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Deliverable D7.7
Final Report on Dissemination, Standardization and Exploitation Plans

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Abbreviations

Acronym	Description
3GPP	Third Generation Partnership Project
5G	The Fifth Generation of Mobile Communications
5G-IA	5G – Infrastructure Association
AE	Analytic Engine
AI	Artificial Intelligence
AR	Augmented Reality
B5G	Beyond 5G
BSS	Business Support System
CL	Closed loop
CLA	Closed-loop Automation
CN	Core Network
CNF	Cloud Native function
CNSM	Conference on Network and Service Management
COSLA	Closed-loop SLS Assurance
DDoS	Distributed Denial of Service
DE	Decision Engine
DNN	Deep Neural Networks
DRL	Deep Reinforcement Learning
ETSI	European Telecommunication Standards Institute
EuCNC	European Conference on Networks and Communications
eMBB	Enhanced Mobile Broadband

ENI	Experiential Networked Intelligence
ETSI	European Telecommunications Standards Institute
FG	Focus Group
FL	Federated Learning
GCN	Graph Convolutional Networks
HRB	Horizon Results Booster
IEEE	Institute of Electrical and Electronics Engineers
IFIP	International Federation for Information Processing
IMT-2020	International Mobile Telecommunications
IPR	Intellectual Property Rights
ISG	Industry Specification Group
ITU	International Telecommunication Union
ITU-T	ITU Telecommunication Standardization Sector
KPI	Key Performance Indicator
LCM	Lifecycle Management
LTE	Long Term Evolution
MANO	Management and Orchestration
MAPE	Monitor-Analyse-Plan-Execute
MEC	Multi-access Edge Computing
ML	Machine Learning
mMTC	Massive Machine Type Communications
MNO	Mobile Network Operator
MS	Monitoring System

MWC	Mobile World Congress
NFVI	NFV Infrastructure
NFVO	Network Function Virtualisation Orchestrator
NGMN	Next Generation Mobile Networks
NGN	Next Generation Network
NS	Network Slice
OAI	Open Air Interface
ONAP	Open Network Automation Platform
ORAN	Open Radio Access Network
OSM	Open-Source MANO
OSS	Operation System Support
PaaS	Platform as a Service
PDES-A	Portfolio Dissemination & Exploitation Strategy - Module A
PDES-C	Portfolio Dissemination & Exploitation Strategy - Module C
PoC	Proof of Concept
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
ROI	Return on investments
SBA	Service Based Architecture
SFC	Service Function Chaining
SG	Study Group
SLA	Service Level Agreement

SLS	Service Level Specification
SMEs	Small and Medium-sized Enterprises
SON	Self-Organizing Network
TRL	Technology Readiness Level
TSCG	Technical Specifications Group
TSCG SA	Technical Specifications Group Service and System Aspects
uRLLC	Ultra-Reliable Low-Latency Communication
VNF	Virtual network Function
VR	Virtual Reality
WG	Working group
WMNC	Wireless and Mobile Networking Conference
WP	Work Package
ZSM	Zero-touch network and Service Management

Executive Summary

This document provides a summary of the dissemination, communication, standardization and exploitation activities carried out by MonB5G partners during M25-M42 of the project following the definition of the MonB5G impact KPIs.

This report offers an overview of the project's accomplishments in four thematic areas:

- Communication activities, such as the project website and social media.
- Industrial and scientific dissemination activities, such as scientific publications and participation in events.
- Standardization/industry fora.
- Exploitation plans and intellectual property.

In addition to a report of the dissemination and communication activities carried out, this document contains an evaluation of the impact realized in relation to the dissemination/communication KPIs. In general, this evaluation is conducted using absolute figures, i.e., comparing the total number of publications, press releases, etc., against the target ones.

Even though the primary objective of this deliverable is to report on and detail the previously mentioned subjects for the second phase of the project's lifecycle, certain subsections take a step back and examine the relevant project results in their totality. This is especially the case for 5G-PPP Participation-Contributions, for which it is believed that, in addition to the comprehensive description of the events occurred during M25-M42 of the project's duration, any interested stakeholder. may need an additional overview of these activities that occurred throughout the project.

The exploitation activities involve efforts that promote additional valorization of the project's results, which includes those that were not fully addressed during the project's duration. These include the development, production, and marketing of products or services.

1 Introduction

1.1 Scope

This deliverable is part of Work Package 7 deliverables and includes the work conducted during M25-M42 of the project within the following tasks:

- Task 7.1: Dissemination and Communication Activities
- Task 7.2: Standardization Activities
- Task 7.3: Exploitation and IPR Management

The Dissemination section describes the events attended and planned by the MonB5G consortium to promote, disseminate, and actively engage various technical audiences with the project during the last period of the project M25-M42.
During the period covered by this report, the communication channels and tools used to increase the project's visibility have been utilized during the project's lifetime and have been maintained and managed accordingly. The scope of channels and means, which have been used during the reporting period for the completion of MonB5G communication activities, are listed and updates on their status and results are provided in the relevant sections.

Standardization task primary objective was to promote project results within standardization bodies. In this effort, the MonB5G project coordinated and planned the contribution strategy in a three-step process. Initially, Standardization Bodies relevant to the project were identified. The standardization bodies were then monitored to ensure that the technical work of the project is aligned with the evolution of standards and that high-level interactions are implemented, based on the progress and maturity of the work to be carried out. After that, the partners of the project proceeded to provide actual contributions whenever it was feasible to do so. These activities have identified the gap between technical research and the work items of standardization bodies, which promoted MonB5G results.

The exploitation section examines what was accomplished during the project and identifies potential next steps for an effective continuation and advancement of these outcomes. This section also discusses the partners' potential future activities that could guarantee continued MonB5G adoption when the project is finished. We describe the project's goal of advancing the State of the Art (SotA), in the areas of network slicing and machine learning, based on the specific progress made so far as indicated by scientific papers that have been published or accepted during M25-M42. Next, we outline the project's Intellectual Property Rights (IPR) Council, which is responsible for protecting the publications and innovations of the project. In addition, MonB5G has filed four new patent applications during this reporting period in addition to the one that was previously filed (which we describe in Section 6.5).

1.2 Target Audience

This document is a public deliverable that aims to reach and engage a broad audience:

- **Mobile Network Operators**. Using scalable MonB5G solutions, 5G market leaders can expand their total service, market size, and growth rate.
- **Telco vendors** specializing in network monitoring, management, and security can benefit from scalable and distributed MonB5G solutions.
- **SMEs**. Those involved in MonB5G can establish strong R&D connections with both industry and academia by providing innovative services, products, and the necessary innovative expertise.
- **The public**, to familiarize themselves with the 5G technology's market potential in order to gain a greater understanding of the project's work and economic impact.
- **The Research Community.** Universities and research institutions may further develop their 5G/6G expertise through the dissemination of project results by the consortium's research partners and collaboration with other prominent universities. We also inform them of the project's intended innovations and their potential impact on Standard's Development Organizations (SDO) activities.
- **The Project Consortium**, to consider the exploitable capabilities of the MonB5G framework, the developed use cases, and to investigate the business case opportunities individually or collectively.
- **The European Commission**, to justify the reported effort for the pertinent activities.

1.3 Structure

Section 1 provides the reader with an overview of the deliverable, the target audience, and a brief description of the document's objectives.

Section 2 summarizes the project's communication and dissemination activities and strategies that were implemented at various stages of the project.

Section 3 covers all dissemination-related activities, including the publication of journal articles, conference papers, lectures, and other types of dissemination. In addition, the Key Performance Indicators (KPIs) that have been utilized for regular evaluation and tracking are detailed in the third section. These metrics allowed us to quantify our achievements and challenges, provide information on deployment progress, and guarantee that we did not deviate from our main objectives.

Section 4 includes a summary of the project's communication tools and activities. The website and social media platforms, material, and control/monitoring tools employed. This section concludes with a report on the project's communication target KPIs and outcomes.

Section 5 describes the contributions and outcomes made by the partners within specific working groups of SDOs such as ETSI and ITU-T and the interaction with 5G-PPP WGs.

Section 6 covers exploitation activities that intend to use the findings of the project beyond the scope of the project such as product or process development, marketing and service provisioning.

2 Dissemination and Communication Overview

In order to maximize the visibility of the projects results in the relevant scientific and industrial community, the MonB5G consortium defined a number of objectives, described in the following section.

2.1 Dissemination and Communication Objectives

1. **Plan**: Identify targets, tools, messages and channels, by creating 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 easy identification of the project and 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, 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 main aim of the MonB5G consortium was to target key players in the communications industry and research community to raise awareness of the MonB5G solutions' benefits. For this reason, a clear and solid set of well-defined dissemination and communication activities were designed ensuring a wide promotion of the project as a vital initiative for the growth of the European industry.

2.2 Dissemination and Communication Strategy

The dissemination strategy comprised of three phases: awareness formation, outreach to relevant stakeholders and global outreach, which are described below:

Phase A - MonB5G awareness formation (M01-M06)

During the first phase of the dissemination strategy, the project consortium defined the explicit target groups, selected the appropriate dissemination tools and informed the relevant stakeholders for the project's scopes and objectives.

The main outputs of this phase were the project's communication channels including the project's website, the project social network channels, an event calendar, a flyer and a newsletter.

More details about the communication channels are included in chapter 4.

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

The main target of the second phase of the dissemination strategy was to build a groundwork of interest for the project. For this reason, the consortium achieved arrangement and commitment with the appropriate stakeholders and open-source and standards communities. The progress of the project was disseminated through the communication channels mentioned above throughout the project duration and are presented in this report.

Phase C – MonB5G global outreach (M15-M42)

The third and final phase of the dissemination strategy was dedicated to promoting the adoption of the developed MonB5G technologies and solutions by the relevant stakeholders. This was achieved through various activities such as publications and deliverables, creation of promotional materials, participation in events, organization of innovation workshops and collaboration with standardization bodies and major players in the field, including other ICT-20 funded projects.

2.3 MonB5G Stakeholders

The identified stakeholders were described in the previous version of this deliverable D7.6 [1]. In brief, the targeted stakeholders included mobile network operators, telecom infrastructure providers, SMEs, end-users and the academia.

3 Dissemination

Dissemination activities and tools specifically focused on project's results. The target audience for these activities included the project partners, research peers, industry and commercial stakeholders, professional organizations, policymakers and the broader scientific community. Their primary interest in the project's outcomes is to utilize and apply the results to their respective work, field, and products.

3.1 Research Publications

Publication is an important means of disseminating and validating research findings. MonB5G partners have directed their efforts to primarily publish project research results in top-tier scientific journals and conferences.

3.1.1 Scientific Journals

MonB5G partners have submitted and published their results in prestigious international peer-reviewed journals, including IEEE Transactions on Network and Service Management, IEEE Open Journal of the Communications Society, IEEE Transactions on Wireless Communications, IEEE Transactions on Intelligent Transportation Systems and ITU-T JFET Network Management.

The final period of the project included **17** new publications in scientific journals, all of which are published and included in *Table 1* (full citation in References).

#	Title	Authors	Publications
J13	Deep Learning for B5G Open Radio Access Network: Evolution, Survey, Case Studies, and Challenges [2]	Bouziane Brik, Karim Boutiba, Adlen Ksentini	IEEE Open Journal of the Communications Society

J14	A Heuristically Assisted Deep Reinforcement Learning Approach for Network Slice Placement [3]	Jose Jurandir Alves Esteves, Amina Boubendir, Fabrice Guillemin, Pierre Sens	IEEE Transactions on Network and Service Management
J15	On the Robustness of Controlled Deep Reinforcement Learning for Slice Placement [4]	Jose Jurandir Alves Esteves, Amina Boubendir, Fabrice Guillemin, Pierre Sens	Journal of Network and Systems Management
J16	ONETS: Online Network Slice Broker From Theory to Practice [5]	Vincenzo Sciancalepore, Senior Member, Lanfranco Zanzi, Xavier Costa-Pérez, Antonio Capone,	IEEE Transactions on Wireless Communications
J17	Service Function Chaining in 5G & Beyond Networks: Challenges and Open Research Issues [6]	Hajar Hantouti, Nabil Benamar, and Tarik Taleb	IEEE Network Magazine
J18	Statistical Federated Learning for Beyond 5G SLA-Constrained RAN Slicing [7]	Hatim Chergui, Luis Blanco, Christos Verikoukis	IEEE Transactions on Wireless Communications
J19	Zero-Touch AI-Driven Distributed Management for Energy-Efficient 6G Massive Network Slicing [8]	Hatim Chergui, Luis Blanco, Luis. A. Garrido, Kostas Ramantas, Slawomir. Kukliński, Adlen Ksentini, Christos Verikoukis	IEEE Network Magazine
J20	Towards zero-touch management and orchestration of massive deployment of network slices in 6G [9]	Hatim Chergui, Adlen Ksentini, Luis Blanco and Christos Verikoukis	IEEE Wireless Communications
J21	Deep data plane programming and AI for zero-trust self-driven networking in beyond 5G [10]	Othmane Hireche, Chafika Benzaïd, Tarik Taleb	Computer Networks, Elsevier
J22	Deterministic Latency Bounded Network Slice Deployment in IP-Over-WDM Based Metro-Aggregation Networks [11]	Hao Yu; Tarik Taleb; Jiawei Zhang; Honggang Wang	IEEE Transactions on Network Science and Engineering

J23	Deterministic Latency/Jitter-aware Service Function Chaining over Beyond 5G Edge Fabric [12]	Hao Yu; Tarik Taleb; Jiawei Zhang	IEEE Transactions on Network and Service Management
J24	Blockchain-based Service Orchestration for 5G Vertical Industries in Multi-Cloud Environment [13]	E. Zeydan, J. Baranda, J. Mangues, Y. Turk and S. B. Ozturk	IEEE Transactions on Network and Service Management
J25	SCHE2MA: Scalable, Energy-Aware, Multi-Domain Orchestration for Beyond-5G URLLC services [14]	Anestis Dalgkitsis, Luis A. Garrido, Farhad Rezazadeh, Hatim Chergui, Kostas Ramantas, John S. Vardakas, Christos Verikoukis	IEEE Transactions on Intelligent Transportation Systems
J26	On the Specialization of FDRL Agents for Scalable and Distributed 6G RAN Slicing Orchestration [15]	Farhad Rezazadeh, Lanfranco Zanzi, Francesco Devoti, Hatim Chergui, Xavier Costa Perez, Christos Verikoukis	IEEE Transactions on Vehicular Technologies
J27	Post-Quantum Blockchain-based Secure Service Orchestration in Multi-Cloud Networks [16]	Engin Zeydan, Jorge Baranda, Josep Mangues-Bafalluy	IEEE Access
J28	AI-driven predictive and scalable management and orchestration of network slices predictive and scalable management and orchestration of network slices [17]	Sławomir Kuklinski, Lechosław Tomaszewski, Robert Kołakowski, Anne-Marie Bosneag, Ashima Chawla, Adlen Ksentini, Sabra Ben Saad, Xu Zhao, Luis A. Garrido, Anestis Dalgkitsis, Bahador Bakhshi, Engin Zeydan	ITU-T JFET Network Management
J29	Zero-touch security management for mMTC network slices: DDoS attack detection and mitigation [18]	Radouane Niboucha, Sabra. Ben Saad, Adlen. Ksentini and Yacine. Challal	IEEE Internet of Things Journal

Table 1: MonB5G Publications in Scientific Journals

3.1.2 Conferences

Project outcomes were also published at international conferences such as the IEEE Global Communications Conference (GLOBECOM), the International Conference on Network and Service Management (CNSM) and the IEEE INFOCOM, in order to attract a large number of distinguished researchers.

The following table shows the conference publications since the last reporting in deliverable D7.6 [1].

#	Title	Authors	Published in
C15	MonB5G: AI/ML-Capable Distributed Orchestration and Management Framework for Network Slices [19]	Sławomir Kukliński, Robert Kołakowski, Lechosław Tomaszewski, Luis Sanabria-Russo, Christos Verikoukis, Cao-Thanh Phan, Lanfranco Zanzi, Francesco Devoti, Adlen Ksentini, Christos Tselios, George Tsolis, Hatim Chergui	2021 IEEE International Mediterranean Conference on Communications and Networking (MeditCom)
C16	Context-Aware Traffic Prediction: Loss Function Formulation for Predicting Traffic in 5G Networks [20]	Luis A. Garrido, Prodromos-Vasileios Mekikis, Anestis Dalgkitsis, Christos Verikoukis	ICC 2021 - IEEE International Conference on Communications
C17	Machine Learning for Network Slicing in Future Mobile Networks: Design and Implementation [21]	Luis A. Garrido, Anestis Dalgkitsis, Kostas Ramantas, Christos Verikoukis	2021 IEEE International Mediterranean Conference on Communications and Networking (MeditCom)
C18	Learning Sparsity of Representations with Discrete Latent Variables [22]	Zhao Xu, Daniel Onoro Rubio, Giuseppe Serra and Mathias Niepert	2021 International Joint Conference on Neural Networks (IJCNN)
C19	DRL-based Slice Placement Under Non-Stationary Conditions [23]	Jose Jurandir Alves Esteves, Amina Boubendir, Fabrice Guillemin and Pierre Sensy	2021 17th International Conference on Network and Service Management (CNSM)
C20	A network tomography approach for anomaly localization in Service Function Chaining [24]	Mohamed Rahali, Jean-Michel Sanner, Cao-Thanh Phan, and Gerardo Rubino	2021 International Symposium on Networks, Computers and Communications (ISNCC)
C21	Distributed AI-based Security for Massive Numbers of Network Slices in 5G & Beyond Mobile Systems [25]	Benzaid Chafika, Tarik Taleb, Cao-Thanh Phan, Christos Tselios, George Tsolis	2021 Joint European Conference on Networks and Communications & 6G Summit (EuCNC/6G Summit)
C22	KRS: Kubernetes Resource Scheduler for resilient NFV networks [26]	Mohamed Rahali, Cao-Thanh Phan, and Gerardo Rubino	2021 IEEE Global Communications Conference (GLOBECOM)

C23	Entropy-Driven Stochastic Policy for Fast Federated Learning in Beyond 5G Edge-RAN [27]	Brahim Aamer, Hatim Chergui, Mustafa Benjillali, Christos Verikoukis	2021 IEEE Global Communications Conference (GLOBECOM)
C24	A Collaborative Statistical Actor-Critic Learning Approach for 6G Network Slicing Control [28]	Farhad Rezazadeh, Hatim. Chergui, Luis Alonso, Luis Blanco, Christos Verikoukis	2021 IEEE Global Communications Conference (GLOBECOM)
C25	DRL-based Slice Placement under Realistic Network Load Conditions [29]	Jose Jurandir Alves Estevesy, Amina Boubendir, Fabrice Guillemin and Pierre Sensy	2021 17th International Conference on Network and Service Management (CNSM)
C26	Deterministic Service Function Chaining over Beyond 5G Edge Fabric [30]	Hao Yu, Tarik Taleb, Jiawei Zhang	2021 IEEE Global Communications Conference (GLOBECOM)
C27	Towards SDN-based Deterministic Networking: Deterministic E2E Delay Case [31]	Aiman Nait Abbou, Tarik Taleb, JaeSeung Song	2021 IEEE Global Communications Conference (GLOBECOM)
C28	Performance evaluation of the OSM orchestrator [32]	Robert Kołakowski, Lechosław Tomaszewski, Sławomir Kukliński	2021 IEEE Conference on Network Function Virtualization and Software Defined Networks (NFV-SDN)
C29	SCHEMA: Service Chain Elastic Management with Distributed Reinforcement Learning [33]	Anestis Dalgkitsis, Luis A. Garrido, Prodromos-Vasileios Mekikis, Kostas Ramantas, Luis Alonso, Christos Verikoukis	2021 IEEE Global Communications Conference (GLOBECOM)
C30	Demo: Blockchain-based Inter-Provider Agreements for 6G Networks [34]	Farhana Javed, Josep Mangues-Bafalluy	2022 18th International Conference on Network and Service Management (CNSM)
C31	Uncertainty Propagation in Node Classification [35]	Zhao Xu, Carolin Lawrence, Ammar Shaker, Raman Siarheyeu	2022 IEEE International Conference on Data Mining (ICDM)
C32	Microservices Configurations and the Impact on the Performance in Cloud Native Environments [36]	M. Mekki, N. Toumi and A. Ksentini	2022 IEEE 47th Conference on Local Computer Networks (LCN)
C33	SafeSCHEMA: Multi-domain Orchestration of Slices based on SafeRL for B5G Networks [37]	Anestis Dalgkitsis, Ashima Chawla, Anne-Marie Bosneag and Christos Verikoukis	GLOBECOM 2022 - 2022 IEEE Global Communications Conference

C34	Scalable end-to-end slice embedding and reconfiguration based on independent DQN agents [38]	Pavlos Doanis, Theodoros Giannakas, Thrasyvoulos Spyropoulos	GLOBECOM 2022 - 2022 IEEE Global Communications Conference
C35	5G-Enabled Defence-in-Depth for Multi-domain Operations [39]	Sławomir Kukliński, Krzysztof Szczypiorski, Konrad Wrona, Jędrzej Bieniasz	MILCOM 2022 - 2022 IEEE Military Communications Conference (MILCOM)
C36	In-Slice Management Decomposition and Implementation Issues [40]	Slawomir Kukliński	IEEE Future Networks World Forum 2022
C37	A Cloud Native SLA-Driven Stochastic Federated Learning Policy for 6G Zero-Touch Network Slicing [41]	Swastika Roy, Hatim Chergui, Luis Sanabria-Russo, Christos Verikoukis	IEEE International Conference on Communications (ICC) 2022

Table 2: MonB5G Conference Publications

In addition to the above, 5 more conference papers have been accepted and are presented in the following table:

#	Title	Authors	Accepted in
C38	A Systematic Approach to Security Management in the MonB5G Architecture	Slawomir Kukliński, Jacek Wytrębowicz	International Symposium on Mobile Internet Security 2022 (MobiSec 2022), Jeju, Korea
C39	Optimizing Network Slicing in Distributed Large-Scale Infrastructures	Jose Jurandir Alves Esteves, Amina Boubendir, Fabrice Guillemin, Pierre Sens	IEEE/IFIP Network Operations and Management Symposium (NOMS 2023)
C40	A Multi-Agent Deep Reinforcement Learning Approach for RAN Resource Allocation in O-RAN	Farhad Rezazadeh, Lanfranco Zanzi, Francesco Devoti, Sergio Barrachina-Muñoz, Engin Zeydan, Xavier Costa-Pérez, Josep Mangues-Bafalluy	IEEE International Conference on Computer Communications 2023
C41	Graph-based Interpretable Anomaly Detection Framework for Network Slice Management in Beyond 5G Network	Ashima Chawla, Anne-Marie Bosneag, Anestis Dalgkitsis	IEEE/IFIP Network Operations and Management Symposium (NOMS 2023)

C42	Dynamic and Multiprovider-based Resource Infrastructure in the NFV MANO Framework	Sławomir Kukliński, Jordi Mongay Batalla, Janusz Pieczerak	IEEE/IFIP Network Operations and Management Symposium (NOMS 2023)

Table 3: MonB5G Accepted Conference Publications

Within the framework of the Monb5G project, a PHD thesis was published:

Thesis publications

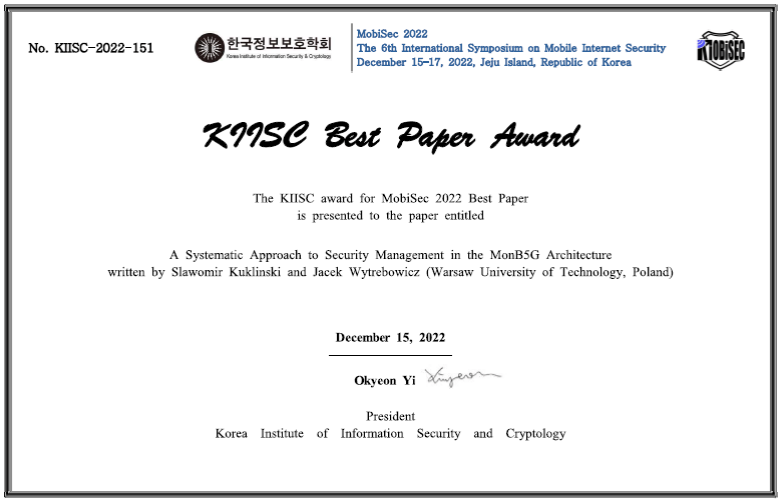
José Jurandir Alves Esteves has completed his PHD thesis titled "Optimization of Network Slice Placement in Distributed Large Scale Infrastructures: From Heuristics to Controlled Deep Reinforcement Learning" as a researcher at Orange Labs and Sorbonne Université.

Awards

José Jurandir Alves Esteves, Amina Boubendir and Fabrice M. Guillemin *received* the Best Demo Paper Award at the 17th International Conference on Network and Service Management (CNSM 2021) for the presentation of the demo paper entitled "DRL-based Slice Placement Under Realistic Network Load Conditions", submitted as part of his PHD.

Figure 1: Best Demo Paper Award at CNSM

Dr. Sławomir Kukliński and Dr. Jacek Wytrębowicz have received the "Best Paper Award" for their paper "A Systematic Approach to Security Management in the MonB5G Architecture" at the 6th International Symposium on Mobile Internet Security, Jeju Island, South Korea. The paper will be published in Springer Mobile 2022 Conference proceedings soon.



No. KIISC-2022-151

한국정보보호학회

MobiSec 2022
The 6th International Symposium on Mobile Internet Security
December 15-17, 2022, Jeju Island, Republic of Korea

KIISC Best Paper Award

The KIISC award for MobiSec 2022 Best Paper
is presented to the paper entitled

A Systematic Approach to Security Management in the MonB5G Architecture
written by Slawomir Kuklinski and Jacek Wytrebowicz (Warsaw University of Technology, Poland)

December 15, 2022

Okyeon Yi

President
Korea Institute of Information Security and Cryptology

Figure 2:Best Paper Award at Mobisec

3.2 Workshops

I. Event: WS-27: WORKSHOP ON ARTIFICIAL INTELLIGENCE FOR SUSTAINABLE B5G/6G NETWORKS (ASNET) (Organized with the support of MonB5G)
Location: Madrid, Spain
Title: Zero touch management and orchestration of network slices in 5G and beyond networks
Date: 7 December 2021
Person: Adlen Ksentini (EUR)
Link: https://globecom2021.ieee-globecom.org/workshop/ws-27-workshop-artificial-intelligence-sustainable-b5g6g-networks-asnet

Figure 3: IEEE Global Communications Congress 2021

The 2021 IEEE Global Communications Congress (GLOBECOM) was held in Madrid, Spain, from December 7th through the 11th. The technical program for this flagship IEEE Communications Society meeting was extensive and of outstanding quality, featuring 12 symposia, selected areas in the communications track, and a number of tutorials and workshops. Keynote speeches and panels by recognized research, industry, and government leaders, business and industry panels, as well as vendor exhibits were all part of the interesting Industry Program at IEEE GLOBECOM 2021.

MonB5G co-organized and funded the IEEE Globecom Conference's "**Workshop on Artificial Intelligence for Sustainable B5G/6G Networks** (ASNET)" from 7-11 December 2021. Prof. Adlen Ksentini of Eurecom, the technical manager of MonB5G, delivered the keynote speech with the title "Zero-touch Management and Orchestration of Network Slices in 5G and Beyond Networks."

The workshop addressed the latest problems associated with the sustainability of next-generation networks, focusing on how artificial intelligence (AI) techniques such as deep, federated, and reinforcement learning act as a catalyst for cost-effective and environmentally friendly B5G/6G networks.

II. Event: 5G-I Technology Board Workshop
Location: Virtual
Title: Distributed AI-based Security for Massive Number of Slices for 5G and beyond
Date: 19 January 2022
Partner: BCOM (Cao-Than Phan) AALTO (Othmane Hireche)
Link: https://bscw.5g-ppp.eu/sec/bscw.cgi/469002

On 19th January 2022, Dr. Cao-Thanh PHAN presented the work of BCOM, AALTO, and CITRIX partners on the Network Slicing Security Orchestration Framework for the MonB5G platform at the 5G-I Technology Board Workshop and the effectiveness of the network in threat detection and mitigation using MonB5G components.

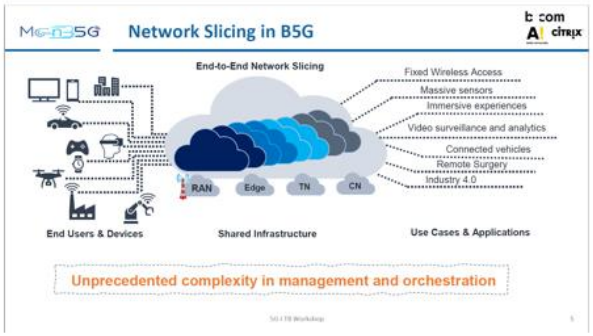


Figure 4:5G-I Technology Board Workshop presentation slides

III. Event: IEEE/IFIP Network Operations and Management Symposium (NOMS 2023): 8th IEEE/IFIP International Workshop On Analytics For Network And Service Management
Location: Miami, Florida, USA
Title: Graph-based Interpretable Anomaly Detection Framework for Network Slice Management in Beyond 5G Network
Date: 8-12 May 2023
Partner: LMI, IQU
Link: https://annet2023.moogsoft.com/

Figure 5: International Workshop On Analytics For Network And Service Management

The 8th IEEE/IFIP International Workshop on Analytics for Network and Service Management (AnNet 2023) was held together with the IEEE/IFIP Network Operations and Management Symposium (NOMS) between the 8th – 12th of May 2023 in Miami Florida, USA. The primary goal of AnNet is to present research and work-in-progress results in the fields of data analytics and machine learning applied to the improvement of operations and management of IT systems and networks.

Ashima Chawla and Anne-Marie Bosneag from LMI and Anestis Dalgkitsis from IQU gave a presentation regarding "Graph-based Interpretable Anomaly Detection Framework for Network Slice Management in Beyond 5G Networks" during Session 3 of the first day of the workshop that was about Machine Learning for Network Management.

3.3 Keynotes/Tutorials

I. Event: The 6th International Conference on Smart City Applications
Location: Karabuk University, Virtual Safranbolu, Turkey
Title: Zero Touch Management and Orchestration of Network Slices in 5G and Beyond Networks
Date: 27–29 October 2021
Partner: Adlen Ksentini (EUR) - keynote
Link: https://www.medi-ast.org/SCA2021/index.html

Figure 5: The 6th Smart City Applications International Conference

The Sixth International Conference on Smart City Applications was a multidisciplinary forum co-organized by the Computer Engineering Department of Karabuk University (KBÜ) in the partnership with Mediterranean Association of Sciences and Technologies (Medi-AST) and took place online from the 27th to the 29th of October 2021.

Dr Adlen Ksentini (EUR) gave a keynote speech titled "Zero Touch Management and Orchestration of Network Slices in 5G and Beyond Networks".

II. Event: IEEE URUCON 2021 Virtual Conference
Location: virtual
Title: Zero touch management and orchestration of network slices in 5G and beyond networks
Date: 22 November 2021
Partner: Adlen Ksentini (EUR)
Link:https://ci2s-enterprise.com.ar/2021/10/26/ieee-urucon-2021-virtual-conference/

Figure 6: IEEE UROCON 2021 Virtual Conference

IEEE URUCON 2021 Conference sponsored by IEEE Cono Sur Council and IEEE Uruguay Section, was held in Montevideo, from the 24th to the 26th of November 2021.

Dr Adlen Ksentini (EUR) gave a tutorial on “Zero touch management and orchestration of network slices in 5G and beyond networks” presenting the challenges related to the management and orchestration of network slices in 5G and beyond mobile networks.

III. Event: Journées Cloud 2021
Location: Brest
Title: Zero touch management and orchestration of network slices in 5G and beyond networks
Date: 26 November 2021
Partner: Adlen Ksentini (EUR) keynote
Link: https://journeescloud2021.github.io/program

Figure 7: Journées Cloud 2021

The 2021 edition of the Cloud Days was organized in Brest, France on November 25th and 26th, 2021. The GdR RSD (Networks and Distributed Systems) has set up a "Virtualization" working group that since 2014, organizes the Cloud Days to bring together French academic and industrial players addressing issues related to the administration and use of virtualized/cloudified environments.

Dr. Adlen Ksentini gave a keynote speech on the 26th of November 2021, titled “Zero Touch Management and Orchestration of Network Slices in 5G and Beyond Networks”. This talk covered the challenges associated with network slice management and orchestration in 5G and beyond mobile networks. 6G systems are expected to serve a massive amount of extremely heterogeneous Network Slices that span multiple technological domains posing significant challenges to traditional centralized management and orchestration approaches in terms of scalability and sustainability. On the basis of these challenges, a hierarchical, distributed, AI-driven management framework with a zero-touch service management concept is introduced. Two use-case scenarios utilizing the proposed architecture are presented as a conclusion.

IV. Event: 13th International Conference on Network of the Future (NoF 2022)
Location: Ghent, Belgium
Title: Recent Advances in Data Engineering for Networking
Date: 05-07 October 2022
Partner: E. Zeydan and J. Mangues (CTTC)
Link: Tutorials NoF 2022 (dnac.org)

Figure 8 : 13th International Conference on Network of the Future (NoF 2022)

The Network of the Future (NoF) conference is a premier annual conference that covers advances in the area of Future Internet design, with emphasis on enabling technologies, architectures and services. It was organized between the 5th and 7th of Ocotber 2022 in Ghent, Belgium.

Dr Engin Zeydan and Dr Josep Mangues-Bafalluy gave a tutorial about Recent Advances in Data Engineering for Networking explaining how the recent advances in data science and engineering technologies in both academia and industry have spurred the adoption of various Artificial Intelligence (AI)/Machine Learning (ML) platforms and frameworks in telecommunication network infrastructures.

V. Event: 14th IFIP Wireless and Mobile Networking Conference
Location: Tunisia/Sousse
Title: Why 6G has to be a federation of autonomous domains?
Date: 17-19 October 2022
Partner: Sławomir Kukliński (ORA-PL)
Link: https://wmnc.dnac.org/2022/keynotes/

Figure 9: 14th IFIP Wireless and Mobile Networking Conference

The 14th edition of the IFIP Wireless and Mobile Networking Conference (IFIP WMNC) was held in Sousse in Tunisia on October 17-19, 2022.

Sławomir Kukliński (ORA-PL) attended the Conference as a keynotes speaker, member of a panel and chair of a technical session. The keyonte speech title was “Why 6G has to be a federation of autonomous domains?” while the goal of the WMNC 2022 Distinguished Expert Panel was to shed light on recent network technologies and the key research directions related to 5G networks and beyond and more particularly on how to embed Artificial Intelligence (AI) in next-generation networks to ensure further agility, resiliency, customization, and security. The panel also debated and discussed ethical, regulatory, and policy implications that arise from the development of AI.

VI. Event: 18th International Conference on Network and Service Management
Location: Thessaloniki, Greece
Title: Recent Advances in Data Engineering for Networking
Partner: Engin Zeydan, Josep Mangues-Bafalluy (CTTC)
Date: 31 October - 4 November 2022
Link: http://www.cnsm-conf.org/2022/tutorial.html

Figure 10: 18th International Conference on Network and Service Management

The 18th International Conference on Network and Service Management (CNSM) was held in Thessaloniki, Greece between the 31st of October and 4th of November 2022. CNSM is a selective single-track conference, covering all aspects of the management of networks and services, pervasive systems, enterprises, and cloud computing environments.

The tutorial given by Engin Zeydan and Josep Mangues-Bafalluy, presented a clear link between the data engineering ecosystem (including data connection, data ingestion, data processing & analysis, data storage, data monitoring & visualization and data management & orchestration frameworks) and recent developments in networking, an overview of standardization efforts in network management and orchestration and how these can be related to data engineering frameworks, the relationship to data science frameworks, ML platforms used in the industry, and related data engineering use cases for telecommunications networks will be discussed. During the tutorial, two examples on log management in NFV service orchestration and AI/ML-driven scaling of digital service were demonstrated while the gap analysis, challenges, and future directions were also discussed.

VII. Event: IEEE International Workshop on Computer-Aided Modeling and Design of Communication Links and Networks (CAMAD)
Location: Paris,France
Title: Simulation of 5G/6G networks – selected issues
Date: 2-3 November 2022
Partner: Sławomir Kukliński (ORA-PL)
Link: https://camad2022.ieee-camad.org/program/keynotes/

The International Workshop on Computer-Aided Modeling Analysis and Design of Communication Links and Networks (CAMAD) provides a forum for discussion of recent developments on analytical and simulation tools and techniques for the performance evaluation of communications systems.The theme of the IEEE CAMAD 2022 conference, "Towards Connecting Everything", covered not only 5G technologies but also system design. Emphasis was placed on the communication and experimental aspects of satellite broadband, Open RAN, quantum communications and networking, Industry 5.0, brain-to- brain communication, AI-enabled wireless networks, digital twin of wireless systems and beyond. IEEE CAMAD 2022 included an extensive program with numerous seminars, keynote speeches and special sessions, bringing together a diverse group of scientists, engineers, manufacturers and service providers to exchange and share their experiences and new ideas focusing on the results of research and innovation in the areas of 5G and Industry 5.0.

VIII. Event: Online Seminar at Manisa Celal Bayar University
Location: Online
Title: ZERO-TOUCH NETWORK AND SERVICE MANAGEMENT IN THE CONTEXT OF MONB5G (DECENTRALIZED MANAGEMENT SYSTEM FOR NETWORK SLICING IN BEYOND 5G)
Date: 21 December 2022
Partner: Engin Zeydan (CTTC)

Figure 11: Online Seminar at Manisa Celal Bayar University

On the 21st December 2022 Dr. Engin Zeydan gave an online seminar at Manisa Celal Bayar University about MonB5G's ZSM approach that aims to facilitate self-managed slices composed of self-managed functions, achieve specific management goals and minimize interactions between architectural entities by means of embedding Artificial Intelligence at multiple levels (for example by means of hierarchical closed-loop controls and aggregated Key Performance Indicators (KPIs)) and ensure secure management, programmability and energy efficiency of network slicing for beyond 5G networks.

IX. Event: IEEE Consumer Communications & Networking Conference
Location: Las Vegas, USA
Title: ZERO-TOUCH SERVICE MANAGEMENT (ZSM) FOR 6G NETWORK SERVICES
Date: 08 January 2023

Partner: Adlen Ksentini (EUR)
Link: https://ccnc2023.ieee-ccnc.org/program/tutorials

The IEEE Consumer Communications and Networking Conference (CCNC) is a major annual international conference organized with the objective of bringing together researchers, developers, and practitioners from academia and industry working in all areas of consumer communications and networking. IEEE CCNC 2023 was held in Las Vegas between the 8th and 11th of January 2023.

The purpose of this tutorial was to provide an overview of the challenges associated with the orchestration and management of emerging 6G network services when deployed in various technology areas, as well as the solutions that will be primarily based on AI and ML to achieve the ZSM vision. The tutorial was split into two sections. The first section was more theoretical and attempted to present some 6G architecture visions, as well as 6G service requirements and the difficulties associated with orchestrating 6G network services. Then, existing approaches for managing 6G network services based on the ETSI ZSM and ENI standards as well as the European H2020 MonB5G project were examined. The second section of the tutorial demonstrated with concrete examples how the ZSM concept can be realized through technology domain and an end-to-end perspective. Among the provided examples, several have been implemented using real testbeds based on Open Air Interface (OAI) and Kubernetes.

Future dissemination activities

"Recent Advances in Data Engineering for Networking" tutorial will be presented at the following conferences:

i. Event: IEEE/IFIP Network Operations and Management Symposium
Location: Miami, FL, USA
Title: TU3: Recent Advances in Data Engineering for Telecommunication Networks
Date: 12th May 2023
Partner: Engin Zeydan and Josep Mangues-Bafalluy
Link: https://noms2023.ieee-noms.org/program/tutorials

This tutorial provides a thorough overview of recent advancements in data engineering frameworks and ties the ecosystem's capabilities to future telecommunication systems in network management and orchestration. The subject matter connects the data engineering ecosystem (data connection, data ingestion, data processing & analysis, data storage, data monitoring & visualization, and data management & orchestration frameworks) to recent networking developments and provides an overview of network management and orchestration standardization efforts in relation to data engineering frameworks and associated data engineering use cases. Network Function Virtualization service orchestration log management and AI/ML-driven digital service scalability will be demonstrated. The conclusion will cover a gap analysis, problems, and future directions.

ii. Event: INTERACT 5th MC and 5th Technical Meeting
Location: Barcelona, Spain
Title: Recent Advances in Data Engineering for Networking
Date: 22nd May 2023

Partner: Engin Zeydan and Josep Mangues
Link: https://interactca20120.org/meetings/5th-mc-and-5th-technical-meeting/

INTERACT vision is to go beyond the capabilities of the 5G and to make the radio network itself intelligent. This is required to enhance the human experience of both human-to-human and human-to-machine communications, and make it seamless, with the perception of no intermediary. Machine learning is an important tool in implementing this vision, since along with advanced network architectures and distributed content provision, it provides a means of implementing many aspects of this network intelligence. However, its use must be informed by theoretical and experimental research on radio channel models, network architectures and signal processing algorithms. INTERACT 5th MC and 5th Technical Meeting is organized by the COST Action CA20120, "Intelligence-Enabling Radio Communications for Seamless Inclusive Interactions".

iii. Event: 2023 IEEE 97th Vehicular Technology Conference (IEEE VTC2023-Spring)
Location: Florence, Italy
Title: T5: The Role of Data Engineering in the Realization of Network Automation
Date: 20-23 June 2023
Partner: Engin Zeydan and Josep Mangues-Bafalluy
Link: https://events.vtsociety.org/vtc2023-spring/tutorials-available/t5-the-role-of-data-engineering-in-the-realization-of-network-automation/

The 2023 IEEE 97th Vehicular Technology Conference: VTC2023-Spring will be held in Florence, Italy 20-23 June 2023. This semi-annual flagship conference of IEEE Vehicular Technology Society will bring together

individuals from academia, government, and industry to discuss and exchange ideas in the fields of wireless, mobile, and vehicular technology. The attendees to this tutorial will have the chance to learn more about data engineering for networking and its applications from the perspective of telecommunication operators.

iv. Event: IEEE 24th International Conference on High-Performance Switching and Routing (IEEE HPSR 2023)
Location: Albuquerque, NM, USA
Title: The Role Of Data Engineering In Network Automation
Date: 5-7 July 2023
Partner: Engin Zeydan and Josep Mangues-Bafalluy
Link: https://hpsr2023.ieee-hpsr.org/program/tutorials/

The IEEE Communications Society (ComSoc) is a leading global community comprised of a diverse set of professionals with a common interest in advancing all communications and networking technologies. IEEE HPSR High-Performance Switching and Routing is the flagship conference of the Communications Switching and Routing Technical Committee of IEEE COMSOC**.** IEEE HPSR will address numerous challenges of today's data networks, which are being subject to significant changes driven by cloud computing, the Internet of things, data science and analysis in communication networks, and other new concepts.

3.4 Exhibitions/Booths

MWC 2022

Mobile World Congress (MWC Barcelona) is the world's largest and most influential event for the connectivity industry, bringing together technology, community, and commerce. MWC is attended by tens of thousands of professionals from mobile network operators, manufacturers, technology providers, and other companies from around the globe. The topic for this year, 'Connectivity Unleashed,' illustrated the power of mobile technology in everyday life and explored the innovative technologies that will change industry and society in the future. Booths and demos revealed the opportunities by next generations of connectivity and data technologies. At the 17th "Mobile World Congress" (MWC 2022) in Barcelona on March 3rd, the MonB5G project was presented by Project Coordinator Dr. Engin Zeydan, who demonstrated the project's video, highlighting its innovations in management and orchestration beyond 5G.

Figure 12: Mobile World Congress 2022

EuCNC 2022

The European Conference on Networks and Communications (EuCNC 2022) was conducted concurrently with the 6G Summit in Grenoble, France from 7-10 of June 2022. Both are premier European conferences in the field of communication networks, with the 6G Summit originating from the 6G Flagship program in Finland and EuCNC receiving support from the European Commission.

The deployment of 5G and mobile IoT, as well as the investigation of 6G, dominated the conference's conversations. Through experimentation and testbeds, over 1500 delegates, researchers, and stakeholders from over 40 countries participated in the development and testing of future communications systems. Innovations in the field of applications and services were also presented.

MonB5G had a significant presence with a booth in the main exhibition center, as shown in Figure 12. During the event, CTTC and Eurecom from the MonB5G consortium participated by demonstrating two demos to show the MS provisioning, AE virtualization and the efficiency of MonB5G to detect and mitigate security threats.

- Demos

1. MS provisioning and AE virtualization (CTTC)
2. Threat detection and mitigation mMTC attack (EUR)

Figure 13: EuCNC and 6G Summit Booth

SCEWC 2022

The Smart City Expo World Congress is the most important urban gathering on a global scale. The goal of the event is to empower cities and promote urban innovation collectively and improve the lives of city residents by stimulating social innovation and fostering cross-sector partnerships. Cities Inspired by People was a topic that was discussed at the Smart City Expo World Congress 2022. Cities Inspired by People are sustainable cities in which public transport coexists with new mobility options; inclusive cities where streets and public services are accessible for all; safe cities which address both security and privacy concerns; collective cities where collaboration and participation becomes a pivot to build a better, more thriving future.

Figure 14: Smart City Expo World Congress 2022

IoTSWC 2023

As a result of its growth and success, the IOT Solutions World Congress has established itself as the top gathering for discussing the latest developments in digital transformation based on disruptive technologies.

MonB5G partners Centre Tecnolgica de Telecomunicaciones de Catalunya (CTTC), EURECOM, OTE Group of Companies (HTO), and NEC Laboratories Europe demonstrated **ETSI ZSM PoC #7** "Zero-touch closed-control security management of attacks detection and mitigation" at the IoT Solutions World Congress (IOTSWC) held in Barcelona from January 31 to February 2, 2023.

Figure 15: Participation in IoT Solution World Congress 2023

The Proof-of-Concept was designed to show the MonB5G ZSM strategy, which relies on a closed-control loop employing machine learning to detect abnormal traffic of MTC devices that could cause DDoS attacks on the control plane of the 5G Core network and extract the list of potential UE involved in the attack.

MWC 2023

Mobile World Congress 2023 (MWC Barcelona) was held at the Fira Barcelona Gran Via from February 27 to March 2, 2023. MonB5G was exhibited at the Centre Tecnològic de Telecomunicacions de Catalunya (CTTC) booth: Congress Square, Catalonia Pavillion, Hall 210, Booth 19. Our coordinator, Engin Zeydan, deputy

coordinator Josep Mangues-Bafalluy and project manager Selva Via from CTTC took this opportunity to disseminate the results of the project.

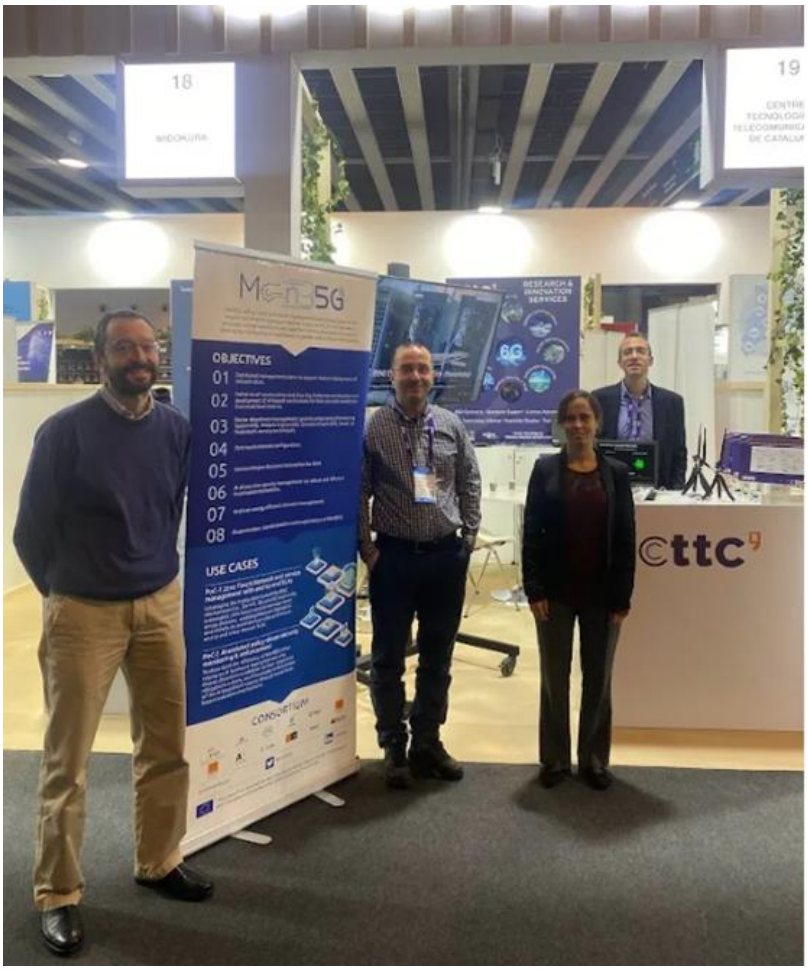


Figure 16 : Participation in Mobile World Congress 2023

3.5 Demos, Events and Invited Talks

InfoCom World 2021 Conference

MonB5G was represented at the InfoCom World 2021 Conference "Recharging Greece: Revolution for the Evolution" on November 26, 2021, in Athens, Greece. Dr. Ioannis Chochliouros organized and chaired the scientific session "5G Innovations for Long-Term Development". The entire conference was comprised of a total of thirty-five separate lectures, with each one focused on one of twenty-two European projects. In the framework of the MonB5G project, within the longer-term vision, targeting the realization of ubiquitous mobile virtual services, we presented a broader approach on concerns for the integration of AI and ML techniques to achieve better network management. In this section, Ms. Vasiliki Vlahodimitropoulou highlighted the "Distributed Orchestration and Management with AI-Driven Techniques for the MonB5G

MS/AE/DE" while Dr. Chochliouros described the "MonB5G: Proposing an Innovative Architecture Able to Support Scalable and Autonomic Network Slice Management in B5G" on behalf of the MonB5G project.

Figure 17: InfoCom World 2021

Athlone Technology and Innovation Day

The "Analytics Engine for Slice KPI Prediction in MonB5G" presentation was given by Dr. Anne-Marie Bosneag and Dr. Ashima Chawla on October 6, 2022, at the Ericsson OSS Technology Day in Athlone, Ireland.

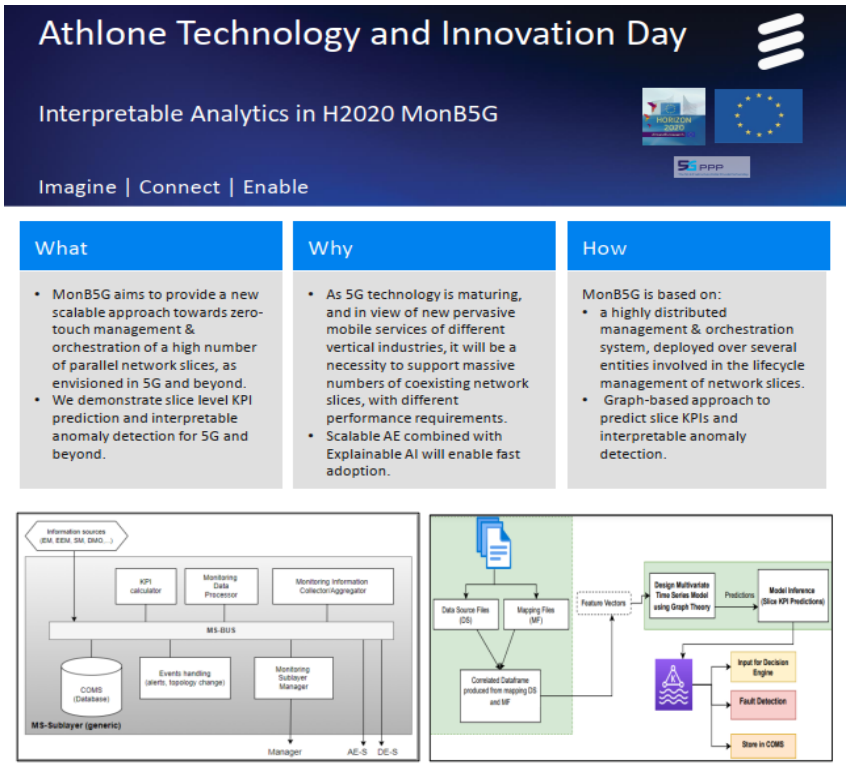


Figure 18 : Presentation in Athlone Technology and Innovation Day

IEEE International Workshop on CAMAD

Dr.Slawomir Kuklinski gave an invited talk about the Simulation of 5G/6G networks – selected issues at IEEE International Workshop on Computer Aided Modeling and Design of Communication Links and Network CAMAD 2022 Conference that was held in Paris, France between the 02-03 November 2022.

Figure 19: IEEE International Workshop on CAMAD conference

In the talk selected issues related to simulations of AI-driven 5G+ network management and virtualization (including RAN specific issues) as well as simulations of the 6G network considered as 'network of networks' were discussed. The applicability of the digital twins paradigm was described in the context of AI

The most recent 24th Infocom World Conference, which took place in Athens, Greece, on November 29-30, 2022, is widely regarded as "the greatest ICT & Media Conference in South-Eastern Europe" and "the biggest annual meeting of all the digital market stakeholders" to implement digital transformation, in line to current market needs and related challenges and particularly contributing to the effort for innovation.

InfoCom World 2022 Conference

Following a successful tradition of 24 years, the Infocom World Conference 2022 focused on the transformative effects of the deployment of "Fiber & 5G Highways: DigitAll Greece". As digital transformation becomes a "key pillar" of growth for many areas of our modern economy, the deployment of appropriate network infrastructures capable of supporting rapid data transfer becomes a crucial objective for future development, especially because such digital "highways" will also support the corresponding transformation of public and private sectors. This rapid digitization process is anticipated to not only strengthen the digital-based economy at all levels, but also provide new business "paths" and growth opportunities. This, however, necessitates a widespread and efficient deployment of the required connectivity infrastructures (especially 5G) for highly innovative services and/or applications.

Figure 20: InfoCom World 2022 presentation

In this context, market participants, particularly telecommunications operators, are increasing their investments in the global development of 5G and Fiber infrastructure. Taking these trends into account, we are in fact at a time when large and significant multinationals are selecting Greece for the development of their own hubs whether they are data centers that serve the broader region, technology and product development centers, or hubs that strengthen human resource skills. Thus, a dependable telecommunications infrastructure with cutting-edge technology will not only strengthen the operation of such centers but also attract new investments, making Greece a "hub for hubs" Within the primary objectives of the Infocom World Conference 2022 were the ways in which Fiber and 5G are reshaping the market and presenting new opportunities for market participants, with the goal of establishing an innovation ecosystem for investment and growth.

Ms. Vasiliki Vlahodimitropoulou of the OTE Group of Companies (HTO) presented the "Energy Efficiency Techniques of the MonB5G Project" during session 8 of the Research-oriented Workshop at the 24th Infocom World Conference. The presentation demonstrated the MonB5G reference architecture for energy management and orchestration, the architectural building blocks, and the most important energy-efficient algorithmic innovations of MonB5G.

3.6 Report on Dissemination Targets/KPIs

The MonB5G project has been successful in disseminating the project's research activities and outcomes to the wider community through various channels. The consortium members of MonB5G managed to reach and exceed the ambitious dissemination targets that were initially set, including at least 15 journal publications and more than 30 conference publications, participation in more than 8 exhibitions and conferences, as well as have more than 5 exhibition booths. Regarding public engagement, the project aimed to participate in over six public engagement events, two technical workshops, and five tutorials.

The publication of 29 journal and 37 conference papers, along with 5 more accepted, demonstrates the significant contribution of the project to the academic field. Moreover, the contribution in three white papers of 5G-PPP WGs which are described in subsection 5.2 further highlights its impact on the development of 5G

technologies. The project's active participation in workshops, exhibitions, and keynote speeches has helped to raise awareness and understanding of its objectives and findings. Overall, the dissemination activities of the MonB5G project have been effective in reaching and engaging with relevant stakeholders, both within the research community and beyond.

Activity	Target	Achieved
Publications	Journals > 15	29
	Conferences > 30	37 (+5 accepted)
Exhibitions/Conferences	> 8	17
Exhibition Booth	> 5	6
Public Engagement Events	6	6
Technical Workshops	2	3
Tutorials & Schools	3 tutorials 2 schools	7

Table 4: Dissemination Targets summary

4 Communication

The main objective of the communication activities was to spread awareness about the MonB5G Project and its results among the various stakeholders, that includes both the media and the public. For this reason, the necessary infrastructure was created including a website, press releases, social media accounts and newsletters.

In the following sections the selected channels are presented as well as the KPIs and targets reached by the consortium during the project.

4.1 Website

This section presents the project's website and its analytics. The project's website is live and has been publicly available since the project start. It was first presented to partners during the Kick-Off Meeting (KOM) which took place at CTTC offices at Barcelona, Spain on 3rd and 4th December 2019. The website was maintained and continuously updated during the project's lifetime by eBOS Technologies Ltd., which coordinated the contributions from all partners and can be reached through.

Figure 21: MonB5G Website screenshot

4.1.1 Website Analytics

In order to track the activity on the project's website, we have been using Google's free web-analytics service. Google Analytics provides information about the activity of the website's visitors such as traffic, session duration, pages per session, bounces and traffic sources in addition to others.

During the last period of the project, the new users were 1895 while the average duration of a session was 2:13. The total users of the website for the whole project duration were 3603 and the average session duration 2:16. Figures 19, 20 and 21 present the statistics and analytics for the total duration of the project.

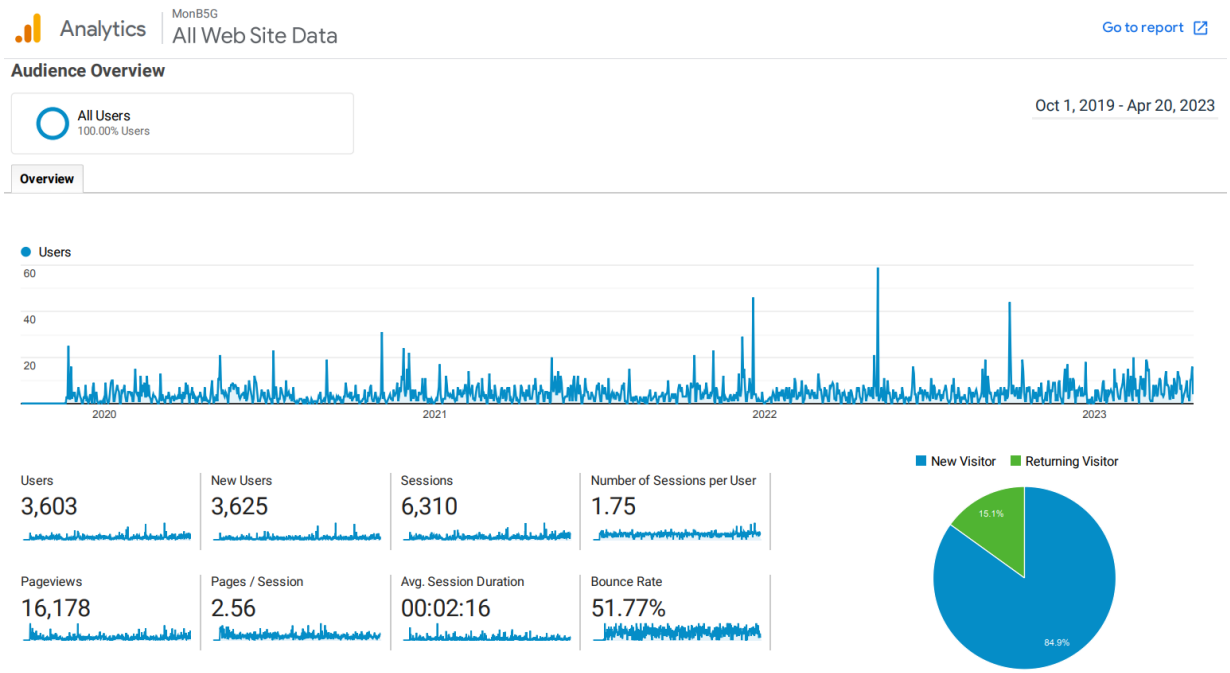
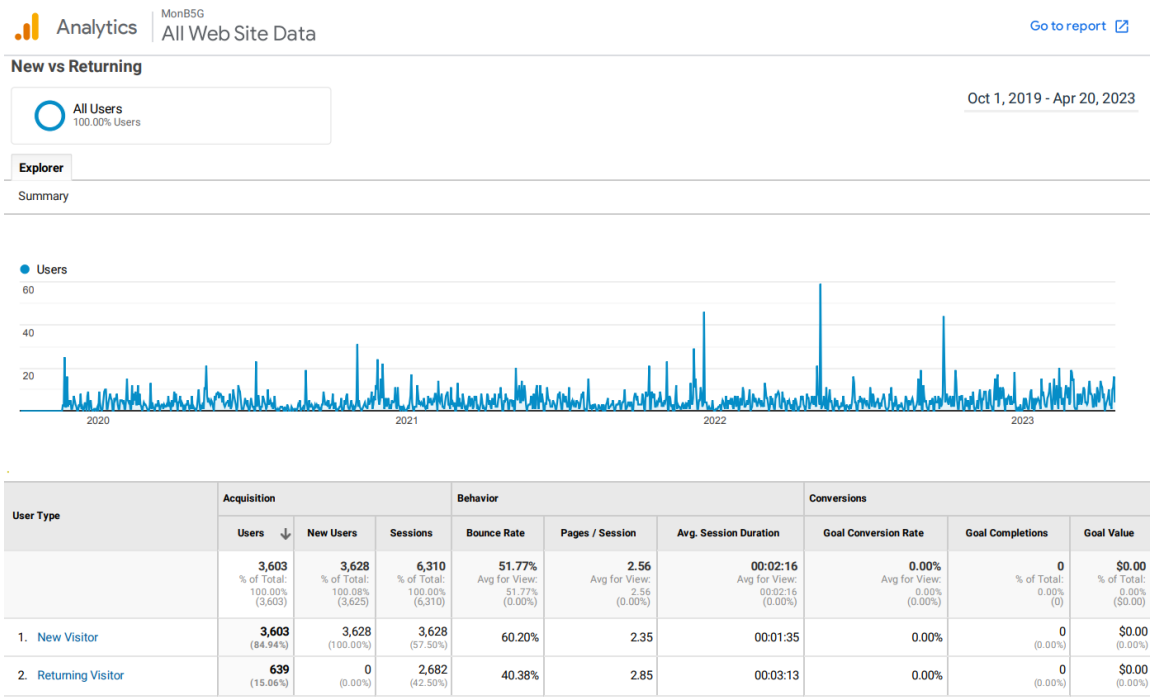


Figure 22: Website Analytics - Audience Overview



User Type	Acquisition			Behavior			Conversions		
	Users	New Users	Sessions	Bounce Rate	Pages / Session	Avg. Session Duration	Goal Conversion Rate	Goal Completions	Goal Value
	3,603 % of Total: 100.00% (3,603)	3,628 % of Total: 100.08% (3,625)	6,310 % of Total: 100.00% (6,310)	51.77% Avg for View: 51.77% (0.00%)	2.56 Avg for View: 2.56 (0.00%)	00:02:16 Avg for View: 00:02:16 (0.00%)	0.00% Avg for View: 0.00% (0.00%)	0 % of Total: 0.00% (0)	$0.00 % of Total: 0.00% ($0.00)
1. New Visitor	3,603 (84.94%)	3,628 (100.00%)	3,628 (57.50%)	60.20%	2.35	00:01:35	0.00%	0 (0.00%)	$0.00 (0.00%)
2. Returning Visitor	639 (15.06%)	0 (0.00%)	2,682 (42.50%)	40.38%	2.85	00:03:13	0.00%	0 (0.00%)	$0.00 (0.00%)

Figure 23: Website Analytics-New vs Returning Visitors

	Country	Users	% Users
1.	United States	607	16.65%
2.	Spain	467	12.81%
3.	France	366	10.04%
4.	Greece	286	7.84%
5.	Cyprus	285	7.82%
6.	Finland	175	4.80%
7.	China	158	4.33%
8.	Germany	122	3.35%
9.	Italy	100	2.74%
10.	Netherlands	95	2.61%

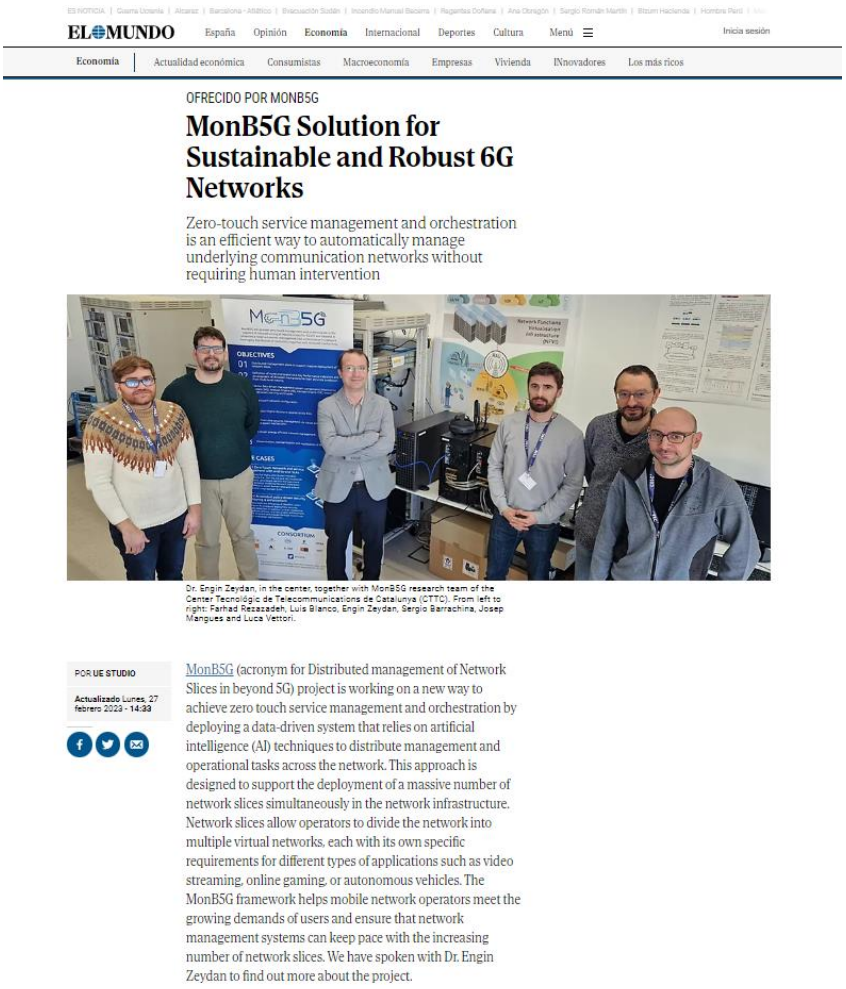
Figure 24: Website Analytics: Audience Overview by Top 10 Countries

4.2 Press Releases

Press releases were one of the key communication activities that were used to reach out to various stakeholders including the research and business community and the public and inform them about the MonB5G project.

Five press releases have been published so far and one last one will be published by OTE on the organization's website by the end of the project (not available to preview at the time of writing this report).

The 5th press release [42] was an interview of Dr. Engin Zeydan to the Spanish newspaper El Mundo in a special edition ahead of Mobile World Congress Barcelona 2023 on topics related to MonB5G's solutions for 6G networks. Below is presented a preview of the press release:



EL MUNDO España Opinión Economía Internacional Deportes Cultura Menú Inicia sesión

Economía | Actualidad económica Consumistas Macroeconomía Empresas Vivienda INnovadores Los más ricos

OFRECIDO POR MONB5G

MonB5G Solution for Sustainable and Robust 6G Networks

Zero-touch service management and orchestration is an efficient way to automatically manage underlying communication networks without requiring human intervention

Dr. Engin Zeydan, in the center, together with MonB5G research team of the Center Tecnològic de Telecomunicacions de Catalunya (CTTC). From left to right: Farhad Rezazadeh, Luis Blanco, Engin Zeydan, Sergio Barrachina, Josep Mangues and Luca Vettori.

POR UE STUDIO

Actualizado Lunes, 27 febrero 2023 - 14:33

MonB5G (acronym for Distributed management of Network Slices in beyond 5G) project is working on a new way to achieve zero touch service management and orchestration by deploying a data-driven system that relies on artificial intelligence (AI) techniques to distribute management and operational tasks across the network. This approach is designed to support the deployment of a massive number of network slices simultaneously in the network infrastructure. Network slices allow operators to divide the network into multiple virtual networks, each with its own specific requirements for different types of applications such as video streaming, online gaming, or autonomous vehicles. The MonB5G framework helps mobile network operators meet the growing demands of users and ensure that network management systems can keep pace with the increasing number of network slices. We have spoken with Dr. Engin Zeydan to find out more about the project.

Figure 25: Press Release in El Mundo newspaper

4.3 Social Media

Social media has become an important tool for engaging with people and promoting research programs. Platforms such as LinkedIn and Twitter provide a unique opportunity to reach out to a large audience and engage them.

This section aims to analyse the success of using social media to engage people and to identify the key factors that contribute to effective social media engagement.

4.3.1 LinkedIn Page

LinkedIn is the platform of choice for researchers, companies, and industry professionals as it is a valuable tool to establish a presence and build relationships within their industries.

The MonB5G Project LinkedIn Page https://www.linkedin.com/company/monb5g was created and launched during the first month of the project. It has been extensively used for communication and dissemination of the project's news, events, and outcomes. The easy 'sharing' of the posts, by the project consortium's individual pages, which has helped maximize the impact and the reach of the dissemination and communication activities.

The project's page on LinkedIn has reached 175 followers. The following Figures show the LinkedIn page analytics overview:

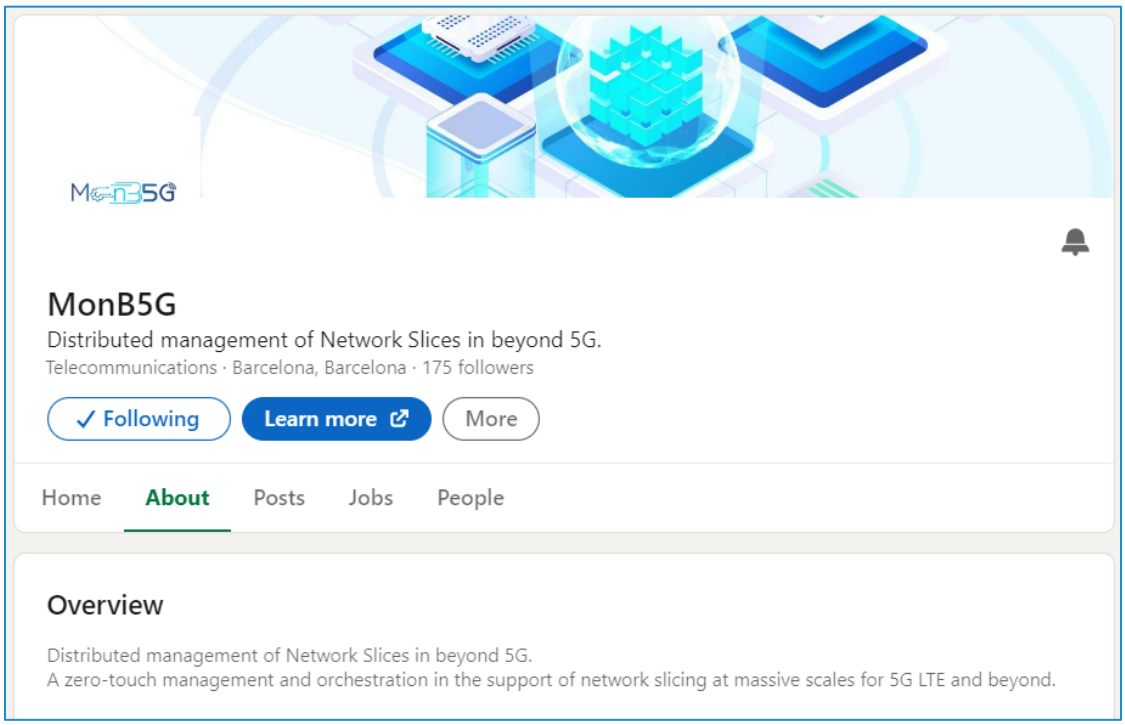


Figure 26:MonB5G LinkedIn page heading

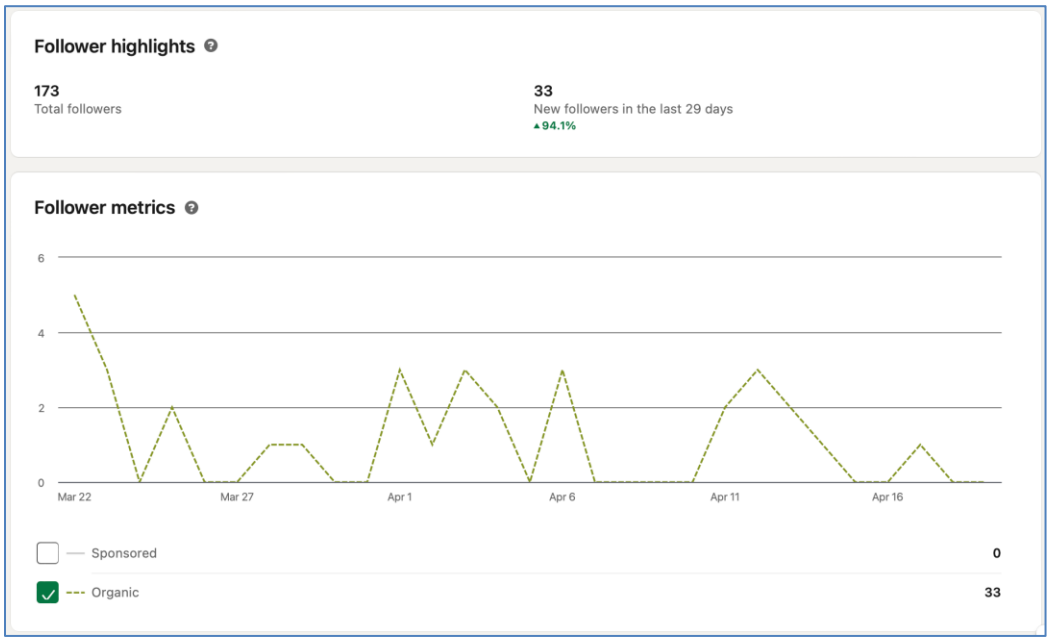


Figure 27: LinkedIn Follower analytics

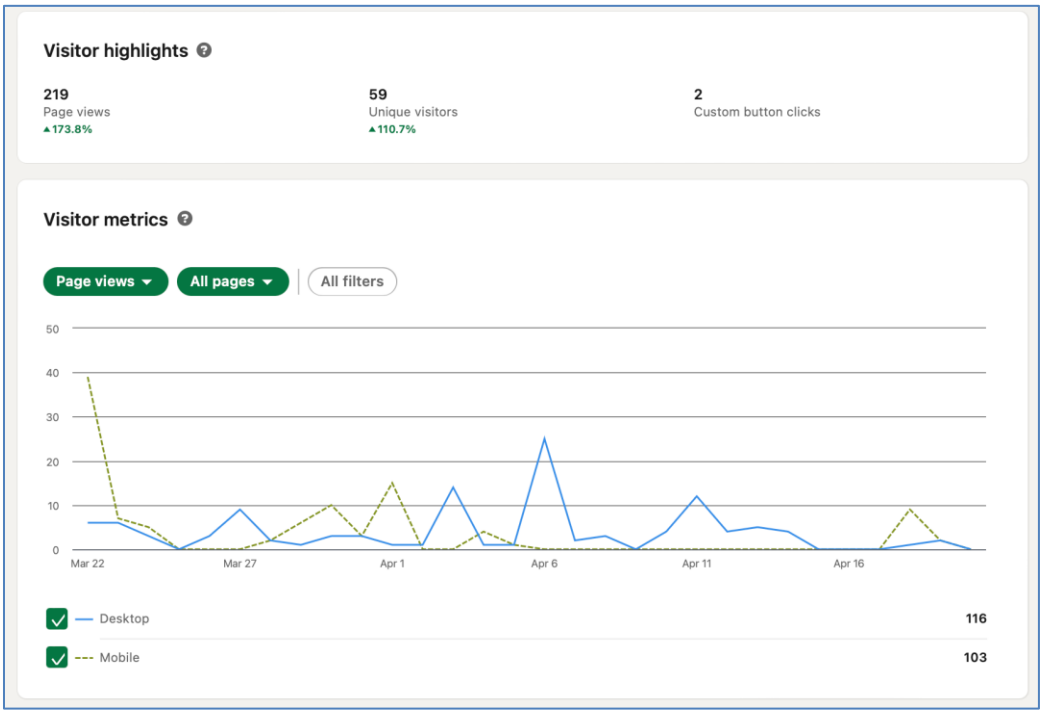


Figure 28: LinkedIn Visitor highlights

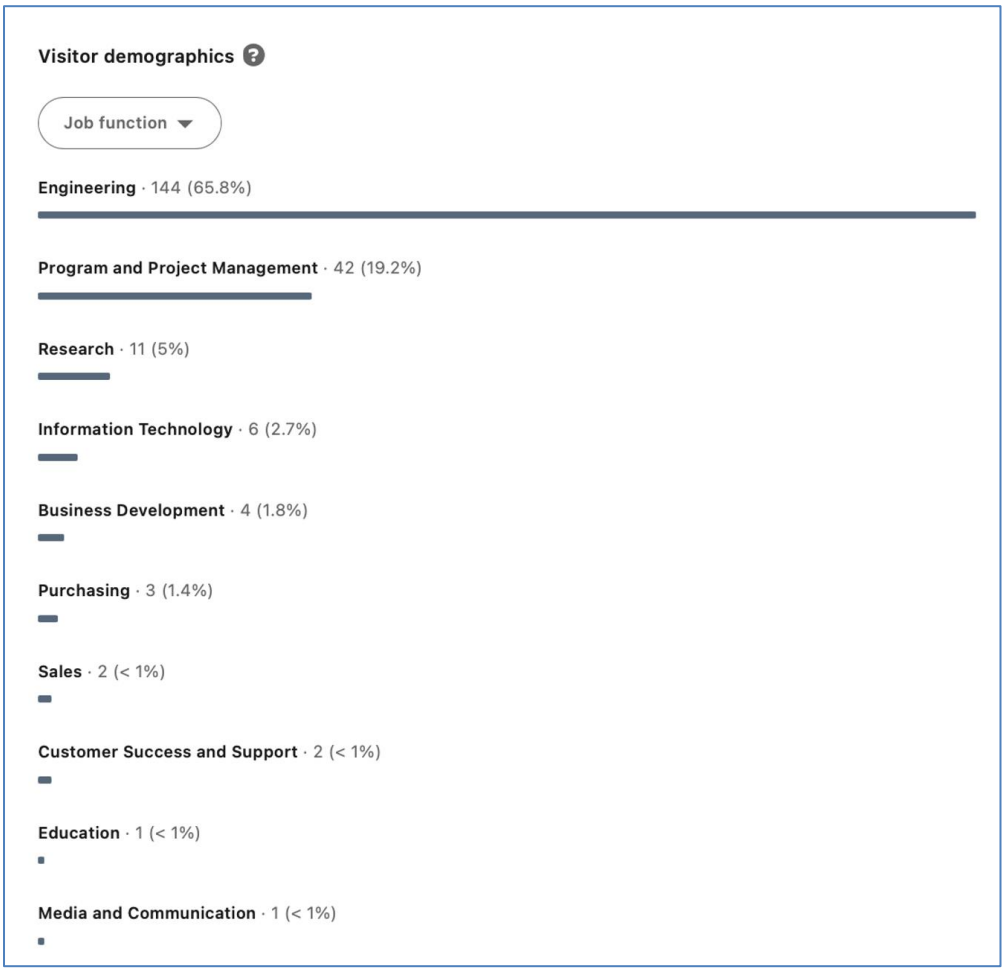


Figure 29: LinkedIn visitor demographics

4.3.2 Twitter Page

The MonB5G Project Twitter Page https://twitter.com/monb5g was created and launched during the first month of the project with the aim to be utilized as a communication and dissemination tool. The use of twitter in combination with LinkedIn, maximized the engagement and response to potential interest in all the topics that were covered by the project activities, events and outcomes.

In total, MonB5G Twitter page reached 197 followers and in total 90 tweets/re-tweets were posted. The following figure shows the project's twitter page header.

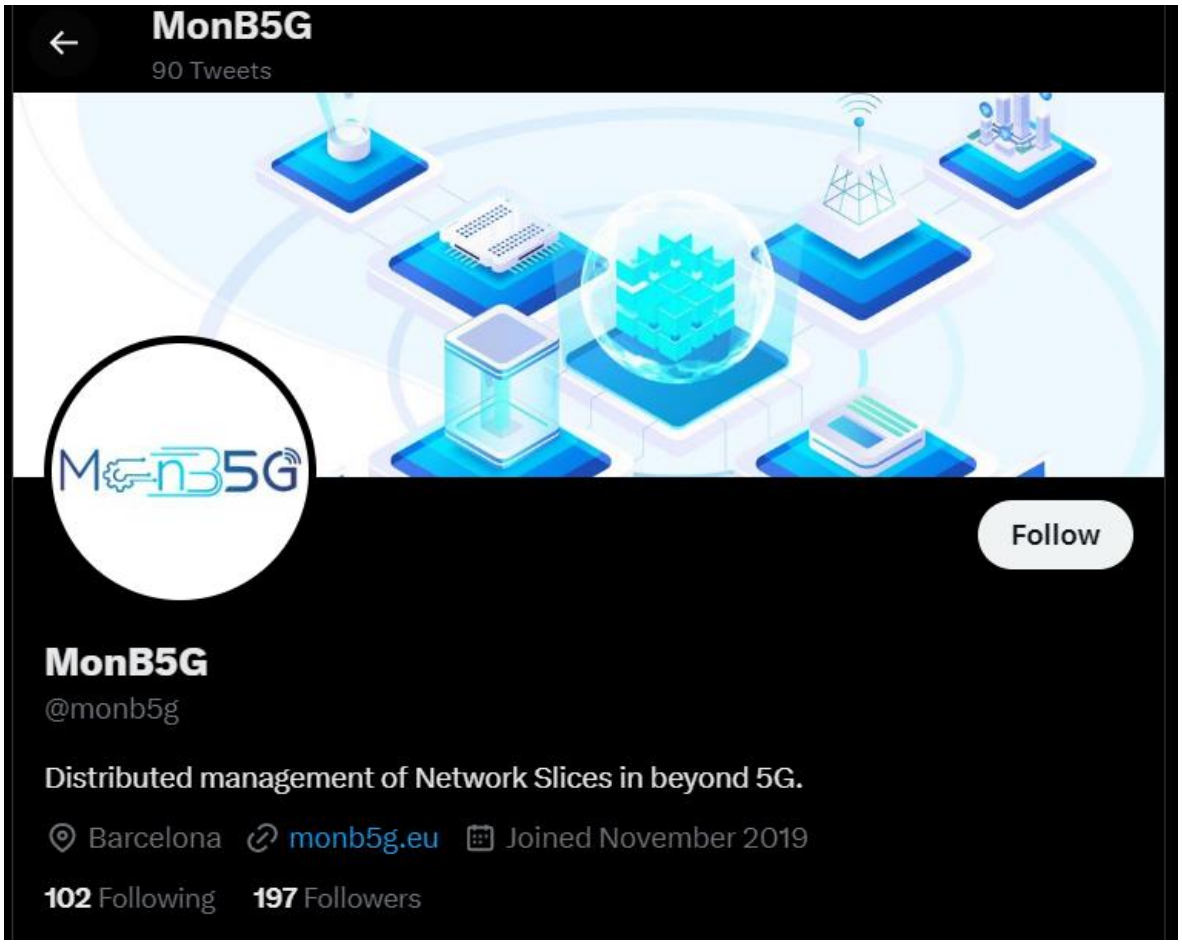


Figure 30: Twitter profile header

4.4 Video Clips

During the last period of the project, 9 more videos were published on the project's YouTube channel

Link: https://www.youtube.com/@monb5gproject875/featured).

I. MonB5G WP5 MS10 aLTEr use case

This video was published on May 31st, 2022, and it shows a demo of aLTEr attack scenario detection and mitigation in the context of 5G. The demo shows how AI/ML can be used to ensure Zero-touch Service Management (ZSM) in the context of 5G networks. The demo is run in the context of the H2020 MonB5G project. The video has 21 views.

Link: https://www.youtube.com/watch?v=vu-kLlZUvc8

II. Demo mMTC DDoS attack detection in 5G

This video was also published on May 31st, 2022, and it shows a demo of DDoS attack detection and mitigation on mMTC slices in the context of 5G. The demo shows how AI/ML can be used to ensure Zero-touch Service Management (ZSM) in the context of 5G networks. The demo is run in the context of the H2020 MonB5G project. The video has 133 views.

Link: https://www.youtube.com/watch?v=-lCIukCTTFY

III. MonB5G: Distributed management of Network Slices in beyond 5G

This video was published on July 27th, 2022, and it presents an interview of the Project Coordinator Dr. Engin Zeydan from CTTC who gives an overview of the project's innovations in 5G and beyond management and delivery. The video highlights the two use cases in CTTC and EURECOM platforms as well as the MonB5G architecture which provides management and orchestration scalability by distribution of management functions and explicit separation of runtime management of network slices. This video has reached 417 views and it is the most viewed video of the project.

Link: https://www.youtube.com/watch?v=MbOVirzqZig

IV. MeditCom2021 Demo Threat detection and mitigation Video

This demo was published on the 29th of July 2022 and presents a new approach to detecting and countering the aLTEr attack by proactively searching for the threat and automatically remediating it. These processes leverage AI/ML techniques and the automation framework offered by the MonB5G architecture. The video has 24 views.

Link: https://www.youtube.com/watch?v=_oQbRAk6AGY

V. MonB5G MS demo at EuCNC 2022

This video was published on August 1st, 2022 and describes MS which was presented at EUCNC 2022. https://www.monb5g.eu/monb5g-booth-at-eucnc-6g-summit-2022/ . It has 47 views.

Link: https://www.youtube.com/watch?v=-wc4R8ascnk

VI. MonB5G: CTTC DE using DRL and Integration with MS

This video was published on the project's youtube channel on August 3rd, 2022, and it presents the integration of MS with DE running Deep Reinforcement Learning. It has 72 views

Link: https://www.youtube.com/watch?v=2Ne-pFPLKHM

VII. Demo: Stochastic Policy for Scalable AE

This demo was published on September 29th, 2022, and it presents the stochastic policy for scalable AE. It has 31 views.

Link: https://www.youtube.com/watch?v=fHuwOFaxJIc

VIII. A Multi-Agent Deep Reinforcement Learning Approach for RAN Resource Allocation in O-RAN

This video was published on the 13th of January 2023. Artificial intelligence (AI) and Machine Learning (ML) are considered as key enablers for realizing the full potential of fifth generation (5G) and beyond mobile networks, particularly in the context of resource management and orchestration. In this demonstration, we consider a fully-fledged 5G mobile network and develop a multi-agent deep reinforcement learning (multi-agent DRL) framework for RAN resource allocation. By leveraging local monitoring information generated by a shared gNodeB instance (gNB), each DRL agent aims to optimally allocate radio resources concerning service-specific traffic demands belonging to heterogeneous running services. We perform experiments on the deployed testbed in real-time, showing that DRL-based agents can allocate radio resources fairly while improving the overall efficiency of resource utilization and minimizing the risk of over provisioning. The video has 112 views.

Link: https://www.youtube.com/watch?v=Hw4kcaVk94I

IX. ETSI ZSM PoC #7 "Zero-touch closed-control security management of attacks detection and mitigation"

This video was published on February 13th, 2023 and shows the presentation for MonB5G at ETSI ZSM PoC #7 titled "Zero-touch closed-control security management of attacks detection and mitigation". The video has 26 views.

Link: https://www.youtube.com/watch?v=Vclyp-N03mI

4.5 Newsletters

The aim of the newsletters was to keep the stakeholders informed about the progress and development of the project within a given period. The newsletters were shared on all the project channels.

The first newsletter was issued and published in May 2020, the second was issued on January 2021, the third one was published on August 2021, the fourth newsletter was published on March 2022, the fifth one on November 2022 and the 6th and last one will be published by the end of April 2023 (not available for preview at the moment of writing this deliverable).

The 5th newsletter is shown in screenshots below, while the full versions of all newsletters are available in the following link:
https://www.monb5g.eu/newsletters/

Figure 31: Newsletter Issue #5 November 2022

4.6 Report on Communication Targets/KPIs

In conclusion, the communication activities of the project have been highly successful, exceeding most of the KPIs set at the beginning of the project.

In particular the target KPIs included attracting at least 1000 visitors to the project's website with an average duration of 2:00, publishing more than 50 posts and 20 documents in the repository. Also, the KPIs included publishing more than 3 press releases, reaching more than 150 followers on LinkedIn, more than 100 followers on Twitter, and publishing more than 3 videos with more than 1000 views in total, as well as more than 6 newsletters.

The project's actual results exceeded most of the KPIs set at the beginning of the project. The website attracted 3603 users in total, which is well above the target of 1000 visitors. Additionally, the average duration of their visit was 2:16, exceeding the expected average duration of 2:00. The project was also successful in publishing more than 50 posts (59) and 38 documents in the repository, which demonstrates their commitment to providing valuable content for their visitors.

The project exceeded the KPI for press releases, publishing 6 instead of the expected 3, and also published 6 newsletters, achieving the target. The project was also successful in publishing 10 videos, including 7 demo videos, with a total of more than 1000 views.

Regarding social media, the project exceeded the KPI for LinkedIn followers, with 175 followers instead of the expected 150, and also has 197 followers on Twitter, exceeding the target of 100. The project made 90 posts and reposts on Twitter, engaging with their followers and keeping them up to date on their work.

Overall, the project's communication activities have been a great success, helping to promote the project's work to a wider audience, and engaging with partners and followers across multiple platforms.

Activity	Target	Achieved
Website	Visitors 1000, ave. duration 2:00, Posts >50, Documents in repository >20	Visitors 3603, ave. duration 2:16, Posts 59, Documents in repository 38
Press Releases	3 (1 per year)	6
Social Media	LinkedIn >150 followers Twitter >100 followers Tweets/reTweets >150	LinkedIn: 175 followers Twitter: 197 followers Tweets/reTweets: 90
Video Clips	3 videos, 1000 views	10 videos, 1085 views
Newsletters	6	6

Table 5: Communications Targets summary

5 Standardization

Standards are the result of the communications industry agreeing on a technology's functionality, including its fundamental features and common implementation. The 5G standardization process is complex and highly innovative. The process entails reaching an agreement on a technical course of action with a wide range of stakeholders, including vendors, operators, and other interested groups, while maximizing technological compatibility, interoperability, security, consistency, and quality.

The deployment of MonB5G mainly depends on existing specifications and standards. The MonB5G framework has been designed for AI-driven management and orchestration of massive number of NSIs. The framework is based on key features, which are compatible with **ETSI ZSM** [43] requirements, and follows the MAPE paradigm [44] as well as the International Telecommunication Union - Telecommunication Standardization Sector (ITU-T) management system decomposition [45]. The ETSI ZSM CL framework is implemented by the MonB5G DE and its associated administrative elements (MS, AE, and ACT). We have relied heavily on ETSI OSM for VNF management and orchestration in the Management and Orchestration Layer in both the Core (Cloud) and MEC (Edge) which creates an Open Source NFV Management and Orchestration (MANO) software stack that is compliant with **ETSI NFV** specifications. In accordance with **ETSI NFV-IFA** 029, Kubernetes serves as a Platform as a Service (PaaS) for CNFs, which are the nature of MonB5G Slice Management Layer (SML) components (such as MS, AE, and DE functions). MonB5G architecture strictly

applies to the **ETSI MEC** standard guidelines to assure compatibility and provide an E2E slice management solution suitable for the current telecom business environment. The project's successful contributions to standards, which also demonstrate its influence and added value, verify the output's quality and relevance.

5.1 Standardization activities

Standardization activities were identified as one of the most important means of achieving a high impact of the results and demonstrating the technical progress of the project. The project has always viewed standardization in the broadest sense possible, being aware of the new standardization mechanisms offered by SDOs as the basis for project development and the subsequent distribution of project results. Particular emphasis was placed on the application of machine learning techniques and on the concept of closed-loop automation to develop a novel end-to-end architecture framework and enablers designed for the network's self-management.

ETSI provides platforms where interested parties come together & collaborate on the development & promotion of standards for Information & Communication Technology (ICT) systems and services, used globally for the benefit of all.

In collaboration with other standardization organizations and Open-Source projects, the **ETSI ISG ZSM** (Zero-touch Network and Service Management) proposes a novel, future-proof, horizontal and vertical end-to-end management and orchestration framework with the objective of having all operational procedures and activities completed automatically. The ZSM framework is adaptable and service-based, providing scalability, modularity, extensibility, and flexibility. It enables the transfer of operator autonomy to the network using intent-based interfaces. The framework enables the integration of AI-based capabilities and closed-loop automation. The ultimate target of the ZSM concept is to enable an autonomous network system capable of self-configuration, self-monitoring, self-healing, and self-optimization based on service-level policies and rules without human intervention.

Because of the ZSM framework's openness, the threat surface in a ZSM system is extensive. Protecting the interfaces and management services within and between domains is crucial for ensuring the framework's credibility. The ZSM architecture uses developing technologies such as AI/ML, data lake, and the cloud, which provide new attack vectors and impose extra security needs. However, the ZSM framework can leverage these developing technologies to improve security management effectiveness. Using AI/ML-powered analytics to trigger actions, for instance, can help automate security monitoring and real-time incident response. The ETSI ZSM ISG coordinates experimentation and presentation of ZSM solutions to demonstrate the viability of the technology and to incorporate the results and lessons learned into the specification work.

The **ETSI ZSM PoC 7** "Zero-touch closed-control security management of attacks detection and mitigation" [46] demonstrated the zero-touch security management system developed by the MonB5G project, which utilizes a closed-control loop with machine learning to identify and counteract in-slice attacks launched by Machine Type Communication (MTC) devices against 5G Core Network (CN) components, with a strong focus on Distributed Denial of Service (DDoS) attacks.

As ETSI ISG MEC member, CTTC contributed to the **ETSI MEC** SDO submitting and presenting the Demo: Embedding distributed MonB5G intelligence for 6G networks in ETSI MEC #33 meeting that was held in Castelldefels, Spain on 15 March and having approved the following Item MEC (23)000121 [47].

(Title: A demonstration of embedding distributed MonB5G intelligence).

Figure 32 : Participation and contribution to ETSI Multi-access Edge Computing meeting

ITU-T Study Group 13 (ITU-T SG13) is the primary ITU-T study group for the following topics: future networks, such as IMT-2020 networks (non-radio related aspects), mobility management, cloud computing, and trusted network infrastructure. Research is designated to be conducted in relation to questions concerning the non-radio components of IMT 2020 networks and beyond.

The purpose of Question Q20: "Networks beyond IMT-2020 and machine learning: Requirements and architecture" aims to investigate the requirements, architecture, and utilization of technologies such as artificial intelligence (AI)/Machine learning (ML) to implement networks to meet the expected network and application service requirements in the next years.

The Recommendations that define the framework, service scenarios, requirements, and architecture of network softwarization in IMT 2020 networks and beyond fall under the responsibility of Question 21: "Network softwarization including software defined networking, network slicing and orchestration". Network softwarization is an approach that utilizes software programming for network design, implementation, deployment, management, and maintenance. In the Y.3000, Y.3100, and Y.3300 series of ITU-T, key technologies such as SDN/NFV and data plane programmability supporting network slicing and orchestration have been explored.

The standardization of NGN architecture was supported significantly by ITU-T SG13. The ITU-T is presently examining how to optimally deploy AI/ML in future networks, particularly 5G networks and defines recommendations concerning generic network slicing, i.e., beyond the 3GPP approach. 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 and Question 21 further discussions will take place. Recent standardization achievements of ITU-T 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 actively participates in ITU-T SG13 activities. Orange Poland, on behalf of the MonB5G consortium, has made contributions and proposals to the following work items related to Questions 20 and 21 of Study Group 13's rapporteur group meetings:

- Contribution to **Y. SLOA-arch**: "End-to-end service level objective assurance architecture for future networks including IMT-2020" adding the prediction aspect to SLO issues.
- Proposal for modification of Draft Recommendation **Y.IMT-2020-EIL**: "Evaluating intelligence capability for network slice management and orchestration in IMT-2020".
- Proposal for modification of Recommendation **Y.IMT-2020-DL-AINW-fra**: "A communication model for AI-based management in IMT-2020 and beyond".
- Proposal for modification of Draft Recommendation **Y. IMT2020-SOCN-req-frame**: "Future networks including IMT-2020: requirements and framework for self-organizing core network".
- Proposal for modification of Draft Recommendation **Y. IMT2020-AINDO-req-frame**: "Requirements and framework for AI-based network design optimization in future networks including IMT-2020".
- Proposal for modification of Recommendation **Y.IMT-2020-DL-AINW-fra**: "A communication model for AI-based management in IMT-2020 and beyond". The work on this document has been finalized. It was accepted as recommendation **Y.3325** "Framework for high-level AI-based management communicating with external management systems".
- Proposal for modification of Draft Recommendation **Y. IMT2020-SOCN-req-frame**: "Future networks including IMT-2020: requirements and framework for self-organizing core network".

Autonomous Networks are crucial for operators to meet the anticipated demands of Beyond 5G and future networks. ITU-T FG AN has made great effort as a pre-standard, open cooperation platform to facilitate the development of Autonomous Networks.

CTTC delivered the presentation to **ITU-T Focus Group on Autonomous Networks** (FG-AN) "Cloud–Native driven Stochastic Policy for Scalable Analytics Engine" FGAN293-R1 [48]. A unique SLA-driven stochastic FL policy was designed to provide scalability under massive slicing by selecting a subset of active AEs in each FL round, based on their violation rate (convergence time & communications overhead improvement, energy efficiency). The deployment of the suggested solution utilizes a cloud-native containerized environment. The scalable SLA-driven stochastic FL policy for zero-touch network slicing resource allocation reduces the corresponding computation cost and SLA violation.

The 3GPP standards cover cellular telecommunications technologies, which includes radio access, core network, and service capabilities, and provide an in-depth description for mobile telecommunications.3GPP TSG Service and System Aspects (SA) is responsible for the architecture and service capabilities of 3GPP-compliant systems. The primary goals of **3GPP TSG SA WG5 (SA5)**, a subgroup of the 3GPP Technical Specification Group Service and System Aspects (TSG SA), are Management, Orchestration, and Charging for 3GPP systems.

In the era of 5G and beyond, it is no longer feasible to orchestrate and guarantee services by utilizing conventional, technology-centric tools and procedures that are isolated from one another. The automation process needs to be founded on contractual service level agreements (SLAs) as well as the business intent, which should combine network and service assurance. Autonomous Networks can be supported by the Closed-loop SLS (Service Level Specification) assurance feature of **3GPP SA5**. Closed loop assurance applies to communication services and mobile network optimization. When a performance degradation affects or is anticipated to affect the objectives of SLS as defined for communication service, closed loop assurance assists a service provider in continuously delivering the expected level of communication service quality by automatically reconfiguring the mobile network realized by resources and resource affecting services.

The following table summarizes the contributions made by **Ericsson LMI** to **3GPP Technical Specification 28.535** "Management and orchestration; Management services for communication service assurance; Requirements" on the concept of closed control loops based on Monitor/Analytic/Decide/Act and multi-layer closed control loops.

SDO/ WG	Document	Title	Contributor	WG/TSG meeting reference	TS	CR	Release	WI
3GPP SA5	S5-206321	Update figure and description of Communication service assurance service	Ericsson LMI	SA5#134-e/ SA#90	28.535	0014	**Rel-16**	**COSLA** Closed loop SLS Assurance
3GPP SA5	S5-211474	Clarify intelligence in clause 4	Ericsson LMI	SA5#135-e/ SA#91	28.535	0029	**Rel-16**	**COSLA** Closed loop SLS Assurance
3GPP SA5	S5-213464	Update management control loops with lifecycle description	Ericsson LMI	SA5#137-e/ SA#92	28.535	0044	**Rel-16**	**COSLA** Closed loop SLS Assurance
3GPP SA5	S5-223215	CR eCOSLA for TS 28.535	Ericsson LMI	SA5#143-e/ SA#96	28.535	0065	**Rel-17**	**eCOSLA** Enhanced Closed loop SLS Assurance

Table 6: Contributions to 3GPP SA5

5.2 5G-PPP Participation and Contributions

MonB5G project, since its inception, has participated in a number of collaborative activities with other on-going phase 3 projects supported through the 5G PPP. Activities include participation in 5G PPP boards, Working Groups (WGs) and webinars, as well as contributions to white papers, newsletters and annual journals. In The European 5G Annual Journal 2021 [49], which was published in May 2021, a thorough analysis of MonB5G, along with Phase 2 and Phase 3 5G PPP projects, was presented. We also contributed to the 6G Start Annual Journal, which will be published in May 2023 and will feature the most recent project results and accomplishments. In the 5GPPP Phase 3 Projects Brochure [50], released in June 2021, we outlined the main objectives and challenges of the project, as well as the proof-of-concepts and expected results.

We had contributions in three different 5G-PPP white papers. These are:

- Edge Computing for 5G Networks (February 2021) [51]
- AI and ML enablers for Beyond 5G Networks (May 2021) [52]
- 5G PPP – View on Architecture V4.0 (November 2021) [53]

The first white paper explains why Edge Computing and 5G are linked and how 5G may benefit the most from Edge Computing. MonB5G contributed to the preparation and reviews of the white paper, with contributions relevant to the project, as part of its regular participation in the 5G PPP Technology Board and 5G PPP Software Networks Working Groups.

In the second white paper, CTTC and NEC contributed to the area of end-to-end slicing with AI and ML solutions in Continuous multi-objective reinforcement learning for joint admission control and resource allocation. This white paper on AI and ML as enablers of beyond 5G (B5G) networks is based on contributions from 5G PPP projects that research, implement and validate 5G and B5G network systems.

MonB5G contributed to network slicing related AI/ML use case of joint slice admission control and resource allocation in all technological domains. (Continuous multi-objective reinforcement learning for joint slice admission control and resource allocation). To enable zero-touch end-to-end network slicing, a closed-loop modular architecture can be designed, wherein a deep reinforcement learning (DRL) agent over all technological domains (e.g., RAN, Cloud, Edge, Core) performs end-to-end slice joint admission control and resource allocation/reconfiguration in either pseudo real-time or non-real-time granularities.

As part of the 5G PPP Initiative, the 5G Architecture Working Group is identifying novel trends and key technological enablers for the implementation of 5G and 6G architecture of Mobile and Wireless Communications Networks.

Since the beginning of the MonB5G project, ORA-PL and OTE have participated in 5G Architecture WG discussions and monitored the WG's activities. ORA-PL contributed to “View on 5G Architecture white paper” in the chapter Automated Management & Orchestration (MANO) architecture and presented the E2E slice management and orchestration approach of MonB5G which is focused on scalability. The orchestration and management architecture proposed in MonB5G aims to provide a new framework for the concurrent provisioning of high numbers of network slices as envisioned in 5G and beyond. The primary goal of this approach is to achieve scalable and automated management of network slices in multiple orchestration domains.

The most recent white paper of 5G PPP Architecture Working Group which is titled "The 6G Architecture Landscape: European Perspective" focuses on the architectural evolution towards 6G that will enable the transition from 5G and beyond to a fully-fledged 6G architecture while providing a consolidated view of the technical directions for architecture design in the 5G/6G era.

CTTC, Ericsson LMI, NEC, and Orange-Poland contributed to the 6G Architecture book, which is an extension of the most recent 5G PPP Architecture WG white paper in the Chapter “Intelligent Networks”, which details the enablers for intelligent networks and how the 6G architecture can benefit from automation and Artificial Intelligence (AI). The ultimate target for the intelligent network is to enable autonomous and adaptable networks, with no (or minimal) human intervention, leveraging cognitive, closed-loop control network functions that can be instantiated on an on-demand basis even across network domain boundaries. The contributions of MonB5G partners illustrating interpretable machine learning models and distributed Zero-Touch Network and Service Management for 6G networks. The 6G Architecture book will be presented during the 2023 EuCNC and 6G Summit special session titled “6G Architecture – European View”.

Significant progress was made in the last 3 years for 5G networks and their evolution thanks to the efforts of the 5G Infrastructure PPP Program and the related projects. MonB5G project results were listed in Phase 3 Key Achievements version 3.1 [54] and version 3.2 [55] of 5G PPP program. Most of the reported achievements of MonB5G project are related to 5G architecture, security, privacy and resilience of B5G Networks, network management and orchestration of the services with the use of AI techniques. The latest version of the Key achievements list (v3.2) demonstrated that the introduction of ICT-20 projects has further stimulated research across all technological domains.

Network Management and Orchestration Services
AI-driven and decentralized management and orchestration architecture, including security, of network slices, achieving the concept of Zero-touch Service Management (ZSM) AI-driven In-Slice Management (ISM) concept, which reduces number of external slice interfaces and separates slices’ management plane. Multi-domain orchestration framework, which provides a strong separation between orchestration domains
Security, Privacy and Resilience
AI-based closed control loop framework to detect and mitigate attacks on network slices. Introduction of the Security orchestration and Security as a Service concept Trusted architecture for network slicing deployment. Demonstration of the capabilities of the closed control loop to detect and mitigate attacks using three use cases: 1. In-slice mMTC DDoS attacks on AMF, 2. aLTEr attacks (traffic steering and VNF instantiation), 3. Attack detection and mitigation on Federated Learning (FL) training process

Other Technology Enablers
Definition of novel E2E slice KPIs for monitoring performance of slices
Graph-based learning for slice KPI prediction
Federated Learning for low SLA violations in beyond 5G network slicing
AI-based Intra and Inter slice admission control
MonB5G energy techniques:
Decentralized cross-domains Energy Efficient Decision Engine
Energy efficient at RAN and Edge
Publication of 5G Datasets collected from project testbeds contributing to the future research of the community

Table 7: MonB5G Key Achievements version 3.2

We participated to the following 5G-PPP Working Groups/Boards:

Board/Working Group	Representatives	Company
5G-PPP Initiative Steering Board	Engin Zeydan, Selva Via	CTTC
5G-PPP Technology Board	Engin Zeydan, Adlen Ksentini	CTTC, EURECOM
5G Architecture Working Group	Slawomir Kuklinski, Vasiliki Vlahodimitropoulou	ORA-PL OTE
Software Networks Working Group	George Tsolis	CITRIX
Trials	Dimitris Manolopoulos	EBOS

Table 8: Participation in 5G-PPP WGs

Dr. Thrasyvoulos Spyropoulos represented MonB5G at this TB meeting, during which he primarily discussed the following topics: End-to-End Optimization for 5G+/6G, Jointly Optimizing 5G+ Functions, Data-Driven Distributed Orchestration, MonB5G Architecture and Implementation, and the Distributed Deep Neural Networks.

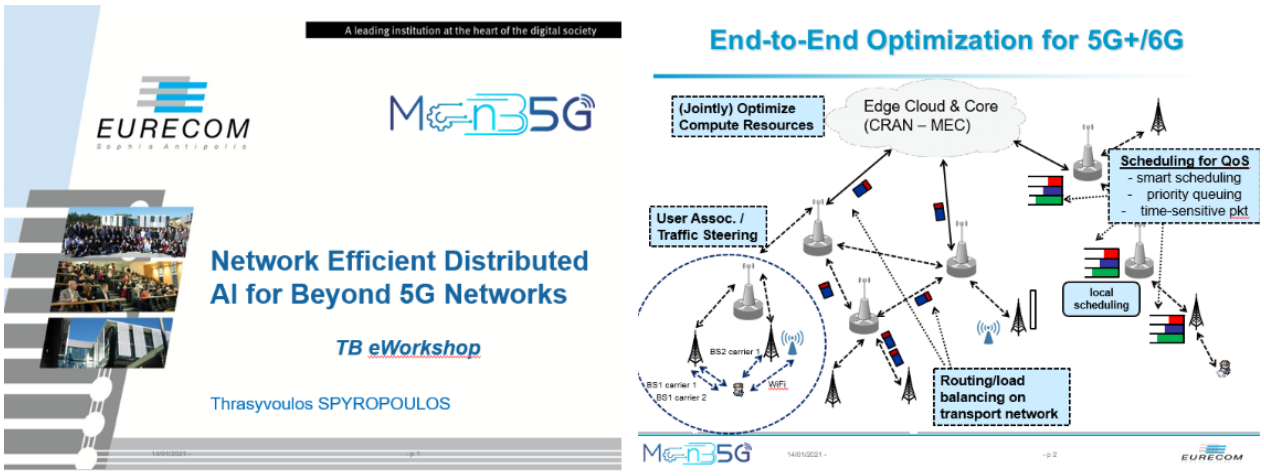


Figure 33: Presentation in 5G-PPP technology Board

Dr. Cao-Thanh PHAN presented at the 5G-I Technology Board Workshop on 19 January 2022 the work of BCOM, AALTO, and CITRIX partners on the Network Slicing Security Orchestration Framework for the MonB5G platform, as well as the effectiveness of the network in threat detection and mitigation using MonB5G components.

6 Exploitation

The activities relevant to the exploitation of the outcomes of the project are executed under Task 7.3: Exploitation and IPR Management (M1-M42). At a high level:

- Substantial know-how and original intellectual property (IP) were generated during the development of MonB5G. Please refer to Section 6.4 for the progress beyond the state of the art achieved by the project.
- The consortium used all possible means to protect generated IP with focus on post-project commercial exploitation. Please refer to Section 6.5 for all the activities and outcomes that supported this objective.
- The consortium includes a number of industrial partners, which can directly exploit the project results to develop commercial products/services.
- Academic partners also 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 was also carried out in this task to ensure quality of highest possible standards and identify potential market opportunities. Please refer to Section 6.3 for the process and measures, but also the analysis of the market, including the updated competitive landscape and growth potential.

At the beginning of the project, an IPR Council, consisting of one representative from each MonB5G beneficiary, was set up to continuously monitor the knowledge generated in the relevant areas of MonB5G worldwide and ensure the activation of IPR protection strategies prior to publication.

Participant No.	Partner Short Name	Member
1	**CTTC**	Engin Zeydan
2	**EUR**	Adlen Ksentini
3	**OTE**	Vasiliki Vlachodimitropoulou
4	**LMI**	Jimmy O'Meara
5	**CTXS**	George Tsolis
6	**ORA-FR**	Fabrice Guillemin
7	**ORA-PL**	Slawomir Kulkinski
8	**AAL** (until M30)	Tarik Taleb
9	**BCOM**	Eric Gatel
10	**IQU**	Luis A. Garrido Platero
11	**NEC**	Zhao Xu
12	**EBOS**	Georgia Pantelide

Table 9: MonB5G IPR Council Membership

6.1 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 quantifies their exploitation potential. The set of tools that MonB5G used for its exploitation strategy are:

- Competitive analysis: MonB5G members performed 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 industrial 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 recognized the necessity to have a clear view of the trends, standards and roadmaps that shape the 5G sector that allows 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 6.5.1* presents the updated exploitation map of the innovation actions that the industrial partners of MonB5G have qualified as commercially exploitable.

6.2 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 was carried out to gauge its effectiveness. The exploitation KPIs refer to i) the number of patent applications or awarded patents (MonB5G aimed 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).

6.3 Innovation Management

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

6.3.1 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:

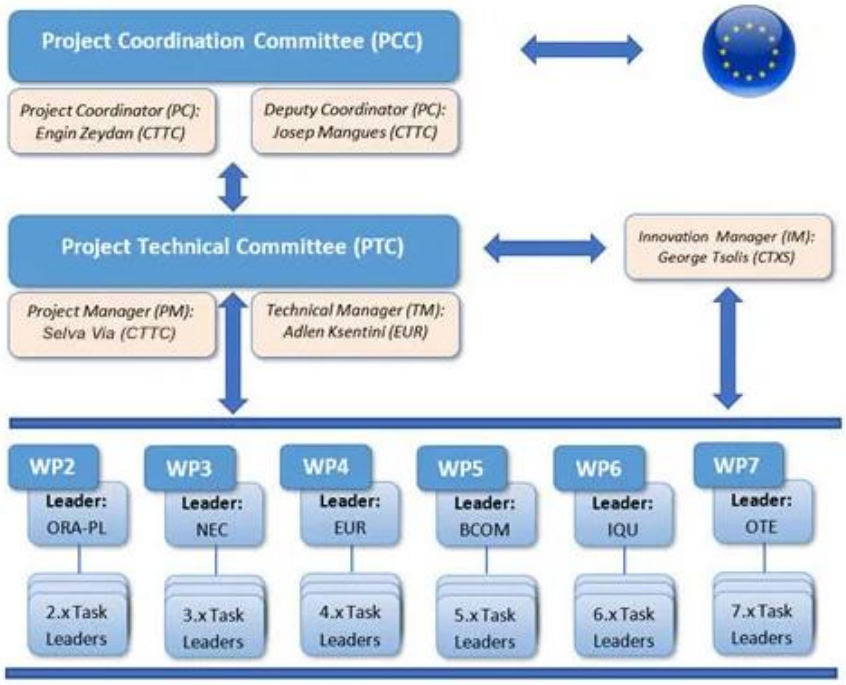


Figure 34: MonB5G Management Structure

The **Innovation Manager** (IM) role is to support the innovation driven research and to amplify the project's impact. In this context, The IM assists 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.

6.3.2 Inhibitors and Mitigating Measures

The MonB5G impact on innovation is a function of the adopted methodology for 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 have implemented, 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 incrementally, 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 free 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 6.3.1* has adequate provisions for breaking this type of stalemates.

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 6.3.3)*. To maintain focus throughout the entire duration of the project, activities are tracked by the Innovation Manager and IPR Council, 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 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.

6.3.3 Potential and Competitive Analysis

MonB5G is a highly ambitious project, which 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 were actually developed (see Section 6.4), 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 further. *Section 5* of *Deliverable D2.2* (Techno-economic analysis of the beyond 5G environment, use case requirements and KPIs) captured 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 Figure 35.

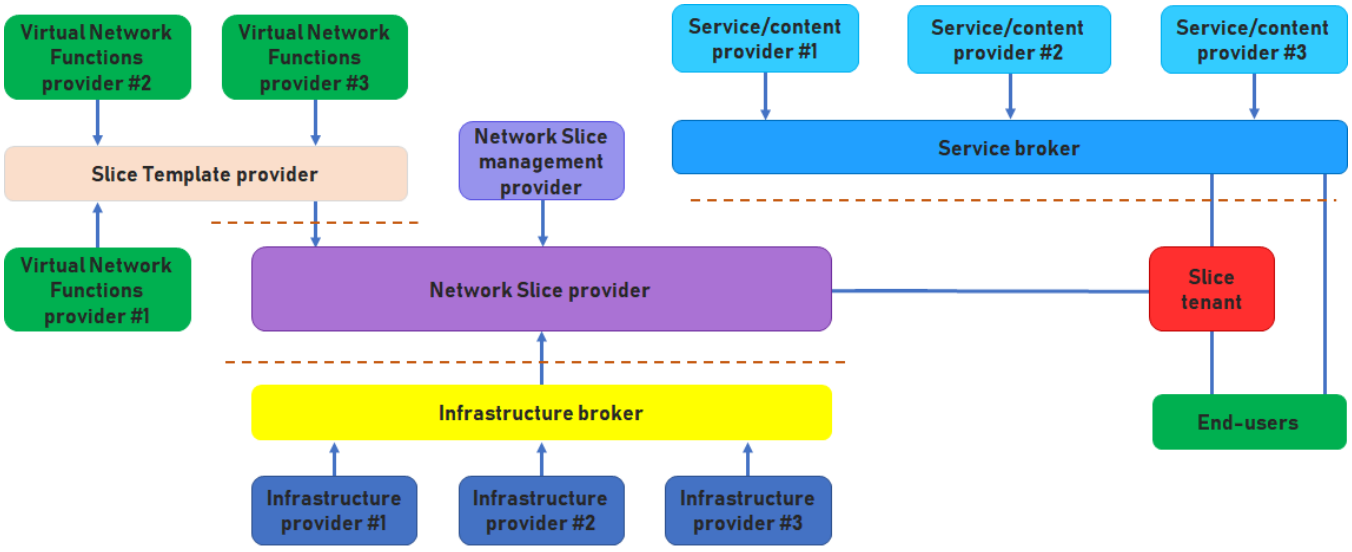


Figure 35: MonB5G Slice Lifecycle Business Model

Different stakeholders map to different segments of the market and respective products are positioned to fulfil their requirements. In addition, their interdependencies form chains for which MonB5G has the potential of generating benefits and value. The summary of the value chain that MonB5G brings to the stakeholders is captured by Figure 36.

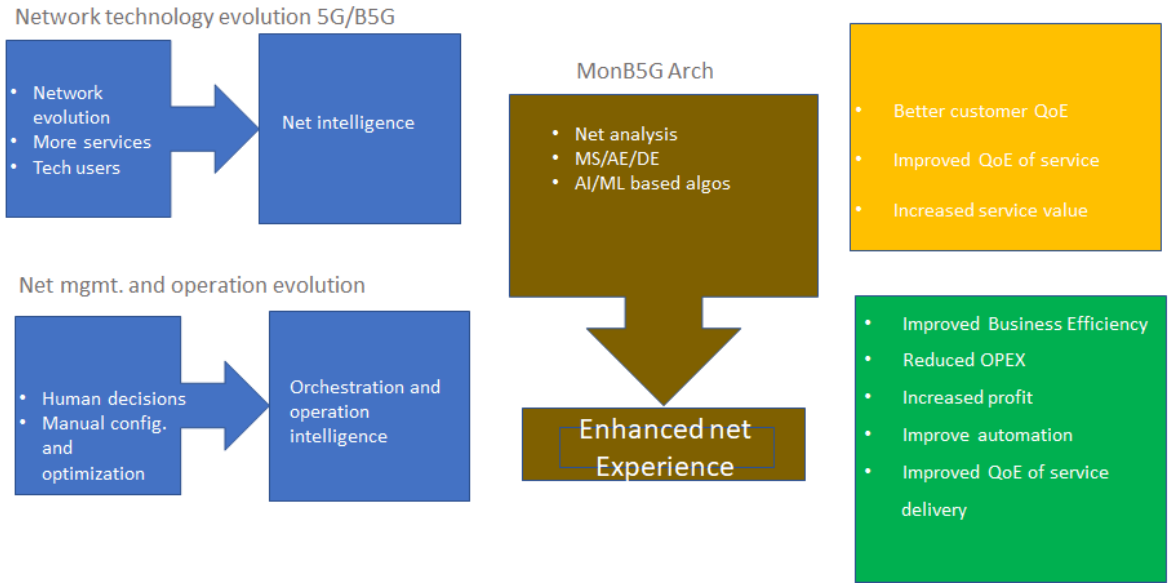


Figure 36: Value chain that MoNB5G brings to the stakeholders

Competitive Landscape

Based on Gartner's 2023 Magic Quadrant for 5G Network Infrastructure for CSPs[1], top 5G vendors include Ericsson, Huawei, Nokia (leaders quadrant) and ZTE, Samsung, NEC, Fujitsu, Mavenir (visionaries quadrant). According to the same report (mentioning GSMA as the source), as of November 2022, >220 3GPP-compliant 5G networks have been commercially launched in 92 countries/territories, only ~35 having launched 5G-SA.

Gartner's analysis highlights that "to provide real value through 5G, CSP networks need to be more agile, flexible and reliable by implementing technical innovations, including edge computing, SDN/NFV and cloudification, orchestration/automation, and network slicing". As a result, 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 their 5G RAN Slicing solution (https://www.ericsson.com/en/network-slicing/ran-slicing)
- Nokia's Network Slicing portfolio (https://www.nokia.com/networks/network-slicing/), including their automated solution (https://www.nokia.com/networks/network-slicing/automated-network-slicing/) for 4G/5G network slicing (https://www.nokia.com/networks/mobile-networks/5g-slicing/)
- Huawei's Network Slicing portfolio
- ZTE's 5G E2E Network Slicing Solution (https://sdnfv.zte.com.cn/en/solutions/VNF/5G-core-network/network-slice)
- 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)

[1] https://www.gartner.com/en/documents/4121999

- Juniper Networks 5G Networking/Slicing Solution (https://www.juniper.net/us/en/solutions/5g-networking.html)
- Amdocs 5G Slice Manager (https://www.amdocs.com/solutions/use-case/5g-network-slice)
- Sandvine 5G Service Intelligence Engine (https://www.sandvine.com/service-providers/5g)
- Blue Planet 5G Automation Solution (https://www.blueplanet.com/solutions/5g-automation.html)
- Parallel Wireless Network Slicing for 5G, 4G, 3G, and 2G (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 two leading vendors) increasingly embrace AI in the solutions they offer, while also enhancing their management and orchestration with zero-touch service automation:

- Ericsson AI in Networks: https://www.ericsson.com/en/ai
- Ericsson Intelligent RAN Automation: https://www.ericsson.com/en/ran/intelligent-ran-automation
- Ericsson Intent-based Networks: https://www.ericsson.com/en/ai/intent-based-networks
- Ericsson AI-Driven Zero-touch Ops: https://www.ericsson.com/en/ai/lessons-in-zero-touch-operations
- Nokia AVA AI and Analytics: https://www.nokia.com/networks/ai-and-analytics/
- Nokia Telco AI for the Real World: https://www.nokia.com/networks/ai-ops/
- Nokia Service Orchestration and Service Assurance: https://www.nokia.com/networks/operations-support-systems-oss/service-orchestration-assurance/
- Nokia Digital Operations Center: https://www.nokia.com/networks/bss-oss/digital-operations-center/

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

- Ericsson Telecom Security: https://www.ericsson.com/en/security
- Ericsson Future Network Security: https://www.ericsson.com/en/security/future-network-security
- Nokia Cybersecurity Operations: https://www.nokia.com/networks/security/cybersecurity/

Market Opportunity

As evidenced by the proliferation of relevant products, the network slicing, zero-touch service management and 5G cyber security markets are 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 Market Research: https://www.alliedmarketresearch.com/network-slicing-market-A07916
- or a slightly 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
- a more recent analyst report by ABI Research (https://www.abiresearch.com/press/5g-slicing-revenue-to-grow-from-us309-million-in-2022-to-approximately-us24-billion-in-2028/) estimates the same market in 2022 to be at 309M USD, i.e. growth seems to be at a rate that is between the two reports above. However, the report proceeds to predict that the market will grow to 24B USD in 2028, at a

CAGR of 106%! But this is based on an assumption a sizable part of the private 5G market will be converted to 5G network slicing.

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

- 7.2B USD by 2027 with a CAGR of 41.6% since 2022, when it was estimated to be at 1.3B USD Markets & Markets: https://www.marketsandmarkets.com/Market-Reports/5g-security-market-261636732.html
- 37.8B USD by 2031 with a CAGR of 40.5% since 2022 (same base estimate as report above) Allied Market Research: https://www.alliedmarketresearch.com/5g-security-market-A12820

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).

6.4 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 advancement, as reflected in published/accepted publications. Please note that progress until October 2021 was reported in Section 7.4 of Deliverable D7.6.

6.4.1 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

[J20] "Towards zero-touch management and orchestration of massive deployment of network slices in 6G" (IEEE Wireless Communications) proposes a novel framework featuring a distributed and AI-driven management and orchestration system for a massive deployment of network slices in 6G. The proposed framework is compliant with both ETSI standards focusing on autonomous and intelligent network management and orchestration, i.e., Zero touch Service Management (ZSM) and Experimental Networked Intelligent (ENI), leveraging their visions to enable autonomous as well as a scalable management and orchestration of network slices and their dedicated resources.

[J21] "Deep data plane programming and AI for zero-trust self-driven networking in beyond 5G" (Elsevier Computer Networks) presents recent advances in automation, data analysis, artificial intelligence, distributed ledger technologies (e.g., Blockchain), and data plane programming techniques, which have sparked the hope of the researchers' community in exploring and leveraging these techniques towards realizing the much-needed vision of trustworthy self-driving networks (SelfDNs). In this vein, the article proposes a novel framework to empower fully distributed trustworthy SelfDNs across multiple domains. The framework vision is achieved by exploiting (i) the capabilities of programmable data planes to enable real-time in-network telemetry collection; (ii) the potential of P4 – as an important example of data plane programming languages – and AI to (re)write the source code of network components in a fashion that the network becomes capable of automatically translating a policy intent into executable actions that can be enforced on the network components; and (iii) the potential of blockchain and federated learning to enable decentralized, secure and trustable knowledge sharing between domains. A relevant use case is introduced and discussed to demonstrate the feasibility of the intended vision. Encouraging results are obtained and discussed.

[J28] "AI-driven predictive and scalable management and orchestration of network slices predictive and scalable management and orchestration of network slices" (ITU-T JFET Network Management) presents the novel management and orchestration platform devised by MonB5G project. The proposed framework is a highly scalable solution for network slicing management and orchestration that implements a distributed and programmable AI-driven management architecture. The cognitive capabilities are provided at different levels of management hierarchy by adopting necessary data abstractions. Moreover, the framework leverages intent-based operations to improve its modularity and genericity. The mentioned features enhance the management automation, making the architecture a significant step towards self-managed network slices.

[J16] "Service Function Chaining in 5G & Beyond Networks: Challenges and Open Research Issues" (IEEE Network Magazine) outlines the Service Function Chaining (SFC) paradigm, which has helped to introduce unseen flexibility in telecom networks. Network service providers, as well as big network infrastructure providers, are competing to offer personalized services for their customers. Hence, added value services require the invocation of various elementary functions called Service Functions (SFs). The SFC concept composes and imposes the order in which SFs are invoked for a particular service. Emerging technologies such as Software Defined Networking (SDN) and Network Function Virtualization (NFV) support the dynamic creation and management of SFC. Even though SFC is an active technical area where several aspects were already standardized and many SFC architecture flavors are currently deployed, yet some challenges and open issues are still to be solved. In this paper, we present different research problems related to SFC and investigate several key challenges that should be addressed to realize more reliable SFC operations.

[J22] "Deterministic Latency Bounded Network Slice Deployment in IP-Over-WDM Based Metro-Aggregation Networks" (IEEE Transactions on Network Science and Engineering) presents the Deterministic Networking (DetNet) concept, which has been recently proposed to investigate deterministic service provisioning with bounds on service latency, loss, and jitter. A critical issue for providing deterministic services is how to allocate the right amount of resources that ensures the QoS requirements within a network slice. In this paper, we first obtain the amount of network resources needed for a network slice, using the stochastic network calculus (SNC) method, to ensure the end-to-end latency requirement under specific traffic demands. We then study the network slice deployment problem in an IP-over-WDM (wavelength division multiplexing) metro aggregation network and propose a heuristic with three different objectives: minimizing traffic hops, minimizing lightpaths and minimizing wavelengths, which can help network service provider to optimize network deployment under different considerations. The simulation results show the comparison of the resource utilization under different strategies.

[C26] "Deterministic Service Function Chaining over Beyond 5G Edge Fabric" (IEEE GLOBECOM 2021) observes that Service Function Chains (SFC) are typically formed by steering traffic through a series of VNF instances in a predefined order. Moreover, the required network resources and placement of VNF instances along SFC should be optimized to meet the deterministic latency requirements. Therefore, it is significant for ISPs to determine an optimal SFC deployment strategy to ensure network performance while improving the network revenue. In this paper, we investigate the resource allocation and SFC placement in 5G edge networks for deterministic latency assurance. We formulate this problem as a mathematic programming model with the objective of maximizing the overall network profit for ISP. A novel Deterministic SFC deployment (Det-SFCD) algorithm is subsequently proposed to efficiently embed SFC requests with deterministic latency assurance. The performance evaluation results show that the proposed algorithm can provide better performance in terms of SFC request acceptance rate, network cost reduction, and network resource efficiency compared with benchmark strategy.

[J23] "Deterministic Latency/Jitter-aware Service Function Chaining over Beyond 5G Edge Fabric" (IEEE Transactions on Network and Service Management) expands the work of the conference publication above. This article studies the deterministic SFC lifetime management problem in beyond 5G edge fabric with the objective of maximizing the overall profits and ensuring the deterministic latency and jitter of SFC requests. We first formulate this problem as a mathematical model with the maximal profits for ISP. Then, the novel Deterministic SFC Deployment algorithm (Det-SFCD) and SFC Adjustment algorithm (Det-SFCA) due to traffic load variation are proposed to efficiently solve the SFC lifetime management problem. Extensive simulation results show that our proposed algorithms can achieve better performance in terms of SFC request acceptance rates, overall profits and latency variation compared with the benchmark algorithm.

[C27] "Towards SDN-based Deterministic Networking: Deterministic E2E Delay Case" (IEEE GLOBECOM 2021) starts by noting that SDN and NFV introduced the term" Network Softwarization", which is the main enabler of network slicing and 5G networks. Specifically, SDN separates the control plane from the data plane, this concept brings many benefits such as dynamism, flexibility, and innovation. However, when it comes to the assurance of Quality of Service (QoS), SDN is running behind. Not only SDN was not optimized for real-time communications, but also SDN networks cannot offer a deterministic E2E delay. In this paper, we study OpenFlow-based communications with a focus on the delay. The modeling of queuing delays shows a stable linear development of the mean waiting time under a probability of 0.2 that 10 switches generate packet in message. After that, the increase becomes exponential and thus hard to predict.

[C22] "KRS: Kubernetes Resource Scheduler for resilient NFV networks" (IEEE GLOBECOM 2021) focuses on resource allocation in a Kubernetes infrastructure hosting different network services. The objective of the proposed solution is to avoid resource shortage in the cluster nodes while protecting the most critical functions. A statistical approach is followed for the modeling of the problem as well as for its resolution, given the random nature of the treated information.

[C28] "Performance evaluation of the OSM orchestrator" (IEEE NFV-SDN 2021) presents the results of experiments carried for performance evaluation of the Open-Source MANO (OSM), which is the most popular ETSI-compliant orchestration solution. The performance assessment is focused on the lifecycle operations on multiple instances of Linux Foundation MAGMA Evolved Packet Core (vEPC) template that are treated as network slices. The experiments have shown excellent scalability of the OSM orchestrator.

[C32] "Microservices Configurations and the Impact on the Performance in Cloud Native Environments" (IEEE LCN 2022) assumes a cloud-native application architecture that has embraced a micro-services approach, where each microservice is packaged into containers to run in a centralized or an edge cloud. When deploying the container running the micro-service, the tenant has to specify the amount of CPU and memory limit to run their workload. However, it is not straightforward for a tenant to know in advance the computing amount that allows running the microservice optimally. This will impact service performance and the infrastructure provider, particularly if the resource overprovisioning approach is used. To identify ways of overcoming this, we conduct an experimental study aiming to detect if a tenant's configuration allows running its service optimally. We run several experiments on a cloud-native platform, using different types of applications under different resource configurations. The obtained results provide insights on how to detect and correct performance degradation due to misconfiguration of the service resource.

[C36] "In-Slice Management Decomposition and Implementation Issues" (IEEE FNWF 2022) starts by surveying previous papers that explored the In-Slice Management (ISM) concept, in which network slicing system management is autonomic, distributed, and slice management is a part of the Network Slice (NS). We find that none of these previous works provide implementation details, or address issues related to unified NS reconfiguration, including NS run-time orchestration combined with classical management and the impact of NS reconfiguration on IMS components. The paper addresses these issues by defining ISM services and proposing, common for all ISM services, cooperative monitoring and actuating sublayers to smoothly handle reconfigurations. The mutual impact of ISM management services responsible for performance, fault, and security management is also addressed. The presented concept can be a basis for a generic ISM template that can be adapted to many NS types with marginal efforts.

6.4.2 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, which are able to capture inter-slice dependencies accurately yet minimally. 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

[J13] “A Heuristically Assisted Deep Reinforcement Learning Approach for Network Slice Placement” (IEEE Transactions on Network and Service Management”) establishes that Network Slice placement with the problem of allocation of resources from a virtualized substrate network is an optimization problem which can be formulated as a multiobjective Integer Linear Programming (ILP) problem. However, to cope with the complexity of such a continuous task and seeking for optimality and automation, the use of ML techniques appears as a promising approach. We introduce a hybrid placement solution based on Deep Reinforcement Learning (DRL) and a dedicated optimization heuristic based on the Power of Two Choices principle. The DRL algorithm uses the so-called Asynchronous Advantage Actor Critic (A3C) algorithm for fast learning, and Graph Convolutional Networks (GCN) to automate feature extraction from the physical substrate network. The proposed Heuristically Assisted DRL (HA-DRL) allows to accelerate the learning process and gain in resource usage when compared against other state-of-the-art approaches as the evaluation results evidence.

In [J14] “On the Robustness of Controlled Deep Reinforcement Learning for Slice Placement” (Journal of Network and Systems Management) we propose to evaluate the robustness of online learning for optimal network slice placement. A major assumption to this study is to consider that slice request arrivals are non-stationary. In this context, we simulate unpredictable network load variations and compare two Deep Reinforcement Learning (DRL) algorithms: a pure DRL-based algorithm and a heuristically controlled DRL as a hybrid DRL-heuristic algorithm, to assess the impact of these unpredictable changes of traffic load on the

algorithms' performance. We conduct extensive simulations of a large-scale operator infrastructure. The evaluation results show that the proposed hybrid DRL-heuristic approach is more robust and reliable in case of unpredictable network load changes than pure DRL as it reduces the performance degradation. These results are follow-ups for a series of recent research we have performed showing that the proposed hybrid DRL-heuristic approach is efficient and more adapted to real network scenarios than pure DRL.

In [J17] "Statistical Federated Learning for Beyond 5G SLA-Constrained RAN Slicing" (IEEE Transactions on Wireless Communications) we introduce statistical federated learning (SFL) provisioning models that can learn over a live network non independent identically distributed (non-IID) datasets in an offline fashion, while respecting slice-level SLA long-term statistical constraints. Specifically, we consider three resource SLA metrics, namely, cumulative distribution function (CDF), Q-th percentile and maximum/minimum bounds. These metrics are dataset-dependent and non-convex non-differentiable and, to sidestep the inaccuracy of settling only for surrogates, we propose a novel formulation that jointly considers the statistical objective and constraints as well as their smooth approximation using the proxy-Lagrangian framework, which we solve via a non-zero sum two-player game strategy. Numerical results on various slice-level resources show that SFL enables SLA enforcement while significantly reducing the overhead compared to both state-of-the-art FedAvg and centralized constrained deep learning schemes. Finally, we provide an analysis for the lower bound of the so-called reliable convergence probability in the SFL setup.

[C15] "MonB5G: AI/ML-Capable Distributed Orchestration and Management Framework for Network Slices" (IEEE MeditCom 2021) presents the novel management and orchestration platform for network slices devised by MonB5G. The presented concept addresses the scalability of network slicing management and orchestration by using a distributed and programmable management architecture that is AI-driven. AI-enabled management operations are adopted at different levels of the management hierarchy. The proposed architecture is a significant step towards self-managed network slices.

[C17] "Machine Learning for Network Slicing in Future Mobile Networks: Design and Implementation" (IEEE MeditCom 2021) summarizes some of the AI-based solutions developed by the authors as contributions to the problems of orchestration and management in 5G/B5G networks developed within the framework of the MonB5G project. The contributions in this scope are: 1) SCHEMA, a distributed RL mechanism for Service Function Placement (SFC), 2) CATP, a Context-Aware Traffic Predictor, and 3) Pre-BAC, an admission control mechanisms that exploits advanced time-series forecasting.

[C19] "DRL-based Slice Placement Under Non-Stationary Conditions" (CNSM 2021) demonstrates a network slice placement optimization solution based on Deep Reinforcement Learning (DRL), referred to as Heuristically-controlled DRL, which uses a heuristic to control the DRL algorithm convergence. The solution is adapted to realistic networks with large scale and under non-stationary traffic conditions (namely, the network load). We demonstrate the applicability of the proposed solution and its higher and stable performance over a non-controlled DRL-based solution. Demonstration scenarios include full online learning with multiple volatile network slice placement request arrivals.

[C25] "DRL-based Slice Placement under Realistic Network Load Conditions" (CNSM 2021) considers online learning for optimal network slice placement under the assumption that slice requests arrive according to a non-stationary Poisson process. We propose a framework based on Deep Reinforcement Learning (DRL) combined with a heuristic to design algorithms. We specifically design two pure-DRL algorithms and two families of hybrid DRL-heuristic algorithms. To validate their performance, we perform extensive simulations

in the context of a large-scale operator infrastructure. The evaluation results show that the proposed hybrid DRL-heuristic algorithms require three orders of magnitude of learning episodes less than pure-DRL to achieve convergence. This result indicates that the proposed hybrid DRL-heuristic approach is more reliable than pure-DRL in a real non-stationary network scenario.

[C23] "Entropy-Driven Stochastic Policy for Fast Federated Learning in Beyond 5G Edge-RAN" (IEEE GLOBECOM 2021) notes that the exchange of raw monitoring data should be minimized across the network by bringing the analysis functions closer to the data collection points. While federated learning (FL) is an efficient tool to implement such a decentralized strategy, real networks are generally characterized by time- and space-varying traffic patterns and channel conditions, making thereby the data collected in different points non independent and identically distributed (non-IID), which is challenging for FL. To sidestep this issue, we first introduce a new a priori metric that we call dataset entropy, whose role is to capture the distribution, the quantity of information, the unbalanced structure and the "non-IIDness" of a dataset independently of the models. This a priori entropy is calculated using a multi-dimensional spectral clustering scheme over both the features and the supervised output spaces and is suitable for classification as well as regression tasks. The FL aggregation operations support system (OSS) server then uses the reported dataset entropies to devise 1) an entropy-based federated averaging scheme, and 2) a stochastic participant selection policy to significantly stabilize the training, minimize the convergence time, and reduce the corresponding computation cost. Numerical results are provided to show the superiority of these novel approaches.

[C24] "A Collaborative Statistical Actor-Critic Learning Approach for 6G Network Slicing Control" (IEEE GLOBECOM 2021) proposes a novel model-free deep reinforcement learning (DRL) framework, called collaborative statistical Actor-Critic (CS-AC) that enables a scalable and farsighted slice performance management in a 6G-like RAN scenario that is built upon mobile edge computing (MEC) and massive multiple-input multiple-output (mMIMO). In this intent, the proposed CS-AC targets the optimization of the latency cost under a long-term statistical service-level agreement (SLA). In particular, we consider the Q-th delay percentile SLA metric and enforce some slice-specific preset constraints on it. Moreover, to implement distributed learners, we propose a developed variant of soft Actor-Critic (SAC) with less hyperparameter sensitivity. Finally, we present numerical results to showcase the gain of the adopted approach on our built OpenAI-based network slicing environment and verify the performance in terms of latency, SLA Q-th percentile, and time efficiency. To the best of our knowledge, this is the first work that studies the feasibility of an AI-driven approach for massive network slicing under statistical SLA.

In [C29] "SCHEMA: Service Chain Elastic Management with Distributed Reinforcement Learning" (IEEE GLOBECOM 2021) we formulate the SFC placement problem and then we tackle it by introducing SCHEMA, a Distributed Reinforcement Learning (RL) algorithm that performs complex SFC orchestration for low latency services. We combine multiple RL agents with a Bidding Mechanism to enable scalability on multi-domain networks. Finally, we use a simulation model to evaluate SCHEMA, and we demonstrate its ability to obtain a 60.54% reduction of average service latency when compared to a centralised RL solution.

In [J12] "Deep Learning for B5G Open Radio Access Network: Evolution, Survey, Case Studies, and Challenges" (IEEE Open Journal of the Communications Society) we first provide an overview of the evolution of RAN architectures toward 5G and beyond, namely C-RAN, vRAN, and O-RAN. We also compare them based on various perspectives, such as edge support, virtualization, control and management, energy consumption, and AI support. Then, we review existing DL-based solutions addressing the RAN part. We also show how they can be integrated/mapped to the O-RAN architecture since these works were not originally adapted to the

O-RAN architecture. In addition, we present two case studies for DL techniques deployment in O-RAN. Furthermore, we describe how the main steps of deployed DL models in O-RAN can be automated, to ensure stable performance of these models, introducing ML system operations (MLOps) concept in O-RAN. Finally, we identify key technical challenges, open issues, and future research directions related to the Artificial Intelligence (AI)-enabled O-RAN architecture.

[J15] "ONETS: Online Network Slice Broker From Theory to Practice" (IEEE Transactions on Wireless Communications) proposes and analyzes ONETS: an Online NETwork Slicing solution that (i) builds on the budgeted lock-up multi-armed bandit mathematical model and properties, (ii) derives its analytical bounds in our proposed extension for network slicing, (iii) seamlessly integrates into the 3GPP architecture, (iv) proves its feasibility through a proof-of-concept implementation on commercial hardware considering three network slices and (v) allows for the design of a low-complexity online network slice brokering solution that maximizes multiplexing gains.

[C37] "A Cloud Native SLA-Driven Stochastic Federated Learning Policy for 6G Zero-Touch Network Slicing" (IEEE ICC 2022) presents a new cloud-native SLA-driven stochastic policy to guarantee a scalable and fast operation of constrained federated learning (FL)-based analytic engines that perform statistical slice-level resource provisioning at RAN-Edge in a non-IID setup. Both simulated and cloud-native emulated scenarios are implemented to demonstrate the superiority of the solution in reducing SLA violation, convergence time and computation cost compared to different FL baselines, showcasing thereby a higher scalability.

[J26] "On the Specialization of FDRL Agents for Scalable and Distributed 6G RAN Slicing Orchestration" (IEEE Transactions on Vehicular Technologies) proposes a hierarchical architecture to manage network slices resources in a federated manner. Driven by the rapid evolution of deep reinforcement learning (DRL) schemes and the Open RAN (O-RAN) paradigm, we propose a set of traffic-aware local decision agents (DAs) dynamically placed in the radio access network (RAN). These federated decision entities tailor their resource allocation policy according to the long-term dynamics of the underlying traffic, defining specialized clusters that enable faster training and communication overhead reduction. Indeed, aided by a traffic-aware agent selection algorithm, our proposed Federated DRL approach provides higher resource efficiency than benchmark solutions by quickly reacting to end-user mobility patterns and reducing costly interactions with centralized controllers.

[C33] "SafeSCHEMA: Multi-domain Orchestration of Slices based on SafeRL for B5G Networks" (IEEE GLOBECOM 2022) notes that the safe interaction of AI agents with the network is one of the predominant challenges, especially when Reinforcement Learning (RL) is used in critical environments. This is particularly important when the RL agent actions have a high or irreversible impact on the network or service. Slice management is one of the major features that operators want to automate, to offer future services at large scales with manageable complexity to the operator. However, during the exploration phase, RL agents can cause significant performance degradation during operation and possibly introduce irreversible damage to the service being offered. To address this major challenge, we propose a multi-agent, modular, SafeRL architecture for distributed slice orchestration. We study the problem of zero-touch slice management and orchestration, in the context of URLLC services for B5G networks. Our results demonstrate improved performance over competing solutions, while ensuring the safety of the performed actions during real-time slice orchestration.

In [C34] "Scalable end-to-end slice embedding and reconfiguration based on independent DQN agents" (IEEE GLOBECOM 2022) we provide a model that attempts to capture the problem of dynamic slice embedding and reconfiguration supporting a multi-domain setup and diverse, end-to-end SLAs. We then show that such problems can be optimally solved, in theory, with (tabular) Reinforcement Learning algorithms (e.g., Q-learning) even under, a priori, unknown demand dynamics for each slice. Nevertheless, the state and action complexity of such algorithms is prohibitive, even for very small scenarios. To this end, we propose a novel scheme based on independent DQN agents: The DQN component implements approximate Q-learning, based on simple, generic DNNs for value function approximation, radically reducing state space complexity. The independent agents then tackle the equally important issue of exploding action complexity arising from the combinatorial nature of embedding multiple VNFs per slice, multiple slices, over multiple domains and computing nodes therein. Using realistic data, we show that the proposed algorithm reduces convergence time by orders of magnitude with minimum penalty of decision optimality.

6.4.3 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 timescale, 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.

Progress Beyond SotA

[C16] "Context-Aware Traffic Prediction: Loss Function Formulation for Predicting Traffic in 5G Networks" (IEEE ICC 2021) notes that state-of-the-art research has demonstrated the effectiveness of ML predictors for traffic prediction in 5G networks. However, the problem is not only the accuracy of the predictor, but also the usability of the predicted values to drive resource orchestration and scheduling mechanisms, used for resource utilization optimization while ensuring performance. In this paper, we introduce a new approach that consists of including problem domain knowledge relevant to 5G as regularization terms in the loss function used to train different state-of-the-art deep neural network (DNN) architectures for traffic prediction. Our formulation is agnostic to the technological domain, and it can obtain an improvement of up to 61,3% for traffic prediction at the base station level with respect to other widely used loss functions (MSE).

[C18] "Learning Sparsity of Representations with Discrete Latent Variables" (IJCNN 2021) looks at deep latent generative models, which have attracted increasing attention recently, due to the capacity of combining the strengths of deep learning and probabilistic models in an elegant way. The data representations learned with the models are often continuous and dense. However, in many applications, sparse representations are expected, such as learning sparse high dimensional embedding of data in an unsupervised setting, and learning multi-labels from thousands of candidate tags in a supervised setting. In some scenarios, there could be further restriction on degree of sparsity: the number of non-zero features of a representation cannot be larger than a pre-defined threshold L0. In this paper we propose a sparse deep latent generative model SDLGM to explicitly model degree of sparsity and thus enable to learn the sparse structure of the data with the quantified sparsity constraint. The resulting sparsity of a representation is not fixed but fits to the observation itself under the pre-defined restriction. In particular, we introduce to each observation i an auxiliary random variable Li, which models the sparsity of its representation. The sparse representations are then generated with a two-step sampling process via two Gumbel-Softmax distributions. For inference and learning, we develop an amortized variational method based on MC gradient estimator. The resulting sparse

representations are differentiable with backpropagation. The experimental evaluation on multiple datasets for unsupervised and supervised learning problems shows the benefits of the proposed method.

In [C20] "A network tomography approach for anomaly localization in Service Function Chaining" (ISNCC 2021) we describe a new monitoring procedure, customized for NFV-based network infrastructures deployed with the SFC mechanism, one of the most important key enablers for NFV networks. Our solution allows the deployment of efficient probing schemes that guarantee the localization of multiple simultaneously failed nodes with a minimum cost. This is formulated as a graph matching problem and solved with a max-flow approach. Simulations show that our solution localizes the failed nodes with a small rate of false positives and false negatives.

In [C31] "Uncertainty Propagation in Node Classification" (IEEE ICDM 2022) we look at quantifying predictive uncertainty of neural networks and we focus on measuring uncertainty of graph neural networks (GNNs) for the task of node classification. Most existing GNNs model message passing among nodes. The messages are often deterministic. Questions naturally arise: Does there exist uncertainty in the messages? How could we propagate such uncertainty over a graph together with messages? To address these issues, we propose a Bayesian uncertainty propagation (BUP) method, which embeds GNNs in a Bayesian modeling framework, and models predictive uncertainty of node classification with Bayesian confidence of predictive probability and uncertainty of messages. Our method proposes a novel uncertainty propagation mechanism inspired by Gaussian models. Moreover, we present an uncertainty-oriented loss for node classification that allows the GNNs to clearly integrate predictive uncertainty in learning procedure. Consequently, the training examples with large predictive uncertainty will be penalized. We demonstrate the BUP with respect to prediction reliability and out-of-distribution (OOD) predictions. The learned uncertainty is also analyzed in depth. The relations between uncertainty and graph topology, as well as predictive uncertainty in the OOD cases are investigated with extensive experiments. The empirical results with popular benchmark datasets demonstrate the superior performance of the proposed method.

6.4.4 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.

Progress Beyond SotA

[J18] "Zero-Touch AI-Driven Distributed Management for Energy-Efficient 6G Massive Network Slicing" (IEEE Network Magazine) starts by elaborating on the architectural and AI-based algorithmic designs to achieve energy efficiency (EE) in 6G, as well as analyzing their trade-offs. The article then introduces a novel statistical federated learning (StFL)-based analytic engine for zero-touch 6G massive network slicing, which performs slice-level resource prediction by learning in an offline fashion while respecting some preset long-term SLA

constraints defined in terms of the empirical cumulative distribution function and the percentile statistics, and hence uses a new proxy-Lagrangian two-player strategy to solve the local non-convex federated learning task without settling for surrogates only. This guarantees 20 × lower SLA violation rate with respect to the federated averaging (FedAvg) scheme, while achieving more than 10 × EE gain compared to an SLA-constrained centralized deep learning algorithm, which paves the way to sustainable massive network slicing. Finally, the key open research directions in this emerging area are identified.

[J25] "SCHE2MA: Scalable, Energy-Aware, Multi-Domain Orchestration for Beyond-5G URLLC services" (IEEE Transactions on Intelligent Transportation Systems) recognizes that the impact of network automation on energy consumption and overall operating costs is often overlooked. Guaranteeing strict performance constraints of URLLC services, while enhancing energy efficiency is one of the major critical problems of future communication networks, given the urgency to reduce carbon emissions and energy consumption. In this work, we study the problem of zero-touch SFC orchestration for multi-domain networks, targeting the latency reduction of URLLC services, while improving energy efficiency for B5G networks. Specifically, we propose SCHE2MA, a Service CHain Energy-Efficient Management framework based on distributed Reinforcement Learning (RL), that can intelligently deploy SFCs with shared VNFs into a multi-domain network. Finally, we evaluate SCHE2MA through model validation and simulation while demonstrating its ability to jointly reduce average service latency by 103.4% and energy consumption by 17.1% compared to a centralized RL solution.

6.4.5 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

[C21] "Distributed AI-based Security for Massive Numbers of Network Slices in 5G & Beyond Mobile Systems" (EuCNC & 6G Summit 2022) observes that the benefits of network slicing will not be attained without ensuring a high level of security of the created network slices and the underlying infrastructure, above all in a zero-touch automated fashion. In this vein, the paper presents the architecture of the innovative network slicing security orchestration framework of MonB5G. The framework leverages Security as a Service (SECaaS) and Artificial Intelligence (AI) to foster fully distributed, autonomic and fine-grained management of network slicing security, from the node level to the end-to-end and inter-slice levels.

[C35] "5G-Enabled Defence-in-Depth for Multi-domain Operations" (IEEE MILCOM 2022) discusses the existing 5G security mechanisms related to the connection of trusted and untrusted non-3GPP access networks (wireless and wired), 5G roaming, and the 3GPP approach to support Uncrewed Aerial Services, which provides authentication between the mobile terminal and an external server. The identified use cases show the need and opportunities for reusing 5G security mechanisms beyond the 5G network domain. We discuss the options for end-to-end defence-in-depth security provisioning in multi-domain networks, and we present two approaches to providing end-to-end defence-in-depth mechanisms. The first relies on the alignment of security policies in multiple domains and is based on security proxies. The second is based on the multi-domain network slices.

In [J24] "Blockchain-based Service Orchestration for 5G Vertical Industries in Multi-Cloud Environment" (IEEE Transactions on Network and Service Management) we propose a permissioned distributed ledger (PDL)-based blockchain supported architecture for a network management and orchestration platform. The work focuses on creating a trusted environment for both Cloud Service Providers (CSPs) and Mobile Network Operators (MNOs) for managing the lifecycle of network services (e.g., instantiation, scaling, termination, etc.) in a multi-cloud environment. We also validate our proposed approach with an experimental scenario using the Quorum blockchain network (BCN) to measure various performance metrics (e.g., number of transactions and blocks, time to write, and transactions per second) of different service orchestrator (SO)-related instantiation metrics. Our evaluation results show that the values for the service instantiation time and the corresponding BCN metrics can be completely different, suggesting that some logs arrive very quickly and generate a high transaction load, while others take longer and generate a low number of transactions. As a solution, at the end of the paper, we also provide some recommendations for appropriate optimizations during transfer of SO-related logs to BCNs and some observed challenges.

[C30] "Demo: Blockchain-based Inter-Provider Agreements for 6G Networks" (CNSM 2022): With their transparency and smart contract features, blockchain and Distributed Ledger Technologies (DLT) can pave the way toward a decentralized marketplace for multi-administrative domains. An open and decentralized marketplace can aid 6G use cases such as inter-provider agreements, where multi-administrative domains can lease or buy resources to meet the needs of consumers. These agreements between multi-administrative domains can be performed using blockchain, increasing trust and transparency for Service Level Agreement (SLA) management, penalty, or billing. In this demonstration, we present the use of the Ethereum smart contract for a use case where the consumer can buy resources from a provider. However, Ethereum suffers from high transaction costs and latency; therefore, we aim to leverage IOTA Tangle to reduce the cost of transactions on the Ethereum blockchain and minimize the latency. In particular, we show the process of domains registered on an Ethereum blockchain network, consumers selecting a service from the list of available services to buy, and finally, transferring the agreed amount after the services are delivered.

[J27] “Post-Quantum Blockchain-based Secure Service Orchestration in Multi-Cloud Networks” (IEEE Access) explores how network services can be managed in a multiple administrative domain scenario. Our approach uses Block Chain Networks (BCNs) to track the operational steps of network service instantiation metrics, while benefiting from the security features of post-quantum cryptography (PQC). Together with the use of N-th degree Truncated polynomial Ring Units (NTRU), as an example of a PQC algorithm that relies on the parallelization power of the Toom-Cook computation method with different security levels, we have shown that Quorum can provide a lower average time-to-write value compared to other BCNs considered (Ethereum and Hyperledger). We then discuss the evaluation results and future directions regarding the coexistence of PQC algorithms and BCNs for network service orchestration and service federation between multiple administrative domains.

[J29] “Zero-touch security management for mMTC network slices: DDoS attack detection and mitigation” (IEEE Internet of Things Journal) proposes a zero-touch security management solution that uses ML to detect and mitigate in-slice attacks on 5G CN components, focusing on Distributed Denial of Service (DDoS) attacks. To this aim, we propose: (1) a novel closed-control loop that assists the 5G CN in detecting and mitigating attacks; (2) a ML algorithm that predicts the upper bound of expected MTC devices Attach Requests during a time interval (or an event); (3) a detection algorithm that analyzes an event and uses the ML output to compute a probability that a specific device has participated to an attack; (4) a mitigation algorithm that disconnects and blocks MTC devices suspected to be part of an attack; (5) a Proof of concept implementation on top of a 5G facility.

6.5 Innovation and Exploitation Activities

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 submitted 5 patents related to technical activities in WP3, WP4 and WP5.

No	Title	Inventor/Partner	Date of patent filing
1	Method and network device for determining causes of network slice performance degradation in an open radio access network	Zhao Xu (NEC)	April 19, 2021
2	System and Method for Deriving Network Address Spaces Affected by Security Threats to Apply Mitigations	Aikaterini Kalou (CTXS)	December 3, 2021
3	System and methods for autonomous policy conflict detection and mitigation in Open Radio Access Network (O-RAN) deployments	Lanfranco Zanzi, Francesco Devoti (NEC)	May 9, 2022
4	Recommending Network Security Rule Updates Based on Changes in the Network Data	Aikaterini Kalou (CTXS)	October 18, 2022
5	Distributed intelligence for evolved open radio access network management and corresponding method	Luis Blanco, Engin Zeydan, Luca Vettori, Sergio Barrachina, Josep Mangues, Farhad Rezazadeh (CTTC)	April 13, 2023

Table 10: Patents of MonB5G project

We have identified one project-wide innovation that has already been accepted and published by the European Commission's Innovation Radar:

Innovation Title: AI-Based Distributed Architecture for Automatic Management and Orchestration of Massive Network Slicing in Beyond 5G [in]

Other exploitation activities involved generating and making publicly available the datasets listed below:

No	Title	Partner	Access Link
1	Benchmarking on Microservices Configurations and the Impact on the Performance in Cloud Native Environments	EURECOM	https://zenodo.org/record/6907619
2	Dataset from VR Streaming Server (Emulated) and Radio Access Network for Streaming Traffic	CTTC	https://zenodo.org/record/7854715
3	Dataset of a 5G RTSP video streaming use case	CTTC	https://zenodo.org/record/7858064

Table 11: Public Datasets of MonB5G project

Several experiments were conducted by Eurecom on a cloud-native platform using various application types and resource configurations. The results obtained were published in the IEEE LCN paper (https://www.eurecom.fr/publication/6971). The datasets were collected for three types of applications:

Web servers written in python and Golang, RabbitMQ data broker and the Open-Air Interface 5G Core network function AMF (Access and Mobility Management Function).

The second dataset contains an experiment in a site where UEs attach to a gNodeB that provides access to a streaming server that is stressed with high demanding transcoding workloads to emulate VR/AR processes. The UEs are realized through the Remote UE mode enabled by Amarisoft Simbox emulator, and the gNodeB is realized through the Amarisoft Callbox, which also provides the user plane function. The emulated VR streaming server is deployed as a Nginx pod in a Kubernetes cluster.

The third dataset collects data from a 5G video streaming use case. A video is streamed by a cvlc server (realized as a Kubernetes pod) through RTSP to a variable number of 5G UE clients that activate according to a daily traffic pattern. The values of the 4 dataset features (number of active UEs, gNB's downlink bit rate, pod's outbound traffic, and pod's CPU usage) are collected by a custom monitoring system deployed in the context of the MonB5G project.

6.5.1 Individual Partners

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

6.5.1.1 OTE

<table>
<tr><td colspan="3">Innovation</td><td>TRL M01</td><td>TRL M42</td></tr>
<tr><td colspan="3">ML and DE enabling improvement of network performance</td><td>2</td><td>5</td></tr>
<tr><td colspan="2">Type of exploitation</td><td>Exploitation potential</td><td colspan="2">Conflicting IP</td></tr>
<tr><td colspan="2">Enhance our knowledge of ML and DE for network Improvement</td><td>High</td><td colspan="2">No</td></tr>
<tr><td>Competition</td><td>Strengths</td><td>Weaknesses</td><td colspan="2">Risks</td></tr>
<tr><td>Other Operators</td><td>Leading Operator</td><td>Strong Competition</td><td colspan="2">No adoption by Standards yet</td></tr>
<tr><td>Targeted market</td><td>Time to market estimate</td><td colspan="3">Expected ROI</td></tr>
<tr><td>End users</td><td>~3 years</td><td colspan="3">Increase customer base by improving QoE, Reduce energy consumption (OPEX)</td></tr>
<tr><td colspan="5">Path to market</td></tr>
<tr><td colspan="5">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.</td></tr>
</table>

6.5.1.2 LMI

Innovation			**TRL M01**	**TRL M42**
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.				

6.5.1.3 CTXS

Innovation			**TRL M01**	**TRL M42**
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 M42**
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)			

6.5.1.4 ORA-FR, ORA-PL

Innovation	**TRL M01**	**TRL M42**
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.			

6.5.1.5 BCOM

Innovation			**TRL M01**	**TRL M42**
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.

6.5.1.6 IQU

Innovation			**TRL M01**	**TRL M42**
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.				

6.5.1.7 NEC

Innovation			**TRL M01**	**TRL M42**
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 M42**
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.				

6.5.1.8 EBOS

<table>
<tr><td colspan="3">Innovation</td><td>TRL M01</td><td>TRL M42</td></tr>
<tr><td colspan="3">ML algorithms and new AI approaches for anomaly detection in networks</td><td>2</td><td>4</td></tr>
<tr><td colspan="2">Type of exploitation</td><td>Exploitation potential</td><td colspan="2">Conflicting IP</td></tr>
<tr><td colspan="2">• Enhance our knowledge of ML for anomaly detection
• Enhance knowledge of attack detection in networks
• Increase company’s capabilities using new AI methodologies</td><td>Medium</td><td colspan="2">No</td></tr>
<tr><td>Competition</td><td>Strengths</td><td colspan="2">Weaknesses</td><td>Risks</td></tr>
<tr><td>• Open-source alternatives
• Commercial solutions
• New ML approaches</td><td>Short time to market</td><td colspan="2">• Resources for support depending on demand,
• Data limitations</td><td>Limited uptake by industry</td></tr>
<tr><td>Targeted market</td><td>Time to market estimate</td><td colspan="3">Expected ROI</td></tr>
<tr><td>• Anomaly detection for Telecom operators and System vendors
• Security components for Vertical markets (e.g., firewall)</td><td>2-3 years</td><td colspan="3">Increase revenue and security of the company’s products and services</td></tr>
<tr><td colspan="5">Path to market</td></tr>
<tr><td colspan="5">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.</td></tr>
</table>

6.5.1.9 CTTC

CTTC’s participation in this project has stimulated a number of technology transfer and IPR generation activities (1 patent application), which are at the true core of its mission. From participation in MonB5G, CTTC staff has acquired new knowledge in enhancing the capabilities of an existing 5G platform. Extensive efforts related to the PoC setup and demonstrations, dataset releases (2 publicly available datasets), the monitoring system design and implementation and the participation in the ETSI ZSM PoC on security have extended the knowledge of areas of CTTC. The result of the project is planned to be integrated in the Spanish 6G industry ecosystem and initiatives (e.g., through its UNICO I+D Projects) in order to enhance the collaboration with other companies. New projects based on MonB5G project ideas namely Spanish funded 6GDAWN-ELASTIC,

6GDAWN-RESILIENT, ANEMONE projects have already been initiated. The adaptation of the MonB5G platform to the ETSI MEC and ETSI ZSM requirements and AI/ML techniques has further enhanced the existing experimentation platform towards 6G. As a member of ETSI, CTTC has actively participated in the corresponding WGs ETSI MEC, ITU-TU FN group and ETSI ZSM PoC. Moreover, as a member of 5GIA and 5G Vision 2020, CTTC has exploited the project´s results to the 5G industrial community in Europe. In addition, CTTC has enhanced its training activities by producing new material in the area of AI/ML for network management (e.g., tutorial presentations, talks at universities). Moreover, CTTC has used the know-how of the produced results to 3 new ongoing PhD Thesis. Finally, the team has published the results of the project in top-tier journal papers and conferences (8 journals and 11 conferences).

6.5.1.10 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.

6.5.2 Internal and External Activities

To facilitate execution of their exploitation plans above, the partners executed a range of activities, not only internal to their organizations, but also ones that included external audiences or stakeholders. A concise list of such activities is provided below.

6.5.2.1 Internal Activities

- “Ericsson Ireland Tech Day 2020: Presentation about MonB5G to internal audience participating to the event”, Athlone, Ireland (virtual), LMI (Anne-Marie Bosneag), 12 October 2020
- “Presentation to Ericsson Research Sweden about MonB5G project”, Athlone, Ireland & Stockholm, Sweden, LMI (Anne-Marie Bosneag, Erik Aumayr), 20 May 2021
- “Internal briefing on Citrix participation to EU Projects (incl. MonB5G) to General Manager of NetScaler”, Greece/India (virtual), CTXS (George Tsolis), 13 September 2022
- “Discussion of advertising Citrix innovation outcomes from EU Projects with NetScaler Product Marketing”, Greece/US/UK/Ireland (virtual), CTXS (George Tsolis), 19 September 2022
- “Ericsson OSS Tech Day 2022: Analytics Engine for Slice KPI Prediction in MonB5G”, Athlone, Ireland, LMI (Ashima Chawla, Anne-Marie Bosneag), 6 October 2022

6.5.2.2 External Activities

- “22nd Infocom World Conference 2020: Transforming Greece: The 5G and Fiber Enablers – The Future is Now!”, Athens, Greece, OTE (Vasiliki Vlachodimitropoulou), 6 November 2020
- “23rd Infocom World 2021 Conference: Recharging Greece: Revolution for the Evolution”, Athens, Greece, OTE (Dr. Ioannis Chochliouros, Vasiliki Vlachodimitropoulou), 24-26 November 2021

- "Participation to Horizon Results Booster (PDE Module A and PDE Module C)", Multiple meetings and seminars (virtual), CTTC, OTE, CTXS, EBOS, April-October 2022
- "24th Infocom World Conference & Exhibition: Fiber and 5G Highways-DigitALL Greece!", Athens, Greece, OTE (Vasiliki Vlachodimitropoulou), 29-30 November 2022
- "Seminar at Manisa Celal Bayar University on MonB5G", Remote, CTTC (Engin Zeydan), 21 December 2022
- "Presentation/demo at the ETSI MEC #33 meeting", Castelldefels, Spain, CTTC (Engin Zeydan, Luis Blanco), 15 March 2023
- "ETSI ZSM PoC #7: Zero-touch closed-control security management of attacks detection and mitigation", Barcelona, Spain, CTTC, EUR, NEC, OTE, 31 January - 2 February 2023

6.5.2.3 Horizon Results Booster Participation

Towards effectively disseminating MonB5G research results and boosting the exploitation potential of project outcomes, we submitted to and participated in the relevant Service: Portfolio Dissemination & Exploitation Strategy of Horizon Results Booster (https://www.horizonresultsbooster.eu/).

MonB5G partner representatives (CTTC, OTE, CTXS, EBOS) participated to several meetings and seminars with Horizon Results Booster (HRB) experts, in the context of both modules below:

- Module A: Identifying and creating the portfolio of R&I project results
- Module C: Assisting projects to improve their existing exploitation state

After carrying out the required discussions with the HRB experts, completing the necessary questionnaires and compiling the required documentation for the identified Key Exploitable Results, which especially for the case of Module C was quite comprehensive:

1. Exploitation Intentions Summary Table (list of Key Exploitable Results)
2. Characterization Table (for each Key Exploitable Result)
3. Risks Assessment and Priority Map (for each Key Exploitable Result)
4. Use Options (for each Key Exploitable Result)
5. Exploitation Roadmap (for each Key Exploitable Result)

As part of the activities of Module A, a Project Group (PG) was formulated that included participants from MonB5G, 5G Complete and DAEMON 5G PPP projects, which the analysis uncovered strong synergies with. The respective report fulfilled the objectives of this module, specifically to:

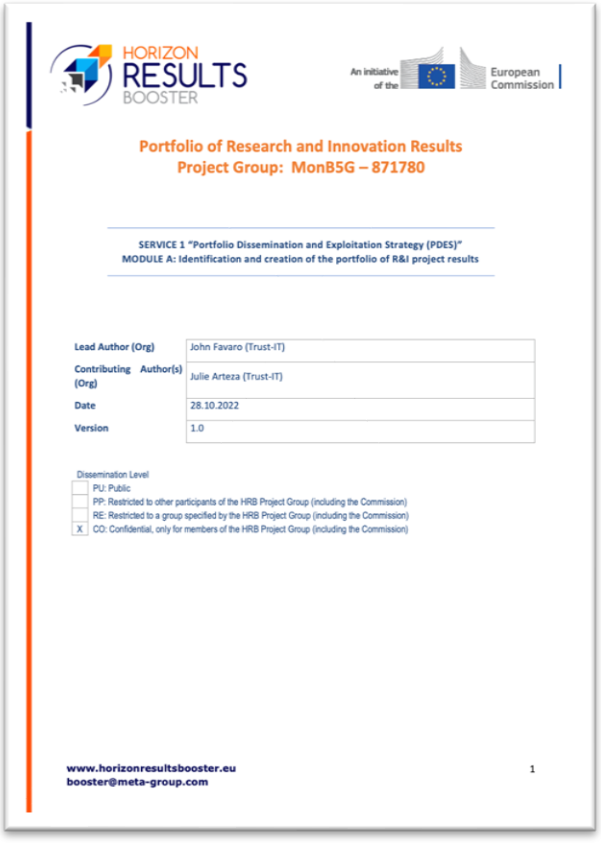
- Identify complementary results from across the PG
- Cluster and group these results into Key Exploitable Results Portfolio
- Perform state-of-the-art analysis and SWOT analysis
- Analyse all relevant stakeholders, prioritize/identify key stakeholders and provide contacts
- Identify relevant channels and potential recommendations for joint dissemination actions

As part of the activities of Module C, CTXS, OTE and EBOS have identified 3 Key Exploitable Results:

KER	Title	Partner
1	Detection of performance and security anomalies in the data and control plane of 5G & beyond networks	CTXS
2	Enhance our knowledge of ML, DE and network automation for network Improvement	OTE
3	Develop novel mechanisms for mitigation of network slicing threats via AI-driven security mechanisms	EBOS

HRB experts produced and shared the corresponding reports, the cover pages of which are showcased below.

Overall, MonB5G project partners were quite satisfied with the efficient collaboration with the HRB experts and very impressed with the indispensable guidance received by them, in the context of both modules.


HORIZON RESULTS BOOSTER

An initiative of the European Commission

Portfolio of Research and Innovation Results
Project Group: MonB5G – 871780

SERVICE 1 "Portfolio Dissemination and Exploitation Strategy (PDES)"
MODULE A: Identification and creation of the portfolio of R&I project results

Lead Author (Org)	John Favaro (Trust-IT)
Contributing Author(s) (Org)	Julie Arteza (Trust-IT)
Date	28.10.2022
Version	1.0

Dissemination Level
PU: Public
PP: Restricted to other participants of the HRB Project Group (including the Commission)
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booster@meta-group.com
1

Module A: Identifying and creating the portfolio of R&I project results (~30 pages)


HORIZON RESULTS BOOSTER

An initiative of the European Commission

PDES – Module C Final Report

for

« MonB5G»

Project ID Number
MonB5G 871780

Exploitation Strategy Seminar
28 June 2022

Provided by:

Julià Manzanas
Axel Gaitan

Module C: Assisting projects to improve their existing exploitation state (100+ pages)

6.5.3 MonB5G as a Whole

The expected impact of the MonB5G project across different objectives and dimensions is provided below. This was the basis for the exploitation plan of the MonB5G platform as a whole, which we have solidified and reported on in this and previous 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 demonstrated several use cases where computing, storage and networking resources of Tactile Internet applications are 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 has developed 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 has developed 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 has proposed 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 leverages the aforementioned developments and achieves 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 outcomes 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. These research results were highlighted in Section 6.4 of this deliverable, incrementally from Section 7.4 of previous Deliverable D7.6. Also, as noticeable from the exploitation plans of Section 6.5.1, the path to market of these outcomes is

well defined and strongly supported by the partners. Further validation and refinement of these plans was accomplished as part of the innovation and exploitation activities (Section 6.5.2). The telecom operator members of the consortium (OTE member of Deutsche Telecom Group, ORA-FR and ORA-PL members of Orange Group) have plans to bring these learnings and innovations to their business. Also, the telecom vendors (Ericsson LMI, NEC, CTXS part of Cloud Software Group, BCOM) have concrete objectives to enable those plans, while enhancing their product /solutions (Ericsson Operations Engine, NEC the WISE, NetScaler ADC, Wireless Edge Factory) to improve competitiveness and market reach.

- **Impact on European economy:** MonB5G impact on the European economy will involve contributing 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. Based on our Market Analysis (Section 6.3.3 of this deliverable) the market opportunity and growth projections across all markets MonB5G "unlocks" (mobile network slicing, AI/automation for mobile network management and operations, mobile network cyber-security solutions) are very significant, not only for the benefit of telecom vendors, but for telecom operators to capitalise on their sizable 5G infrastructure investments and for the vertical industries to fulfil their ambitious digital transformation initiatives.
- **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 goes 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 and paving the way to offer new innovative 5G services over a wide spectrum of vertical sectors at lower costs to consumers. These future services will generate positive societal and environmental impact and are expected to fundamentally reshape the way European citizens work, communicate, travel, keep healthy or entertain themselves, and certainly be a key driver for a more efficient, well-being oriented, environmentally friendly European way of life.

7 Conclusions

Deliverable D7.7 depicts MonB5G outreach, standardization and exploitation activities as well as project's interaction and engagement activities in regard to 5G-PPP projects that took place during the project's third and final phase (November 2021 to April 2023).

The results of the dissemination and communication activities have been presented, analyzed, and evaluated through the use of data dashboards, as well as in comparison to the targets that were established by the original plan of MonB5G.

During this final reporting period, MonB5G has actively collaborated with and contributed to a number of standardization bodies. The focus has been given on ensuring the alignment and conformance of the overall project's implementation with the applicable standards, as well as delivering tangible contributions to the standardization community.

MonB5G's exploitation approach made use of a variety of methods, including a competitive analysis, an application analysis, and an exploitation plan. In addition, each partner's individual exploitation strategies were updated and presented. The MonB5G project evolved in order to facilitate the commercialization of its findings and exploitation activities by integrating exploitation, intellectual property, and technology transfer actions.

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