed to carry and process the user data traffic. Further details of both Control and Data Layer are described in Section 3.2.1.2.

Figure 3-1~~Figure 3-1~~ further depicts the split into common or so-called inter-slice functions and slice-dedicated (intra-slice) functions. This split is maintained from the MANO Layer down to the data layer, i.e., dedicated NFs are controlled (and managed, respectively) by the tenant's own instances of SDM-C and MANO Layer functions (i.e., ETSI NFV functions as well as domain-specific application management functions). Shared functions are controlled (and managed, respectively) by the SDM-X and the respective MANO Layer functions, which are usually in the administrative domain of the Mobile Network Operator (MNO) or the Mobile Service Provider (MSP). The policies regarding the utilization of shared functions, particularly the resource allocation to active slices, are determined by the ISRB and communicated towards the respective control, management and orchestration functions for further enforcement.

3.2.1.2 Control and Data Layer Architecture

5G NORMA introduces a novel concept of network control by extending the software-defined routing (switching) approach to all kinds of mobile NFs from both data and control layer, with a focus on wireless control functions, such as scheduling or interference control. For this purpose, 5G NORMA has defined two controller types (SDM-C and SDM-X) that split between the *logic* of the NF and the part that has to be controlled (*agent*). Generally, the logic comprises the traditional control plane part of a NF and is realized as an SDM-C application, while the agent consists of the user plane (data layer) part.

The major objective of the SDM-C is to abstract from technology-specific or implementation-specific aspects of the NFs. It has northbound interfaces (NBIs) towards different Control Applications implementing, e.g., QoE/QoS control or mobility management (MM). NBIs are used to enforce the conditions defined by the SDM-C applications that have to be realized on NFs for a given traffic flow identifier in order to fulfil the targeted SLA. For instance, via this interface, the MM application passes to the SDM-C the exact configuration information for data layer NFs enforcing the selected mobility management scheme. If such (re)configuration requests include a re-selection of VNFs or a re-composition of a chain of NFs, the SDM-C passes an according request for re-orchestration to the SDM-O. Further, the SDM-C is in charge of building the path for data layer service chains and adjusting the VNF parameters in order to accommodate QoS, policy enforcement, or legal interception requirements.

When the control logic is too time critical or is deemed to be not efficiently implementable in a more centralized way as SDM-C application, this functionality is offloaded to distributed control NFs. For example, the radio scheduler is carried out as distributed control NF because it would incur too much signalling over the southbound interface (SBI) between antenna location and location of the controller. Another example of a distributed NF is RRC, to enable fast reconfigurations triggered by the radio scheduler to adapt to the time variant radio channel and interference.

3.2.1.3 5G NORMA beyond state of the art

Software-Defined Mobile network Control (SDMC)

The work performed by 5G NORMA in this field has been fundamental. The two network controllers that embody the SDMC principle (i.e., SDM-C and SDM-X) are indeed the core of the architecture and all the specific solutions and algorithms that have been devised during the project. We also disseminated these concepts to SDOs such as ONF and in scientific papers.

Joint optimization of mobile access and core network functions & Adaptable (de)composition and allocation of mobile network functions

As described above, both the control and the MANO architecture designed by 5G NORMA support a decomposed network stack that takes advantage of hierarchical cloud deployments. Work performed in WP4 and WP5 targeted this scenario, e.g., among the proposals made by WP4, RAN slicing over a decomposed stack occupies a prominent role. Also the MAC

scheduling SDM-C and SDM-X applications developed in WP5 work on a de-composed stack and allow to jointly optimize them with other functions such as e.g., Mobility Management.

Resource allocation for multi- service & multi- tenancy support

One of the most important contributions of WP3 and WP5 is the MANO architecture: it has been designed to extend the state of the art MANO architecture (the ETSI NFV MANO) to provide enhanced functionalities such as per-service orchestration, and re-orchestration due to QoE/QoS changes. These orchestration-related innovations have been complemented by a number of algorithms such as MANO as a Service (MANOaaS), network slice admission control, and multi-tenant scheduling. The orchestration architecture is partly demonstrated in Demo 2.

Network Security

5G NORMA has substantiated the need for security by analysing important 5G use cases and setting up (black-box) security requirements in [5GN-D2.1]. By building on new networking paradigms such as NFV and SDN, and by introducing multi-tenant, multi-service and multi-connectivity concepts, the 5G NORMA architecture introduces new security risks into mobile networks. These risks have been analysed carefully and mitigation strategies have been outlined. More specifically, a number of innovative security approaches have been specified so that they could be integrated into the new architecture: Virtualised Authentication, Authorisation, Accounting (AAA), tokenization technique for provisioning and deployment of NFs and network services, a new access stratum security approach supporting flexible allocation of RAN security functions, and the Trust Zone approach. The proposed measures, applied carefully, together with other relevant security measures that are not in the focus of the project (as a complete coverage would require an effort at much larger scale) will result in highly secure networks that comply with the challenging security requirements raised by the expected 5G use cases.

3.2.2 Final verification and evaluation

A techno-economic analysis of the 5G NORMA architecture was performed with the purpose of evaluating the economic and social benefits of service-specific architectural solutions, flexible functional allocation, multi-tenancy support, and joint optimization of access and core functionalities, and taking specific account of the EU policy priorities. It was concluded via the multi-service case evaluation in a central London area in D2.3. The three cases were designed to provide a platform for assessment of techno-economic impact of the key innovations of 5G NORMA architecture. D2.3 further includes an analysis of socio-economics and implications for regulators and governments with ties to EC digital policies made when discussing Public Private Partnerships.

For verification of the 5G NORMA architecture design, a network roll-out in an urban London study area has been emulated for three different evaluation cases (*baseline*, *multi-tenant*, *multi-service*). This environment was chosen as a principal focus of analysis as it would be a likely candidate for 5G migration due to the opportunity for a mix of service requirements from different sectors and high density of subscribers, vehicles and businesses. The evaluation cases are based on a clearly defined set of services including KPIs on performance and coverage as well as functional, operational, and security requirements. The objective of identification of use cases and scenarios that will help in the definition of the 5G radio system architecture was first established in D2.1. Services have then been selected by WP2 based on a socio-economic benefit and revenue analysis published in [5GN-D2.2]. Soft-KPIs measure, in a qualitative way, the feasibility of envisioned network flexibility, complexity, and standardisation effort. While the baseline evaluation has documented the performance improvements of key 5G NORMA enablers, the multi-tenant evaluation has confirmed opportunities, benefits, and feasibility of multi-operator deployments for eMBB.

The range of services covered in the multi-service evaluation case enabled assessment of different use cases of 5G and their dynamics. This provides a limited but illustrative service deployment scenario. The dynamics of social benefit emerged through smart meters where low revenue, but high social impact may induce public body support. The multi-service evaluation extended the London baseline network by network slices for mMTC and V2I, thus emulating the deployment of the full set of generic 5G services on a common infrastructure. The analysis of performance, operational, and security aspects as well as the evaluation of soft-KPIs clarified the principal feasibility of 5G NORMA multi-service networks. Nevertheless, together with learnings from the demonstrator set up, the analysis has revealed several remaining challenges (among others, spectrum limitations as well as management and control complexity) to be addressed before a successful migration to multi-service networks can be realised.

The simulation of the London network build was based on appropriate application of TCO and technical constraints to a network builder algorithm that extensively evaluates network options and arrives at a sufficiently dimensioned network to meet forecast traffic demand. The build of the network applied conservative forecasts for spectral efficiency enhancements as a result of the introduction of 5G and the dimensioning constraints considered not only the radio interfaces but also the front and backhaul, reaching exchanges where siting of edge-cloud based resources is desirable. Dimensioning then continued to extend that supply of compute, storage and networking extending the network infrastructure into the cloud based resource domain. The estimation of required compute resources was based on the analysis of papers that establish a general-purpose processing (GPP) requirement for critical parts of the RAN processing, especially the PHY and MAC.

Revenue forecasts are underpinned by the application of standard economic forecast methods that are primarily driven by willingness to pay where sufficient historic data is available. For new services where models may not be so well-established various approaches have been developed to establish expected revenues.

A method for forecasting of traffic demand has established approaches based on the spectral efficiency of connected devices and driven by typical use case narratives, an aggregate temporal-spatial traffic demand is derived. By combining the expected revenue along with expected traffic, and assuming the network is built to address the traffic demand, a high level business case has been established.

For each of the three key evaluation cases C-RAN vs D-RAN (baseline), multi-tenant and multi-service key insights have been derived and finally captured in [5GN-D2.3]. Principal findings with respect to the primary evaluation criteria and techno-economic platforms are:

- For C-RAN vs D-RAN: There are no significant cost barrier to the adoption of a direction towards deployment of C-RAN based architectures based on a 11yr TCO assessment. Whilst capacity of networks should continue to improve the TCO balance between CAPEX and OPEX and the introduction of more cloud oriented approaches results in similar or marginally reduced costs. The business case analysis for eMBB shows a RoI of 6% for medium traffic and medium revenue.
- For multi-tenant: The benefits of sharing infrastructure to an incumbent MNO with assets are established and quantified. This provides a 14% TCO saving for 2-4 MSPs sharing infrastructure. An increase in the number of MSPs sharing (for the high traffic density city environment) does not reduce the costs further as the system is constrained by the quantity of spectrum that is available. With sensitivity analysis, eMBB RoI is lifted from 6% to 17% for the medium traffic and revenue scenario.
- For multi-service: The logical progression of development of infrastructure and addressing different types of use case, be these in the MBB, mMTC or uMTC domain are illustrated. There are disproportionate increases in costs for new services compared with traffic volumes to repurpose the network. However, on the other hand revenues increase at a greater rate so there is an overall positive impact on the business case that helps to de-risk the eMBB only scenario. ROI improvements over the baseline eMBB

only single tenant case of 3%, 6%, 7% and 10% were observed for combining eMBB with each of smart meter, assisted driving, infotainment and semi-automated driving respectively.

Whilst some TCO savings are evident from the evaluation, the merits of the architecture in terms of not establishing a greater cost base and allowing the cost structure to be shifted to OPEX over time are evident. The economies of cloud with respect to scope and scale of the system are illustrated. The qualities of the 5G NORMA architecture in terms of qualitative measures of performance and value creation are established.

The early realisation in WP2 of the limited cost reduction at the Infrastructure Provider layer as a result of the introduction of the 5G NORMA architecture motivated research into the business models and revenue generation potential that a more flexible architecture could enable. The economic externalities or benefits beyond the technical system of such an architecture were also explored through social value analysis. The social value analysis enabled the articulation of regulatory and government oriented opportunities leading to additional costs benefit and public-private partnership views. Where possible economic benefits have been quantitatively assessed. For example, economic value of postulated productivity gains using the UK as a case study over a the ten year period arrived at a figure of ~£20Bn gain. Socio-economic benefits of smart meters and V2I (whilst infrastructure costs are higher) were demonstrated and emphasise the importance of public-private partnership to establish new digital markets.

Identification of technical architectural requirements that need to be satisfied by the solutions devised by WP3, WP4 and WP5 and the effective monitoring of KPI achievement were delivered through WP2 defining service requirements and traffic forecasts for the 5G services analysed in Evaluation Case 3 (multi-service). These fed into the technical assessment in WP3. D2.3 includes discussion of the changing ecosystem with implications of why network slicing is needed to support these new stakeholder relationships. D2.3 specifically references D3.3 and the stakeholders defined there along with the proposed migration scenarios, demonstrating the tight coupling between WP3 architectural constructs and the WP2 evaluations.

The 5G NORMA evaluation framework has been constantly under review due to architectural, KPI and spectrum interactions with the 5G-PPP working groups. WP2 has defined service requirements and traffic forecasts for the 5G services analysed in Evaluation Case 3. These have fed into the technical assessment in WP3. The 5G-PPP whitepaper on system performance evaluation received a techno-economic evaluation input from WP2.

3.2.3 Final demonstrators

In the context of the Work Package 6, we have developed a set of four demonstrators related with three selected 5G NORMA key concepts:

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

To implement these demonstrators, different specific proposals from other WPs are practically implemented in WP6 (e.g.: SDM-C, SDM-O, NFV Management and Orchestration or certain security concepts among others) by means of different services: Mobile Broadband (MBB), Massive Machine Type Communication (mMTC) and Reduced Latency (RL) services. Specifically, the four developed demonstrators are

- Demo 1: Native Multi-Service Architecture. This demo focuses on the Network Slicing concept implementing capabilities defined in WPs 3, 4, and 5. It further shows a complete set of services, providing a pure eMBB service, a Low Latency service and an mMTC example.
- Demo 2: Multi-slice service aware orchestration. This demo also focuses on the Network Slicing concept, although from the NFVs Management and Orchestration

perspective. It addresses the principal concepts of the network slicing adaptation of the mobile network stack, and VNF mobility utilising technologies from WP4 and WP5.

- Demo 3: Secured Multi-Tenant Virtual Network Resources Provisioning via V-AAA. This demo relies on the authentication, authorization and accounting aspects of the architecture as they are defined in the WP3.
- Demo 4: Online Interactive 5G NORMA Business Cases Evaluation Tool. This demonstrator is one of the outcomes of WP2. It can be used to enable the assessment and dissemination of the economic impact of the 5G NORMA innovations.

The implementation of these demonstrators served also as an information source for other work packages; for instance:

- From WP6, due the works carried out in Demo 2, we've actively collaborated in the design of the MANO layer in the 5G NORMA architecture carried out mainly in WP3.
- We've collaborated in the QoS/QoE framework design developed in WP5.
- Also, the Virtual Cells concept introduced in the WP4 has been practically validated in Demo 1.
- The security concepts addressed in the WP3 were conditioned by the works in the Demo 3, since this demo practically implements these security concepts.

By implementing these demonstrators, we've evaluated different qualitative KPIs, and valuable lessons have been learned. For example, in Demo 1 we integrated legacy PNFs (eNB) with surprisingly reasonable effort. Demo 2 showed the indeed drastically shortened setup times through fully automated on-boarding, but equally showed that today's available NFV MANO platforms are not yet sufficiently mature due to interoberability issues, some proprietary formats and missing advanced features. Demo 3 prooved that the proposed security concepts are simple enough to work on low-end hardware. Finally, from Demo 4, we learned how to present results of a complex model through a simple interactive webpage. All of these are described in detail in the last WP6 deliverable D6.2 [5GN-D6.2].

Finally, besides the demonstrators themselves, from WP6 we've also actively collaborated in the project dissemination activities. Technical papers have been written, and intermediate versions of the demos have already been presented in several relevant events such as MWC, EuCNC and ICC.

3.3 Standardisation Opportunities

The report [D7.2, Section 3.1] provides a detailed overview of the contributions by 5G NORMA to standardization bodies, which include the following SDOs.

As in prior mobile radio generations, 3GPP is the dominant standardization body for 5G, and it has been addressed by 36 of 52 standards contributions of 5G NORMA. 5G NORMA mainly contributed to 3GPP RAN, RAN2, and RAN3 mainly based on the innovations discussed in WP4 such as low latency communication (URLLC), slice isolation in RAN and RAN slicing in general, multi-connectivity and interworking of 5G NR and LTE, new RAN state, SON based support of RAN adaptation and configuration, and UE based e2e context aware service delivery in RAN.

5G NORMA has further impact on 3GPP SA1 and SA2 on service requirements, network slicing, distinction between dedicated and shared network functions, application and context aware QoS, session management, and mobility management. Those contributions mainly originated in work packages 3 and 5.

In **ETSI NFV**, among others, two contributions have been submitted as a new use case, based on the migration steps described in D3.3 and edge-cloud orchestration considerations in D5.2. In **IETF**, five contributions have been submitted mainly based on considerations on service function chaining and on the mobility management work performed in WP5, as well as network slicing architecture and its alignment between 3GPP, NGMN, and ETSI (based on WP3 work).

In **BBF**, five contributions to the Cloud Central Office project stream have been submitted on 5G enablers and requirements, infrastructure management (based on WP3 work) and two accepted new uses.

Finally, the **IEEE** standards working group "P1918.1: Tactile Internet: Application Scenarios, Definitions and Terminology, Architecture, Functions, and Technical Assumptions" has been formed as the result of a collaboration of a 5G NORMA partner, King's College London KCL, and Technical University of Dresden. One contribution based on WP4 results [D4.1] on the multi-connectivity architecture has been submitted to the working group.

5G NORMA partners will continue contributing to standardization bodies relevant to the project's five core competencies multi-service, multi-tenancy, software-defined mobile network control, flexible decomposition of network functionality, and joint optimization of radio access and core network. In particular, [D4.2, Section 2.2] provides specific examples for further standardization potential in RAN; [D3.3, Section 3] provides specific procedures, interfaces, and protocols relevant for the overall architecture and hence, may become relevant for future SDO contributions; and [D5.2, Part II] describes specific solutions for network slice orchestration, QoE/QoS control, and mobility management, which may become particularly relevant for 3GPP SA5, ETSI NFV, and IETF.

3.4 Exploitation Activities

Nokia

Nokia is a front-runner in the area with its flexible designed product lines Liquid Application and AirScale. A next level of innovations can be expected from 5G NORMA results, by integrating cloud technologies directly into the base station and allowing for flexibly allocating functions in the base station or in more centralized servers.

In particular, the 5G mobile network architecture defined in work package 3 impacts Nokia's contributions to 3GPP SA2 and the integration of Network Slicing in the mobile network architecture. Furthermore, the results of work package 4, in particular on RAN slicing, multi-connectivity, and user-centric area communication impact Nokia's contribution to 3GPP RAN2 and RAN3, and the implementation of e2e network slicing. The basic concepts developed in 5G NORMA are currently under implementation in the 5G-PPP Phase 2 project 5G-MoNArch, led by Nokia. Finally, Nokia's contributions in work package 5 to QoS/QoE enforcement and control, slice-management, and management of UCA will have impact on Nokia's contributions to 3GPP SA/RAN as well as ETSI NFV. In addition, the concepts are further developed in order to integrate them in Nokia's RAN and CN products, in particular QoS enforcement and slice-management.

Furthermore, Nokia uses results from 5G NORMA in direct customer presentations and discussions with customers in order to shape the 5G mobile network architecture. Nokia Bell Labs has a strong contact to Nokia business lines and provides input to the definition and setup of the 5G product roadmap. In particular, Nokia Bell Labs contributed specific input on e2e network slicing with emphasis of RAN slicing, and multi-connectivity to the Nokia Mobile Networks business group. Among others, Nokia will further explore the application of 5G NORMA's network slicing architecture to novel use cases such as V2X, industrial deployments, and other verticals. Furthermore, 5G NORMA results will be applied to optimize algorithms for service provisioning, in particular QoS delivery such as for video services or gaming. Nokia Bell Labs will maintain this strong cooperation with its business lines to make sure that results from 5G NORMA will be considered for future 5G products as well as 5G prototyping.

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 (MRAN) and Mobile Wireless Networking (MWN). 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. Moreover, NEC has been leading in the area of network virtualization focusing on Software-Defined Networking (SDN) and network functions virtualization.

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 particular, NEC will deeply analyze the market impact of the 5G Network Slice Broker as the main enabler to bring into play the network slicing paradigm for future mobile network generations.

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 has been partially 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.

Atos

ATOS, a global leader in digital transformation with customers across various business sectors, is leveraging the expertise and knowledge gained in 5G NORMA in order to evolve its portfolio and provide their customers with the latest innovations in the telecom area in order to not only satisfy their demands, but also to help them managing the fast changing and complex ecosystem and to enable new business opportunities.

In this sense, the experienced gained in the NFV area during the project has led to the creation of an NFV Lab in Atos as a worldwide center of excellence to get hands-on experience with new network and business technologies. A multi-vendor alliance has been created around it to answer the challenges the telecom operators and network infrastructure providers face today to migrate the telecom networks from a traditional physical model to a modern virtual environment. This NFV Lab leveraged from the architecture and key concepts designed in 5G NORMA. ATOS uses it to carry out different pilots and trials with tier-1 European operators.

The main concepts utilized from 5G NORMA include automated network services deployment and reconfiguration demonstrated within the project; specifically, a VNF-Manager and NFVO were implemented for NFV management and orchestration purposes in the context of the WP6; this development could be used as a seed for the future implementation of a more complete NFV MANO platform.

ATOS, as the Worldwide Information Technology Partner for the Olympic & Paralympic Games, is also very focused on media distribution vertical industry. The expected increase of network requirements, services and content is a high challenge where we are exploring the forthcoming software networks and the new possibilities they offer in terms of multitenancy, network slicing or elasticity.

In addition, ATOS is exploiting the experience acquired in the project to open new research fronts that contribute to strengthen the telecom industry in the European Union and increase its competitiveness.

Deutsche Telekom

Products and services of Deutsche Telekom target consumers, business customers, vertical industries and the public sector (e.g. PPDR). In the future 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. As pointed out by Claudia Nemat, board member of Deutsche Telekom for technology and innovation, 5G is expected to address particularly industrial users and enable a wide range of applications for them [DT17]. Beyond that, the public interest in 5G indicates that demand for communication services in general is likely to grow over the next years.

As one of the initiators of NFV, DT has started already in 2012 to investigate how virtualization and cloudification technologies can be implemented in its networks in the field. 5G NORMA has enhanced these technologies with SDN concepts and thereby enabled the concept of network slicing [NGMN]. While services for industrial users are highly diverse and heterogeneous, nevertheless they shall be produced on a common communications platform for economic reasons. 5G NORMA's network slicing concept provides the necessary flexibility to adapt such a common communications platform dynamically to the requirements of these services and the demands of the customers. Furthermore, the concept allows to introduce innovative services much faster than legacy network architectures. The experiences with network slicing from 5G NORMA have influenced the work in the GSMA's Network Slicing Task Force which is chaired by Deutsche Telekom [GSMA].

Another important concept in 5G NORMA is the flexible allocation of network functions according to the demands of the offered network services and the capabilities of the available physical infrastructure. This concept is relevant for RAN virtualisation which is currently under investigation as well as for the design of edge data centres.

During the runtime of 5G NORMA, Deutsche Telekom has been active in 5G standardisation and submitted contributions to 3GPP working groups, IETF and ETSI NFV. Furthermore, Deutsche Telekom has filed several patents related to 5G NORMA concepts and their application.

Deutsche Telekom aims to extend and apply the research results from 5G NORMA. For this reason, Deutsche Telekom has joined the 5G MoNArch project, where a test bed based on 5G NORMA concepts is setup in a real world environment. Together with an equipment vendor and a vertical industry partner, Deutsche Telekom wants to collect experience in operating a communications platform with network slicing and explore features for improving the reliability of communications services.

Orange

Placing strong emphasis on the flexibility and future proofness of its future networks, Orange aims at using the findings of 5G NORMA in the deployment of a flexible and future-proof 5G network architecture. Towards this end, the 5G NORMA work allows Orange to develop a clear vision on concepts such as RAN as a Service, slicing and multi-tenancy as a valuable input to the process of identifying what type of services can be offered to the customers. Besides, 5G NORMA results enable Orange to shape its roadmap for the commercial deployment of the 5G networks. Another very important benefit for Orange is that the concepts and ideas developed in the 5G NORMA projects guide its contributions in the standardization organizations such as 3GPP and ETSI.

Telefónica

As a network operator, Telefónica is interested in extending cloud technologies to all the segments of the network in an optimized way and with a focus on a phased approach to minimize upfront costs to deploy VNFs at the edge of the network. In this respect, current central offices are a very good candidate to be evolved to Edge Cloud locations.

Telefonica has already deployed a central cloud platform called UNICA. Telefonica will use the 5G NORMA results as input to define the UNI-CO (UNICA Central Office) which is the evolution of the UNICA platform for deploying VNFs at the Telefonica Central Offices. In particular Telefonica will use for that purpose the contributions made from the 5G NORMA work to the Broadband Forum Cloud Central Office project and to ETSI IFA 022. Telefonica is already working with other industry partners to incorporate these 5G NORMA outcomes in products to be taken to the network.

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 has been tackled by redefining the software architecture to allow such flexibility, leveraging the virtualization layer and the network programmability

Azcom has developed a Network In a Box (NIB) product, where all the network functions from the RAN and the Core Network are implemented in a small portable box, exploiting the network function relocation concept proposed in the 5G NORMA flexible architecture. During the project, the Azcom hardware eNB has been adapted to be controlled by the 5G NORMA SDM-C component. Moreover, Azcom has also implemented the virtualization of its EPC, which is now a virtual function and in future it is planning to enable the Azcom EPC ability to be orchestrated allowing the full support to the 5G NORMA MANO concepts.

The participation in the 5G NORMA project has allowed Azcom to show its demos in several conferences such as EUCNC and ICC, in addition to industrial events such as Mobile World Congress, which has seen Azcom participating since 2012.

All the above developments and applications of 5G NORMA are in line with Azcom's business strategy evolution, starting from the continuous improvement of the existing Small Cell hardware and software platforms but also including the implementation of new applications. By integrating such innovative concepts earlier, Azcom is foreseeing the future challenges in the Small Cell platform implementation domain.

Nomor

Nomor has used the valuable opportunity provided by the 5G NORMA project to extend its service portfolio. During this project, Nomor developed a new 5G simulator to study the innovation in 5G networks and extended its related simulators and demonstrators, 5G-specific radio algorithms, and standardisation and consulting services.

The new simulator/demonstrator of Nomor can connect to a stand-alone SDM-C (developed in the framework of WP6 demos) and present the concept of network function decomposition (WP3). To enable low-delay real-time platform as the critical requirement for offering Gaming Platform-as-a-Service (PaaS), SDM-C pushes the network function elements from the central-cloud to the edge-cloud. It also pushes the network functional elements to the central-cloud enabling interference coordination to increase the total network throughput and meet the QoS requirements of different services such as high definition video streaming. The SDM-C and

simulator also extended with uplink and support of TDD mode, to support the formation of the virtual cell (i.e., the centralised radio resource management techniques developed in the framework WP4). Using the centralised control over the eNodeBs, the UEs placed near the edge of cells can be served by both eNodeBs. The primary focus of the algorithm above is to offer the concept of virtual cell based on the flexibility provided by 5G NORMA architecture and innovations. Using the Q-learning agent to form a virtual cell, Nomor considers machine learning approaches for developing radio resource management algorithms.

Nomor has successfully updated its GUI (Graphic User Interface) for demonstration. The developed demo, in collaboration with Azcom, has been one of the primary demos of the project presenting 5G technologies in many noted conferences and workshops, e.g., Mobile World Congress 2016 (MWC'16), International Conference on Communication 2016 (ICC'16), EuCNC'16, EuCNC'17 and MWC'17.

Finally, NOMOR is using the experiences and knowledge gained in designing the architecture of the next generation of mobile networks to improve its standardisation and consulting services. 5G NORMA provides NOMOR with the chance of partnership with other active SMEs, companies, and universities in the area of 5G networks to extend the diversity of its services to its clients. The successful presentations in the well-known scientific stages bring NOMOR new business opportunities.

Real Wireless

Real Wireless Ltd (RW) is the world's leading independent wireless advisory firm and provides services addressing the wireless industry and wireless users (now generally referred to as verticals) sectors. The socio-economic insights gained from the early work in 5G NORMA were utilised and built upon for two large reports into the Socio-Economic benefits of 5G for the European Commission and a UK government national mobile infrastructure study for the National Infrastructure Commission exploring future communications infrastructure needs at a National level. Both studies were completed in 2016. The substantive and representative use cases and their costs we identified, methods applied in 5G NORMA WP2 and WP3 were pertinent to the task and informed the outcomes. Within those strategic and industry oriented projects vertical industry opportunities emerged such as Transport and Gaming which have subsequently informed dialogues around innovation management within the 5G NORMA project and in dialogues with clients.

The RW unique capabilities are underpinned by a platform of models and simulation tools. These tools are utilised by our consultants when engaging with regulators investigating long term spectrum policy matters and those seeking to evaluate investment opportunities in the industry. This platform has traditionally focused on Capacity Demand scenarios based purely on macro and small cell radio topology considerations. However, the C-RAN architectural insights of 5G NORMA coming through WP3 and then tested through techno-economic approaches in WP2 enabled the development of a capability to investigate wider system level matters and establish RW expertise in dimensioning of Edge, Cloud and Core domains as Cloud based architectures dominate the evolution of networks.

We have evolved our high resolution geospatial and temporal traffic demand modelling capability through application of traffic centric and revenue centric perspectives. These demand profiles with appropriate modifications based on market addressing requirements have been applied into a consulting project with a Tier1 global MNO in their 5G strategy review. The demand data in combination with a process of Use driven analysis; significant elements of which were developed through the approaches taken in WP2.

The renewed modelling platform capability (called CAPisce) enhances the service offering of RW; enabling a wider addressable market and establishes significant opportunity for RW to act as a technology broker in the market, a change agent, establishing business case and viability insights for strategic decision influencers and decision takers. Our developing capability is

already proving beneficial in the Cities sector where the ability to model capacity demand and the implications for dimensioning of a system are attracting early business development interest and we have supported a City deployment analysis looking at global cities. Within this client's project the deployment approach and evolution of the multi-service platform (based on steps and analysis considerations from WP2 and WP3) were invaluable.

The development of the business model demonstrator in WP6 has led to the refinement of the RW capability to "compress" data generated from complex scenarios and distil down to the essence for a more dynamic communication of the business case through the development of dashboards. The prospect of offering a dashboard to allow high level what-if analysis by future clients has led to an additional marketable RW value add proposition over and above the originally intended exploitation opportunity, the dashboard can be a deliverable product and as such an example of reverse-servitisation through data.

King's College London

King's College London (KCL) is one of the top 20 universities in the world (2015/16 QS international world rankings World University Rankings). The Centre for Telecommunications Research (CTR) has had a consistent impact on mobile communications over the last 3 decades, resulting in more than 120 PhD graduates, over 1500 publications, 20 books, 10 industry standards, 50 patents and more than 30,000 citations; hence this project is of immerse importance to our overall activities.

The research finding in the project have been linked in one recently funded and two submitted national (UK) cross-disciplinary research project proposals within the area of network orchestration for ultra-low latency communication and game theoretic algorithms for network slicing. The recently funded project where we expect results from the 5G NORMA project to provide explicit as well as implicit influence is the £16M 5G-UK project that aims to create a federated national 5G testbed across the UK. In addition to that, we aim to utilize the research undertaken in 5G NORMA in various PhD research Theses revolving around the area of 5G networks, since the research insights arrive in a timely manner to pave the way for further insights especially related to future directions of 5G research. There are already two PhD research thesis which have been linked with the 5G NORMA project and will continue their research well beyond the timeline of the project; both of those relate to the research on virtual network function routing, chaining and location.

Within the next academic year we also envision that the NORMA research will filter into our postgraduate courses, especially those related to our highly successful MSc in Mobile and Personal Communications; these will be mostly related to overall architectural aspects of 5G networks rather than specific techniques and/or algorithms. Relevant project results related to security research work have been presented to regulatory authorities (such as for example in the International Telecommunication Union – ITU – in Geneva) with the aim to influence their rulemaking towards more efficient and secure 5G networks.

Finally, regarding the implementation aspects achieved in the project, we aim to utilize those to further build innovation potential linked to novel ideas—particularly around database management, for example. This could potentially involve a spin-off company around distributed spectrum management.

Technical University of Kaiserslautern

The Technical University of Kaiserslautern exploited 5G NORMA results in a variety of ways, as dissemination of technical 5G NORMA results and dissemination of TUKL's technical contributions is considered of the highest importance.

Our different courses in the Masters and Bachelor programs used the results of 5G NORMA to show students the edge of research and technology currently being developed in 5G. Topics like "QoE in Mobile Networks" and "5G mmWave Technologies" have been part of seminars. Results from 5G NORMA have also guided the research of PhD students. Specifically, motivating further investigation on flexible allocation of service function chains, which is grounded on the 5G NORMA enabling feature of adaptive decomposition and allocation of network functions.

Topics explored by TUKL are mobility of virtual network functions, routing augmented with QoE, inter RAT multi-connectivity, congestion reduction in mMTC, and secure edge cloud trust zones. These topics are closely related to the project goals, since they benefit from the dynamic and adaptive decomposition and allocation of network functions, the software-defined control and orchestration, and the multi-service adaptation of network functions provided by the architecture. Dissemination of TUKL's results from these topics was achieved high quality papers in top journals and conferences. Some notable examples of journals and conferences are IEEE Communications Magazine, European Wireless 2017, ICT 2017, ISCC 2017, CSCN 2017 and Globecom 2017.

Universidad Carlos III de Madrid

UC3M used and will continue using the results of the 5G NORMA project mainly along three lines: strengthening the academic leadership, foster the technology transfers to enterprises and the consolidation of the academic courses portfolio. We detail them in the following.

The participation of UC3M in the 5G NORMA project allowed us to publish our research results in the top-rated conference and journals in the field of communication networks. Among others, the research performed in the 5G NORMA project (specifically, in the context of WP4) led us to two papers accepted at INFOCOM (which is arguably the most important conference in the field) and to one paper accepted at IEEE Communications Magazine. This helped us to strengthen our position and increased even more our visibility as one of the top academic institutions active in the field of 5G Networking. The leading role of UC3M in this area has been recognized by the research community as well: UC3M led several special issue on different 5G NORMA topics (such as the one in the IEEE Communications Magazine) and organized three editions of the 5G Arch Workshop, held in conjunction with IEEE ICC.

Technology transfer to enterprises is one of the key activities of UC3M. One way to achieve that goal is through the standardization of our research activities in 5G NORMA. Specifically, UC3M authored IETF drafts in the field of mobility management for mobile network and the specific SFC needed for an architecture such as the one studied in the project. Also, the network programmability concepts introduced by the SDM-C/X modules have been pushed into an ONF WG. This allowed UC3M to highlight its academic excellence in these fora, enhancing the technology transfer opportunities.

According to several national rankings, UC3M is classified among the top university in Spain for computer science and telecommunication network studies. The knowledge achieved from the participation in 5G NORMA allowed us to fertilize the courses currently taught with innovative content. More specifically, concepts such as network slicing, RAN softwarization, Network Programmability and flexible QoE/QoS control have been included in the syllabus of the "Wireless Networks" course in the Telematics Engineering MSc programme. Also, the innovative work performed in 5G NORMA has been seminal for the brand-new Master in 5G Network that will start in March 2018. Finally, three PhD thesis are being supervised on the topics addressed by 5G NORMA.

4 Innovation Management

4.1 Innovation Management Approach

The Innovation Management (IM) process was designed to capture conceptual ideas that are to be evaluated against innovation criteria by the utilization of widely recognized models. The models were chosen to establish a measure of relevance to potential future 5G markets. Fundamental to the success of IM was the identification of nascent ideas which upon initial inspection may or may not be fully aligned with the pre-determined innovation narrative of 5G NORMA. However, through capturing of the idea, and then analysis and maturing of the potential through a simple gating process, the project was able to progress the maturity of the idea. Ideas were captured in a central innovation repository or innovation database.

Ideas were identified through a continual process of brainstorming at face to face meetings (strategic) and capturing of identified ideas through WP reports (tactical). Aspects of entrepreneurship were also explored as a secondary process. 5G NORMA explicitly sought value add and potential for new eco-systems or business models that would benefit from the 5G NORMA architecture and research insights. This took the scope of innovation management beyond just considerations of new products and services, to include potential for potential value creation and value capture. These issues emerge in particular in collaboration with WP2.

Four principal perspectives of product, process, position and paradigm (4Ps model) enable the initial framing of the emerging idea that is discovered, including a tentative evaluation of the merits for the key stakeholders in the 5G NORMA architecture. The Innovation Management process (Figure 4-1~~Figure 4-1~~) structured the progression of the ideas over the lifetime of the project.

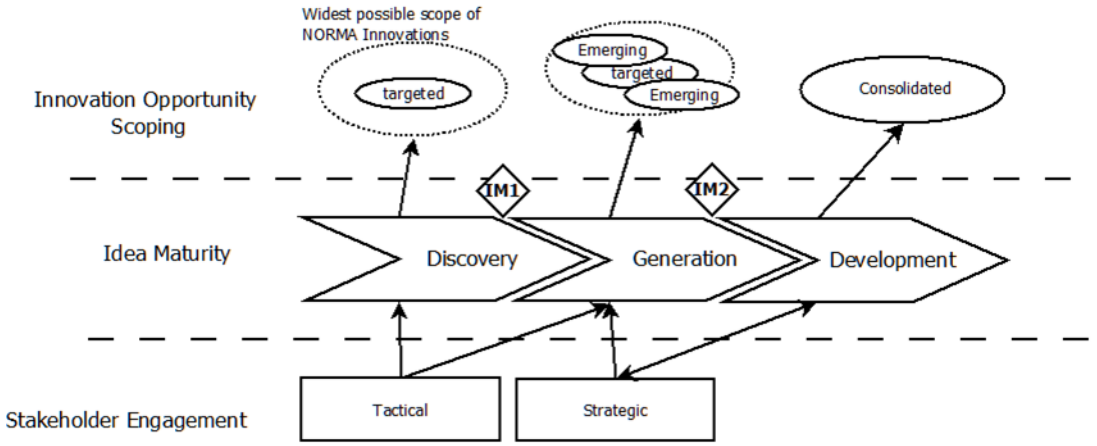

Figure 4-1 : Innovation Management Process

4.1.1 Innovation Framework

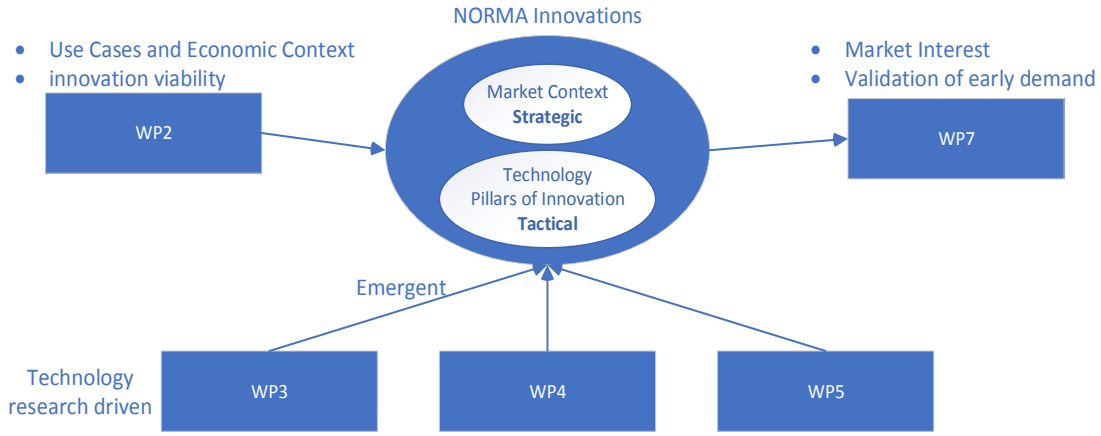

Figure 4-2 : Reach of Innovation Framework

The reach of the innovation dialogue within the project (see Figure 4-2~~Figure 4-2~~) was driven by two significant perspectives, Market Context and Technology Pillars.

Market Context Strategic ideas were developed during plenary discussions and Idea Development partners were encouraged to encompass some of these ideas in their exploitation plans. As the research matured, some of the IM activities worked in collaboration with WP7 where a focus on workshops and conference steering oriented activities enabled early validation of innovation ideas from market oriented discussions and seeking wider stakeholder engagement.

The Technology Pillars of Innovation provided the technical direction for the research and were developed during early stages of the research and validated as the project progressed.

4.1.2 The Pillars of Innovation – Technical Direction

As 5G NORMA is predominantly a technology research activity, the 5G NORMA direction in terms of technical invention that will be valued highly was guided by the Pillars of Innovation. These pillars comprise enabling and functionality perspectives and established in the project scope the significant technical objectives.

Enabler – Pillars

- E1 – Adaptive (de)composition and allocation of mobile network functions between the edge and the network cloud depending on the service requirements and deployment needs
- E2 – Software-Defined Mobile Network Control and Orchestration which applies the SDN principles to mobile network specific functions
- E3 – joint optimization of mobile access and core network functions localized together in the central cloud or the edge cloud

Functionality – Pillars

- F1 – Multi-service and context-aware adaptation of network functions to support a variety of services and corresponding QoE/QoS requirements
- F2 – Mobile network multi-tenancy to support on-demand allocation of radio and core resources in a full multi-tenant environment.

4.1.3 Directing Stakeholder Engagement

An important touchpoint with WP7 (Dissemination) was the promotion of architectural concepts and relevant enabling technologies at conferences and publications. The Innovation Management activity enabled the setting of narratives around innovation viability with pathways to exploitation of the technologies.

Innovation management identifies and promotes open eco-system approaches enhancing the prospects of impact of the research (see Figure 4-3~~Figure 4-3~~). Innovation Management has generally sought to establish workshop like opportunities in commercially oriented conferences at which sales, investment, and industrial strategic management may be present.

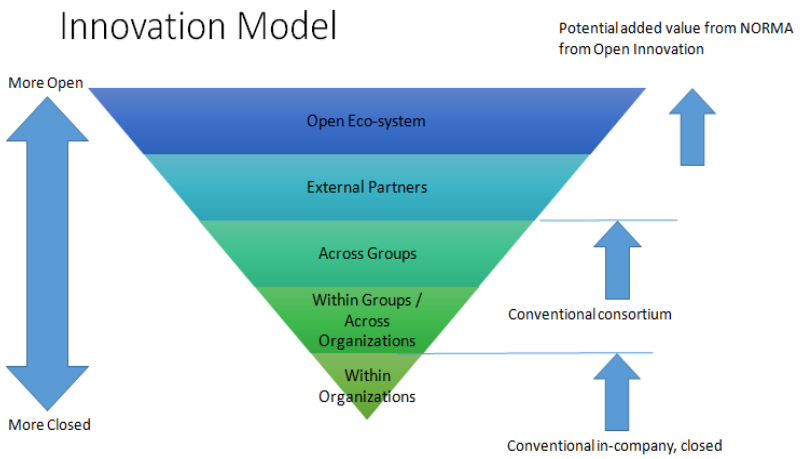

Figure 4-3 Stakeholder Innovation Model

4.2 Innovation Outcomes

Each WP was designed to uncover innovative approaches to address the challenges as set out by the pillars of innovation. A more detailed treatment of the technologies is to be found in the WPs' respective final deliverables; however, here we highlight the essential aspects.

4.2.1 WP3 Emergent Innovations

Through WP3 research, the focus of service specific network slices and their customization emerged. Interdependent with the slicing concept was the multi-tenant network and the control and resource allocation thereof. To assure a highly agile network, the adaptive allocation of network functions established the appropriate dependencies to the service requirements and deployment needs.

RAN paging for efficiency and its implications in the context of multi-tenancy. The SDMC creates a critical element in the support of the flexible and centralized radio resource management. Realising multi-service and the approaches to context-aware adaptation of network functions was a significant outcome with Q-routing providing an end-to-end enhancement to control of QoE.

Improvements in eMBB QoE performance can be expected through 5G NORMA, with the opportunity for the user to "set" the QoE. The market oriented narrative around V2I driven first through the Use Case analysis established the need for improvements in V2I. Infotainment delivery needs enhancements due to the deployment considerations and 5G NORMA established a new routing scheme. Models for control of QoE for audio and video services without the need for user intervention were developed. As Q-Routing algorithms need time to stabilize, the approach to market introduction for this feature in V2I were investigated to establish possibilities to overcome its limitations in this context.

4.2.2 WP4 Emergent Innovations

The focus on technologies required for multi-tenancy in the Radio Resource Management (RRM) and admission control domains established several innovations. The multi-connectivity feature was enhanced through a focus on reliability, creating a framework for integration of mmWave, virtual cells, increasing efficiency and service quality in TDD networks.

Convergence of functions that are logically in the Core in today's networks towards the RAN, was enabled through architectural thinking in WP3 leading to technology discovery. Significant findings in the domain of cross layer innovations oriented towards User Centric Connection (UCA) that reduce mobility related signaling. The development of Edge Computing features enabled a reduction in application latency and congestion in the case of mMTC applying novel approaches to clustering of signaling with a central geolocation database.

4.2.3 WP5 Emergent Innovations

The SDM-Controller, SDM-Coordinator and SDM-Orchestrator components of the network were identified and refined from within this WP. An approach to the adaptive (de)composition and allocation of functions to allow functions to run either on the central cloud or edge cloud with intelligence to drive these functional location based on cognisance of service and deployment needs.

Innovative techniques to migrate or replicate a VNF were developed. Addressing the imperative for efficient realization of mobility, the SDM-C mobility management application was researched to establish the software-ised approach to joint optimization of the converged core and RAN.

4.2.4 Market Context Oriented View

4.2.4.1 Economic Drivers

It is now well understood that consumer market ARPU from data services is on a steady decline. There is little evidence to support a claim that 5G will increase ARPU for data services. Therefore, the revenue generation opportunity that is of particular interest to 5G NORMA is increasing the scope and scale of addressable market by creating value for B2B and B2B2C revenue, addressing vertical markets with mobile services that may enhance revenue. WP2 business model analysis provides a reference source, given a set of use cases defined in WP2 the project was able to see a clear categorisation of use cases based on a dependence to the automotive sector Figure 4-4~~Figure 4-4~~. We highlight in this figure where automotive sector relevance is identified, these categorisation exercises were carried out across the use cases as part of innovation management to identify verticals, platforms and business models and refine value creation opportunities and potential products and services that stimulate innovation narratives in that context.

Industry sectors, also referred to as Verticals, that have emerged as beneficiaries in the analysis such as entertainment (gaming and video) and automotive. The automotive sector may be generalised to transport, the broader environment that establishes a focus for evaluation of innovation ideas is **Cities**.

Whilst the opportunity for efficient service delivery of the MNO is ever present in the research, in fact the greatest opportunity for 5G to generate economic value exists in the delivery of platforms that create value within verticals. Such verticals cannot be expected to move from their strategy of procurement of IT and Digital services as a result of the introduction of 5G. If they take an interest in 5G – which is still a matter of debate – they regard 5G as a technology platform that either improves their operational efficiency or creates more opportunities for the creation and capturing of value to generate greater revenue. Seamless integration into their technological and business operations must be delivered to assure wide adoption of 5G.

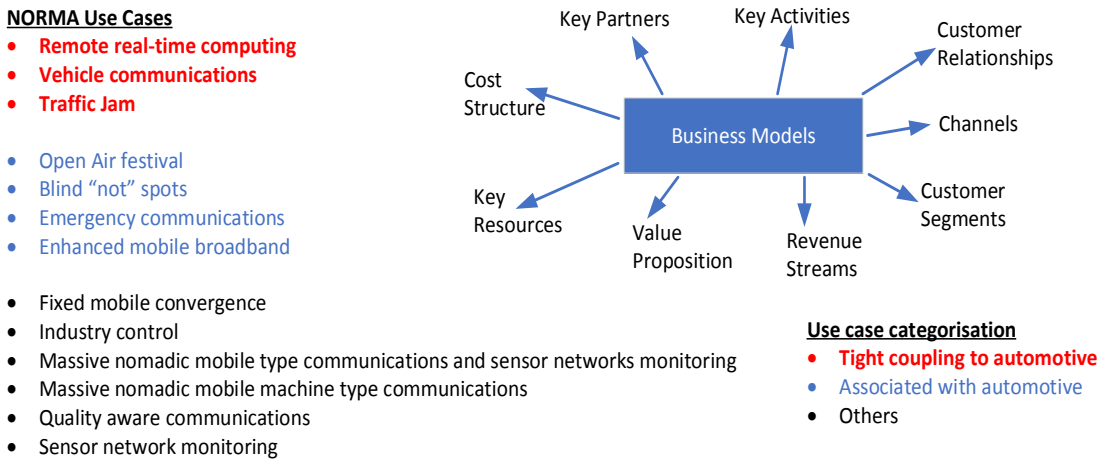

Figure 4-4: WP2 Business Models (with illustration of automotive framing)

4.2.4.2 The Mobile Service Provision Value Chain

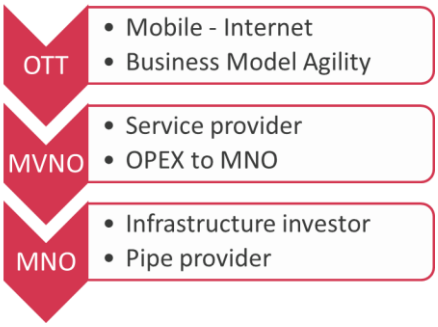

Figure 4-5: Mobile service provision value chains

Today's value chains (Figure 4-5~~Figure 4-5~~) have generally resulted in unfavourable financial performance of MNOs leading to poor shareholder returns and undercapitalisation to invest in new infrastructure. An investigation of the Mobile Service Provision Value Chain and the desire to establish a level playing field based on the "Tenant" and other paradigms of 5G NORMA has established that three broad innovation classifications may be realised through potential innovations enabled by 5G NORMA. **Schumpeter** like effects which enable creative destruction "disruption" but also establish technological unemployment. The **Exponential Organisation** realisation which brings the prospect of impact (or output) that is disproportionately large – at least 10x larger – compared to its peers because of the use of new organisational techniques that leverage accelerating technologies. The **eCommerce** model typical of OTT where disintermediation linked to "direct from product producers" supply chains dominate and success is based on curation of content or customer, and not the distribution channel.

The nature of the hybrid-OTT model was explored to discover the levers of influence and control that shall be available through the realization of the 5G NORMA architecture. The opportunity to redefine the concept of a mobile service offered by an MNO that goes beyond the constraints of the application operating on a device is apparent.

4.2.4.3 Innovation Value visualisation in 4Ps framework

A framework for the mapping of innovations established a simple visualisation mapping the innovation space within the 4Ps of innovation, creating the primary axis of analysis (see Figure 4-6~~Figure 4-6~~).

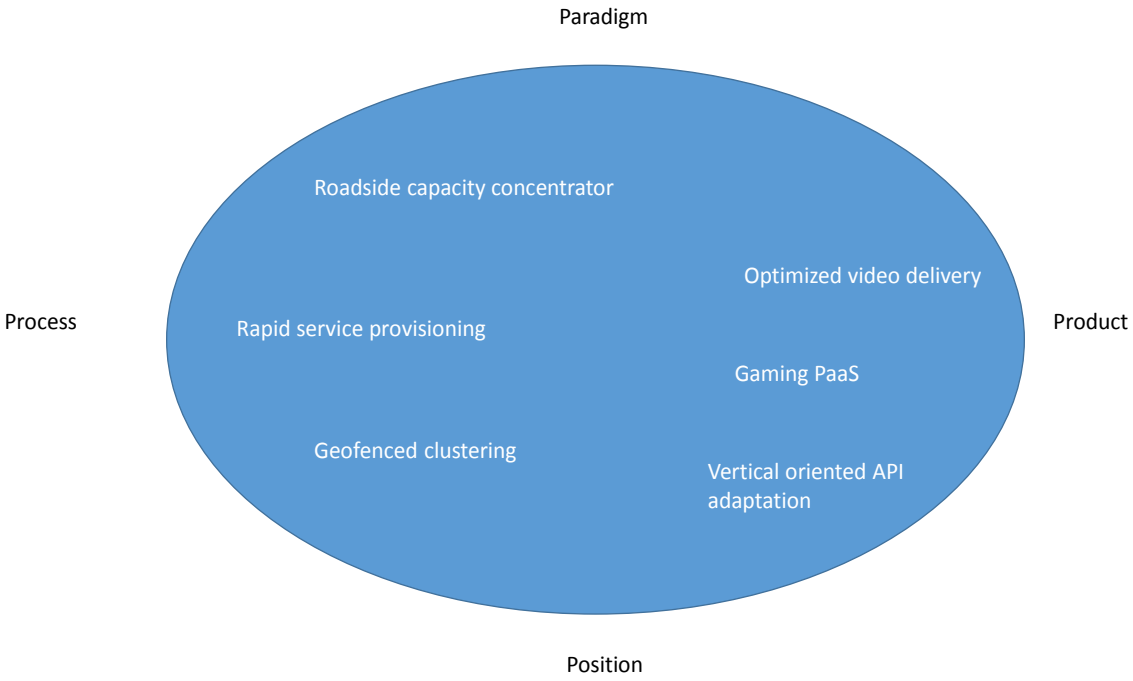

Figure 4-6: Mapped Innovation Space

Technology driven innovations have emerged enabled by the architecture with emphasis on various parts of the architecture from Service Layer (Gaming Platform-as-a-Service, Optimised Video Delivery, Roadside Capacity Concentrator) to the Infrastructure Layer (>6 GHz access enabler). The objective during the Innovation Management process has been to take into account potential for impact, business models and verticals as primary drivers and socialise this within and externally to the project.

A number of market context oriented innovations as depicted in Figure 4-6~~Figure 4-6~~ emerged which nudged the exploitation plans of project partners and set the wider ecosystem context.

4.2.4.4 Conference and Eco-system building

An important element of the innovation management was to augment the objective of dissemination of outcomes with engaging in dialogues. Generally, these were carried out in the latter stages of the project, some outcomes or developments to note.

Telecom Infra Project: During the lifetime of this project the Telecom Infra Project (TIP) was created primarily through Facebook initiative however one of the very early founding members was Deutsche Telekom. This project seeks to disrupt existing approaches of telco equipment provision and resonates well with the core value of 5G NORMA demonstrating that the research objectives were timely. DT now provides the Chairmanship for this organization. One of the key TIP projects initiated during the later months of 2017 has been End-to-End Network Slicing (E2E-NS); this shows the direction of the eco-system and the relevance of the direction that was set during the initiation of 5G NORMA.

5GAA: The 5G NORMA use case driven analysis in partnership with the Innovation management activity established automotive as a significant potential market; with V2I becoming an emergent theme through the WP2 assessment framework and also part of WP4

deliberations. During the life of this project the creation of this forum again demonstrated the timely nature of the research, with several of the project members now part of this forum.

RAN World Virtualisation Workshop: Through the knowledge gained in 5G NORMA a questionnaire on the challenges relating to the wider adoption of virtualization and software-isation of telecoms systems was developed and used to catalyse a workshop at the RAN World Conference. Useful data was gathered from the participants on the business drivers behind virtualisation and insights were provided to the attendees on some of the preliminary findings from the WP2 analysis.

URLLC Conference: The Innovation Manager took part in the formation of the agenda as a committee members and chaired several of the conference sessions during this inaugural conference in 2017. The conference will continue and already has established a date for 2018, such was the success of the theme and the interest in the industry in addressing the challenges of URLLC which so clearly reaches into the vertical industries.

4.2.5 Assessment of innovation viability

The evaluation tools in WP2 established a timeframe over which it is reasonable to expect an MNO to invest to establish and then mature a 5G platform and service delivery capability. The viability assessment period is one decade, from 2020 to 2030. Within WP2, the evaluation of the baseline (cloud transformation), multi-tenant, and multi-service based scenarios tests innovation in all of these domains [5GN-D2.3].

4.3 Alignment with impact objectives

4.3.1 Societal Impact

The outcomes of 5G NORMA establish societal impact benefits on a number of fronts. From an end-user perspective, a major societal objective of the project has been to improve access to high speed and better performing Internet services, which is one of the key pillars of the European Digital Agenda for 2020. 5G NORMA established the viability of key capabilities which through WP2 analysis can be seen to support sustainable development of the industry capability and place the industry in a strong position to contribute to the societal objective of supporting “ubiquitous access to a wider spectrum of applications and services offered at lower cost, with increased resilience and continuity, with higher efficiency of resources usage (e.g. spectrum), and to reduce network energy consumption.”. The objective has been supported by identification of novel technologies that can flexibly provide higher capacity when needed, but can also provide lower latencies when required. Such flexibility will provide a service provision capability supported by a flexible platform within which a MSP, InP and Tenant can co-exist with viable innovations and business models that will establish benefits for end-users.

The architecture proposed by 5G NORMA ultimately benefits end-users, which will enjoy a wider variety of services in their mobile device with reasonable expectations that slicing provides a method to efficiently deploy resources such that pricing of services remains reasonable. It is worth highlighting that some of the technological solutions proposed by 5G NORMA do not only provide the potential for lower cost services but also in an improved user experience, e.g., by reducing the latency for some of the scenarios, or allowing for increasing reliability.

At a more general level, 5G NORMA is also contributing to the community societal challenge on inclusive, innovative and reflective societies. The analysis within Innovation Management tightly coupled with stakeholder views in WP3 and economic analysis in WP2 illustrate new ways in which market opportunities can be identified and thus a framework into which the revenues of telecommunication providers and their market positioning of equipment and solution vendors, as well as application providers can fit. Such a framework establishes 5G NORMA as contributing to “inclusive societies” by promoting “smart and sustainable

growth." Indeed, the business model behind 5G NORMA architecture introduces significant novelty: (i) it introduces new stakeholders and thus points to how the service delivery value chain can evolve so stakeholders such as the infrastructure provider can capture value, (ii) it opens the mobile network ecosystem creating the opportunity for smaller players such as providers of virtualized network functions, and (iii) it enables the flexibility in architecture such that cost structures are manageable and efficiency of services delivery can be assured. As a result, 5G NORMA strongly contributes to creating a route to sustainability for the telecommunications sector.

Finally, from a European perspective, by bringing innovative solutions to the market validated by industrial partners, 5G NORMA is further contributing to the inclusive societies target by "closing the research and innovation divide in Europe" and "strengthening the evidence base and support for the Innovation Union and European Research Area." In this context, the activities of 5G NORMA within the 5G-PPP initiative are particularly relevant, which is further explained in the next section.

4.3.2 Impact on 5G-PPP

5G NORMA has been one of the key contributors to the collective 5G-PPP effort within Europe. Recognising that Europe is making a strong investment in 5G technologies with the objective of placing itself in the forefront of research and innovation for the enabling technologies of 5G. Europe is well positioned and directed towards this goal, there is industrial strength in this sector (network operators and manufacturers) as well as a strong tradition of leading technological advances in the area all the way back to GSM. However, similar initiatives to 5G-PPP are taking place in China, Japan, Korea, and the USA, and Europe needs to leverage the areas of competitive advantage to establish a strong position in the nascent market for 5G.

As one of the 5G flagships projects, 5G NORMA is playing a prominent role in the 5G-PPP. In particular, 5G NORMA is playing a unique role at the apex between access network, core network, and virtualization. Being one of the very few projects that comprise all of these perspectives, 5G NORMA has been in a strong position to serve as a bridge between the various 5G-PPP projects. This potential has been demonstrated by the many successful collaborations with other projects within the cluster of H2020 Phase 1 projects. Among other activities, it is worth highlighting the role played by 5G NORMA in the various 5G-PPP WGs, with special emphasis on the architecture group, the contributions of 5G NORMA to the KPIs identified by 5G-PPP, and the worldwide leadership role around 5G architectures.

In terms of the participation in 5G-PPP WGs, 5G NORMA has contributed to the 5G Architecture WG, the Pre-Standards WG, the Vision and Societal Challenges WG, and the Security WG, and monitored and applyed the latest views from the Spectrum WG to its verification activities. As the key architectural 5G-PPP project, 5G NORMA has played a leading role in the 5G-PPP Architecture WG, which covers almost all ongoing European 5G projects. This WG has edited the "View on Architecture" white paper that provides the European vision on the fundamental architectural elements of future 5G networks. It has been published in June 2016 and an update that captures the latest outcomes of 5G-PPP Phase 1 will be released beginning 2018. The white paper continues to receive significant attention and positive feedback from the industrial community. It is worth highlighting the technical depth and cutting-edge vision of the document. Besides, 5G NORMA has contributed to the development of the business model narrative in the "Business and Stakeholders Roles Transformations with 5G" brochure of the Vision WG that was released for MWC2017, as well as with its security architecture and trust model to the "5G PPP Phase1 Security Landscape" white paper of the Security WG.

In terms of the KPIs defined by 5G-PPP, 5G NORMA has designed various technologies that are contributing to the 5G-PPP KPIs. Such KPIs are collective objectives that have been set for the entire 5G-PPP initiative, and the results of 5G NORMA are greatly contributing to these

goals. The KPIs addressed by 5G NORMA are related to the flexibility of customizing the architecture to specific services, which results in better performance as well as a higher efficiency. The broad architectural nature of 5G NORMA leads to a broad set of KPIs that are within scope.

5G NORMA has established itself as a leading project in 5G architecture thought leadership worldwide, and has strongly contributed to the objective of asserting a global leadership role for Europe and 5G-PPP. 5G NORMA has initiated the creation of the flagship workshop in this area, "International Workshop on 5G Architecture (5GArch)", which has already been organized four times and was always co-located with top IEEE conferences in the area. Starting with its 5th occurrence in Spring next year, workshop organization will be taken over by our successor project in 5G-PPP Phase 2, 5G-MoNArch.

5G NORMA has also played a significant role in the organisation of and participation in events focused on the demonstration of the technology towards audiences that are more industrially oriented such as MWC, RAN World, URLLC, and ITC.

4.3.3 Economic and Commercial Impact

The ultimate goal of 5G NORMA's architecture is to contribute to the development of new products and services that are adopted by the market and enable novel ways of operating the network and the adoption of the approaches. The architecture developed by 5G NORMA includes the following novel entities, creating product concepts that establish an opportunity for providers of these products:

- Enhanced and flexible 5G base stations. 5G NORMA technology enables new base stations that are light (as a result of moving part of the functionality to the edge and central clouds), flexible (allowing for modifying the base station behaviour through its interface) and efficient (by allowing specific operation for different services). We expect that these features will contribute to increasing the base station's value for the network operator and reduce its costs.
- Software-based centralized controllers. 5G NORMA's architecture also incorporates the SDMC concept, which includes novel, cloud-based, centralized controllers, which are based on software and hence can be quickly modified and adapted to different scenarios and services. Accordingly, the 5G NORMA architecture introduces a new type of device (the SDMC controller) as well as enhanced controlled devices that incorporate a flexible interface towards the controller.
- Software-based network orchestrator. One of the fundamental aspects of the 5G NORMA architecture is the orchestration of network slices. Orchestration functionality is responsible for the allocation of functions of each slice in the most appropriate location. While some open-source software for this functionality is already available, e.g., OPENMANO software produced by one of the 5G NORMA partners, we expect that new commercial products will result from current 5G NORMA efforts.
- Software-based network functions. One of the key capabilities enabled by 5G NORMA is the softwareisation of the network. In particular, the 5G NORMA architecture incorporates new software elements: the software-based applications running on top of the SDMC controller, and the virtual network functions that are orchestrated by the 5G NORMA MANO. This function creates the opportunity for new entrants in the supply chain that may focus on the marketing of such software-based network elements.

The impact of 5G NORMA will not be limited to new products but also the way in which operators build and operate their networks and the way in which their products and services will be provisioned in the future. The approach to network slicing promises significant implications for viability of new services, how they may be bundled and on the business models that underpin mobile networks and the ecosystem they support:

- Efficient service-specific slices for traditional operators. Network slicing allows for instantiating different slices, which can be efficiently customized to deliver services with specific requirements. This opens new business opportunities for traditional operators, which may be able to efficiently support extreme requirements that could not be supported by today's equipment. In particular, 5G NORMA opens the door to new industry verticals such as manufacturing automation, vehicular or tactile Internet, whose stringent requirements in terms of reliability and latency could not be efficiently supported without dedicated slices.
- Slices for new tenants. At the same time, network slicing creates opportunities for new entrants that may acquire a network slice in order to provide specific services to their customers. Such new players could be, for instance, Over-The-Top (OTT) service providers that pay for a network slice to ensure satisfactory service to their users. They could equally come from the vertical where their expertise on the requirements of the vertical and they existing customer relationships place them in a strong position to provide a tuned experience for those that use their slices.

In summary, the novel architecture designed by 5G NORMA has potential for profound commercial and economic impact as it changes very substantially the functions within the architecture (opening the door to new products that implement the related functionality), and the way the network is operated (offering new business opportunities to the traditional players and enabling new entrants in the ecosystem). It can be inferred from the exploitation activities that 5G NORMA partners are planning to leverage the commercial prospects of the 5G NORMA architecture to strengthen their business and strategic position, but at the same time the architecture design also opens new opportunities to players outside the consortium.

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