Deliverable D7.6
2nd Report on Dissemination, Standardization & Exploitation Plans

Document Summary Information

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V1.0	21/10/2021	100	Final Review by Coordinator	Hatim Chergui (CTTC)

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TABLE OF CONTENTS

1 Executive Summary

This public deliverable D7.6 -"2nd Report on dissemination, standardization & exploitation plans" of the MonB5G project provides an update of the Dissemination, standardization and exploitation activities of the project between months 16-24.

On the dissemination front the project demonstrated the following results in the last period:

- 6x *new* public engagement events (in addition to 6x from previous period);
- 11x *new* publications to journals and conferences (in addition to 24x from previous period).

On the communication front the project demonstrated the following results in the last period:

- 2x *new* press releases published (in addition to 2x from previous period);
- 1x Project Video Clip;
- 1x newsletters published (in addition to 3x from previous period).

*6*In *Section 5* all the actions of the MonB5G consortium in the relevant standardizing bodies are documented. Each standardization body is briefly introduced and the actions outlined include a range of engagement levels, from monitoring the activities to contributions to a new standard. The collaboration with 5G-PPP Architecture WG and the contribution to the fourth release of "View on 5G Architecture" white paper is also described.

On the exploitation front, covered in *Section 7* of this document: After establishing the project's IPR Council, the project solidified the exploitation strategy and the tools used (competitive analysis, application analysis, exploitation plan/map). Adopting innovation management best practices, the project analysed the strengths of its innovation potential, mapped the benefits & value it aims to create to the business model stakeholders, while continuously analysing the target market and the competitive landscape. Progress beyond the state of the art is already significant across all the domains of interest, as evidenced by the corresponding research publications (please see section 7.4). This empowers the project partners to confidently revise their individual exploitation plans, while MonB5G as a whole further solidifies and refines its overall exploitation map. We have also made the first step towards fulfilling the patents submitted KPI by filing the first such application.

At the time of writing and submitting this report (M24) the technical integration is taking place to pave the way for the upcoming proof-of-concepts. After deployment and pilot testing, the results will provide fuel for dissemination, communication, standardization and exploitation during and beyond the final phase of the project. Future engagement of these activities will be reported in the final version of this deliverable D7.7 'Final Report on dissemination; standardization & exploitation plans' (M36).

List of Figures

List of Tables

Abbreviations

Acronym	Description
3GPP	3rd Generation Partnership Project
5G IA	5G Infrastructure Association
5G PPP	5G Infrastructure Public Private Partnership
AI	Artificial Intelligence
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenditure
ENI	(ETSI) Experiential Networked Intelligence
ENISA	European Union Agency for Cybersecurity
ETSI	European Telecommunications Standards Institute
EuCNC	European Conference on Networks and Communications
GSM	Global System for Mobile Communications
GSMA	GSM Association
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IM	Innovation Manager
IPR	Intellectual Property Rights
IRTF	Internet Research Task Force
ISG	Industry Specification Group
ITU	International Telecommunication Union

LTE	Long Term Evolution
MANO	Management and Orchestration
MEC	(ETSI) Multi-access Edge Computing
ML	Machine Learning
MWC	(GSMA) Mobile World Congress
NFV	Network Functions Virtualization
NGMN	Next Generation Mobile Networks (Alliance)
NIST	National Institute of Standards and Technology
ONAP	Open Network Automation Platform
OPEX	Operational Expenditure
OSM	Open-Source MANO
PTC	Project Technical Committee
QoS	Quality of Service
SDO	Standards Developing Organization
SDN	Software Defined Networking
SLA	Service Level Agreement
TRL	Technology Readiness Level
UAV	Unmanned Aerial Vehicle
V2X	Vehicle to Everything
VNF	Virtual Network Function
WG	Working Group
WP	Work Package
ZSM	(ETSI) Zero touch network & Service Management

2 Introduction

MonB5G is a 5G PPP Phase 3 project that will provide a zero-touch management and orchestration solution, in the support of network slicing at massive scales for 5G LTE and beyond. It proposes a novel autonomic management and orchestration framework, heavily leveraging distribution of operations, together with state-of-the-art data-driven AI-based mechanisms. MonB5G is designed around a hierarchical approach that allows flexible and efficient management of network tasks, while introducing a diverse set of centralization levels through an optimal adaptive assignment of monitoring, analysis, and decision-making tasks.

All the tasks within work package 7 'WP7: Dissemination, Communication, Standardization and Exploitation' aim to continuously and collaboratively make effective use of all the established communication channels (website, factsheet, social media) to keep the media and general public informed about and engaged with the ongoing project activities and results.

Execution of WP7 activities involves the following tasks:

- Task 7.1: Dissemination and Communication Activities (M1-M36)
- Task 7.2: Standardization Activities (M1-M36)
- Task 7.3: Exploitation and IPR Management (M1-M36)

2.1 Scope

This is a public deliverable that reports on the progress of the MonB5G project across all tasks of WP7, for the M16-M24 period. It serves as a continuation and update to initial 'D7.5: 1st Report on Dissemination, Standardization and Exploitation Plans', thus will not repeat the methodologies, plans and metrics reported previously, but will focus only on the updates in the task activities since then.

2.2 Target Audience

The target audience of this deliverable are partners within the project community, who are interested in exploiting project results, peers in the scientific community, industrial partners, professional organizations or policy makers, who have interest in potential use and uptake of project results, as well as stakeholders beyond the project community, including media and the general public, interested to learn about the MonB5G project and its results.

2.3 Structure

The overall structure of this deliverable can be summarized as follows:

- *Section 3* provides an overview of the communication & dissemination objectives, strategy & stakeholders;
- *Section 3* serves as an update on the dissemination activities of the project;
- *Section 5* covers the update on the activities of the project on the communication front;
- *Section 6* describes the update on the activities and future plans related to standardization;
- *Section 7* outlines the revised exploitation plans of each partner and overall;
- *Section 8* concludes the deliverable and sets expectations for next steps.

3 Dissemination and Communication Overview

The MonB5G consortium has set a number of objectives so as to maximize the visibility of the project results in the corresponding scientific and industrial community.

3.1 Dissemination and Communication Objectives

1. **Plan**: Identify targets, tools, messages and channels, by building an adequate and effective communication and dissemination plan to ensure the best impact of project results;

2. **Design**: Produce dissemination tools by designing a comprehensive set of communication material to ensure an easy identification of the project and a major exposure;

3. **Distribute and represent**: Use the dissemination and communication channels (both internal and external), organize project events and participate in workshops, conferences and international/EC meetings, so as to ensure spread knowledge about the project and its results.

4. **Sustain**: Ensure a persistent and long-lasting visibility of the project activities and outcomes.

The MonB5G consortium aims to target key players in the communications industry in order to raise awareness of the MonB5G solutions' benefits, by designing a clear and solid set of well-defined dissemination and communication activities, in order to secure a wide promotion of the project as a vital initiative for the growth of the European industry.

3.2 Dissemination and Communication Strategy

The MonB5G project will continuously engage a triple-phased methodology strategy in order to achieve a broad promotion of the developed concepts and solutions.

The dissemination strategy comprises of 3 main phases:

Phase A - MonB5G awareness formation (M01-M06)

In this primary stage, the project consortium will initiate awareness by defining the explicit target groups, selecting the appropriate tools, and informing the corresponding stakeholders for the scopes and objectives of the project.

The main output of this phase is the project's communication channels (detailed in chapter 3):

i) The project website,
ii) The project social network channels,
iii) An event calendar,
iv) A flyer,
v) A newsletter.

Phase B - MonB5G outreach of relative stakeholders (M07-M14)

This phase includes arrangement and commitment with the proper stakeholders and open-source and standards communities, in order to build a groundwork of interest for the project. To this end, the first

MonB5G progress will be disseminated through the aforementioned channels, and the detail of this phase activities makeup the contents of this report at hand.

Phase C – MonB5G global outreach (M15-M36)

This final phase focuses on the engagement of the corresponding stakeholders to consider and adopt the developed MonB5G technologies and solutions. This will be achieved through:

i) Publications and deliverables,
ii) Development and distribution of promo materials,
iii) Participation to selected events,
iv) Organization of dedicated innovation workshops,
v) Liaisons with standardization bodies and main players, including other ICT-20 funded projects.

3.3 MonB5G Stakeholders

MonB5G dissemination and communication actions will aim to ensure visibility and raise awareness about MonB5G, reach and engage a significant mass of relevant stakeholders to ensure that the project results are well-known, taken up, and used even beyond the project's lifetime, and finally exhibit that public funding will lead to advancements in the 5G infrastructure management space and keep European industry at the leading edge within the global marketplace.

To this end the project consortium has unanimously agreed to take a consistent approach to engaging the following relevant stakeholders.

Target Stakeholders

1. **Mobile network operators** as one of the key players in the 5G technology market will be informed about the possibility of expanding their total service offering by incorporating the MonB5G solutions, thereby increasing their market size and subsequently they growth rate.
2. **Telecom infrastructure providers** will be also reached, in order to provide them the knowledge regarding the need for enhancing their infrastructure and network functions in order to provide comprehensive support to the new services. Equipment vendors including industries and SMEs developing advanced 5G solutions in the areas of network monitoring, management and security.
3. **SMEs** engaged in MonB5G will provide an innovative character with necessary edge competence, services and products, while creating strong R&D links with both industry and academia.
4. **End-users**: MonB5G will also target the general public, including citizens and public authorities, in order to inform them about the implication of project's research in everyday lives, to create awareness over the communication customers' policy rules and SLAs, the network's flexibility and robustness, and to inform about the societal benefits of 5G and beyond networks.
5. **Academia**: universities and research centers that are particularly interested in further developing their research strength on advanced 5G technologies and solutions will be aware of the project results. This target group can be effectively reached through the consortium's research partners and partnership with other leading universities.

4 Dissemination

In distinction to communication activities (see *Section 5*), the dissemination and the relevant tools focuses on project's results. Thus, the dissemination audience mostly consist of the project partners, research peers, industry, commercial actors, professional organizations, policymakers, and the scientific community in general. Their interest in the project results will be to direct uptake of results and their application to their work, field, and products.

4.1 Research Publications

4.1.1 SCIENTIFIC JOURNALS

The following table shows the publications to date, in Scientific Journals (full citation in *References*).

This period included **six** new journal publications all of which are **published**.

#	Publications	Title	Partners	Authors
1	IEEE Network	Trust in 5G and Beyond Networks [1]	AALTO	Chafika Benzaid, Tarik Taleb, Muhammad Zubair Farooqi
2	Transactions on Intelligent Transportation Systems (IEEE)	Data Driven Service Orchestration for Vehicular Networks [2]	IQU, CTTC	Anestis Dalgkitsis, Prodromos-Vasileios Mekikis, Angelos Antonopoulos, Christos Verikoukis
3	IEEE Transactions on Mobile Computing	QoS and Resource-aware Security Orchestration and Life Cycle Management [3]	AALTO	M. Bagaa, Tarik Taleb, Jorge Bernal Bernabe, Antonio Skarmeta
4	Wiley International Journal of Communication Systems	On using reinforcement learning for network slice admission control in 5G: offline vs. online [4]	EUR	Sihem Bakri, Bouziane Brik, Adlen Ksentini
5	Security and Privacy Journal (Wiley)	An end-to-end trusted architecture for network slicing in 5G and beyond networks [5]	EUR	Sabra Ben Saad, Adlen Ksentini, Bouziane Brik
6	IEEE Network Magazine	Towards an Optimal MEC Resources Dimensioning for Vehicle Collision Avoidance System: A Deep Learning Approach [6]	EUR	Bouziane Brik and Adlen Ksentini

Table 1: MonB5G Publications in Scientific Journals

4.1.2 CONFERENCES/WORKSHOPS

The following table shows the publications to date, in Conferences/Proceedings. This period included **five** new conference proceedings all of which are **published**.

#	Publications	Title	Partners	Authors
1	IEEE INFOCOM 2021	π-ROAD: a Learn-as-You-Go Framework for On-Demand Emergency Slices in V2X Scenarios [7]	NEC	Armin Okic, Lanfranco Zanzi, Vincenzo Sciancalepore, Alessandro Redondi, and Xavier Costa-Perez
2	IEEE ICC 2021	A Trust architecture for the SLA management in 5G networks [8]	EUR	Sabra Ben Saad, Adlen Ksentini, Bouziane Brik
3	IEEE ICC 2021	CDF-Aware Federated Learning for Low SLA Violations in Beyond 5G Network Slicing [9]	CTTC	Hatim Chergui, Luis Blanco and Christos Verikoukis
4	IEEE ICC 2021	Actor-Critic-Based Learning for Zero-touch Joint Resource and Energy Control in Network Slicing [10]	CTTC	Farhad Rezazadeh, Hatim Chergui, Loizos Christofi, Christos Verikoukis
5	IFIP AIAI 2021	A Novel Architectural Approach for the Provision of Scalable and Automated Network Slice Management, in 5G and Beyond [11]	Orange Polska, OTE, CTTC	Sławomir Kukliński, Lechosław Tomaszewski, Ioannis P. Chochliouros, Christos Verikoukis, Robert Kołakowski, Anastasia S. Spiliopoulou, Alexandros Kostopoulos

Table 2: MonB5G Conferences Proceedings

4.2 Workshops

Event: **CNSM 1st Joint International Workshop on Network Programmability & Automation (NetPA 2021)**

Co-organized by: **ORA-FR (MonB5G)**

Location: **Izmir, Turkey, Virtual**

Title: **Distributed Management of Network Slices in Beyond 5G**

Date: **25 October 2021**

Panel: MonB5G represented by **Hatim Chergui (CTTC)**

http://www.cnsm-conf.org/2021/workshop_NetPA.html

17th International Conference on Network and Service Management
Izmir, Turkey // 25-29 October 2021 // Virtual
Smart Management for Future Networks and Services

Home | Committees | Registration | Virtual | Program | Keynotes | Panel | Tutorials | Workshops | Meeting | Authors | Patrons

NetPA

1st Joint International Workshop on Network Programmability & Automation (NetPA 2021)
Monday 25 October 2021

With the same spirit of CNSM as a whole, the workshop on "Network Programmability and Automation" (NetPA) aims at providing an international forum for researchers and practitioners from academia and industry at large, including network operators, service providers, equipment manufacturers and IT companies, to discuss and address the challenges deriving from network programmability and network zero-touch automation for the delivery and operation of networks and services. On the one hand, the workshop will discuss the use of analytics and AI-based models to perform decision making at abstracted levels of the network to bring flexible and adaptive network service provisioning while ensuring smooth service continuity, SLA-compliance and service assurance. On the other hand, the workshop captures the evolutions of networking protocols towards more performance and security. This includes the design of high-level languages and associated tool chains for specifying network and nodes behaviors, automated methods and tools for validating both control and data plane operation; protocols for network programmability like Segment Routing; programmable data plane architectures, hardware platforms, software execution environments; network applications addressing open problems in traffic engineering, measurement, and problem diagnosis.

Workshop Co-chairs:

Amina Boubendir, Orange Labs, France
Stefano Salsano, University of Rome Tor Vergata, Italy
Carlos Guimarães, UC3M, Spain
Josep Mangues-Bafalluy, CTTC, Spain
Xi Li, NEC Laboratories, Germany
Lisandro Zambenedetti Granville, Federal University of Rio Grande do Sul (UFRGS), Brazil
Marco Bonola, CNIT, Italy
Gabor Retvari, Budapest University of Technology and Economics, Hungary
Ahmed Abdelsalam, CISCO, USA
Diego R. López, Telefonica I+D, Spain

Workshop sponsors:

NetPA workshop is sponsored by the following 4 European projects:

- Hexa-X project: https://hexa-x.eu/
- MON-B5G project: https://www.monb5g.eu/
- 5G-DIVE project: https://5g-dive.eu/
- 5Growth project: https://5growth.eu/

Figure 1: CNSM NetPA

Event: **WS-11: WORKSHOP ON DECENTRALIZED AI FOR WIRELESS NETWORKS WITH ZERO-TOUCH (DAWN'Z)**
Organized by: **MonB5G (CTTC)**
Location: **Montreal/Virtual**
Title: **Zero-touch Management and Orchestration of Network Slices in 5G and Beyond Networks**
Date: **14-23 June 2021**
Keynote by: **Dr. Adlen Ksentini (EUR)**
https://icc2021.ieee-icc.org/workshop/ws-11-workshop-decentralized-ai-wireless-networks-zero-touch-dawnz/program

Figure 2: IEEE ICC Organized by MonB5G

4.3 Exhibitions/Booths

Event: **Mobile World Congress MwC 2021**

Location: **Barcelona, Spain**

Date: **1 July 2021**

By: **Dr. Christos Verikoukis (CTTC)**

Figure 3: MonB5G Booth at MwC 2021

4.4 Demos, Events and Invited Talks

Event: **IEEE International Mediterranean Conference on Communications and Networking**

Title: **Demo: Threat detection and mitigation with MonB5Gcomponents in the aLTEr scenario**

Location: **Athens, Hybrid**

Date: **7-10 September 2021**

By: **Cao-Thanh Phan, Mohamed Rahali, Cédric Morin (BCOM)**

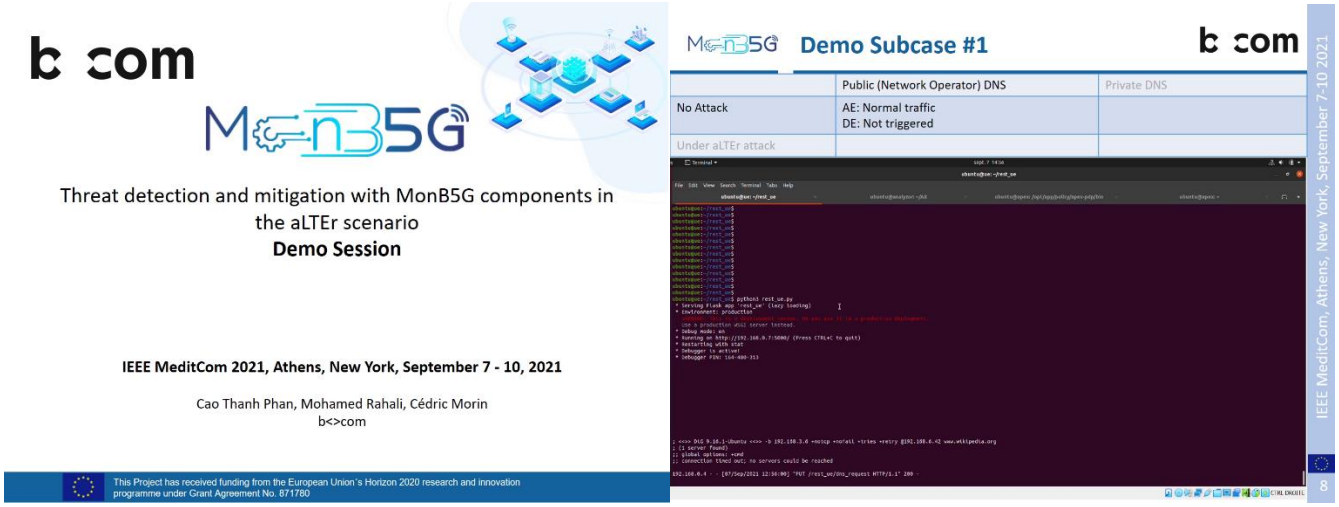


Figure 4: MonB5G Demo at MeditCom21

Event: **Presentation to Ericsson Research Sweden**

Title: **MonB5G & SafeRL**

Location: **Athlone, Ireland & Stockholm, Sweden**

Date: **20 May 2021**

By: **Anne-Marie Bosneag, Erik Aumayr (LMI)**

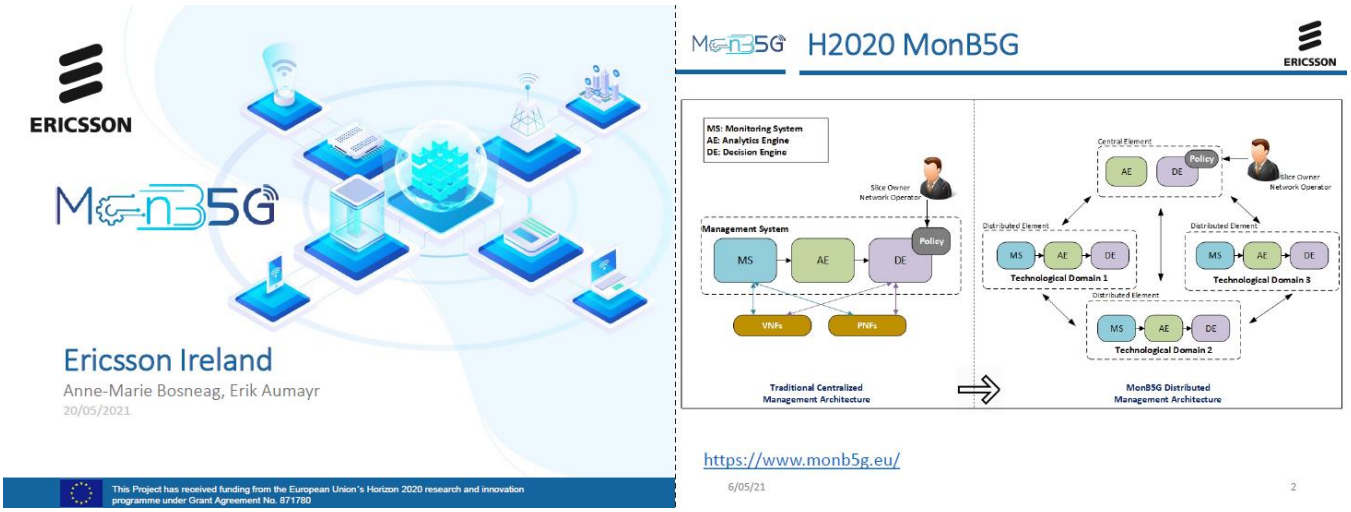


Figure 5: MonB5G Presentation at Ericsson Research (Sweden)

Event: **5G Enabled Middle East**

Title: **Network Slicing for 5G – Challenges and Opportunities**

Location: **Agadir, Morocco**

Date: **25-26 May 2021**

By: **Dr. Sławomir Kukliński (Orange Polska)**

http://v3-events.com/5g.phphttp://menacomm20.ieee-morocco.org/speakers.php

Figure 6: 5G Enabled Middle East

Event: **IEEE 5G World Forum**

Title: **Security challenges in military applications of 5G technology**

Location: **Virtual**

Date: **13 October 2021**

By: **Dr. Sławomir Kukliński (Orange Polska)**

https://ieee-wf-5g.org/security-challenges-in-military-applications-of-5g-technology/

Security challenges in military applications of 5G technology

The 5G standard has the potential to revolutionize wireless communications and computing, with 5G expected to enable orders of magnitude gains in performance over current systems. Although the standard and technologies are designed with a focus on the civilian market, the promised capabilities of 5G technologies and use cases have immense potential to bring opportunities to modernize military communication systems as well. This panel intends to explore and discuss the security of these technologies in the context of military applications; security is of paramount concern in military communications, with military security requirements differing from those of commercial applications for which many 5G technologies were primarily developed.

Figure 7: 5G World Forum

5 Communication

Communication activities about the project and results, involve the use of the project's available channels and tools by the partners to reach multiple audiences that include both the media and the public. With the aim to inform and reach out to society and show the benefits of the research work performed and accordingly the results of the MonB5G project.

The following sections will reflect the updated KPIs and targets reached by the consortium through the available channels.

5.1 Website

This section provides a description of the project's website, it structure, analytics, as well as the project social media pages which are considered as the main online presence of the project. The project website is live and has been publicly available since the project launch. Links to access the project website, as well as, the social media pages, have been shared with the Consortium during the Kick-Off Meeting (KOM) which took place at CTTC offices at Barcelona, Spain on 3rd and 4th December 2019.

The website and social media accounts were launched during M1 (November 2019) and will be continuously updated throughout the project's lifetime. The website was developed and will be maintained by eBOS Technologies Ltd., while the social media channels were created and will be updated by IQUADRAT.

5.1.1 *WEBSITE ANALYTICS*

Through Google Analytics' dashboards (shown below), we have access to the aforementioned data and also further in-depth are available as report sets. These metrics will provide insight into the engagement on the website since February 2021 until October 2021.

For reference, the new users for the past period totalled ***924***, in addition to the current peried **654**, totaling **1578** new users in **two years**.

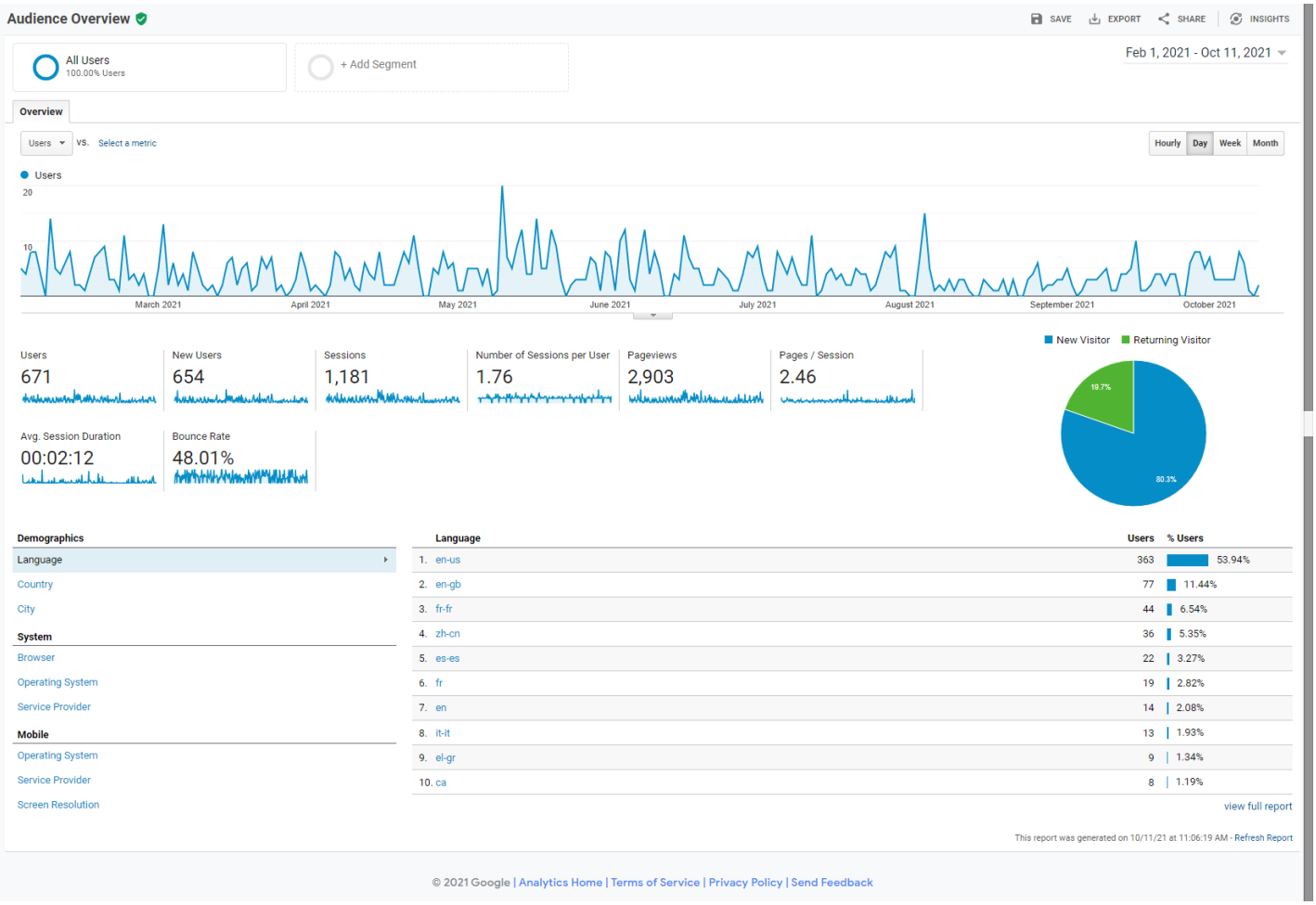


Figure 8: Website Analytics: Audience Overview

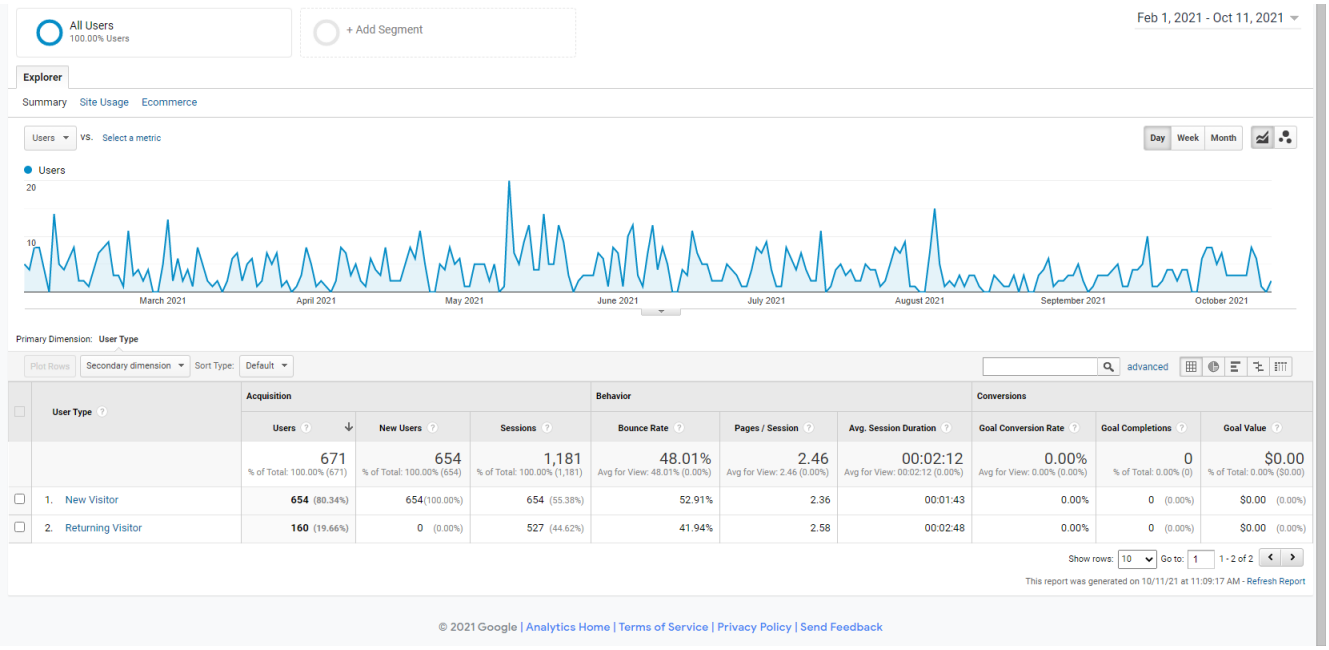


Figure 9: Website Analytics: New vs Returning Visitors

5.2 Press Releases

Amongst the key communication outreach activities that target all various stakeholders, e.g., the research community, business community, and the public at large, are press releases, which will ensure that the public will be aware of the MonB5G project.

In this period, we present the new two press releases published in electronic newspapers, for a total of four releases including the previous period.

The project partners eBOS and BCOM prepared and published two *new* press releases for the research project MonB5G.

The new press releases were published in two popular Cypriot and German online newspapers:

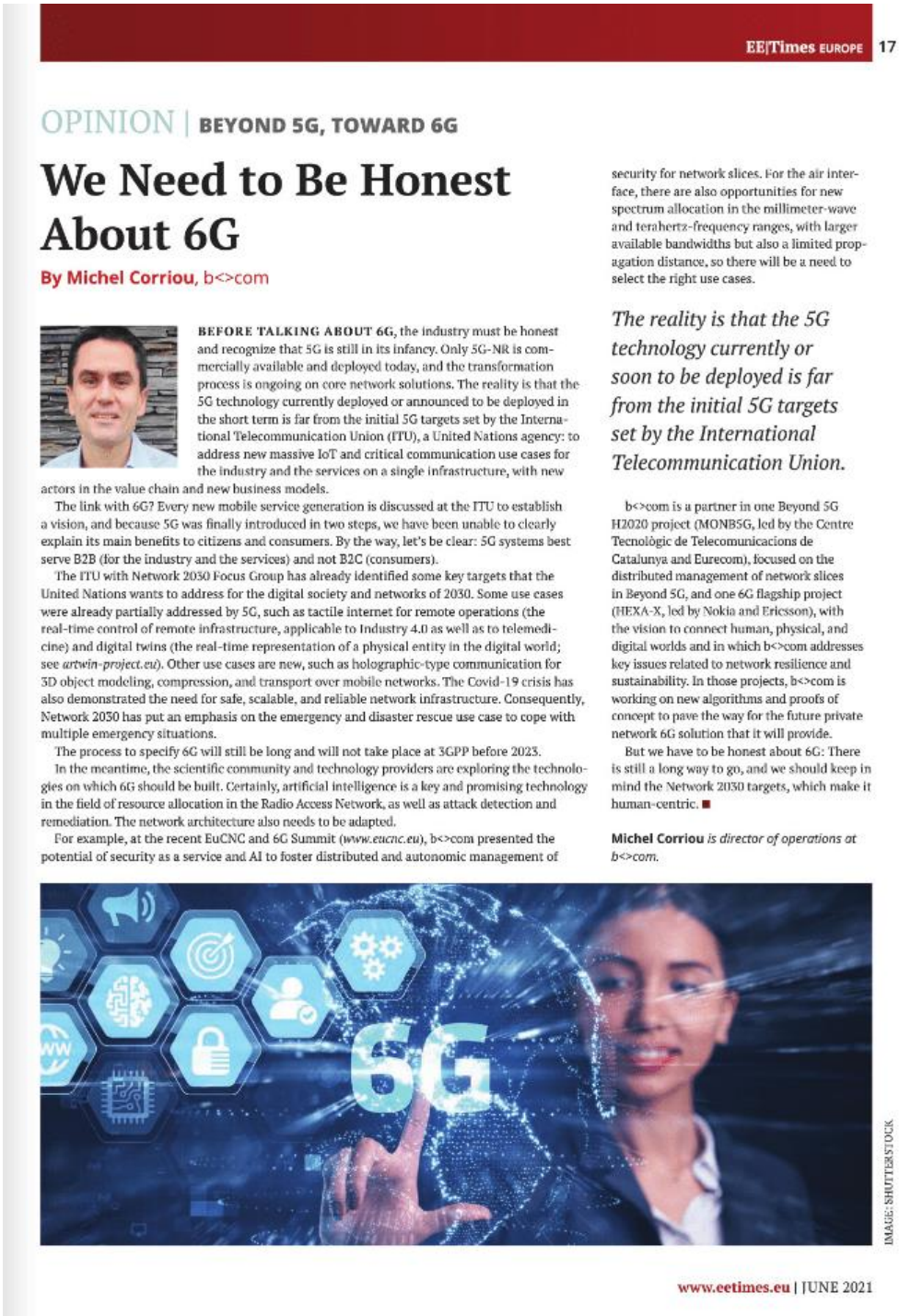
- In Business News (Cyprus) on 1st June 2021

https://inbusinessnews.reporter.com.cy/business/ict918/article/278998/ebos-technologies-diktya-epomenis-gnias

- EE Times Europe on 23rd June 2021 https://www.eetimes.eu/ee-times-europe-magazine-june-2021/

The aforementioned press releases are presented in the following screenshots:

Figure 10: Press release in In-Business News



EE|Times EUROPE 17

OPINION | BEYOND 5G, TOWARD 6G

We Need to Be Honest About 6G

By Michel Corriou, b<>com

BEFORE TALKING ABOUT 6G, the industry must be honest and recognize that 5G is still in its infancy. Only 5G-NR is commercially available and deployed today, and the transformation process is ongoing on core network solutions. The reality is that the 5G technology currently deployed or announced to be deployed in the short term is far from the initial 5G targets set by the International Telecommunication Union (ITU), a United Nations agency: to address new massive IoT and critical communication use cases for the industry and the services on a single infrastructure, with new actors in the value chain and new business models.

The link with 6G? Every new mobile service generation is discussed at the ITU to establish a vision, and because 5G was finally introduced in two steps, we have been unable to clearly explain its main benefits to citizens and consumers. By the way, let's be clear: 5G systems best serve B2B (for the industry and the services) and not B2C (consumers).

The ITU with Network 2030 Focus Group has already identified some key targets that the United Nations wants to address for the digital society and networks of 2030. Some use cases were already partially addressed by 5G, such as tactile internet for remote operations (the real-time control of remote infrastructure, applicable to Industry 4.0 as well as to telemedicine) and digital twins (the real-time representation of a physical entity in the digital world; see *artwin-project.eu*). Other use cases are new, such as holographic-type communication for 3D object modeling, compression, and transport over mobile networks. The Covid-19 crisis has also demonstrated the need for safe, scalable, and reliable network infrastructure. Consequently, Network 2030 has put an emphasis on the emergency and disaster rescue use case to cope with multiple emergency situations.

The process to specify 6G will still be long and will not take place at 3GPP before 2023.

In the meantime, the scientific community and technology providers are exploring the technologies on which 6G should be built. Certainly, artificial intelligence is a key and promising technology in the field of resource allocation in the Radio Access Network, as well as attack detection and remediation. The network architecture also needs to be adapted.

For example, at the recent EuCNC and 6G Summit (*www.eucnc.eu*), b<>com presented the potential of security as a service and AI to foster distributed and autonomic management of security for network slices. For the air interface, there are also opportunities for new spectrum allocation in the millimeter-wave and terahertz-frequency ranges, with larger available bandwidths but also a limited propagation distance, so there will be a need to select the right use cases.

The reality is that the 5G technology currently or soon to be deployed is far from the initial 5G targets set by the International Telecommunication Union.

b<>com is a partner in one Beyond 5G H2020 project (MONB5G, led by the Centre Tecnològic de Telecomunicacions de Catalunya and Eurecom), focused on the distributed management of network slices in Beyond 5G, and one 6G flagship project (HEXA-X, led by Nokia and Ericsson), with the vision to connect human, physical, and digital worlds and in which b<>com addresses key issues related to network resilience and sustainability. In those projects, b<>com is working on new algorithms and proofs of concept to pave the way for the future private network 6G solution that it will provide.

But we have to be honest about 6G: There is still a long way to go, and we should keep in mind the Network 2030 targets, which make it human-centric. ■

Michel Corriou *is director of operations at b<>com.*

IMAGE: SHUTTERSTOCK

www.eetimes.eu | JUNE 2021

Figure 11: Press release in EE Times

5.3 Social Media

This chapter describes the MonB5G project social media accounts, which are Twitter and LinkedIn pages, as part of the dissemination activities undertaken for this project. The social media accounts are managed by **IQUADRAT INFORMATICA SL**.

5.3.1 LINKEDIN PAGE

The MonB5G Project LinkedIn Page https://www.linkedin.com/company/monb5g was created and launched during the first month of the project. LinkedIn is the platform of choice for researchers, companies, and industry professionals. Thus, it will be extensively used for communication and dissemination of the project's news, events, and outcomes. This platform also provides easy 'sharing' of the posts, by the project consortium's individual pages, which will in turn maximize the impact and the reach of the dissemination and communication activities.

The following Figures shows the LinkedIn page analytics overview.

Figure 12: MonB5G LinkedIn Page Engagement Rate

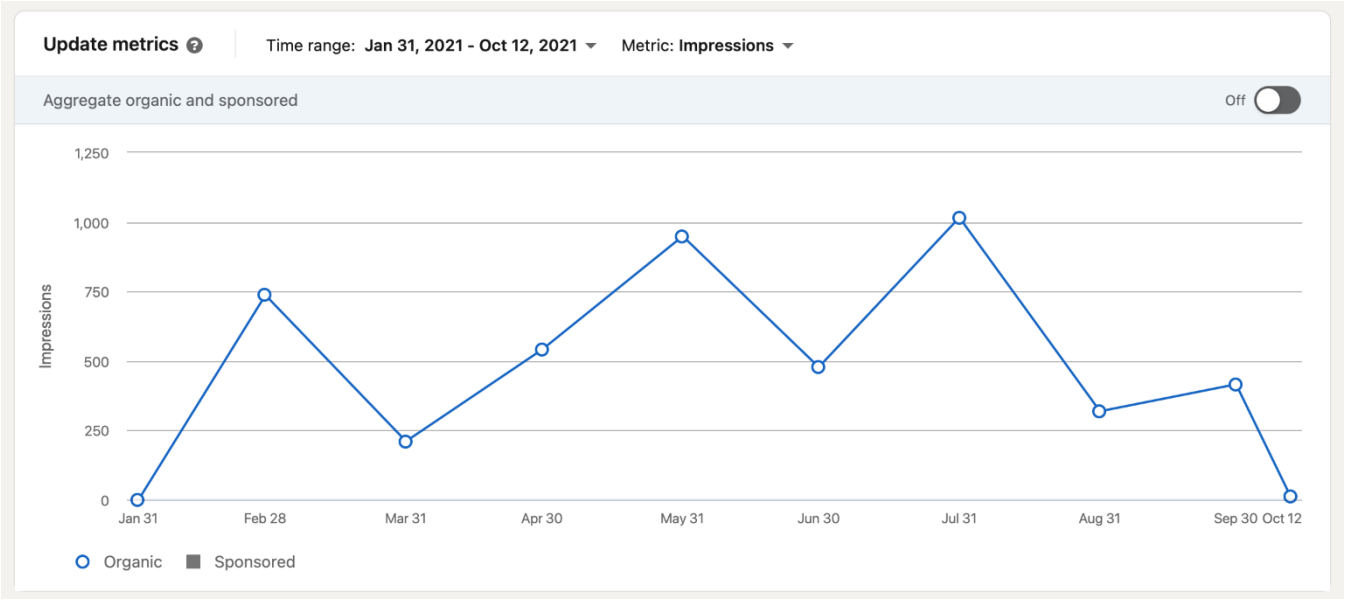


Figure 13: MonB5G LinkedIn Page Impressions

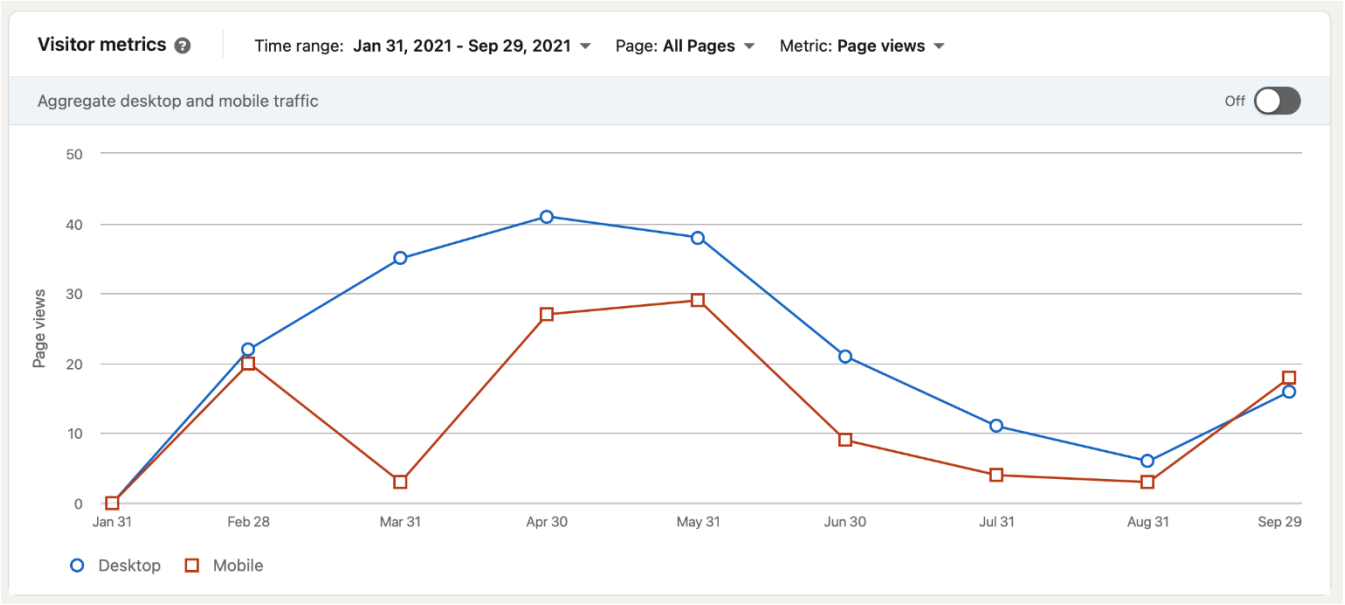


Figure 14: MonB5G LinkedIn Visitor Metrics vs Page Views

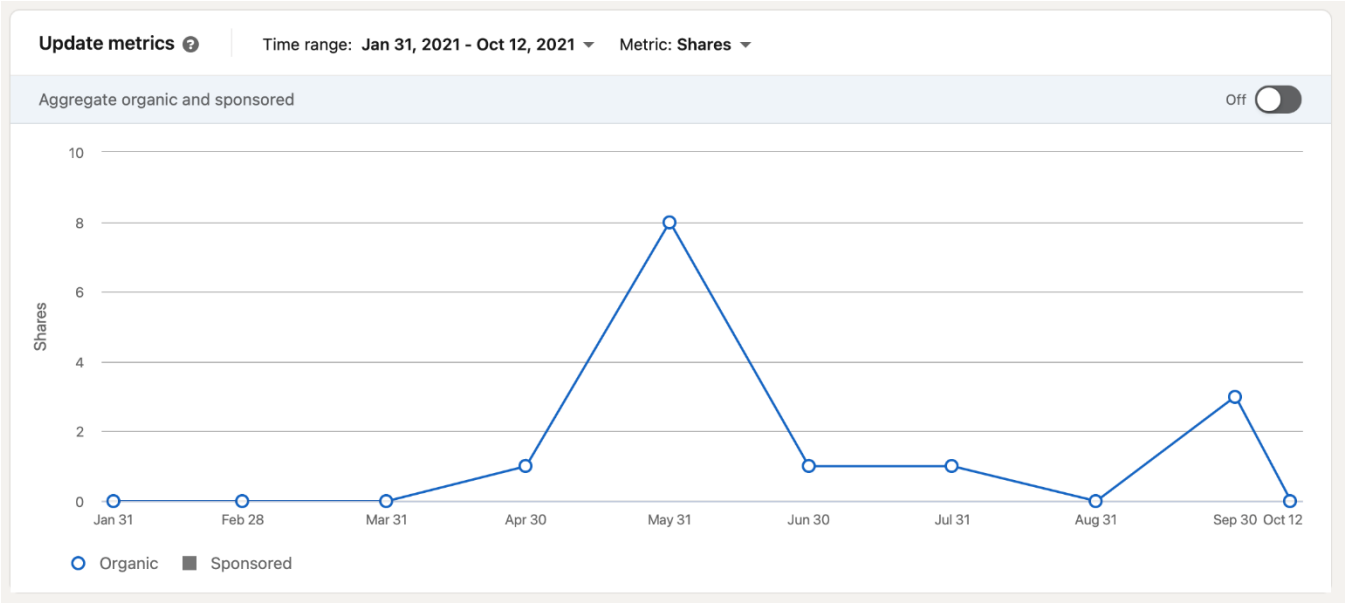


Figure 15: MonB5G LinkedIn Page Shares

5.3.2 TWITTER PAGE

The MonB5G Project Twitter Page https://twitter.com/monb5g was created and launched concurrently with the LinkedIn Page. With the same purpose to be utilized as a communication and dissemination tool. Consequently, by using both platforms, we will maximize the engagement and response to potential interest in all the topics that will be covered by the project activities, events and outcomes.

The following figure shows the number of tweet impressions periodically over the last period.

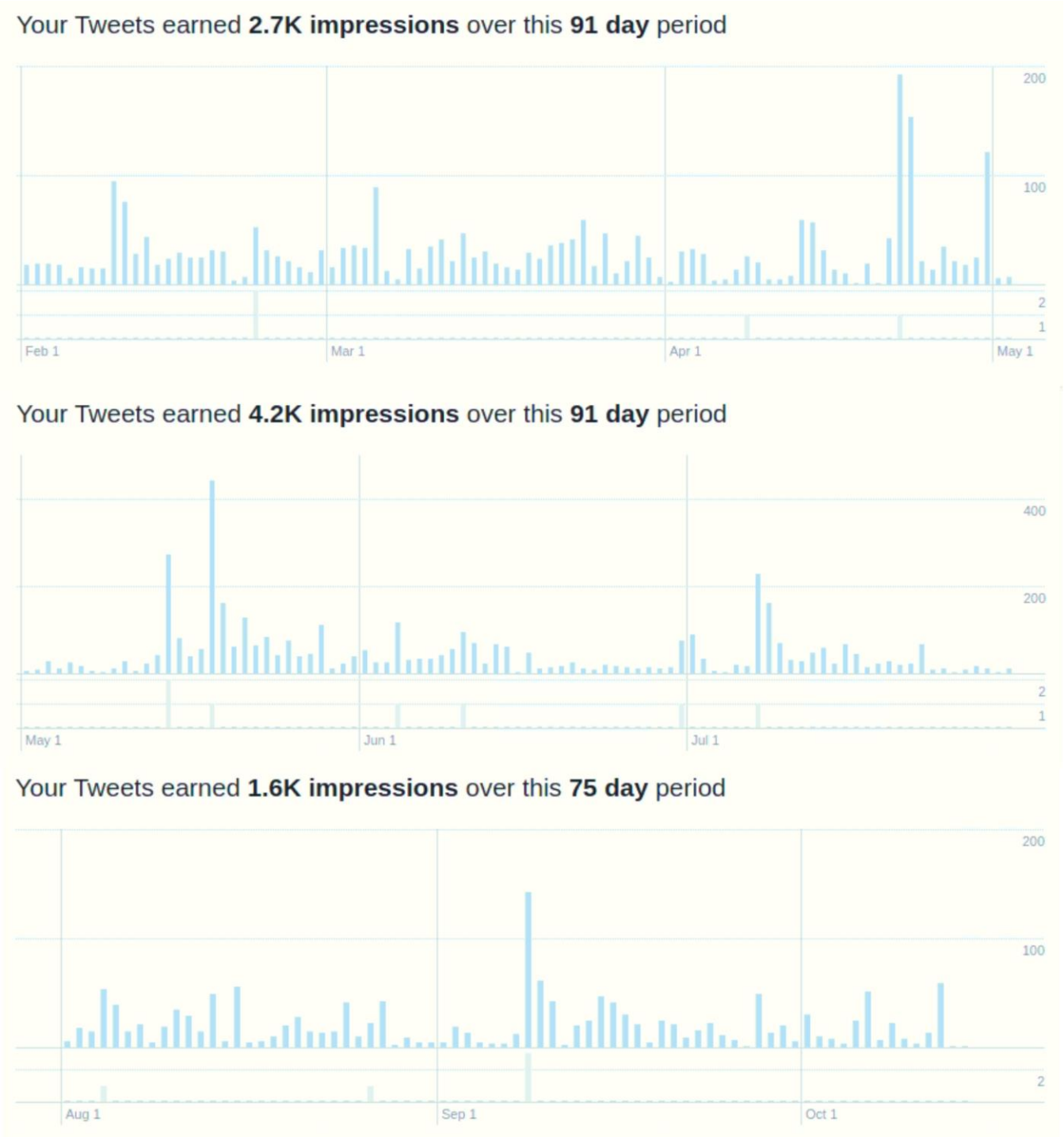


Figure 16: MonB5G Twitter Analytics

5.4 Video Clips

The first video clip presented an overview of the project's concepts, innovations and goals. Its production and contents were detailed in its own *Deliverable D7.4* (Project Video Presentation) submitted in Month 17.

The video was published on MonB5G Youtube channel on 14th May 2021, then shared on the website and project social media. To date achieved 152 views.

https://www.youtube.com/watch?v=TzWEuUEyjUY

Figure 17: Screenshot of MonB5G first Video Clip

5.5 Newsletters

The newsletter aims to keep the stakeholders informed about the project progress and developments within a given period. As originally planned, two newsletters will be issued per year and shared on all of the project channels.

The first newsletter was issued and published on May 2020, while the second was issued on January 2021, and the third was published on August 2021. The latter shown in screenshots below, while the full versions of the three issues are available in the following link:

https://www.monb5g.eu/newsletters/

Figure 18: Newsletter #3 Pages 1-2

Figure 19: Newsletter #3 Pages 3-4

6 Standardization

This section presents in detail the activities performed by the MonB5G partners in the context of standardization. The activities include monitoring, collaborating with, and contributing to the work of important standards bodies and discussion forums. As described in Deliverable 7.5 since the beginning of the project, the MonB5G consortium has identified SDOs and ISGs/WGs whose technical reports and specifications can have an impact on project outcomes.

MonB5G platform will heavily leverage the distribution of operations, zero-touch management across multiple technology domains (e.g., Radio Access Network, Core Network, Cloud), and data-driven distributed AI-based mechanisms. AI can be used at multiple levels of the architecture structure of MonB5G platform, having their relevant entities of Monitoring System (MS), Analytic Engine (AE) and Decision Engine (DE). ***Deliverable D3.1*** (Initial Report on AI-Driven Techniques for the MonB5G AE/MS) examines cutting-edge monitoring and analytics tools, as well as new requirements and relevant specifications as 3GPPP (TR 38.801 O-RAN.WG1.O-RAN-Architecture-Description-v03.00, ETSI, "Open Source MANO" and ONAP, "Open Network Automation Platform", required for zero-touch management of massive coexisting network slices. Moreover, it investigates the capabilities and techniques of foremost analytics tools implemented in 5G network, e.g. the Network Data Analytics Function (NWDAF) as defined in 3GPPP standards (TS 23.501, TS 23.503 TS 23.288, TS 29.520) from Release 15 to Release 17 and Management Data Analytics Function (MDAF), which provides Management Data Analytics Service (MDAS) as defined in the specification TS 28.533. In D3.1 we also analysed the context promoted by the Zero-touch network and Service Management (ZSM) standards (ETSI GS ZSM 009-1,V0.10.5) and the intelligence capabilities proposed in ETSI ENI Architecture (ETSI GS ENI 005 V1.1.1)

In ***Deliverable D4.1*** (Initial Report on AI-Driven Techniques for the MonB5G Decision Engine) we examined the network slice representation in NGMN Alliance, 3GPPP (TS 23.501), IETF and ETSI NFV (ETSI GR NFV-EVE 012 V3.1.1) standards, as well as, the network slice models. We adopted the hybrid based model which integrates ETSI NFV (service-based) and ETSI MEC (infrastructure-based) model. We presented also the mapping between the functional blocks of the MonB5G control architecture, which is built around the Decision Engine (DE) on one hand and ETSI ZSM Closed Loop (CL) automation framework on the other hand (ETSI GS ZSM 009-1 V0.10.5). MonB5G DE and its serving administrative elements (MS, AE, and ACT) follow the ETSI ZSM CL framework.

Deliverable D5.1 (Initial report on AI-driven MonB5G security and energy-efficiency techniques) presents a study of the state of the art in security orchestrators as proposed by key 5G PPP projects and the relevant standards 3GPP (TS 33.401), (TS 23.101). Furthermore, it proposes a new security orchestration architecture (SECaaS) that can deal with the ever-evolving and diverse security threats intended at slicing-enabled beyond 5G mobile systems in an effective and fast way. A comprehensive examination of potential attack threats and mitigation measures is provided taking into account the relevant security standardization e.g., ETSI SAI 004, ETSI GS NFV-IFA 033 and 3GPP (TS 33.501, TS 22.368, TS 23.502, TR 37.868) and the security threat analysis by ENISA (5G Threat Landscape and Sectoral/Thematic Threat Analysis) and NIST (National Vulnerability Database).

ETSI ZSM

In 2017, the Zero Touch Network and Service Management Industry Specification Group (ZSM ISG) was founded by ETSI. The ETSI ZSM ISG's main purpose is to define an end-to-end network and service management reference architecture that enables the management and automation of developing and future networks and services in a flexible and effective way. ETSI GS ZSM 002 specifies the overall architecture of the ZSM framework. Control Loops CLs may exist in any of the management domains of the ZSM architecture. ETSI has presented in ETSI ZSM 009-1 some insights on the Zero-touch Service Management (ZSM) framework for Closed Loop (CL) management automation. The proposed MonB5G framework's core features align with a number of ETSI ZSM standards that have already been specified. The management elements in the MonB5G design such as the Monitoring System (MS), Analytic Engine (AE), Decision Engine (DE) and Actuators (ACT), provide a powerful framework that aligns well with the recently proposed ETSI ZSM Closed Loop (CL) automation architecture. ISG ZSM can leverage the ENI system's closed-loop service to improve network and service management automation.

ETSI ENI

The ISG ENI focuses on improving the operator experience by incorporating closed-loop artificial intelligence techniques based on metadata-driven policies that are context-aware. Making it possible to quickly recognize and incorporate updated knowledge, and hence make relevant decisions. ENI has specifically defined a set of use cases as well as the functional architecture for a network supervisory assistant system based on the 'observe-orient-decide-act' control loop model. This paradigm can help decision-making systems, such as network control and domain orchestration systems, adapt services and resources offered in response to changes in user needs, environmental conditions, and business requirements. MonB5G aims to contribute to **ETSI ENI** through the AE algorithms and functions.

IRTF/NMRG

The Network Management Research Group (NMRG) is a platform for researchers to discuss innovative Internet management technology. The Network Management Research Group (NMRG) will emphasize on management services that interact with the existing Internet management architecture. This covers customer-oriented management services as well as communication services between management systems that may apply to different management domains. To manage the increased complexity of networks in terms of scale, flexibility, and heterogeneity, which is created by the technology evolution NMRG investigate the following related areas (i)) self-driving/managing networks, (ii) intent-based networking, and (iii) artificial intelligence in network management.

Orange France presented at the 61th interim meeting of IRTF Network Management Research Group (NMRG) on May 17th 2021 the distributed and zero-touch management of Network Slices of MonB5G project. The presentation covered organization, main concepts and main proposals from MonB5G on scalable and programmable slice management whith AI-driven techniques.

ITU-T SG13

The standardization of NGN architecture was supported significantly by SG13. The ITU-T is presently examining how to optimally deploy AI/ML in future networks, particularly 5G networks. SG13 began AI/ML-related activities through FG ML5G, which was formed to investigate the potential AI/ML applications in networks. The work of FG ML5G, which started operations in 2018, was concluded in June 2020, and

submitted the deliverables to SG13. In relevant questions such as Question 20 "IMT-2020: Network requirements and functional architecture" and Question 21 "Network softwarization including software-defined networking, network slicing, and orchestration," further discussions will take place. Recent standardization achievements of SG13 include Y.3156 “Framework of network slicing with AI-assisted analysis in IMT-2020 networks”, Y.3157 “IMT-2020 network slice configuration” and Y.3177 “Architecture framework of artificial intelligence-based network automation for resource and fault management in future networks including IMT-2020”. Orange Poland is actively participating in activities of SG13.

Orange Polska in representation of MonB5G consortium is participating in Question 21 of Study Group 13 rapportteur group meetings, Orange Polska, in the name of the consortium has made the following contributions (July 2021):

- Contribution to ITU-T Y.SLOA-arch: “End-to-end service level objective assurance architecture for future networks including IMT-2020” adding the prediction aspect to SLO issues. Contribution 19143-C4 (210705)
- Proposal for modification of Draft Recommendation Y.IMT-2020-EIL: “Evaluating intelligence capability for network slice management and orchestration in IMT-2020”. Contribution 19143-C3 (210705).
- Proposal for modification of Recommendation Y.IMT-2020-DL-AINW-fra: “A communication model for AI-based management in IMT-2020 and beyond”. Contribution 19143-C2 (210705).

FG-AN

Self-configuring, self-optimizing, and self-healing functionalities are becoming increasingly important for future mobile networks as network complexity rises. The study conducted in SG13 on use cases, requirements, and architecture for cloud computing and AI/ML integration in future networks, set the path for the formation of the Focus Group on Autonomous Networks (FG AN). The Focus Group's main goal is to provide an open platform for performing pre-standards activities in relation to this subject and, where applicable, leveraging the technologies of others.

5G-PPP

The purpose of **5G Architecture WG** is to provide a common forum for 5GPPP projects creating architectural concepts and components to discuss and stimulate conversations based on the KPIs outlined in the 5GPPP contract. The organization could also aid in the development of a 5G architecture agreement. **5G Architecture WG** does not conduct technical standardization work, on the other hand, provides a platform for leveraging and supporting standards adoption, as well as monitoring actions that are relevant to the key technology enablers and the very forefront design concepts in the framework of the 5G Architecture.

MonB5G has actively participated in the WG calls and contributed to View on 5G Architecture white paper in chapter Automated Management & Orchestration (MANO) architecture. The design concepts of the high-level MANO architecture described are aligned with the ETSI and 3GPP standards as well as from the architectures suggested by several projects from 5GPPP Phase II and Phase III. The model proposed by MonB5G is based on the MAPE (Monitor-Analyze-Plan Execute) paradigm and utilizes AI-driven operations to

achieve the management system decomposition recommended by ITU-T. The architecture allows to create a "management slice" that can be used to manage numerous slice instances of the same template at the same time (Management as a Service - MaaS). The MAPE concept is implemented in our case in a distributed way using multiple AI-driven operations. Furthermore, slice management is distributed and programmable in real time. Additionally, by distributing many orchestration functions, the MANO approach has been noticeably improved. The suggested concept is based on existing network slicing management and orchestration solutions established by other EU-funded projects or research and standardization organizations.

7 Exploitation

The activities relevant to the exploitation of the outcomes of the project are executed under Task 7.3: Exploitation and IPR Management (M1-M36). At a high level:

- Substantial know-how and original intellectual property (IP) will be generated during the development of MonB5G
- The consortium will use all possible means to protect generated IP with focus on post-project commercial exploitation
- The consortium includes a number of industrial partners, which can directly exploit the project results to develop commercial products/services
- Academic partners will greatly benefit, applying their experience to the development of novel concepts for production of high-quality prototypes, test methods, numerical modeling, and experimental validation in support of developments leading to qualified products
- Innovation management will be also carried out in this task to ensure quality of highest possible standards and identify potential market opportunities

At the beginning of the project, an **IPR Council** was established, comprising by one representative from each MonB5G beneficiary, who will continuously monitor the generated knowledge in the relevant MonB5G fields worldwide and ensure that IPR protection strategies will be activated before publishing.

Participant No.	Partner Short Name	Member
1	**CTTC**	Christos Verikoukis
2	**EUR**	Adlen Ksentini
3	**OTE**	Vasiliki Vlachodimitropoulou
4	**LMI**	Jimmy O'Meara
5	**CTXS**	George Tsolis
6	**ORA-FR**	Amina Boubendir
7	**ORA-PL**	Slawomir Kulkinski
8	**AAL**	Tarik Taleb
9	**BCOM**	Eric Gatel
10	**IQU**	Luis A. Garrido Platero
11	**NEC**	Zhao Xu
12	**EBOS**	George Guirgis

Table 3: MonB5G IPR Council Membership

7.1 Exploitation Strategy

The innovative solutions proposed in MonB5G, which answer directly to market needs and future roadmaps, and the strong commitment of the consortium's industrial members are the key elements of MonB5G quest for success. In order to protect and maximize the project's exploitation potential, the MonB5G consortium has agreed on a "first exploit, then disseminate" exploitation strategy. All results generated within the project are monitored by the Innovation Manager (IM) and Project Technical Committee (PTC) and, at the general assembly's decision, are characterized either commercially exploitable, or available for dissemination. The results that fall into the first category are incorporated in the project's exploitation plan that will quantify their exploitation potential. The set of tools that MonB5G uses for its exploitation strategy are:

- Competitive analysis: MonB5G members perform a continuous market and research watch, in order to promptly identify relevant new works on targeted scientific fields, new market/research trends in 5G, and the roadmaps of large industrials and international organizations. The most frequent means of competition monitoring are market intelligence, scientific and technical publications, press notices and other sources. Each partner is responsible for monitoring the competition form that is more relevant to its interest, i.e. academic partners focus more on scientific publications, while market/patent watch and standardization tracking is handled mostly by industrial partners.
- Application analysis and exploitation plan: MonB5G recognizes the necessity to have a clear view of the trends, standards and roadmaps that shape the 5G sector that will allow its consortium to better position MonB5G in its likely market and better align the targeted specifications of the developed technology platform. In this effort, the industrial partners collaborate on application analysis and exploitation plan, which serves to provide a rationale for the continuing work program, or propose changes of direction where this is indicated by market/commercial forces, and the emergence of new product opportunities.
- Current exploitation map: MonB5G presents huge exploitation potentials for its consortium members, already identified before the project start. *Section 7.5.1* presents the updated exploitation map of the innovation actions that the industrial partners of MonB5G have qualified as commercially exploitable.

7.2 Expected Impact of Exploitation Strategy

Through the upgrade of existing platforms for the full support of multiple services and the demonstration of the beyond 5G capabilities to meet the requirements of the considered use-cases, MonB5G is expected to have a significant impact to the currently shaping 5G/6G landscape. In order to maximize its exploitation potential, aligned with the exploitation strategy, constant monitoring and in depth evaluation is carried out to gauge its effectiveness. The exploitation KPIs refer to i) the number of patent applications or awarded patents (MonB5G targets to submit at least 5 patents) and ii) the percentage of participating SMEs introducing innovations to the company or the market (covering the period of the project plus three years).

7.3 Innovation Management

Innovation management aims at identifying and implementing new creative ideas and introducing new services, processes or products to the market.

7.3.1 PROCESS AND STRUCTURE

The innovation collection process is managed by the consortium in the relevant WPs and is continuously integrated in the overall project results. Innovation management is thus pervasive throughout the execution of the project, as also reflected by the project's management structure:

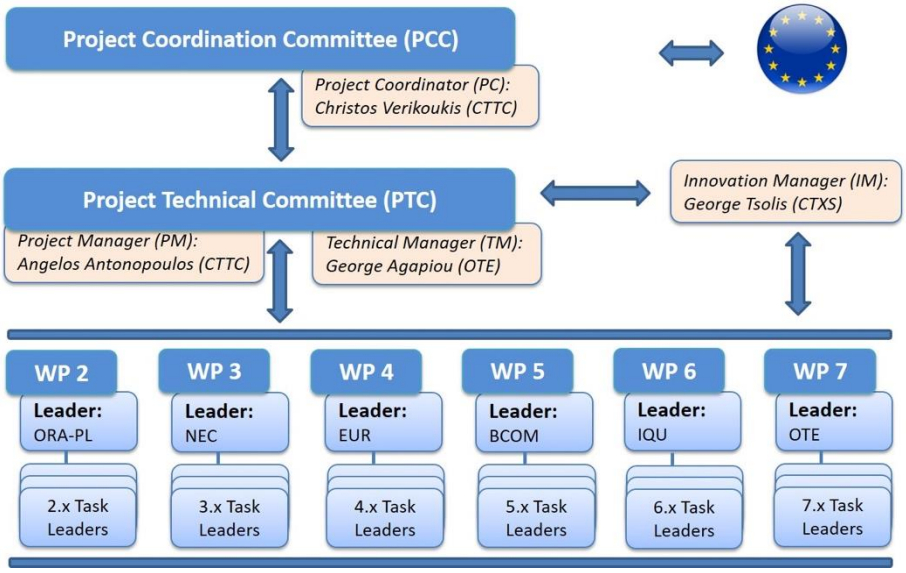


Figure 20: MonB5G Management Structure

The **Innovation Manager** (IM) role is to support the innovation driven research and to amplify the project's impact. In this context, The IM will assist the WP leaders and the Project Manager (PM) in handling all matters concerning IP protection for the produced innovations, as well as their inclusion in the exploitation plans.

7.3.2 INHIBITORS AND MITIGATING MEASURES

The MonB5G impact on innovation will be a function of the adopted methodology regarding the protection of the partners' legitimate interests regarding the know-how and IPR protection with respect to global competition. The consortium follows all the governance procedures specified by the Consortium Agreement and IPR management procedure, in addition to the reliable innovation management procedure.

Beyond the above provisions, the consortium has proactively identified potential innovation and commercial exploitation inhibitors, in and between the work packages, during the course of the technical activities. For each such inhibitor that we analyse below, we also cover corresponding measures we are implementing, towards addressing or alleviating those:

1. No Shared Vision: Vision is the spark of innovation. MonB5G's vision and ambitions are highly ranked, but ratifying and sharing them across a project with many partners is not straightforward.

Measures: The project vision was discussed with all partners in the kick-off meeting and was refined, in parts, in the first few plenary meetings.

2. Closed-ness: Exploitation may be an individual objective of each partner, but, in collaborative projects like MonB5G, innovation maximises its potential when it is open and unconstrained.

Measures: The formal agreements signed by all partners govern information sharing between them, setting a framework that encourages openness in the exchange of innovative ideas. Mailing lists, document repositories, meetings and calls are open to all partners, allowing the fee exchange of thoughts and making certain that all opinions are heard and respected.

3. Stalemates: The inability of reaching a joint decision, when it involves pursuing a research direction, an innovation pathway, or a joint exploitation plan, can slow progress to a halt, and create contention.

Measures: Fortunately, the project has not run into such a situation. But the management structure (see *Section 7.3.1*) has adequate provisions for breaking this type of stalemates, if they ever occur.

4. High Complexity: An ambitious project, like MonB5G, involves high complexity. This may introduce challenges, in terms of focusing innovation generation activities on items that really matter.

Measures: The project has clearly identified the areas where innovation creation will concentrate on (see *Section 7.3.3)*. To maintain focus during the remainder of the project, activities will continue to be tracked by the Innovation Manager, in terms of maintaining alignment with the vision of the project.

5. Lack of Initiative: Innovation cannot be someone else's job. Innovation thrives, when it is part of everyone's responsibilities.

Measures: The project does not put any constraints whatsoever in terms of who can participate to innovation activities.

6. No Clear Ownership: This is a side-effect of the above. Not making innovation someone's job, creates confusion on who owns the responsibility of driving it forward.

Measures: When a research direction or innovative idea is identified, the project will follow the best practice of identifying a champion, who will be responsible for driving it forward, involving others as required.

7. Limited Opportunities: When focused on short-term project obligations, partners may not be encouraged or incentivized to invest sufficient time on exploring new ideas or disseminate results.

Measures: Through anticipating the integration activities, partners are offered more opportunities to collaborate to well-defined common objectives that produce innovative results. Also, targeting high-profile scientific conferences or journal publications "persuade" partners to drive research work to completion and, moreover, to generate high-quality research publications.

8. Low Visibility: Encouraging work towards advancing the state of the art sometimes requires making it more visible, not only within the project, but also in the individual organizations of each partner.

Measures: The project communication and dissemination activities aim to address this specific need. Broader visibility of outcomes is also achieved through the web site and social networking channels.

9. Not Being Part of the Community: Collaboration becomes even stronger if it expands beyond the ranks of the project. Sharing with the community is a powerful form of exploiting project results.

Measures: Contributing to standardisation activities and open source projects aims to this direction. Working together with 5G PPP, in the context of the various working groups, and (eventually) with the other projects of the 5G PPP Programme, aligns project outcomes with the overall 5G vision, objectives and KPIs.

10. Ignoring the Ecosystem: A common mistake is to look at opportunities through internal lenses. Exploitation plans must be aligned with customer needs and adapt to the usual ecosystem shifts.

Measures: MonB5G partners play a vital role in the European and Worldwide CSP market and ecosystem. Along with the Innovation Manager, they communicate any notable news, events, etc. to the project in a continuous basis.

7.3.3 POTENTIAL AND COMPETITIVE ANALYSIS

MonB5G is a highly ambitious project, that aspires to contribute numerous beyond SotA algorithms, system architectures, design concepts and technologies. The MonB5G innovation potential lies in different levels:

- **Algorithmic innovation**, stemming from the development of new ML/AI-based techniques in different domains, i.e., network management, energy efficiency, security provisioning
- **Network and system innovation**, stemming from the design and implementation of a dynamic slicing framework along with the required interfaces
- **Data innovation**, stemming from the design of advanced novel techniques for data generation based on ground-truth real/realistic data extracted from mobile operators, online databases and testbed statistics

The specific innovations below were identified at project inception, but more are being actively developed, as part of the technical WPs of the project:

- Scalable, hierarchical, distributed and recursive beyond 5G network slicing management and orchestration architecture
- Cutting-edge, data-driven, distributed artificial intelligence mechanisms to drive the operation of all its core components
- Distributing the layers of DNNs between local components (e.g., AEs running at MEC level) and central components, and introducing local exit points
- Complementing all local AE/DE decisions with confidence/uncertainty measures based on (deep) Bayesian networks and Gaussian processes
- Auto-encoder based compression/feature extraction at the local/edge AEs
- Network-aware training and inference
- Multi-agent reinforcement learning for distributed DE tasks

Market Analysis

Since project inception, products & projects relevant to MonB5G technologies that were identified included:

- Commercial 5G Platforms from telecom equipment vendors (i.e., Ericsson, Nokia, and Huawei), back then at a pre-production stage.
- Open Source MANO frameworks with wide industry adoption, such as ETSI OSM and ONAP, promised policy-based service Lifecycle Management automation.
- AI-based managed network services and operations offerings, such as the Ericsson Operations Engine, which project partner LMI has launched back then.
- Apache Spot IDS used ML as a filter for anomaly detection and separating malicious from benign traffic.

The market has apparently evolved since. *Section 5* of *Deliverable D2.2* (Techno-economic analysis of the beyond 5G environment, use case requirements and KPIs) captures progress of our further analysis of the

market, including an update on the open source projects & products (in *Section 5.2* of that deliverable), as well as creation of end-user value through the adoption of AI/ML techniques (*Section 5.3* of that deliverable).

We based our market analysis on a clear definition all stakeholders in the slice lifecycle business model, as well as their roles and interrelations. The outcome of this analysis is summarized on the following figure.

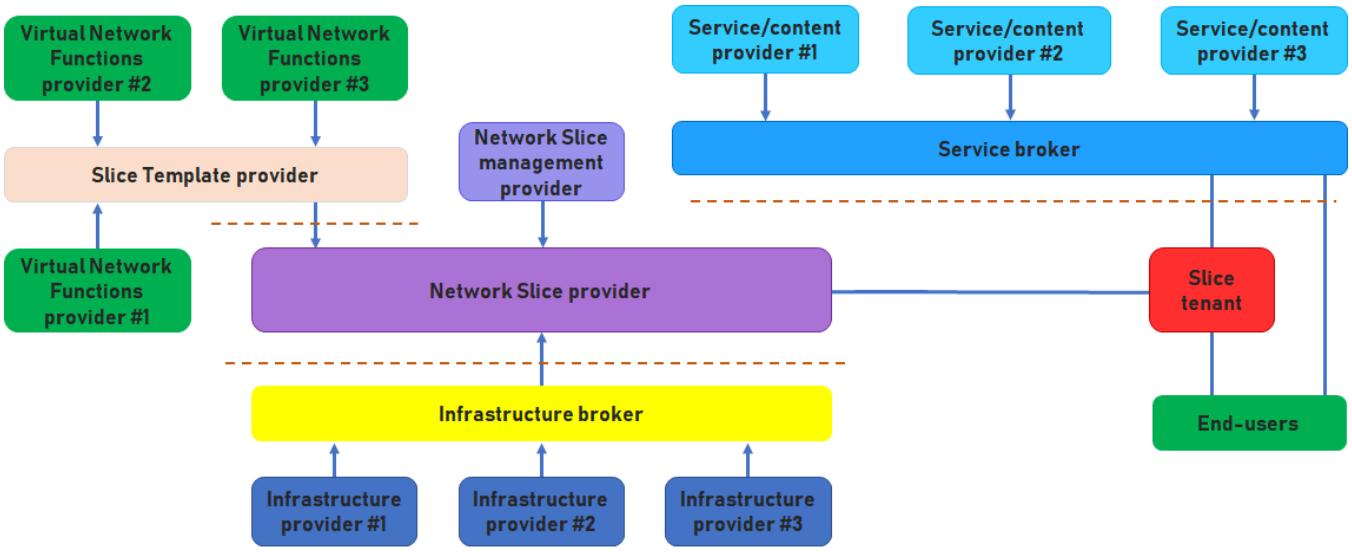


Figure 21: MonB5G Slice Lifecycle Business Model

Different stakeholders map to different segments of the market and respective products are positioned to fulfil their requirements. Also, their interrelations form chains MonB5G can create benefits and value for. The summary of the value chain that MoNB5G brings to the stakeholders is captured by the figure below.

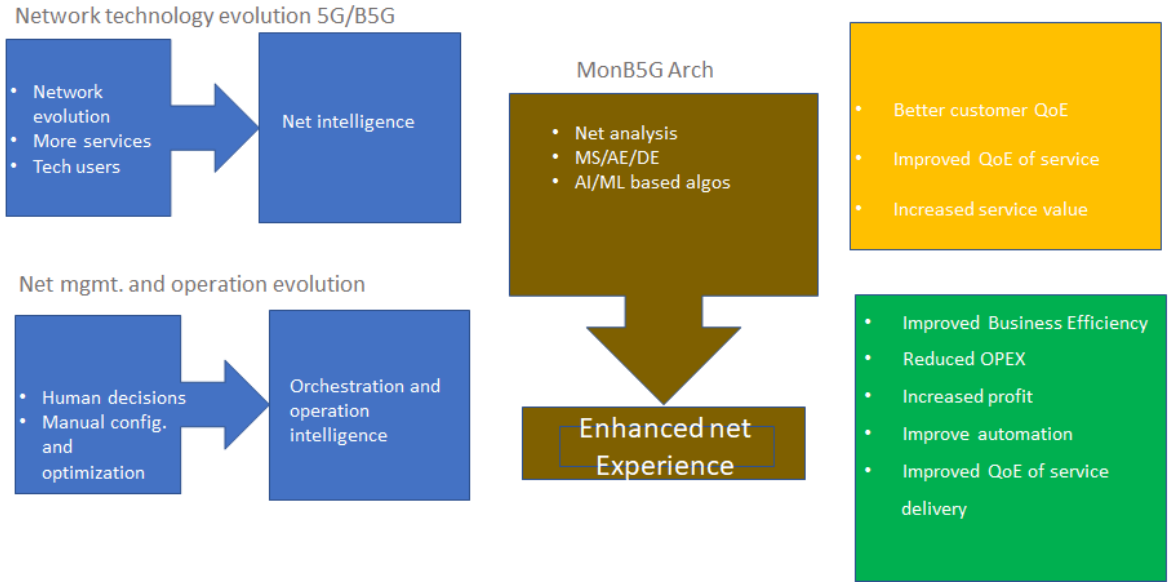


Figure 22: Value chain that MoNB5G brings to the stakeholders

Competitive Landscape

If we would like to have a fresh look at the competitive landscape, we would highlight that many vendors, established and emerging ones, promote portfolio solutions that aim at managing network slices:

- Ericsson's Network Slicing portfolio (https://www.ericsson.com/en/network-slicing), including the recently announced Ericsson 5G RAN Slicing (https://www.ericsson.com/en/network-slicing/ran-slicing)
- Nokia's Network Slicing portfolio (https://www.nokia.com/about-us/newsroom/articles/network-slicing-explained/), including the automated solution for 4G/5G network slicing across RAN, transport and core network (https://www.nokia.com/about-us/news/releases/2020/10/01/nokia-offers-worlds-first-automated-4g5g-network-slicing-within-ran-transport-and-core-domains/)
- Huawei's Network Slicing portfolio
- ZTE's 5G E2E Network Slicing Solution (https://www.zte.com.cn/global/solutions/201905201709/201906050910/5G-E2E-Network-Slicing-Solution)
- Samsung's Network Slicing Solution (https://www.samsung.com/global/business/networks/solutions/network-slicing/)
- Cisco's Network Services Orchestrator (https://www.cisco.com/c/dam/en/us/products/collateral/cloud-systems-management/network-services-orchestrator/white-paper-sp-5g-network-slicing.pdf)
- Amdocs 5G Slice Manager (https://www.amdocs.com/media-room/amdocs-launches-5g-slice-manager-automation-5g-network-slicing)
- Blue Planet 5G Automation Solution (https://www.blueplanet.com/solutions/5g-automation.html)
- Parallel Wireless Network Slicing Solution (https://www.parallelwireless.com/products/network-slicing/)
- Affirmed Networks (now acquired by Microsoft) Network Slicing Solution (https://www.affirmednetworks.com/products-solutions/network-slicing/)
- and even implementing 5G network slices with Cloudify on Amazon Web Services (https://aws.amazon.com/blogs/industries/implementing-5g-network-slicing-with-cloudify-on-aws/)

Also, Ericsson and Nokia (just to focus on the established vendors) increasingly embrace AI in the solutions they offer, while also enhancing their management and orchestration with zero-touch service automation:

- Ericsson Embracing AI: https://www.ericsson.com/en/ai
- Ericsson Next Generation Management and Orchestration: https://www.ericsson.com/en/blog/2020/11/next-generation-cloud-ran-management-and-orchestration
- Ericsson Zero-touch with Service Automation: https://www.ericsson.com/en/blog/2020/11/next-generation-cloud-ran-management-and-orchestration
- Nokia Self-organizing networks: https://www.nokia.com/networks/portfolio/self-organizing-networks/
- Nokia Digital Operations Center: https://www.nokia.com/networks/solutions/digital-operations-center/
- Nokia AVA AI Edge: https://www.nokia.com/about-us/news/releases/2020/11/11/nokia-brings-ai-to-network-edge-for-superior-5g-experience/
- Nokia AI 5G RAN: https://www.sdxcentral.com/articles/news/nokia-claims-ai-5g-ran-triumph-with-china-mobile/2021/01/

Last but not least, they provide complete 5G cyber security solutions

- Ericsson 5G Cyber Network Security: https://www.ericsson.com/en/public-policy-and-government-affairs/cyber-network-security
- Nokia 5G Cyber Security: https://www.nokia.com/networks/portfolio/cyber-security/

Market Opportunity

As evidenced by the proliferation of relevant products, the network slicing, zero-touch service management and 5G cyber security market is forecasted to thrive. In terms of estimating the market opportunity, it is not straightforward to find relevant analyst reports, but the network slicing market is estimated to grow to:

- 921M USD by 2027 with Compound Annual Growth Rate (CAGR) of 23.7% between 2020-2027
  Allied Markets Research: https://www.alliedmarketresearch.com/network-slicing-market-A07916
- or an even more optimistic 1,284M USD by 2025, with CAGR of 51.5% between 2020-2025
  Markets & Markets: https://www.marketsandmarkets.com/Market-Reports/network-slicing-market-120515704.html

With regards to the 5G security market, it is estimated to grow to:

- 5,226M USD by 2026 with CAGR of 44.3% between 2020-2026
  Markets & Markets: https://www.marketsandmarkets.com/Market-Reports/5g-security-market-261636732.html

If we include adjacent markets (vertical industries), in a recently released report, ABI Research predicts that industrial manufacturing, C-V2X, and logistics alone will potentially generate cumulative revenues of US$12 billion by 2026, representing a significant portion of an overall 5G slicing market that will likely exceed the US$20 billion mark (https://www.abiresearch.com/press/5g-network-slicing-will-generate-revenue-excess-us20-billion-2026/)

With respect to cloud-edges, the broader AI industry is witnessing a migration of AI to the edge. For example, the edge AI training and inference market for chipset sales is expected to grow from US$2.6 billion in 2020 to US$10.7 billion in 2025, at a CAGR of 35% ("AI and Operations Automation in 5G Networks", https://www.abiresearch.com/press/bid-capture-new-growth-telcos-turn-ai-and-operations-automation-5g-networks/).

ABI Research has also analysed the impact of combined 5G and AI on business productivity across many industry segments. The analysis indicates that this combination will generate US $3.1 trillion worth of value in 2025, 41% of which will be driven by direct revenue in the 5G value chain. The report forecasts 5G and AI combination will create value worth 9.2% of global GDP in 2035 and will be a catalyst for new services and enable explosive growth of revenues. Per the report, AI's direct contribution to GDP represents the value created by cloud providers, infrastructure vendors and AI application vendors. By 2035, 55% of the AI impact on the GDP will be generated by AI infrastructure suppliers ("5G and AI: The Foundations for the Next Societal and Business Leap", https://www.intel.com/content/dam/www/public/us/en/documents/reports/5g-and-ai-report.pdf).

7.4 Progress Beyond State of the Art

In the paragraphs that follow we outline the ambition of the project to advance the State of the Art (SotA), organized by domain of interest, as well as the specific progress so far, as reflected in published/accepted publications.

7.4.1 NETWORK SLICING (MANAGEMENT AND ORCHESTRATION)

Ambition Beyond SotA: MonB5G will go beyond the existing state of the art network slicing solutions in several directions. In particular, we will design and implement different "layers" of network slicing, from coarse-grained high level slices that satisfy the operator SLAs to fine-grained slicing techniques that go even up to the user/application level. To that end, advanced ML concepts will be leveraged to process the big data volume in different parts of the network (e.g., MEC, RAN, core network), enabling an automated zero-touch virtual and physical function chaining that dynamically binds the heterogeneous resources (i.e., computational, storage, communication) in an end-to-end manner across different network domains. Finally, the proposed ML-aided network slicing mechanisms will be able to satisfy various distinct KPIs (e.g., delay, rate, QoE, massive connectivity), thus being application-independent and completely transparent to the end user, applicable to the whole cohort of 5G use cases.

Progress Beyond SotA

[12] "The Road beyond 5G: A Vision and Insight of the Key Technologies" (IEEE Network) provides an insightful analysis for mobile networks Beyond 5G (B5G) considering the advancements and implications introduced by the evolution of softwarization, agile control and deterministic services. It elaborates the 5G landscape, also investigating new business prospects and the emerging use cases, which will open new horizons for accelerating the market penetration of vertical services. It then overviews the key technologies that constitute the pillars for the evolution beyond 5G considering new radio paradigms, micro-service oriented core network, native IP based user plane, network analytics and the support of low latency – high reliability transport layer. The open challenges considering both technical and business aspects are then overviewed, elaborating the footprint of softwarization, security and trust as well as distributed architectures and services towards 6G.

According to [8] "A Trust architecture for the SLA management in 5G networks" (IEEE ICC 2021), 5G will open the business market to new stakeholders with the introduction of Network Slicing, namely the vertical or tenant, the network slice provider, and the infrastructure provider. The Network Slice provider sells end-to-end network slices (virtual end-to- end mobile network) to the vertical while leasing virtual and physical resources from Infrastructure Providers to enforce these end-to-end network slices. Accordingly, there is a need to establish Service Level Agreement (SLA) among these actors to ensure: (1) that the service is well-delivered to the vertical and (2) the infrastructure providers are respecting their involvement with the network slice provider. To fill this gap, in this paper, we propose a trust architecture to automatically manage the SLAs and apply penalties and compensations if the SLAs are not respected by one of the involved actors.

[11] "A Novel Architectural Approach for the Provision of Scalable and Automated Network Slice Management, in 5G and Beyond" (IFIP AIAI 2021) discusses the novel architecture proposed within the scope of the project. Considering a multiplicity of challenges towards realizing an effective network slice management in modern 5G networks, our work considers explicitly the context promoted by the Zero-touch network and Service Management (ZSM) framework, assessed as an indispensable part of next-generation management systems. Within this scope, we propose a detailed architecture composed of static and dynamically deployed components. Altogether, they support operations related to slicing orchestration, fault management (self-healing), self-configuration, performance optimization (including energy saving), and security-related operations of slices. In the paper, we identified each separate architectural layer and explained all involved modules and interfaces. The proposed framework is able to support the deployment

of a massive number of slices in different administrative and technological domains. Furthermore, the potential extensions and/or enhancements of the architecture are also proposed and assessed.

[13] “MonB5G: AI/ML-Capable Distributed Orchestration and Management Framework for Network Slices” (IEEE MeditCom 2021) further elaborates on the above work.

[14] “A novel QoS framework for network slicing in 5G and beyond networks based on SDN and NFV” (IEEE Network), we propose a novel QoS framework of Network Slicing (NS) in 5G and beyond networks based on Software Defined Network (SDN) and Network Function Virtualization (NFV) to guarantee key QoS indicators for different application scenarios, such as enhanced Mobile Broad-Band (eMBB), massive MachineType Communications (mMTC) and Ultra-Reliable and LowLatency Communications (URLLC). In this QoS framework, 5G network is divided into three parts, Radio Access Network (RAN), Transport Network (TN) and Core Network (CN) to form three types of NS with different network resource allocation algorithms. The performance evaluation in the simulation environment of Mininet shows that the proposed QoS framework can steer different flows into different queues of Open Virtual Switches (OVS), schedule network resources for various NS types and provide reliable E2E QoS for users according to preconfigured QoS requirements.

[15] “A Service-Based Architecture for enabling UAV enhanced Network Services” (IEEE Network) provides an overview of enhanced network services, while emphasizing on the role of Unmanned Aerial Vehicles (UAVs) as core network equipment with radio and backhaul capabilities. Initially, we elaborate the various deployment options, focusing on UAVs as airborne radio, backhaul and core network equipment, pointing out the benefits and limitations. We then analyze the required enhancements in the Service-Based Architecture (SBA) to support UAV services including navigation and air traffic management, weather forecasting and UAV connectivity management. The use of airborne UAVs network services is assessed via qualitative means, considering the impact on vehicular applications. Finally, an evaluation has been conducted via a testbed implementation, to explore the performance of UAVs as edge cloud nodes, hosting an Aerial Control System (ACS) function responsible for the control and orchestration of a UAV fleet.

[16] “On SDN-driven Network Optimization and QoS aware Routing using Multiple Paths” (IEEE Transactions on Wireless Communications) concentrates on reducing the operating expenditure (OPEX) costs while i) increasing the quality of service (QoS) by leveraging the benefits of queuing and multi-path forwarding in OpenFlow, ii) allowing an operator with an SDN-enabled network to efficiently allocate the network resources considering mobility, and iii) reducing or even eliminating the need for over-provisioning. For achieving these objectives, a QoS aware network configuration and multipath forwarding approach is introduced that efficiently manages the operation of SDN enabled open virtual switches (OVSs). The paper proposes and evaluates three solutions that exploit the strength of QoS aware routing using multiple paths. While the two first solutions provide optimal and approximate optimal configurations, respectively, using linear integer programming optimization, the third one is a heuristic that uses Dijkstra short-path algorithm. The obtained results demonstrate the performance of the solutions in terms of OPEX and execution time.

[3] “QoS and Resource-aware Security Orchestration and Life Cycle Management” (IEEE Transactions on Mobile Computing) analyzes the large-scale, complexity and security issues brought by virtualized IoT networks, which embrace different network segments, e.g. Fog, Edge, Core, Cloud, that can also exploit proximity (computation offloading of virtualized IoT functions to the Edge), imposes new challenges for ZSM orchestrators intended to optimize the SFC, thereby achieving seamless user-experience, minimal end-to-end delay at a minimal cost. To cope with these challenges, the paper proposes a cost-efficient optimized

orchestration system that addresses the whole life-cycle management of different SFCs, that considers QoS (including end-to-end delay, bandwidth, jitters), actual capacities of Virtual Network Functions (VNFs), potentially deployed across multiple Clouds-Edges, in terms of resources (CPU, RAM, storage) and current network security levels to ensure trusted deployments. The proposed orchestration system has been implemented and evaluated in the scope of H2020 Anastacia EU project, showing its feasibility and performance to efficiently manage SFC, optimizing deployment costs, reducing overall end-to-end delay and optimizing VNF instances distribution.

[17] "Service Function Chaining in Next-Generation networks: Challenges and Open Research Issues" (IEEE Network), presents different research problems related to Service Functional Chaining (SFC) in next-generation networks and investigates several key challenges that should be addressed to realize more reliable SFC operations.

7.4.2 MACHINE LEARNING FOR SON AND SLICE MANAGEMENT

Ambition Beyond SotA: MonB5G will innovate beyond the state of the art, along the following main directions:

(1) We will propose novel, scalable slice admission control policies, based on AI for massive slice environments, to both accurately estimate the footprint of new slices as well as to decide its admission or not. Due to the very large number of parameters involved in the envisioned 5G+ slice environments, methods based on Q-learning will be applied, that can be proven to converge to optimal configurations, with no a priori knowledge. Nevertheless, as the convergence time for Q-learning tends to be high, in large problems like the ones considered, we will explore the use of warm-up methods based, for example, on Multi-Layer Perceptrons (MLP), to jump-start the Q-learning method from a reasonable initial policy. We will also consider approximate Q-learning, for implementation in local DEs with less computational power, as well as semi-uniform distributed exploration and Boltzmann-distributed exploration.

(2) Local AE algorithms, which provide updated KPI estimates (for the new potential configuration), will complement these with confidence metrics, based on (Deep) Bayesian Networks and Gaussian processes. The latter is able to quantify the confidence in the ability of the locally optimized/reconfigured slice to resolve the potential problem (e.g., slice performance predicted to violate some SLA metric). Local and remote DEs will use AE produced KPI estimates to reconfigure a specific slice based on (deep) reinforcement learning algorithms that will be responsible to both decide which features are relevant to be communicated, and which chain specific actions (scaling up/down, migration, etc.) to initiate. Finally, we will investigate multi-agent RL algorithms to implement a decomposition of the proposed DE algorithms.

(3) We will propose appropriate graph structures and new deep learning methods optimized for such graph structures, that are able to accurately yet minimally capture inter-slice dependencies. These dependencies include (i) the coupling between potentially large numbers of resources, where re-configuring one slice can affect numerous others and their respective SLAs; (ii) the coupling between slices is partial, which creates complicated dependencies that give rise to hard optimization problems, beyond the sharing of individual resources between users or even slices. While deep-learning has had considerable success on image and sound-like inputs, graph-based relations have significant differences from the former, and existing methods are not directly applicable. To this end, we will adapt novel methods from the recently emerging field of graph-specific deep learning methods to extract the key dependencies between slices. These will be

combined with RL methods (local DEs) and deep RL (central DE) to efficiently (re-)allocate radio, transport, computation, and storage resources between massive numbers of co-existing slices.

Progress Beyond SotA

In [18] “Optimized Network Slicing Proof-of-Concept with Interactive Gaming Use Case” (ICIN 2020) we focus on Network Slice placement optimization problem to give an insight about a latency-aware Network Slice Placement model through a Proof-of-Concept (PoC) illustrated by an Interactive Gaming time-sensitive use case. Therefore, we showcase the proposed Network Slice Placement solution considering user location as a primary constraint to ensure Quality of Service (QoS) and Quality of Experience (QoE).

In [19] “Location-based Data Model for Optimized Network Slice Placement” (IEEE NetSoft 2020) we focus on Network Slice Placement as an optimization problem, intimately related to the VNF Placement and Chaining problem. Contrarily to most studies related to VNF placement, we deal with the most complete and complex Network Slice topologies going beyond the currently used Service Functions Chains concept and we pay special attention to the geographic location of Network Slice Users. We propose a data model formalized using Integer Linear Programming (ILP). Extensive numerical experiments and evaluation results assess the relevance of taking into account the user location constraints, especially for ensuring strict end-to-end delay requirements.

In [20] “Latency-aware Service Placement and Live Migrations in 5G and Beyond Mobile Systems” (IEEE ICC 2020) we address the problem of initial placement and live migration of multiple mobile services across centralized and edge cloud by taking into account service types, network conditions and users’ mobility features. As a solution to this problem, in this paper, we suggest and evaluate a solution that orchestrates the network services in a cost-efficient way, ensuring that each user could be simultaneously served by multiple slices while perceiving a high QoS and ensuring that the service level agreements (SLAs) of the consumed services are not violated.

In [21] "LACO: A Latency-Driven Network Slicing Orchestration in Beyond-5G Networks" (IEEE Transactions on Wireless Communications), we pioneer a novel radio slicing orchestration solution that simultaneously provides latency and throughput guarantees in a multi-tenancy environment. Leveraging on a solid mathematical framework, we exploit the exploration-vs-exploitation paradigm by means of a multi-armed-bandit-based (MAB) orchestrator, LACO, that makes adaptive resource slicing decisions with no prior knowledge on the traffic demand or channel quality statistics. As opposed to traditional MAB methods that are blind to the underlying system, LACO relies on system structure information to expedite decisions. After a preliminary simulations campaign empirically proving the validness of our solution, we provide a robust implementation of LACO using off-the-shelf equipment to fully emulate realistic network conditions: near-optimal results within affordable computational time are measured when LACO is in place.

In [22] "Edge-enabled Optimized Network Slicing in Large Scale Networks" (NoF 2020) we consider the network slice placement optimization problem and give some insights into a fast heuristic algorithm tailored to placement in large scale networks. We consider an online optimization scenario with multiple and volatile network slice request arrivals and we showcase the applicability of the proposed Edge-enabled network slice placement solution through a PoC illustrated by large scale networks scenarios.

In [23] “Heuristic for Edge-enabled Network Slicing Optimization using the “Power of Two Choices”” (CNSM 2020) we propose an online heuristic algorithm for the problem of network slice placement optimization. The

solution is adapted to support placement on large scale networks and integrates Edge-specific and URLLC constraints. We rely on an approach called the “Power of Two Choices” to build the heuristic. The evaluation results show the good performance of the heuristic that solves the problem in few seconds under a large scale scenario. The heuristic also improves the acceptance ratio of network slice placement requests when compared against a deterministic online Integer Linear Programming (ILP) solution.

Per [6] “Towards an Optimal MEC Resources Dimensioning for Vehicle Collision Avoidance System: A Deep Learning Approach” (IEEE Network) collision detection and avoidance between vehicles is one of the key services envisioned in the Internet of Vehicles. Such services are usually deployed at the multi-access edge computing (MEC) to ensure low-latency communication and guarantee real-time reactions to avoid collisions between vehicles. In order to maximize the coverage of the road and ensure that all vehicles are connected to an optimal MEC host (in terms of geographical location), the collision avoidance application needs to be instantiated on all the MEC hosts. This may add a burden on the computing resources available at the latter. In this article, we propose an AI-empowered framework that aims to optimize the computing resources at the MEC hosts. Our framework uses deep learning to predict the vehicle density to be served by a MEC host and derive the exact computing resources required by the collision detection application to run optimally. We evaluate the proposed framework using a real dataset representing vehicle mobility in a big city. Obtained results show the accuracy of our prediction model, and hence the efficiency of our resources assignment framework to exactly deduce the optimal computing resources needed by each instance of the application.

In [2] “Data Driven Service Orchestration for Vehicular Networks” (IEEE Transactions on Intelligent Transportation Systems) we devise a unique fusion of DL-based mobility prediction and Genetic Algorithm assisted service orchestration to retain the average service latency of vehicular networks minimal, by offering personalized service migration, while tightly packing as many services as possible in the edge of the network, for maximizing resource utilization. Through an extensive simulation based on real data, we evaluate the proposed mobility orchestration combination and we find gains in low latency in all examined scenarios.

In [24] "Dynamic Resource Aware VNF Placement with Deep Reinforcement Learning for 5G Networks" (IEEE GlobeCom 2020) we leverage a Deep Deterministic Policy Gradient Reinforcement Learning algorithm, to fully automate the Virtual Network Functions deployment process between edge and cloud network nodes. We evaluate the performance of our solution and compare it with alternative solutions to prove its superiority while demonstrating results that pave the way for Experiential Network Intelligence and fully automated, Zero touch network Service Management.

In [25] “Continuous Multi-objective Zero-touch Network Slicing via Twin Delayed DDPG and OpenAI Gym” (IEEE GlobeCom) 2020), we tackle the problem of cloud-RAN (C-RAN) joint slice admission control and resource allocation by first formulating it as a Markov decision process (MDP). We then invoke an advanced continuous deep reinforcement learning (DRL) method called twin delayed deep deterministic policy gradient (TD3) to solve it. In this intent, we introduce a multi-objective approach to make the central unit (CU) learn how to re-conFigure computing resources autonomously while minimizing latency, energy consumption and virtual network function (VNF) instantiation cost for each slice. Moreover, we build a complete 5G C-RAN network slicing environment using OpenAI Gym toolkit where, thanks to its standardized interface, it can be easily tested with different DRL schemes. Finally, we present extensive experimental results to showcase the gain of TD3 as well as the adopted multi-objective strategy in terms of achieved slice admission success rate, latency, energy saving and CPU utilization.

In [7] "π-ROAD: A Learn-as-You-Go Framework for On-Demand Emergency Slices in V2X Scenarios" (IEEE INFOCOM 2021) we propose π-ROAD, a deep learning framework to automatically learn regular mobile traffic patterns along roads, detect non-recurring events and classify them by severity level. π-ROAD enables operators to proactively instantiate dedicated Emergency Network Slices (ENS) as needed while re-dimensioning the existing slices according to their service criticality level. Our framework is validated by means of real mobile network traces collected within 400 km of a highway in Europe and augmented with publicly available information on related road events. Our results show that π-ROAD successfully detects and classifies nonrecurring road events and reduces up to 30% the impact of ENS on already running services.

Per [4] "On using reinforcement learning for network slice admission control in 5G: offline vs. online" (Wiley International Journal of Communication Systems) achieving a fair usage of network resources is of vital importance in Slice-ready 5G network. The dilemma of which network slice to accept or to reject is very challenging for the Infrastructure Provider (InfProv). On one hand, InfProv aims to maximize the network resources usage by accepting as many network slices as possible; on the other hand, the network resources are limited, and the network slice requirements regarding Quality of Service (QoS) need to be fulfilled. In this paper, we devise three admission control mechanisms based on Reinforcement Learning, namely, Q-Learning, Deep Q-Learning, and Regret Matching, which allow deriving admission control decisions (policy) to be applied by InfProv to admit or reject network slice requests. We evaluated the three algorithms using computer simulation, showing results on each mechanism's performance in terms of maximizing the InfProv revenue and their ability to learn offline or online.

In [9] "CDF-Aware Federated Learning for Low SLA Violations in Beyond 5G Network Slicing", we address the concept of dynamic resource allocation for radio access network (RAN) slicing in beyond 5G (B5G) systems under service-level agreement (SLA). Using live network distributed key performance indicators (KPIs) mini-datasets, we introduce a new class of federated learning models that can capture the long-term cumulative distribution function (CDF) statistic—is usually used to define SLA—and enforce some preset constraints on it. Given that the CDF is also dataset-dependent and non-convex non-differentiable, we formulate the corresponding local optimization task using the proxy-Lagrangian framework and solve it via a non-zero sum two-player game strategy. Numerical results show that the proposed decentralized resource allocation approach enables SLA enforcement and significantly reduces the SLA violation rate for various slice-level KPIs.

7.4.3 MACHINE LEARNING FOR TRAFFIC PREDICTION AND ANALYTICS

Ambition Beyond SotA: MonB5G will go well beyond the state-of-the-art in terms of traffic prediction and general data analytics along a number of key directions:

(1) It will identify appropriate representations for the diverse network and application related monitored data that will be the basis of all proposed machine learning algorithms. While deep neural networks have had significant recent success, the majority of state-of-the-art methods operate on image-like (2D) or time-series like (e.g., 1D sound clips) inputs, with very specific correlation properties. Where appropriate, we plan to adapt these techniques leveraging wireless data properties with similar patterns (e.g., the spatio-temporal correlation properties of traffic demand). We will also devise new representation methods for network graph related data (a common abstraction for slicing and VNF chaining) that are not well captured by existing NN models.

(2) A significantly higher number of parameters will be monitored, beyond simple BS traffic loads, both horizontally (RAN to core) and vertically (all the way up to application layer). However, modeling the impact

of each such parameter on a high level KPI or SLA metric would be: (a) prohibitively complex, (b) highly sensitive to assumption accuracy. We will instead train model-free predictors to automatically adapt the relation between the massive number of monitored parameters and end-to-end KPIs or SLA-specific metrics. To this end, we will use both regularized regression models (e.g., Lasso), that are easily interpretable, as well as advanced deep learning methods like convolutional LTSMs that are able to exploit both spatio-temporal correlations through convolutional neural layers (e.g., similarity of daytime traffic patterns in cells of similar nature, such as metro stations or other commute points), as well as the stateful nature of some network parameters (e.g., queue sizes) through recursive structure. We will also investigate the tradeoff between model-free (e.g., deep learning) and model-based ML (e.g., data-driven convex optimization) using measurable concepts like complexity, generalizability, and convergence times.

(3) We will distribute the layers of Deep Neural Networks (DNN) between local components (e.g., AEs running at MEC level) and central components, and introduce local exit points. Unlike standard DNNs with a single output layer at the end, an intermediate output layer placed after the 3 hidden layers might already be able to make a confident classification decision (e.g., KPI X will exceed the agreed SLA in the next time window), without communicating with the central AE and further processing through the remaining layers. Additionally, we will complement all local AE/DE decisions with confidence/uncertainty measures based on (deep) bayesian networks and gaussian processes. Unlike standard ML-based regression and classification methods based on (deep) bayesian networks and gaussian processes are able to complement such predictions with a confidence (interval) for such predictions[66]. Such ML-driven confidence measures will complement all local AE/DE decisions, in order to identify whether further interaction with other local MS/AE/DE components, or fallback to their centralized counterparts is needed.

(4) We will use auto-encoder based compression and feature extraction at the local/edge AEs, in order to significantly reduce the amount of raw data that need to be communicated and processed by remote or central AEs. Auto- encoders (a class of DNNs) excel at producing highly compressed representations of data, without any assumptions on their statistics or underlying network these emanate from. In addition, we will make this feature extraction network- aware, where the number and type of features to be extracted/communicated, will depend on the network conditions, and will also be controlled with reinforcement learning type algorithms, running at a lower time-scale, and providing guidelines to the local feature-extraction AE, periodically.

(5) We will propose distributed data analytics algorithms specifically for 5G+ environments that can learn from data distributed across different locations (e.g., edge clouds or ``fog'' environments), as is also required in the context of Federated Machine Learning[67].

Progress Beyond SotA

[26] "Towards ML/AI-based Prediction of Mobile Service Usage in Next-Generation Networks" (IEEE Network) highlights the new features and capabilities offered by the "Network Slice Planner" (NSP) in its second version. It also proposes a method combining both supervised and unsupervised learning techniques to analyze the behavior of a mass of mobile users in terms of service consumption. We exploit the data provided by the NSP v2 to conduct our analysis. Furthermore, we provide an evaluation of both the accuracy of the predictor and the performance of the underlying MEC infrastructure.

In [27] "Federated Deep Reinforcement Learning for Internet of Things with Decentralized Cooperative Edge Caching" (IEEE Internet of Things Journal) we propose a FederAted Deep reinforcement learning-based

cooperative Edge caching (FADE) framework. FADE enables base stations (BSs) to cooperatively learn a shared predictive model by considering the first-round training parameters of the BSs as the initial input of the local training, and then uploads near-optimal local parameters to the BSs to participate in the next round of global training. Furthermore, we prove the convergence of the proposed FADE, and it achieves the expectation convergence. Trace-driven simulation results show that the proposed FADE framework reduces 92% of performance loss and average 60% system payment over the centralized deep reinforcement learning algorithm, achieves only a 4% performance loss of the desirable omniscient oracle algorithm, and obtains 7%, 11% and 9% network performance improvements compared to existing schemes, i.e., least recently used (LRU), least frequently used (LFU) and first-in first-out (FIFO), respectively.

In [28] "ARENA: A Data-driven Radio Access Networks Analysis of Football Events" (IEEE Transactions on Network and Service Management), based on data provided by a major European carrier during mass events in a football stadium comprising up to 30000 people, 16 base station sectors and 1 Km2 area, we performed a data-driven analysis of the radio access network infrastructure dynamics during such events. Given the insights obtained from the analysis, we developed ARENA, a model-free deep learning Radio Access Network (RAN) capacity forecasting solution that, taking as input past network monitoring data and events context information, provides guidance to mobile operators on the expected RAN capacity needed during a future event. Our results, validated against real events contained in the dataset, illustrate the effectiveness of our proposed solution.

[29] "On Predicting Service-oriented Network Slices Performances in 5G: A Federated Learning Approach" (IEEE LCN 2020) considers that, to achieve the vision of ZSM for network slices in 5G, it is important to monitor and predict the performances of the running network slices. The performance parameters of telco system or sub-system (KPIs) are usually monitored, but also, with the advance of Machine Learning (ML) techniques, predicted. Indeed, predicting KPIs is critical for ZSM, as it allows the system to proactively react to any service degradation of a running network slice. While network- and computation-oriented KPIs can be easily monitored and predicted, service-oriented KPIs are difficult to obtain due the privacy issue, as they disclose critical information on the performance of services. Hence, centralized ML techniques cannot be used to predict such type of KPI. To tackle this issue, in this paper, we rather propose to use a new ML technique, known as Federated Learning (FL). It consists in keeping raw data where it is generated, while sending only users' local trained models to the centralized entity for aggregation. Due to its privacy-preserving, FL is adequate to predict slices' service-oriented KPIs.

7.4.4 MACHINE LEARNING FOR ENERGY EFFICIENT MANAGEMENT

Ambition Beyond SotA: In MonB5G we will introduce the concept of energy slicing, to guarantee the required energy supply in different network parts (e.g., core, access) and resources (e.g., MEC, communication) in order to satisfy various levels of SLAs. To that end, we will deploy and train Deep Neural Networks using as an input a plethora of relevant features (e.g., explicit power consumption in each network component, cooling systems, air temperature, etc.). The DNN output will provide metrics of interest, such as the energy efficiency and the achieved QoS. In our effort, we will study i) the linear independence of the input parameters so that to minimize the training time and avoid the model overfitting, ii) the balance between the RNN complexity (e.g., number of hidden layers) and the prediction accuracy.

[10] "Actor-Critic-Based Learning for Zero-touch Joint Resource and Energy Control in Network Slicing" (IEEE ICC 2021) proposes a novel knowledge plane (KP)-based MANO framework that accommodates and exploits

recent NS technologies and is termed KB5G. Specifically, we deliberate on algorithmic innovation and artificial intelligence (AI) in KB5G. We invoke a continuous model-free deep reinforcement learning (DRL) method to minimize energy consumption and virtual network function (VNF) instantiation cost. We present a novel Actor-Critic-based NS approach to stabilize learning called, twin-delayed double-Q soft Actor-Critic (TDSAC) method. The TDSAC enables central unit (CU) to learn continuously to accumulate the knowledge learned in the past to minimize future NS costs. Finally, we present numerical results to showcase the gain of the adopted approach and verify the performance in terms of energy consumption, CPU utilization, and time efficiency.

7.4.5 NETWORK SLICING SECURITY

Ambition Beyond SotA: MonB5G will advance the state of the art in network slicing security in the following directions:

- We will provide new trust models and metrics for the multi-stakeholder beyond 5G environment that the project targets, which will be used as a basis for developing appropriate trust and reputation management schemes, and incentives-compatible mechanisms for network slice composition, monitoring, and dynamic management.
- We will devise novel distributed machine learning schemes for fast and localized attack identification and the selection of the appropriate countermeasures.
- We will improve the robustness, security, and privacy of distributed learning schemes in the face of adversaries in a non-fully cooperative decentralized environment. To this end, MonB5G will apply trust-based evaluation mechanisms on the monitored (and other) data reported.
- We will provide security orchestration components capable of applying dynamic security policies per slice and per attack episode, effectively mitigating traditional and new slicing-specific forms of attacks and ensuring slice isolation and security. This involves the instantiation and configuration of the appropriate virtualized security appliances using NFV/SDN technologies and towards Security-as-a-Service.
- By means of blockchain technologies, we will design secure and decentralized monitoring and accounting mechanisms, and tools for fully automated slice composition, and SLA management and arbitration. In this direction, it will apply trust and reputation-based mechanisms to alleviate the need for trusted third parties for auditing SLA compliance and ensuring trustworthy monitoring.
- We will study emerging MEC-specific attacks in the context of network slicing and enhance MEC orchestration components with security functionality to respond to them in real-time and in a localized manner.

Progress Beyond SotA

In [30] "NSBchain: A Secure Blockchain Framework for Network Slicing Brokerage" (IEEE ICC 2020) we propose NSBchain, a novel network slicing brokering (NSB) solution, which leverages on the widely adopted Blockchain technology to address the new business models needs beyond traditional network sharing agreements. NSBchain defines a new entity, the Intermediate Broker (IB), which enables Infrastructure Providers (InPs) to allocate network resources to IBs through smart contracts and IBs to assign and re-distribute their resources among tenants in a secure, automated and scalable manner. We conducted an extensive performance evaluation by means of an open-source blockchain platform that proves the feasibility of our proposed framework considering a large number of tenants and two different consensus algorithms.

[31] "AI for Beyond 5G Networks: A Cyber-Security Defense or Offense Enabler?" (IEEE Network) sheds light on how AI may impact the security of 5G and its successive from its posture of defender, offender or victim, and recommends potential defenses to safeguard from malevolent AI while pointing out their limitations and adoption challenges.

[1] “Trust in 5G and Beyond Networks” (IEEE Network) sheds more light on the trust concept in 5G and beyond networks and its dimensions, while pointing out potential emerging trust enablers and research directions. Furthermore, we propose a blockchain-based data integrity framework to foster trust in data used by a machine learning pipeline.

In [5] “An end-to-end trusted architecture for network slicing in 5G and beyond networks” (Wiley Security and Privacy Journal), we propose a Blockchain-based trust architecture that aims to: (1) create and negotiate the deployment of an end-to-end slice network; (2) manage automatically the service level agreements (SLA) established between the involved actors; while guaranteeing security and anonymous transactions.

7.5 Exploitation Planning

The sections that follow provide the updated exploitation map of the innovation actions that the industrial and academic partners of MonB5G have qualified as exploitable, commercially or for academic research.

The project KPIs relevant to exploitation are:

i) the number of patent applications or awarded patents

ii) the percentage of participating subject matter experts introducing innovations to the company or the market (covering the period of the project plus three years)

MonB5G targets to submit at least 5 patents**.** Until the time of preparing this, the patent application(s) below have been submitted by MonB5G partners:

- Title: “Method and network device for determining causes of network slice performance degradation in an open radio access network”. Inventors: Zhao Xu (NEC). Date of patent filing: April 19 2021.

7.5.1 INDIVIDUAL PARTNERS

The updated exploitation plan of each partner individually is provided in the sections/tables that follow.

7.5.1.1 OTE

Innovation			**TRL M01**	**TRL M36**
ML and DE enabling improvement of network performance			2	5
Type of exploitation		**Exploitation potential**		**Conflicting IP**
Enhance our knowledge of ML and DE for network Improvement		High		No
Competition	**Strengths**	**Weaknesses**	**Risks**	

Other Operators	Leading Operator	Strong Competition	No adoption by Standards yet
Targeted market	**Time to market estimate**	**Expected ROI**	
End users	~3 years	Increase customer base by improving QoE, Reduce energy consumption (OPEX)	
Path to market			
OTE will exploit the results of MonB5G with regards to the exploitation of ML and DE to assess their efficiency by implementing them in the network for testing its performance. The R&D labs of OTE belong to the Strategy and Development Department and always the deliverables and milestones of the projects provide useful results to the upper management. In addition, every year a workshop is organized in which the results and the milestones of the projects are presented to OTE's staff and in general to the Deutsche Telecom group since OTE is part of it. The results are surely used for future initiatives and for the establishment of new technologies and services. With the synergy and cooperation of OTE with Deutsche Telecom AG, as part of its group, the project results and the dissemination plans will be even more beneficial for bringing new ideas and propositions to the planning and strategy managerial staff.			

7.5.1.2 LMI

Innovation		**TRL M01**	**TRL M36**
Enhancements on advanced analytics and ML for insights for 5G management		3	5
Type of exploitation	**Exploitation potential**	**Conflicting IP**	
Strengthen the understanding and knowledge of advanced ML for 5G management, which will influence product decisions in the future	High	No	
Competition	**Strengths**	**Weaknesses**	**Risks**
Other telecom providers, open source	Very important step needed for the development of intelligent 5G management systems	If 5G standards evolve, algorithms need to evolve too	Algorithms too specific for the specified use cases
Targeted market	**Time to market estimate**	**Expected ROI**	
Internal to Ericsson 5G Customers (Operators & Verticals)	2 years	Increase knowledge in this area, which will ripple down into internal decisions, discussions with customers, and further collaborations	
Path to market			

LMI is actively involved in the advancement of 5G end-to-end deployments and their role for vertical industries. LMI is therefore interested in further understanding the technical implications of such deployments and their usability in various scenarios. The results coming from MonB5G will be internally & externally disseminated, with the goal of increasing the know-how of LMI's engineers, managers and product development leaders, and also of furthering the discussions on 5G that we have with our partners. Furthermore, LMI's participation in MonB5G will also enable to strengthen and enlarge LMI's collaborations within the EU. The knowledge that will be gained is envisioned to ripple into our current and future collaborations and influence internal and customer discussions on 5G management.

7.5.1.3 CTXS

Innovation			**TRL M01**	**TRL M36**
Citrix Application Delivery Controller (ADC)			5	7
Type of exploitation		**Exploitation potential**		**Conflicting IP**
Product development		High		No
Competition	**Strengths**	**Weaknesses**	**Risks**	
F5, Radware, A10	Market leader in enterprise and cloud	Lower penetration of telecom operator market	Competitive solutions by traditional telecom vendors	
Targeted market	**Time to market estimate**	**Expected ROI**		
Telecom operators, System integrators	1-2 years	Extend applicability of product to 5G networks. Enable deployment at the 5G network edge. Increase relevance to IoT/mMTC applications		
Path to market				
CTXS will exploit the lessons learnt from integrating parts of the Citrix Networking product suite (ADC, ADM and potentially SD-WAN) with the facilities of MonB5G, to expand their applicability to 5G networks and improve their alignment with the 5G services architecture. The evolution of the products will be funded internally, as per the company's roadmap.				

Innovation			**TRL M01**	**TRL M36**
Citrix Application Delivery Management (ADM)			5	7
Type of exploitation		**Exploitation potential**		**Conflicting IP**
Product and cloud-service development		High		No
Competition	**Strengths**	**Weaknesses**	**Risks**	
Same as above (Citrix ADM is an attachment to Citrix ADC)				

Targeted market	Time to market estimate	Expected ROI
Telecom operators, System integrators	1-2 years	Improve management & orchestration capabilities for better alignment with 5G services architecture
Path to market		
Same as above (Citrix ADM is an attachment to Citrix ADC)		

7.5.1.4 ORA-FR, ORA-PL

Innovation			TRL M01	TRL M36
Slice management			2	6
Type of exploitation		**Exploitation potential**		**Conflicting IP**
Orange Group is working to offering slices to vertical markets. Orange is already offering SDN-based VPNs (EasyGo Networks). The results of the project can help Orange offering services to verticals.		High		No
Competition	**Strengths**	**Weaknesses**	**Risks**	
The slice market may be very competitive in the forthcoming years to meet requirements by verticals	Methods of improving services offered by Orange in terms of customization and resource usage	The network elements need to rely on intermediate functions to support the ad-hoc analytics computation and export	The ML based techniques may be complicated to integrate into existing network operation systems	
Targeted market	**Time to market estimate**	**Expected ROI**		
Operational network services of Orange (notably Orange Business Services and wholesale) towards vertical market requirements	3-4 years	Thanks to virtualization and automation: - Faster TTM: reduced dev. & deployment cycles - Significant savings in CAPEX and OPEX: reuse of infrastructures and smart allocation of resources, move (gradually) from the configuration of networks to automation of LCM.		
Path to market				
The Network Slicing technology is a key area for Orange Group. Orange Business Services is already offering SDN based services (e.g., EasyGo Networks, SD-WAN) and is going very fast to offer slices to vertical markets (industry, automotive, health, etc.) based on 5G SA by 2023. The need for carrier-grade scalable, automated and intelligent solutions for slice orchestration will become critical very soon. Moreover, the AI-based algorithms for proactive root-cause analysis and early detection of problems during run-time of slices are needed. The objective of ORA-FR and ORA-PL with the project is to promote				

the solutions proposed by MonB5G in Orange and especially Orange Business Services and Orange Wholesale.

7.5.1.5 BCOM

Innovation			**TRL M01**	**TRL M36**
Slice Manager			4	6
Type of exploitation		**Exploitation potential**		**Conflicting IP**
Product development		Medium		No
Competition	**Strengths**	**Weaknesses**	**Risks**	
4G LTE solutions	Dynamic and adaptable	TRL level to address Verticals	Market access for a new entrant	
Targeted market	**Time to market estimate**	**Expected ROI**		
Private wireless network integrators for Verticals	1-2 years	Add features relevant to private 5G network infrastructures		
Path to market				
BCOM is already bringing solutions to the market like the “Wireless Edge Factory”, a 5G Mobile Edge private connectivity enabler. This set of VNFs can already be orchestrated by a VNF orchestrator. BCOM would like to enhance its offer with a slice manager and security orchestrator to deploy on-demand 5G private network slices with the highest level of security for Verticals. With MONB5G project, BCOM aims to reach a TRL compatible demonstration and Proof-of-Concept in order to test market interest.				

7.5.1.6 IQU

Innovation			**TRL M01**	**TRL M36**
Dynamic slicing protocols			2	6
Type of exploitation		**Exploitation potential**		**Conflicting IP**
Product development		Medium		No
Competition	**Strengths**	**Weaknesses**	**Risks**	
Nokia, Huawei	Ethernet friendly solution	Strong competition	Full features non adopted by standards	
Targeted market	**Time to market estimate**	**Expected ROI**		

Telecom operators, System vendors, Verticals	2-3 years	IoT nodes controlled by slicing upgrade targeting new contracts with telecom operators
Path to market		
MonB5G solutions for dynamic slicing will be embedded in the company's evaluation tools for enhancing the existing product´s portfolio and testing platforms for 5G wireless networks. Therefore, IQU will strengthen its capability to test different applications and will sell the existing solutions as a service to different vertical providers. The required resources required for the development that will take place after the end of the project will come from own resources.		

7.5.1.7 NEC

Innovation			**TRL M01**	**TRL M36**
Graph AI for network analysis			2	5
Type of exploitation		**Exploitation potential**		**Conflicting IP**
Develop and enhance the know-how of the advanced graph AI techniques for network slice data analysis		High		No
Competition	**Strengths**	**Weaknesses**	**Risks**	
Other telecom providers, open source	Very important step needed for the development of intelligent 5G management systems	If 5G standards evolve, algorithms need to evolve too	Algorithms too specific for the specified use cases	
Targeted market	**Time to market estimate**	**Expected ROI**		
5G Customers (Operators & Verticals)	3 years	Improve the understanding and knowledge about application of graph AI for 5G data management, and develop intelligent data analysis systems able to understand the status of the network slices.		
Path to market				
Please refer to item below				

Innovation		**TRL M01**	**TRL M36**
Smart network Slicing		3	5
Type of exploitation	**Exploitation potential**		**Conflicting IP**

Influence NEC's Networks Slicing Solutions Product development		High	No
Competition	**Strengths**	**Weaknesses**	**Risks**
Other telecom providers, open source	Required to attract Industry Verticals as customer	Increases significantly the complexity of 5G systems	Industry Verticals option for Private Networks
Targeted market	**Time to market estimate**	**Expected ROI**	
5G Customers (Operators & Verticals)	3 years	Development of key differentiation technologies for achieving a cost-efficient Network Slicing solution	
Path to market			
NEC counts with a big portfolio of 5G products and that are deployed by operators worldwide. The advances obtained by MonB5G will improve the existing products placing NEC at a vantage point with respect to the competence by providing smart network slicing. Moreover, the newly created line of AI technologies "NEC the Wise", devoted to the creation and commercialization of advanced AI solutions will incorporate to its portfolio the different algorithms developed in the project.			

7.5.1.8 EBOS

Innovation		**TRL M01**	**TRL M36**
ML algorithms and new AI approaches for anomaly detection in networks		2	4
Type of exploitation		**Exploitation potential**	**Conflicting IP**
• Enhance our knowledge of ML for anomaly detection • Enhance knowledge of attack detection in networks • Increase company's capabilities using new AI methodologies		Medium	No
Competition	**Strengths**	**Weaknesses**	**Risks**
• Open source alternatives • Commercial solutions • New ML approaches	Short time to market	• Resources for support depending on demand, • Data limitations	Limited uptake by industry
Targeted market	**Time to market estimate**	**Expected ROI**	
• Anomaly detection for	2-3 years	Increase revenue and security of the company's products and services	

Telecom operators and System vendors • Security components for Vertical markets (e.g. firewall)		
Path to market		
Advance knowledge and reinforce understanding of security in 5G technologies extending the company's R&D activities. Apply the results in the company's product portfolio for developing new innovative applications and solutions with classification capabilities, and expanding the customer base.		

7.5.1.9 CTTC

CTTC's participation in this project is expected to stimulate a number of technology transfer and IPR generation activities, which are at the true core of its mission. From participation in MonB5G, CTTC staff will acquire new knowledge in enhancing the capabilities of an existing 5G platform. The adaptation of the platform to the ETSI ENI and ETSI ZSM requirments and AI/ML techniques will further enhance the existing experimentation platform towards 6G. The results of the project will be integrated in the 5GBarcelona initiative in order to enhance the collaboration with other companies. As a member of ETSI, CTTC will actively participate in the corresponsing WGs ETSI ENI and ETSI ZSM. Moreover, as a member of 5GIA and 5G Vision 2020, CTTC will exploit the project´s results to the 5G industrial community in Europe. In addition, CTTC will enhance it training activities by producing new material in the area of AI/ML for network management. Moreover, CTTC will use the know-how of the produced results to 2 new PhD Thesis. Finally the team will publish the results to top-tier journal papers and conferences.

7.5.1.10 EUR

Through MonB5G, EUR will continue to promote the use of open-architecture radio systems. The equipment and software developed by EUR in the context of the MonB5G project will be made available in the public-domain for future use in collaborative initiatives. In particular, the software generated during the project along with the measurement methodology will be contributed to the OAI Software Alliance community to allow for its use in future collaborative projects around the world. Through its presence at 3GPP starting in 2019, EUR will also contribute any appropriate IPR related to extensions for PPDR systems to 3GPP TSG RAN either in the form of study items or actual layer1 or layer2 procedures. EUR will promote the use of the facility and integration with vertical partners in Linux Networking Foundation projects such as OPNFV.

7.5.1.11 AAL

Defines an ambitious plan to support the exploitation of the main findings and outputs arising from MonB5G. As an academic institution, AAL is aiming to enrich its teaching activities at different levels. Incorporating

different technological aspects of the project in the teaching content will allow exposing students to real-world technologies. The project results will be also exploited as a catalyzer for further research projects in relevant scientific and technological areas. Moreover, AAL will leverage the research findings from MonB5G to continuously evolve its network facility. The project will make use of the X-Networks site. We plan to explore the output of the project for enhancing the network automation and orchestration in the X-Networks site. The Aalto Center for Entrepreneurship of Aalto university ensures the connection to the surrounding ecosystem of incubators, accelerators, and investors. The co-working space of the Startup Sauna accelerator program is situated at the university's campus and provides excellent opportunities for startup ambitions. The center also deals with the management of technology transfer and the coordination of activities related to intellectual propriety, ensuring the suitable environment for innovation. MonB5G considers emerging 5G use cases with less coverage that AAL will promote for business creation.

7.5.2 MONB5G AS A WHOLE

The expected impact of the MonB5G project is provided below. This is the basis for the exploitation plan of the MonB5G platform as a whole, which we will be solidifying and reporting on in upcoming deliverables.

- **Evolution of networks towards OTT like platforms integrating connectivity, storage and computing resources opening for new service models to telecom/ISP providers:** Being in line with the ETSI ZSM vision, MonB5G will demonstrate several use cases where computing, storage and networking resources of Tactile Internet applications will be hosted in different domains under the control of local NFVOs and Decision Engines while covering i) cross-domain end-to-end SLA and ii) elastic end-to-end slice lifecycle management.
- **Network scalability towards high number of resource constrained devices, multiplicity of service requirements, and new connectivity paradigms (user controlled):** MonB5G is developing i) a scalable monitoring system (MS) that enables to analyse a massive set of running slices while minimizing the measurement overhead ii) sophisticated data-driven methods for optimal slice configuration per device- and application-type for massive number of devices iii) Distributed architecture where local MS/AD/DE can be instantiated in edge domain reducing reaction times and thus improving device performance iv) local security orchestrator for autonomic threat identification and fast, local response.
- **Characterisation and availability of secure and trusted environments for software based virtualised networks, enabling trusted multi-tenancy:** MonB5G is developing a Trust Management and a Security Orchestrator by leveraging AI techniques (such as federated learning and blockchain) and emerging technologies, including TPM, TEE, SECaaS, SDN, NFV, and VNF security, for enhancing the infrastructure and service management trust and creating a trustworthy environment for running different virtual services while ensuring isolation between different tenants and enhancing the timely identification/detection and mitigation of security threats.
- **Dynamic scalability of network capabilities through availability of managed and enhanced resources:** MonB5G is proposing a zero-touch slicing design featuring autonomic, cognitive (data- and AI-driven), and closed-loop management and orchestration by enhancing e.g., the OSS/BSS, MANO, and MEC orchestration with analytics and decisions entities embedded inside domain and inter-domain managers. Slice-level resources are automatically assigned, scaled, migrated and while simultaneously optimizing (i) slice operation, (ii) managerial overhead, and (iii) slice coexistence with performance guarantees.

- **Network energy consumption reduction, a factor of at least 10 is targeted:** MonB5G will leverage the aforementioned developments and achieve the ambitious goal of 10-times reduction in the network power consumption by extending and developing new energy-aware AI-based techniques for end-to-end slice-level resource allocation as well as VNF placement so that to enable the deactivation of the non-utilized network elements.
- **Impact on the telecommunications industry:** MonB5G will help keep the telecom industry at the forefront of this strategic technology by providing research which will support partners who have products and services in the network management, SDN and NFV market.
- **Impact on European economy:** MonB5G impact on the European economy will be to contribute to accelerate 5G and beyond deployment in Europe, through its capabilities to provision new innovative services that demand 5G capabilities in a faster and a more secure way.
- **Reducing the financial costs of cyber-attacks - impact on enterprises and SMEs:** By effectively protecting 5G infrastructures, networks and network management systems and increasing their resilience to cyber threats, MonB5G will contribute to reducing and preventing the financial consequences of cyber-attacks and data breaches, achieving a high impact on telecom and service providers.
- **Impact on consumers and society:** MonB5G will go beyond traditional monolithic approaches that focus only on the radio spectrum optimisation, orchestrating a multitude of network components and resources across different domains. The decentralized autonomic network management and orchestration proposed by MonB5G, will enable telecom and service providers to optimize their resource usage thus reducing both CAPEX and OPEX paves the way to offer new innovative 5G services at lower costs to consumers.

8 Conclusions and Next Steps

In this deliverable we reported the progress of the MonB5G project as relevant to the WP7 dissemination, communication, standardization and exploitation activities, for the time period from M16 to M24. Which concludes the second phase of the WP7 strategy 'Accelerate Impact' that aimed to present the capabilities and present the possible solutions/results to the external stakeholders.

As the project makes further progress with the technical implementation and integration activities, through the next phases in the WP7 strategy 'Results' (M27-M33) and 'Valorization' (M34-M36) we anticipate exceeding the goals and objectives that we have set at project inception.

Further progress will be reported in:

- Deliverable D7.7: Final Report on dissemination; standardization & exploitation plans (M36).

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